RÖNTGENOLOGY

THE BORDERLANDS OF THE NORMAL AND EARLY PATHOLOGICAL IN THE SKIAGRAM

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BY

ALBAN KÖHLER

Prof.Dr.med., Wiesbaden

EX-PRESIDENT OF THE GERMAN RÖNTGEN SOCIETY, HONORARY OR CORRESPONDING MEMBER OF THE SWEDISH MEDICAL SOCIETY, VIENNA MEDICAL SOCIETY, AMERICAN RÖNTGEN-RAY SOCIETY, SPANISH AND MEXICAN RADIOLOGICAL SOCIETY, MEMBER OF THE BRITISH INSTITUTE OF RADIOLOGY, HONORARY PRESIDENT OF THE INTERNATIONAL CONGRESS FOR ELECTROLOGY AND RADIOLOGY IN AMSTERDAM, 1907, MEMBER OF THE EXECUTIVE COMMITTEE OF THE SOCIETY OF GERMAN SCIENTIFIC AND MEDICAL RESEARCHERS.

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ARTHUR TURNBULL

M.A., B.Sc., M.B., Ch.B.(Glasg.)

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PREFACE TO THE ENGLISH EDITION

THE translator of Dr. Alban Köhler's book " Grenzen des Normalen und Anfänge des Pathologischen im Röntgenbilde " has requested me to write a short introduction to the translated edition. While it has been a great pleasure to comply with Dr. Turnbull's request, I am constrained to quote the old English proverb, " Good wine needs no bush." In other words I feel that the merits of the work are so apparent that the task of the introducer is a peculiarly easy and pleasant one.

Dr. Köhler's work is familiar to English readers. There are certain conditions in the category of diseases to which his name has been attached, but it is in the field of radiology that his reputation is so fairly established. His many contributions to the literature of this subject, each and all stamped with the hallmark of outstanding ability, have placed him in the front rank of continental investigators. The present volume, the title of which may be translated as "Outlines of the Normal and the Pathological in X-Ray Pictures," is the fifth edition of a contribution originally published in 1910. Such a record speaks for itself. Four of the editions have been limited to the German text ; we are fortunate on this occasion in having an English translation.

The real object of the book was well described in Professor Köhler's preface to the edition of 1910, " an adviser on those findings which exhibit or appear to exhibit slight and not particularly noticeable divergencies from the normal anatomical picture." It might be expressed as the borderline of disease as shown by X-Rays, and no one will deny or dispute the importance of drawing attention to this aspect of Röntgenology. In these days, when the importance of preventive medicine is receiving the attention it so obviously demands, the appearance of a book of this description is particularly welcome.

Perhaps the most outstanding feature of the book is the accuracy with which the details of the various changes are recorded, and it is evident that the author has spared no pains in investigating and elaborating the different aspects of the individual problems. Not content with his views and observations, an unusually full summary of the recent literature is appended to any disputed point, a feature which adds immeasurably to the value of the book from the scientific point of view.

I have been particularly interested in the type of illustration adopted.

At first sight it would seem that for a text-book of X-Ray diagnosis the number of X-Ray reproductions is unusually small. The observation is a true one, but the explanation is that Professor Köhler has replaced them by something of practically equal value, carefully detailed line drawings which, because of the ease of their reproduction, give accurate information of the outline of the part. When the necessity for an X-Ray reproduction arises such illustration is provided.

The book is a veritable mine of information : the normal processes of ossification are given in fullest detail, while rare anomalies and errors are illustrated and described. Each of the various systems of the body is considered. The excellent scheme of describing the normal is followed, and thereafter the various early changes which disease engenders are traced and demonstrated. I would say that it is difficult to conceive of any abnormality or early pathological change demonstrable by X-Ray which is not considered in this excellent treatise.

The work of the translator is never an easy one, but in this instance it has been accomplished in a most commendable manner. Nothing of the original spirit of the work has been lost ; neither idiom nor metaphor has suffered in the interpretation, and so we are presented with a translation which is both accurate and readable. Dr. Turnbull has to be congratulated on the way in which the responsible task has been accomplished. I do not profess ability as a prophet, but I shall be surprised if this volume does not meet with immediate and widespread approval ; it is certainly endowed with the virtues of a most successful treatise.

JOHN FRASER,
Regius Professor of Clinical Surgery,
Royal Infirmary, Edinburgh.

15*th September*, 1928.

INTRODUCTION TO THE ENGLISH EDITION

It required very little effort on my part to persuade my friend, Dr. Turnbull, to undertake the translation of the fifth edition of Professor Köhler's book "Grenzen des Normalen und Anfänge des Pathologischen im Röntgenbilde." The result more than fulfills my expectations and amply repays such advice and assistance as I have been able to give him. He is to be congratulated on a good translation of a good book. The first edition, published in 1910, at once became a standard reference work for Radiologists. In successive editions the scope of the work gradually extended until, in the fifth edition, we have a book which occupies a unique position in the literature of Radiology. The title of the English translation, along with the sub-title, clearly indicates the intention of the Author, who deals not only with normal but with the beginning of the pathological, and one might say that in the present edition he has gone some way beyond the beginning of the pathological. This book is a necessity for the student, who is taking out a course in Radiology with a view to a Diploma and is a welcome addition to the reference library of the expert, as it contains numerous references, and in the English Translation a number of the more important British and American references have been added. All those associated with this translation gratefully acknowledge the advice and assistance given by Dr. James R. Riddell, Radiologist to the Western Infirmary, Glasgow, and Dr. D. O. Macgregor, Superintendent and Radiologist to the Victoria Infirmary, Glasgow. The proofs were read by Dr. D. Campbell Suttie, Medical Superintendent and Radiologist to the Glasgow Royal Sick Children's Hospital, and one cannot emphasize too strongly the value of his assistance.

I feel sure that this book, which is the life work of Alban Köhler, will be appreciated by all Radiologists. It is a good book and, as Milton has written, "A good book is the precious life blood of a master spirit, embalmed and treasured upon purpose to a life beyond life."

J. M. WOODBURN MORISON.

Royal Infirmary,
Edinburgh,
10th August, 1928.

AMERICAN PREFACE TO THE ENGLISH EDITION

For more than a decade Alban Köhler and his book on the normal and borderline findings in radiologic practice have been familiar to every student in this field who has kept abreast of the German literature ; to such radiologists this work of Köhler's has been as indispensable as a standard work on anatomy to the student of surgery. And because theirs is such a relatively young branch of medical diagnostics, the need of such a guide and referee for radiologists has been specially marked.

Until within recent years, at least in English-speaking countries, the radiologist, on account of scarcity of set courses or special schools in X-Ray interpretation, has been obliged to learn in the school of experience, supplemented by such help as he could pick up here and there among established physicians devoting themselves to radiology. One is confronted by X-Ray appearances which are, to him at least, seen for the first time : and it is often difficult to find a satisfying explanation ; Köhler's monumental book supplies the data on which a decision may be safely based.

The English-speaking section of the world fraternity of radiologists will join in gratitude to the author and to the translator for making this valuable dictionary and atlas of radiologic criteria available in our own language. We feel certain that the book will find a very hearty welcome. It is needed not only by specialists in radiologic diagnosis, but by General Surgeons, Orthopedists, Urologists, Anatomists, Gastroenterologists, specialists in pulmonary diseases, as well as by physicians and lawyers whose work brings them in contact with problems of legal medicine. There is no other work in any language which contains all the facts pertaining to radiologic interpretation so patiently and painstakingly collected, digested and organised for ready and easy reference in this book. The commoner types of the normal in radiography are not so difficult to recognise ; and the frankly pathological appearances are almost dramatically striking. The difficulties are encountered chiefly in the discernment of atypical normals, and especially those borderline changes in conditions not yet definitely diseased. How many foolish actions would be avoided and unjust decisions righted by a sufficient dissemination of the knowledge of developmental appearances in the radiogram, the anomalies, the bifid spines, the divided sesamoids, the progressive changes in skeletal manifestations just as much to be expected with advancing years as grey hair, and numerous other anatomical facts as seen in the radiogram, a familiarity with which would at once exclude such findings as evidence of disease or injury ; we are reminded of a ridiculous damage suit over an alleged fracture of the spine, allowed as a just claim in a high court of law. The deciding testimony was that of a surgeon who declared the radiogram clearly demonstrated a fracture, whereas in reality what he saw was a long-standing hypertrophic osteoarthritis with huge osteophytes almost uniting the lumbar vertebrae into one bony mass ; and what he interpreted as fracture was in reality only a small island of calcification just separating two of the opposing bony outgrowths. Any radiologist of experience knows that such islands of lime deposits are frequently encountered in cases of osteoarthritis who claim no injury ; yet in this instance faulty evidence based on ignorance led to serious miscarriage of justice. Such wrong testimony would soon be branded as such if the knowledge laboriously hoarded up by Dr. Köhler from painstaking digestion of the radiologic literature of the last twenty years, had been available to English readers.

The writer at last sees realised the hope he has fostered for years that this valuable storehouse of facts on radiologic interpretation be made generally available to the medical profession of English-speaking lands.

JAMES T. CASE,

Professor of Röntgenology, North-Western University, Chicago.

BATTLE CREEK, MICHIGAN.

FROM THE PREFACE TO THE FIRST GERMAN EDITION

For doctors, who are beginners in röntgenology or have not yet sufficient experience, the work is an adviser on the diagnosis of those findings which exhibit or appear to exhibit slight and not particularly noticeable divergencies from the normal anatomical picture. For such cases there was no complete work in the Röntgen literature and the atlases of normal anatomy give only röntgenograms of the usual everyday typically normal conditions, while the atlases of pathological anatomy contain only pictures of very pronounced diseases, recognisable as such without any difficulty; whether, for example, a small bony process, an indentation, a roughness, a small translucency or opacity of the spongiosa structure, a thickening the size of a pea in the shadow of certain soft tissues are to be reckoned as belonging to the normal or to the pathological, is a question no one ever asks. To recognise and correctly diagnose these slight alterations is quite as important as, indeed more important than, the diagnosis of pronounced diseases; for the earlier a disease is diagnosed, the more successful can its treatment be. On the other hand we are enabled to avoid regarding quite normal findings as pathological ones, for example to mistake the fabella in the external tendon of the gastrocnemius for an articular body may result in operations harmful to the patient.

The book has the further purpose of preventing a structure accidentally projected into an area regarding which the patient complains—not necessarily a physiological condition, but still quite harmless—from being at once regarded as the cause of the trouble. This prevents mistakes in diagnosis.

Further, there have been added to the book physiologically important figures and tables which the röntgenologist must know or at least have immediately to hand, such as the size in centimetres of certain organs, the number and arrangement of the sesamoid bones, also diagrams of the many varieties of the bones of the hand and foot, also tables of the slight distortions of the heart shadow in teleröntgenography due to focal projection; further, in every part of the skeleton the order and time of appearance of the principal osseous nuclei are given.

The work may be regarded as a lexicon and not suited for systematic study. All the sections are treated with the greatest possible brevity.

ALBAN KÖHLER.

Wiesbaden,
September, 1910.

FROM THE PREFACE TO THE FIFTH GERMAN EDITION

A SHORT three years from the appearance of the fourth edition a further edition has been found necessary. It has been increased by 135 pages. The illustrations are not the most important in the work, they are only aids to the text.

In judging the illustrations reproduced in autotype one should consider that a great number of these illustrations were taken 20–25 years ago and do not show the completeness of technique that one can attain to-day. On the other hand they are of interest both to beginners and practitioners who believe the latest and most expensive instruments are indispensable for a good technique, for these illustrations, made of the most difficult regions (spine, stomach, intestine), have withstood the test and were taken with a 12-year-old high-tension rectifier.

I have not yet decided to take up certain particular methods of Röntgen diagnosis, such as insufflation of gas into the joints, pyelography, cholecystography, encephalography, myelography, seeing that in several of these the limits of the normal do not make their appearance.

I have agreed with the translator of the work to introduce such references to the separate articles in the footnotes from the English and American literature as were unknown to me or not obtainable. He has selected the most important of some 2,000 articles and introduced a selection of these into the footnotes.

A. KÖHLER.

WIESBADEN,
January, 1928.

The Fifth German Edition is inscribed to the famous ballad-writer and poet, Baron Börries von Münchhausen, Dr. jur., Dr. phil. h.c., by the Author.

The Editor desires to acknowledge the courtesy of Mr. Walter Hurst, Honorary Secretary to the Faculty of Physicians and Surgeons, Glasgow, and of Mr. David Willox, the Librarian.

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ABBREVIATIONS IN THE NOTES

Fortschritte = Fortschritte auf dem Gebiete der Röntgenstrahlen. Leipzig. Publishers: Georg Thieme.

Röntgen-Archiv = Archiv und Atlas der normalen und pathologischen Anatomie in typischen Röntgenbildern. Leipzig. Publishers: Georg Thieme.

Atlas I Grashey = Atlas typischer Röntgenbilder vom normalen Menschen. München, 4 Auflage 1917. Publisher: Lehmann.

Atlas II Grashey = Atlas chirurgisch-pathologischer Röntgenbilder. München, 1909 Publisher: Lehmann.

Atlas Groedel = Atlas und Grundriss der Röntgendiagnostik in der inneren Medizin, München, 3 Auflage, 1914. Publisher: Lehmann.

Rieder-Rosenthal = Rieder-Rosenthal: Lehrbuch der Röntgenkunde. Leipzig 1918 ff. Publisher: A. Barth.

Röntgen-Kongress = Verhandlungen der Deutschen Röntgen-Gesellschaft. Leipzig. Publishers: Georg Thieme.

Amer. Journ. of Röntg. = American Journal of Röntgenology. Herausgegeben von Hoeber-New-York.

Arch. d'Electr. Méd. = Archives d'Electricité médicale experimentales et cliniques. Bordeaux. Publisher: Hamel.

Soc. de Rad. Med. = Bulletins et Memoires de la Société de Radiologie médicale de France. Paris. Publisher: Steinheil.

Journ. de Rad. = Journal de Radiologie. Annales de la Société belge de Radiologie. Brussel. Publisher: Severeyns.

Revista Espan. Rad. = Revista Espanola de Electrologia y Radiologia Médicas. Publishers: Calatayud, Valencia.

Radiologia med. = La Radiologia medica. Rivista mensile. Organo Ufficiale della "Societa Italiana di Radiologia Medica." Pavia, Mattei & Co.

Lehrbuch Schittenhelm = Lehrbuch der Röntgen-Diagnostik (Enzyklopædie der klinischen Medicin, von Langstein v. Noorden, Pirquet u. Schittenhelm). Berlin. Publisher: Julius Springer, 1924.

Leitfaden Gerhartz = Leitfaden der Röntgenologie. Berlin. Publishers: Urban & Schwarzenberg, 1922.

The Journ. of Rad. = The Journal of Radiology, published by the Radiological Society of North America; Omaha, Nebraska.

Arch. Roent. Ray = The Archives of the Roentgen Ray. London.

Brit. J. Rad. = The British Journal of Radiology. William Heinemann, Ltd. London.

FOREWORD

In no single instance can the Röntgen findings be regarded as absolutely authoritative. With every statement one should bear in mind the proviso: "Provided the anamnesis and the clinical findings favour, or at least do not oppose."

Indications for the Use of the Book.

Begin by looking up in the Index of Contents at the front the particular organ, bone or part of the body on which information is desired. Look up the page and run the eye from paragraph to paragraph, along the italicised words, till you find what you are after. Then refer in the paragraphs, above and below, to complete the inquiry. If you do not find what you are looking for, read the list of the Contents again, in case it is under another heading. Further, refer to the Index at the end of the book. If this search be also fruitless, then go through the "General Part," in pages 1–13; in most cases this will achieve one's purpose. In order that several pages or whole chapters should be gone through as quickly as possible, the principal words of every article are printed in italics.

Illustrations are added by the author only when they are indispensable to an exact understanding.

In accord with the lexicon-character of the book the whole literature of every reference is not included, but usually the most important recent works, especially those that are complete and contain lists of the literature; in a word, the references to the literature are made from the standpoint of giving each inquirer facts suitable to his question, and to the purposes of further research.

Hints for the Concrete Study of a Röntgen View.

Estimate every film from the negative, not from the print; the latter at the best is only an extra aid. The worst film is always better than the best copy. Viewing boxes with ground glass and direct irradiation are quite inadequate for the recognition of finer details. The best are the boxes with indirect light. For the better recognition of small shadow differences, the best way is to stand well back, and also to view the film from the sides, that is obliquely to the line of vision.

If one does not possess a viewing box:—The film should never be held direct against a source of light, but should be examined against a uniform illuminated background. The sky, uniformly clouded or unclouded, is the best for this purpose, or pure white paper on which bright daylight or artificial light is falling.

It is possible at times to put a ground-glass at the back of the film and hold it up to direct light or the sky, but this is of use only in grosser pathological findings.

Very pale, so-called flat negatives should be laid upon white paper, pressed, best in a printing frame, and so inspected.

RÖNTGENOLOGY

LIMITS OF THE NORMAL AND PATHOLOGICAL DIAGNOSIS

GENERAL

Bones, Cartilages, and Articular Capsules

Cartilaginous parts of the body that are neither calcified nor ossified cannot be clearly differentiated from the soft tissues in a Röntgen plate.

In normal skeletal growth the osseous centres do not manifest the *first signs of calcification* symmetrically, that is, simultaneously on the two sides.

The most careful investigations have shown beyond a doubt [1] that people equally advanced in health and characteristics do not develop the various *osseous centres* in anything like the same order; some nuclei are quicker, others slower in development. One ought never to base a judgment upon the degree of development seen in a single osseous centre or in a single bone. Thus the nuclei present at a certain stage of development in the os calcis, capitulum radii or olecranon may be entirely absent, although they are quite conspicuous in most cases at an earlier stage of growth. The order of appearance of the ossific nuclei in the carpal bones appears to some extent to be a hereditary characteristic.[2] The great variability in their order of appearance is explained by differences in the inherited fixed types of the ossification process. Thus in the five children of one family the order of ossification was: Cuneiform, Semilunar, Scaphoid, Trapezoid, Trapezium; while in four children of another contemporaneous family the following was the sequence: Cuneiform, Trapezoid, Semilunar, Scaphoid, Trapezium.

Further, one cannot infer the stage of growth of the entire bony framework from the growth of any single part of it. The skeleton of the hand, for instance, can be less ossified in one case than in another, whereas the foot and elbow bones in the first case may be more highly developed.

[1] Åke Åkerlund: Entwickelungsreihen in Röntgenbildern von Hand, Fuss und Ellenbogen im Mädchen- und Knabenalter. Röntgen-Archiv, Band 33, 1918.—P. Sessa and O. Alberti: Atlante rad. dello sviluppo delle ossa delle estremità. Bologna, 1922.—Bundy Allen: The development of the ossification centers of the skeletal system. Radiology, 1926, VII, 398–409.

[2] K. R. Schinz, Zürich: Vererbung und Knochenbau. Schweiz. medizin. Wochenschr., 1924, 50–51.

Generally a more advanced ossification is present in those of stronger constitution (*cf.* bones of the wrist).

In the *girl*, the process of ossification is more rapid than in the boy. This is apparent even in the first five years of life, with a difference of from one to two years in the appearance of the osseous centres. Briefly stated: In the female the osseous nuclei appear earlier and while the body is smaller than in the male, and the osseous primitive-formation is completed in a shorter time. The union of epiphyses and apophyses with the diaphyses takes place earlier in the female; for example, in the female toe-phalanges it takes place between fifteen and seventeen years of age, in the male from seventeen to twenty-two years, that is, at the time of maturity of each sex. Further, in small individuals the period of union is retarded, being accelerated in tall people.[1] Some writers aver the process takes place first of all in the first metacarpal epiphysis and as early as in the sixteenth year.[2]

Interruption of epiphysial fusion, or protracted disunion of the epiphysial line, is a direct consequence of want of development of the genital organs, eunuchism, infantilism, constitutional hypoplastic anomaly, pluriglandular insufficiency, disease of the hypophysis and thyroid glands, and some forms of dwarfism. Protracted disunion between shaft and epiphysis is a feature of each and all of these conditions; in eunuchism there is in addition a disproportion of the skeleton, conditioned by a hypophysis reaction to the stimulus of castration.[3]

Röntgen photographs show a series of transitional forms between an underdevelopment that is within normal limits and a stage of pathological dwarfism.[4]

The *epiphysial plates* exhibit in the skiagram only a straight band of light, when they are in line of the rays; when the plates and the rays are at an angle, on the other hand, an irregular and etched view is obtained, according to whether the angle at which the rays meet the cartilage is large or small, and according to the amount of curving in the epiphysial plates themselves (*e.g.* in the femur and the tibia at the knee). Articular cartilage and fractures of bone show a similar appearance.

Isolated *persisting pieces of cartilage* are sometimes found, most frequently at the distal end of the radius. The decision from a suspected case of fracture should not be difficult. To be quite certain, take a photo-

[1] Hasselwander: Die Röntgen-Strahlen in der Anatomie. Lehrbuch Rieder-Rosenthal. 2. Band, 1918.—Holmgren, quoted by Hasselwander.

[2] Fischer, Heinrich: Beziehungen der inneren Secretion zur Genese einiger im Röntgenbilde praktisch wichtiger Skelettvarietäten. Fortschritte, Bd. 29, 1922.

[3] H. Fischer, *l.c.*

[4] A. Hasselwander: Die Bedeutung des Röntgenbildes für die Anatomie. München-Wiesbaden (Bergmann), 1921; with complete literature.—Hasselwander: Untersuchungen über die Ossification des menschlichen Fuss skeletts. II. Der Abschluss der Verknöcherungszone. Zeitschrift fur Morphol. u. Anthropol. Bd., 12, 1910, p. 1.—H. A. Harris: Some problem of bone growth. Proc. Roy. Soc. Med., Vol. XVII, No. 12, October, 1924. Section Electrotherapeutics, p. 35.—R. A. Currie: Case of the Charcot-Marie-Tooth type of muscular atrophy with a note on the conditions of the bones. Glasg. Med. J., January, 1927.—W. Rankin: On osteomyelitis in childhood. Glasg. Med. J., April, 1927.

graph of the other side, for persistent nodules of the cartilaginous plates are usually bilateral.

At the point where the epiphysial plates existed during the period of growth, a thick line appears within the bone years after the completion of ossification, the so-called *epiphysial scar*.

The *contours of growing bones* in some skeletons are not smooth even under normal conditions, but irregular, rough, and notched (*e.g.* the acromion, the glenoid facet, the distal epiphyses of the humerus, the calcaneus).

If we are in doubt whether we have a *fracture*, an infraction, or an articular foreign body, or whether we are dealing with supernumerary bones, sesamoid bones, and similar varieties, we should look to the other side, for varieties are often symmetrical or equally well marked at the two sides, and the variation may be at least indicated.

An epiphysial centre can also occasionally fracture, a fracture that may not be at all easy to diagnose.[1]

Regarding the *inconstant skeletal parts* we may remark that their number increases with age,[2] that they are frequently found in cases of arthritis deformans and other arthritic lesions, that they are without a doubt ætiologically related to arthritis deformans and trauma, and that they almost always exhibit in arthritis deformans definite variations from the normal.[3] It may therefore be taken that cartilage cells delayed in development and not utilised can be brought into further growth by trauma or a compensatory chronic stimulus. Such a stimulus can emanate from the hypophysis, whose relation to the growth of bone is an established fact. Thus one observer saw the appearance of supernumerary carpals and tarsals in two cases of acromegaly.[4]

Within the cancellous tissue of at any rate those bones laid down in cartilage there not infrequently appear extremely dense shadows, usually oval and about the size of a pea. They need never occasion any trouble. They are the so-called *Compact-Islands*.[5] They are most often noticed incidentally in examining the bones of the carpus and tarsus and appear to form most frequently at the points where a crossing of bony trabeculæ takes place. They are apt to be mistaken for pathological lesions of the bone.[6] In the vicinity of the epiphysial lines these compact formations partake more of the appearance of streaks than of islands: the latest interpretation is that these are broken-off cells of the epiphysial cartilage that have ossified later and are referable to disturbances in the genital function. Although this view would require to be confirmed by further Röntgen work, these compact-streaks can be regarded as a sign of persistent

[1] F. Kautz: Isolierte Epiphysenfractur am Finger. Fortschritte, Bd. 31, 1923.

[2] Heinr. Fischer: Beitrag zur Kenntnis der Skelettvarietaten (supernumerary carpals and tarsals, sesamoid bones, compact islands). Fortschritte, Bd. 19, 1912.

[3] Probably first mentioned by the author, see p. 73 of the 1st German Edition of this book.

[4] Heinr. Fischer, *l.c.*

[5] A. Stieda: Über umschriebene Knochenverdickungen im Bereich der Substantia spongiosa im Röntgenbilde. Beitr. z. klin. Chirurgie, Bd. 45, Heft 3, 1905.

[6] Heinrich Fischer, *l.c.*

hypogenitalism, with which there may be associated skeletal disproportion and a condition of transitional eunuchism. Definite inferences can thus be drawn as to the constitution of an organism. At all events the amount of delay and interference of epiphysial fusion seems to proceed parallel with an underfunction of the genital glands. How far the remaining compact-islands (in the small bones of the foot and the hand) are dependent upon a hypogenital or other internal secretory disturbance is a matter not yet determined.[1]

Generalised disturbances in the growth of the skeletal tissue are best exhibited at the distal ends of the radius and ulna, at the distal end of the femur, and at the spheno-occipital suture. In rickets especially there is delay in the appearance of the osseous nuclei. In myxœdema the osseous nuclei are much retarded. In mongolism their appearance is very irregular, some of the nuclei appearing up to time, others being delayed, others appearing before their time. (Refer also to the bones of the carpus.)

If an epiphysis be suspected of disease and the bony centre found to be larger on the affected than on the sound side, *tuberculosis* is the possible cause; for though the nuclei usually ossify equally on the two sides, a tubercular irritation hastens, at any rate at first, the process of ossification.

Small thorn-like projections of the bones at the level of the former epiphysial lines or somewhat on the distal side thereof suggest a *cartilaginous exostosis*. The other limb should then be examined, for in multiple cartilaginous exostoses the outgrowths on the other side are well and clearly marked. (Large cartilaginous exostoses are not difficult to recognise. In them there exists a direct continuity of osseous structure from the shaft of the bone.)

Fractures in the epiphysial lines, that is, true epiphysial separations, are extremely rare, thus if an epiphysial nucleus does not appear to fit exactly on to the bony diaphysis, *e.g.* at the distal end of the humerus, the condition may be quite a normal one, as a control negative of the other side will reveal. But in the event of that not being found, the conditions relative to each of the different parts of the skeleton have been thoroughly described and explained by means of sketches. Fractures occur more often *near* than *in* the epiphysial line; or they follow the epiphysial line for a short way and then run into the diaphysis.

It may happen that *the sesamoid bones* are divided into two or more parts, and so may simulate fractures (*cf.* pp. 17 and 18).

Periosteal thickenings are possible in all the bones of the extremity, in the form of a *generalised hyperplastic periostitis*. They are especially distinct in the proximal phalanges and in the metacarpal bones of persons (usually males of from twenty to fifty years) suffering from chronic lung-affections associated with purulent inflammation or disintegration of tissue, bronchiectasis, purulent bronchitis, gangrene consequent therefrom or from other causes, empyemas, and—less frequently—in cases of chronic phthisis. The middle and terminal phalanges may be entirely free from

[1] Fischer, Heinrich: Beziehungen der inneren Secretion, etc. Note 2, p. 2.

the hyperplastic process. Phalangeal hyperplasia is also found in cases of valvular cardiac disease and in malignant tumours of the lung. (The absorption into the body of the products of decomposition gives an impetus to the formation of bone, especially in the long and short medullary bones.) Similar changes occur in the bones of the other side. (Bulbous hypertrophy of the phalanges affecting the soft tissues may accompany or precede the osseous changes.) Bony changes in the metacarpus and metatarsus are to be regarded as pathological.[1]

The röntgenogram may appear quite normal after severe contusions and also after replacement of luxations; but on a similar view ten weeks later many highly pathological changes may be visible. *Capsular-bands, pieces of periosteum, and tendon insertions* may all have been torn at the time of the injury, ossification has ensued in the interval and the tissues have become visible (for wherever there is connective tissue, there bone can form, provided the two other components, necrosis and deposition of lime, are present).

Marked *atrophy* (lack of calcium) of the longer bones is very seldom the direct consequence of inactivity; in about four-fifths of all the cases it is a sign of an acute or subacute inflammation, or it has occurred reflexly after fractures and other injuries. If the spongy tissue of the bone exhibits an irregularly mottled appearance, while the cortex is as thin as a pencil line, that is the highest degree of an *acute atrophy of the bone;* if there be no fracture or severe injury, this atrophy is a sign of commencing tuberculosis, acute osteomyelitis, or gonorrheal arthritis; it is never met with in syphilitic cases, nor in arthritis deformans. Senile atrophy of bone in comparison to this acute atrophy is relatively slight and is usually homogeneous, *i.e.* without mottling or marbling.

Typical, non-purulent, sterile, *necrotic lesions* in the whole osseous system, that affect also the ossification centres and thereby can hinder their growth, were observed in two cases after small-pox.[2]

About twenty cases have been reported of numerous dense spots of the size of lentils scattered in the whole skeleton, with the exception of the vertebral column, the bones of the skull, the shoulder-blades, the clavicles,

[1] An extremely good Röntgen picture is found in Sielmann: Periostitis sämtlicher Extremitätenknochen bei Empyem nach Schussverletzung. Fortschritte, Bd. 25, 1917. With numerous illustrations by Eugen Fraenkel: Über allgemeine Periostitis hyperplastica (Osteoarthrophiante hypertrophiante pneumique). Fortschritte, Band 25, 1918.—O. Schirmer: Beitrag zur Kenntnis der Akropachie. Wien. Arch. f. Inn. Med. 5. 2–3, p. 345.—C. Gouldesbrough: Pulmonary osteoarthropathy. Arch. Röntg. Ray, 1913, 18, p. 208.—See also Giles, Boston: Röntgen examination of non-luetic periosteal diseases of bone. Am. J. of Röntg., August, 1923.—P. E. Puschin: Fortschritte, Bd. 35.—H. K. Taylor: Periosteal changes in a case of lymphatic leukæmia. Brit. J. of Rad., 1926.—A. Keith: The true nature of multiple exostoses. Brit. Med. J., December 27, 1919, p. 847. Also Journ. of Anat., LIV., p. 101, Studies on the anatomical changes which accompany certain growth-disorders of the human body.—G. H. Edington: Spongy exostosis of the long bones. Glasg. Med. J., May, 1923.

[2] Cathcart, El Paso: Dystrophy of the bones in small-pox. Am. J. of Röntg., March, 1924.—An article on carcinosis to skin, glands, pleuræ, clavicle, skull, vertebræ, long bones of limbs, liver, lungs and kidneys, with metastatic fractures of clavicle, humerus and femur: see George T. Beatson. Brit. J. of Surg., Vol. XII, No. 47, 1925.

and the knee-caps.[1] They were found accidentally and were described as harmless appearances. The lesions are placed with their long axes in the long axis of the affected bone. The whole Röntgen negative looks sprinkled with them. The size of the spots varies between 2–3 mm. and 4–5 mm. They are thickest in the spongiosa of the epiphyses of the long bones, while the central diaphyses are free. In all these cases the distribution of the spots resembles that described by Lexer as typical tuberculosis hæmatogenes ossium : a condition arising from a bacterial embolism of the small end-arteries of the spongiosa. The distribution of the spots in the bones of the skeleton seems to coincide with the embolism points of the end-arteries. Nature appears to offer us in this anomaly a view of the narrower passages of the circulation within the bones. The following names have been suggested for this condition : *Osteopoikilia, ostitis condensans generalisata* and *osteopathia condensans disseminata, osteosclerosis fragilis generalisata. Spontaneous fractures* are usually the principal feature of the disease. Enlargements of the liver, spleen, and lymph glands may be present. Anæmia is generally present, and is the cause of death in cases that end fatally. Extensive calcifications of the soft tissues are also found. In one instance the disease affected three sisters (children). Remarkable pictures were obtained showing broader or narrower bands of calcium at the diaphysial ends of the metatarsals, the metacarpals, and the phalanges (possibly due to remissions of the pathological process). In later stages necroses of the jaws were in several instances found present, invariably associated with dental caries. The disease appears to be a congenital one, at any rate in one case the changes in the bone were well in evidence in röntgenogram as early as the eighteenth day after birth. Exogenous toxic injuries do not seem to be the cause, any more than a syphilitic ancestry. One author considers the disease develops upon the basis of a rachitic osteomalacia. Others dispute that interpretation and seek the cause of the disease in an abnormal calcium-metabolism in intrauterine life continued into post-natal life. In a recently described case [2] this marbling disease of the bone was found accidentally in a fracture of the os calcis in a doctor of thirty-four years, who was otherwise " quite healthy, stout, and strong." The only remarkable thing was his relatively high lymphocytic

[1] Albers-Schönberg: Eine seltene, bisher nicht bekannte Structur-Anomalie des Skelettes. Fortschritte, Bd. 23, 1915.—Ledoux, Lebard, Chahaneix and Desanne, further Laurent-Moteau: Journ. de rad. et electr., Bd. 2 and 3, 1916, 1917.—H. Wachtel: Über einen Fall von Osteopathia condensans disseminata. Fortschritte, Bd. 27, 1920.—Laurell and Wallgren: Untersuchung über einen Fall einer eigenartigen Skeletterkrankung (Osteosclerosis fragilis generalisata). Upsala hältare förennings förtandlingar, Bd. 25, Heft 5–6.—Lorey and Reye: Über Marmorknochen (Albers-Schönbergsche Krankheit). Fortschritte, Bd. 30, 1923.—Fr. Schulze, Arch. f. klin. Chir., Bd. 118, p. 411.—William G. Alexander: Amer. J. of Röntg., X, 4, April, 1923.—Clairmont and Schinz: Arch. f. klin Chir., 132/3.—N. Voorhoeve: L'image röntgenologique non encore décrite d'une anomalie du squelette. Ses rapports avec la dyschondroplasie et l'osteopathia condensans disseminata. Act. Rad., 1924, No. 15.—Rolla G. Karshner: Osteopetrosis. Am. J. of Röntg., November, 1926.

[2] A. Schell-Lund: A case of a rare skeleton anomaly. Acta-Radiologica, Vol. I, 1922. (With very good pictures.)

count and a low blood-pressure. With one or two exceptions the diaphyses were free. The spots were found in clavicle and scapula, in knee-cap and spinal column. The best name for the disease is to call it the *Albers-Schönberg disease* after its discoverer.

A quite recent work states [1]: The Albers-Schönberg disease is a locally conditioned disturbance of the primary bone-marrow in the sense of a constitutional systemic disease. It appears to have close relations to leukæmia with osteosclerosis.

Sclerosed areas of bone reveal no cancellous architecture even with very hard tubes, and negatives of sound bones taken with very soft rays that do not penetrate the bone may simulate sclerosis.

Pus within the bone cannot be recognised (and in the soft tissues only under extra favourable circumstances). Yet where pus is present, breakdown of the bony tissue is present too, and the presence of pus can hence be inferred with a strong measure of certainty. The same applies to tuberculous granulations.

In contradistinction to myelogenous sarcomata the *periosteal sarcomata* are often hardly to be seen in the skiagraph in their early stages (see later the sketch and description of such a tumour of the femur).

The joint-cavity in a Röntgen plate corresponds to the articular cartilage. Diminution of the line of the joint corresponds to erosion of the cartilage or shrivelling of the cartilage. Broadening of the line indicates under certain circumstances the presence of an intra-articular *effusion*. Small articular effusions do not appear in Röntgen rays: moderate-sized effusions may appear with certain conditions, *e.g.* projection forwards of the patella.

Minute sharpening, pointing, and edging at the margins of the articular surfaces are one of the earliest signs of a commencing *rheumatoid arthritis* (see the illustrations of the knee-joint).

If a *foreign body* (" joint mouse ") be suspected, a negative Röntgen finding proves nothing, for joint-bodies in the majority of instances are of a purely cartilaginous nature. Shadows resembling articular bodies in cases of chronic arthritis originate mostly from bony deposits in the articular capsule: rarely from free intra-articular pieces of bone or ossified articular bodies. A free body can be distinguished from a localised ossification by taking several photographs from the same angle and seeing whether the body stays in one position or changes its position: the joint being thoroughly moved between the different exposures.

If on one and the same plate a part of a joint is more translucent than the similar joint on the other side, this is often a sign of *commencing articular tuberculosis*. One finds this condition most frequently with commencing coxitis.

Shadows of calcareous concretions in the vicinity of a joint, but not corresponding to the outline of the articular cartilage, can arise from a *calcified synovial membrane*.

[1] Erich Joh. Kraus and Arno Walter, Prague: Zur Kenntniss der A.-Schönbergschen Krankheit. Med. Klin., 1925/1.

Deposits of uric acid in the neighbourhood of gouty joints are not distinguishable in Röntgen plates. Gouty affections of large joints do not appear to exhibit any particular characteristics in the negative. But gouty deposits of uric acid in the ends of the small bones of the joints of the hand and foot, often give very definite pictures (see in addition drawing and text in Fig. 2 C. and Fig. 7).

Long, straight, or slightly wavy translucent streaks in the shadow of the bones or of the kidneys are due to *creases of the skin* or to intermuscular fatty tissue. They are recognisable in that they extend beyond the shadow of the bones or that of the kidneys.

Healthy *periosteum* does not show up in a skiagraph, even when it is raised from the bone by blood or pus; it is only when it begins to ossify that it is recognisable as a narrow dense line.

Places in the bone shadows that look as if they had been erased out with eraser (in rickets, late rickets, osteomalacia, starvation-diseases of the bone, etc., also in conditions in which the resistance against mechanical demands is much reduced), are the so-called *transformation zones of Looser*. They are not fractures, displacements, or cracks in the bone. At the affected spots there is *a transparency traversing usually the whole bony shadow transversely or obliquely*, giving one the impression as if there were a solution of continuity; in some other cases the transparencies are more patchy in form. Clinically these spots do not attract attention by any pronounced subjective or objective symptoms, they are seen first in the röntgenogram, and the tissues around are only slightly more sensitive to pressure. Examination of these places often shows nothing abnormal beyond perhaps a slight flexibility with tenderness, or even some pain on pressure. Marked abnormal mobility or crepitation is never found at these places. In late rickets and osteomalacia the slightest degree of these infractions is seen at the convex side of curved bones as a little local transparency of the thin corticalis. Upon closer view there is seen emerging from the corticalis a very narrow bright radiating transparency running across or obliquely through the bone, sometimes reaching as far as the opposite corticalis. Occasionally these transverse or oblique transparencies may be eight or more millimetres broad. The transparency can be so well marked that we might think we were dealing with a complete defect in the bone. Changes may also be seen at the periosteum in the presence of more or less opaque deposits. The transparencies occur both in curved and straight bones, and lateral displacements of the bony fragments are never seen, as are to be expected in real fractures. A history of definite trauma is therefore almost always absent. The sharply dentated edge of the fragments, nearly always visible in actual fractures, are here wanting. The zones of transparency should really be included in the infractions. Upon microscopic examination the discoverer found that at points of curvature the old laminated bone disappears by lacunar absorption, being replaced at the same time in the marrow (always fibrous in these areas of irritation) by mottled bone devoid of calcium to begin with: in other words that under the action of the traumatic influence of a bending there takes place a transformation of the bone ; hence "Transformation zones." [1]

Soft Tissues

Remains of earlier *iodoform-glycerin injections* can simulate a bony foreign body ; the same applies to iodipin, and even dermatol throws a definite shadow. In puzzling shadows of the soft tissues these medicaments have to be thought of, and *salvarsan* too, and the patient at once interrogated. When these are not in question we have then to consider calcified fatty lobules, osteomata, calcified tumours of the skin, calcified subcutaneous granuloma, calcareous varices and phleboliths, finally calcified parasites.

The *halogens* give a striking röntgenogram, and hence also sodium chloride injections, as used for sciatica.

Fluids from discharging fistulæ may reach the surface of the plate and appear on the negative as misleading bright spots, that have been mistaken for sequestra and foreign bodies. This mistake can be recognised by viewing the surface of the plate obliquely. In doubtful cases a second negative should be taken, with the glass side of the plate uppermost.

Adhesive plaster and clothes that have not been turned back sufficiently may occasion definite shadows that may sometimes lead to errors in diagnosis.

Even many years after *inunction treatments* small quantities of confluent mercury, as large as a lentil, can be demonstrated in the subcutaneous tissue. One should always think of that possibility, when one finds a few circular or oval shadows of a metallic density directly under the epidermal surface, and not at a deeper level.

When puzzling shadows of a *bony* density are found in the region of the muscle, one should envisage the possibility of calcified trichinæ and cysticerci. For *Cysticerci*, which measure 2–4 mm. broad and 7–12 mm. meter, see more fully later under "Soft tissues of the knee." They have hardly ever been radiologically diagnosed on the living patient, only on anatomical preparations. *Progressive myositis ossificans* in its early stages also yields quite definite shadows in the region of the muscles ; [2] it appears symmetrically on both sides of the body, and is regularly associated with microdactyly in the thumbs and big toes.

When dealing with osseous shadows in the region of the skin we have to consider calcified multiple atheromata, calcified epitheliomata of the fat

[1] E. Looser, Zürich : Über Spätrhachitis und Osteomalacie. Klinische, röntgenologische und pathologische Untersuchungen. D. Ztschr. f. Chirurgie, vol. 152, 1, sections 1–6, 1920.

[2] Krause and Trappe : Ein Beitrag zur Kenntnis der Myositis ossificans progressiva. Fortschritte, Bk. 11, 1907 (with complete literature up to 1907).—Caronia : Su di un caso di miosite ossificante progressiva. La Pediatria, fasc. 3, 1918.—Weglau : Beitr. z. klin. Chir., Bd. 126, H.2/3, p. 432.—Wiesenthal, Vienna : Ein neuer Fall von Myositis ossificans progressiva. Ztschr. f. orthop. Chir., 45, 3–4, p. 608.—Westmann, Karlstadt : Ein Fall von Myositis ossificans. Acta Rad., III, 1.—Fritz Schulze : Über Calcinosis interstitialis. Arch. f. Klin. Chir., 136/2.—S. G. Scott, London : Charcot's joint associated with myositis ossificans. Arch. of Rad. and Elec., 1917, 21, p. 239.

glands, calcified sweat-glands, and calcareous deposits in skin affected by tuberculosis. All these conditions are distinctly rare and can usually be readily enough diagnosed without the aid of the rays. Also in other rare skin conditions bony platelets are found in the skin.

In the subcutaneous tissue, and occasionally deeper, calcium deposits may appear. Not more than a dozen cases are recorded in the whole medical literature. The film shows little groups the size of a lentil or almond of bony density and punctate or streaky in appearance; they are situate in the hand, especially at the tips of the fingers, on the dorsum of the forearm, in front of the patella, also in other parts of the body especially near the joints. In this we are dealing with so-called epidermal stones, hypodermoliths, gout stones, petrification of the skin.[1] They are quite distinct from ordinary gout. The deposits are composed of phosphate of calcium, are developed slowly, without inflammatory reaction, without swelling of the neighbouring lymph-glands, and are occasionally accompanied with vaso-motor, trophic and sensory disturbances. In the prints published of the hand atrophy of bone is clearly visible. The disease was recognised and described as early as the middle of the seventeenth century. It is difficult or impossible to describe the characters of the Röntgen shadows in the earliest stages of these cutaneous conditions (when they are well advanced they scarcely require a plate to make a diagnosis, and the description is outside the scope of

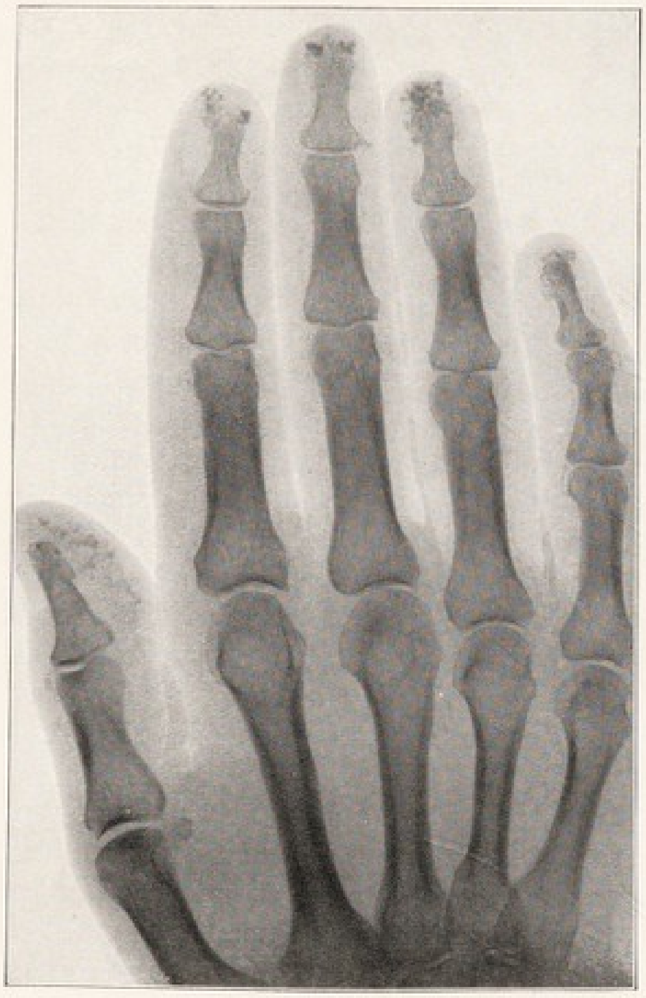


Fig. 1.

[1] Proficher: Pierres de la peau. Thèse de Paris, 1900.—Aristide Busi: Di un caso della malattia che va sotto il nome di "pietre della pelle." Bulletino delle Scienze mediche di Bologna 1907 (with list of the literature).—Eugen Holländer: Kalksteingicht. Deutsche mediz. Wochenschrift, No. 14, 1917.—Umber: B. kl. W. 1921, No. 32.—H. Fock, Abo: Ein Fall von Kalkablagerungen unter der Haut, oder sogen. Kalkgicht. Acta med. Scandin., 1926/65/1–2, p. 169.—Guhrauer: Beitrag zur Frage der Kalkansammlungen in der Haut. Dermat. Wschr., 1925/4.—Fritz Schulze: Über Calcinosis interstitialis. Arch. f. klin. Chir., 136/2.—J. R. Logan: Unusual calcareous deposits in the soft tissues of the hands. Arch. of Rad. and Elec., Vol. 28, July, 1923.—T. M. Woodburn Morison, Edinburgh: Gas in the tissues. Arch. of Rad. and Elec., December, 1915.

this work). According to the work of the pathologists the condition of "gout-stone" is identical with the chronic calcification of the media in old age.

Similar shadows to those cast by hypodermoliths are the *phleboliths* of the extremities (for abdominal phleboliths, see "Pelvic markings," "Ureter," and "Pelvic soft tissues"). But phleboliths in the arm and leg are not nearly so common as in the abdomen. They are often related to *hæmangioma* of the muscles and in multiple subcutaneous cavernous hæmangiomata where large numbers of them may appear. Such hæmangiomata, however, are known to be extremely rare. The characteristics of the Röntgen shadows are: (1) its sharply delimited and mostly rounded form, (2) its isolated and usually irregular position, (3) the size varying from that of a just visible spot to that of a bean, and usually about the size of a pea. In the larger and less opaque forms a concentric stratification can often be observed.[1]

Calcification may supervene upon *laparotomy scars*. These give a shadow on the röntgenogram, and give rise to gross errors in diagnosis, if one forgets their possibility.[2]

There are other *deposits of lime* in the tissues that cause a greater or less shadow according to their size and their thickness in the path of the rays. The pathological textbooks make mention of calcification in fibrinous exudates and thrombi, in thickened caseous exudates, in hyaline masses, *e.g.* blood vessels showing hyaline change, in psammomata, after fatty necrosis from the action of the pancreas, in old infarcts and necrotic epithelium, in elastic fibres, in the tunica propria of glands, and in the layers of the connective tissue.

In shadows in the pelvis resembling teeth one must consider the possibility of a dermoid cyst.[3] In one photograph even the root canal could be seen.

Specially translucent areas in the shadows of muscles (dark in the negative) may be due to gas-containing abscesses or interstitial emphysema, if the clinical evidence be confirmatory.

Pus in the soft tissues, as already mentioned, gives a shadow only now and then, and in favourable circumstances, as when gas in the intestines or a fatty envelope make a clear picture of the area possible. But old chronic pus-lesions with calcareous particles are easily recognisable.

The same applies to *tumours of the soft tissues*. Lipomata are sometimes quite clearly demarcated from the surrounding denser tissues. In the thoracic cavity the great majority of soft tissue tumours can be

[1] E. Fabian: Über Phlebolithen. Fortschritte, Bd. 27, 1920 (with complete list of the literature).—Sträter: Vorweisung seltener Röntgenbefunde. a. Multiples, subcutanes, cavernöses Hæmangiom mit zahlreichen Phlebolithen. Fortschritte, Bd. 30, 1. Kongressheft 1922.

[2] See also Nierendorf: Knochenbildung in Laparotomie-Narbe. Inaugural-Dissertation, Würzburg, June, 1916.—Further Häbler: D. Zschr. f. Chir., 181, 1–2, p. 140.

[3] H. Laurell: Ein Beitrag zur Röntgenologie der echten Mischgeschwülste des Rumpfes. Acta Radiologica, Vol. I, 1922.

differentiated from the more translucent pulmonary tissue. In the organs where contrast methods are employed tumours show a defect with irregular contours of the pharynx, œsophagus, stomach, or bowel.

Vessels in their normal state are not distinguishable, with the exception of the aortic arch and the pulmonary vessels. But the channels of some of the blood vessels within the bones are plainly visible.

Arteriosclerosis with calcification renders the vessels clear and distinct. If not calcified the only one that shows up is the posterior tibial artery where it crosses over the calcaneus. On the other hand, calcified coronary arteries have never yet been observed.

For arteriosclerosis in young children, see " Forearm : distal end."

Very small projections of *the skin*, tumours of the skin, nævi, soft warts, sometimes give remarkable pictures and are the cause of trouble in diagnosis (they may be pressed by the plate into the skin layers, with a ring of air round them). If they pass unnoticed, it is easy to mistake what is a surface shadow for an internal one.

In large *survey plates* of the abdomen and in dorsal views of the pelvis of stout people, without the use of the diaphragm and before the introduction of the Potter-Bucky diaphragm, there often appeared a large circular or oval area (bright in the negative and dark in the positive), which together with the clinical findings and the result of palpation was taken for a tumour-shadow ; this was quite a mistake. This large shadow is nothing more or less than the exact area of the body in direct contact with the plate or cassette, while the surrounding area appears darker owing to the smaller body diameter in the line of the rays at this point, and perhaps in consequence of a contrast-effect it makes an exaggerated impression of darkening. In the author's recollection there was the reference from the medical radiological side about the year 1905, that the surrounding darker areas of the plate were due to the increase of secondary radiation from the air between the body and the photographic plate. Such an effect is physically unthinkable, for the density of the air there (at 0° Centigrade and 760 mm. of pressure) amounts only to a thousandth-part (reckoning water and blood at 1), and therefore its absolute absorption and equally its absolute scattering is only one-thousandth part as much as that of blood and water. Hence the scattered radiation from the air cannot apply to the diagnosis ! [1]

Abrasion marks on the surface of old intensifying screens simulate " shadows." And if the screen is not pressed in absolute contact with the film, faded marks may ensue, that are particularly deceptive in negatives of the lungs.

Personal adornments should always be discarded before screening or filming. That advice is often given in the literature, yet not always enacted in practice. There are röntgenologists of great experience who believe it impossible to be deceived by the shadow of a metallic body. But that is correct only when the adornments and the metallic bodies are situate

[1] Private communication from Prof. Küstner of Göttingen.

on the plate and not on the tube side. A necklet on the side away from the plate is not likely to lead to error in diagnosis, although it is always preferable to remove them prior to an examination because they are in the way. An ear-ring can, however. The following case illustrates that possibility. In taking the usual oblique photograph of the lower jaw the röntgenologist did not deem it necessary to remove the ear-rings. The finished plate indicated an unusual shadow as dense as any tooth near the roots of the second molar, that at first received no explanation. It required a second röntgenologist to diagnose the shadow as belonging to the ear-ring on the other side of the head, *i.e.* the side nearer to the tube. Owing to the oblique projection of the inferior mandible the shadow of the ear-ring in the ear opposite to the plate was thrown forwards downwards and medially over the shadow of the second molar tooth. It is well known that metal bodies near the plate give strong shadows, but owing to the wide distance of the ear-ring from the plate, the nearness of the tube, the consequent want of sharpness of the shadow-picture, and especially the secondary radiation of the intervening head-tissues so diminished the shadow cast by the metal body, that it appeared hardly as dense as the shadow of the root of a tooth. During the preparation of this new edition my attention was drawn to an almost identical case.

SPECIAL PART

HAND[1]

General

Ossification of the bones of the hand begins in the ninth week of intra-uterine life and is seen first of all at the ends of the terminal phalanges. In the next week the metacarpals begin to ossify, and a week later the basal phalanges; directly thereafter, the mid-phalanges ossify, those of the fifth finger last of all, about the fifteenth or sixteenth week. At the time of birth not one of the phalangeal or metacarpal epiphyses is ossified. The ossification of these epiphyses does not commence before the beginning of the third year.[2]

At from $2\frac{1}{4}$ to $2\frac{1}{2}$ years appear the nuclei of the proximal epiphyses of the basal digital phalanges, together with that of the proximal epiphysis of the terminal phalanx of the thumb; about the same time or shortly afterwards osseous nuclei form in the epiphyses of the heads of the meta-carpal bones. At three years the bony nuclei of the proximal epiphyses of the terminal and middle phalanges and of the first metacarpal make their appearance.

For rare epiphyses in the metacarpal bones, see " Metacarpus."

For the appearance of centres of ossification in the bones of the wrist, see " Carpus."

[1] For the normal Röntgen anatomy of the hand refer to Grashey's Atlas, I, 4th edition, also to the older atlas of Jedlicka, Katzenstein and Scheffer: Die topographische Anatomie der oberen Extremität. Röntgen-Archiv, Hamburg, 1900.—Wilms and Sick: Röntgen-Archiv, Hamburg, 1902.—Åkerlund: Entwicklungsreihen in Röntgenbildern von Hand, Fuss und Ellenbogen im Mädchen- und Knabenalter. Röntgen-Archiv, Bd. 33, 1918.—Hasselwander: Die Röntgenstrahlen in der Anatomie. II. Bd. des Lehrbuches der Röntgen-kunde, by Rieder and Rosenthal.—P. Sessa and O. Alberti, *l.c.*, p. 1.—M. Bertolotti: Con-tributi röntgenologici allo studio dello sviluppo osteogenetico dei metacarpei. La Rad. Med., Vol. II, fasc. 3, 1915.—D. Buxton and R. Knox: Wrist joint and hand. Brit. J. of Rad., January, 1927.—T. Magnus Redding: X-Ray diagnosis, London, 1926.—R. Morton, London: Absence of thumb. Some congenital abnormalities. Arch. Röntg. Ray, 1914, 18, p. 442.—R. Jones and D. Morgan: On benign cysts of the long bones. Arch. Röntg. Ray, 11, pp. 316, 342.—T. H. Mather: A calcified fibroma of the hand. Brit. J. of Rad., July, 1927.

[2] Also in Lambertz: Entwicklung des menschlichen Knockengerüsts während des fötalen Lebens. Röntgen-Archiv, Bd. 1. See also in Alexander: Momente aus der Entwicklung des knöchernen Handskeletts. Verhandlungen des ersten Röntgen-Kongresses 1905.

Fingers

Terminal Phalanges

The *unguicular tubercule* is almost always completely symmetrical in form, in contrast to the toes, which in man are almost without exception deformed. In *drum-stick fingers* the tubercule is not enlarged, rather one finds small defects in it; the greater volume of the finger tips is due to the soft tissues. In *acromegaly* it is enlarged, but regularly, like the broad base of the phalanx; or both tubercule and base can form sharp thorny projections, similar to that in Fig. 2, B a b. Even in the very worst destructions and erosions of the phalanges in gout the tubercule is usually the last to be affected.

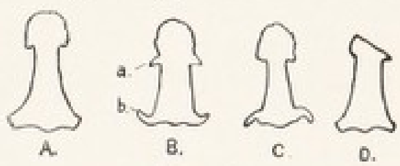


Fig. 2.

Occasionally in elderly people one finds small *thorn-like projections* immediately adjoining the tubercule. These have no particular pathological significance, and are present in hands in which the middle and terminal phalanges also show thorny processes; reference will be made to that later on.

If the Röntgen view shows greater or smaller defects in the terminal phalanges, one looks for *vasomotor trophic neuroses*, Raynaud's disease,[1] syringomyelia, sclerodactyly, arthropathic psoriasis;[2] in erythromelalgia some have seen enlargements, and others atrophy of the phalanges. Also in lepra nervorum the terminal phalanges may be as shown in Fig. 2, D. In cases of psoriasis an acromegalic structure of the skeletal parts of the hands was found in a large percentage of the cases.[3] See also "Hypophysis" under "Sella turcica." Arthritic changes have been described peculiar to psoriasis, "Arthritis psoriatica" and "Psoriasis arthritica," with atrophy of the bone and destructive processes in the cartilage and the bone, correlated only to a slight extent, and going on to ankyloses and extreme degrees of contracture.[4]

The *basis of the phalanx*, usually broad and flat (Fig. 2, A), tends in acromegaly and syringomyelia to be mushroom-shaped, sharp-edged, and canted over distally (Fig. 2, B d); the author has observed the converse of this in gout (Fig. 2, C). Injuries from athletics may also appear here.[5]

[1] One should not omit investigating in Reynaud's disease whether the sella turcica is enlarged. N. Nicolis: Raynaud'sche Krankheit u. Hypophyse. La Rad. Med., March, 1922.

[2] Ström: A case of arthropathia psoriatica. Acta Radiologica, Vol. I, 1921.—A. Neve: A case of leprosy diagnosed by Röntgen rays. Brit. Med. J., 1915, Vol. II, 814.

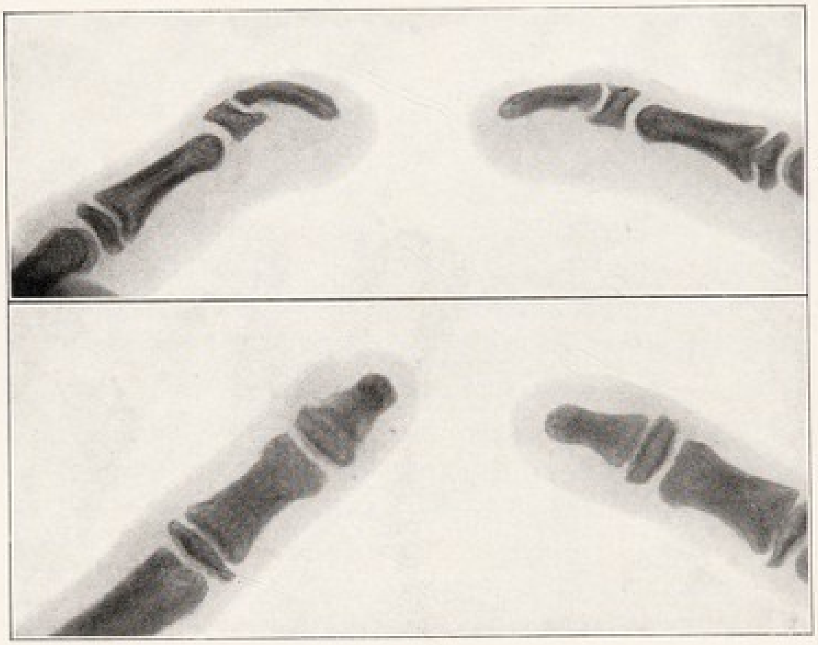
[3] Rochlin, Schirmunsky and Kotschneff: Über einige Eigentümlichkeiten der constitutionellen Beschaffenheit der mit Schuppenflechte behafteten Kranken. Fortschritte, Bd. 33, 1925. See also footnote No. 2, above.

[4] Nobl and Remenowsky: Die arthropathia psoriatica. Fortschritte, Bd. 34, 1926.

[5] Hall and Stover: Baseball-fingers. Archives of the Röntgen-Ray, 1908.

Broadening and shortening of (1) *the terminal phalanges of the thumb* were found by Pfitzner in about $1\frac{1}{2}$ per cent. of hands. But he could express no distinct opinion regarding the meaning of this nor offer any suggestion. These short stumpy thumbs appear to be inherited. It is the condition called *Brachyphalangy*, and it has nothing to do with drum-stick fingers. Other associated anomalies in the skeleton appear to be absent. Brachyphalangy also occurs (2) in the mid-phalanx of the little finger, (3) in the mid-phalanges of the fifth and fourth fingers, (4) in the mid-phalanges of the fifth and second fingers, (5) in all the mid-phalanges, (6) in the metacarpal of the thumb. (2)–(5) may be combined with (1) or (6).[1]

Quite an extraordinary finding in the little finger on both sides was recently sent to the author—see illustrations 3 A and 3 B—from a twelve-year-old girl, otherwise sound. For six to nine months previously the mother



A

B

Fig. 3.

noticed a gradual twisting of the end of the left little finger, and a similar condition although in a less degree was then found in the right little finger. The case is being published in detail by the observer with reports upon identical or similar alterations in the toes and other parts of the body.[2] The cause and nature of the condition is still unknown.

Shortening of the thumb and of the little finger at the same time makes one suspect *mongolism* (see also in mid-phalanges). According to some authors shortening of three fingers is typical of mongolism, others say they are present in idiot children of all kinds, and can occur even in healthy children.

[1] A. Knote: Über Brachyphalangie. Fortschritte, Bd. 32, 1924, p. 437.—Esau: Die Brachyphalangie—eine erbliche missbildung. Arch. f. klin. Chir., 130/4, p. 786.—Esau: Zur Brachyphalangie des Daumens. Fortschritte, Bd. 33, 1925, p. 203.

[2] Private article and illustration by J. Kirner-Waldshut (Baden).

The fourth finger is larger than the second, and so the terminal phalanx of the fourth is larger and thicker than that of the second ; the difference is sometimes so great that it might be held as pathological.

On the flexor side of the thumb between the first and second phalanges is a little *sesamoid bone*. The anatomical literature refers also to a sesamoid bone in the index finger : it is illustrated as being between the terminal and central phalanx ; the author found it there in one case (see Fig. 12).

Partial *hypertrophy* of the second and third fingers (similar to that of the second and third toes) is not uncommon. The enlargement of the bone commences at the distal third of the metacarpal affected and increases to the terminal phalanx.

Middle Phalanges

Normally the thinnest part of the shaft is half the diameter of the base. Sometimes, and especially in large-boned males, the *shaft* is thicker relatively to the base, and that is usually the case in *acromegaly*. At the junction of the middle and distal third round or pointed processes are frequently found in people over thirty years with strongly marked bones (also in the gorilla) (Fig. 4). That is normal. These are the ends of small rough ledges of bone, which run along the edges of the palmar surfaces and are doubtless the origin of the transverse and oblique ligaments strengthening the tendon-sheaths. In acromegaly they are especially large and prominent. These large ledges are best seen in profile views of the mid-phalanges (see Fig. 5). One must know that in order not to diagnose a periostitis ossificans. In palmar pictures very narrow translucent strips in the bone are seen traversing the corticalis to these processes ; these are normal and ought not to be mistaken for fissures.

Fig. 4.

Fig. 5.

Shortening of the mid-phalanx of the fifth finger is found in cases of progressive myositis ossificans (see below under " First Metacarpal " and under " Great Toe ") ; a similar shortening has been observed in cases of psoriasis.[1]

The mid-phalanx of the fifth finger is shortened in mongolism and in addition usually deformed (see also p. 16, " Shortening of the Thumb "). At the same time the terminal phalanx is bent towards the fourth finger, so that the fifth finger forms a kind of arch (see Fig. 6). One investigator[2]

[1] Rochlin, Schirmunsky and Kotschneff. Fortschritte, Bd. 33, 1925.

[2] E. Stettner : Über die Beziehungen der Ossification des Handskeletts zu Alter und Längenwachstum bei gesunden und kranken Kindern von der Geburt bis zur Pubertät. Archiv f. Kinderheilkunde, 68. Bd. (1921 ?).

found this condition present in each of his four cases of mongolism, and met them further in 700 Röntgen plates of all kinds of children's hands in ten additional cases, without finding in these ten cases any other sign of mongolism. A brachydactyly of the fifth mid-phalanx is regarded as a retrogressive tendency of the fifth finger (analogous to the normal brachydactyly of the mid-phalanges of the toes).[1] For other forms of brachydactyly see above in " Terminal Phalanges."

Small indentations (later half-circular or three-quarter circular) at the *articular surfaces* of the phalanges, as in Fig. 7, indicate uric acid deposits. The peculiar characteristic arrangement of these foci in the phalanges is probably correlated with the distribution of the finest blood-vessels. That they are typical of gout has been attacked recently in certain quarters. The author cannot agree with that. See further under the section " First Metatarsal " and the accompanying illustration.

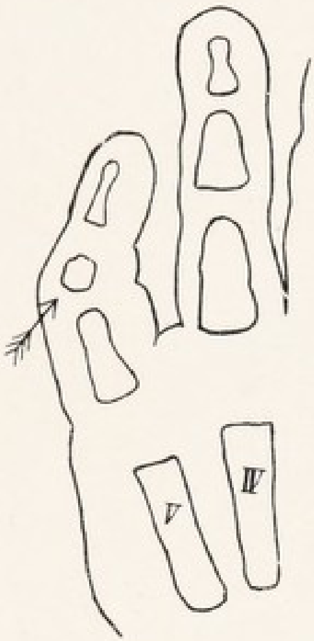


Fig 6.

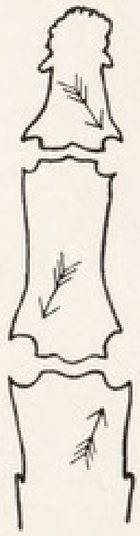


Fig. 7.

In youths of from twelve to sixteen years there occurs a remarkable *interruption of epiphysial growth,* which affects the bases of the middle phalanges of the second, third, and fourth fingers, but in their earliest stages are apt to be missed by inexperienced röntgenologists, see Fig. 8. The epiphysial line is or (in consequence of projection) appears to be raised in its centre and is widely open at its outer ends ; the joint-fissure is reduced or appears to be so. The epiphysis itself can be divided into two parts, as if fractured through. Where that is not the case or not yet the case the bony part of the epiphysis has not its usual form, that of a flat scale with the greatest thickness in the middle, but rather that of a meniscus ; the edge is thickest, and in the middle the bone is thinner or—in an extreme case—entirely absent for a millimetre or two. Also the epiphyses of the basal phalanges show similar, although less marked, changes ; they are flat, their edges sharper, their structure thick, and the opposing diaphyses slightly wavy and indented. Simultaneous alterations appear at the toes. In more advanced cases the long cylindrical bones are also altered. At the end of the growth period the interruption appears to come to a stop. The cause of the trouble is still a matter of complete conjecture. Syphilis, rickets, and Möller-Barlow's disease do not appear to be causative factors. The usual acceptation is that primarily the elasticity and firmness of the epiphyses have been injured by a certain constitutional state, internal secretion, injury, or disturbance of the nutrition. It is tentatively described

[1] See also Hasselwander : Ztschr. f. Morphol. u. Anthropol., Bd. 6, p. 511.

as "idiopathic disease of the epiphysial cartilages" or "multiple juvenile epiphysitis." [1]

Cases, as illustrated in Fig. 9, are very rare. The author has seen only one such in his practice, which occurred in a definitely tubercular child. In the middle and terminal phalanges are translucent spots, some larger, some smaller, like lenticular cysts, with coarsely irregular osseous trabeculæ, together with reduction in size and shortening of the phalanx. We have here to deal with *ostitis tuberculosa multiplex cystica*.[2] When it is as slightly marked as in the author's case, the condition is easily overlooked by the unskilled. It should therefore be mentioned here. There are also more severe cases, which have even brought about disablement of the extremities. Further identical and similar changes in the bones appear to be occasioned after other than tuberculous infections.[3]

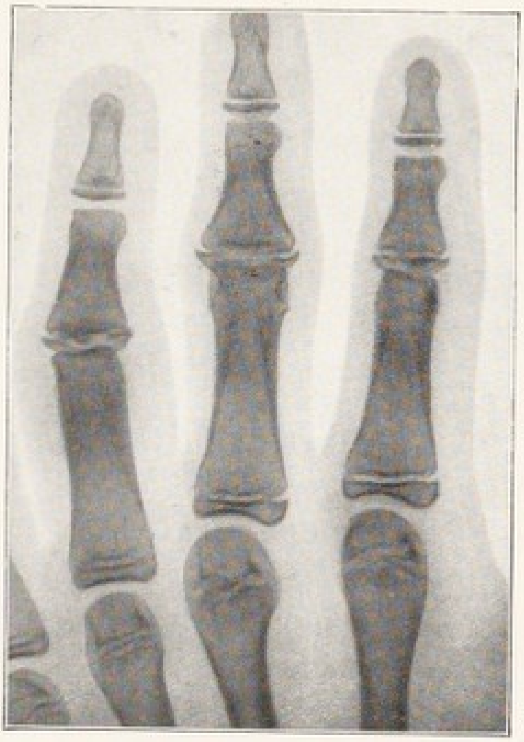


FIG. 8.[4]

In the middle joints of the fingers congenital *ankyloses* occur.

Basal Phalanges

What has been said upon the mid-phalanges applies in the main to these. Profile views of the phalanges often show a palmar *contour* less marked than the dorsal contour ; moreover, the concave palmar contour may be slightly convex in the middle. These conditions are not abnormal.

For *periostitis* thickenings in all the other long bones, see "General Part."

Malformations of the basal phalanges of the fingers are generally present also in the first metacarpal bone, in an identical or similar way.

The *basal portions* of the first phalanges do not show the beautiful symmetry of the mid-phalanges at the ulnar side of the articular surfaces, and often end more sharply than on their radial side.

[1] H. Thiemann: Juvenile Epiphysenstörungen. Fortschritte, Bd. 14, 1909.—F. Fleischner: Multiple Epiphysenstörungen an den Händen. Fortschritte, Bd. 31, 1923.—S. Reinberg: Die Röntgendiagnostik der Osteochondropathien. (Russian.) Reference: Fortschritte, Bd. 34, p. 406.—H. Kloiber: Symmetr. Epiphysenerkrankung beider Hände. Fortschritte, Bd. 34, 1926.

[2] After Jüngling.—N. Voorhoeve: Ostite à kystes multiples et son étiologie. Acta Rad., 1923, No. 5.—R. Hanson: Ostite déstructive non tuberculeuse à foyers multiples et circonscrits. Acta Rad., 1927, No. 41.—Schmid, Leysin: Schweiz. Med. Wschr., 1924, No. 35.

[3] F. Fleischner: Die Erkrankung der Knochen bei Lupus pernio und Boecks Miliarlupoid. Fortschritte, Bd. 32, 1924.

[4] After H. Thiemann. See footnote No. 1 above.

A *distal epiphysis* of the first phalanx of the fourth finger has been observed upon both sides in a case of fœtal chondrodystrophy,[1] and in the same case a considerable broadening of the distal half of the terminal phalanx of the third finger.

In the middle of the first phalanx of the fifth finger a *compact-island* has been observed; see "General Part," p. 3.

Exceptional sesamoid bones appear at the base of the first phalanx of the third finger; they are extremely rare and are illustrated in Fig. 10, A and B (Fig. 10, A, is a sketch taken from Fig. 113 in Atlas I, 2nd edition of Grashey, a rare sesamoid bone, not a detached piece of bone). Fig. 10, B, the author reproduces with some reserve. The photograph was sent him.[2]

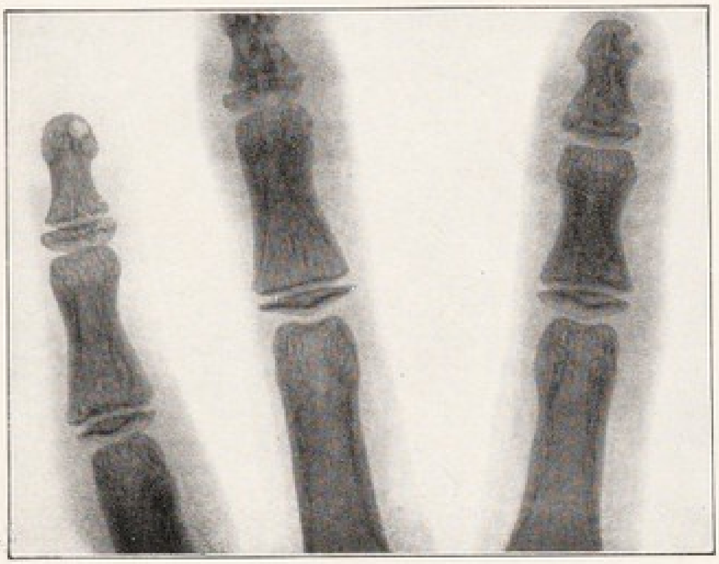


Fig. 9.

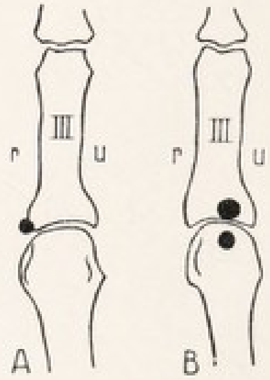


Fig. 10.

There had been a definite injury, yet the faultless rounded form of the ends of the bones is opposed to it being a case of detached particle of bone; also at the head of the third metacarpal there was another little sesamoid bone, which is all the more remarkable, because in this case no such sesamoid was present in the second and fifth metacarpal. It is perhaps only a compact-island, after all, for such has been described in this first phalanx, albeit somewhat more distally. A profile view should always be taken to make certain.

Metacarpus

General

On the *ossification of the diaphyses*, see above under "Hand."

As regards *normal and abnormal epiphyses* of the metacarpal bones the following points should be noted: While the first metacarpal has

[1] Reyher: Über bemerkenswerte Ossificationsbefunde an den Händen bei foetaler Chondrodystrophie. Fortschritte, Bd. 20, 1913.

[2] A case of Dr. Hörnig, Gotha (private communication). Pictures of the other hand could not be obtained.

usually a *proximal* epiphysis, the second, third, fourth, and fifth metacarpals have only a *distal* epiphysis, for in them the proximal end ossifies from the diaphysis. Proximal epiphysial nuclei are occasionally met with, most frequently in the second, and after that in the fifth, very rarely in the third and fourth; they are known in the anatomical literature as pseudo-epiphyses. In the whole division of vertebrata proximal metacarpal epiphyses appear only in these mammals, which the fight for existence has forced to take to the water, in the whales, seals, and walruses. Here there is an incomplete ossification, a slowing of the process of ossification, to render the extremity (the fin) more bendable. The failure of the proximal epiphysial nuclei of the metacarpals in man and the other mammals is explained osteogenetically, that a proximal epiphysial nucleus is always present in the primitive-formation, but that the epiphysial line is reached by the ossifying diaphysis before it gets time to attain to an independent formation. In retarded ossification, as is found in the fins of marine mammals, the proximal long nucleus gets time to form, because the ossification process from the diaphysis goes forward very slowly indeed. Analogous conditions can be expected in man in diseases in which the ossification of the skeleton is delayed, and that is really the case: for in myxœdema (see Fig. 11) and mongolism all five metacarpal bones have been found with proximal epiphyses present.[1] In Fig. 11, in a case under the observation of the author, only four proximal epiphysial nuclei were to be seen, yet it is likely that the nucleus of the first metacarpal present in every known instance, will appear later. Two similar cases are known and are under observation. And although the cases of a proximal epiphysis of the second or fifth metacarpal (or both) are relatively frequent and their finding considered unimportant, in future it will pay the examiner to search for other signs of retarded ossification. Thus pseudo-epiphyses would be regarded in general as an endocrine stigma. Their appearance indicates an endocrine retardation of skeletal growth.[2]

FIG. 11.

[1] A. Köhler: Vollzählige *proximale* Metacarpalepiphysen (Case of infantile myxœdema). Münchener Medizin. Wochenschrift, 1912, No. 41; more complete in A. Köhler: Vollzählige *proximale* Metacarpalepiphysen (Case of infantile myxœdema). Fortschritte, Bd. 19, 1912. —Siegert: Myxödem, Mongolismus. Ergebnisse d. Inneren Medizin u. Kinderheilkunde, 6. Bd., 1910.

[2] Josefson, Stockholm: Die Pseudo-Epiphysen ein Stigma der endokrinen Hemmung des Skelettwachstums. Fortschritte, Bd. 24, 1916.—D. Rochlin: Über Pseudo-Epiphysen u. ihre Bedeutung in der Endokrinologie. (Russian.) Refer Fortschritte, Bd. 35, p. 809.

In every adult metacarpus one finds two little *sesamoid bones* on the flexor side of the head of the first metacarpal bone, of which the ulnar one is sometimes poorly developed. Not in every film, but still fairly often, a little sesamoid bone is seen in the fifth and in the second metacarpal. Anatomists have established no less than nine sesamoid bones in the metacarpus ;[1] with the exception of the third metacarpal, which can boast only one, two sesamoids can appear in every metacarpal bone. The author found in one instance a hand with ten sesamoid bones (see Fig. 12), of which eight were in the metacarpus. Whether the remarkable delicacy of the bones of this hand possesses any relation to the unusual number of sesamoid bones present, only time can say. Further researches upon this point are advisable. According to Pfitzner's findings, a maximum of sesamoid bones of the hand are found in individuals of average size.

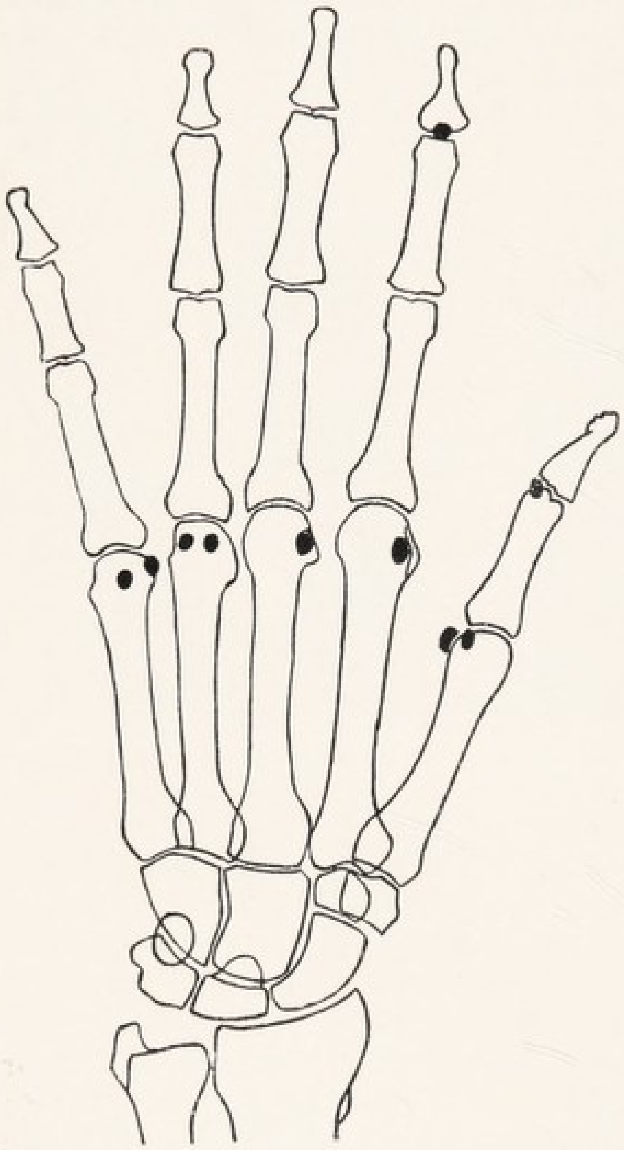


Fig. 12.

The three most peripheral sesamoids (the first radial, first ulnar, and fifth ulnar) are the ones most constantly present. In spite of many scientific efforts on the part of the anatomists we are not yet clear as to their cause. In one of the most thorough recent studies,[2] the special function of the thumbs and the little fingers (for possibilities of prehension and abduction) is given as an explanation.

The *number and distribution of the sesamoid bones* can be different on the right and left sides of one and the same individual. They are situated always on the palmar side[3] and first appear in the Röntgen view between the thirteenth and the sixteenth year of life. It is now anatomically certain that the sesamoid bones are real portions of the skeleton, preformed in cartilage and enchondrally ossified, and show

[1] According to Pfitzner they are originally all pairs.

[2] Grumbach: Das Handskelett im Lichte der Röntgenstrahlen. Vienna and Leipzig (Braumüller), 1921.

[3] Pfitzner believes he once saw a sesamoid bone on the dorsal side (quoted from Fick: Anatomie der Gelenke, Jena, 1904).

a complete agreement ontogenetically with other skeletal parts, differing from them only by a higher inconstancy.

In severe atrophic processes of the hand bones the sesamoids do not always partake of the *atrophy;* they then appear all the more distinctive through the transparent head of the metacarpal.

One should be very cautious about the diagnosis of "*Sesamoid-bone fracture.*" For double formations of sesamoid bones appear frequently (especially in the thumb and the great toe), which can easily be mistaken for a fracture. One does occasionally, however, meet with a real fracture, although that is rare. In the differential diagnosis one should note—fractures show sharp edges or points, congenital separations show rounded surfaces; in recent fracture-lines the corticalis or the corticalis-like thickening of bone is absent, and the broken surfaces can show the most varied forms; congenital pieces are nearly always of a rounded or oval form; the fractured pieces show signs of healing after a certain time and finally unite completely, congenitally divided sesamoids exhibit always the same appearance at every exposure. Only technically first-class negatives are of any use in deciding these points.[1]

For *periosteal deposits* in other metacarpals, see "General Part: Periostitis Hyperplastica."

First Metacarpal

The dorsal contour of the *capitulum* has normally a somewhat regular rounded outline; a small *spur* is sometimes seen in chronic arthritic changes, affecting both its base and the trapezium also (see Fig. 14).

A symmetrical *synostosis* of the first metacarpal with the first phalanx of the thumb is a regular sign in progressive myositis ossificans (see also under "Middle Phalanges" and under "Great Toe").

In *dislocations* between finger and metacarpus the sesamoid bones stay always on the finger side, never on the metacarpal head, because the sesamoids are more tightly bound by the two sesamoid-phalangeal ligaments with the first phalanx than with the head of the metacarpal bone.

Dislocations of the carpo-metacarpal joint towards the radial side are sometimes observed in the first or in the first and second metacarpal. The difference is not so very striking and is therefore often missed by beginners. It is typical of this injury that there is a displacement between the base of the second and first and that of third and second metacarpal. Dislocation of the first metacarpal is one of the typical injuries to which boxers are subject.[2]

The artery of the first metacarpal bone runs parallel to the palmar side

[1] Stein and Preiser: Über Fractur und Doppelbildung der Daumensesambeine. Arztliche Sachverständigen-Zeitung, 1907, No. 19.—Stumme: Über Sesambeinfracturen. Fortschritte, Bd. 13, 1908, p. 312 (with list of the literature).—Stieda: Zur Kenntnis der Sesambeine der Finger und Zehen. Bruns Beiträge zur klin. Chirurg., Bd. 42, Heft 1.

[2] R. Délapchier: Lésions traumatiques observées chez les Boxeurs. Paris, 1909 (Rousset).

of the first metacarpal, and in arteriosclerosis with infiltration of lime it can, under certain conditions, be so projected that its shadow is taken for that of an ossifying periostitis, especially if—as occurs—the radial artery is not specially prominent.

In the *capitulum* of the first metacarpal there may occur a *pseudo-epiphysis*, often simultaneous with those appearing at the proximal ends of the other metacarpals (compare p. 21).

At the proximal end of the first metacarpal *fractures* are not uncommon. But the beginner may be apt to mistake a transverse transparent line at the base for a fracture, especially when the other metacarpals exhibit no such transparency. This line is none other than *the normal epiphysial line*, for the first metacarpal in respect of epiphysial formation behaves like a phalanx. One should not neglect in real fractures at the proximal end to take two views at right angles to each other: (1) an ordinary palmar photograph of the hand, the metacarpal of the thumb appearing in profile; and (2) an ulno-radial exposure (with pronation, inward rotation of the shoulder, and palmar-dorsal projection of the thumb and its metacarpal). In fractures at the proximal end of the first metacarpal one ought not to miss an associated fracture of the trapezium (see Fig. 17).

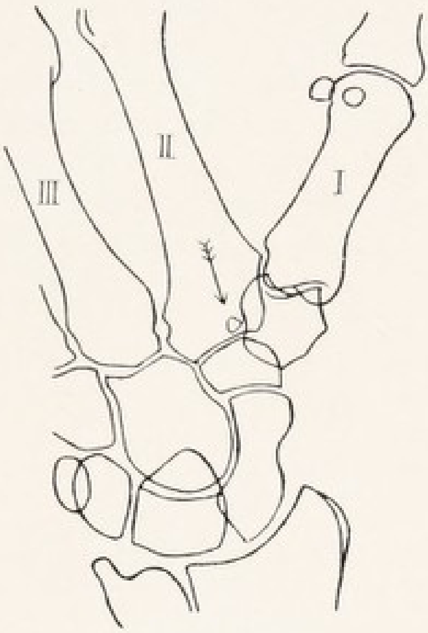


FIG. 13.

With the diagnosis "*separation* of a small chip on the proximal and ulnar side of the bone of the first metacarpal" one should be careful, especially when the "separated" part is rounded and smooth in contour. In the latter case we are dealing with the trapezoid bone (see Fig. 13).[1] Yet real separations do appear at this corner (see, for example, Fig. 17, which shows also a fracture of the trapezium).

Second Metacarpal

Narrowness of the *capitulum* is often a striking feature, without any pathological change being present (a consequence of projection).

In the spongiosa of the proximal half of the bone a *compact bone islet* is sometimes met with (see "General Part," p. 3).

In the chronic arthritic changes described above the lateral half of the *base* often shows a thorny or sharp process (see Fig. 14).

A rarer variation occurs at the base in the form of an *epiphysial line*.

[1] In the röntgenogram reproduced in Fig. 13 the trapezoid is situated quite a distance from the first metacarpal; it is often much closer to it.

A basal epiphysis is rare. Usually one finds only a transverse notch at that point (see also the explanation given above, p. 21).

An unusual appearance, but one quite normal, is sometimes met with in the proximal third of the second metacarpal, bilaterally—small shadows as thick as lead-pencil marks (Fig. 15). It is the contrast between the rest of the spongy trabeculæ and the unusual density of this shadow that is so striking. The appearance can be interpreted as an intercrossing of the spongy plates running a good way in the direction of the rays. Whether

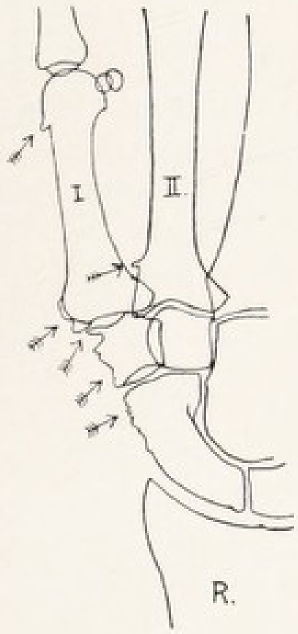


Fig. 14.

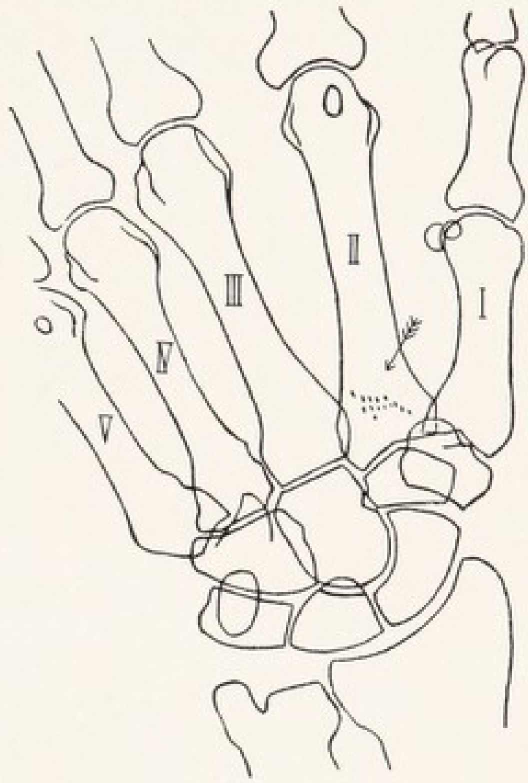


Fig. 15.

this appearance has anything to do with the formation of compact bone islets cannot yet be said.

Third, Fourth, and Fifth Metacarpals

In these bones anomalies that can occasion mistakes are not common. Occasionally the shaft of the fourth metacarpal may be exceptionally thin (in comparison with the other metacarpals). This, however, is normal.

By projection (transverse arching and consequent greater distance of the metacarpus from the plate) the third metacarpal often appears enlarged.

In one form of brachydactyly the third metacarpal alone is shortened, occasionally also the fifth,[1] the fourth only rarely.[2]

At the attachment of the abductor minimi digiti muscle to the cortex

[1] Wagner: Brachydaktylie. Fortschritte, Bd. 7, 1903, p. 94.

[2] L. Hoffmann: Missbildungen der oberen Extremität. Forschritte, Bd. 17, p. 301.

on the ulnar side two or three flat irregular archings forwards of the bone can be seen. When complaint is made by the patient these are apt to be mistaken for ossifying periostitis, while really they are quite normal. Their origin and purpose is unknown.

Compact-islands have been observed in the base of the fifth metacarpal;[1] harmless and without pathological importance. See "General Part," p. 3.

Small spurs like that shown on the radial side of the proximal end of the second metacarpal may appear also in analogous position in the fifth metacarpal (and also in the fourth). They can be regarded as normal.[2]

Carpal Bones

General

The form of the carpal bones is very different in different individuals. The bones in their shadows cover each other at a number of points. In order not to overlook the smaller changes and luxations one should go through the bones singly and compare with two or three other radiographs of the carpus. In cases not clearly diagnosed a second plate is often more useful, using a somewhat different tube-distance, than a comparison-plate of the sound side. The neglect of a profile photograph is here, as elsewhere, a technical error.

A Röntgen examination of the carpal bones is the principal factor in establishing *interruptions in growth* (myxœdema, cretinism, mongolism, etc.). Therefore we should have a fair knowledge of the time of appearance of *the individual bony centres* in the normal child, and their differentiation. The osseous centre appears and is clearly visible in the Röntgen plate.

Os magnum in the fourth month of life.
  Extreme values—end of first to middle of sixth month.
Unciform in the fourth month of life.
  Extreme values—end of first to middle of sixth month.
Cuneiform in the third year.
  Extreme values—beginning of second to middle of fourth year.
Semilunar at the end of the fourth or beginning of the fifth year.
  Extreme values—middle of third to beginning of sixth year.
Trapezium and trapezoid in the sixth year.
  Extreme values—middle of sixth to beginning of seventh year.
Scaphoid in the sixth year.
  Extreme values—beginning of fifth to end of seventh year.
Pisiform in the eleventh year.
  Extreme values—end of ninth to end of twelfth year.[3]

[1] Atlas I, Grashey, 4th edition.

[2] *Ibid.*

[3] The average values for these times do not show much alteration from those given in the 2nd edition. The extreme values were taken from Aakerlund's tables (Röntgen-Archiv,

The extraordinarily differing statements of anatomists and radiologists are explained, as Röntgen plates show, by the great *differences* in the beginnings of osseous nuclei formation ; girls especially may be one to two years ahead. The difference in the appearance of the nuclei according to other authorities [1] may be—

Os magnum—five months (one month to six months).
Unciform—the same.
Cuneiform—over two years.
Lunar—about three years.
Trapezium and trapezoid—about $1\frac{1}{2}$ years.
Scaphoid—about $2\frac{1}{2}$ years.
Pisiform—about three years.

Also *the order* in which the osseous centre appear can vary ; thus they often appear earlier in the trapezium and trapezoid than in the semilunar bone, and in the scaphoid earlier than in the trapezoid ; see the further working out of the subject in "General Part," p. 1. In spite of these considerable normal differences a number of interruptions in growth can be easily made out ; but one has to be aware of the following additional facts of normal development.[2] The ossification of children of the same age and of the same sex, but of different size, is proportionately more advanced the larger the individual. The children of the well-to-do are wont to exhibit even in their earliest childhood an acceleration in growth in regard both to increase of length and more particularly the early appearance of the osseous nuclei. It would appear as if an early stimulation of the spirit and of the intellect had elicited an early maturing of the organism, in which doubtless the same kind of influence had acted for many generations. The country child is slowest in development (see Fig. 16). Now, as regards disturbances of growth : *Chondodystrophy* with its disproportionate diminution of size, which is marked by its incidence in the long bones, and in which there is usually an early or normal, rarely a late, appearance of the ossification centres, frequently an advanced fusion of the epiphysial lines, hardly comes into the scope of this book on account of the definite external clinical signs of the patients. In *mongolism*, in which reduction in the body length and curving of the middle phalanx of the fifth finger and shortness of the thumb (see the same) are the rule, the differentiation of the osseous nuclei is partly delayed, partly accelerated,

Bd. 33) ; see also Goett, p. 151, in Rieder-Rosenthal, Lehrbuch der Röntgenkunde, 2. Bd. ; and Hasselwander, pp. 192 *et seq.* Sessa and Alberti, Note 1, p. 1.—M. Bürger and H. Schlecht : Erkrankungen der endokrinen Drüsen ; in Schittenhelm : Lehrbuch der Röntgendiagnostik. Berlin, 1924.

[1] Fujinami : Über die Entwicklung des Kindes. 7. Deutscher Röntgen-Kongress, 1911.

[2] E. Stettner : Über die Beziehungen der Ossification des Handskeletts zu Alter u. Längenwachstum bei gesunden und kranken Kindern von der Geburt bis zur Pubertät Archiv f. Kinderheilkunde, 68. Bd. (1921 ?). From that work the present entire section has been taken with the exception of the points referred to in footnotes 1, p. 28, and 1, p. 29.—G. B. Batten : Case of Achondroplasia. Brit. J. of Rad., March, 1925.

partly normal. In *lymphatic disease* also the processes of growth in the bone appear to suffer a slight retardation. In *asthenia* one finds on the one hand delay in differentiation, on the other hand in many cases an increase in the growing length. In *myxœdema* there is a reduced development of length, and it has long been known that this is accompanied by a marked arrest of differentiation. The state of the bony nuclei present usually corresponds to what is normal at birth or in the first months of life. A delay of five years is not uncommon. In *rhachitis* (where the growth in length is diminished for the period of the florid and healing stage, but makes up again almost completely in the healed stage) the appearance of the osseous nuclei (the differentiation) was somewhat delayed in the

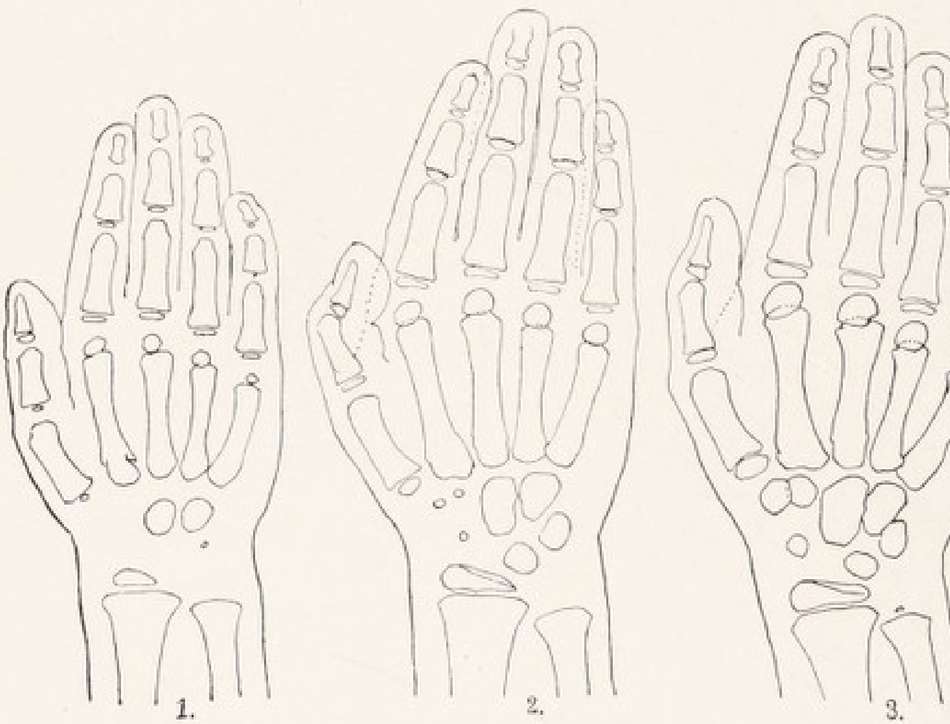


Fig. 16.

1. H. A. ♂ 5 yrs. 4 months. 105 centimetres in length. Peasant's child.
2. F. H. ♂ 5 yrs. 7 months. 111 centimetres in length. Worker's child.
3. N. H. ♂ 5 yrs. 3 months. 118 centimetres in length. Well-to-do child.

majority of cases, perhaps in consequence of intercurrent diseases, and in a few cases was found definitely accelerated. According to the researches of another observer,[1] the ossification process of the carpus is in rickets somewhat behind that of the normal, and this difference becomes gradually greater with increasing years. In the first year of life it amounts on the average to about four months, in the second year about six months, in the third year 1–1½ years, and in the fourth year of life to even two years. In moderate rhachitis, especially in infancy, the ossification process shows

[1] Fujinami: Über die Ossification der Handwurzel bei Rhachitis. Zeitschr. f. Röntgenkunde, 1912.—Reyher: Das Röntgenverfahren in der Kinderheilkunde. Berlin, 1912. (Meusser.)—M. Klotz: Die Rhachitis. Ergebnisse der Inn. Med. u. Kinderheilkunde, Bd. 24, pp. 254–309.

no deviations. That in general a striking retardation in the formation of the bony nuclei cannot be determined röntgenographically is referable to the fact that about the time at which the rhachitic disease of bone commonly occurs, a retardation in the development of the bony nuclei takes place physiologically at the carpus; for normally, after the appearance of the bony nuclei in the fourth year, it is another $2\frac{1}{2}$ years until the next osseous nucleus, that of the cuneiform, makes its appearance. In early cases of *rhachitis tarda* no retardation of ossification of the carpal bones is observed, except when the late rickets has been present for several years at the forearm epiphyses. Other röntgenologists found that no new osseous nuclei appeared in the negative, as long as a moderate or extreme degree of rickets occurred in the growing period. If one then examines from the time the healing sets in, then within a few days osseous nuclei become visible in the film, of a size equal to nuclei that had been there for several months.[1] In moderate and severe rickets the shadow density is somewhat reduced. *Under-nutrition* appears to produce an arrest of the process of growth. Severe *acute infections* cause over years a prolonged retardation and arrest of growth; a succession of slight acute diseases have a similar effect. Obviously every detriment to the organism manifests itself in a depression of the processes of growth. It is remarkable that *scrophulosis* and *tuberculosis* have only an extremely slight influence. In *syphilis* the processes of growth are delayed in a great measure; in growth, in length and differentiation there may be a complete stoppage of growth for quite a time. Also diseases of the blood (*severe anæmias*) produce a considerable delay in the processes of growth. *Hyperthyroid* cases may show an increase in the growing length and especially an acceleration of differentiation, being just the reversed condition of what is found in myxœdema. In those rare cases of *pubertas præcox* one examiner found the ossification process of the bones five to ten years in advance.[2] It was indeed well known that infectious diseases also like *enteric fever* and *scarlet fever*, especially in young individuals, can bring about a general stimulus to growth; in the course of a very few weeks increases in the general body-length were observed, that usually took months to be seen. *Congenital syphilis* exerts a delaying and deformant effect upon growth in many other functions, and this is also apparent in a delay in the growth of bone. On the other hand, an acceleration in the ossification of such osseous nuclei has been repeatedly established, although they themselves may be entirely free from pathological changes, when a tubercular process is at work in its neighbourhood, either in the bones or in the soft tissues.[3] Also in *Still's disease* (chronic inflammation of the

[1] F. Plaut: Scheinbare u. wirkliche Verzögerung der Knochenkernbildung bei Rhachitis. Fortschritte, Bd. 32, 1924.—F. Plaut: Röntgenuntersuchungen über die Kochenkernbildung bei Rhachitis. Ztschr. f. Kinderheilkunde.

[2] Neurath: Die vorzeitige Geschlechtsentwicklung. Ergebn. der Inneren Med. u. Kinderheilkunde, 4, 36, 1909.

[3] R. Gralka: Über den Einfluss chronischer Entzündungen auf die Ossification. Fortschritte, Bd. 33, 1925.

periarticular soft tissues without destruction of bones and cartilages) such an acceleration was seen.[1]

Trapezium

Isolated *fractures* of this bone are almost impossible ;[2] but it may be simulated when the end of the base of the first metacarpal is broken off (see also p. 24). They occur in combination with other fractures, especially that of the base of the first metacarpal, as Fig. 13 shows, but even they are rare.[3]

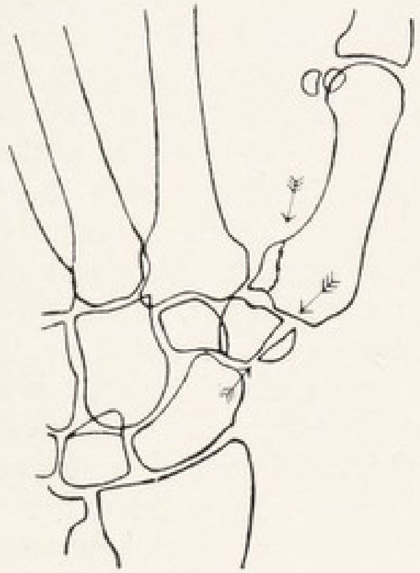


FIG. 17

Changes are found in *chronic arthritis* of the joint between the thumb and the wrist (articulatio carpometacarpea pollicis). These are usually of gouty origin (although recently this view has been denied in certain quarters), see Fig. 14.

If in a clinical case strongly suspected of a carpal fracture one can find no break in volar and profile negative one should never neglect to take a dorsal photograph also.

Between the trapezium and trapezoid and the first and second metacarpals one finds in a few cases a small circular or oval shadow 3–4 mm. in diameter ; the *os trapezoideum secondarium*, an important variety (see Figs. 13, 24, and 25). Occasionally through the overshadowing of the projecting angle of carpal bones one obtains a pseudo-picture of a supernumerary independent carpal bone. The trapezoideum secondarium is situated at the dorsal surface of the carpus (see also below under " Supernumerary carpal bones ").

The illustration of a case, perhaps unique in the röntgenological literature, was sent a short time ago to the author (see Fig. 18).[4] The patient, a woman of fifty years, experienced a relatively slight accident. Seizing upon the two handles of a heavy cooking pot she felt pains at first in the left hand in the region of the metacarpus, soon afterwards in the right hand also. There were no signs of tuberculous disease in any other part of the body. The Wassermann was negative. The nervous system was examined by a nerve specialist and found normal. There was very little swelling, only a moderate tenderness on pressure and movement,

[1] From Johannescu, quoted by R. Gralka.

[2] Ebermayer: Über (isolierte) Verletzungen der Handwurzelknochen. Fortschritte, Bd. 12, 1908.—A. Heimerzheim: Ein Fall von Os paratrapezium, gleichzeitig ein Beitrag zur Lehre von den isolierten Fracturen des Os multangulum majus. D. Ztschr. f. Chir., 186. Bd., 1/2 Heft.

[3] Very small isolated processes were observed by C. C. Anderson: Two unusual fractures of the wrist joint. Brit. J. of Rad., May, 1927.

[4] Private communication by Dr. Harms, Hanover. Henriettenstift.

without impairment of mobility. The symptoms were so little marked that the photograph was taken only eight weeks afterwards; the first metacarpal was dislocated on both sides and there was a circumscribed oval cavity-formation in both right and left scaphoids; further, many cavities of different sizes in both trapezia, the trapezoids being apparently quite intact, a slight involvement of the radial half of the base of the second metacarpal, and, most striking of all, an extensive cavity-formation in the whole base of the first metacarpal, right and left. All the other bones of the hands appear uninvolved. It is very questionable whether we are here dealing with an accidental finding. The probability is that the

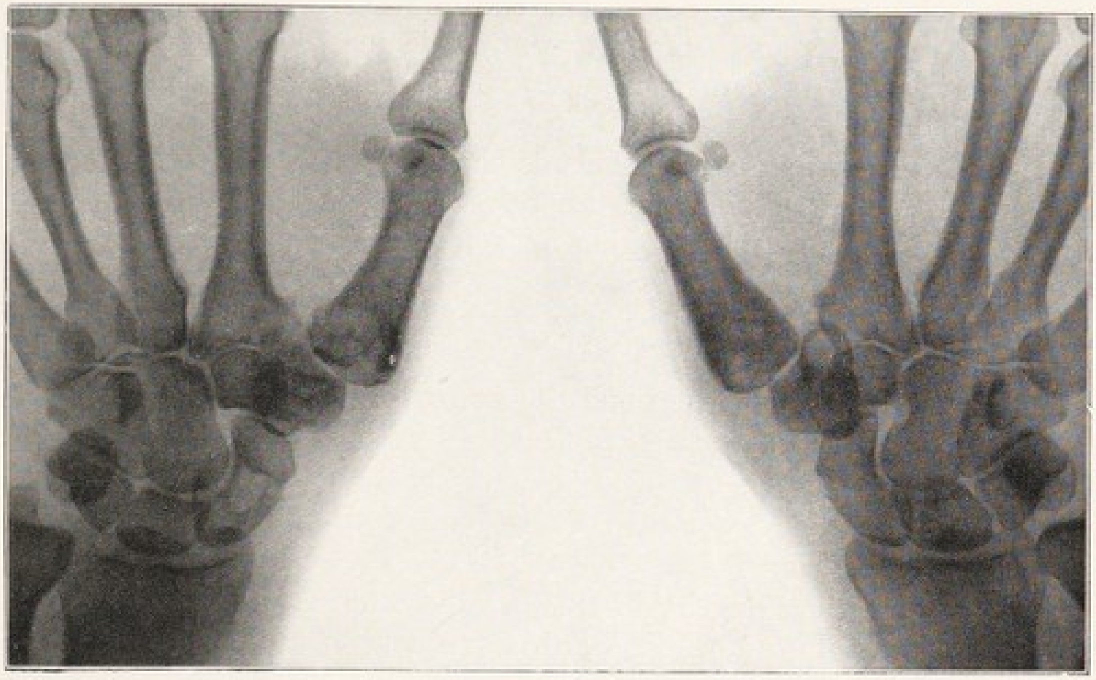


Fig. 18.

changes are related to the lifting of the pot. (Some constitutional predisposition is doubtless also necessary.) The appearances remind one of malacia of the semilunar (which see). The dislocation of the first metacarpal—which is quite definite—indicates this. Disturbances of nutrition of the bones have been brought about by stretching and tearing of the capsular ligaments of the affected joints—as in malacia of the semilunar—and cavity-formation has followed, as is well known in malacia of the semilunar. A more distant possibility might be ostitis fibrosa, but the symmetry of the processes would be against that. That a predisposition to a pathological change is present in the patient is evidenced perhaps by the space in the carpal bones, which may be related to an os centrale (see below under " Os centrale carpi ").

Trapezoid. Os magnum. Unciform

The trapezoid and the os magnum are those bones of the carpus that are subject to the fewest changes. Sometimes, especially in *commencing* *atrophy of bone,* there appear very distinctly a couple of circular meshes of the spongiosa of the os magnum, due to the normal architecture, as if stamped with a punch.

The trapezoid may appear divided, or appear fused with the os magnum. Extremely rare cases.[1]

A dorsal dislocation of the trapezoid has been described. According to the principle of the parallelogram of forces a dislocation must take place towards the dorsum of the hand.[2]

At the radial contour of the os capitatum there is sometimes *a semicircular indentation ;* that is, without practical importance but anatomically interesting, because it is here the os centrale carpi appears, usually preformed in cartilage and therefore röntgenologically invisible, sometimes indicated in bone ; its occurrence is extremely rare. For further particulars, see " Scaphoid."

In *the unciform bone* the corticalis shadow of the unciform process is often so distinctly raised from the rest of the bony shadow that to a beginner in röntgenography looking for a foreign body it may be taken for an oval hidden piece of metal wire.

Isolated *fractures* or fissures are very rare, and hitherto only a few have been described.[3]

In the distal half of the bone the occurrence of *a compact-island* has been described ; see " General," p. 3.

Scaphoid Bone

To estimate the integrity of this bone is often a point of the greatest difficulty (see *e.g.* Fig. 19). It is fairly frequently injured but sometimes difficult to show up clearly, because the entire normal bone varies much in its form, especially in various projections, and further, its shadow falls for the most part into that of the os magnum and semilunar bone.[4] (Regarding " Naviculare bipartitum," see below.) If one finds a shadow—as in Fig. 19, right—which reveals no line of fracture but looks like an overgliding of two fragments, one should photograph the sound carpal bone in exactly the same position (difficult !). Fractures are best shown in maximal ulnar flexion. According to the author's experience *fractures of the scaphoid,* which are really frequent and occasionally associated with luxation of the semilunar bone and with fracture of the styloid process of the radius, are unrecognisable in the majority of cases. *The line of fracture* usually passes

[1] According to Pfitzner.

[2] J. Franke : A rare case of injury of the carpus : dorsal dislocation of the multangulum minus. Acta Rad., 1925, No. 19.

[3] Ebermayer, *l.c.*, and Albers-Schönberg : Forschritte, Bd. 13, 1909, p. 323.—Esau : Os hamatum-Fracturen. Forschritte, Bd. 33, 1925.—Sven Johansson : Ein Fall von Luxationen des Os hamatum. Acta Rad., Nos. 35–40.

[4] See also Nogier : La pseudoluxation physiologique de scaphoide. Journ. de Rad. et d'Electr., 1914/15, p. 238. Meran.—S. Lange, New York : Obscure fractures discovered by Röntgen examination. Lancet Clinic, 1908.

through the middle, and one sees (in volar röntgenograms) through the line of fracture of the displaced fragments, separate ½–1 mm. If one compares such a fracture again in six months, one should not conclude from the want of a bony union that there is an os bipartitum, for fractures of the scaphoid, it is well known, do not heal by bone. Only if the tubercle of the scaphoid has been torn off extracapsularly, is good bony healing to be expected.[1]

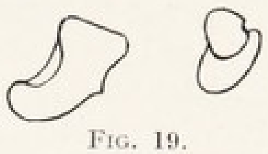


Fig. 19.

Absence of the scaphoid and semilunar on both sides has occurred.[2]

Pfitzner has described the *os naviculare bipartitum*. But as congenital preformed division into two of the scaphoid bone has not yet been observed since the use of Röntgen-rays started, it is supposed [3] that the majority of the cases of naviculare bipartitum are simply pseudarthroses following upon fractures, which further can be also produced experimentally in preparations on the subject. One anatomist and röntgenologist [4] saw the ossification pre-formation of the navicular undoubtedly doubled, but they were two ossification points scarcely the size of the head of a pin a few millimetres distance from each other, so that this was apparently only a double ossification bud in an undivided area of large-celled cartilage. This area being the real ossification-centre. The same inquirer noticed another observation at the hands of a hypothyroid dwarf. Here were found on both sides in the region of the scaphoid bone two very irregularly formed well-marked bony nuclei. The formation of two separate pieces of bone in the cartilage of the scaphoid is also possible, although probably only under the influence of certain factors interfering with the course of ossification (hypothyroidism, cretinism, etc.).

As regards *finer alterations* in the bone it should be remarked: the external contour of the bone forms the quarter of a circle, into which opposite the outermost end of the radius a small concavity is impressed; more rarely at this point there is a small arching outwards of the bone. The external articular end is blunted or rounded off towards the trapezium. In *chronic arthritis processes* there usually forms here a pointed process, which in advanced stages can also show traces of erosions. The condition illustrated in Fig. 13 is the appearance not infrequently presented to the röntgenologist; it is quite typical. Isolated tuberculosis is very rare.

The *os radiale externum*, to be sought for at the radial end of the scaphoid between the latter and the trapezium (hitherto seen only in two cases by anatomists [5]), does not appear to have been shown yet in Röntgen pictures.

The sharp or blunt edge of the scaphoid introduces itself more or less between the os magnum and the trapezoid, or a larger or smaller defect

[1] Hirsch: Deutsche Naturforscher Versammlung. Meran.

[2] L. Hoffmann: Missbildungen der oberen Extremität. Fortschritte, Bd. 17, p. 301.

[3] R. Wolff: Anatom. Praeparate von Fracturen des Os navic. der Handwurzel. Arch. f. klin. Chir., 77, 1905.

[4] A. Hasselwander: Die Bedeutung des Röntgenbildes für die Anatomie, Erg. der Anat. u. Entwicklungsgesch, Bd. 23, 1921. See further Grumbach, *l.c.*

[5] According to Pfitzner; see also Grumbach, *l.c.* below.

is seen at this spot—remarkable even to the beginner—and is related to the *os centrale carpi* ; in man it occurs very rarely indeed as an isolated piece of bone. Pfitzner estimated its appearance in general at the most 1 per cent. It is not so much a more or less reduced remainder of a centrale that attained its complete value in human ancestry ; it is quite a definite skeletal part specific to man, of fixed form, size, and position. According to others,[1] it might be described in man simply as an accessory element. At the place where the os centrale has its original formation the following

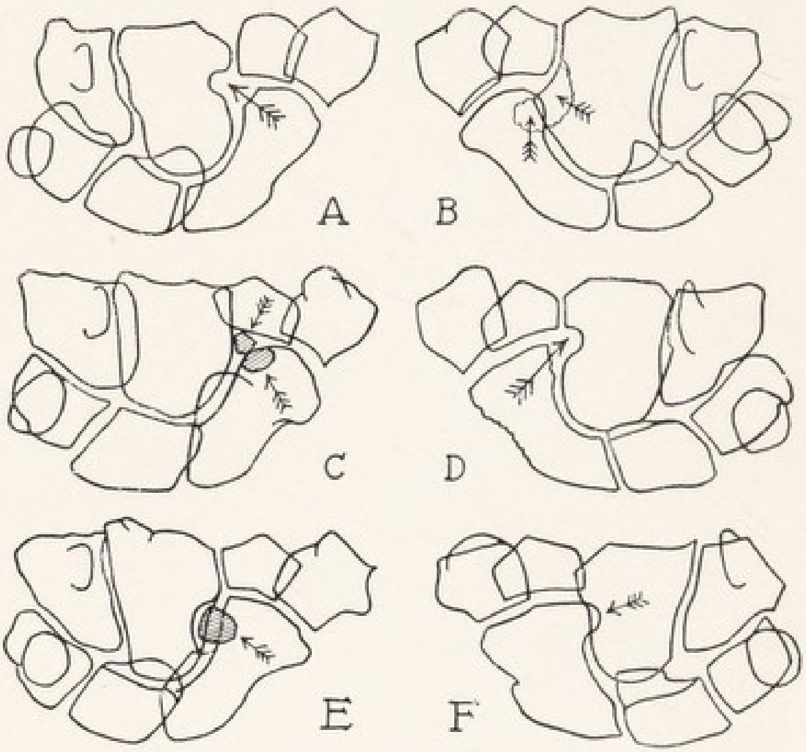


Fig. 20.[2]

conditions may occur in Röntgen picture : (*a*) The scaphoid and the os magnum show particularly sharp delimited portions, between which there is an independent osseous centrale (Fig. 20, C and E). (*b*) The scaphoid shows instead of the described portion a strap-like process, which repeats the form of an independent centrale and is produced either by a completely assimilated centrale or by a compensatory formation of the scaphoid (Fig. 15, E). (*c*) The scaphoid has a form as in (*a*), in which, however, the centrale has completely disappeared, undergone cystic change, or remained at a cartilaginous stage (Fig. 20, A and D). (*d*) The presence of a cartilaginous centrale in apparently normal articular fissures can be inferred from an oval or similar transparency, which extends itself both over scaphoid and os magnum (and trapezoid ?) (Fig. 20, B). Cases like (*d*) are

[1] A. Grumbach : Das Handskelett im Lichte der Röntgenstrahlen, 1921, Vienna and Leipzig (Braumüller).

[2] A and B are drawn from pictures by Grumbach, *l.c.* C and D from pictures by Grashey (Atlas, 4th edition). E and F after pictures by the author.

found fairly often, if one goes through one's negatives of the hand with care. One of the anatomists has strenuously opposed the idea that this transparency that has just been described speaks for the presence of a cartilaginous centrale.[1] Regarding a cartilaginous persistence of the os centrale there is nothing to be found in the whole anatomical literature. Pfitzner's thorough inquiries would not have missed that.[2] Pfitzner found the centrale only seven times among 1450 hands, and taken in all it is described only in twenty-five cases. The above transparency in the röntgenogram is found almost every day in photographs of the hand (Köhler). The cartilaginous primitive-formation, described for the first time by Rosenberg, either disappears altogether in the further development and makes room for the scaphoid, as Rosenberg described it (Morphol-Jahrb. 1); or (as Thilenius described it) it fuses with the cartilaginous primitive-formation of the scaphoid. This method is not unknown also in the development of the os trigonum, where the formation of a joint-fissure persists, two blastomas being united into one. Regarding the further development Pfitzner writes: "The primitive-formation of the os centrale unites with that of the scaphoid. But the portion of the scaphoid thus formed nevertheless retrogresses in its development, on account of the smaller energy of its growth, so that finally a cavity is produced in the centrale, or an excavation in the scaphoid." Thus Pfitzner finds fairly often a deep excavation instead of the centrale which has disappeared. We are dealing therefore in the translucent places described not with a cartilaginous persistent centrale but just with a cavity. It is in fact just the place where a centrale would be placed if it were there.[3]

An irregular *central translucency* of the scaphoid bone is pathological and appears not infrequently. Its origin is, however, not yet clear. It is sought to explain it thus: Some months before, a primary injury (tearing of a ligament) brought about a disturbance in the nutrition of the bone, while the vessels entering the scaphoid from the volar side may have been injured. Later a further accident may produce a real transverse fracture of the weakened bone (see "Semilunar").[4]

The shadow projecting forwards to the volar side in ulnar profile pictures of the carpal bones corresponds to *the tubercle* of the scaphoid bone.

[1] Private communication to the author from A. Hasselwander.

[2] The only point relative thereto is the following: "For all the surfaces apart from that of the dorsal side—carry a cartilaginous coating, and as further the thickness of this cartilaginous coating is almost the same as in the adjoining normal carpals, the centrale loses a great amount of volume in maceration, and one obtains much to one's surprise 'quite a minute ossicle'" (Pfitzner) instead of quite a definite piece of bone. But even then an ossicle that one should see! (Hasselwander).

[3] A. Hasselwander: private communication.

[4] Preiser: Zur Frage der typischen traumatischen Ernährungsstörungen der kurzen Hand- und Fusswurzelknochen. Fortschritte, Bd. 17, 1911. See further also the literature, footnote 1, p. 37.—Wollenberg: Über die Preiserschen Navicularezysten. Fortschritte, Bd. 18, 1912.—Wohlauer: Fortschritte, Bd. 31, 1924.—I. J. Blauwkuip: Een typische traumatische Aandoening van het os naviculare carpi. Tijdschr. v. ongefallen geneesk. 5. Jaargang, No. 11.—M. Kappis: Über Fracturen der Handwurzelknochen und Höhlenbildungen in ihrem Röntgenbild. Arch. f. orthop. u. Unfall-Chir., Bd. 21, H. 3.

Semilunar Bone

The form of this bone is not so various as that of the scaphoid; *its size*, however, varies greatly. Occasionally one meets with remarkably *small* semilunar bones and might easily diagnose from the clinical conditions a tuberculous destructive process or a bone compressed after tuberculous destruction, until a comparison view of the normal carpal bones of the other side brings a similar narrow semilunar bone to view. We have then to reject the diagnosis of tubercule. The cause of this reduction is not quite clear. It is probably an arrest of growth occasioning complaints of a moderate degree. Whether it forms an analogy to a similar condition in the scaphoid bone of the foot cannot at the moment be settled (see also p. 37, below).[1]

In the semilunar bone *a compact-island* may appear; see "General Part," p. 3.

Fusions of the semilunar bone with the cuneiform have been described in anatomical literature. For absence of the semilunar bone, see p. 33 below.

As regards the finer details in the semilunar bone we should mention that in *commencing atrophy* circular translucencies, the head of a darning needle in size, are found in the spongy structure of the semilunar; as a rule this appearance is seen at the same time in the os magnum, and less markedly in the scaphoid. These small round foci should not be held at a first glance to be tuberculous foci; they are caused only by structure and projection and are evidently associated with an absorption of calcium. There appear also real round diseased foci or defects in this bone, which appear as cavities in the Röntgen picture. They have been investigated very thoroughly of recent years.[2] From the bilaterality of the ailment and its limitation to one bone (semilunar or scaphoid or cuneiform) one concludes on the ground of microscopic findings that we are dealing with a fibrous change of the bone arising out of a defective or diseased congenital pre-formation of disturbance of development. But also osteomyelitic foci, central abscesses, degenerative cavities following acute or subacute inflammatory changes of bone might form the substratum in a unilateral pathological finding. Bones with cavity formations of this kind are naturally less resistant than normal bones and may fracture upon slight trauma or simple usage. See also the next paragraph on "Traumatic malacia."

Occasionally one encounters a smaller semilunar bone than the normal, one devoid in normally defined outer contours, showing defects in its spongy architecture, and moreover poor in calcium or even much thickened in its calcium contents. One takes it to have been (see also under "Scaphoid") primarily a ligament or vessel rupture with subsequent

[1] See also Walther Müller: Doppelseit. Hypoplasie des Mond- u. Kahnbeins, angeb. Luxation des einen Os naviculare. Arch. f. Orthop. und Unf.-Chir., Bd. 22, Heft 4, 1924.

[2] M. Kappis: Über Fracturen der Handwurzelknochen u. Höhlenbildungen in ihrem Röntgenbilde. Archiv. f. Orthop. u. Unfall-Chir., Bd. 21, Heft 3, 1923.

disturbance in nutrition, softening, porosis, and finally also sclerosis. Later there also occur erosions, evidences of breaking down, and spontaneous fracture. A primary infraction is often present, but is subsidiary; the important point is the interruption of the vascular supply (*Traumatic malacia*).[1] The most characteristic and unusual point in the whole picture of disease is certainly the want of relation between the slightness of the early symptoms immediately after the trauma and the relatively late appearance of symptoms. This explanation of tearing of ligaments and the disturbed nutrition of the bone conditioned thereby has been recently denied and the blame laid on compression injuries.[2] Three forms are said to occur: (1) In the anatomically conditioned forms a pathological process of the semilunar is brought about by the special and abnormal anatomical conditions. (2) In the "professional" forms continual small compression injuries in special occupations (especially agriculture) are blamed as the cause. (3) In the traumatic form a single compression injury can elicit the disease. The latter runs its course in three stages and this is pathognomonic: first a short stage of slight articular irritation, then a stage of relative absence of symptoms, several months in length, finally a definite stage of disease with severe manifestations. The Röntgen finding is usually met with unchanged after years have elapsed.

The disease is best referred to as "secondary post-traumatic malacia" One author [3] describes a case in relation to a trauma, in which the Röntgen findings gave a normal finding for nearly a month, while a year later—during which time the pain steadily increased—a typical finding of semilunar malacia was made. The same author also adduces eleven other cases, in which the same trouble developed after a fracture of the semilunar. He believes a constitutional predisposition is necessary to the occurrence of the disease. Recently a microscopic finding has been advanced.[4] It showed complete necrosis of the spongiosa of the semilunar bone including the bone marrow. Any embolic process is rejected as a cause for the

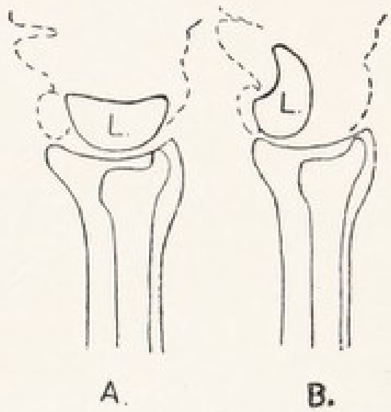


Fig. 21.

[1] See Kienböck: Fortschritte, Bd. 16, 1911.—E. W. Baum: Über die traum. Affektion des Os lunatum und naviculare carpi. Beitr. z. kl. Chir., Bd. 87, Heft 3.—Frenkel-Tissot: Fortschritte, Bd. 21, 1914, p. 536.—Hering: Zur Frage der Mondbein-Malacie. Ztrlbl. f. Chir., 1924, p. 505.—F. Kautz: Zur isolierten Malacie des Os naviculare carpi. Fortschritte, Bd. 31, 1923.—Henderson: J. of bone and joint surg., 1926, p. 504.

[2] Walther Müller: Über die Erweichung und Verdichtung des Os lunatum, eine typische Erkrankung des Handgelenks. 1922, Bruns Beitr., Bd. 34.

[3] Dudan, Geneva: Le ramollissement du semilunaire du carpe et ses conséquences pratiques. Revue médicale, 1923, p. 656.—Axhausen: Nicht Malacie, sondern Nekrose des Os lunatum carpi. Arch. f. klin. Chirurgie, 129, 1–2, p. 26.—W. Müller, Marburg: Ein Beitrag zu den angeborenen Missbildungen der Carpalknochen. Arch. f. Orthop. u. Unf.-Chir., 22/4, p. 401.

[4] M. Kappis, *l.c.*—See further E. Saupe: Beitr. z. klin. Chir., 128, H. 1, p. 187.

necrosis (as the question of the embolic necroses of bone has not yet been explained). A compression fracture may be blamed as the cause, which may appear at once or in several stages. For if the lines of the fracture run at once or gradually in such a way that the blood-vessel supply of the greater part of the bone is interrupted, an almost complete necrosis of bone is inevitable. (This particular microscopic examination happened in a case of softening of the semilunar bone occasioned by a chronic trauma.) All these diseases of the semilunar might be fractures with incomplete and irregular formation of callus. A simple overstrain suffices to the production of the fracture. The injury is not necessarily at once recognised in the Röntgen picture, in a case where the line of fracture of the semi-

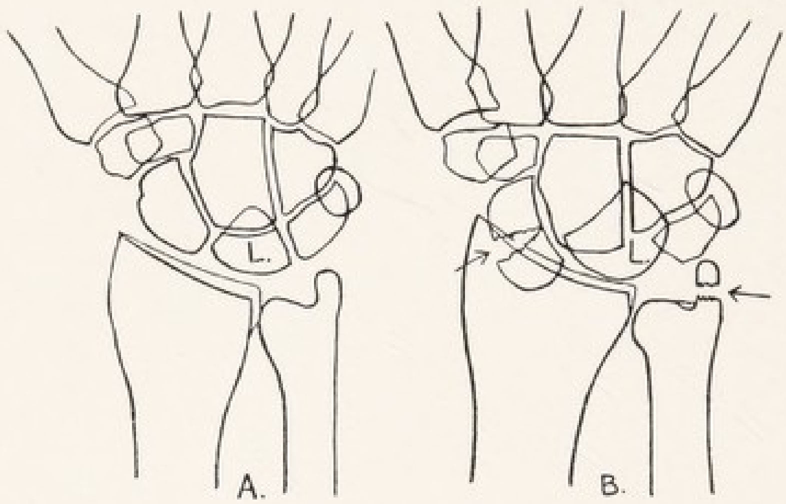


Fig. 22.

lunar bone comes to be in a plane parallel to the surface of the hand. The spotted dotted appearance of the Röntgen shadow of the semilunar bone, which is so very definite in a well-marked case, is brought about by cavity formation. Cystic formations seem to be frequent in the carpal bones, regarding whose ætiology and pathology very little is yet known, but they usually are observed after trauma. On the other hand, when a cavity is already present it predisposes naturally to a compression fracture (see also the foregoing paragraph).

Luxation of the semilunar bone is a relatively frequent injury, often combined with *fracture of the scaphoid and tearing of the styloid process of the ulna* (see Fig. 22, B) ; it is easily overlooked by beginners. And yet it gives an unmistakable sign that clarifies the diagnosis. If the semilunar bone is found in its normal position, then in profile views its proximal semicircular contour runs parallel to the articular contour (see Fig. 21, A) ; on the other hand, if the lunar bone is luxated (mostly towards the volar side), then these same contours run not only in parallel, but they usually are placed to each other at an angle of 90° (see Fig. 21, B). Further, while under normal conditions in volar negatives the shadow of the semilunar bone is only partly covered by the capitatum (see Fig. 22, A), in luxation the greater part of it is covered by the shadows of the unciform and cuneiform (see Fig. 22, B).[1]

Isolated fractures of the semilunar bone occur. They should be easily recognised, for the broken bone is much altered in shape.[2] Sometimes symptoms are at first absent, which only appear after a certain interval.

Cuneiform

According to Pfitzner, it can be found divided. Isolated gross *fractures* of this bone appear impossible and have hitherto not yet been described.[3]

In negroes *a union* of the semilunar bone with the cuneiform bone is said to occur.[4] In the Röntgen literature such cases have also been described in white people, unilateral and bilateral.[5]

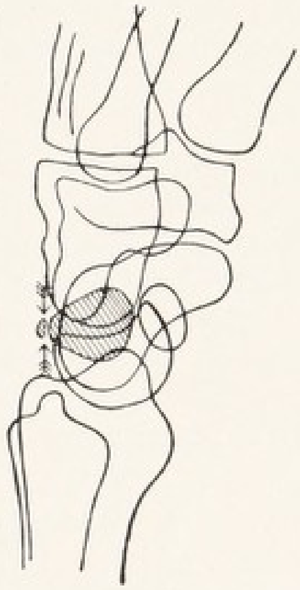


Fig. 23.

An injury not very uncommon is the *detachment of a small flat piece of corticalis* at the dorsum of the cuneiform bone. Since, however, the dislocation is as a rule almost completely nil and the injury can appear only on the profile view, the beginner can hardly find his bearings in the many covering shadows of lateral carpal-bone photographs, and the lesion may easily be overlooked. For orientation, see Fig. 23. Recently more particular attention has been taken up with this injury, which in poorly defined pictures can be easily overlooked.[6] The fact that the detached piece belongs to the cuneiform can be made out by means of oblique negatives. The detachment is probably due to tearing of the dorsal carpal ligament attached to the point of fracture by powerful pronation combined with powerful flexion.

In the cuneiform bone a *compact-island* may occur; see "General Part," p. 3.

In marked translucencies of the cuneiform bone, see also under "Traumatic malacia" of the semilunar bone.

Pisiform Bone

In this bone changes are rare. Cases are described in the anatomical

[1] See also W. Todtenhaupt: Zwei Fälle von Mondbeinverrenkung. Fortschritte, Bd. 34, 1926.

[2] See Ebermayer, *l.c.*

[3] Zehnder, Zürich: Isolierte Fractur des Os triquetrum. I.-Diss. Zürich, 1924.

[4] Sömmering and Elliot Smith: Anatom. Anzeiger, 23. Bd., 1903, p. 494.

[5] Atlas I, Grashey, 4th edition, fig. 93, p. 159.

[6] W. Fischer: Die dorsale Absprengung am Triquetrum und ihre Entstehung. Fortschritte, Bd. 25, 118; further: Deutschländer: ibidem, Bd. 18, p. 264 (with list of the literature).

literature where the styloid process is united with the pisiform bone (and cuneiform bone) by a joint, a condition found in many mammalia.[1]

In young individuals the pisiform can appear divided, torn, and crumbly, like an olecranon nucleus.[2] "The ossification nucleus of the pisiform, like so many others, may have a divided primitive-formation."

The pisiform, which for a long time was considered by the anatomists, in consequence of researches on the human hand, to be a sesamoid bone, owes the recovery of its rights to the later work of Gegenbaur and above all to the works of Leboucq.[3]

Fractures of the pisiform are very rare, although some few cases have been reported.[4]

Deposits of calcium have also been observed at the outer edge of the pisiform bone, sometimes on both sides.[5]

Supernumerary Carpal Bones

Of the *varieties of carpal bones* the os trapezoid secundarium was mentioned above. That is the commonest variety according to the author's experience, the next commonest being the os centrale, which is situated between the trapezoid, the scaphoid, and the os magnum, and also occurs divided (see above). The other varieties are very rare, but according to the anatomists there are many more. We add two diagrams after Pfitzner from Grashey, Atlas I, Figs. 19 and 20.

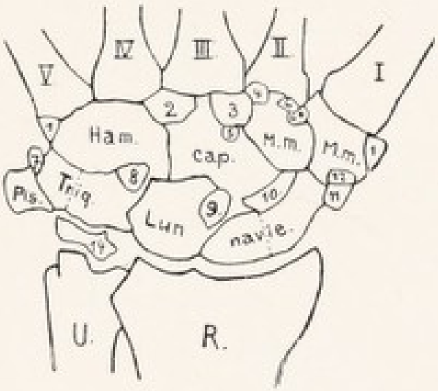


Fig. 24.

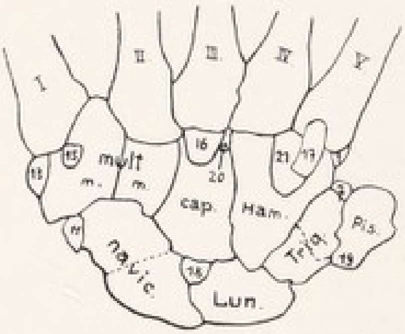


Fig. 25.

Fig. 24, dorsal ; Fig. 25, volar aspect : (1) Os vesalianum ; (2) Os capitatum secondarium ; (3) Styloid ; (4) Parastyloid ; (5) Metastyloid ; (6) Trapezoides secondarium ; (6*) Trapesium secondarium ; (7) Ulnare

[1] Quoted from Fick : Anatomie der Gelenke. Jena, 1904, p. 235.

[2] See also Atlas I, Grashey, 4th edition.

[3] A. Grumbach : Skeleton of the Hand. Vienna and Leipzig, 1921.

[4] Jean and Solcard, Toulon : Erbsenbeinbrüche. Revue d'Orthop., November, 1923.—B. Pfahl, Vienna : Ein Fall von Fractur des O. pis. Arch. f. klin. Chir., 129/4, p. 800.—E. Bergmann : Zur Casuistik seltener Knochenbrüche. Arch. f. Orthop. u. Unf.-Chir., 23/5, p. 667.—Al. Engel : Isolierte Fractur des Os pisiforme. D. M. W., 1926, No. 8.—See also J. H. Mather : Dislocation of the pisiform bone. Brit. J. of Rad., 1924.

[5] L. Haas : Röntgenologisch festgestellte Kalkablagerungen bei gichtartigen klinischen Symptomen. Fortschritte. Bd. 35, 1926.

externum; (8) Epipyramis; (9) Epilunatum; (10) Centrale; (11) Radiale externum; (12) Epitrapezium; (13) Paratrapezium;[1] (14) Triangulare (intermedium antibrachii); (15) Prætrapezium; (16) Supcapitatum; (17) Os hamuli proprium; (18) Hypolunatum; (19) Pisiform secondarium (synostosed); (20) Ossiculum Gruberi; (21) Hamulare basale. (For further particulars refer to Grumbach, *l.c.*, and pp. 43 and 44 and pp. 34 and 35 of this book.)

Fusions occur between the semilunar and cuneiform, trapezium and scaphoid, trapezoides (multangulum minus) and capitatum, third metacarpal and capitatum. Once a remarkable bilateral synostosis of semilunar, cuneiform, unciform, and one part of the os magnum was found combined with bilateral synostosis of several bones of the foot.[2] With the union of supernumerary bones to the normal ones small appendices are formed, like the first metacarpal with fifteen, and the third with three, in Figs. 24 and 25.

The *os triangulare* (*intermedium antibrachii*) (see 14 above, Fig. 24) is met with very rarely in Röntgen picture. Its hyaline cartilaginous primitive-formation can often disappear in its very early stages or may unite with the styloid process of the ulna. Pfitzner found it twice unilateral in adults, and describes it as a flat triangular piece of bone of 13 mm. greatest length, and 5 mm. greatest thickness, situated between the styloid process of the ulna, the radius, and the cuneiform. It turns its somewhat broad edge towards the radius, its surfaces towards the cuneiform and the ulna. The styloid process was short and thick, on the other side the process was equally so, but the triangulare was absent on that side. The röntgenologist finds now and then detachments of the styloid process, which are definitely enlarged and show no longer the form of a fragment, but have well rounded off and delimited forms, eventually making a pseudarthrosis with the broad well-formed process. In such cases it is thought " the trauma has affected a process which has included the cartilaginous pre-formation of a triangulare." This nucleus does not reach maturity, but by the stimulus of a trauma can yet experience a special formation and proceed to an independent growth of the fragment.[3] The percentage of the occurrence of the triangulare is about 0·6. A non-traumatic occurrence of the triangulare has been recorded in Röntgen picture in one case of generalised disturbance of ossification development, in a case of post-operative myxœdoma.[4] It has recently been stated from the surgical röntgenological side[5] that

[1] Through an error the paratrapezium which is figured at the trapezium proximal to the first metacarpal should have been labelled number 13 in Fig. 24 instead of number 1.

[2] Illustrated in Grashey, Atlas I, 4th edition.

[3] Fischer: Fortschritte, Bd. 19, 1912.

[4] Bircher: Neue Fälle von Varietäten der Handwurzel und des Fussgelenks. Fortschritte, Bd. 26, 1918; see further: Howard Pirie: Extra bones in the wrist and ankle. Am. Journ. of Röntg., October, 1921.—See further: A. Heimerzheim: Über einige accessorische Hand- und Fusswurzelknochen. D. Ztschr. f. Chir., 190/1–2.—G. G. Davis: Os vesalianum pedis. Am. J. of Röntg., May, 1927, p. 551.

[5] H. R. Schinz: Der Abbruch des Proc. styloid. ulnae. D. Ztschr. f. Chir., 175. Bd., 1922.

the anatomical findings of an os triangulare by Pfitzner might be due to broken-off pseudarthrotically healed processes of the styloid, that even the embryological proofs by Thilenius and Leboucq of an independent ossifying cartilaginous primitive-formation of the os triangulare in the sense of an atavistic supernumerary piece of bone is not a maintainable proposition. For the so-called os triangulare appears very often and almost always on the one side only. It might therefore well be a detached and pseudarthrotically healed styloid process of the ulna, especially as it is wont to heal only pseudarthrotically. But seeing without a doubt a couple of non-traumatic bilateral cases have been described, we cannot say the last word with a simple denial of this accessory element, even though a simple twist of the hand is sufficient to lead to the isolated fracture of the styloid process of the ulna (see, however, the next paragraph).

In summing up *the supernumerary carpal bones* the following may be recommended to the practising röntgenologist: The decision whether a fracture of a carpal bone is present or not rests with the röntgenologist and is of special importance in accident cases. Supernumerary bones may very easily simulate a fracture. In the inquiries of anatomists up to Röntgen's discovery the first factor in their origin, the fracture, is not mentioned at all in apparent double osseous formations,[1] and the röntgenologist must therefore know exactly what has already been scientifically established and debated. The reader will have understood from the foregoing paragraphs that there is still much contention and want of clearness, and the author fears even that in his short summary a very critical anatomist might find small contradictions here and there. Therefore I add the results that recently a very critical observer [2] obtained in an exact examination of 800 anatomically and röntgenologically investigated cases. Taking into consideration the results obtained in comparative anatomy, anatomy, embryology, and röntgenology, he recognises the accessory nature in the following elements (whereby "accessory" expresses only its natural occurrence in healthy carpal bones, without regard to whether the formations are progressive or retrogressive and atavistic): centrale and centrale bipartitum, ulnare externum (?), pisiform secundarium, trapezoides secundarium, and styloideum. Whether the epitrapezium and the epipyramis, about whose comparative anatomy nothing is known, are to be also reckoned, he could not for certain decide. From all the other pieces of bone which are described both anatomically and partly also embryologically, which he could not describe as "accessory," he first divides off a group, the units of which he was able to determine röntgenologically, and for which he brought proof at the same time that these elements had been produced by trauma. These are: the naviculare bi- and tripartitum and the os triangulare. A further and much larger group includes the elements regarding whose origin he could obtain very little information, whether they were not perhaps fracture-pieces or were to be considered even as

[1] According to A. Grumbach, *l.c.*, p. 120.

[2] Grumbach, *l.c.*, note 35, p. 1.

products of an inflammatory alteration of the particular element: radiale externum, epilunatum, hypolunatum, triquetrum bipartitum, trapezium secundarium, trapezoides bipartitum, metastyloid, parastyloid, subcapitatum, capitatum secundarium, and the ossicle of Gruber. A further group are those elements which it is true have apparently not hitherto been found and described röntgenologically, whose natural appearance is possible on the ground of well-known comparative anatomical, embryological, and anatomical observations: os styloideum, os hamuli proprium, and os vesalianum. For the clinical observer, therefore, we may say that all elements which are not included in the first group, with the addition of the ulnare externum, are to be straightway regarded as of traumatic origin. So much for actual practice. (It is a different matter for the researcher, for it is exactly in the last-mentioned group that elements are found, which earlier or later may require to be placed in the group of real "accessories.")

LOWER ARM

Distal End

General

At the time of birth there is no ossification centre in the distal epiphyses either of the radius or ulna. In the radius the osseous nucleus of the distal epiphysis appears between the first to the beginning of the third year of life; most frequently towards the end of the second year. The corresponding osseous nucleus of the ulna appears in the beginning of the sixth to the middle of the eighth year (occasionally an accessory nucleus is said to occur in the styloid process of the ulna [Schwegel], so that we have two isolated osseous nuclei close together in the distal ulnar epiphysis). That was observed röntgenologically in a thirteen-year-old mongol idiot.[1] The nucleus of the ulna unites with the diaphysis after the eighteenth year, as also does that of the radius.

The *epiphysial lines* of the distal end of the radius and ulna are the ones chosen for demonstrating *rhachitic* or *congenital syphilitic* alterations of bones. The normal cartilaginous lines show an even, translucent, narrow, straight, or slightly curved and quite sharply delimited band. In the cartilaginous plates affected by the above-mentioned disturbances of growth on the other hand, the shadow of the diaphysis runs into the cartilaginous plate in an irregular rough and fringe-like fashion. The band cast by the epiphysial plate is, moreover, broader than normal, also the diaphysial bone is more translucent, and the more so the extremer the process. The radiological difference between congenital syphilis and rickets is not great; nevertheless, in the former the irregular calcium band shutting off the diaphysis runs on the whole regularly, while in rickets it is more irregular, waved once or twice, and the diaphysial end is broadened

[1] See Schinz, *l.c.*, note 5, p. 41.

out in the form of a cup and thickened like a club. These changes can be shown to be symmetrical in rickets, a unilateral manifestation being against the diagnosis of rickets. In Möller-Barlow's disease (" scurvy ") the findings are in general like those of rickets, with the additional manifestation in the Röntgen picture of extravasation of blood in the region of the shafts of the femur and tibia. Regarding more detailed differential diagnosis, see the author's chapter on " Diseases of the Skeleton " in Groedel's " Atlas and Outline of Röntgen Diagnosis," Munich, 1921 ; further, the author's " Diseases of Bone in Röntgenology," Wiesbaden, 1901.[1] Also the changes in the epiphysial plates in *Barlow's disease* are found most typically marked at the distal end of the femur (see the same). In addition see also the author's chapter on the subject in Schittenhelm's text-book, 1924.

It was mentioned above in the carpal bones (see " Carpal Bones—General ") that severe acute infectious diseases can produce delays of growth lasting for years and even arrest of growth.[2] That is also shown at the epiphysial plate margins of the diaphyses of the long bones by an evident band-like *thickening of the border line of the diaphysis ;* this is expressed in an increased deposit of mineral salts, *i.e.* deposit of calcium salts in the cartilaginous ground substance goes on further, while the growth in length, the cartilaginous proliferation, has already stopped. Generally in every kind of arrest in growth one of these " transverse beams " can be seen at the diaphysis, and after renewal of the growth in length a " transverse strip " parallel to the epiphysial line. This transverse strip which is present both in the healing process of rickets and of Barlow's disease continues both in healing rickets and in Barlow's disease ; after acute diseases it continues especially obstinate, remaining for years, until it is finally completely absorbed.

FIG. 26.

Findings, as shown in Fig. 26, are indeed somewhat uncommon, but need hardly ever be mistaken. We are here dealing with rickets, in the course of which remissions and recurrences are frequently taking place.

[1] Regarding rhachitis one should refer to the atlases : Eugen Fraenkel and Lorey. Hamburg, Gräfe and Sillem, 1910, and Wohlauer : Atlas und Grundriss der rhachitis. Lehmann's Med.—Atlanten, Bd. 10 ; also to the more complete differential diagnosis in the chapter, " Röntgen examination in Children's disease," by Th. Goett, in 2nd Bd. of Rieder and Rosenthal's text-book ; see further Ra. G. Giles, American Journal of Röntgenography, June, 1922.—H. Wimberger : Die Rhachitis im Röntgenbilde. Mschr. f. Kindhk., 24, 4–5, p. 563.—Jamin : Röntgen-Unters. in d. Kinderheikunde. Atlas Groedel, 1924.

[2] Stettner, *l.c.*

The denser bands are the zones of remission. It is unusual to meet with more lines of calcification than in this case. In one case similar numerous band-zones could be seen, also in the other bones both long and short, being particularly distinct at the iliac crest.

The so-called *epiphysial separations* in *osteochondritis syphilitica* (in the first months of life) are not so plainly recognisable in the röntgenogram as is usually thought. Sometimes one sees only a few larger or smaller bony granules and little splinters surrounding the epiphysial end. The bones especially affected are the distal end of the ulna, the proximal and distal epiphysis of the humerus, and the proximal epiphysis of the femur.[1]

In *injuries*, slight as well as severe, it is absolutely essential to make exposures in two directions at right angles to each other. Although that is self-evident it is often forgotten by beginners. *Fractures of the radius* occur—and not so rarely either—which are marked in a volar picture only in a displacement of the structure of the spongiosa, and this slight alteration in structure is easily missed by beginners. A profile photograph clears up the diagnosis, even if the shadows of the two bones are for the greater part superimposed.

In the middle third of the bones of the forearm *fissures* may be diagnosed where none exist, owing to the *nutrient foramina*, which in a few cases appear in the Röntgen picture.

Epiphysial-separations and fractures, usually with detachment from the diaphysial end, are not uncommon. Clinical appearances: after two months callus is visible in Röntgen picture: periosteal shadow.

One occasionally meets multiple cartilaginous *exostoses* as a chance finding. The more advanced stages are not difficult to diagnose, the slighter degrees have roughly the form and size of a rose-thorn; in doubtful cases we should take control photographs not only of the other side, but also of the other bones!

For extensive *periosteal deposits* of all the long bones of the extremities with the exception of the second and third phalanges, see "General," pp. 4 and 5.

The author should here mention that he has had in his possession since 1903 several good negatives of a case of mongolism, in which *the radial and ulnar arteries* can be seen, although the child was less than a year old (Fig. 27). This puzzling discovery should be thought of, so that in other cases the negatives can be examined for a like condition. Recently (1921) a case of osteogenesis imperfecta has been published,[2] in which the Röntgen pictures of the arms and legs (photograph post-mortem) indicate the brachial and radial arteries on both sides very clearly, as also the femoral and tibial arteries which are usually seen only in the adult in extreme degrees of

[1] Eugen Fraenkel: Röntgenologisches über Epiphysenlösungen und über Heilung der Osteochondritis syphilitica congenita. Fortschritte, Bd. 23, 1915–16.

[2] Sven Johansson: Ein Fall von *Osteogenesis* imperfecta mit verbreiteten Gefässverkalkung. Acta Radiologica, Vol. I, Stockholm, 1921.—Regarding extra röntgenological literature, see the work of Symnitzky in "Zeitschr. f. Heilkunde," 1903.—See further F. Schulze: Mitt. Grenzgeb., 36, 2–3, p. 243.

arterial calcification The microscopic findings were made in the latter case by an expert pathologist, who reported : " The media of the larger arteries is here destroyed in almost its whole extent, the tissue replaced by large flakelets of lime. The elastic tissue of the intima is also encrusted with lime and appears to limit off the degenerative processes from the vascular lumen. The destruction of the media is most marked at the region corresponding to the thickest parts of the intima. The walls of the veins show no alterations. The tissue of the vessel walls in general are found in a fairly embryonic stage with but slight differentiation." (For diagram of the latter case, see later in the lower extremity.)

FIG. 27.

Ulna

The *styloid process* of the ulna appears normally as a rounded blunt process ; it can also appear curved in the form of three-quarters of a circle ; in chronic arthritis of the carpal bones and the radio-carpal joint on the other hand, its end sometimes forms two right angles opposite the cuneiform bone ; appearing as if ground down.

Partial and apparently congenital *defects* of the distal end have been described.[1]

Cases occasionally occur, although they are rare, in which without any previous injuries the styloid process is *not united* by bone with the epiphysis (cause : separate epiphysis, Schwegel, 1858 ; its surface towards the ulna is then flatter than usual, straight or rounded, see also pp. 40, 41 and 42).

It is scarcely possible to mistake *Madelung's disease* for anything else, its external appearance being so typical ; hand apparently sub-luxated to the volar side of the forearm, the distal end of the ulna projecting well on to the dorsum, the distal end of the radius curved somewhat forwards

[1] L. Hoffmann : Missbildungen der oberen Extremität. Fortschritte, Bd. 17, 1910, p. 301.

towards the volar surface.[1] Cases are frequent in which only a slight indication of the deformity is present. The female sex is specially affected, and in half the cases it appears on both sides ; the favourite time for the malady to appear in a marked degree is the age of puberty (after fracture of the radius in childhood, after acute polyarthritis, after scarlet fever with articular rheumatism, " inflammation of the metaphysis in the growing period "), but it can also occur congenitally ; it is usually unaccompanied by any pain. Its Röntgen picture is typical (see Fig. 28),[2] and keeps us from confusing it with hyperostosis of the head of the ulna following upon chronic arthritis (rare in any case), and with somewhat similar deformities after

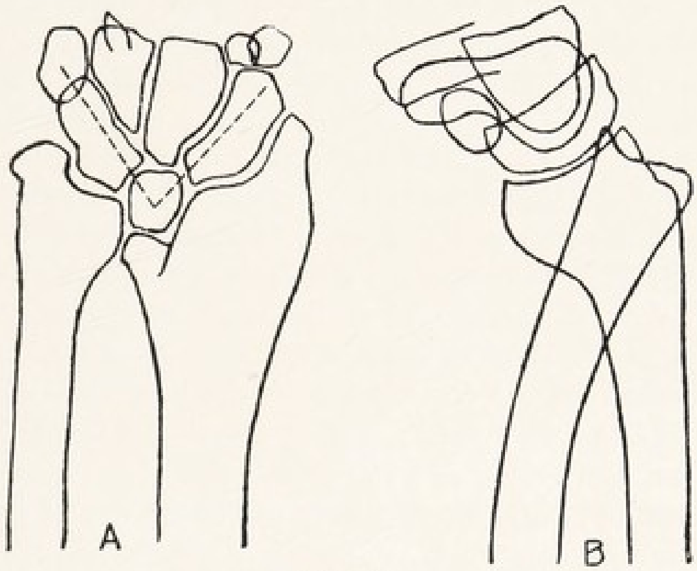


FIG. 28.

fractures of the radius. One should particularly note in the picture the acute-angled arrangement of the proximal carpal row (compare the normal Fig. 22, A). One should never omit photographing the whole forearm, for in Madelung's disease the radius shows in its course a latterly convex curvature, just as if the radius had grown too long in comparison with the ulna, and in order not to dislocate it had adopted a compensatory curvature.

In *fractures of the styloid* process one usually sees the indented line of fracture and the dislocation towards the carpus (see Fig. 22, B), occasionally also towards the radius. The space between it and the cuneiform bone (corresponding to the triangular fibrocartilage), which is normally empty,

[1] An inverse type is said also to occur.

[2] E. Melchior : Die Madelung'sche Deformität des Handgelenks. Ergebn. d. Chir. u. Orthop., Bd. 16, 1913 (with the most complete survey of the literature).—Bossi : Contributo allo studio delle deformità congenite delle articolazioni del carpo. I Congresso italiano di Radiologia medica. (Pavia, 1914.)—Anzilotti : Sopra una deformità del polso tipo Madelung. Arch. di Ortopedia, Anno XXVIII, fasc. 6, 1911.—V. Putti : La deformità di Madelung (Arch. int. de chir. Gand., 1906).—Erlacher : Arch. f. klin. Chir., 125, p. 776.—Andrassy : Ein Beitrag zur Aetiologie der Wachstumsstörungen der Hand : Ztschr. f. orthop., Chir. 44, 3, p. 401.—Levyn, Buffalo : Madelung's Deformity. Radiology, August, 1924 (2 cases).—R. de Bernardi, Acqui : Madelung'sche Deformität. La Rad. Med., June, 1925.

often disappears (Bayonet position of the hand), the bones coming together. The process does not often break off alone, the break is usually combined with a typical fracture of the radius, to whose classical complex and symptoms it belongs. (The break does not belong to the picture of symptoms of fracture of the scaphoid, nor to the dislocation of the semilunar bone and intercarpal dislocation-fracture, although in these injuries, especially in the two latter, it is met with very frequently. It does not usually heal by osseous union, the function being usually retained. Fractures of the process are not at all rare, and can easily be overlooked. Occasionally bits like the end of a darning-needle are torn off, and these should not be overlooked (see also above, " Os triangulare ").

It might have been thought almost impossible to mistake the broken-off *styloid process for a sesamoid* bone, and yet the author found that mistake made in one instance.

The external shadow contour of the styloid process passes immediately in lateral photographs into the external shadow contour of the epiphysis of the ulna. If the shadow of the process is situate more to the middle of the epiphysis, which in reality corresponds to a small rotation of the distal end of the ulna or an abnormal position of the tube, one should not immediately diagnose a pathological condition ; first take a control plate. Even in dorsal photographs the shadow of the process is situate always in the middle of the capitulum ulnæ ; that is due to the fact that in supination of the hand the ulna itself does not rotate. But the radius is then on the other side of the ulna, and also the tube which is centred between the two bones.[1]

Complete luxation in the distal ulnar joint is very rare, it could be either dorsal or volar. Palpation is usually decisive, so that radiological errors can scarcely occur.

Loosening of the distal end of the ulna and gliding dorsally occur, although they are rare. The diagnosis is not quite easy, or rather, this injury is not infrequently diagnosed by beginners where it is not present. In an exact profile photograph of this region in a normal forearm the ulnar end is more dorsal than the radial end. Therefore a real moderate backward gliding is all the more difficult to diagnose. In a doubtful case one should make a control negative of the other hand in exactly the same position ; also recollect that normally the axes of the bones in this position of the arm run almost parallel, while in luxation or subluxation of the ulna backwards they form a definite angle.

In washerwomen a *subluxation* occurs in the distal ulnar joint, which is due to wringing out the washing.

The capitulum ulnæ is a favourite spot for *tuberculosis of bone*. (In advanced cases usually one or two of the carpal bones are diseased at the same time with it.) A transparency due to the form of the lesion is

[1] Explanation given in Atlas I, Grashey, 4th edition.—J. Wynn Thomas: An inquiry into the condition of the styloid process of the ulna in Colles' fracture. Arch. Röntg. Ray, 4, p. 4.

unfortunately not often seen in the first stages, one finds usually only a slightly *diffuse atrophy* of the distal portion of the ulna, which, however, is usually so insignificant that it sometimes misses attention. A more certain sign, and not uncommon, is a periostitis ossificans, which, although it does not give a very intense shadow—the rule in tuberculosis—is still plainly recognisable.

The distal end of the ulna is further the favourite site of *Compact-islands ;* see "General Part," p. 3.

A little inequality (elevation) on the radially directed *contour of the ulna*, 4–5 cms. distant from the distal end, is not pathological ; it probably corresponds to the origin of the M. extensor indicis proprius.

In the middle third of the ulna *ledges* apparently springing from the corticalis give normally the edges of the ulna a somewhat rounded off appearance. Otherwise there is very little in the middle third of the shaft of the ulna that can occasion any difficulty in diagnosis. *Transverse fractures* without much dislocation, "parry fractures," do occur, but can hardly be overlooked in good pictures. In smooth transverse fractures one should think of the possibility of syringomyelia, tabes, osteomalacia, osteoporosis, etc., being present.

For *proximal end* of the ulna, see under "Elbow."

Radius

Persistent epiphysial lines in the radius occur.

The (volar) distal *articular surface* of the radius appears in Röntgen picture, if it be normal, either like the sixth part of a circle or with a small projecting process opposite the fissure between the semilunar bone and the scaphoid.

Small *longitudinal fissures* and fractures at the end of the radius are sometimes accidentally seen in certain directions of projection.

The styloid process of the radius can sometimes fracture, although more rarely than that of the ulna, without the break being very evident to view ; such a break when no further dislocation is present is often marked only by a distortion of the structure of the spongiosa. A profile photograph should not be neglected, although the volar negative is usually the one we do first.

The styloid process of the radius is a not unusual site of giant-cell *sarcoma*. Such tumours show, in contradistinction to tuberculosis, bright spots without atrophy of the neighbouring bone, and sharply delimited from the same. In its very earliest stage its sharp border may be absent, as the author saw recently in one case. This circumstance unfortunately prevents to some extent a sure and early diagnosis of a tumour, for firstly almost every normal radius shows a somewhat more delicate spongiosa in its lateral half, which therefore manifests a slight transparency similar to atrophy and fading off into the surrounding tissue ; secondly, commencing tuberculosis gives here a similar picture ; the translucency is then somewhat stronger, but the question what degree of translucency is here normal, and what already is pathological, is very difficult to answer. The control photograph of the other side sometimes does not afford a definite decision. In every somewhat striking transparency in the latterly placed part of the spongiosa of the distal end of the radius the röntgenologist is faced with great difficulties in patients complaining of pains here. He has to decide: Is this transparency a physiological feature? Is it pathological? If pathological, is it a commencing tuberculosis or a commencing tumour? In the latter case no time is to be lost, and the patient—in cases where a diagnosis is not possible from the complaints and the clinical findings—is to be kept under strict observation and given a second röntgen examination in three weeks. A normal transparency remains constant: a tuberculous increases with indefinite margins; one due to tumour is later sharply delimited. A tuberculous ossifying periostitis of the neighbourhood may also be simulated in the first beginning of the disease, for unfortunately an osseous marking occurs normally at this place which bears a close resemblance to a flat ossifying periostitis.

In the distal end of the radius *a compact-island* is sometimes met with; see "General," p. 3.

The *distal radio-ulnar joint* calls for special investigation; in fractures of the radius it is not uncommonly separated.

It sometimes happens that in the adult between the twentieth and thirtieth year an epiphysial line that is not ossified simulates a fracture. The want of any signs of dislocation enables us to guard against confusion; in a doubtful case one should take a photograph of the other forearm also, where the anomaly is also usually present; see also p. 2.

Fractures transversely through the whole radius may sometimes exhibit in the volar picture only an interruption of the spongiosa, and this is wont to be overlooked by beginners. The profile view will show in doubtful cases the fragments standing at an angle to each other.

In the middle of the shaft of the radius a periostitis ossificans appears to be situated at the corticalis on the ulnar side. This is, however, a normal finding and represents *the interosseous crest.* The more curved the shaft of the radius, the higher as a rule is this ledge, being arranged like a bow-string; it gives attachment to the interosseous ligament.

The *osseous nuclei* of the diaphysis of the forearm appear in the sixth to the eighth fœtal week.

For *proximal end of radius,* see under "Elbow."

Elbow [1]

General

The *osseous centre* of the olecranon becomes visible between the tenth and thirteenth years in Röntgen picture, and occasionally there appear

[1] For the normal Röntgen anatomy of the elbow, see in Atlas I, Grashey, 4th edition, also in the older work of Jedlicka, Katzenstein and Scheffer: Die topographische Anatomie

two and more centres. Fusion with the diaphysis follows in the sixteenth to the twentieth year. The ossification of the epiphysis of the radius takes place in the fifth to the sixth year, its union between the sixteenth and nineteenth years. The osseous nucleus of the eminentia capitata (capitulum humeri) appears between the first and third years of life, that of the external epicondyle between the eighth and tenth, that (or those) of the trochlea about the eleventh year of life. The nuclei of the external epicondyle in the eminentia capitata and trochlea unite first between the fifteenth to the seventeenth year, being separated from the internal epicondyle and the diaphysis. The union of the whole epiphysis with the diaphysis is completed during the next (eighteenth) year.

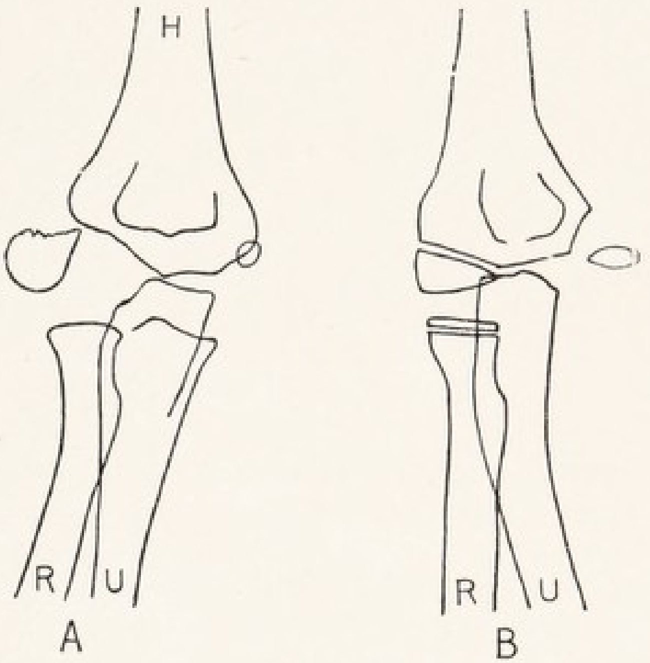


Fig. 29.

It is especially in the estimation of negatives of children's elbows that the beginner meets with very many difficulties, unless he is dealing with gross lesions. Many of the bony processes, fractures of which we find and diagnose without difficulty in the adult, ossify comparatively late in children. One should also be aware that fractures of parts yet to be ossified sometimes cannot be demonstrated röntgenographically. The question is whether such *separation of processes not yet calcified* occurs often. Apparently not ; there are no reports in the surgical literature bearing on the point. It is also fairly improbable that such elastic cartilaginous parts break easily. The röntgenologist, when he sees in a case all the nuclei-containing epiphyses intact, is in a position to conclude that no fracture is present.

In order to be certain as far as possible in cases suspected of fracture of the epiphysis, whose ossification has started, the following advice may be given : the profile photograph is technically easy, but it should not be the only one made ; a sharp dorsal negative should be secured under all circumstances in the position of greatest extension. That is often very difficult in crying children, but never impossible (sometimes a volar photograph is better taken instead of it, which gives us the same result). The

der oberen Extremität. Röntgen-Archiv. Hamburg, 1900—Åkerlund, 1918, quoted in " Hand."—Hasselwander : Die Röntgenstrahlen in der Anatomie ; in Rieder-Rosenthal's text-book, 2. Bd.—R. Balli : Anatomia röntgenografica normale dello scheletro. Ferrara, S. T. E. T., 1924.—Roques : Etudes röntgénographiques sur le Développement du squelette du coude de l'enfant normal. Journ. de Rad. et d'Electr., 1923.—St. J. Dudley Buxton and Robert Knox : A radiographic survey of the normal joints. II. Elbow-joint. Brit. J. of Rad., Nov.-Dec., 1924.

dorsal or volar photograph often clears up the diagnosis completely; but in half of the cases the student has still to encounter a number of other complicated diagnostic difficulties. The control negative of the healthy elbow will help in a number of cases out of the difficulty; but to be successful it must take the arm in exactly the same projection. Then we can act as

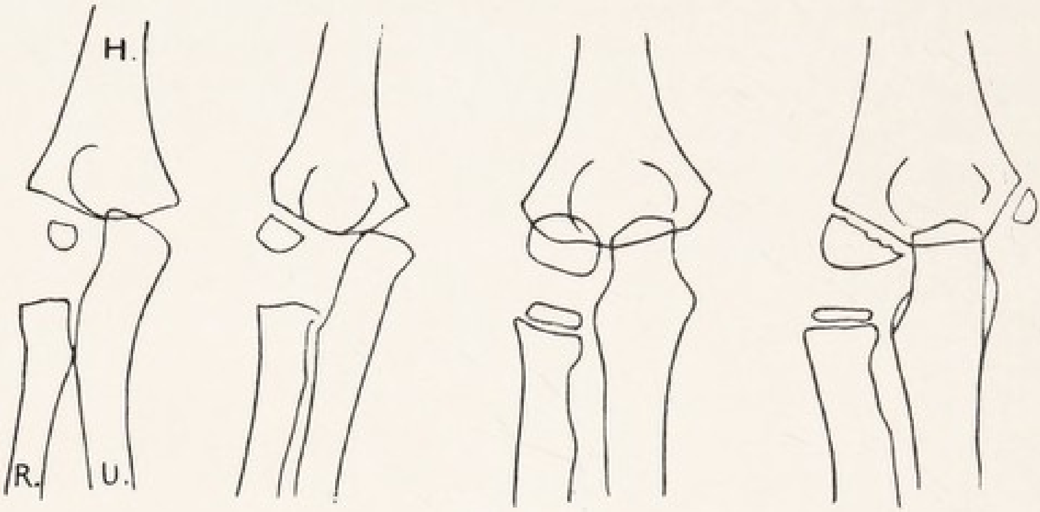


Fig. 30.

follows: imagine the contour of the shaft of the bone joined up with the contour of the suspected fracture and of the other epiphyses (or draw it in with ink on the back of the negative). If the resulting sketch resemble the form of the particular bone depicted in the anatomical text-books, we are then dealing with normal conditions. This procedure is really very

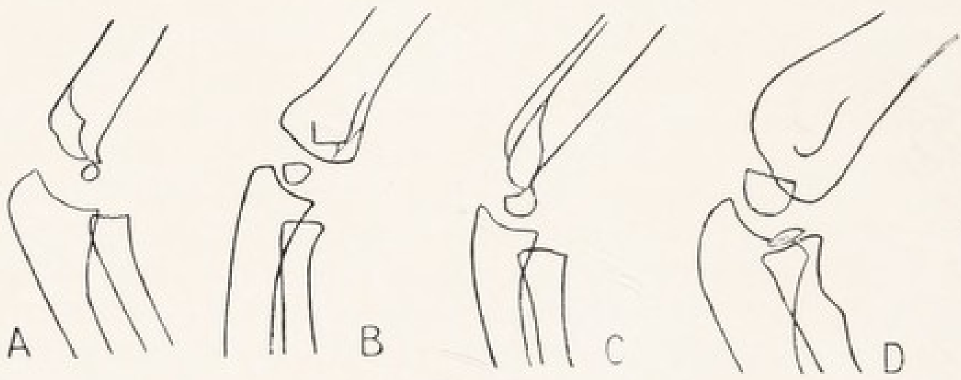


Fig. 31.

useful, because slight rotations of separated epiphyses according to the author's experience hardly ever occur; rather the separated epiphysis generally turns a considerable way, in the majority of cases about 90°. If the contours have been prolonged in the manner recommended, one obtains in a real separation some quite impossible forms (see Fig. 29, A and B). (A=separation of eminentia capitata, B=separation of internal epicondyle.) A reservation should, however, be made in the case of the first osseous nucleus, that of the capitulum humeri (=eminentia capitata, rotula). One should know the projection of this in the normal condition exactly, otherwise one is apt to diagnose a separation of it when it is perfectly normal (see Figs. 30 and 31, which are diagrams of quite normal conditions).

In the cases where all the osseous nuclei are present (see Fig. 32, normal), the Röntgen picture in *a suspected fracture* gives the observer special difficulty. It should be noted also that the *nucleus of the trochlea* exhibits normally on the median side a very remarkable indefinite outline with well-marked indentations (Fig. 32, left sketch), and that further the normal epiphysial line of the olecranon, before it ossifies (sixteenth to seventeenth year), shows a very wavy course (Fig. 33, right) that can mislead one into diagnosing a pathological condition.[1]

The *ossification of the olecranon* epiphysis often presents peculiar pictures, and therefore may easily lead to errors in diagnosis; a few diagrams of normal conditions are illustrated (Fig. 33; see also Fig. 32, right). The ossification primitive-formation can also be completely fissured with indefinite delimitation of the shadow.

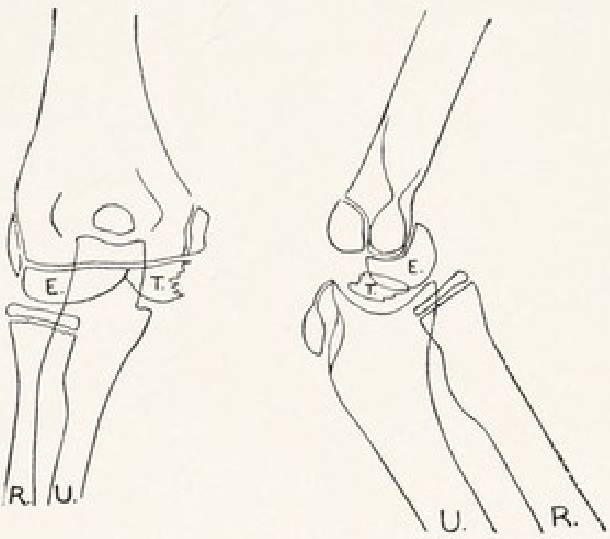


Fig. 32.
(E.=Eminentia capitata. T.=Trochlea.)

The *process of ossification* of the epiphyses of the elbow is usually much further advanced in girls than in boys of the same age; see also pp. 1–2.

For examinations into *disturbances of growth* of the whole skeleton (myxœdema, etc.) the best place to select for examination is the carpus. For particulars refer above (pp. 27, 28–31). Regarding Röntgen view of osteochondritic syphilitic separations of epiphyses, which occur at the distal end of the humerus, see " Forearm—Distal end."

Proximal End of the Ulna

About 4–6 cms. distant from the joint in the adult the *spongiosa architecture*, especially in profile views, shows some long lacunæ running parallel to the axis of the bone=normal.

Although in profile picture *in the adult* the shadow of the proximal end of the ulna may cover in a variety of ways that of the joint, the trochlea and the radius, the conditions are usually so plain that mistakes are uncommon. The most easy to miss is a *transverse fracture of the radius* immediately below its capitulum, or vertical fracture-fissures in the

[1] For a complete study of the ossification conditions, see Röntgen-Archiv; Wilms-Sick: Entwickelung der Knochen der Extremitäten. Hamburg, 1902.—Jedlicka: Topographische Anatomie der oberen Extremität. Hamburg, 1900.—Wendt: Verletzungen des Ellenbogengelenks im Röntgenogramm. Hamburg, 1910.—Åkerlund, quoted in " Hand," p. 12.

capitulum, in cases where this part is cast for the most part into the shadow of the ulna. Where this is suspected the dorsal view should be examined all the more carefully.

The *proximal osseous nucleus of the olecranon* is projected in dorsal pictures usually into the transparent area of the supra-trochlear fossa of the humerus (see Fig. 32). The resulting view can only deceive one who has seen it for the first time.

The *proximal lateral edge of the olecranon* has usually a right-angled outline in dorsal pictures. It sometimes forms a very small process projecting upwards and inwards, which may be reckoned a physiological condition.

The author once saw in a soldier as a chance finding on the flexor surface of the proximal end of the ulna 3·5 cms. distal from the tip

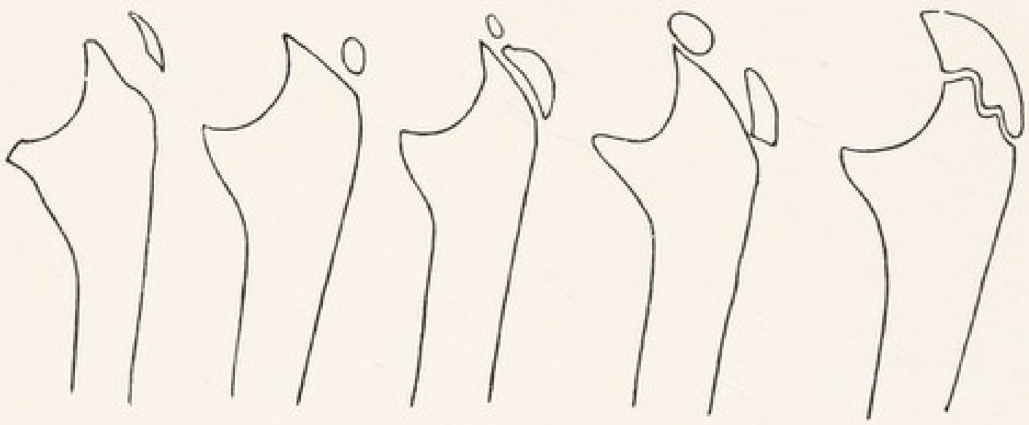


FIG. 33.

of the olecranon a large *thorn-like process;* see Fig. 34. Old tear of the insertion of the brachialis to the coronoid process of the ulna? The history of earlier trauma was, however, lacking.

In lateral photographs of the elbow[1] there is frequently seen at that part of the olecranon where *the triceps muscle* is inserted a bony process or a ledge "processus anguli olecrani" (Fig. 35), which in some cases attains a great size, up to $1\frac{1}{2}$ cms. in length. It is usually bilateral. It is said to occur more frequently in the female sex; it is seldom met with before the thirtieth year of life. In the opinion of some authors its origin is due to a certain bone-building diathesis (like the calcaneal and occipital spurs).[2] And the latter having sometimes been observed as a congenital peculiarity of the skeleton in families, it is believed that similar conditions here prevail. The question of the genesis of spur-formation is not by any means settled; several factors, primitive-formation, heredity, trauma, and other occasional causes have to be reckoned with. Bursal sac inflammations of acute and chronic kinds are favoured by the presence of a spur. When the spur is

[1] According to Esau, "in about 2 to 3 per cent. of unselected individuals": Bemerkungen zu den Spornbildungen (Olekranon- und Occipitumsporn). D. Zeitschr. f. Chirurgie, Bd. 117, 1912.

[2] Esau, *l.c.*, and Chrysospathes: D. Zeitschr. f. Chir., Bd. 110, vols. 4–6. Also Krüger: Über Spornbildungen am Olekranon. Bruns Beiträge, Bd. 73, Heft 2.

large, it is exposed to injury from its superficial position and can break off, showing a fracture-line in the Röntgen picture. The diagnosis "recent fracture" should only be made when crepitation is actually felt; for it appears that there are not a few cases in which without any previous injury a jagged transverse line goes through the base of the spur or the spur itself. At all events, one should be very chary of adopting the diagnosis of fracture in such pictures. More numerous inquiries in unselected individuals appear desirable. There are also similar shadows at the same place, only less dense and separating up towards the triceps, which are the consequence of tears

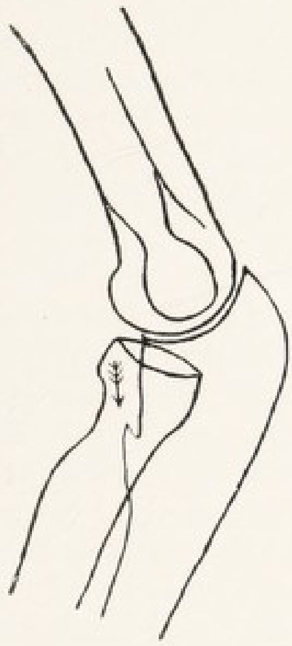


Fig. 34.

Fig. 35.

and ossifications (see below in the reference of Kienböck to "elbow-cap," further also in "patella genu" and in "great trochanter of the femur").[1]

Sesamoid bones in the triceps tendon have been described only about five times in the anatomical literature, in the Röntgen literature a large sesamum cubiti has been described.[2] In all the cases there has probably been an old fracture of the olecranon.[3]

The coronoid process of the ulna varies much in its length and form, without being pathological. It is often strikingly long and pointed, reaching far into the coronoid fossa of the humerus; it is also often met with divided in fork-like fashion.

The dorsal corticalis of the proximal third of the ulna is the favourite

[1] See also R. Jones and D. Morgan: On osseous formations in muscles due to injury (traumatic myositis ossificans). Arch. Röntg. Ray, 9, p. 245; 10, pp. 10, 72, 99, 199 (with literature), 249, 275, 304.

[2] Kienböck: Über Varietäten des Ellenbogengelenks, Patella cubiti und Processus anguli olecrani. Wiener Mediz. Presse, 1903.

[3] Kienböck: "Ellenbogenscheibe" ("Patella cubiti") und Olecranonfraktur. Fortschritte, Bd. 22, 1914–15 (with list of the literature).—Fiedler: Ein Fall von Verknöcherung in der Tricepssehne nach Trauma. Fortschritte, Bd. 24, 1917.

site of gumma. If one finds in profile views of this region a periostitis ossificans and a periostitis rareficans combined, and the history corresponds, we have probably to deal with a commencing gumma.

Proximal End of the Radius

The spongiosa structure in the *tuberosity of the radius* often shows a peculiar mixture of shadows in people with strongly built bones, which can easily be held to the pathological, especially when the patient complains of that part.

Photographs of an accident case about two to three months afterwards may show thick, thorny, or cloudy shadows in the soft tissue shadow radiating from the tuberosity and extending upwards; these are usually *ossifications* of the tendinous insertion of the biceps brachii that has torn in the accident or in replacement of a dislocation. These ossifications may reach the size of a little finger.

The *capitulum radii* has usually the form of an inverted mushroom. In dorsal exposures the transparency (relative deficiency in calcium) affects the most lateral part, which is normal. When the lateral part of the head of the radius is enlarged, bent over distally, or otherwise increased in thickness, arthritis chronica or incipiens is usually present. If the head of the radius projects out from the external condyle of the humerus, that is, pathological, for normally the contour of the lateral condyle passes right over into that of the radial head. It is said to be typical of tennis-elbow, a mechanical affection of the joint, which is manifested in a local inflammation of the capsule and tenderness of the radio-humeral joint.[1]

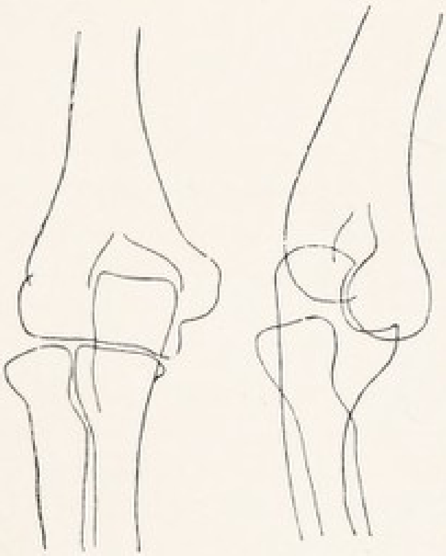


FIG. 36.

Regarding a flat piece of bone demarcated from the head of the radius, see "Distal end of the femur. Osteochondritis dessicans."

Fractures of the capitulum radii, like that of the neck, are quite common and yet are not always very noticeable; in the head longitudinal fractures are the rule, in the neck transverse fractures.

The head of the radius may show not a concave articular surface turned proximally, but a more or less *convex articular surface* (as in Fig. 36); there is usually present *a congenital subluxation* of the radius; in the majority of cases the patient is quite unaware of the abnormality in his elbow.

Congenital luxations are not easily overlooked, and yet the beginner may miss them, for they appear most clearly in dorsal pictures, but in these,

[1] Ochsenius: Über die Prognose des Tennisellenbogens. D. M. Wochschr., 1925, No. 48.

owing to a peculiarity of the dislocation backwards, the head of the radius is covered by the shadow of the ulna.[1]

Congenital union of the ends of radius and ulna is not at all so uncommon; it is, however, not particularly noticeable in Röntgen picture, and may therefore be missed.[2] The ætiology of the fusion is still uncertain.

Total luxation of the radius laterally may in profile view resemble quite normal conditions, when the examiner has omitted to take a dorsal picture at the same time.

In young children up to the age of three to four years a peculiar *subluxation forwards of the radius* may occur, in which, strange to relate, the clinical picture is much more noticeable than the Röntgen finding. The French describe the condition as "Pronation douloureuse." The child is unable to supinate the painful forearm, the elbow-joint is held slightly flexed, the hand hangs by the side, and is abducted slightly ulnarwards. One can palpate a sharp constriction between the external condyle of the humerus and the capitulum radii, which allows the proximal end of the head of the radius to project more prominently. Sometimes, too, there is a marked displacement in position of the head of the radius inwards, upwards and forwards. The injury is always produced by the nurse or attendant jerking the stumbling or falling child suddenly upwards. Naturally such a subluxation is due to appear in Röntgen view in some way, but it is not at all obvious, and a comparison photograph of the sound arm in exactly the same position is an impossibility. At present there does not seem to be sufficient Röntgen material. It may, perhaps, be possible with a larger material to define a characteristic Röntgen picture. The condition has also been called subluxatio radii perannulare, thus indicating that the head of the radius has slipped out of the annular ligament of the radius, which slides upwards with its anterior and lateral portion over the head of the radius and is stretched very tight.[3] *Lateral subluxation of the radius* may be caused by a cartilaginous exostosis.

Fig. 37.

Distal End of the Humerus

Cloudy dense shadows (*ossification*) *along the epicondyles* of the humerus (Fig. 37), appearing several months after an accident, indicate that the

[1] See also G. Andreini: La lussazione congenita della testa del radio. Archivio di Ortopedia, 1904, p. 704.

[2] A complete discussion of this and similar cases is by Kienböck: Die radio-ulnare Synostose. Fortschritte, Bd. 15, 1910.—B. Baisch: Ztschr. f. orthop. Chir., Bd. 31.—Sonntag: Beitr. z. klin. Chir., Bd. 127, p. 716.—Lüdin, Basel: Über familiäre congenitale radio-ulnare Synostose. Schweiz. med. W., No. 13, 1924.—K. Vogeler: Die radio-ulnare Synostose. Arch. f. klin. Chirurgie, 136/2, p. 427.

[3] Erlacher: Subluxatio radii perannulare. D. Zeitschr. f. Chir., 1914, Bd. 126.

articular capsule has been torn (probably the collateral ligaments). They may in time disappear again.[1]

In profile views *a bony-dense, band-like line*, in form like the third of a circle, on the flexor aspect of the distal end of the humerus a few millimetres away from the shadow of the bone and parallel with it, is met with, especially some time after a trauma.[2] The shadow is an ossification of the articular capsule.

Below the internal epicondyle of the humerus, roughly parallel with the contour of the ulna, a very thick longitudinal band is visible in the shadow of the soft tissues in many dorsal pictures, = normal tendon shadow (M. flexor carpi ulnaris).

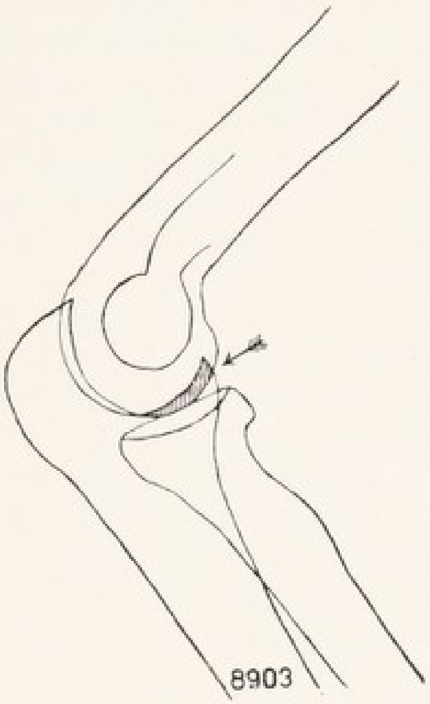


Fig. 38.

Regarding *the general outline of the distal end* of the humerus in dorsal projections, we may say that the capitulum humeri (eminentia capitata) forms normally a beautiful semi-circular arch ; also the contour of the internal epicondyle is well rounded. (At the point where the shadow-border of the capitulum intersects that of the external epicondyle, there is seen a thicker slightly wavy line.) In manual labourers this arch is not so regular and one finds rounded-off edges in these people. If it is even rectangled with small swellings on the surface, this is ascribable in the majority of cases to a *chronic arthritis* (see deformans incipiens). In these cases the joint fissure is generally narrowed, which in the elbow is often a difficult matter to recognise ; more readily recognisable in chronic arthritis is the serrated interruption of the articular contour of the humerus which is normally so beautifully curved.

In profile pictures of the elbow the superposed shadow of the end of the humerus at its crossing with the flexor aspect of the end of the ulna is sometimes so dense that the accidental prominence of this double shadow makes one think of a detached piece of bone (about the size of a sixpence) ; see Fig. 38.

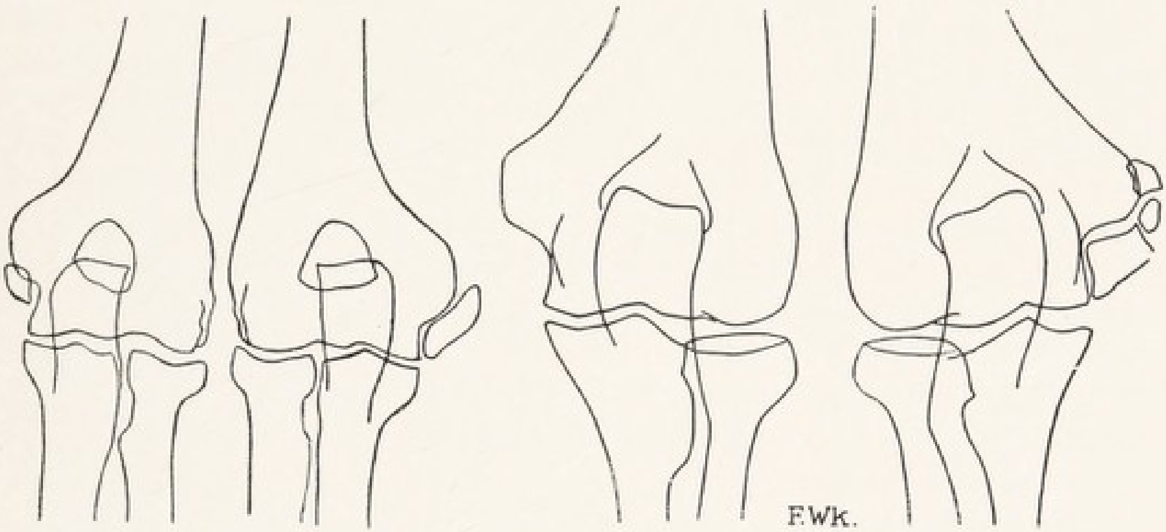
The contour passing over from the external condyle to the humeral shaft forms sometimes an elongated slightly convex arch about 5–8 cms., which the inexpert is wont to diagnose as an ossifying periostitis, while perfectly normal conditions obtain.

The density (*i.e.* the Röntgen shadow density) of the humerus in the *supratrochlear fossa* (fossa olecrani, fossa coronoidea) is very various. Often there is no trace of bony structure to be seen ; that is not pathological, for

[1] See, moreover, the work of H. Vulliet. Schweiz. med. W., 1923/16, p. 203.

[2] Engels : Kasuistischer Beitrag und einige Bemerkungen zu pathologischen Knochenbildungen. Fortschritte, Bd. 24, 1917.

the bone may be not only thin at this point, but there may occur a physiological opening, " supratrochlear foramen." According to recent researches,[1] this finding (in Röntgen view) is quite a frequent occurrence in the adult. In many races of mammals (among others marsupials, pigs, in certain carnivora and insectivora) it is typical; but in the embryonic stage one finds always an unperforated humerus. In monkeys and apes the foramen is not rare, so that Darwin regarded the perforation of the humerus in man as a proof for the descent of man from an inferior form, and wrote that although not constantly found it occurred in different anthropomorphic and other apes. According to others, it is regularly present in the gorilla and orang-outan, also in the chimpanzee. In younger individuals before puberty a supratrochlear foramen can never be found. It is usually bilateral, but with great



A Fig. 39. B

differences between the right and left sides. It varies within wide limits in size and form. In connection with supracondyloid fractures of the humerus a small round unilateral foramen appears sometimes owing to interruption of the ossification process. Supratrochlear foramina have been found to occur hereditarily in families. The presence of a bilateral supratrochlear foramen is related to a strong capacity for hyperextension.—Regarding an oval shadow in the fossa, see p. 54.

In profile pictures the normal condyles of the humerus give shadow-outlines of three-quarter circles, which pass over gradually into concave arches; dorsally a further flat convex-arch may also appear; in heavy manual labourers the edges are usually quite blunt; but if one finds small processes at the flexor side of the condyles, that speaks for chronic or deforming arthritis. (See above, also in " Dorsal projection.")

A semicircular shadow, displaced on the flexor aspect of the humerus, corresponds to a *detached eminentia capitata.*[2]

[1] H. R. Schinz: Das Foramen supratrochleare humeri. Fortschritte, Bd. 29, 1922. With complete list of the literature.

[2] Haenisch: Isolierte Fractur des Capit. humeri. Fortschritte, Bd. 15, 1910.

The internal condyle of the humerus in profile negatives is often so transparent at the flexor side at the point where it is not overshadowed by the other condyle, that one is inclined to diagnose an advanced tuberculosis when the conditions are quite normal. Tuberculosis can doubtless be localised to this part, and then one may have difficulties. The dorsal negative then clears up the diagnosis; it has further to be noted that in tubercule the surrounding bony tissues are usually deficient in lime.

A peculiar and very rare condition is illustrated in Fig. 39: we see there a shadow distal to the internal epicondyle, in size from a pea to over a bean, which may be bilateral. In the anatomical literature the author could find no mention of this piece of bone. In the cases which he saw [1] a moderate but definite appositional deformity was seen at the lateral epicondyle, and at the head of the radius. In another case (Fig. 39, B), where three such bony nodules were present at the same time, the largest one (in the two smaller ones it could not be distinguished) showed a regular fine cancellous structure. In the latter case, and also in another unilateral case, a history of accident was given, in the last case five and a half months previously. I regard it as impossible that such a complete osseous architecture could have formed in such a short time. Such findings have been present probably for years, if not since childhood, and are now discovered röntgenographically only after a trauma (see also the explanation of Fig. 37). The latest case brought to my attention (by Dr. Stolz) was on one side: a history of injury ten years before, microscopically examined (by Hasselwander), yielding photographs that are never seen in the usual course of ossification. The estimation of the histological appearances was extremely difficult. It appeared highly probable that there was an element laid down in cartilage or possibly a separation away of a cartilaginous particle in the childhood stage before ossification was completed.

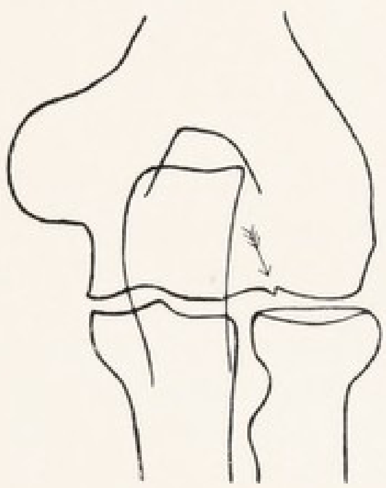


Fig. 40.

Slight or more definite *defects in the articular contour of the capitulum humeri* are sometimes met with in youths and young men with an accompanying clinical picture of a chronic arthritis of the elbow with slight deficiency in extension and some muscular weakness. These are traumatically or mechanically produced detachments which lead to the formation of joint-mice and later to an arthritis deformans. The joint-mice become visible earlier or later by calcification.[2]

[1] A case of our own, further two cases kindly placed at our disposal by Dr. Hartung, Dresden (Fig. 33, A), Dr. Wittek, Graz (Fig. 33, B), and Stoltz, Wittenberg.

[2] M. Kappis: Über eigenartige Knorpelverletzungen am Capitulum humeri, etc. D. Ztschr. f. Chir., Bd. 142, Heft 3 and 4, 1917; see further the same, *ibid.*, Bd. 171, vols. 1 and 2, 1922.—H. J. Panner: Separations from the capitulum humeri as the most frequent determining cause of arthritis deformans. Acta Rad., 1924, Nos. 12–13.

Small thorn-like processes at the spot shown in Fig. 40 should not be written down at once as pathological. At the knee such a thorn-process corresponds to the sharp dorsal edge of the femoral condyles, which are projected all the larger the nearer the focus of the tube is to the hip. By analogy the thorn-process at the elbow corresponds to the dorso-lateral edge of the condyle, or rather to that between the capitulum humeri and the trochlea, and in chronic arthritis forms a sharply marked projecting ledge.

Translucent areas two and more centimetres in length may be found at the juncture of the diaphysis and epiphysis of the humerus, and may run far into the soft-tissue shadow ; they are due to the fat and bursal membrane between the muscle-fibres.

A small periosteal knuckle of bone or small distally pointing exostoses at the external condyle has been observed in *epicondylitis.*[1] According to one authority it makes its appearance principally in women (three to four times as often as in men) ; according to others it appears in shoemakers, glass-blowers, and tennis-players—" tennis-elbow," as a consequence of a chronic traumatic irritation. (See, also, above, " Proximal end of the radius. Capitulum radii.")

Shaft of the Humerus

Diagnostic difficulties of what is normal and what is pathological are here rare.

The *ossification centre* appears in the seventh to eighth fœtal week.

The shaft of the humerus is the favourite site of a sequestrating *acute osteomyelitis.* We have to believe this present, when with typical clinical appearances the periosteum is ossified a good way along, and at a stage later the bone appears atrophied in spots.

Syphilis is not very common here ; in commencing gumma one sees a marked periostitis ossificans, but in its midst there soon appear rarefications of the corticalis, which rapidly increase. The process never proceeds to a spotted chequered atrophy of the surrounding neighbourhood of the gumma.

If *the lumen of the shaft* is obliterated and dense like the corticalis, while the contour of the shaft is slightly uneven in a patient who has been complaining for years, we may be dealing with a slow chronic osteomyelitis or an old syphilitic process ; for both affections go on usually to eburnation. The history must determine the correct diagnosis.

In the shaft of the humerus there also occurs *metastases of tumours ;* these can be diagnosed without difficulty from their definite transparency as contrasted with the normal bony tissues, their edges being more or less sharply defined.

[1] Blecher : Über Röntgenbefunde bei Epicondylitis humeri. Fortschritte, Bd. 20, 1913.—Jungmann : Erg. d. Chir. u. Orthop., 16. Bd., p. 155.—E. Bergmann : Epicondylitis. Arch. f. Orthop. u. Unf.-Chir., 23/3, p. 368.—Sourdat : L'epicondylite des joueurs de Tennis. Ref. Journ. de Rad. et d'Electr., 1922, p. 42.—G. Franco : VII. Congresso italiano di Rad. Med., 1926.

Regarding *periosteal deposits* around both the shafts of the humerus and all the long bones, see "General Part. Generalised periostitis hyperplastica," pp. 4 and 5.

On the upper and outer aspect of the shaft one meets frequently with simple *exostoses*, whose recognition is not difficult.

In the middle of the shaft *oblique longitudinal transparencies* do not correspond to processes in the bone, but arise from deposits of fat between the muscle fibres. They can usually be definitely diagnosed as such, in that they can be followed outside the shadow of the bone deep into the soft tissues.

The *triceps muscle* can frequently be clearly distinguished in Röntgen pictures, sometimes in the bony shadow, sometimes in the other soft tissue shadows.

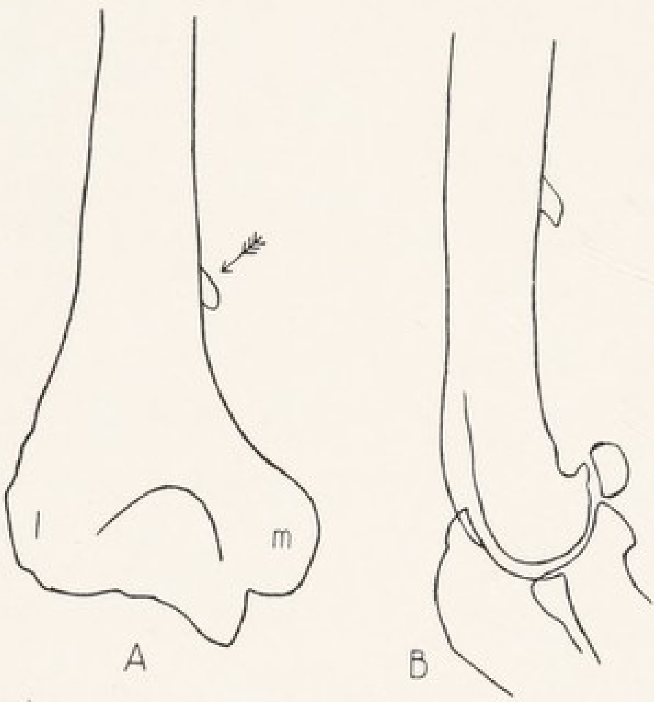


Fig. 41.

A small thorn-like shadow at the volar side of the shaft at the juncture of the distal and middle thirds can be distinguished as an ossification after tearing of the *insertion of the brachialis anticus ;* it is also found in cases of pronounced arthritis deformans.

A bony process is found very occasionally on the inner flexor side of the humeral shaft, as shown in Fig. 41.[1] That is, the so-called *supracondyloid process of the humerus.* (A = a preparation, B = an actual case.) The anatomists found it in 1–2·5 per cent. in all subjects ; slight indications of it are doubtless more frequently met with. In completely formed cases there springs from the osseous process a more or less definite band, which runs down to the internal epicondyle. This band is, however, rarely ossified in man (it has been described only by two anatomists) ; one can then speak of a supracondyloid foramen ; the latter is regularly present in many rodents, edentates, insectivora, carnivora (cat, otter), also in apes, but not in the anthropoid apes ; it is met with also in reptiles (sphenodon). In many instances the hereditary nature of the process can be established in man. The supracondyloid process serves usually for the attachment of an abnormal extra slip of the pronator teres.[2]

[1] The left picture A is taken from Grashey, Atlas I, 4th edition, and is from a preparation ; the right picture is a case of the author's, the first that was seen by him after fifteen years' Röntgen activity (in this particular case arthritis deformans cubiti was present) ; one further case up to the date of this edition.

[2] Albers-Schönberg : Skelettanomalie von atavistischem Interesse, Proc. supracondyloideus oder endepicondyloideus. Fortschritte-Röntgenstrahlen, Bd. 23, 1915–16.—

SHOULDER [1]

Proximal End of the Humerus

As regards *the ossification* of the proximal *epiphysis* of the humerus, in a few cases an ossification centre is found at the date of birth.[2] It commences as a rule between the fourth and the eighth month of life and is placed in the half of the articular epiphysis adjacent to the glenoid cavity of the scapula. In the lateral half there appears an osseous nucleus between the middle of the second and third year; it belongs to the greater tuberosity. In the fourth to the fifth year there is added a third osseous nucleus, corresponding to the lesser tuberosity. It is usually difficult to recognise, for it is apt to be confused with that of the greater tuberosity. Towards the fifth to the sixth year the nuclei of the two tuberosities unite together to form a uniform epiphysis of the tuberosities. In the thirteenth to the fourteenth year the epiphyses of the tuberosities fuse with the epiphysis of the head. The whole epiphysis unites with the diaphysis about the twentieth year. The appearance of a special epiphysis for the lesser tuberosity has been denied from the röntgenological side.[3]

The epiphysial line runs normally not simply transverse to the shaft, but partly ridged; the two parts of the ridge do not require to be straight, but may appear more or less wavy. In this way there are produced in Röntgen view triangles with more or less straight sides, sometimes also ovals, sometimes quite peculiar figures, without the condition being in the slightest degree pathological. A number of illustrative diagrams of normal conditions are given in Figs. 42 and 43. (For the first epiphysial nucleus to appear refer also to the explanation under " Childbirth paralyses.")

Flad: Klinische Beobachtungen über den Proc. supracond, humeri und dessen familiäres Vorkommen. Jahrbuch für Kinderheilkunde, Bd. 85, Heft 4, 1915 (with list of the literature). —Giovetti: I. Riunione dei Radiologi Toscani in Firenze (May, 1921).—Moreali: Su quattro casi famigliari di "processus supracondyloideus internus humeri Gruber." IV, Riunione dei Radiologi Emiliani, Bologna, 1922.—R. Balli: Anat. röntgenogr. normale dello scheletro. Ferrara, 1924.—F. Sorge: Über den atavistischen Pr. suprac. humeri. Anatom. Anzeiger, vol. 60.

[1] For the normal Röntgen anatomy of the shoulder, see Grashey, Atlas I, 4th edition, and the older atlas of Jedlicka and Katzenstein and Scheffer: Die topographische Anatomie der oberen Extremität. Röntgen-Archiv, Hamburg, 1900.—Hasselwander: " Die Röntgenstrahlen in der Anatomie" in Rieder Rosenthal's text-book, 2. Bd., 1918.—P. Sessa and O. Alberti, *l.c.*, p. 1.—J. Cohn: Observations on the normally Developing shoulder. Amer. Journ. of Röntg., December, 1921.—Belot and Lepennetier: Journ. de Radiol. et d'Electrol., March, 1923, p. 97.—St. J. D. Buxton and R. Knox: A radiological survey of the normal joints: I. Shoulder-joint. Brit. Journ. of Rad., vol. 29, No. 285, 1924.—Schinz, Zürich: Die Schulter, eine anatomische und röntgenol. Studie. Arch. f. orthop. u. Unfall-Chir., Bd. 22, April, 1924.—Massart and Cabouat, Nimes: Etude röntgénographique du développement de l'épaule. Journ. de Rad. et d'Electr., Tome VII, 1923.—M. King and G. W. Holmes: A review of 450 Röntgen-ray Examinations of the shoulder. Am. J. of Röntg., February, 1927.

[2] Real separation of the epiphysis with dislocation in consequence of injuries in childbirth can therefore be established röntgenographically in these cases. See also the footnote to Figs. 44 and 45.

[3] Schinz, *l.c.*

Fractures in the epiphysial line are relatively uncommon, they often run along the epiphysial line for a bit and then pass distally into the bone.

For the Röntgen-ray appearance of osteochondritic and syphilitic separations of the epiphysis, which take place at the proximal end of the humerus and are easily overlooked, see " Forearm—Distal end."

Many mistakes have been made in the interpretation of röntgenograms

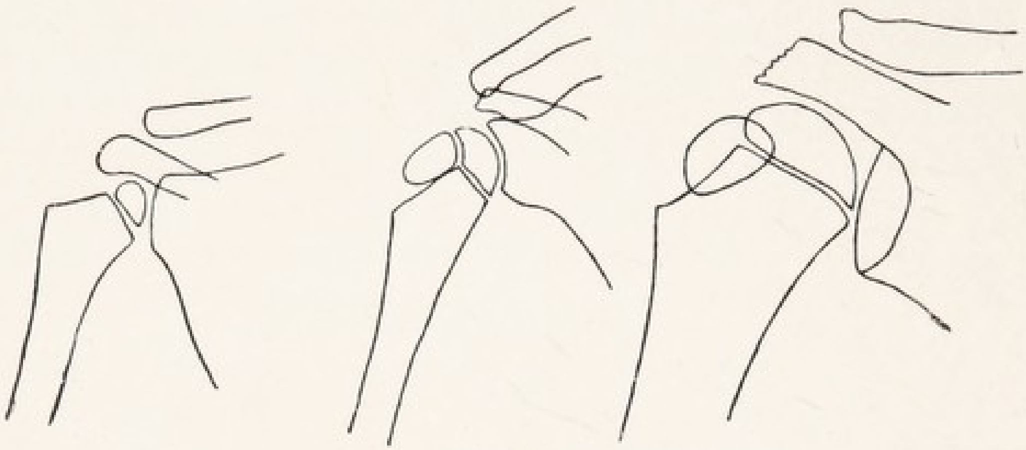


Fig. 42.

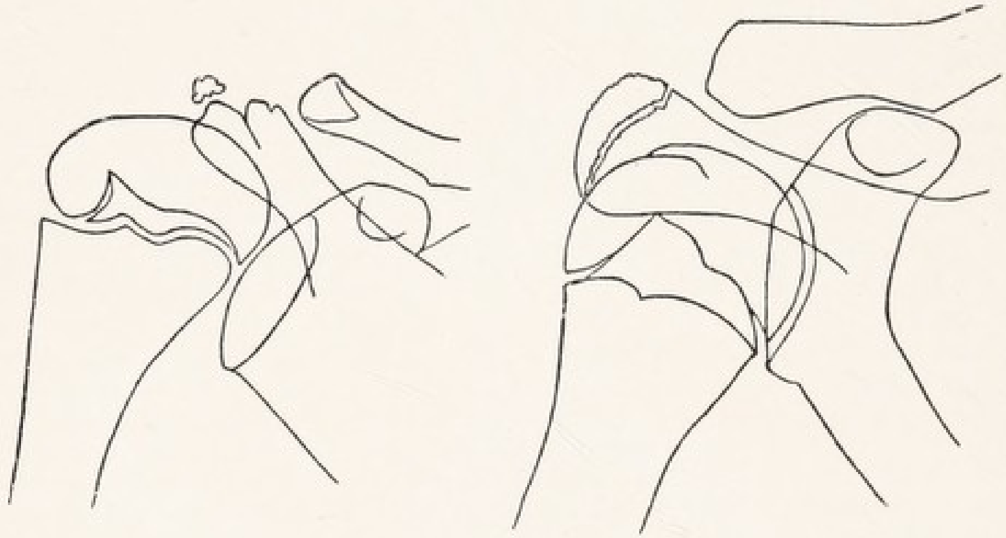


Fig. 43.

in cases of true childbirth shoulder-paralysis, by the reading of traumatic separations of epiphyses in the röntgenograms. A separation of the epiphysis was diagnosed at the upper end of the humerus, if the first nucleus to appear in the humeral head appears lateral to the upper pointed end of the shaft instead of medial to it. (The normal view is seen on the left side in Fig. 42.) But it now appears to be proved [1] that in many cases this lateral displacement of the particular epiphysial nucleus is nothing else than an error of projection in consequence of marked internal rotation of the whole arm, as

[1] C. Mau: Die röntgenologischen Veränderungen bei der angeborenen Schulterlähmung unter besonderer Berücksichtigung der sogenannten Lateralverschiebung der oberen Humerusepiphyse. (With list of the literature.) Fortschritte, Bd. 31.

is quite typical for congenital paralysis of the shoulder (see Figs. 44 and 45). (Fig. 44, four months old. Internal rotation. Fig. 45, the same patient. Complete external rotation.) If one photographs a sound arm with a difference of about 150° (!), one in external and another in internal rotation, a considerable displacement of the shadow of the epiphysis occurs from medial to lateral. The internal rotation typical of congenital paralysis of the shoulder allows the medial epiphysial nucleus to appear laterally in the röntgenogram (Fig. 44), and so simulates a separation of the epiphysis.

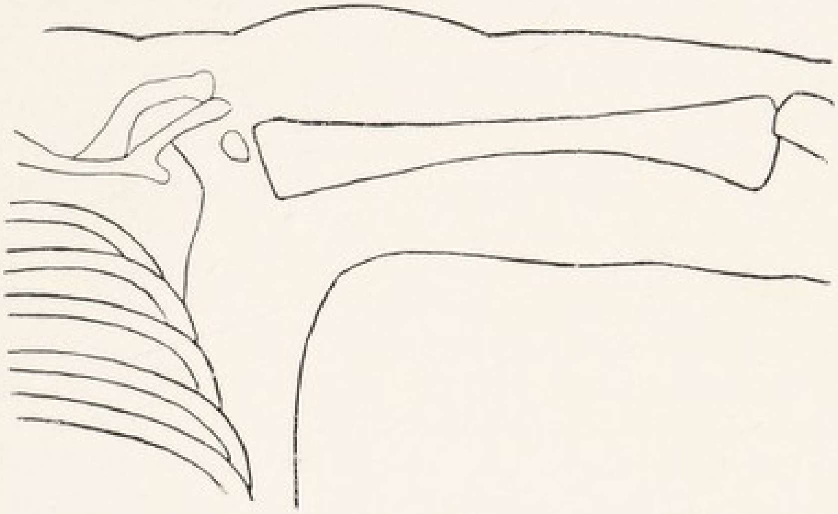


Fig. 44.[1]

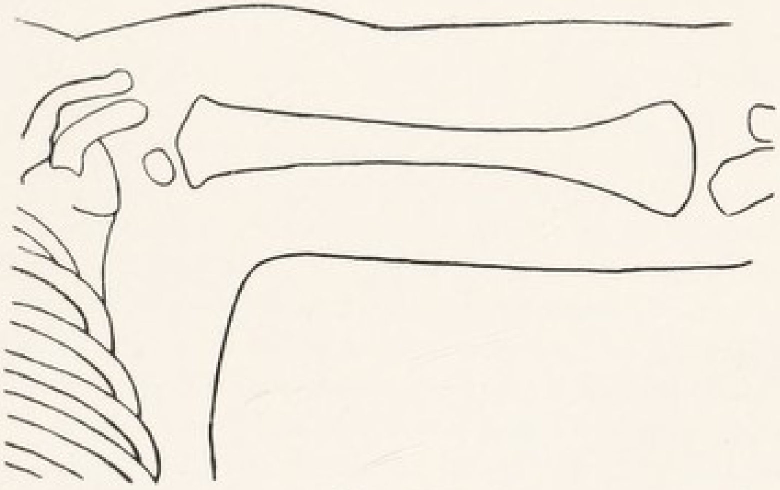


Fig. 45.[1]

(Naturally, too, one sometimes sees a true separation of epiphysis. But these cases show quite other findings, especially when ossifying callus is already present.) It appears ever more likely that the changes in so-called birth-paralysis are the expression of a trophoneurotic atrophy, in which the period of nerve lesion took place in intrauterine life; also the so-called "congenital plexus paralysis" is said to be a central-nervous disturbance of development.

[1] C. Mau, *l.c.*

5

In the true *birth—or forceps—paralysis* investigation by the Röntgen rays has yielded no special results ; nevertheless in "pseudo-birth-paralysis " (with its characteristic position and interference with function with transient paralysis or entire absence thereof) definite findings are said to have been secured ; [1] altered direction of the axis of the humeral diaphysis, abnormal distance between the end of the diaphysis and clavicle, displacement of the nucleus of the head outwards, in subsequent years marked retardation of the nucleus of the head in size, irregularities of the outline of the nucleus of the head, and flattening of the inferior margin of the glenoid cavity.

The judging of shoulder röntgenograms is one of the most difficult tasks even for the skilled worker ; profile photographs of the shoulder in the living subject are not easy, and therefore it may happen to the beginner and the less expert inquirer that he overlooks severe fractures completely or mistakes them for severe injuries. Accordingly, at the proximal end of the humerus one ought to remember that a complete fracture does not require to show any displacement in the dorsal (or ventral) picture, and that notwithstanding a maximal displacement may be present in the lateral view. (See also below under " Y-shaped fractures.")

Profile exposures of the shoulder are less important for the diagnosis of the shoulder-joint, they are used principally for the estimation of foreign bodies (whether the position of the body is dorsal or ventral to the scapula), for representation of the scapular spine and the outer edge of the acromion process.

The *head* is normally circular ; if it appears more like an egg in the negative, that is usually not pathological but simply a consequence of the projection (with the underlying plate set too much at an angle).

If one desires to bring the head of the humerus with *the joint cavity* and the glenoid cavity into good view, one should set the focus of the tube somewhat medial to the joint and somewhat above it ; if one wishes to get the best possible survey of *the coracoid process, the acromion, and the end of the clavicle,* one should set the focus about 3 cm. further outwards and 2 cm. further downwards than in the above case, or one may choose the following more laborious procedure [2] : the patient sits with the arm held horizontal and takes a firm grip with the pronated hand on some support. The rays from the tube pass vertically upwards towards the axilla. The plate rests horizontal on the curve of the shoulder ; see further under " Axial röntgenograms."

The diagnosis of slight changes in the shoulder is rendered extremely difficult by the circumstance that it is quite impossible to project the sound joint in the same way as can be done in the diseased one. Exact comparisons are therefore not possible, unless one neglects the advantage of the diaphragm and photographs both shoulder-joints during a single exposure. In general, however, one must say that in the shoulder-joint

[1] Peltesohn quoted by Wollenberg in Gerhartz : Leitfaden d. Röntgenologie, 1922.—Valentin : Arch. f. Orthop., Bd. 19.

[2] Stated by Iselin ; a corresponding picture, see Grashey, Atlas I, 4th edition, Fig. 157, B.

apparently considerable complaints may exist months or even years, without the Röntgen picture necessarily showing the slightest change. It is the soft tissues that appear to be selected: the articular capsule, the ligaments, and the cartilage being the tissues especially affected.

The illustrations given in Fig. 46 correspond to quite *normal findings*, only with different setting of the tube; it is usually a matter of luck in obtaining a picture in which the various bones are as little as possible superimposed.

If the glenoid cavity projects downwards a distance of about 1 cm. beyond the articular edge of the humeral head, we have to do with quite a normal appearance, which is best obtained with the upper arm in the abducted position (see the diagram on the right, Fig. 46).

Fig. 46.

In clinical signs of *chronic arthritis* one should not forget to determine on the röntgenogram—even if it shows quite normal contours of the bones—the breadth of the joint cavity (=articular cartilage); for disappearance or absorption of cartilage may be the only marked feature present. The normal thickness of the articular cartilage at the head of the humerus and of the articular cartilage of the glenoid cavity naturally varies somewhat, but not in wide limits. It amounts to 2–4 mm. In a narrow joint fissure one should think of erosion, in the broader joints one should think of effusion.

As already indicated, complete *transverse fractures of the surgical neck* undergo hardly any dislocation in the frontal direction; such cases are very frequent. If in such a case the picture is still a little indefinite in consequence of the breathing, we might think that the bone in front of us was normal (apart naturally from the clinical findings). But if the röntgenogram is a very sharp one then on careful search one will find the line of fracture or, if the Röntgen rays pass at an angle to the break, the lines of fracture, which are then wont to form a more or less complete oval. Palpation must discover which fragment is in front and which behind. If one does not arrive at a certain result, then the difficulty can be cleared up by projecting the rays very obliquely, or by means of photographing from above with a film in the axilla.

In many such cases one does not succeed without taking exposures with the extremest possible *rotations of the humerus*. They show us the humeral head and neck in quite a different shadow-outline; see Fig. 47.[1] They often give us the best view in cases where it is impossible to arrive at a conclusion with an axial photograph.

But in certain cases *axial röntgenograms* are absolutely essential; see Fig. 48. The patient is placed on the back, the arm is abducted to the horizontal position, the film rests on the top of the shoulder, the central ray passes from below, *i.e.* from below up into the axilla. The patient stands with the hand pronated against a stand or piece of apparatus. An exposure obtained in this way shows the humeral head, the glenoid cavity of the scapula, the coracoid process, the acromion and the clavicle, occasionally also the neck of the scapula is visible, as well as the shoulder-blade.

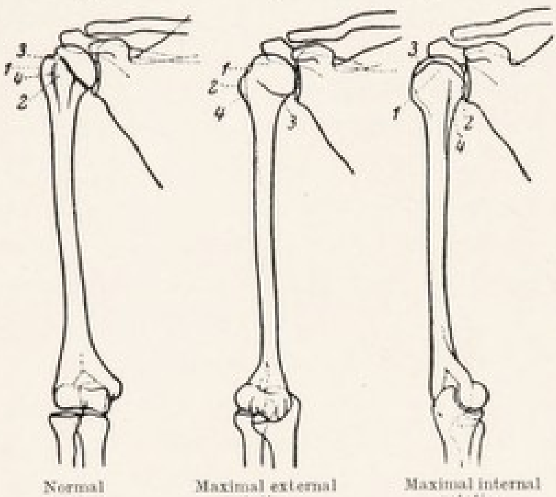


Fig. 47.[1]

1. Greater tuberosity.
2. Lesser tuberosity.
3. Anatomical neck.
4. Bicipital groove.

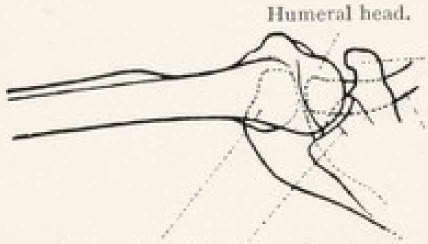


Fig. 48.[2]

Y-shaped fractures without any dislocation to speak of are also a frequent injury; they are not noticeable in the röntgenogram but require rather to be sought for (see Fig. 49). One should try to take two photographs in directions vertical to each other, one with inward rotation, one with outward rotation of the humerus, provided the humerus is capable of being rotated.

A further severe and not uncommon injury, one inconspicuous in the Röntgen plate, is *the compression-fracture of the head with impaction*. When one sees such a picture for the first time (Fig. 50, left) one thinks that one has to do with a simple fracture at the greater tuberosity, provided the injury is sufficiently well photographed and has not been entirely overlooked. The nature of the symptoms point, however, to a severe injury. By means of preparations made from accident cases we know what the condition really is[3] (illustrated in Fig. 50, right). In addition to the articular part of the head the greater tuberosity is also detached.

[1] From Schinz, *l.c.*, Bailleul and Dubois-Roquebert.

[2] From Schinz, *l.c.*, axial exposure first recommended by Iselin and Kloiber.

[3] See Staffel: Compressionsfractur des Humeruskopfes. Archiv. f. klin. Chirurgie, Bd. 85, Heft 3.

A destructive fracture of the greater tuberosity without displacement of the separate pieces of bone cannot be seen in a picture in which the patient has moved. In a case strongly suspected of clinical injury the photograph should be repeated, the patient holding his breath.

FIG. 49.

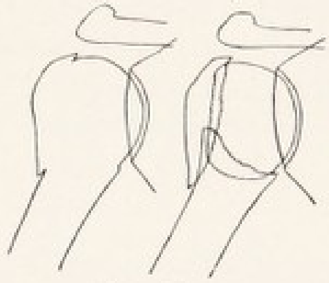


FIG. 50.

Simple *fractures, detachments, and separations* of the *greater tuberosity* are certainly very frequent ;[1] in some of the cases they are not difficult to indicate, in others when the traumatic cause of the injury is not definitely established, something quite different has to be considered, namely, a *deposit of lime in the bursal sacs of the shoulder* (subacromial and subdeltoid bursæ) arising probably from a chronic inflammation.[2] One might suppose

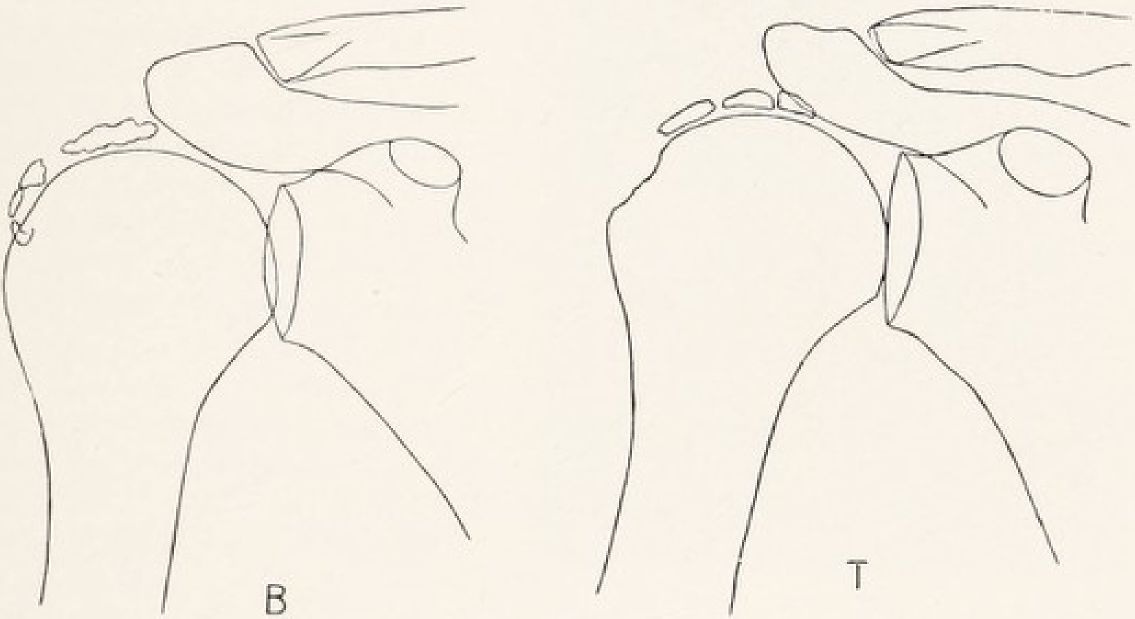


FIG. 51.
B.=Bursitis or Supraspinatus ossification. T.=Trauma.

that it would be possible to diagnose the nature of the shadow at once, whether a broken-off fragment of bone or a calcareous formation is present. Sometimes one recognises at once from a small defect at the greater tuberosity (Fig. 51, right diagram) and from the form of the

[1] Wohlgemuth : Fractur des Tuberculum majus humeri. Archiv. f. klin. Chirurgie, Bd. 61, Heft 3.

[2] Stieda : Pathologie der Schultergelenksschleimbeutel. Archiv. f. klin. Chirurgie, Bd. 85, Heft 4.—Haenisch : Verhandlungen des 6. Kongresses der Deutschen Röntgen-Gesellschaft. Hamburg, 1910.—Calatayud and Estopina : A proposito de un caso de bursitis calcificante subdeltoidea diagnosticada por la Röntgenografia. Revista espan. Rad., 1912, No. 8.—St. Nicolis, Belluno : Sulla calcificazione della borsa sottoacromiale. La Rad. Med., October, 1924.—Coulomb : Refer to Journ. de Rad. et d'Electr., 1922.—L. Lamy and P. Pérès : Presse méd., 1926, p. 739

shadow, that one is dealing with a traumatic separation; another time the intactness of the greater tuberosity or the oval fragmentary shadow (Fig. 51, left diagram) indicates we are dealing with deposits in the bursal sacs; they are usually found on both sides; nevertheless there are quite a large number of cases, where the nature and arrangement of the shadow in question allow of both possibilities; a thorough inquiry into the clinical history must then decide. When shadows, as seen in Fig. 51, are found immediately after a severe trauma, we have no reason to doubt but that we have to deal with a tearing off of the bone (even if it has been reported only once in the whole literature that after accident to a completely painless shoulder a similar shadow has been discovered). If immediately after the accident there is a negative Röntgen finding in spite of considerable pain, but three months later a positive finding, we have to think of ossification in the soft tissues; the author, like other authors, describes them as ossifications in the vicinity (tendon sheath) of the biceps tendon.[1] According to radiological experience all three kinds of shadow can in time disappear completely. If there has not been any severe trauma, then we have to think of concretion formation first of all. The characteristic clinical symptoms of the chronic affection leading to calcification of the bursæ and the tissues in their neighbourhood, called by Duplay "Periarthritis humeroscapularis," are as follows: severe pains often radiating into arm and hand, limitation of movement, especially of abduction, but of rotation also (to differentiate from joint affections in which all movements are interfered with, but the arm can be lifted forwards), tenderness on pressure in the region of the bursa and sometimes muscular atrophy.

Fig. 52a.

Simple mobilisation does not always effect a cure, and the condition sometimes requires operation. In these cases deposits of calcium have been found not only in the synovial bursæ, but also in the neighbouring tendinous insertions of the supraspinatus and infraspinatus, in the loose spaces between the tissues and in the articular capsule.[2] The description

[1] See Grashey, Atlas II, p. 96. Explanation to Fig. 137.

[2] Wrede: Über Kalkablagerungen in der Umgebung des Schultergelenks und ihre Beziehungen zur Periarthritis humero-scapularis (with complete list of the literature). Archiv f. klin. Chirurgie, Bd. 99, Heft 1.

of this Röntgen finding as subacromial bursitis is therefore an incorrect one, also that of "periarthritis humeroscapularis," at any rate seeing one associates a clinical train of symptoms with the idea "periarthritis humeroscapularis." There are indeed cases with such typical Röntgen shadows, which offer clinically not the slightest sign of shoulder trouble; in these cases there are usually symmetrical shadow-conditions found in both shoulders, but clinical symptoms only on one side. Further, it has been repeatedly shown that while the symptoms of disease disappeared from the shoulder the Röntgen finding remained unchanged. The clinical appearances and the Röntgen finding did not bear a definite relation to each other. The clinical idea of periarthritis humeroscapularis does not correspond with the Röntgen finding of such lime shadows. For a considerable percentage of definite periarthritis cases show no such anatomical condition on the plate. It need certainly not be wondered at that slight and recent cases fail to show any deposits of lime. For the lime deposit is certainly secondary. The primary condition is an alteration in the connective tissue of the synovial bursa and its neighbourhood in consequence of a slight trauma or an over-strain. In time and with treatment the lime deposits can disappear, yet the healing is not dependent thereon. It has in addition been asserted that in some Röntgen pictures published as bursitis there is present a so-called "os acromiale secondarium" (see later under "Os acromiale" and the literature given there). For all cases, see also Fig. 58 and text.

Circumscribed transparencies of the spongiosa in the humeral head must arouse immediate suspicion of commencing tumour. Sarcomata are the most frequent, then cysts and enchondromata.[1] Occasionally one sees a circular figure like that in Fig. 52B, more or less completely and evenly transparent, which simulates a large tumour. A comparison photograph of the other healthy shoulder gives a similar appearance. The finding is normal and a sign of simple slight osteoporosis. One meets the condition especially in women and elderly people. In the case illustrated in Fig. 52A the transparency in the lateral part of the humeral head was all the more suspicious, for the clinical finding appeared to point to a commencing tumour of the bone. The operation certainly gave a negative result. The röntgenologist in many of these cases bears a very heavy responsibility.

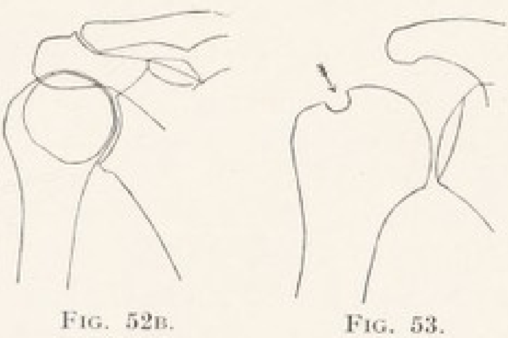


FIG. 52B. FIG. 53.

Large, thick, compact-like foci have been met with in the head of the humerus; these turned out to be not innocent compact-foci but *ossified sarcoma-metastases*.[2]

[1] Rumpel adduces many illustrations: Über Geschwülste und entzündliche Erkrankungen der Knochen im Röntgenbild. Röntgen-Archiv, Hamburg, 1908.

[2] Heinecke: Fortschritte, Bd. 13, 1909.

The *least resistant part* of the caput humeri is the part between the articular surface and the greater tuberosity. Here one frequently meets a defect of pea to hazel-nut size associated with considerable complaint of pain (see Fig. 53). That is always pathological. It is a relatively innocent feature in chronic arthritis (Fig. 55, right), in which it is a rare and a typical appearance. Usually, however, it is a consequence of a severe inflammatory process ; we have here to consider primarily tuberculosis, and less often osteomyelitis. Occasionally in cases in which the defect is visible, there is *a strikingly broad joint-fissure* (effusion, loose-joint).

Humerus varus.[1] In the embryonic state and in the anthropoid apes the proximal end of the humerus approximates to the varus position.

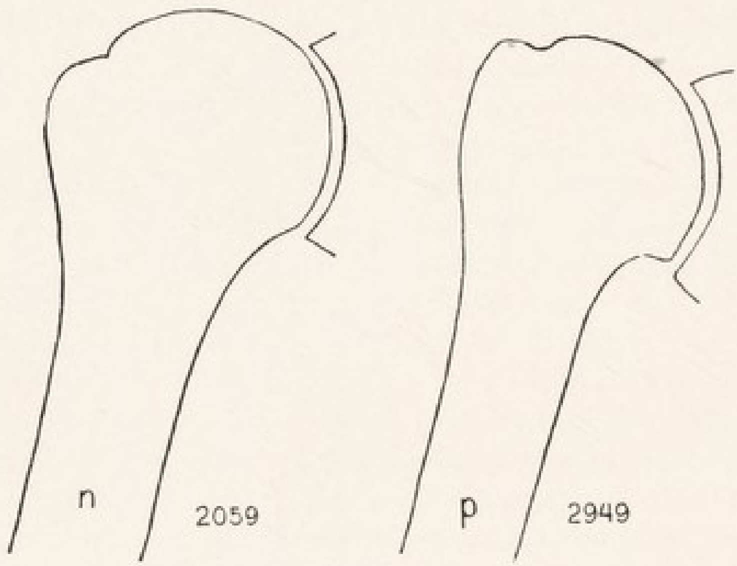


Fig. 54.

One finds also in the adult, although rarely, humerus varus (in cretins it appears frequently). It is usually met bilateral. The humeral head is in these cases directed only sideways, not upwards (see Fig. 54, p ; Fig. 54, n=normal). The angle of inclination can lessen to 100°, instead of the normal 130°–140°. Occasionally there is present a moderate shortening of the head of the radius of the humeral head. The great tuberosity in these cases stands evidently higher to about 1 cm. above the normal, and therefore the furrow between the head of the humerus and the greater tuberosity disappears more and more. The line of constriction is displaced in some to the surgical neck, in others to the anatomical neck. The deformity has nothing to do with generalised arthritis ; it appears " to be a static deformity which must rest upon a pathological change of the bones (abnormal softness), and its origin must be referred to learning to walk too late,"

[1] Bircher : Beitrag zum Humerus varus cretinosus. Fortschritte, Bd. 16, 1911, p. 325. —See further Angeleti : Sulla spalla vara (stadio röntgenographico). La chirurgia d. org. di movimento, 1919, p. 513.—(Compare Giovetti : Sull' omero varo. IV. Congresso ital. di Rad. Medica, 1922.)—Nicolis : La Radiol. med., X, July 7, 1923.

that is, to over-long crawling about on all fours. In cases which fall in the limits of the normal or the beginning of the pathological, we have usually to deal with rickets suffered from in childhood and perhaps occasionally with late rhachitis.[1] In radiograms of the shoulder taken in the prone position, the appearance of humerus varus may occasionally be brought about in consequence of an unusual displacement of the projection (Author).

A partial atrophy (translucency) is found in all kinds of slight complaints in the greater tuberosity; that is due to pure inactivity or old-age atrophy. In cases suspected of malingering after injury the atrophy speaks for the actual presence of the condition.

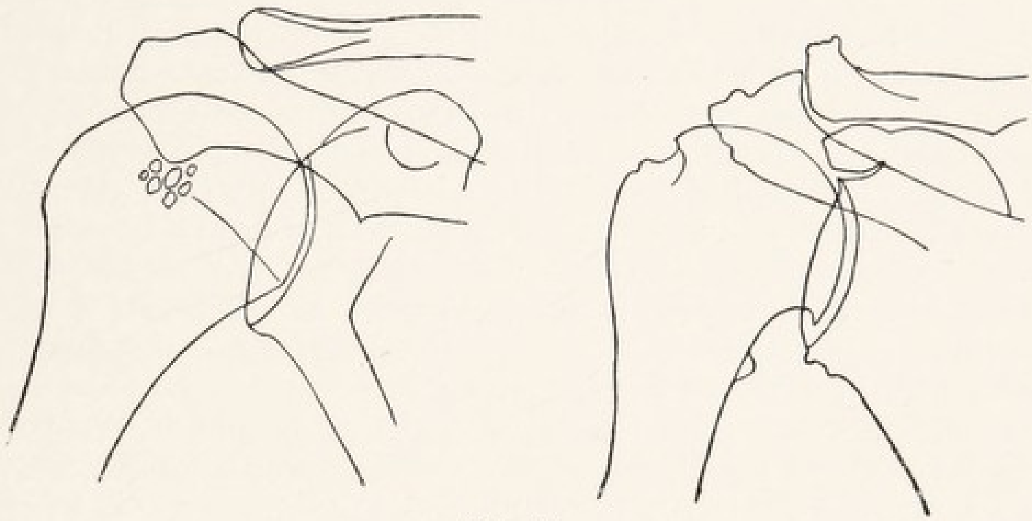


Fig. 55.

The slight irregularities, which are illustrated in Fig. 55, right, are typical signs of chronic (or commencing deformative) arthritis. In these cases one sometimes finds under the humeral head, and close up against it, a small round shadow from 2–5 mm. diameter, doubtless a bony platelet in the articular capsule; similarly one frequently meets with a small comet-tail-like ossification situate above at the groove of the anatomical neck (Fig. 56), which is probably to be ascribed to the articular capsule and is encountered not merely in chronic articular rheumatism but as a consequence of twists and stretchings.

Fig. 56.

A markedly thickened corticalis above at the greater tuberosity is physiological. Equally so a marked *ray-like structure of the greater tuberosity* (with the centre above and lateral, see Fig. 56) is not to be looked upon as pathological, although such a shadow configuration is but rarely met with.

An exceptionally gross translucent *dotting in the middle of the humeral head* (see Fig. 55, left picture) may mislead the examiner in suspicious symptoms on the part of the patient into making a diagnosis of com-

[1] Riedinger: Deutsche Ztschr. für Chirurgie, 54 Bd

mencing tuberculosis, acute osteomyelitis, or tumour. The appearance is normal, or at the most a sign of slight atrophy of bone, the counterpart of which we see in certain bones of the wrist (see *e.g.* " Semilunar bone ").

A wedge-shaped or rounded defect at the posterior surface of the head of the humerus, immediately internal to the greater tuberosity, which is clearly distinguishable in röntgenograms, has been observed in *habitual dislocation of the shoulder* (in external rotation and forward inclination).[1]

Tears of the *coraco-clavicular ligament* with wandering of the clavicle (see Fig. 59) ought not to be overlooked.

SCAPULA

The first osseous nucleus appears in the seventh to eighth fœtal week in the vicinity of the neck. *At the time of birth* the vertebral border of the scapula, the acromial process and the coracoid process are the only parts still cartilaginous. The latter receives a bony nucleus in the first year. Fusion of it with that of the scapula takes place after the sixteenth to eighteenth year of life. It rests like a cap on the coracoid process and appears prominently only in very oblique exposures. We are here dealing not with an ossification of an epiphysis, but with an ossification equivalent to the main ossifications of the independent skeletal parts, laid down at an early period and persisting right through.

Towards the fifteenth to the eighteenth year *three to five bony points* appear at the outermost zone of the acromion, which can be confused with fractures. They soon unite with each other (see Fig. 43) and form a bony union with the acromial diaphysis about the twentieth to the twenty-fifth year; they are said to occur only in males,[2] but that is not the case.[3]

As a variation anatomists mention a " joint of the point of the shoulder epiphysis," *i.e.* there sometimes remains a movable connection between the acromial-epiphysis and the spine of the scapula in later years up to old age. One speaks then of an *os acromiale.*[4] In Röntgen view nevertheless these persistent epiphyses are very seldom found. (The author does not recollect ever having found one in twenty-four years' Röntgen practice; other röntgenologists describe them as varieties, while anatomists have reckoned their appearance as high as 7–15 per cent.) There occur also *regular fractures of the acromion;* these appear to be more frequent. In making a diagnosis the possibility of the occurrence of a persistent epiphysis should not be forgotten, in order not to make mistakes, especially seeing fractures usually run in the same line. Absence of consolidation and of callus speaks against fracture, also the presence of thick swellings at the " articular

[1] W. Pilz: Zur Röntgenuntersuchung der habituellen Schulterverrenkung. Arch. f. klin. Chir., 135/1–2, p. 1.

[2] Nieber: Fortschritte, Bd. 22, 1915, p. 226 (with complete list of the literature).

[3] S. Schinz, *l.c.*

[4] Bernardeau: L'os acromial. (Thèse de Bordeaux, 1907).—Gruber: The principal literature is given in Lilienfeld (see next note).

surfaces." The occurrence of an os acromiale and fracture at one time is of course possible. Also *an os acromiale secondarium or accessorium* has been described in the anatomical and röntgenological literature.[1] It is described in Röntgen pictures as "a rounded body directly above the greater tuberosity of the humerus." "Its form is best described as a triangle with rounded angles, whose longitudinal diameter measures 1·3 cm. and is equally broad at the base; . . . its distance from the acromion measures 1 cm." In the opinion of one author the shadow of a secondary os acromiale can be recognised at the same time in several of the cases of *subdeltoid bursitis* of other authors, published with Röntgen illustrations. Apparently there may be as many ossa acromialia in a shoulder as there are bony nuclei in the cartilage of the acromial epiphysis. But there may be fewer of them, by the separate osseous nuclei uniting with each other, but not with the scapula. While one group of authors regards the os acromiale as the whole acromion, which has not fused with the spine of the scapula, the other group believes that in this bony anomaly there is represented only a part of the acromion. One therefore speaks of an *intra*-acromial joint.[2]

The acromion of adults, especially its outermost marginal contour, belongs to those skeletal parts that exhibit the greatest variety of form. The contour can offer a sharp arch, it can consist of many small pieces, it can be indented or blunted or fissured, it can show a large, flat, concave hollow, and still be intact. Its clavicular end may suddenly become reduced to about the half; this is an abnormality and not just a consequence of projection. The acromion does not appear to be diseased often, even fractures do not often affect it.[3] In *chronic and deforming arthritis* of the shoulder-joint the acromial contour is in every case indented and hillocky.

Given more favourable projection conditions an independent ossification might also be seen inside the cartilage of the glenoid fossa. It has the form of half a ring and is completed in an upward direction by the os infracoracoideum to form a complete ring (see later).

The *coracoid process* cannot often be seen in its entirety in projection; one obtains the best view of it by photographing the shoulder with abduction of the upper arm. Injuries, which are really infrequent, can thus best be seen. One sees more frequently, several months after severe contusions, ossifications of its muscle-insertions (biceps, short head; coraco-brachialis; pectoralis minor). In the dorsal position of the patient it is advisable to raise the arm to a right angle and set the tube out of the usual position 5 cm. below and 10 cm. towards the mid-line of the body, so that the

[1] Lilienfeld: Über das Os acromiale secundarium und seine Beziehungen zu den Affectionen der Schultergegend. Fortschritte, Bd. 21, 1914.

[2] The conditions are very complicated and not yet completely anatomically explained; they are stated very thoroughly by Neumann: "Über das Os acromiale." Fortschritte. Bd. 25, 1918 (with complete statement of the literature); and by Schinz, *l.c.*

[3] Lepennetier: Fracture de l'acromion. Journ. de Rad. et d'Electrologie, 1925.

central ray is directed from anterior-internal-below to posterior-external-above.[1]

The epiphysial and apophysial ossifications of the coracoid process are very various. In the tenth to twelfth year the first nucleus to make its appearance is the os infracoracoid or subcoracoid at the base of the coracoid process, which also forms a part of the upper margin of the glenoid fossa. Osseous union at the eighteenth to twenty-fourth year. At the tip of the coracoid there arises in the sixteenth to eighteenth year a terminal cap-like epiphysis ossification; union in the twentieth year with the real coracoid. About the same time a semi-cylindrical coracoid apophysis appears at the cranial margin of the coracoid, which soon fuses with the coracoid.[2]

Fig. 57.

Diseases of the shoulder-blade itself, as can be easily understood, are evident only in perfect negatives; they are very rare. Fractures can be seen more plainly, but even they are not common. In the majority of cases they are combined with fractures of the ribs. At the upper border fractures appear more or less parallel to the spine; fractures of the scapular neck do not appear to suffer much displacement. Less evident fractures of the lower half of the scapula are better seen when one takes a further photograph with the arm abducted. In a suspected fracture and in spite of negative findings in the dorsal position, one should never omit to project the shoulder-blade in transverse section on to the plate.[3] Sometimes this is the only way a fracture can be rendered evident; also ventral and dorsal outgrowths of the scapular body can thus be demonstrated.

The inferior angle can show an *independent osseous nucleus* [4] (see Fig. 57), and after injury with pain referred to this spot a fracture may be incorrectly diagnosed in cases in which growth has not yet stopped. It appears in

[1] Fr. Cæsar: Isolierter Bruch des Rabensschnabelfortsatzes und seine Röntgendarstellüng. Fortschritte, Bd. 35, 1926.

[2] After Schinz, *l.c.*

[3] Lorenz: Die röntgenographische Darstellung des subscapularen Raumes und des Schenzelhalses im Querschnitt. Fortschritte, Bd. 25, 1919.

[4] Grashey, Atlas I, 4th edition, illustrated in Fig. 47.

the sixteenth to eighteenth year. At the same period a comb-like apophysis arises at the vertebral border of the scapula.

At the external border of the scapula and $\frac{1}{2}$–1 cm. below the glenoid cavity a process is often observed, which serves for the insertion of an independent bundle of the subscapularis muscle.[1]

The superior angle of the scapula may show great differences in form in young people, on the one hand blunter and more rounded, on the other definitely pointed. In people used to carrying heavy weights the angle on the affected side may be deformed and scapular bodies make their appearance.[2]

Congenital elevation of the scapula is usually combined with other anomalies, like defects of the ribs, defects of the radius, anomalies of the vertebræ, etc.

If one finds near the external soft tissue contours and approximately parallel to the lateral border of the scapula, one or more shadow-strands, as thick as a finger and of bony density, that indicates a generalised *myositis ossificans,* which usually starts here in the latissimus dorsi and pectoralis major muscles.

CLAVICLE

Its *ossification* begins earliest of all, as early as the seventh week of fœtal life and in the middle of the bone. A cartilaginous epiphysis develops at the sternal end, in which an epiphysial nucleus appears after the fifteenth year and usually between the eighteenth and twentieth years (visible only on oblique exposures), which unites with the other parts of the clavicle in the twentieth to twenty-fifth year. Defects of the clavicles on one or both sides are sometimes associated with malformations of the skull.[3]

Individual differences in the curvature of the clavicle are recognised already in the fœtus, but are still more evident in the adult, and are accentuated in Röntgen pictures according to the position of the focus of the tube. Shadow-pictures are found with curves and angles, which without experience one could hardly believe normal, and yet are so. To avoid mistakes one should always photograph the other side under the same or similar conditions of projection.

At the sternal end of the clavicle two findings have been reported,[4] which indicate that we are here dealing with a similar picture of disease as in the scaphoid- and metatarsal-disease described by the author. At this end of the bone we saw irregular areas poor in shadow-density, and in between a shadow-picture that looked like a sequestrum. Both cases were

[1] Schwegel: Z. f. rat. Med., quoted by Grashey, Atlas I, 4th edition.

[2] Grashey, Atlas II, Fig. 118, p. 88.

[3] Reichmann: Congenitaler Defect der Schlüsselbeine. Fortschritte, Bd. 18, 1912, p. 207.—H. Blencke: Arch. f. orthop. u. Unfall-Chir., Bd. 20, Heft 4, p. 534.

[4] H. Friedrich: Über ein noch nicht beschriebenes, der Perthes'schen Krankheit analoges Krankheitsbild des sternalen Clavikel-Endes. D. Ztschr. f. Chir., 187. Bd., 1924.

sectional and histologically examined, and found to consist of aseptic wedge-necroses as in Perthes' disease.

In one instance [1] *a pseudarthrosis* of the clavicle was found upon both sides between the middle and the outer thirds together with typical cervical ribs. The inner fragment was drawn upwards and somewhat backwards by the sternocleidomastoid muscle. As an additional anomaly there was a persistence of the milk-teeth.

Fractures are almost always visible, even when the fragments are displaced only in the direction of the rays. Repeat fractures of this bone, occurring at different times, are not uncommon.

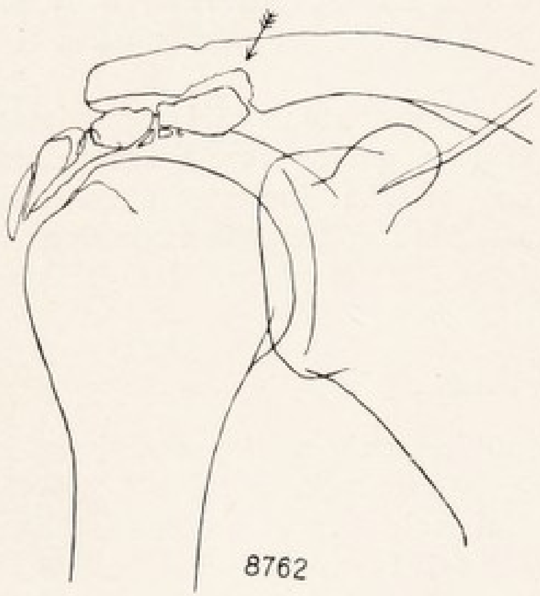


FIG. 58.

FIG. 59.

The translucent fissure between clavicle and acromion amounts normally to a few millimetres; its edges are, even normally, not always parallel; indented, ridged, ill-defined *appositions* are frequently met at the clavicular (and also at the acromial) end in chronic arthritis, and as an aftermath of injuries, in which the ligamentous insertions are torn and have ossified; further, also, in manual labourers.

In one patient who for only six weeks complained of a rheumatism in one shoulder, *a defect* almost the size of an almond was found in the clavicle, and in relation thereto a row of large flake-like deposits of lime or calcareous plates as far as the greater tuberosity, a very exceptional finding. Whether the affection has any relation to subdeltoid and subacromial bursitis (see Fig. 58, arrow) cannot be definitely said. The late appearance of the trouble is a striking feature.

The acromial end of the clavicle is not infrequently the seat of *malignant tumours*. They are characterised by well-marked transparency sharply delimited towards the sound bony tissue.

If the clavicle is several millimetres higher than the acromion (Fig. 59),

[1] A. Mouchet and P. Errard: Congenitale Pseudarthrose der beiden Schlüsselbeine und Halsrippen. Journ. de Rad. et de l'Electr., May, 1922.

a not all too rare occurrence after certain accidents, we have to deal with a complete tearing of the capsular ligaments and a *dislocation of the clavicle.* One naturally can see and feel that clinically in most of the cases even without any Röntgen examination.

Parallel to the upper border of the clavicle there runs a clear *shadow-band* about 4 mm. in breadth. That is produced by the skin above the clavicle, which folds over into the supra-clavicular fossa, and is thus removed from the plate. (See this in illustration in the chapter " Lungs ").

The acromial end of the clavicle sometimes shows a fairly striking transparency in the form of an isosceles triangle with its base to the acromion, =physiological (see also under " Sternum ").

Under the acromial end of the clavicle one encounters sometimes a flat elevation which might simulate a periostitis ossificans or an old callus. That is the *coracoid tubercule* (insertion of the coraco-clavicular ligament).

Several cases of *coraco-clavicular joint-formation* have been described.[1]

FOOT [2]

General

In examining Röntgen pictures of the foot, it is to be remembered that the feet in civilised races from childhood upwards get compressed by very badly fitting shoes, and that in consequence the bones of the adult foot are usually displaced in a very marked degree and twisted out of shape, without necessarily causing the patient any pain. Therefore, before one diagnoses a rather unusual configuration of a bone or of part of a bone as the cause of the complaints made, one should convince oneself by a control exposure of the other foot, whether the same Röntgen findings are not shown in it also. For not everything that appears so is due to compression by tight-fitting footgear. Similar deformities of the bones of the foot are found, not only in uncivilised peoples who have never worn boots or shoes, but even in the newly-born child, and indeed even in the fœtus, a proof that we are dealing with variation-differences, which arise from internal causes, and are manifestly inherited. Their clearest expression is found, *e.g.* in the divergences of the toes from the typical construction of the long bones,

[1] F. Frasetto, La Chir. d. org. di movimento, 1920.—F. Giongo, La Rad. Med., 1927.

[2] For the normal Röntgen anatomy of the foot, see Grashey, Atlas I, 4th edition, also Wilms and Sick: Die Entwicklung der Knochen der Extremitäten von der Geburt bis zum vollendeten Wachstum. Röntgen-Archiv, Hamburg, 1902.—Åkerlund: Entwicklungsreihen in Röntgenbildern von Hand, Fuss und Ellenbogen im Mädchen- und Knabenalter. Röntgen-Archiv, Bd. 33, Hamburg, 1918.—Sessa and Alberti, *l.c.*, p. 1.—Balli: Anat. röntgenograf. normale dello scheletro. Ferrara, 1924.—F. Delitala, Bologna: Sull' anatomia normale e patologica dello scheletro del piede con particolare riguardo alle lesioni traumatiche. La chir. degli org. di movim, March, 1917.—Dumail: Etude röntgenographique de l'ossification du squelette du pied normal. Ref. Journ. de Rad. et d'Electr., 1926.—Bundy Allen: Development of the ossification centers of the skeletal system. Radiology, November, 1926.—Bertwissle, Leeds: A descriptive atlas of röntgenographs of the bones and joints. Bristol, 1925.—J. Magnus-Redding: X-Ray Diagnosis. London, 1926.—H. Virchow: Überzählige Skelettstücke an Händen und Füssen eines Gorilla. Ztschr. f. Ethnol., 1910.

in the middle bones of the toes, that is, in the bones of the second phalanges; in the little toe this phalanx is completely absent in a third of the cases, or, more correctly, "absorbed" or "assimilated" by the terminal phalanx, an appendage of it although still to be demarcated from it. The other second phalanges usually exhibit a reduction in form, but in 1·6 per cent. of the cases not only the little toe, but also the fourth toe, or even the fourth and third toes, are possessed only of two phalanges; and, finally, in the rarest cases, in 4 per cent. of the cases, none of the toes exhibit the normal number, and the upshot is a "brachy and hypophalangy," a shortening and reduction in the phalanges of the toes. A similar reduction is sometimes observed also in the hand.[1]

In the joy over minute particulars of a beautiful negative of the foot the beginner should never omit the study of *the skeleton of the foot as a whole;* the single bones of the tarsus have, *e.g.* in an arched foot quite a different form from that seen in flat foot, etc.

Regarding *the ossification of the long bones* of the foot, it commences a week later than that in the hand, that is, in the ninth to the tenth week of fœtal life, first in the metatarsals, then in the terminal phalanges, then in the other phalanges, with considerable individual variations. In the newly born there is no epiphysis yet ossified, but all the diaphyses are ossified up to the middle and terminal phalanges of the fifth toe. The epiphysis-ossification begins about the end of the third year; in the fifth year the epiphysial centres of all the phalanges and metatarsals can normally be seen.

Toes

General

In the toes somewhat different conditions prevail in development than in the fingers. In comparison with the latter there occur important reductions in the toes (which is not the case in the apes, where the foot serves primarily as an organ of prehension). *Delayed appearance of ossification, simplification of the process of ossification*, and *absence of joint formation* are not pathological in the toes. For union of the epiphysial cartilages, see under "Basal Phalanges."

Unusually circular ring-formed or very dense oval shadows of bone appear in one or several phalanges when the affected toe is in a strongly flexed position at right angles to the photographic plate during the exposure. That gives us the outline of the transverse section of the particular phalanx in transverse section.

Terminal Phalanges

Quite apart from the result of tight shoes, one finds an enormous *variety of forms*. The clearness of the Röntgen shadow suffers because the

[1] The second part of this paragraph is taken almost verbally from Hasselwander: Die Variabilität der Organismen. Erlangen, 1926. (Rectorial Inaugural Address.)

terminal phalanges in plantar pictures are partly overshadowed by the middle phalanges owing to a greater or less degree of flexion. In the little toe the terminal and middle phalanx are fused to form one bone in about the half of the cases, see Fig. 64.[1] On the other hand, one sometimes finds in the little toe (only in children ?) four phalanx-like bones, hyperphalangia. In the water mammals the phalanges have double epiphysis. By the ever-growing homogeneity of the single parts and the retardation of ossification, the epiphyses become finally of the same size as the diaphyses, and so they become homogeneous pieces. Thus hyperphalangia is finally produced in the whales and right-whales.[2]

Fractures of the second, third, fourth, or fifth terminal phalanges are very rarely disclosed by the Röntgen rays ; such fractures are extremely rare ; breaks of the conjoint second and third phalanges of the fifth toe have been demonstrated by the Röntgen rays. One should not overlook such a break by diagnosing it as a joint fissure.

The terminal phalanx of the great toe, as it is the largest and is not flexed, is the one best seen. Its form shows numerous variations. The capitulum is almost always unsymmetrical, a little hillock about half the size of a pea being usually situated on the internal border of its base. Fractures, especially crushing fractures, are common, and are usually easily recognised.

Congenital obliquity of the terminal phalanges of the toes, usually in the first or second toes, and also Digitus V varus, also occur.[3]

Middle Phalanges

They also vary much in *form*. They have sometimes no " taille " ;[4] if they are photographed in the slightly flexed position they give an almost quadrate shadow. *Fractures* are extremely rare (for the diagnosis of fractures, see " Basal phalanges "). Complete absence and shortening may also occur.

Symmetrical synostosis of the phalanges of both great toes is regularly present in generalised myositis ossificans. A similar analogous process is found in the hands (q.v., and further under "First metatarsal").

Very rarely there occur definite changes in the epiphysis (basal) of the mid-phalanx. For further information refer to the description of similar changes in the mid-phalanges of the fingers (Fig. 8).

[1] Pfitzner has shown that this, the fusion between the middle and terminal phalanges of the fifth toe, as was earlier thought, is not the consequence of pressure by footwear, but is already present in the cartilaginous state of the embryonic foot, as has been observed in Egyptian mummies of children. See also above under " Foot ; General."

[2] Kükenthal : Zoolog. Jahrbücher. System. Abt. 5. Bd. 1891.

[3] Stracker, Vienna : Über Zehendeformitäten. 19. Orthopäden-Kongress, 1924

[4] The history of development points to a reduction of the middle phalanx taking place in phylogeny. (Hasselwander : Untersuchungen über die Ossification des menschlichen Fussskeletts. I. D. Verlag Nägele, Stuttgart, 1903.)

Basal Phalanges

The synostosis of the epiphysis with the diaphysis is completed in the female sex between the fifteenth and seventeenth, in the male sex not until the seventeenth and the twenty-second years of life. Their form is more regular than that of the middle and terminal phalanges. The medial half of the base is usually more voluminous than the lateral; it is only in the great toes that this is sometimes reversed. *Fractures* are common, especially in the first and fifth toes; they are mostly oblique fractures, and they are quite easily recognisable. But sometimes in plantar pictures a break is simulated where none is present, especially when the band of light that regularly is produced between the balls of the metatarsus and the flexed toes (removed somewhat from the plate) lights up and interrupts the shadow of the phalanges. The appearance is recognised as such by the bright line being continued into the soft tissues. In profile photographs the plantar half of the base is more massive than the dorsal.

In profile pictures of the toes a shadow similar to periostitis often occurs in the larger phalanges at the plantar contour; that has been explained in the literature as a periostitis ossificans, and has been regarded as a sign of flat foot. But this finding is quite a normal one, and quite comparable to what often obtains in the fingers, and is described and illustrated in Figs. 4 and 5; in the toes the condition is usually even more pronounced than in the fingers.

A little *sesamoid bone* is found on the plantar surface of the phalanges of both great toes (see Fig. 60B).

Even in *hallux valgus*, especially if it is a well-marked one, one should not overlook the possibility of a luxation of the second toe being also present. In gout even the first toe may luxate.[1]

For gouty changes, see under "First metatarsal."

For general periosteal deposits in the small and large tubular bones of the foot—*general hyperplastic periostitis*—see "General," p. 4.

In the base of the basal phalanx of the fifth toe *a compact-island* has been observed; see "General," p. 3.

Metatarsus

General

Regarding ossification of the short tubular bones, see under "Foot."

Regarding ossification of the normal epiphysis and the appearance and ossification of abnormal epiphysis and their relation to delays in growth

[1] A. Köhler: Luxacion espontanea del dedo gordo de un pie y del segundo del otro pie en un caso de gota. Revista espan. Rad., 1912, No. 2.—v. Dittrich: Über die Entstehungsursache des Hallux valgus. Arch. f. orthopäd. u. Unfall-Chir., 1921, 1, p. 142.—A. Weinert: Die richtige Deutung des Röntgenbildes beim Hallux valgus. Zbl. f. Chir., 1923, No. 10, p. 377.—Nilsonne: Ztschr. f. orthop. Chir., 43, p. 619.

in diseases such as myxœdema, see the complete explanation under "Metacarpus," pp. 20 and 21.

The nuclei of the capitula of the second to the fifth metatarsal, may be found divided, although this is extremely rare.[1]

The *synostosis of the epiphysis with the diaphysis* takes place in the woman at the fifteenth to the seventeenth year of life, in the man not until the seventeenth to the twenty-second.

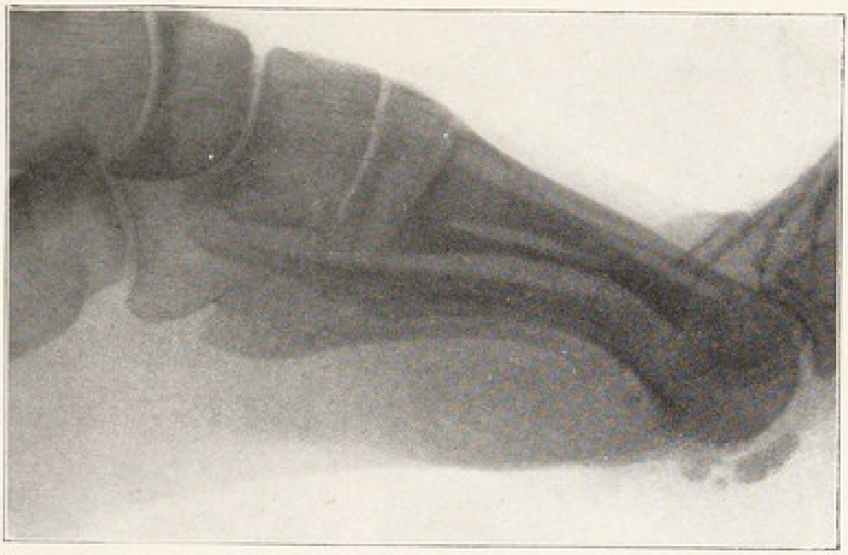


Fig. 60a.

The following *sesamoid bones*[2] are regularly met with (see Fig. 60b); two sesamoids at the capitulum of the first metatarsal bone; frequently one sesamoid at the fifth capitulum and one at the second capitulum; rarely two at the fifth capitulum, one at the fourth capitulum, and very rarely one on the tibial side of the third capitulum. (These little sesamoid bones are always situated on the plantar side.) In a shadow that has not been distorted by badly fitting boots the two sesamoid bones of the first metatarsal are placed in the shadow of the bone, but in the majority of civilised feet the fibular sesamoid is partly situate outside the shadow of the bone, and in very marked hallux valgus it comes entirely into the soft tissue shadow. It is very important to know that *double sesamoids* occur; these are often taken and treated for fractures of the sesamoid, although such breaks are always possible. Regarding differential diagnosis, see

[1] Fig. 187 in Grashey, Atlas I, 4th edition.

[2] See also Stieda: Über die Sesambeine der Metatarsophalangealgelenke. Münchener Medizin. Wochenschr., 1906, No. 40.—L. Coleschi: Un caso di frattura di un sesamoide dell'alluce. La Rad. Med., Vol. VI, 1919.—K. Koch: Über Fracturen und Pseudofracturen der Sesambeine der grossen Zehe. M. M. W., 1924.—C. Thurstan-Holland: On rarer ossifications seen during Röntgen-ray examinations. Journ. of Anatomy, Vol. 55, Part 4, July, 1921.—*Ibid.*: Two cases of rare deformity of feet and hands. Arch. of Rad. and Elec., 1918, 22, p. 234.—T. Shillington Scales: Fracture of sesamoid bones. Arch. of Rad. and Elec., August, Schunck, 1901, Momberg, 1907.—Müller, Philadelphia: Annals of Surgery, 1912, p. 101.—Hall-Edwards: Arch. of Rad. and Elec., May, 1918.—R. Morton: Proc. Roy. Soc. Med., Vol. IV, p. 96.—C. Thurstan Holland: Arch. of Rad. and Elec., June, 1918,

"Metacarpus." Seeing the sesamoid bones in a plantar photograph are covered by the shadow of the head of the metatarsal bone, it is naturally difficult to estimate the finer conditions. For such cases, especially in the first metatarsal, the profile photograph often affords the best means of deciding whether the case is one of fracture or of congenital division of the sesamoid. (See also anatomical remarks upon sesamoid bones in the section "Metacarpus.") Fig. 60A shows a sesamoid fracture.

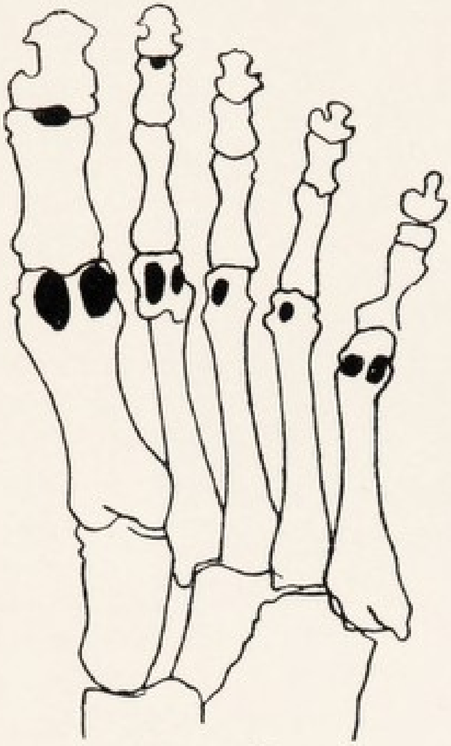


FIG. 60B.

The *number* and *distribution of the sesamoid bones* is often different on the right and left sides of the same individual.

The sesamoid bones of the first metatarsal show normally a fine oval or in profile a semilunar shell (the partial covering of the two shadows in profile often produces very striking pictures); in tight-fitting boots they sometimes suffer from deformities, often of a very considerable degree; whether they can produce pain in this condition is very doubtful.

In arteriosclerosis the shadow of the *calcified artery* usually appears between the first and the second metatarsus.

Certain diseases appear to occur in the sesamoid bones, at least in the internal sesamoid bone of the first metatarsal,[1] and this takes the form of a typical *osteochondropathy*, as in Perthes, Schlatter and Köhler's diseases. The disease may remain latent and first show up with a slight trauma followed by symptoms. The patients are usually women. The symptoms are local tenderness on pressure, pain on maximal dorsiflexion of the great toes, and usually an intermittent œdema of the soft tissues on the dorsal aspect between the heads of the first and second metatarsals. Röntgen finding: a stippled appearance in place of the normal spongiosa structure of a sesamoid bone. In order to show up the sesamoid bones, one should press the foot with the hyperextended great toes on the plate and irradiate from above at a sharp angle to the sole of the foot.

For general periosteal deposits in the small and large tubular bones—*general hyperplastic periostitis*—see "General," p. 4.

First Metatarsal

The *head* of this bone, without being pathological, is represented in plantar pictures in a great variety of forms. The half of it towards the

[1] A. Renander, Karlskrona: Zwei Fälle von typischer Osteochondropathie des medialen Sesamknochens am ersten Metatarsale. Acta Rad., III, No. 6, p. 521.—W. Müller, Marburg: Malacie des Sesamknochens des 1. Metatarsale, ein typisches Krankheitsbild. Beitr. z. kl. Chir., 134/2.

medial border of the foot is more massively formed than the other, in hallux valgus there is also present a broad bony swelling, while the contour of the fibular half often forms a straight continuation of the diaphysial contour.

The *proximal epiphysis* has sometimes in its middle a *fissure* which should not be mistaken for a fracture. It is usually present in both feet.

A shortening of the first metatarsal on both sides by about 2 cm. with a constriction deformity of the head of the metatarsal bone and synostosis of the phalanges of both great toes is found regularly in general progressive myositis ossificans. Analogous processes are met with in the thumb.[1]

A relatively frequent finding is *a transverse process at the fibular articular edge of the head of the first metatarsal*, about 7 mm. long. It is sometimes found associated with hallux valgus and chronic arthritis processes in the joint between the metatarsus and the great toe. This is not a rounded process, but the ledge situate on the fibular border of the articular surface, which is present in about half of the cases. This ledge can be present quite a long time before it brings about any symptoms.[2] Slighter degrees of it are frequently met as an accidental finding. It is more of a rarity to find a small process at the tibial articular end of the affected capitulum. Also in Pes planus such processes are frequently met with.

In the capitulum the author found *a compact-island*, and at the same time one in the capitulum of the second metatarsal bone (the condition is not important), see p. 3.

It is important to be aware of the purely *gouty changes* at the balls of the great toes. The arrows in Fig. 61 show the beginning of the typical defect-changes.[3] The appositional changes are fairly similar to those of the hand, as a comparison of Fig. 61 with Fig. 14 (the hand) shows. According to the experience of others these alterations are not typical of gout, but of " genuine ulcerous arthritis sicca of endocrine origin " (Munk).[4]

At the capitulum of the metatarsal bone *a pseudo-epiphysis* may occur, as in the hand at the same spot.

The *diaphysis* of the first metatarsal offers scarcely any abnormalities or conditions that can give rise to a false diagnosis.

On the fibular contours of the proximal half of the metatarsus there occur in certain positions of the tube pictures which simulate the long striped appearance of *periostitis ossificans*. This condition is quite normal and caused by the shadows of the plantar and dorsal lateral edge of the bone being cast close to each other in the projection.

In medial profile photographs of the metatarsus a periostitis ossificans can be simulated by an accidental projection of *the calcified first dorsal*

[1] A good survey of this condition is given with complete list of the literature by Michelsohn: Ein Fall von Myositis ossificans progressiva. Zeitschrift f. orthopäd. Chirurgie, 12. Bd.—For literature see also under " General Soft Tissues."

[2] See Köhler: " Knochenerkrankungen im Röntgenbilde " (Wiesbaden, Bergmann, 1901), Table I, Fig. 4 and text, further: Preiser: " Zur Pathologie der grossen Zehe." Fortschritte, Bd. 12, 1908, p. 88.

[3] For further details see Köhler: Typical Alterations of Bones in Gout. Archives of the Röntgen-ray, February, 1912.—See further Amelung: Fortschritte, Bd. 31, H. 1.

[4] Munk, *l.c.*—Amelung: Fortschritte, Bd. 31, and Krebs: M. m. W., 1925.

metatarsal artery upon the dorsal cortical shadow of the metatarsal. The diagnosis is confirmed without difficulty by a plantar or dorsal negative, so that the shadow of the calcified vessel falls between the first and second metatarsal bone.

In photographs of the metatarsus from twelve to sixteen years the beginner should not be misled into considering the epiphysial line of the first metatarsal (which is at the proximal end of the bone) as a fracture, a mistake which can happen all the easier because the remaining metatarsals at their proximal ends have, as is well known, no epiphysial cartilages (see " Metacarpus "), and the distal epiphyses of the remaining metatarsals may be already ossified.

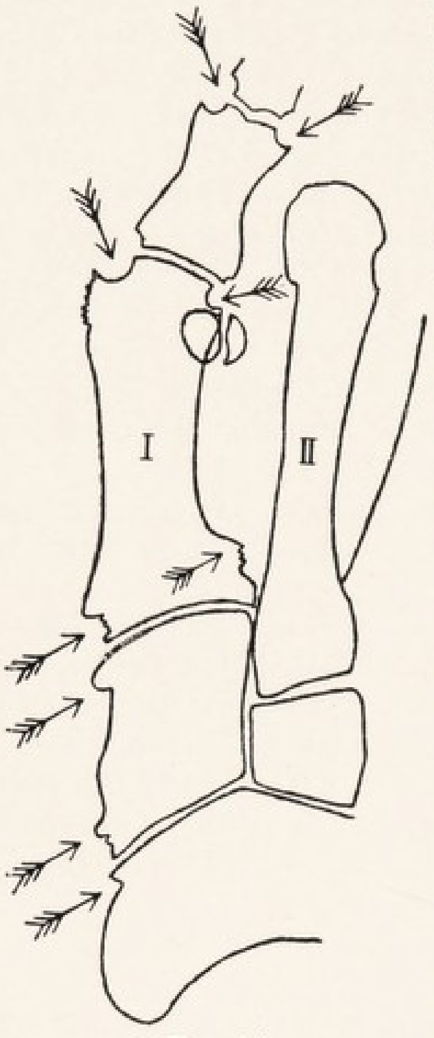


Fig. 61.

Between the bases of the first and second metatarsals the anatomists describe an *os intermetatarseum.* The author, who was unaware of any such case having been found in the Röntgen literature, saw a single but well-pronounced case of intermetatarseum bilaterally in a woman, Fig. 62. According to the reports of anatomists, it may articulate or unite with the first cuneiform or first metatarsal. In our case the conical form of the distal end of the first metatarsal is striking. The os intermetatarseum is said also to lead to hallux valgus.

According to Pfitzner, the os intermetatarseum is situated on the dorsal side of the foot in the posterior end of the interosseous space. Its anterior end usually tends to be drawn out into a point ; it may also be rounded off or thickened into the form of a button (see Fig. 62). Pfitzner saw it articulate only with the second metatarsal, even in the best developed cases, while Morestin has reported a case in which it articulated with all the three neighbouring bones. In what stage of phylogenetic development this supposed metatarsal bone carried a toe, and whether this inherited bit of bone has come to us from the ichthyopterygians or selachians, Pfitzner does not venture to inquire. According to Kükenthal's observation on whale embryos, not only the marginal but also the internal rays disappear. The os intermetatarseum was found by the Russian anatomist Gruber, and called so by him. Following the author's case, other cases were soon published, which had quite other forms, small sugar-loaf, bean, club and rod-like appearances.[1]

[1] After E. Friedl : Das Os intermetatarseum, etc. D. Ztschr. f. Chir., Bd. 188, 1/2, 1924.

Second, Third, and Fourth Metatarsals

Röntgenographic *appearances similar to fractures*, apparently without any trauma, have been described and illustrated at the juncture of the distal and middle third of the second, also of the third, more rarely of the fourth metatarsal.[1] The condition appears at first under the picture of flat foot, without any external cause of pain, which is spontaneous and considerable ; sharp locally circumscribed tenderness on pressure at the juncture of the middle and the distal third of the metatarsal. The plantar photograph is at first negative, it is only after about eight weeks that a process in the bone can be recognised, which reminds one of the fissure line of an oblique fracture, but a fracture line denser instead of translucent ; then periosteal callus forms similar to what is found in swollen feet due to marching. The patients were usually women of about thirty years of age. On account of the delayed formation of callus (three to four months instead of from three to four weeks as in fracture swellings due to marching) and observations of the rise of temperature, it is supposed that a bacterial invasion from the blood (of reduced virulence) is the cause when such acute ostitis and periostitis are present. Another author [2] holds that we have to deal with a metatarsal fracture more or less slow in progress, on the basis of an incorrect adjustment of weight, of a static inequality. To that it is again objected [3] that the idea of a delayed formation of callus through an incorrect pressure on the foot is such a novel one that it would have to be proven first. It might perhaps be recommended in cases in their earliest stages when a plantar Röntgen

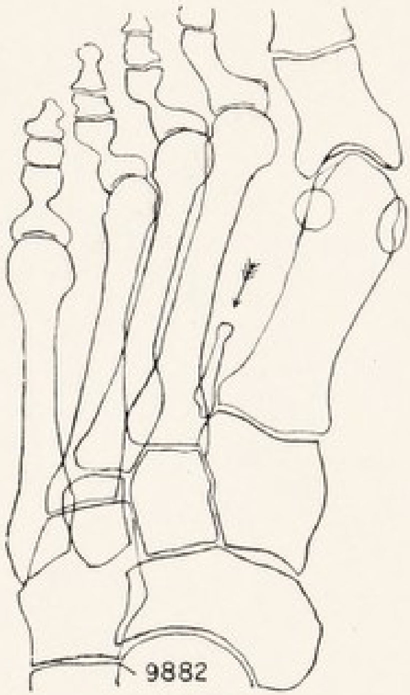


FIG. 62.

[1] C. Deutschländer : Über eine eigenartige Mittelfusserkrankung. Zentralbl. f. Chir., 1921, No. 39.—*Ibid.*: Zur Frage der nichttraumatischen Mittelfussgeschwülste. Ebendaselbst, 1922, No. 27.—*Ibid.*: Arch. f. klin. Chir., 1921, Bd. 118.—E. Jacobsen : Zentralbl. f. Chir., 1922, No. 4.—Vogel : *Ibidem.*, 1922, No. 15.—R. Feller : Zbl. f. Chir., 1922, No. 38, p. 1410.—H. Blencke : Zbl. f. Chir., 1922, No. 51, p. 1889.

[2] Jacobsen, see preceding note.

[3] Deutschländer, *l.c.*—*Ibid.* : Zur Frage der nichttraumatischen Callusbildung der Mittelfussknochen. Orthop. Kongress, 1923. Ztschr. f. orthop. Chirurg., 45, 1–2.—H. Koch : Schleichende Spaltbildung am 5. Mittelfussknochen. Arch. f. klin. Chir., 129/3, p. 535.—Bungart : Nichttraumatische Mittelfussgeschwulst. Zbl. f. Chir., 1925.—Alban Nast, Kolb : Ztrlbl. f. Chir., 1925.—F. Momburg : Zu der " eigenartigen Mittelfusserkrankung," Deutschländers. Ztrlbl. f. Chir., 1925, refers to his (Momburg's) work appearing in 1908 : Der Gang des Menschen u. die Fussgeschwulst.—Walther Müller : Die Insufficienzerkrankung der Metatarsalia. Bruns. Beitr., Bd. 133, 3, 1925.—M. Dubois : Die Entstehung der Fussgeschwulst und verwandter Zustände. Schweiz. Med. Wschr., 1925, No. 36.

picture indicates no break to try whether a profile picture will not show the condition more or less plainly (author).

The latest publications emphasise that the process is pathologically a necrosis of the bone, probably of an embolic nature. It is pointed out that really the greater part of the cases known as " marchers' foot " comes under this category, and are manifestly pathological fractures at necrotic spots. Here and there we are dealing with young individuals, who are well known to have a particular tendency to embolic processes.[1]

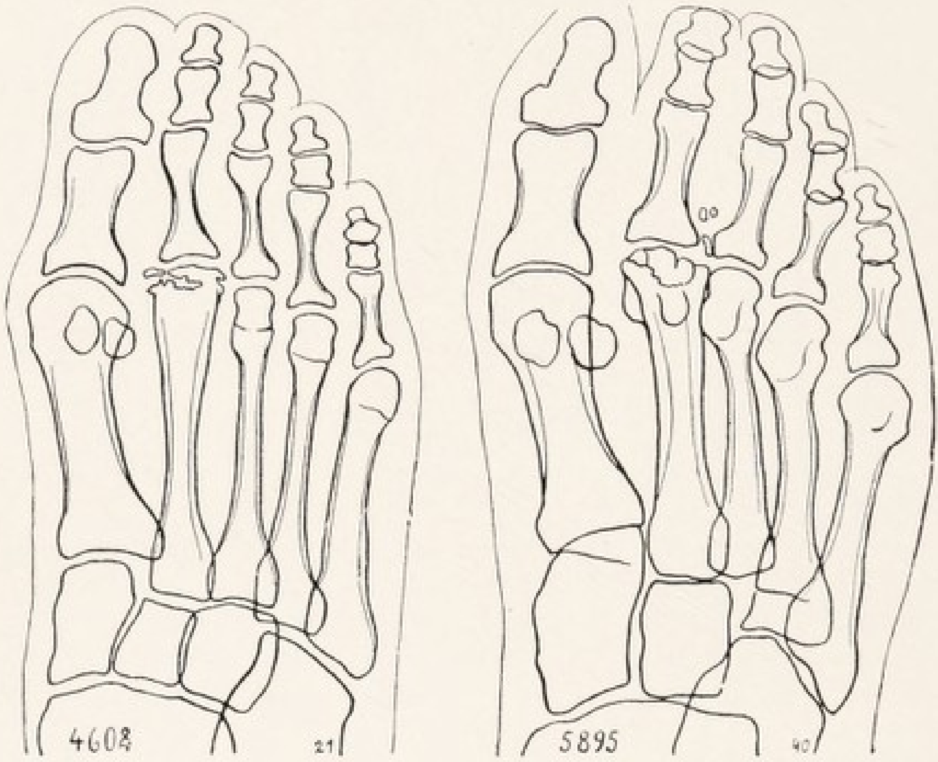


Fig. 63.

In the second capitulum *a compact-island* may appear. The author saw one next to the one in the first capitulum.

The *form of the capitula* two to four is very different in different individuals, some more round, some more sharply edged, but almost quite similar in their form in the same individual.

If the distance of the third and fifth metatarsal capitulum from the fourth is very small and severe pain arises in this neighbourhood we are usually dealing with compressions of the nerve twigs between the heads of the mentioned metatarsals, a condition which goes by the name of " *Morton's metatarsalgia.*" [2]

[1] A. W. Fischer: Zur Frage der Deutschländerschen Krankheit und ihre Beziehungen zur Marschgeschwulst. Frankfurt. Röntgen-Ges., Fortschritte, Bd. 34, 1926.—See further G. Runström: The Röntgen-picture of fresh subperiostal hemorrhage in fractures of the metatarsals. Acta Rad., 1925, No. 11.—A. H. Pirie: Marching fractures. Lancet, July 14, 1917, p. 47.—*Ibid.*: A normal ossicle in the foot frequently diagnosed as a fracture. Arch. of Rad. and Elec., August, 1919.

[2] See also A. Bassetta: Sulla metatarsalgia di Morton, Soc. Lomb. di Scienze med. e biologiche. Milano, June 3, 1914.

In the capitulum of the fourth metatarsal bone *a compact-island* has been observed. One should not confuse it with a sesamoid bone; see "General," p. 3.

In the *second metatarso-phalangeal joint* an extremely unusual disease appears to which the author referred in the second edition of this book, p. 67, as follows: "In complaints at the affected spot one sometimes finds in Röntgen view a joint fissure double the usual breadth at the second or third or both metatarso-phalangeal joints. At the same time the head-epiphysis of the affected metatarsal is plainly compressed. This finding is

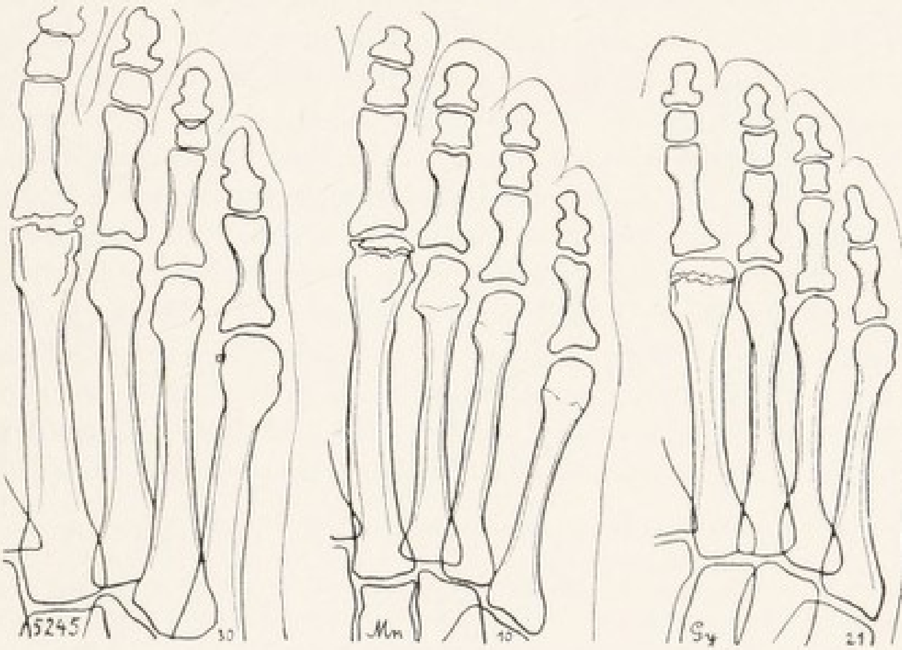


FIG. 64.

not yet mentioned in the literature. The author saw it altogether four or five times. The finding is naturally pathological, but the cause or rather the nature of the condition is still a puzzle to the author." I gave a more complete statement of one case in 1920 at the Eleventh Congress of the German Röntgen Society [1] (see Figs. 63 and 64). In the interval a number of further shorter and longer communications have appeared [2] so that

[1] A. Köhler: Eine typische Erkrankung des zweiten Metatarso-Phalangealgelenkes; Münch. Med. Wochenschr., No. 45, 1920.

[2] Axhausen: Die Ätiologie der Köhlerschen Erkrankung der Metatarsalköpfchen. Bruns Beitr. zur kl. Chir., Bd. 126, 1922.—Bänsch: Ein Fall von Köhlerscher Krankheit des 2. Mittelfussköpfchens. D. M. W., 1922, No. 10.—Feller: Ein Fall von Köhlerscher Erkrankung des 2. Mittelfussknochens. Zentralbl. f. Chir., 1922, No. 28.—A. W. Fischer: Die von A. Köhler beschriebene Erkrankung des 2. Mittelfussknochens. Fortschritte, Bd. 28, 1921.—Fromme: Über die Köhlersche Erkrankung des 2. Mittelfussköpfchens. (Reference.) Münch. M. W., 1922, No. 29, p. 1096.—Herzog: Über die Köhlersche Krankheit des 2. Metatarsusköpfchens. (Ref.) Med. Klin., 1922, No. 33.—Jakobsen: Über eine eigenartige Mittelfusserkrankung. Zentralbl. f. Chir., 1922, No. 4.—Kirner: Zur Köhlerschen Erkrankung des 2. Metatarso-Phalangeal-Gelenks. Münch. M. W., 1921, No. 41.—Liek: Über seltenere Erkrankung der Mittelfusszehengelenke. D. Ztschr. f. Chir., 1921, Bd. 166.—*Ibid.*: Über die Epiphysenerweichung im Wachstumsalter. Arch. f. klin. Chir., Bd. 119, 1921.—Panner: A characteristic Metatarsal Disease. Acta Radiologica (Stockholm), 1922,

up to date (August, 1927) about one hundred cases have been obtained from the literature and from private communications. For typical illustrations, see Figs. 63–66A.

The disease affects—although not always in the same sequence—the articular surface of the base of the first phalanx of the second toe (rarely of the third toe or of both or of the others), the particular metatarso-phalangeal joint (and its nearest vicinity), the articular surface of the capitulum of the second metatarsal (second or third), the capitulum itself and the entire distal half of the particular metatarsal; and these bones are altered in the following way; (1) The shadow contour of the articular surface of the base of the first phalanx forms in plantar or dorsal pictures not a regular arch as if drawn by a compass, but its outline is somewhat irregularly extended, often approximately S-shaped. (2) The articular fissure itself is in nearly all cases broader than the normal, which appears all the more remarkable, in that such a broadening never occurs in any arthritis—apart from ones with effusions; in arthrites the total changes are considerable and always accompanied by a narrowing of the articular fissure (an erosion or contraction of the articular cartilage). (3) The articular fissure is not only enlarged, but extremely various and broadened irregularly, the fibular half of the fissure being often about double that of the tibial half. (4) The articular contour of the head of the metatarsal loses its rounded shape; in recent cases it is only flattened out more or less, in old-standing

Bd. 1.—Sonntag: Beitrag zur Köhlerschen Krankheit am 2. Mittelfussköpfchen. Münch. M. W., 1922, No. 45.—Speed: Infraction of the head of a metatarsal bone. Surg. clin. of North. Americ. Chir., Bd. 2 and 3, 1921/22.—Unger: Eine typische Erkrankung des 2. Metatarso-Phalangeal-Gelenkes. Münch. M. W., 1921, No. 20.—Valentin: Beitr. z. Köhlerschen Erkrankung des 2. Metatarso-Phalangeal-Gelenks. Fortschritte, Bd. 29, 1921.—Vogel: Über eine eigenartige Mittelfusserkrankung. Zentralbl. f. Chir., 1922, No. 15.—M. Weil: Beitr. zur Kenntnis der von A. Köhler beschrieb. Erkrankung des 2. Metatarsophalangealgelenks. Fortschritte, Bd. 28, 1921.—*Ibid.*: Die Köhlersche Krankheit des 2. Metat.-Phal.-Gelenks. Berl. Kl. W., 1921, No. 51.—O. Alberti: La sindrome metatarso-falangea de Köhler. La chirurgia degli organi di movimento, Vol. VI, 1922.—Cahen-Brach: Beitrag z. Ätiol. der Köhlerschen Metatarsalerkrankung. Arch. f. klin. Chir., Heft 124, 1, 1923. (64 cases with almost complete list of the literature up to the end of 1922.)—D. B. Bocks: Over zeldzame afwykingen van middenvoetsbeentjes. Medisch Weekblad., 21, II, 1922, No. 47.—R. M. Bernstein: Case of Köhler's Disease. Am. Journ. of Röntg., August, 1922.—O. Heitzmann and H. Engel: Epiphysen. Erkrankungen im Wachstumsalter. (Osteochondritis def. cox. jur. u. Köhlersche Krankheit.) Klin. Wochenschr., 1923, pp. 397 ff.—W. Klett: Beitrag z. Ät. der Köhlerschen Erkrankung der Metatarso-Phalangealgelenke. Fortschritte, Bd. XXX, 1923.—M. Kappis: Die Ursache der Köhlerschen Krankheit an den Köpfchen der Mittelfussknochen. Bruns Beitr. z. kl. Chir., Bd. 129, Heft 1, 1923.—G. Axhausen: Der Krankheitsvorgang bei der Köhlerschen Krankheit der Metatarsalköpfchen und bei der Perthesschen Krankheit des Hüftkopfes. Zentralbl. f. Chir., No. 14, 1923.—*Ibid.*: Die Köhlersche Erkrankung der Metatarsophalangealgelenke. Medizinische Klinik., No. 17, 1923.—Quirin: D. M. W., 1922, No. 43, p. 1447.—L. Siciliano: La Radiol. med., October, 1922.—O. Schreuter, Leiden: D. Ztschr. f. Chir., 178, 3–4, p. 145.—E. Bircher: Schweiz. med. W., 1923, 9, p. 251.—H. Walter: Centralbl. f. Allg. Path. u. Pathol. Anat., 23, Bd., 1923,—E. König and H. Rauch: Zur Histologie und Ätiologie der Köhlerschen Metatarsal-Erkrankung. Arch. f. kl. Chir., 128, 1–2, p. 369.—Moritz Meyer: Über die Köhlersche Krankheit des Os metatarsale II. Beitr. z. kl. Chir., 130, 3, p. 655.—K. Bragard: Beitrag z. Malakopathie der Metatarsalköpfchen (Köhlersche Krankheit). Ztschr. f. orth. Chir., 46, 1, p. 49.—Engelke: Über 2 weitere Fälle von Alban Köhlerscher Krankheit des 2. Metatarsalköpfchens. Klin. Wochenschr., 1924, No. 25, p. 1129.—Lang, Innsbruck: Über die Bedeutung des cases it shows quite irregular hillocks and intervening defects. (5) In old-standing cases with marked changes one finds at the fibular opening of the articular fissure and far into the soft tissues a shadow of bony density varying in size from the eye of a darning needle up to that of a lentil, similar to the calcareous plates in the articular capsules of the larger joints, but strikingly circular in shape. (6) The capitulum of the metatarsal is definitely shortened, not the whole of it, but only its distal third, as if it were only the articular cap that was being compressed. The result of which naturally is that the metatarsus is on the whole somewhat shorter. Or the metatarsal head looks as if its articular part had been pressed in and had then raised itself away again (which may have led some to make mistakes and diagnose a simple fracture). So far everything might bear a resemblance, albeit a distant one, to a severe type of monarthritis; a further important point is, however, present in addition. (7) In all pronounced cases the whole distal half of the metatarsal is more or less altered, evidently increasing in circumference from the middle of the distal end, so that behind the head there is no indication of any neck. In this way the distal half often resembles the proximal half in form and size. And not merely the marrow cavity becomes broader distally but also the corticalis, the latter becoming reduced to its normal size towards the head. Another striking feature, and one that differentiates it from osteomyelitic changes (also spina ventosa), which give not altogether dissimilar pictures—is the gradual uniform increase of

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the bone distally. Also the spongiosa structure is apparently regular and definite as far as the articular cap.

The large number of cases recorded indicates that the condition is not a very rare one; at any rate it is more frequently met with than the singular disease in the scaphoid bone of the foot (see the same). In ten cases the second metatarsal was affected in nine, the third metatarsal alone or along with the second metatarsal was affected once; twice at least both feet were affected. The patients were ten to forty-eight years of age, and it should be remarked that in people older than eighteen years the condition was in all probability never a recent one, but usually originated unnoticed in the growing period with accompanying changes in the sense of arthritis deformans. Over two-thirds of all the cases occur in the tenth to the eighteenth years of life. The female sex is four times as frequently affected as the male. In two-thirds of the cases the disease affected the right foot. The clinical symptoms are pain in the region of the second metatarso-phalangeal joint, or rather of the metatarsal capitulum, above all, in applying pressure to the foot or taking the pressure off. The effects upon the gait are usually various and moderate and often of such a kind that the patient refrains from using the leg and actually halts so that he suffers inconvenience upon making tours on foot and in any special strain of gymnastics and sport; such exercises indeed may be impossible to him. The objective symptoms are usually some swelling of the soft tissues on the dorsum of the foot, especially in the region of the second metatarso-phalangeal joint and tenderness on pressure, usually dorso-volar, occasionally only dorsal or volar. Pain on movement is less common. Pronounced signs of inflammation are absent, there is no redness or fever. The typical Röntgen picture is described above, at least two authors found in their case in addition a bending of the epiphysis towards the dorsum of the foot. This finding

Fig. 65.

has not been mentioned by other authors and has not been found even by those who have examined the condition particularly. Consequently, the taking of a profile negative is to be recommended in every case, in spite of the superposition shadow of the first and other metatarsals. Further, it is essential to examine both the feet.

Fig. 66a.

For differential diagnosis. Just as in the singular scaphoid-diseases of the foot, so here: if one has once seen the Röntgen picture one will not easily forget it. (That holds good at any rate for all the cases brought to the röntgenologist in the growing period, see above.) Consequently, the diagnosis is very easy. Also the old-standing cases with considerable deformities of the articular ends of the bones are very different from the known pictures of primary chronic monarthritis; the author's opinion thereon is a really good one, for in Wiesbaden nearly all arthritis cases are examined by the Röntgen rays. In no case should one omit to study the thickening of the distal half of the affected metatarsal, which is certainly a diseased condition.

Anatomical-Pathological Findings

Certain contradictions still exist in the interpretation of the anatomical-pathological findings. This is explained by the fact that the majority of these cases of disease received conservative handling and only a relatively small number came to be operated on and accorded an exact histological examination. Axhausen has recorded the largest number of cases, making an exact microscopic examination of the resected head in six cases out of twelve clinical observations. The question of the ætiology of the disease is largely related to the anatomical changes, and upon reviewing the literature one can hardly avoid the impression that the interpretation of the macroscopic and microscopic anatomical findings is considerably influenced by the immediate standpoint of the investigator. It is, indeed, very difficult to say off-hand of the deformities, compressions, and protuberances of the articular head, whether these have arisen primarily, or secondarily after trauma, or are based on inflammations, embolic necroses, or rickets. The macroscopic findings are so very various that special stress has to be laid upon the histological findings. In his two first cases, the anatomy of which Axhausen describes in detail, he found macroscopically in the one an enlarged articular capsule, the synovia of the joint thickened but to a less degree, a generalised thickening of the synovial membrane and a pronounced hyperplasia of the synovial fringes in the plantar part of the capsule. In the other case the synovialis was slightly thickened, but otherwise there were no macroscopic changes. Engelke, M. Meyer, and Hühne also found a moderate enlargement of the articular cavity and a thickening of the synovialis. In his other cases Axhausen makes no nearer mention of the macroscopic condition of the articular surfaces and capsule. The head of the metatarsal itself showed a very various appearance ; part of it appeared to be normal and required a pocket-lens to demonstrate the presence of small irregularities ; in more advanced cases these were flask-shaped swellings of the distal half of the metatarsal, flattening and unevening (compressions) of the articular surface, processes at the articular edge, absorption of cartilage, and broadening of the epiphysis. Finally, there were found macroscopic pictures, that bore a complete resemblance to those of arthritis deformans, and sometimes with detached intra-articular bodies. The histopathology is of especial importance. The author (Köhler) has already reported (at the Eleventh Congress of the German Röntgen Society) a case operated on by Dr. Lossen. " The marrow cavity of the metatarsal was filled with reddish-grey granulations, the metatarsal head was embedded in thick masses of connective tissue. No pus. The whole process appeared atypical, the bone being very like a tuberculosis. Microscopic findings: The only thing to be seen was a dense new formation of connective tissue and plentiful cells of the embryonic type ; giant cells, caseated or purulent areas were not found. The operation wound healed well." In the first of the two cases Axhausen described in detail his attention was especially drawn to a nearly wedge-shaped subchondral necrosis of bone with necrotic lamellar spongiosa and irregular condensations in a quite necrotic marrow. The condition of the connective tissue had in part a mainly fibrous sclerotic character, and in part was distinctly rich in vessels and cells. In the area of granulation tissue there were seen alongside many phases of lacunar absorption with attendant giant-cells (osteoclasts), quite isolated thin seams of newly-formed living bone. In certain parts in the area of connective tissue connecting capsule to bone, the latter was completely necrosed. In the neighbouring retained epiphysial bone there were found isolated bony remnants of old spongiosa, which were surrounded by layers of newly-formed bone. Over the diseased part the articular cartilage was clearly thickened in consequence of infiltration of the hyaline substance. In Axhausen's second case the findings were not so pronounced, yet there also remains of old necrotic spongiosa and irregularly condensed necrotic marrow could be found in a wedge-shaped subchondral area of thickening with a callus-like network of newly-formed bone. The marrow-substance was converted into connective tissue. The regenerative processes which go to the replacement of the dead tissues proceed according to Axhausen from the periosteum of the metaphysis which grows actively, breaks through the articular cartilage at the chondro-osseous junction, and grows on into the dead epiphysis. With this exuberance of the metaphysial periosteum there forms an increasing deposit of newly-formed bone on the outside of the metaphysis and the neighbouring diaphysis. He finds delimited necroses of bone in both of his cases and also in the later ones, and he regards as the cause an interruption in nutrition which he ascribes to an embolic or possibly embolic-mycotic closure of the epiphysial end-artery. According to him, the circumscribed necrosis of bone might be the primary; the subsequent regenerative processes might then lead to a partial coherence between the basal and necrotic part of the epiphysis, which then might give way under the weight of the body. The observable compression-fracture might therefore be not a single fracture in the normal bone, but a pathological fracture in a very much altered and partly necrosed bone, in other words, it is a secondary manifestation. In an interesting case Cahen-Brach found conditions that closely resembled those of Axhausen. He discovered in the metaphysis even macroscopically a debris-cavity which extended its way into the epiphysis and reached in the form of a wedge as far as the articular cartilage. Microscopically the bony lamella were absent over this area, or were broken down. They were replaced by fibrous tissue, which ran without sharp delimitation into the surrounding marrow which formed a definite spongiosa. Holst and Chandrikoff have also described necroses with destruction of the epiphysial spongiosa and with infiltration of fibrous tissue rich in cells and vessels from the periosteum of the metaphysis; they describe also the formation of marginal proliferations and arrive at a confirmation of Axhausen's views. A very extended necrosis of the bone of the epiphysis above the remaining epiphysial cartilage was seen in a case of Heitzmann and Engel. The necrosed lesion affected the osseous lamellæ and the marrow adjoining the entire epiphysis. At the transition of the lateral margins of the cartilage into the epiphysial cartilage a granulation-tissue rich in vessels and cells had penetrated into the epiphysis and replaced the parts of the spongiosa that had broken down. Along with the process of absorption active osseous formation could be seen. A primary injury of the articular cartilage was not observed. In the interpretation of the histological processes Heitzmann adopts the views of Axhausen in their entirety. Hühne found also necrotic parts of the bone, but not wedge-shaped; in all the preparations their typical situation was under the middle of the articular cartilage at a varying distance from it, and only at parts where the articular cartilage and the layer between it and the bone had undergone considerable modification. On account of the form and the position of the necrosed and broken-down lesions, as well as on account of the absence of closure of the vessels, he rejects the theory of Axhausen. In his opinion there is distinct evidence that the observable arthritis deformans changes had preceded the infractions and necrotic destructions of bone. Small irregular necroses of bone with fibrous marrow formation and thickening of the walls of the blood vessels were observed by König and Rauch, but without attaching the same meaning to the finding as Axhausen. Axhausen's view of the matter was especially attacked by Kappis upon the ground of his own histological studies. He found that the bone had undergone absorption under the articular cartilage at certain limited and flattened areas. The region between the cartilage of the joint-surface and the bone was partially occupied by small cavities, but principally by a tissue composed partly of pure fibrous tissue of varying cellular richness and partly of chondroid tissue and one or two osseous remnants. Necrotic bone could not be seen anywhere. Signs of inflammation, embolism, thrombosis, tumour, and ostitis fibrosa were entirely absent. Kappis is therefore inclined to regard the whole change as a consequence of fracture. Subchondral necroses of bone and fibrous spaces in the marrow, which were continuous with the periosteal tissue, was observed also by Engelke. In the zone of broken-down tissue there was an absence of exsudative, productive, and metaplastic changes into cartilage, osteoid- and osseous-tissue, which caused the author to reject the idea of a purely traumatic fracture. He believes rather that the primary change is a transformation of the bone-marrow into fibrous-marrow, whereby the physiological building up and down of the bone tissue is disturbed. Upon this basis a fracture might easily take place with a very slight trauma. On this view we might be dealing with a process very closely related to ostitis fibrosa. Indeed, Klett has gone so far as to affirm that the disease is a localised ostitis fibrosa. Lang examined, in addition to two definitely diagnosed cases of Köhler's disease, the metatarsal heads of sixteen cases of very different age-periods, and on the basis of these investigations he rejects Axhausen's theory. He agrees with Kappis in ascribing the cause to traumatic influences. M. Meyer found raising and loosening up of the articular cartilage from absence of the preparatory zone of calcification, fibrous marrow with small-celled infiltrates, and absence of bony necroses.

According to Ceelen, the chief histopathological fact is the presence of a partly more fibrous, partly more cellular and vascular connective tissue, which appears usually subchondral to a varying extent, replacing a broken-down spongiosa. The development of this connective or granulation tissue is regarded by the majority of authors as starting from the periosteum of the metaphysis, proceeding from there at the transition of the epiphysial cartilage into the articular cartilage, and pressing into the bony substance or even into the canals of the bone-marrow. Evidence of necrosed bone is advanced only by one section of investigators. As the researches relating to the metatarsal bones may well claim a considerable degree of exactness, one must take it that in probably a great number of the cases the osseous tissue becomes necrosed. Whether this tissue-breakdown is to be regarded as a primary or secondary (post-traumatic) phenomenon, cannot at present be determined with any certainty. Axhausen's interpretation (a primary embolic-mycotic necrosis with secondary proliferative inflammatory regeneration) is doubtless attractive, even though the proof of closure of the vessels was seen only in one case. Attractive and all as the theory is, its exact and most important foundation is up till now not proven. It might be the case that constriction of the blood vessels the result of particular mechanical and locally acting influences might lead to limited interruptions of nutrition. It should be observed that the possibility of the production of a limited necrosis in bone in consequence of a partial closure of the vessels has been doubted by many authors. Many histological descriptions reveal certain resemblances to the picture of ostitis fibrosa. The majority, however, are deficient in the appearances typical of that condition, and one must therefore not press this interpretation too far. There remains trauma as an ætiology. The single gross trauma does not apply to the majority of the cases; on the other hand, a chronic mechanical action, *e.g.* in the form of a constant or repeated light compression, cannot be excluded. To arrive at a definite verdict is not yet possible. Further and more exact histopathological studies are required. Late rickets and endocrine influences do not appear to be the cause.

Regarding ætiology: in about every tenth case there was a history of trauma. We do not need to spend any further time on that here. It is certain that a trauma may not be the only cause, and that, on the other hand, perhaps always, a slight perhaps hardly noticeable, mechanical injury (which may be a continuous one) is necessary for the clinical appearance of the disease. Against the single traumatic origin there is also the slow commencing of the disease and its occasional bilaterality, both in histological and Röntgen findings. According to Beely's researches, the principal points of support of the arch of the foot in standing on both feet or in walking are principally the heel and the capitula of the second and third metatarsal bones; on the other hand, if the foot is hanging or if it rests only lightly on the ground, the first and fifth metatarsal capitula serve as supports; as soon as a certain pressure acts upon the anterior transverse arch of the foot, this yields, and one after another the capitula of the second, third, and fourth metatarsal bones come to bear the weight. In flat foot and splay foot this means that the head of the second metatarsal is particularly pressed upon. Flat foot is actually frequently mentioned in the history; thus one author,[1] in a summary of twelve carefully described cases, found a normal arch of the foot in only three, on the other hand flat foot and splay foot in nine; but now when there are altogether sixty cases, there appears to be a flat foot only in every fifth case.[2] Two or three authors blame the use of the bare feet. A lateral support is thereby absent which is usually given by the shoe; if there is in addition weakness of the connective tissue, leading to the sinking in of the transverse arch of the foot, particularly of the second metatarsal owing to the extra pressure, the first metatarsal becomes displaced to the inner side, and in the position of splay foot, the principal weight comes to rest upon the second metatarsal. Three cases showed even a bending of the metatarsus (see above). One observer[3] says the pathological alteration of the bone in response to mechanical insults is consequent upon a process similar to the formation of callus after fracture; reaction of the growing zone; the only pathological feature being that the limit of tolerance of the bony tissue for demands made upon it has been altered. Moreover, the

[1] Sonntag, *l.c.*

[2] Cahen-Brach, *l.c.*

[3] Müller, *l.c.*

modern footwear of women with their high heels, in which the anterior part of the foot is more heavily weighted, is in a way blamed for favouring splay foot, seeing that women are most frequently affected by the condition. Histological as well as röntgenological findings contradict the inflammatory origin of the disease. It is not one of the signs of tuberculosis, syphilis, or osteomyelitis. (Yet it may be mentioned that one author [1] out of his six cases was able to demonstrate tubercle in other parts of the body in four patients.) Another inquirer [2] maintains the theory that the process is an osteochondritis of a late-rhachitic nature. He also includes the Calvé-Legg-Perthes disease of the hip (see the same), Schlatter's disease of the tibial tubercle and disease of the scaphoid bone. The broadened and softened layer of cartilage in rickets or late-rhachitis is particularly susceptible to traumatic injuries. The theory has much to be said for it, but in almost all the patients that come under observation here there was hardly a trace of rickets to be seen. But the particular author replies to that: rhachitis tarda is much commoner than one thinks and clinical signs may often be absent. The osteopathy was not due to lack of food, the patients being usually well nourished. The same holds for people short of vitamines. The microscopic findings are not numerous, but, as already referred to, there are one or two descriptions [3] of highly singular and fairly unanimous findings in the form of epiphysial wedge-necroses owing to interruption of nutrition. König had already asserted in 1905 with regard to the operative cases of osteochondritis ossificans that in addition to trauma there must be still another cause for the condition at present yet unknown to explain how an area of the articular surface becomes broken off. The explanation given is that epiphysial wedge-necrosis is produced by embolic-mycotic closure of the epiphysial end-arteries, but that the mechanical injury is the principal factor. Infection is not the cause, or acts only slightly. But whether necroses in the bone are able to arise at all through closure of the arteries is contested by the pathologists.[4]

A crowd of publications have appeared since the disease was reported, and the author must reserve for a later date their estimation and appreciation, but there are a few works by surgeons and röntgenologists who have made an exceptional research study on the strength of several or many cases of their own. The chief points, important though they are, can only be briefly stated here. (The details of the microscopic examinations are given above in a special paragraph.) The one surgeon [5] establishes in his most recent case the absence of all signs of inflammation, embolism, thrombosis, tumour, ostitis fibrosa, or of any other disease, but found the signs of a fracture in apparently healthy bones. The periosteal thickening of the metatarsal shaft, its importance and cause, remains still a mystery.

[1] Alberti, *l.c.*
[2] Fromme.
[3] Axhausen, Cahen-Brach, Herzog, Sonntag.
[4] M. B. Schmidt in Aschoff's text-book quoted after Cahen-Brach.
[5] Kappis; the other, Axhausen: see towards the end of the list of literature.

Apart from simple fracture the only serious cause appears to be a primary embolus, which another author has suggested as the cause in cases where necrosis is microscopically established. Necrosis, however, cannot be demonstrated in other cases, and therefore cannot be considered the foundation of the diseased condition. (Perhaps many diseases might be considered as occasional causes.) Bony necrosis may arise only through traumatic influences and inflammatory diseases. The other examiner lays stress on the great frequency of the disease (he saw himself fourteen cases in the space of a year in his policlinic). Definite early clinical cases of the disease showed quite a normal Röntgen picture with histological changes already far advanced. The view of a purely traumatic origin must certainly be rejected. The sequestra-like pictures shown by this particular disease are not known as consequences of fracture, and the marked thickenings of the shaft are not to be understood as consequences of epiphysial compression-fractures. Histological pictures of healing fractures in general and of healing fractures in the subchondro-epiphysial region have quite a different appearance. Compression fractures might doubtless occur in this disease, but they would not be the cause but the consequence of quite another primary state of disease, they might be spontaneous fractures at the severely injured epiphyses. The complete interruption of nutrition in the epiphysis might be the primary condition. The interruption of nutrition of the epiphysis might also be the cause of the severe arthritis deformans which is the last stage of the disease. This disease of the metatarso-phalangeal joint represents an early instance of the osseous form of arthritis deformans. The extension and the sharp delimitation of the necroses and the findings in early cases, in which with necrosis of all the bony epiphyses there is an entire absence of any solution of continuity of the bone, indicate that primary traumatic influences may be excluded with complete certainty. The original epiphysial necroses owe their origin to an embolic closure of the vessels through mycotic fragments, especially of tuberculous and pyogenic nature, in which the bacteria are slightly virile and do not progress or are quickly overcome by the defensive powers of the body, " bland embolic necrosis." The continuously increased pressure on the metatarsal capitulum is of more importance in the origin of the pathological processes than any traumatic influences. To secure proper therapy of the process one should avoid the breaking up of the dead epiphysis under strain of weight (and this is effected by means of a " Bradford's protheses "). In addition there is the expressed opinion of a leading pathologist [1] that Perthes disease, the disease of the second metatarso-phalangeal joint, and disease of the semilunar bone, may all be due to the same process. We are dealing with a subchondro-necrosis of bone. Vascular disturbances probably played a rôle in their production. These need not be embolisms in the above-mentioned sense. Traumatic wrenches that might lead to stoppage in the vessels might be among the causes of the disease. From the pathological standpoint the process

[1] Aschoff: 47. Vers. d. deutsch. Ges. f. Chir., 1923. Reference in M. M. W., 1923, No. 20, p. 650.

is a different one from that of arthritis deformans. Also a direct transition of these conditions into a true arthritis deformans hardly ever takes place. A third author [1] explains the necrosis as a mild osteomyelitis ; an indication of this being the markedly thickened periosteum. He advised inoculation tests, which were accordingly carried out.[2] A needle was introduced into the swelling on the dorsal side of the epiphysis and injections made into mice, without producing any reaction. He found also in three out of his six cases a disturbance of the sensibility of the skin in the region supplied by the deep peroneal nerve—that is, the nerve which supplies the affected joints ; he diagnoses a neuritis, and concludes that the changes in the joint are explainable as trophoneurotic disturbances. The microscopic findings of the aseptic necrosis can be brought into accord with this view. Two Russian surgeons report twenty-nine of their own cases with seven operative findings.[3] They never found any trace of rickets. Cystic and fibrous alterations of the bone were found present in one case, which bore a distant resemblance to ostitis fibrosa. On the basis of their histological sections they reject entirely the view (of Kappis) that the disease is a primary fracture of the healthy bone or of bone weakened by unknown causes. Besides, it is scarcely to be thought of that a small compression-fracture should bring about such far-reaching changes in the bone as to cause a necrosis of almost the whole epiphysis. The opinion of another author that the process is of a tubercular nature they consider quite unnecessary. They reject the embolic theory, on the ground that there are no end-arteries in the epiphysis ; but they consider an interruption in nutrition to be the real cause of the disease, and were able to demonstrate to their satisfaction a complete obliteration of the vessels of the periosteum and of the articular capsule, and in addition a rich capillary network near the first blood-vessels to be altered (? secondary and regenerative).

Through excess-tension of the vessels of the articular capsule and the resulting closure of the lumen there is produced an ischæmia in the periosteum and in the epiphysis, and in consequence of this ischæmia the (observed) endarteritis obliterans, further a necrosis and proliferation of the connective tissue, all which phenomena are known to result from the ischæmia of the soft tissues. Alterations in the blood-vessels have also been established by five or six other observers. Owing to the wearing of high heels a condition of griffin-toes is known to occur, by which the vessels of the plantar surface may become overstretched, so that the lumen may disappear altogether ; in elderly people there might even occur processes as in splay foot. In the twenty-nine cases trauma was given as an explanation six times, and twelve times a history of unusually high heels. The head of the second metatarsal bone is the support in raising the foot from the ground, and upon it the weight falls extra heavily on walking, if the os calcis is raised by a high heel and the weight of the body displaced in a forward direction. Five times the foot was overstrained by forced military marches,

[1] Moutier. [2] After Nowotjellmoff.
[3] Holst and Chandrikoff.

three times overstrained at the treadle of the sewing machine combined with high heels, three times there was an entire absence of history of injury. The majority fell ill during the severest hunger-years. Flat foot would appear to be a predisposing factor, as coxa vara is to Perthes disease. Instead of the customary titles: "Osteochondritis juvenilis, epiphysitis juvenilis, osteoarthrosis juvenilis, osteochondropathia juvenilis, malakopathia," the term "osteopathia juvenilis necroticans" is proposed. One author has collected records of fifty cases, of which two were his own.[1] In fifteen patients the statement of the employment is given, in thirteen of these fifteen the exercise of the employment demands more or less strain in standing and walking. Twenty-four per cent. of the cases gave a history of trauma; in seventeen cases the third metatarsal was affected only once; there was also a bilateral case. The Wassermann test was carried out in twelve cases and proved negative every time. Flat foot was found in 22 per cent. of the cases. Female patients were affected thrice as often as males. Rickets played almost no rôle in the history, tubercle was found occurring in 12 per cent. of the cases, but in no single case was there any tubercle in the metatarsal itself. The histological findings of his own cases enables him to conclude that the situation of the commencement of the disease is to be sought at the junction between bone and cartilage in the zone of calcification; the cartilage at the transformation zone in the bone was repeatedly or continually damaged by chronic trauma. Another researcher, himself the subject of metatarsal disease, records a number of cases.[2] He distinguishes: (1) An early stage with the form of the head unaltered, (2) a stage of compression, (3) a stage of arthritis deformans. The disease is ranged with marching fracture of the shaft as a statical disease of the metatarsal. Among 155 marching fractures (according to Muskat) the second metatarsal was affected eighty-four times, the third fifty-seven times, the fourth four times, the fifth once, the second and third four times, the third and fourth five times; in thirty-five cases of metatarso-phalangeal disease the second metatarsal was attacked twenty-six times, the third six times, the second and third once, the first once, and the first to the fifth once. Against a purely chronic-traumatic genesis (statical overstrain) is the fact that the disease selects the female sex. Against high heels as the predisposing factor the use of bare feet has been adduced. In his patients he had two sisters, with disease in the same metatarsal of the one foot, of apparently constitutional origin, which did not need to be congenital; the patients came of a very rickety family. In one case—a man of thirty-five years—a gumma had attacked the head of the second metatarsal. (For an account of the therapy, see below.) His conclusion is that trauma in the widest sense cannot be the primary cause of the disease. Rather, the foundations for the disease are prepared by a relaxation of internal tension and by a lessening in the resistance of the epiphysis due to very various causes. The most favourable predisposing factor is late rickets, but other endocrine disturbances may also predispose; even real infectious processes might be the

[1] Moritz Mayer.

[2] K. Bragard.

cause. It is uncertain whether congenital anomalies of constitution have anything to do with its occurrence. As a predisposing factor to these inner causes there is the statical overstrain in consequence of the splay-foot. The primary factor is the weakening of the epiphysis.

Summing up, it can be said: there are certainly anatomical-physiological conditions for the localisation of the disease at the second (or third) metatarso-phalangeal joint. The body weight is on the second metatarsus, and it is exposed to all manner of strains and stresses, as is shown by the swelling of soldiers' feet affecting the second in the highest percentage of all the metatarsals. This factor of exposed position, however, is never alone sufficient. There must be in addition a factor of a general pathological nature which in particular produces a certain debility of the bony system, perhaps not so much infectious as of a toxic or toxic-infectious, dyscrasic, diathetic, hormonic, or similar nature, by which a diminished resistance of the organs is produced, especially those exposed under physiological conditions of the greatest work and strain, as also here in the head of the second metacarpal bone. Or there arises a particular predisposition somewhat in the sense of a constitutional anomaly, possibly also analogous to the so-called weight-deformities (nor can phylogenetic factors be entirely excluded; they, too, play a rôle).[1] Then with slight repeated strains or greater overstrain a form of osteochondritis malacia is produced. The author pointed out in his first address, Röntgen Congress, 1920, p. 55, the similarity of the Röntgen picture to that of osteochondritis dissecans of the knee. There can be brought about—how? a very important connecting link is here wanting—a general necrosis of bone in the epiphysis, as the above-mentioned microscopic findings from different sides amply prove. This necrosis may be due to a moderate mycotic embolism or to obliteration of the vessels of the head and capsule following upon overstrain and pressure. Secondly, in the course of years the process goes on to alterations of the body articular surfaces in the sense of an arthritis deformans, but always very different from it in Röntgen picture. (This can be preceded, as a thoroughly investigated case shows, by a turning upwards of the head towards the dorsum of the foot; the microscopic findings showing only a normal bone and, in the deeper layers, a normal cartilage, which on the surface stained poorly and was partially divided up into fibres.)

Taking it all in all we may briefly say that as regards ætiology and pathogenesis there is much still to be explained. This short summary

[1] The author was the first to take this possibility into consideration, being influenced by the ideal resemblance offered in his case between the distal half of the second metatarsus and that of the normal first. Since then I have seen a number of pictures in the literature and in private communications, in which this resemblance was lacking, and newly ossified periosteum was clearly seen raised from the corticalis through the difference in contrast; I therefore do not wish to lay stress upon the phylogenetic factor. It is even possible that we have here to deal with a consequence of irritation, with a rapid functional adaptation. The observation made from one side appears to me to be incorrect, that such thickening belongs to the usual picture of chronic or deformative arthritis.

corresponds to the purpose of the work and may prove sufficient for the practitioner.

The treatment may briefly be referred to. Conservative therapy is to be tried first of all, rest, especially rest in bed and dressings, baths, warmth, hot air, massage, etc., also a supporting bandage, especially a well-fitting shoe after a plaster of Paris model of the foot. In addition strengthening general treatment, like good nutrition, fresh air, sunlight, cod liver oil, iron, iodine, arsenic, phosphorus, calcium. Also organic preparations. Some surgeons recommend operation and have almost always a good result. It is perhaps better to wait a year to see whether conservative treatment does not bring about clinical cure. Operation is to be recommended only for adult cases with severe arthritic alterations. It is preferable in the first and second stage to advise immediate application of a Schede's adhesive strapping. This reconstitutes the sunken transverse arch, converts the position of abduction of the front of the foot, raises the longitudinal arch, and so diminishes the retroflexion of the front of the foot. An addition is then made to the sole of the shoe of a leather strap about 1 cm. thick and 3–4 cm. broad—the well-known anterior heel—and is so arranged that as much weight as possible is taken off the heads of the metatarsal bones. If this secures a diminution of the swelling and tenderness, one then proceeds to the handling of the later stage: a Lange's inlay, with an anterior elevation for raising the transverse arch. If the inlay cannot be worn all the time, Sales' leather bandages can be employed with benefit. In cases with weakening of the plantar ligaments the above method may not be sufficient, a plaster of Paris bandage in two portions can be applied, as in tubercle of the foot, to take the weight off the bones. Regarding operations it should always be remembered that a resection of the metatarsal head may cause considerable weakening of the ligaments of the transverse arch. Thus one lady patient with a resected metatarsal head showed two years after an ugly shortening of the toes and a considerable reduction in the carrying capacity of the foot, so that she could walk only a quarter of an hour at a time.

It was brought to the attention of the author that the disease in question was described and printed about the same time or a few months earlier from the American side, by Freiberg, "Infraction of the Metatarsal Head," August, 1914, in "Surgery, Gynæcology, and Obstetrics," and my first communication was written in 1913 or 1914 for the second edition of this book and printed about the end of 1914 or the beginning of 1915. The most important, singular, and perhaps most essential part of the whole process, namely, the usual well-marked and almost always uniformly distally increasing thickening of the distal half of the particular metatarsal with disappearance of the neck, Freiberg has completely missed observing and appreciating, although it is present in his three illustrated cases. In over a hundred described cases it was never absent once, see Figs. 63–66A. On account of its rapid formation and uniform increase in thickness this extremely puzzling symptom at first escaped me too in spite of all the above explanations, for the attention is caught by the articular changes. And only when I discovered it and was able to establish it by a search through the earlier cases did the disease appear to me complete, important, without analogy, and worthy of a thorough investigation and publication. Proof: my remarks at the Röntgen Congress, 1920, p. 51, " In the meantime an important new symptom has been observed, etc." Freiburg admits his failure to observe the thickening of the metatarsal diaphysis in 1926, and acknowledges further that a simple trauma is not sufficient to explain the clinical and röntgenographic phenomena.[1] Also the proper appreciation of the whole picture of disease on the part of other observers only took place since this first communication of mine in 1920. As a pure fracture or even only an " infraction " (as Freiberg believes) in a greater or less insufficiency of the bones of the foot, it would naturally not be of sufficient interest. Accordingly, both Freiberg's short communication and my still shorter one in 1914–1915 was not followed with any work worth mentioning either in America or here. It was only after my complete address of 1920 that every other month up to 1924 some one to three communications have appeared with confirmative observations of other inquirers, who have thoroughly corroborated the seven cardinal symptoms described by me: changes in the base of the first phalanges in the toes, considerable widening of the articular fissure, marked irregularity of the latter, flattening of the articular cap, deposits of lime in the articular capsule, shortening of the head (or of the metatarsal), thickening of the distal half of the metatarsal, the filling up of the neck. I have naturally never maintained that all these changes can occur at the same time, and I have always drawn a clear distinction between them and their frequent termination, arthritis deformans. Freiberg mentions only three of them: compression of the head, calcified articular bodies, and shortening of the head, that is, the symptoms of fracture or infraction. He operates indeed in order to remove the articular bodies, but describes neither the macroscopic nor the microscopic findings. He believes the whole picture of disease to be an ordinary fracture with insufficiency of the bones of the foot in consequence of some trauma (tennis, etc.). It is therefore hardly correct to say, in the words of Lewin: " This picture of disease is incorrectly known as Köhler's metatarso-phalangeal syndrome." [2]

This disease has not yet been observed *in the first metatarsal*, or at any rate not described. I recollect a statement somewhere in the literature [3] that arthritis at the first metatarso-phalangeal joint might be compared to a Jesuit's hat. I have indeed seen two or three cases of this

[1] A. H. Freiberg, Cincinnati: The so-called infraction of the II. Metatarsal. J. of bone and joint surgery, 1926, 8, 2, p. 257.

[2] Ph. Lewin, Chicago: Juvenile Deforming Metatarsophalangeal-Osteochondritis: Freiberg's Infraction of the metatarsal Head. Journ. of the Amer. Med. Ass., July 21, 1923. —Skillern: Amer. Surg., 70, 371, 1925.—W. C. Campbell: Amer. J. Orthop. Surg., 15, 721, October, 1927.—A. Köhler: Münch. Med. Wschr., 1924, p. 109.

[3] ? From Kienböck.

type with the Jesuit's hat in almost thirty years' practice, but without finding anything similar to the disease of the second metatarsal described here; or the cases are very old ones, in which the deformative process is such as to leave nothing characteristic of the original disease. But I have seen cases which bore a complete resemblance to the disease of the second metatarsal. Of the principal symptoms of the disease only a single one is lacking (the absence of which may be quite accidental), namely, the small, round, calcareous bodies, which are not to be observed regularly in every case. In the case in Fig. 66B we have a woman who when eleven or twelve years old struck her foot forcibly against a hard object and then suffered from pains for a considerable time. For the last half-year she has had recurrence of pain on walking any distance. In Fig. 66C we are dealing with a man of forty-seven years, who has complained for about three to four years of pains in the two great toes and the neighbouring toes of the right foot. In both cases the S-shaped base of the first phalanx of the great toes is very beautifully marked, and the pressing in of the articular head into the head of the proximal plalanx, with the thickening of the distal half of the metatarsal diaphysis. In the course of further years or decades a more or less severe arthritis deformans will in all probability supervene.

Fig. 66B.

In many individuals one finds the fourth metatarsal on both sides shortened by about 1 cm. (anomaly).

Infractions and fractures at the diaphysis (marching tumour of soldiers) should not be overlooked.

The shadows of the *bases* of the three bones are partly superimposed in plantar pictures; a misinterpretation appears here to be impossible, especially as neither sesamoid bones nor supernumerary bones nor fractures are wont to occur here.

The base and the middle of the second metatarsal is the favourite site of *syphilis*. If one therefore finds here broad periostitis ossificans and rareficans without previous trauma, one should think first of gumma; but even an actual trauma does not contra-indicate gumma.[1]

[1] Köhler: Knochengummen. Fortschritte, Bd. 10, 1906, Plate 8.—Further Grashey, Atlas II, p. 128, Tab. II, Fig. 4.

Transverse fractures of the second metatarsal are not uncommon in *tabes*.[1]

For *deformities* of the second to the fifth metatarsal refer to " Fifth Metatarsal."

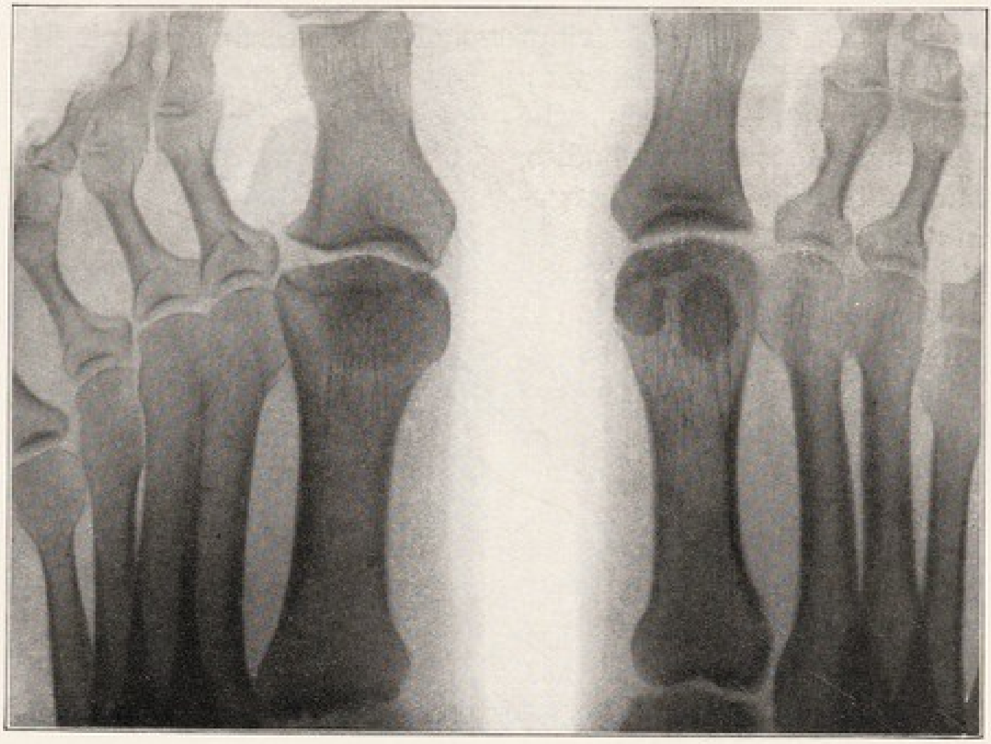


FIG. 66C.

Fifth Metatarsal

The peculiar *defect of the fifth capitulum*, as shown in Fig. 67, is characteristic of a commencing perforating ulcer of the foot. The ulcer in the soft tissues does not require to be in fistulous connection with the joint or the bone, as was formerly believed. Arthropathy and perforating ulcers are more regularly associated, they have a common origin conditioned by a certain disease of the nerves.[2] Therefore changes in the bone can be present even in advance of the ulcerative process in the soft tissues and lead to a diagnosis.

Regarding *sesamoid bones*, see above, " Metatarsus, General."

The *tibial third* of the capitulum is sometimes found strikingly translucent to the Röntgen rays, =normal.

One sometimes finds the *shaft* of the bone, both in plantar and in profile pictures, slightly curved.

The *proximal lateral end* of the metatarsal usually projects consider-

[1] Wohlauer: Röntgenbilder tabischer Osteoarthropathien. 10. Röntgenkongress, 1914.

[2] A short monography with Röntgen pictures and list of the literature appeared 1914 from Max Hofmann: Das Malum perforans pedis. Ergebnisse der Chirurgie und Orthopädie, 8. Bd., 1214.

ably to the side, well beyond the cuboid. A beginner might be in doubt whether a subluxation were not present.

The *form of the proximal end*, especially its lateral part, the *tuberosity*, is extremely various. Fractures occur in it. They were recognised as such in the first Röntgen pictures, then röntgenologists were made aware of Pfitzner's works on the accessory bones of the foot,[1] and Gruber's work on the inconstant epiphyses ;[2] every diagnosis of fracture was then rejected and the fragment explained as a " persisting epiphysis," or as an os vesalianum. Other works[3] indicate that fractures are really present in the majority of these cases. This inconstant piece of bone can be diagnosed

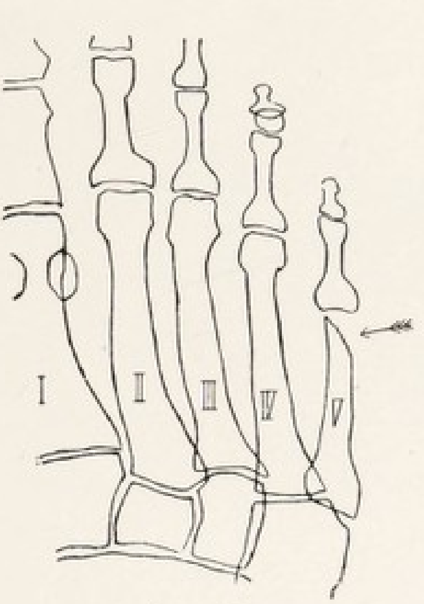


Fig. 67.

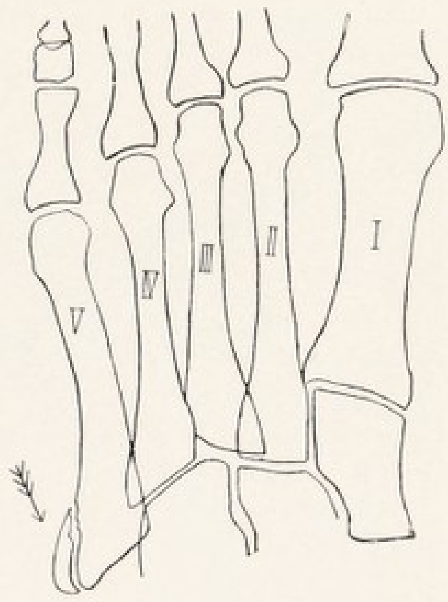


Fig. 68.

from fractures by being almost always bilateral. An inconstant lateral *apophysis* is sometimes seen at the tuberosity of the fifth metatarsal bone (Fig. 68). The proof that the whole tuberosity appears as an inconstant epiphysis has not yet been given. From the cases of os vesalianum already described (Vesalius, Spronk,[4] and Gelinsky[5]) it is believed that we

[1] Pfitzner : Die Variationen im Aufbau des Fussskeletts. Morphologische Arbeiten, Bd. 6, 1896.

[2] Grüber : Über den Fortsatz des Seitenhöckers, Proc. tuberositas lateralis, des Metatarsale V und sein Auftreten als Epiphyse. Archiv f. Anatomie und Physiologie, 1875 : Virchows Archiv, 1885.

[3] Lilienfeld : Die Brüche der Tuberositas ossis metatarsi V und des Processus posticus tali und ihre Beziehungen zum Os Vesalianum und Trigonum. Archiv f. klin. Chirurgie, Bd. 78, Heft 4.

[4] Spronk : Auftreten der ganzen Tuberositas des Os metatarsale V als ein für sich bestehendes, am Metatarsale und Cuboides articulierendes Skelettelement. Anatomischer Anzeiger, II. Jahrgang, 1887.

[5] Gelinsky : Das frei articulierende Os vesalianum tarsi duplex im Röntgenbild. Fortschritte, Bd. 8, 1905.—Sven Johansson : Os vesalianum pedis. Nordisk ortopedisk förenings 2 : a konkress i Helsingfors, 1921.—G. J. Davis : Os vesalianum pedis. Am. J. of Röntg., May, 1927.—Thurstan Holland : see footnote 2, p. 83. Further, there are many shadows of bone labelled " os vesalianum " in the Röntgen literature that are mistakes in diagnosis.

have here to deal with an inconstant epiphysis. It was then asserted [1] that the formation of an epiphysis of the tuberosity of the fifth metatarsal is quite a constant finding. One usually finds this osseous nucleus forming in the thirteenth to the fourteenth year of life. Retardation takes place occasionally in weak and unhealthy individuals ; in general the ossification is complete at $15\frac{3}{4}$ years. (Histological preparations show that the osseous nucleus is first developed in the tendon of the peroneus brevis muscle.) According to others there is not the slightest doubt of the real occurrence of an os vesalianum, but this is not situated on the lateral aspect, but proximal to the tuberosity, has regular contours like other tarsal bones

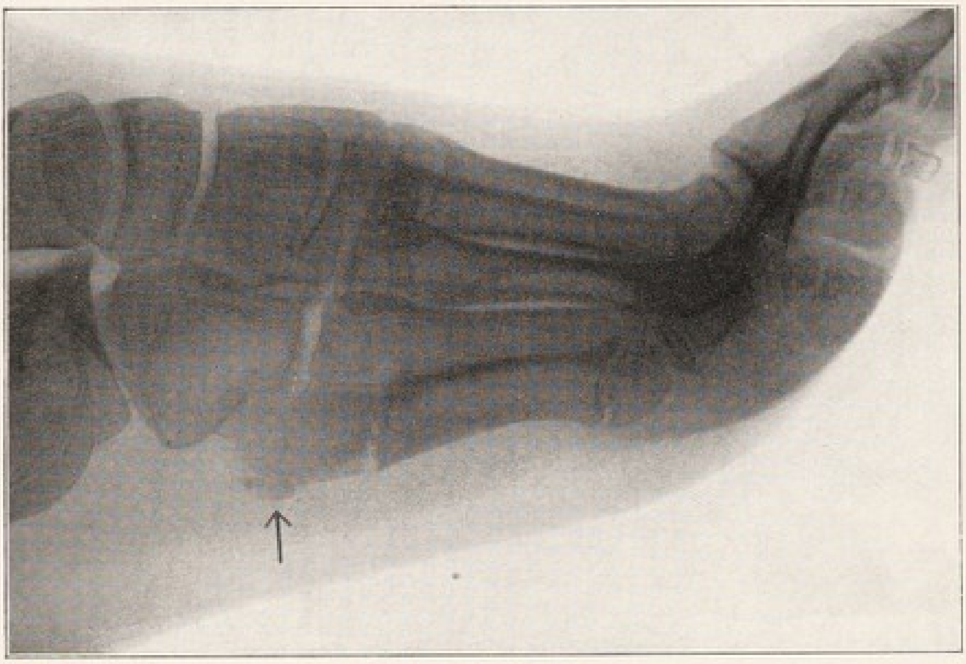


Fig. 69.

and does not form the tuberosity (of the fifth metatarsal bone), but the latter is itself well developed. In the case of the anatomical and Röntgen literature, in which the os vesalianum is said to be placed laterally near the metatarsal, it has probably not been that at all, but only the above-mentioned apophysis. Finally, there appears at the base of the fifth metatarsal in occasional cases an inconstant lateral epiphysis.[2] Rarely has a small ossicle been so often described in the literature.[3] One of the recent investigators arrives at the following conclusions : At the proximal end of the fifth metatarsal bone there occur two epiphysial-like forms. (1) The " apophysis," a frequent, perhaps constant, scale-like epiphyses at the lateral plantar part of the tuberosity of the fifth. Its ossification begins in the tendon of the peroneus brevis muscle. (2) The proximal

[1] Schouwey : Die Entwicklung der Tuberositas metatarsi V. D. Ztschr. f. Chirurgie, 118. Bd., 5 and 6 Heft, 1912.—See also Iselin : *Ibid.*, Bd. 117.

[2] Heinrich Fischer : Fortschritte, Bd. 19, 1912 ; see also p. 3 of this book.

[3] Chr. J. Baastrup : Os vesalianum tarsi and fracture of tuberositas ossis metatarsi V. Acta Radiologica, Vol. I, 1922.

part of the tuberosity of the fifth has occasionally a certain independence with a special ossification centre. Occasionally there occurs an epiphysial-like terminal form, which in three cases proved at the autopsy to be not epiphyses at all, but independent bones, the os vesalianum tarsi. The tuberosity of the fifth metatarsal bone corresponds morphologically, phylogenetically, and ontologically with the fifth os tarsali that has disappeared in the distal row, and the os vesalianum is to be regarded as an atavistic form of the fifth os tarsali. The fact the os vesalianum is found so seldom (although it occurs more frequently than is generally believed) leads one to think that the fifth os tarsali disappears in an earlier stage of development. With such a theory agrees also the fact, that a fifth os tarsali is found only in anura, reptiles, and in embryonic life of the lowest classes of the mammalia. The theory is supported by the varying position of the bones in the early stages of the human embryo. Occasionally the os vesalianum and the above-mentioned apophysis is taken for a fracture of the tuberosity of the fifth metatarsal. The history and the Röntgen pictures must decide the differential diagnosis. The usual criterion advanced for determining real bones, namely, their bilaterality, does not assist us to a correct diagnosis.

Fig. 70.

The fracture or detachment of the fifth metatarsal tubercule has also aroused the interest of röntgenologists. Thus one of the latest works states : [1] Fracture separation of the tuberosity of the fifth metatarsal bone is a typical fracture, which usually occurs by contraction of the peroneus brevis muscle with fixation of the foot in a position of supination. It can easily be diagnosed both clinically and röntgenologically, and can generally be easily distinguished from the variations of the bones of the foot. The prognosis is good. Osseous union and loss of symptoms are the rule in three months. The author of this work in Fig. 69 adduces a case of fracture accompanied by the regular epiphysis, which is just starting to ossify.

A deformity of the second to the fifth metatarsal with the convexity outwards and upwards according to the author's experience is extremely rare, or at any rate appears extremely rarely to the röntgenologist who is not an orthopædic specialist ; it is in all instances pathological and is described as *pes metatarsus varus*, Fig. 70. If the metatarsal bones

[1] Harry Schütz : Der Abrissbruch des 5. Mittelfusshöckers. D. M. W., 1925, No. 26.

have retained their form but turned inwards, one speaks of *metatarsus adductus* (in metatarsus varus of the extremer type there finally take place fractures like those of the fourth and fifth metatarsals of our case). The bending of the second to the fifth metatarsal in metatarsus varus is regarded as a compensatory adaptation to a markedly rickety tarsus valgus.[1] The active compensatory changes of flat foot form an extremely interesting chapter into which we cannot here enter in detail; they are under the influence of the heel and lead on to a *functional pes adductus*. But a few cases of *congenital pes adductus* are also known (deficient germ-anlage, limitation of space in utero, arrested development of the scaphoid, and the first and second cuneiforms). The proximal ends of the second to the fifth metatarsals were imbricated like tiles one above the other, the cuneiforms were compressed laterally so that the shadows of the second and third fell partly in the contours of the cuboid bone; the calcaneo-cuboid joint fissure was wider than usual. The first metatarsal was abnormally developed, and the second to the fifth, on the other hand, were much weaker.[2] According to others, the distinction between pes metatarsus varus and pes adductus congenitus cannot be insisted upon.[3]

Tarsal Bones of the Foot

General

The *osseous nuclei of the bones* of the foot appear in the following order:[4] The *body of the calcaneus* is ossified in the majority of cases from two osseous centres. The first is visible in the fifth month of fœtal life as a disc of about 1 mm. Independent of this a second osseous nucleus appears in the sixth fœtal month. The two unite about the end of the fifth fœtal month. In the apophyses of the calcaneus there appears one or several osseous nuclei between the sixth and the tenth year. The osseous nucleus (or several?) of the *astragalus* appears in the seventh fœtal month. The *os trigonum*, when present, appears to start ossifying in the eighth year or later. The average time of ossification of *the scaphoid bone* is the end of the fourth year of life, often in the form of a double nucleus. Apparently traces of such an ossification from two centres remain quite a time (which may occasion incorrect diagnosis of fracture—Author). Also

[1] Cramer quoted in Dunker; see below.

[2] F. Dunker: Die aktiven Correctionserscheinungen des Plattfusses u. Pes adductus congenitus. Zentralbl. f. chir. u. mech. Orthop., Bd. 8, Heft 9.

[3] S. Weil: Über den Pes adductus congenitus und die Köhlersche Krankheit. Berliner klin. Wochenschr., 1921, No. 18.—Mettenleiter: Metatarsus varus und adductus congenitus. D. Ztschr. f. Chir., 186, 5/6.

[4] According to Hasselwander: Untersuchungen über die Ossification des menschlichen Fussskeletts. Inaug.-Dissert. München, 1903. Published by Nägele, Stuttgart.)—See also Åkerlund, *l.c.* ("Feet").—F. Delitala: Contributo allo studio röntgenografico dell'anatomia normale e patologica del tarso. Atti I Congr. d. Soc. Ital. di Rad. Med. Milano, X. 1913.—P. Sessa and O. Alberti s. p. 1, footnote 1.

a division of the scaphoid bone of the foot has been described as a variety.[1] The ossification of the cuboid begins on the average in the tenth fœtal month, and arises not from one point but from several (two to three points). *The third cuneiform* bone ossifies usually in the sixth month of life, the *first and second cuneiforms* almost simultaneously in the third year or the first half of the fourth year. In the second and third cuneiforms preformations of two nuclei have not been observed, although sometimes in the first cuneiform.

As in the bones of the hand, *sesamoid bones* occur also in the bones of the foot, further also numerous *variations* (Fig. 71). Most frequently of

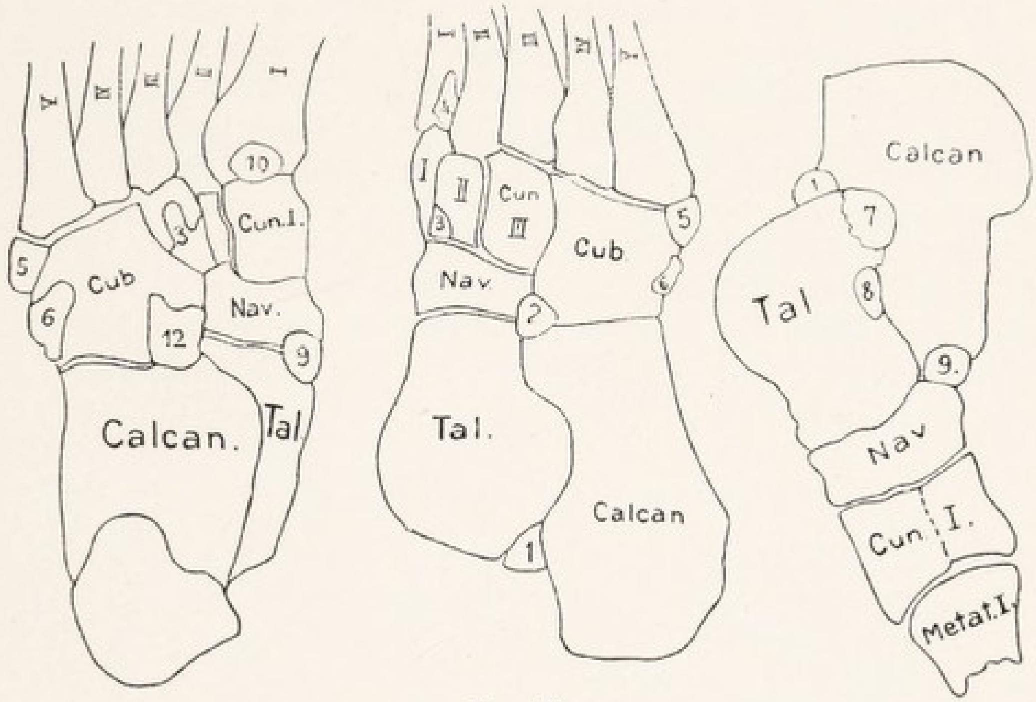


FIG. 71.

all there appears the os trigonum (1) (os intermedium cruris), placed behind the astragalus, next frequently the peroneal sesamoid (6), single or divided (Fig. 72), on lateral profile pictures at the lateral or plantar border of the cuboid bone. In severe deformative processes the sesamoid bone may also be found deformed, and more rarely, in about 10 per cent., one finds the os tibiale externum (9) ; it is situated at the outer side of the scaphoid bone (see same). The remaining varieties known to the anatomists are : calcaneus secondarius (2), intercuneiform (3), intermetatarseum (4), talus accessorius (7), os sustentaculum (8), first pars peronea metatarsalis (10), cuboides secondarium (12), and os vesalianum (5), see pp. 107 and 108 ; according to röntgenological experiences one meets these rarely as bones. Skeletal variations appear to select certain individuals, and especially those individuals in which the normal course of ossifications has been interfered with owing to endocrine cause.[2] This fact was found after

[1] From Gruber, quoted by Hasselwander.

[2] A. Hasselwander, *l.c.* Further statements in the last few years on supernumerary bones of the foot are : Biermann : Amer. Journ. of Röntgen, July, 1922.—C. Guarini : J. Policlinico,

a reinvestigation of Pfitzner's case, and appears to have been missed by Pfitzner himself.

For the examination of *general disturbances of growth* the bones of the foot are not so often chosen as the bones of the hand (see " Bones of the hand "). For all cases, see also the statements above on the appearance of the nuclei.

First Cuneiform Bone

The *internal contour* is sometimes quite a straight line, sometimes it shows little projections and indentations without being pathological.

In certain positions of the tube which can seldom be secured deliberately, there appears a strikingly *broad articular fissure* between the first and second cuneiform bone, which in patients who have been run over can easily be mistaken for a separation apart of the two bones, when everything is normal.

A *subdivided first cuneiform* bone may occur and is frequently found in the röntgenogram upon both sides.[1] On re-examination after several years one can make out a fusion of the divided bone. In one such case the dorsal portion remained ununited.

Second and Third Cuneiform Bones

Their shadows are superposed in plantar negatives as in lateral and medial profile negatives, being still further complicated in profile negatives by the addition of the shadow of the first cuneiform bone. It is extremely difficult to give a typical illustration for the confusion of the different shadows, and with a slight displacement of the focus or a tilting of the axis of the foot quite a different picture immediately arises. In practice the conditions are not unfavourable inasmuch as the cuneiform bones are very seldom the seat of pathological affections.

The dorsal contour of the cuneiform bones in profile pictures is sometimes almost a straight line or slightly wavy. Grosser irregularities are pathological and caused by badly fitting shoes, often without any symptoms of pain.

Congenital fusion of the two cuneiform bones with the metatarsal bones has been described.[2]

Vol. XXIV, 1917.—M. Lupo: La Chir. de org. d. mov, Anno IV, 1920.—A. Heimerzheim: Über einige accessor. Fusswurzelknochen nebst ihrer chir. Bedeutung. D. Ztschr. f. Chir., Bd. 190, Heft 1/2, 1925 (with complete list of the literature).—A. Violato: Arch. di Ortop., 1926, 42, 3.—A. Hasselwander: Skelettvarietäten des Tarsus. Ztschr. f. Const.-Lehre, 1921.

[1] Haenisch: Die Röntgenographie der Knochen und Gelenke und ihr Wert für die orthopädische Chirurgie. D. Med. Woch., 1913, No. 42.—See further: Balli and Sperino: Os cuneiforme I perfecte et unperfecte bipartitum. Accad. di Scienze, Lettere ed Arti, Modena, Serie III, Vol. X, Parte II, 1912.

[2] N. Gentill: Seltenes Bild eines Fusses. La Rad. Med., 12, 9, p. 613.

Cuboid Bone

Its shadow is extremely various in configuration, especially in profile pictures, according to the arching of the foot, the position of the foot during the exposure, and the position of the tube. Its shadow, however, is not covered by any other bony shadow in the usual position of the tube, and it is therefore well seen and mistakes are easy to avoid ; *fractures* are extremely rare,[1] and also *inflammatory diseases of bone and tumours* are scarcely ever situated in this bone.

One appearance can easily lead to misinterpretations, that is, the very great *transparency of the lateral half* of the cuboid. One is much inclined, especially when complaints are made of that part of the foot, to think of a large tuberculous lesion or a subacute atrophy following upon a tuberculosis of the neighbouring joints, while the conditions are perfectly normal. The natural Röntgen-translucency of the lateral half of the cuboid is due to its wide meshy structure and thin corticalis, and it is still more obvious to the eye because of the contrast afforded by the superjacent shadows of the metatarsals, the superimposed shadows of the cuneiforms, and the strong shadow cast by the scaphoid. This normal appearance is all the more important, for it already appears well marked in the dark room in negatives that have not been completely developed. The portion of the calcaneus in apposition to the cuboid usually shows a similar translucency, an important fact in the differential diagnosis.

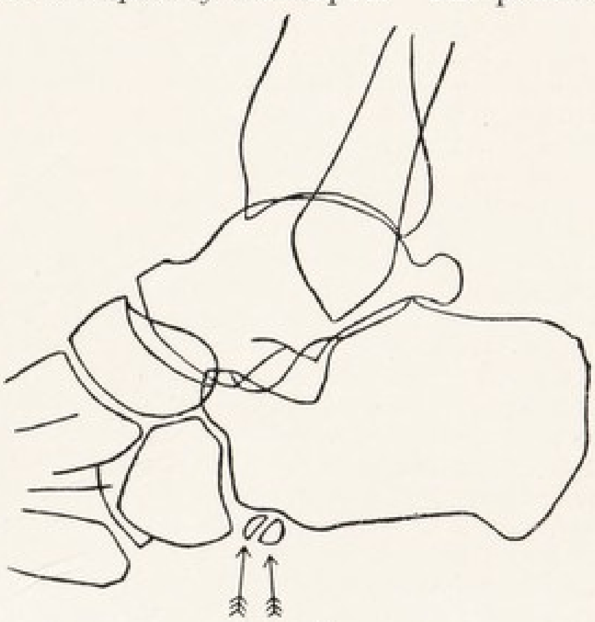


Fig. 72.

The author found once as an accidental finding in a girl of fifteen years a *cystic-like translucency* of almost the size of a walnut, sharply defined, of benign nature, as the subsequent course of events showed, but bearing a gross resemblance to a sarcoma.

The *lateral posterior articular corner* of the cuboid appears approximately rectangular in profile pictures, and it occasionally shows a small process directed backwards ; this, however, is hardly ever the site of much complaint.

A large *opening* in the Röntgen picture between the cuboid, the scaphoid, and astragalus is found in any marked flat-foot deformity.

The *peroneal sesamoid* which fairly often appears double (see Fig. 72), is characterised by a somewhat flattened semicircular or even crescentic form. If it is situated further off in the soft tissues, its form resembles an

[1] Grashey in his Atlas II shows the picture of a small process from the cuboid on the plantar surface towards the calcaneus.

ellipse or circle; these widely displaced elements may even be typical in their form. It is the articular or sliding surface which gives the ossicle its particular form. In projections in which the peroneal sesamoid falls into the shadow of the cuboid it is possible to confuse the condition with a *compact-island* of the cuboid.

In the lateral half of the cuboid distal and proximal *compact-islands* may occur; see "General," p. 3.

Scaphoid Bone

In children from three to ten years one occasionally meets with an isolated *dwarfing of the nucleus of the scaphoid* (the patella is sometimes attacked bilaterally at the same time, but that is a rare happening) (Fig. 73); the osseous nucleus is smaller, narrower, and more irregular in its contour and much denser in lime than the normal. We are dealing here with a disease observed first by the author in three cases and described in detail in 1908, regarding the origin and nature of which there is still much dispute.[1] The disease appears without further therapy than ordinary rest

[1] Literature: Köhler: Über eine häufige, bisher anscheinend unbekannte Erkrankung einzelner kindlicher Knochen. Münch. Med. Wochenschr., September, 1908.—Haenisch: Under the same heading. Münch. Med. Wchnschr., November, 1908.—Behn: Isolierte Erkrankung des Naviculare pedis bei Kindern als Zeichen einer Wachstumsstörung. Fortschritte, Bd. 14, 1909.—Lomon: Atrophie du scaphoïde et pied plat. Soc. de Rad. méd., June, 1914.—Stumme: Compressionsfractur des Knochenkerns des Os nav. pedis. Fortschritte, Bd. 16, 1911.—Kay Schäffer: Die Köhlersche Knochenerkrankung. Münch. Med. Wchnschr., 1910, No. 29.—Wrede: Ein Fall von Köhlerscher Krankheit. Reference: Münch. Med. Wchnschr., 1912, No. 12.—Preiser: Zur Frage der typ. traumat. Ernährungsstörungen der kurzen Hand- und Fusswurzelknochen. Fortschritte, Bd. 17, 1911.—Wohlauer: Über die Köhlersche Erkrankung des Os nav. pedis. Verhandl. der D. Röntgen-Ges. 8. Kongress, 1912.—Forssell: *Ibidem.* Discussion, pp. 37 *et seq.*—Schultze: Arch. f. klin. Chir., Bd. 100, Heft 2.—Grune: Fall von isol. Kahnbeinfractur des Fusses. D. Zeitschr. f. Chir., Bd. 121, Heft 1 and 2.—Köhler: Arch. f. klin. Chir., Bd. 101, Heft 2.—Schultze: *Ibidem.*—Grashey in Rieder-Rosenthal, 1. Bd. Leipzig, 1913.—Köhler: Zur Pathologie des Os nav. pedis der Kinder. 10. Röntgen-Kongr., 1914.—Bles: De Ziekte van Alban Köhler. Nederl. Tijschrift voor Geneeskunde, 1913.—Bertolotti: Contrib. röntgenogr. allo studio dell'ossit. del nav. del tarso. La Radiol. Med., 1915.—Meulengracht: Die Köhlersche Krankheit des Os nav. pedis. Hospitalstidende, May, 1915, complete German references. Fortschritte, Bd. 28.—Cockayne: Isolated Disease of the Scaphoid. The Lancet, vol. 197, No. 5024, December, 1919. Reference: Fortschritte, Bd. 28, 1921.—McClure: Isolated Disease of the Scaphoid. Journ. Amer. Med. Assoc., Chicago, 1918.—Koritzynsky: Et tilfaede ov Köhlers sygdom i os naviculare tarsi. Norsk. Mag. f. Laegev., No. 12, 1919. Reference: Fortschritte, Bd. 28, 1921.—Lorey: Zwei Fälle Köhlerscher Krankheit. Münch. Med. Wchnschr., 1919, No. 15.—Magnard Heath: Isolated Disease of tarsal scaphoid: Köhler's Disease. The Lancet, vol. 197, No. 5019, November, 1919.—Comby: La scaphoidite tarsienne des jeunes enfants. Arch. de Med. des enfants, 1920, No. 12.—Balli: Sindrome scafoidea del Köhler e sua prohabile interpretatione patogenitica. La Clin. pediatrica, 1920, F. IV.—Coenen Blauwknip: Morbus Köhler. Nederl. Tijdschr. v. Geneesk, June, 1920.—Drevon: Un cas de maladie de Köhler. Journ. de Radiol. et d'Electr., 1920.—Mouchet and Roederer: La scaphoidite tarsienne des jeunes enfants. Rev. d'Orth., 1920, No. 4.—Thurstan Holland: On rarer ossifications seen during Röntgen-Ray examinations. Arch. of Rad. and Electr., September, 1921.—Abrahamsen: Köhler's Disease, especially with a View to the Pathogeny of the Same. Acta Radiologica, IX, 1921.—O'Brien: Köhler's Disease of the tarsal Scaphoid in Children. Boston Med. and Surg. Journ., 1919.—Sonntag: Beitr. z. Köhlerschen Krankheit des Kahnbeins am Fusse bei Kindern.

to clear up in one or two years with restoration of a completely normal structure. One should therefore avoid surgical interference. The affection has nothing to do with tuberculosis, although tuberculosis is not unknown

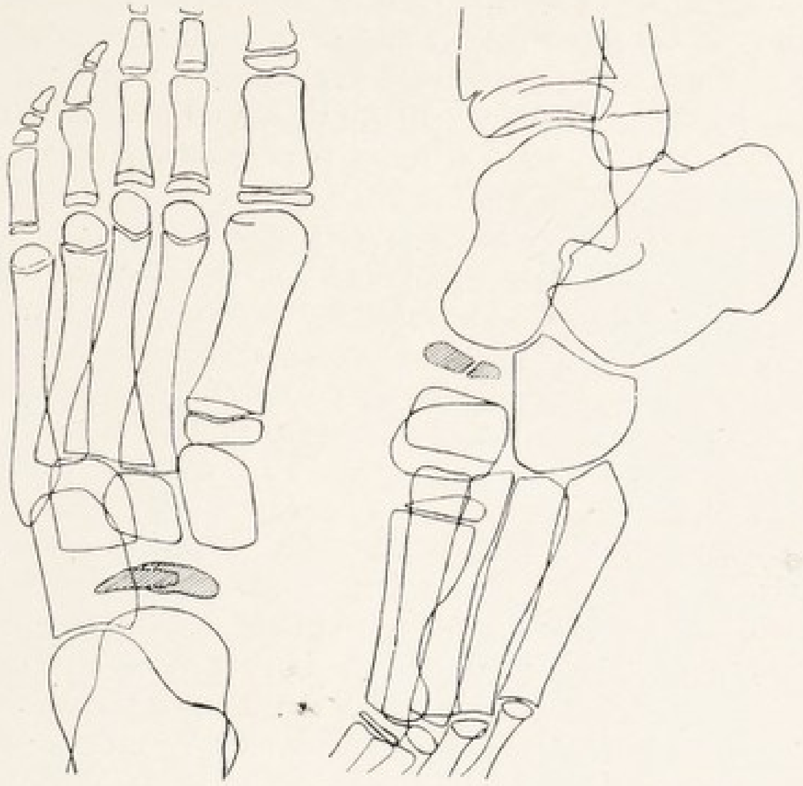


FIG. 73.

in this bone. Röntgen pictures of tuberculosis appear altogether different ; see Fig. 75, tuberculosis of the scaphoid. The attempt was made from the surgical side, without adequate knowledge of the literature on the subject, to explain the Röntgen finding simply as a fracture ; against this it could

D. Ztschr. f. Chir., 1921, Bd. 163.—Weil : Über die Beziehungen der Osteochondritis def. coxae juvenilis und der Köhlerschen Krankheit. Beitr. z. klin. Chir., 1921, Bd. 122.—Zaaijer : Osteochondropatia juvenilis parosteogenetica. (Perthes, Schlatter, Köhler, etc.) D. Ztschr. f. Chir., June, 1921, Bd. 163.—O. Alberti : La sindrome scafoidea del Köhler. La Radiologia Medica, Vol. IX, Fasc. 6, 1922.—Walther Müller : Kohlersche Erkr. des Os navic. mit gleichzeit. Schwund des einen Hüftgelenkkopfes bei Lues congenita. Arch. f. Orth. u. Unfallchir., Bd. XXI, Heft 1, 1922.—H. Laurell : Om Köhlers sjukdom. Kirurgiska sektionens förhandlingar, 1921/22.—Hans Schulze-Gocht : Zur Atiologie der Köhlerschen Krankheit (os nav. pedis). Inaug.-Diss., Berlin, January, 1922.—Fromme : Die Ursache der Wachstumsdeformitäten. D. M. W., 1920, No. 7 ; see further Deutscher Chir.-Kongress, 1920, Bruns Beitr. z. kl. Chir., Bd. 118, 1920 ; Berl. klin. Wchnschr., 1920, No. 45.—A. Risser : Isolated Disease of Scaphoid Bone of Foot. Journ. of the Amer. Med. Assoc., March 4, 1922.—Thurstan Holland : On rarer ossifications seen during Röntgen-ray examinations. Journ. of Anatomy, Vol. 55, Part 4, July, 1921. Arch. of Rad. and Elec., September, 1921.—Van der Linden : Ziekte van Köhler van het 2. metatarso-phalangealgewicht. Nederl. Tijdschr. voor Geneesk, 1925, I, p. 1874.—E. Bril : Wratschebnoje Delo, 1926, Beilage, p. 140. —Among works containing almost exhaustive lists of the literature are those of Schulze-Gocht, Sonntag, Mouchet and Roederer, and by Alberti, and the work of Weil with the surgical and microscopic findings.—F. C. Kidner and Felipe Muro : Journ. Am. Med. Ass., 1924.

easily be urged that no trauma could be shown to exist in at least two-thirds of the many cases described up to date, and in a number of the remaining cases the trauma had been only slight. In two-fifths of the cases the condition was found present in both feet. The author believed in 1912 that one met this Röntgen finding principally in poorly developed children, for among the hitherto published cases it was mentioned in the majority that they had been particularly weak and debilitated in the early months and years of life. Endeavouring to confirm this opinion the author took from a few cases of myxœdema of his earlier practice the only case in which the development of bone corresponded exactly to a normal individual of from five to ten years ; and—as expected—a dwarfing of the scaphoid was found well marked in the Röntgen picture on both sides. That does not seem always to be the case, however, and another investigator did not find anything like it in a similar condition in a case of myxœdema, while again a third had a similar finding to that of the author. In the last ten years about sixty fresh cases have been described, and not so very many of the children were observed to be weakly during the early years of life, so too much stress should not be laid on the observation. At the moment (August, 1927) round about 120 cases have been described, more or less fully. Only the most important of these findings can be referred to in the scope of this work, and only in the briefest terms : Two-thirds of all the cases occurred in children in the fifth to the sixth year of life, the limits being apparently the third and the tenth years. Three-quarters of all the cases occurred in boys. Pain and swelling were usually present in the region of the scaphoid. A local rise in temperature was very rarely found. " The clinical symptoms are almost nil, the Röntgen picture is everything. When one has seen it once, one never forgets it," says one author. Twice analogous changes were found at the patella, twice at the epiphysis of the head of the femur of the other side of the body (Osteochondritis juvenalis of Calvé-Legg-Perthes) ; it should be remembered that the patellæ were examined only rarely, and the femora only by one or two observers ; otherwise the occurrence of these other conditions might have been discovered oftener. Regarding the differential diagnosis one should recollect that the principal symptom is the extremely marked density and want of structure of the bone ; the density may amount, estimated roughly, to as much as double or treble the normal calcium contents. Mere fissuring and reduction in size of the nucleus with irregularity of its edges speaks against our picture of the disease, and in certain circumstances may belong to the realm of the normal. To tuberculosis, osteomyelitis, lues, etc., the typical röntgenogram bears no resemblance, and these processes hardly ever affect the scaphoid. For course, prognosis, and treatment, see above. Ætiology : Hereditary factors do not appear to play any rôle, although gonorrhœa, tuberculosis, syphilis, and rhachitis of parents have been mentioned occasionally. There does not appear to be any special predisposition ; the condition occurs also in well-nourished and robust children. Rhachitis was present in some cases, also in one of the three cases first published by the author. A fracture in consequence of a single trauma is quite out of the question—that is now certain from operation and microscopical findings. (One should not allow oneself to be misled through the division and subdivision of the scaphoid shadow into diagnosing a fracture.) The possibility that numerous small traumata spread over months might act as a cause must always be thought of; the most probable cause is an immoderate strain acting on a normal scaphoid for months at a time or a continuous

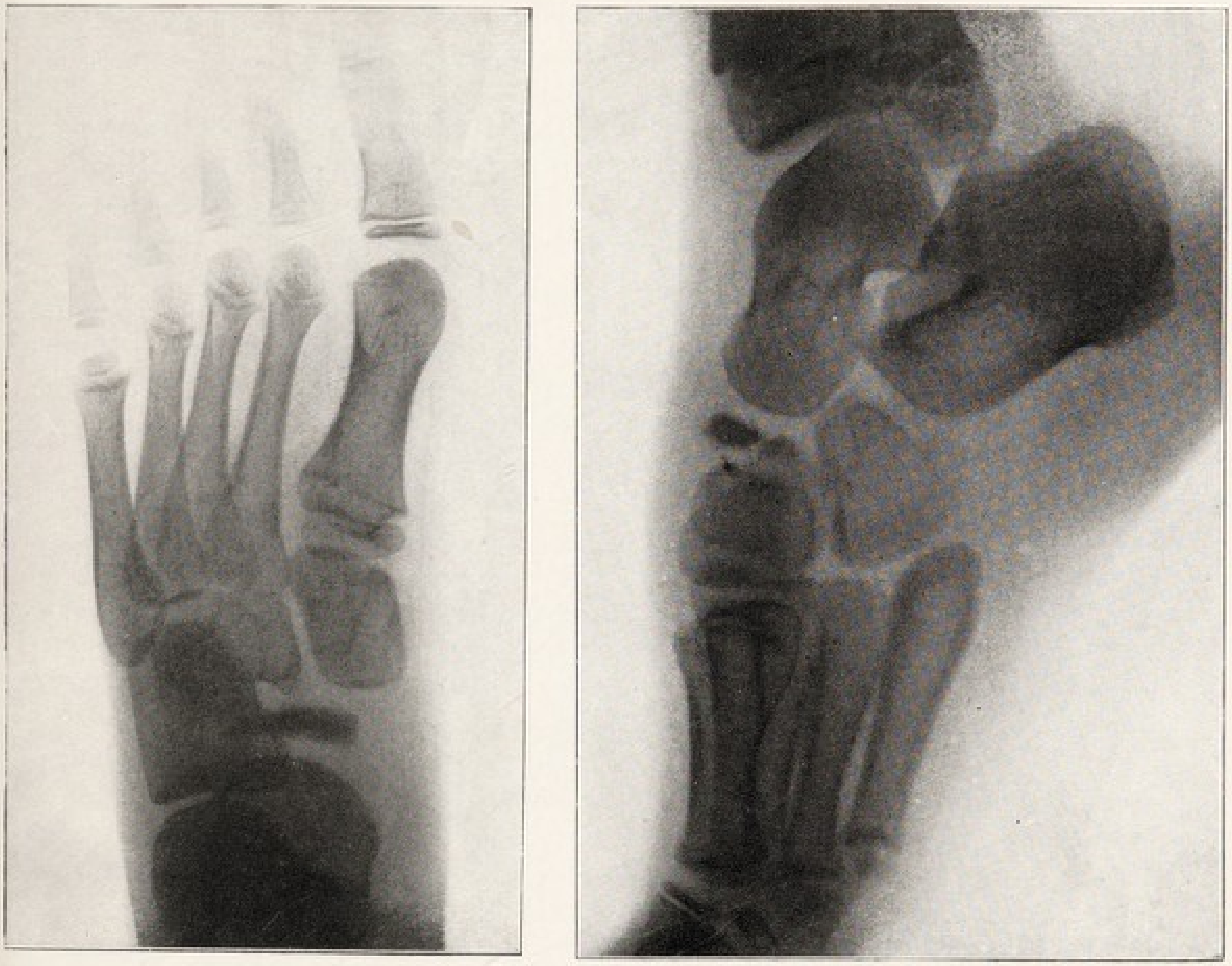


FIG. 74.

normal strain acting on a scaphoid weak in development. At any rate a single factor is not sufficient. A few authors speak of an inflammatory cause. That appears very questionable; at least it is too early to describe the disease as a "scaphoiditis." [1] The author in his first communication considered the cause to be an interruption in development, for it appears frequently in both feet, and other bones (patellæ) may be altered in an identical or similar way. This opinion has up to now found most favour,

[1] Two authors write: "We believe that a clear title must be given once for all *a la française*. We can hardly entitle it Köhler's disease for various reasons. We have proposed the name 'Scaphoïdite tarsienne des jeunes enfants.'"

and one author even saw remarkable results follow treatment of the condition with thyroid preparations. Thus at the same time as the scaphoid was affected interruptions in development were described in the same or the other bone and in the hips, either in the form of defects [1] or of osteochondritis coxæ.[2] (It should be added here that in comparison to the other elements of the tarsus the scaphoid bone ossifies last of all, sometimes more than one nucleus being present.) One röntgenologist determined on the ground of anatomical research that the region of the scaphoid is vascularised very poorly during its whole life, both dorsally and plantar; and that, whenever this poor vascularisation remains in an individual at the lowest limits of the normal, the conditions for our disease are given. Thus a number of inquirers regards it as quite a local change, others again as an expression of a general latent process. The analogy with osteomalacia of the semilunar bone of the hand, as supposed by two or three authors, does not appear to apply. A not important case is one thoroughly investigated clinically, röntgenologically, by operation and microscopically.[3] "The scaphoid bone appears macroscopically in a surprising way normal, and does not manifest the slightest alteration; its articular surfaces towards talus and cuneiforms are absolutely healthy and glistening; the neighbouring bones are also normal. . . . The bone examined was divided up into a great number of small pieces. From this it was seen that only a small centre consisted of spongiosa structure. The macroscopic finding was confirmed histologically. The examined cartilaginous tissue showed just as few peculiarities as the osseous spongiosa tissue. It should be added that there are no signs of a traumatic injury, no hypertrophy, no hæmorrhages; catabolic changes cannot be seen in the bony trabeculæ. There are absolutely no signs of an inflammation. . . . Röntgen pictures of the removed scaphoid show the central tissues to consist of numerous condensations partly isolated, partly irregularly confluent, crumbly in appearance, structureless, and without order, which are far removed from the picture of a normal ossifying scaphoid. A bony trabeculæ architecture there are no indications of. The site of the condensation areas is the lateral part of the piece of bone, while the inner half is almost free from it. . . . The places where the deposits of lime is thickest correspond throughout to the bony tissue, while the cartilage is normally translucent to the Röntgen light. The strong shadow of the bony substance points to an increased content of lime. . . . Both diseases (Köhler and Perthes) are to be regarded as interruptions of development. Our observation certainly proves that for Köhler's disease." One researcher [4] says that the processes of endochondral ossification at the juncture of cartilage and bone must produce a fairly weak tissue layer between the unaltered cartilage and the newly formed bone. In this weak zone very slight stretches and crushes might produce lesions, which might occasion reactions in the vicinity, and give rise in a given case also to interruptions in the processes

[1] Walther Müller, *l.c.*
[2] Laurell, *l.c.*
[3] From S. Weil, *l.c.*
[4] Zaaijer, *l.c.*

of ossification. He proposes to call the condition "osteochondropathia juvenilis parosteogenetica." That would apply also to Perthes' and Schlatter's diseases. Another observer [1] points to the fact that various interruptions of growth might be caused in the growing period by rhachitis tarda. Under the influence of the latter the cartilaginous tissue taking part at the endochondral ossification might be abnormally large and soft, so that it is more susceptible to even minimal traumatic influences. Rhachitis tarda is much more common than one usually believes and clinical signs of it are often absent. Upon one occasion [2] the disease was met with in congenital lues (with simultaneous disappearance of one of the femoral heads). ("In lues one must be prepared to see many surprises in the Röntgen picture." Author, M. M. W., 1908, p. 1924.) Some authorities draw attention to the relation of scaphoid disease with pes cavus, flat foot, or talipes, that is, with congenitally caused interruptions. But there must be in addition another causative factor, for otherwise the condition would be very much more frequent than it is. Either the ligaments normally laid down and intended for normal pressure through special demands (pes cavus, etc.) due to unrestrained movements of the child, would compress the cartilaginous scaphoid wedged between neighbouring and already ossified bones, or when the ligamentous early-formation was overweak the arch of the foot would be abnormally flattened out. These continual mechanical actions are what injure the cartilage of the scaphoid. If the arch of the foot falls in, the upper part of the scaphoid would be first of all exposed to an increased pressure. Thus one observer [3] found in these cases the calcified bony nucleus narrow on the dorsal side, condensed and abnormally constructed, while on the plantar side it showed itself thicker and appeared even to be normal. (He saw also one or two cases combined with tuberculosis or an ostitis of another kind, which, considering the wide prevalence of the former, is not to be wondered at.) Thus in the majority of his twenty-four cases there was present a more or less pronounced

FIG. 75.

[1] Fromme, *l.c.* [2] Walther Müller, *l.c.*

[3] H. Laurell, *l.c.*

insufficiency of the arch of the foot ; in one or two of the others there was no evidence of this.

In the last three to four years comparatively few works have been published dealing exclusively with this disease, on the other hand numerous ones have appeared comprising under the heading of "new affections of bone," "local dyschondroplasia," etc., still another one or two cases of scaphoid disease. Fresh points of view have not been adduced. But it is perhaps too much to expect that a single cause or a single factor might account for several or all the various diseases of the osseous nuclei. To explain all these diseases at once is an impossible task. Thus to classify inflammatory conditions as "epiphysitis" or "apophysitis" ("itis" being the symbol for inflammation) is probably premature. One large research work [1] advances the theory that the arteries in the cartilage are affected by slight traumata and the vasomotor nerves in the adventitia thereby injured ; the paresis of the nerves then brings about active hyperæmia in the cartilage or in the epiphysial nucleus. Two works also deal with a peculiar change of the scaphoid in adults, on both sides in each case. It is too early yet to say whether they can be brought in line with Köhler's disease.[2] As regards the occurrence of the disease in particular constitutional states, it is considered that the asthenic type exhibit a predisposition to it.[3]

Summing up we can now say : The scaphoid bone is the last of all the bones of the foot to ossify, and is therefore the most sensitive to influences of every kind. In consequence of its position the severest statical demands are normally made upon it, from above through the weight of the body, and distally in so far as it has to receive from the front of the foot all the large and small pushes, pressure actions in jumping, slips of the foot, etc. ; moreover, it is a narrow disc in contradistinction to the more resistance cuboid forms of the neighbouring bones. Finally, its normal nutritional blood-supply is the worst imaginable. So in a certain measure the scaphoid is the step-child or the Cinderella among the bones of the foot. Naturally all that is hardly sufficient to explain the development of the diseased form. Almost all the findings up to date, both surgical and microscopic, contradict an inflammatory process or a direct trauma as the cause. If we have to deal with an interruption in development—apparently not a purely local one however—what are the conditions that do that ? One might think of hypothyroidism. If a slight rhachitis can really appear so frequently without definite clinical manifestation, that might well give an explanation for the origin of the trouble. But perhaps no single factor is to be considered as the cause, but all factors, whose action on the development of the bones we are aware of (or are not aware of yet), like endocrine

[1] P. G. K. Bentzon : Experimental studies on the pathogenesis of coxa plana and other manifestations of "local dyschondroplasia." Acta Rad., Vol. VI, Nos. 29–34, 1926.

[2] Walther Müller : Deutsch. Ztschr. f. Chir., Bd. 201, 1927.—Georg Schmidt : M. m. W., 1925, p. 368.

[3] H. Hueck and Fr. Emmerich : Constitutionstypen u. chirurg. Krankheiten. Mitt. aus d. Grenzgeb., 40. Bd., 1926/27.

disturbances, toxic factors, infectious and dyscrasic toxins, etc. It thus would appear as if it would be some time yet before the condition can be completely cleared up.

The *dorsal contour of the scaphoid* bone of adults is in very rare cases a straight line or a slightly convex arch, in the majority of cases it forms two more or less flat elevations with a depression in between (=a wave and a half) ; that is also quite normal. Other and more marked changes belong to the realm of the pathological.

A larger swelling, a *raising up of the articular edges*, as in Fig. 76, is met with fairly regularly in flat feet and in healed fractures of the small bones, and also in fractures of the calcaneus ; it is always combined with a bony swelling at the articular end of the astragalus opposite to it, which

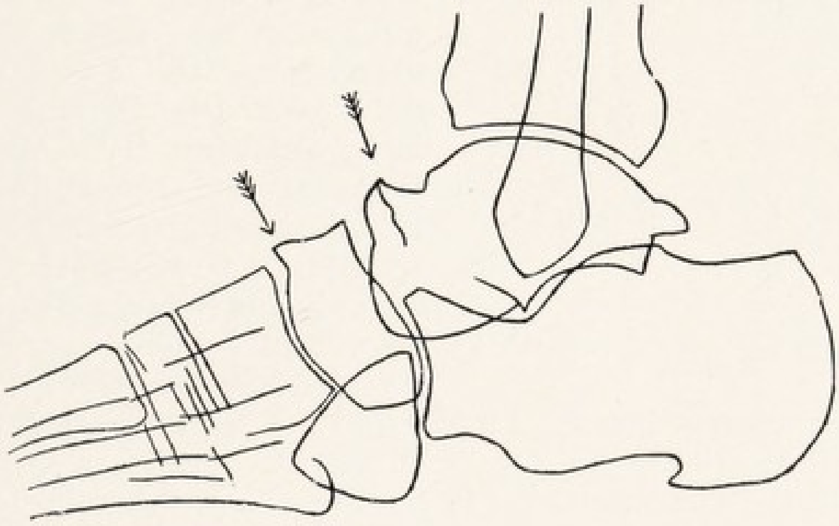


Fig. 76.

is usually even larger. We are here dealing to a certain extent with a process of functional adaptation to the valgus position of the foot, and in the most pronounced cases we can certainly speak of an arthritis deformans.

Isolated fractures of the scaphoid are rare. They could hardly be diagnosed before Röntgen discovered the rays, and since then scarcely ten such cases have been recorded.[1] Nevertheless, one may take it that non-isolated fractures are really fairly frequent, although they have not been published.

The *normal plantar view* of the scaphoid bone shows the form of a crescent ; the proximal outline forms a beautiful geometrical third of a circle, the distal arch is evenly rounded only in its inner (tibial) third, the other two-thirds consist of two or three straight lines, which join each other at obtuse angles and often stop irregularly, so that one is tempted to see pathological processes where none exist. The form of the bone in flat foot is more wedge-shaped.

The inner border of the scaphoid, *the tuberosity*, projects in normal

[1] Günther : Zur Pathologie des Os naviculare pedis. Zeitschr. f. Röntgenkunde, Bd. 13, Heft 6, 1911.

plantar pictures nearly 5 mm. to the inner side of the internal border of the first cuneiform. But one meets with skeletons where the tuberosity projects 1–2 cm. to the inner side and at the same time embraces the shadow of the astragalus proximally by 1–2 cm. On finding this condition and taking a control view of the other side, one sees the same form or a portion of bone projecting about a centimetre medial and proximal and separated from the scaphoid by a transverse fissure. We have here to deal with an accessory piece of bone that is sometimes present, the *os tibiale externum*.[1] Occasionally it consists of two pieces. One should refrain from diagnosing a fracture too soon ; we cannot always certainly exclude it, but in a fracture crepitation and dislocation are nearly always present. The tibiale externum is rarely found the same size in both feet. Occasionally the condition is found only on one side ; on one side one sometimes meets a well-formed ossicle, on the other a rudimentary ossicle the size of a pea. One must not immediately diagnose a fracture in a painful foot, if the os tibiale on the sound and healthy foot is completely synostosed with the scaphoid (Fig. 77), not even when the line of separation is fissured. The occurrence of painful symptoms are especially favoured by the presence of one of these large supernumerary bones. According to Pfitzner a tibiale externum can be demonstrated in 10 per cent. of all people. (According to Bardeleben it arises in the human embryo in the second month as an independent cartilage and in very many mammals it occurs as a constant and complete skeletal part.) In some cases Pfitzner found a partial synostosis of the os tibiale externum with the scaphoid. There probably occurs later a complete synostosis of the os tibiale laid down in youth with the scaphoid. But in these cases the tuberosity of the scaphoid shows an elongation inwards and backwards, the scaphoid appearing to embrace the head of the astragalus more to the inside.[2] While therefore the tuberosity of the scaphoid projects normally in plantar pictures scarcely half a centimetre to the inner side of the internal edge of the first cuneiform, a synostosis of a tibiale with a scaphoid permits of the tuberosity projecting 1 cm. medially and backwards around the head of the astragalus.[3] Fig. 78 shows a number of normal findings of scaphoid and tibiale externum bones. Fig. 79 shows the bone in profile view.

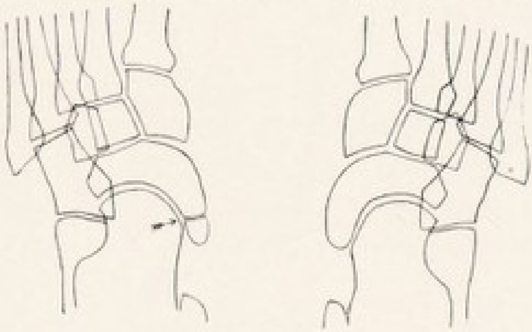


Fig. 77.

To confuse *a tibiale externum with a compact-island* in the astragalus

[1] Peltesohn : Klin. Wchnschr., 1922, p. 783.—St. Simon, Vienna : Das schmerzhafte Os tibiale externum. D. Ztschr. f. Chir., 191, 1/2, p. 127.—M. Lupo, Turin : Contributo allo studio delle ossa sopranumerarie del tarso. La Chir. degli organi di movimento, May, 1920.

[2] As in Fig. 77, right.

[3] Günther : quoted in note 1, p. 121, of this book. See further, Delherm and Laquerrière : L'os tibiale externum. Soc. de Rad. méd., 1914, p. 115.

in profile views of the foot would only be possible, if one were to make the technical mistake of omitting to take also a plantar (or a dorsal) photograph of the foot.

A broad gaping *joint-fissure* on the dorsum between scaphoid and astragalus is a sign of flat foot. On placing the weight on the foot the fissure becomes narrower.[1]

At the dorsal side of the articular fissure between scaphoid and astragalus a small piece of bone about the size of a lentil or pea, which may be present upon both sides, has been observed altogether about eight to ten times.[2] It is called the "dorsal astragalo-scaphoid ossicle." The anatomists might not have seen it, had not in one case an articular facet for such an ossicle been found in the scaphoid.

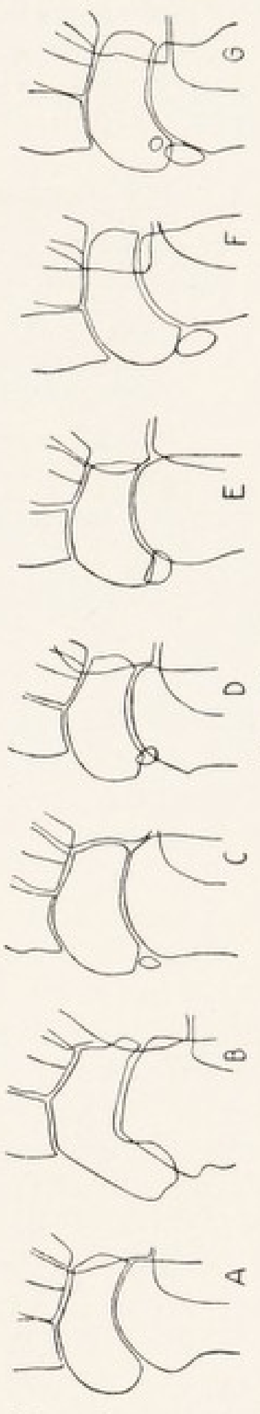


Fig. 78.

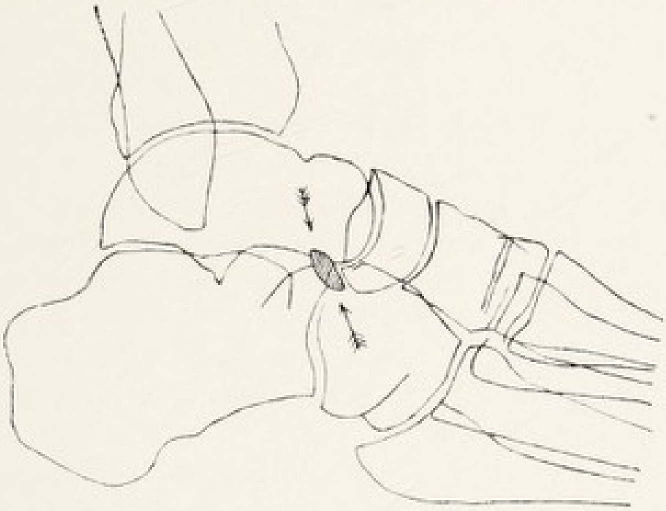


Fig. 79.

In the lateral third of the scaphoid *compact-islands* have been observed; see "General," p. 3.

Astragalus

At the dorsal distal articular end there occur among civilised adults the most manifold *swellings ridges, ledges*, and *processes* in profile pictures; all these are more or less pathological (for normally the free dorsum of the astragalus forms a slightly concave line), and are caused by pathological forms of the whole arch of the foot being occasionally the cause of local symptoms. There is also sometimes a smaller process situated in the middle of the

[1] For the form of the tarsal bones in flat-foot, see P. Ewald: Über den Knickund den Plattfuss. Zeitschr. f. orthopäd. Chirurgie, 24. Bd., 1909.

[2] H. Pirie: Arch. Rad. and Electrology, p. 93, 1919.—Thurstan Holland: On rarer ossifications seen during Röntgen-ray examinations. Journ. of Anatomy, 1921.

dorsum colli, without occasioning its owner any trouble; it is mostly asosciated with a process of the calcaneus.

The inferior part of the astragalus looking towards the calcaneus rarely occasions diagnostic difficulties. There is here a regular complicated confusion of shadows through the shadows of the lateral process of the astragalus, the articular surfaces of both bones and of the sustentaculum tali meeting that of the plantar part of the head of the astragalus. But in every negative that has not been spoiled by movement the details can be seen so well that it is only rarely that a mistake can be made. Moreover, special injuries are not common here.

On the dorsal side towards the scaphoid a ridge, process, or such-like can be simulated by the longitudinal axis of the astragalus occupying a more horizontal position in injuries of the bones of the foot, so that *the head of the astragalus* projects several millimetres up to 1 cm. beyond the scaphoid. On placing the weight on the foot this "stair" usually disappears. The appearance is occasionally found without previous injury to the bones of the foot.[1]

Infractions of the astragalus appear to be rare, *fractures* in the neck are frequent, usually traversing the whole neck through. *Compression fractures* are rarer and more difficult to determine for two reasons: first, because the level of the body of the astragalus varies within considerable limits in different individuals; second, because only one-half of the astragalus can be viewed in dorsal negatives. Thus the astragalus with a compression fracture in profile may appear almost like a normal low astragalus. From this dilemma the best way to rescue the diagnostician is by a control photograph of the other foot.

Further, in the case shown in Fig. 80 we are dealing with a fracture which can very easily be overlooked by the inexperienced. But on close inspection one sees a third line near the two customary upper limiting lines of the saddle-surface, somewhat behind them and parallel with them; this is due to a fragment that has become detached from the upper surface and slid down about 1 cm. (Similar views with three nearly parallel contours can be found in profile radiograms of the knee, when a femoral condyle breaks off level and becomes somewhat displaced.) It is scarcely necessary to explain how the third line is produced.

In the spongiosa of the head of the talus *a compact-island* may occur, it is not important. Confusion of this with an os tibiale externum is possible in photographs in which the inner border of the foot was resting on the photographic plate. Usually, however, the compact-island is higher in position.[2] Generally speaking, in the astragalus compact-islands occur relatively frequently, principally in the distal two-thirds of the bone; see "General," p. 3.

The ankle-joint surface of the astragalus is called the *trochlea*. Its

[1] Els: Über eine Abrissfractur des Tibialis anticus-Ansatzes. D. Zeitschr. f. Chirurgie, Bd. 106, 1910.

[2] Heinrich Fischer, *l.c.* (Fortschritte, Bd. 19, 1913.)

two marginal edges intersect each other more or less in lateral and medial pictures. Where they are not superposed the unshadowed margin is often so translucent that one might believe it to be tuberculous, whereas the appearance is quite a normal one.

The peculiar shadow in the astragalus as shown in Fig. 81 must be regarded as an extremely rare finding, the meaning of which is not yet clear.[1] Seeing the condition is present on both sides, it may be considered an abnormality and not an injury, etc. Above the head of the astragalus a piece of bone the size of a bean has been described in the literature in one case in which a fracture detachment of the insertion of the tibialis anticus was present. The particular piece of bone had therefore been detached from the first cuneiform, as could clearly be seen in the plantar photograph. The author is aware of two cases that bear only a distant resemblance, and are found only on one side. In these cases the free piece of bone was found only on one side and was nearer to the antero-inferior edge of the tibia, from which it appeared to have broken off.

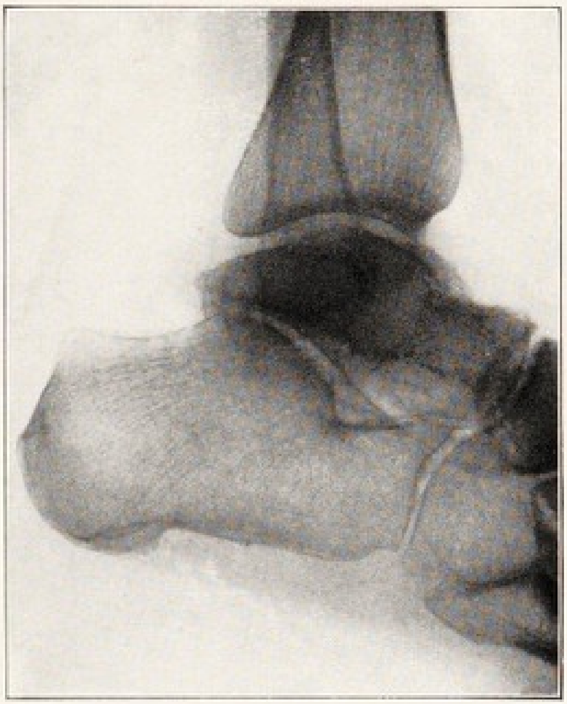


FIG. 80.

Towards the posterior aspect the shadow of the astragalus forms both in lateral and medial profile pictures either a simple termination, or there projects backwards a sharp or rounded long process, the *posterior process of the astragalus* (see Fig. 82). This process appears to break off easily in people over forty years, without becoming dislocated. Photograph the healthy side for a comparison. Behind the posterior process of the astragalus and in immediate opposition to it an inconstant articular particle is occasionally seen—*the os trigonum.* It has a circular or oval form, occasionally it has sharp corners ; it is present almost always on the two sides. (As Bardeleben has shown, it is already present in embryo in the second month as an independent piece of cartilage.) Not uncommonly its diameter in the adult measures 10 to 15 mm. In consequence of the circumstance that the posterior process of the astragalus alters greatly in size and shape and that the os trigonum, if present, almost touches it, confusions have arisen röntgenologically. In the first röntgenograms of the foot in which the os trigonum appeared, it was believed to be a fractured piece from the calcaneus or talus, until anatomists drew attention to the fact that it was an inconstant accessory piece of bone just like the os trigonum

[1] Report and illustrations sent to the author by Dr. Glogau of Hanover.

discovered and described by Rosenmüller in 1804. Once that was known every broken-off posterior process of the astragalus was taken for an os trigonum, and the presence of a fracture was always denied even when the process was typically fractured and the Röntgen picture of the healthy foot showed a normal process. The following procedure is to be recommended in estimating a case: if one finds behind the astragalus a shadow in both feet, in size about 1 cm. in diameter, round, oval, or three-cornered, that is then due to an os trigonum. In addition one almost always sees the posterior process very clearly. If the Röntgen picture shows a smaller triangular shadow, separated by a narrow indistinct interspace from the rounded off posterior process, we have before us a fractured posterior process,

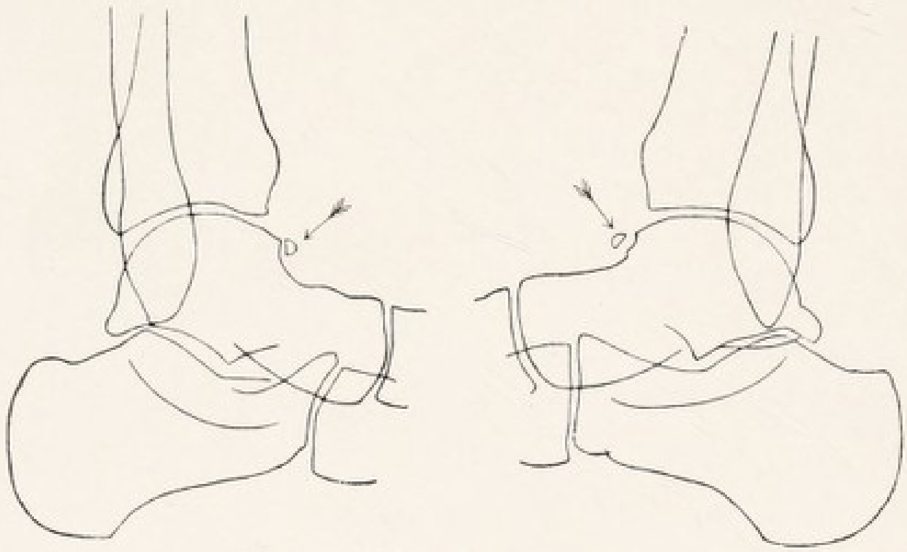


FIG. 81.

especially if the healthy foot exhibits a process without line of fracture. This fracture of the process is really not at all rare in people in adult life who undertake heavy work, forced marches, mountain tours and climbing, and it is not to be wondered at if after a spring upon both feet both processes are found fractured. Painful symptoms are naturally felt after such a break for several weeks, but not every patient consults the doctor on that account, and not every practising doctor sends the patient at once to the röntgenologist (see also Fig. 83, A, C, D).[1] Various forms of the posterior process and of the os trigonum may be reckoned as normal (see Fig. 82, a–m). These opinions of the author have not obtained recent acceptance from the anatomical side.[2] The structure in question might naturally be laid down as a large piece of precartilage and cartilage, but on account of a

[1] See a few pages earlier the work of Lilienfeld. Further: Lilienfeld: Über die sogennanten Tarsalia und ihre Beziehungen zu den Fracturen im Röntgenbild. Zeitschr. f. orthopäd. Chirurgie, 18. Bd.—Siskind Sochor: Os trigonum tali. J. D. Königsberg, 1890. —Baastrup: Act. Rad. II. 2, p. 166.—Harttung: Doppelseitiges Os trigonum. D. Ztschr. f. Chir., 184, 5/6, p. 382.

[2] A. Hasselwander: Die Bedeutung des Röntgenbildes für die Anatomie. Ergebn. der Anatomie u. Entwicklungsgesch, Bd. 23, 1921.

smaller intensity of subdivision of its elements remains considerably behind the astragalus in size, so that it is assimilated by the latter, and finally occupies the position of the posterior lateral process of the astragalus. In a later state of cartilage it is never found by itself, but only in the form of the ossified body. For about the eighth to the tenth years an accessory ossification centre may appear in the posterior process of the astragalus in the form of an epiphysial or pseudo-epiphysial nucleus. A part of these ossification anlages might fail to synostose with the astragalus and for the accessorium os trigonum (Pfitzner). The above anatomist carried

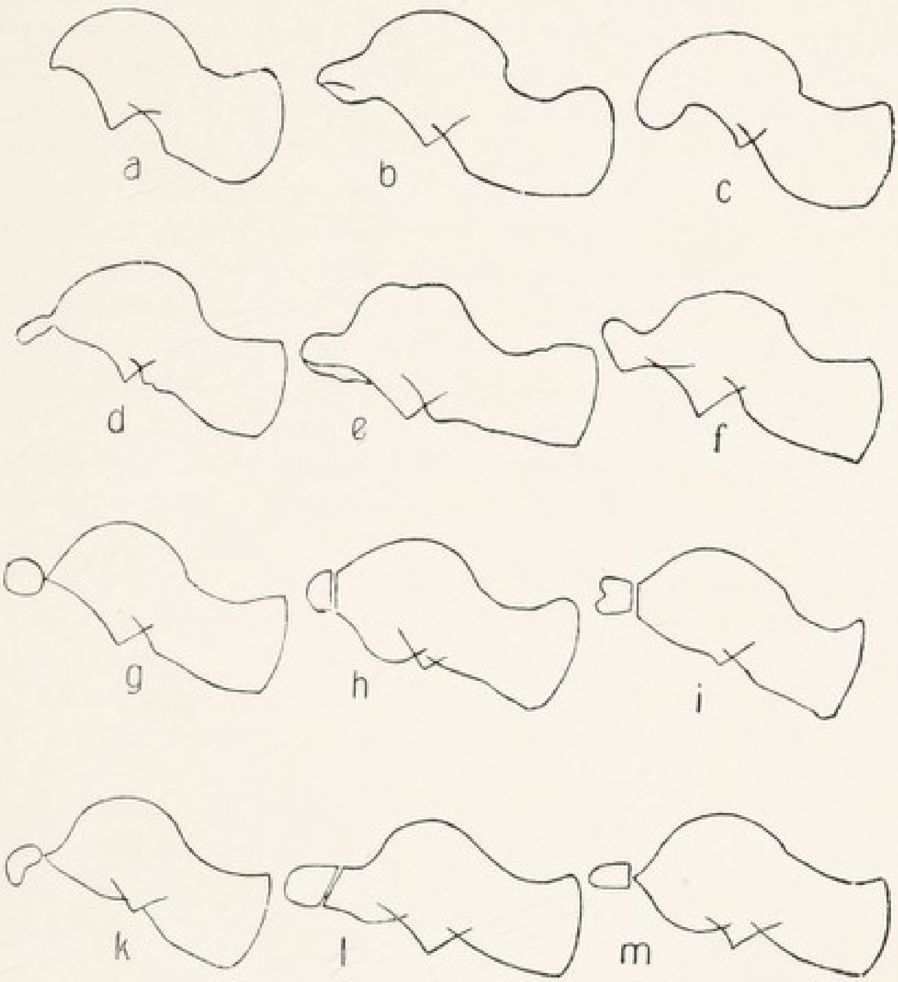


Fig. 82.

out a certain experiment in a prepared subject, the os trigonum being separated from its synchondrotic union with its larger neighbour, which led to the idea that such separations of the os trigonum might occur also in the living subject. He then found in his service in the war among 700 röntgenograms of the foot a remarkable frequency of the os trigonum (11·4 per cent.). 37·5 per cent. of these again with an isolated ossicle in place of the posterior process originated from so-called distortion falls. From this it can be concluded at once that all these feet, which have preserved a synchondrotically connected independent piece of bone (os trigonum) in the posterior process from the time of ossification, are obviously more easily injured, more easily suffer a "distortion." More than a third of these "wrenches," etc., showed a separated trigonum. This accessory element remains hidden in every posterior process, and also in every detachment of the same. Nevertheless, the possibility is admitted that even solutions of continuity go through the bone—that is, actual fractures may occur—cases to which later an arthritis deformans traumatica is added (Pfitzner's "Metamorphoses").

Naturally an *os trigonum* can be present and the *posterior process of the astragalus* be fractured in addition, and this should not be overlooked.

It appears quite certain, if one goes through thousands of röntgenograms of the foot, that in all considerable *deformities* of the metatarsus and tarsus, as we see so extremely pronounced, *e.g.* in flat foot, and above all in arthritis deformans, the form of the posterior process also undergoes changes (it becomes larger and more irregularly edged). Moreover, in regard to the size of the os trigonum there does not appear to be any relationship between the posterior process and the trigonum. The frequency of the trigonum amounts to about 8 per cent. An increase of the percentage with increasing years is undeniable. The trigonum comes into view most clearly when the outer border of the foot rests on the plate.

It hardly requires to be mentioned that the larger or smaller *spindle-like dense shadow* in front in the head of the astragalus in profile exposures is produced by the intersection with the shadow of the scaphoid, and is therefore a normal appearance.

The trigonum, according to anatomists, can form a joint with the calcaneus, indeed it forms that more frequently than it does with the astragalus.

Even in incorrect positioning of the tube it should not be easy to mistake the os trigonum for *a compact-island* in the distal end of the tibia.

A strong *spur of the astragalus* on the dorsum opposite a similar spur in the scaphoid (see Fig. 76), and an articular fissure widely open towards the dorsum (photographed in a foot without any weight on it), appears in extremer degrees of flat foot and altered function years after fractures of the bones of the foot.

Talo-navicular synostoses occur. They are ascribed to a congenital disturbance of development.[1]

Calcaneus

The appearance of *a bony nucleus* in the body of the calcaneus is given by most anatomists as between the fourth and eighth fœtal month. It has recently been found[2] that, although it is not constant, yet in the

[1] H. Blencke: Ein seltener Fall von Synostosis talo-navicularis. Ztschr. f. orth. Chir., 47. Bd.

[2] Hasselwander: Untersuchungen über die Ossificationen des menschlichen Fussskeletts. Inaug.-Diss. München, 1903. (Publishers J. Nägele, Stuttgart.)

majority of cases, the body of the calcaneus ossifies from two centres, of which the first nucleus appears in the fourth to the fifth fœtal month, and on account of its position and small size can easily be missed in an anatomical examination. It is placed laterally, and is said to correspond to the preformation of what afterwards becomes the trochlear process. Independently of this there appears a second osseous nucleus in the seventh fœtal month which unites with the first, but even in the earliest months after birth the first can still be found as an independent piece of bone (calcaneus accessorius of Pfitzner ?). The apophysis, the tuber calcanei, receives its nuclei in six to ten years. *In the child's calcaneus* appearances occur which can easily be misinterpreted. For while all the other contours of the growing calcaneus are seen with sharp edges, the *posterior contour* (in profile pictures) appears irregular, wavy, indented, and ridged ; that is, quite normal. Further, the apophysis is situated at this point ; the fusion of this apophysis with the body of the calcaneus takes place on the average towards the seventeenth year (fifteen to twenty-two). This *calcaneus apophysis* ossifies in two portions, *i.e.* from *two points* (even three have been observed), which Kirchner was the first to observe. Seeing fractures of the apophysis arising from one ossification nucleus also occur, great care is to be exercised in diagnosis. Here again there comes a circumstance to our aid, namely, that the appearance of two points of ossification is usually (always ?) present on both sides.[1]

An instance of a calcaneus in which the normal ossification process was interrupted has also been described as ossifying with a structureless condensation of the apophysis.[2] The cause is thought to be an interruption of the internal secretion together with trauma. Period : appearance of the nucleus of the calcaneal apophysis. Sudden origin in relation to an unusual bodily strain. After two to three weeks of rest, rapid disappearance of the clinical local symptoms. Röntgen-ray findings : in the posterior process of the calcaneus, opposite the apophysis of the calcaneus, there is a cloudy, not well-defined transparency. The calcaneal apophysis, even in its first appearance, is often more definitely segmented than on the healthy side, remains long in the cartilaginous stage, ossifies irregularly, and shows some parts rich in lime, others poor in lime. The clinical findings clear up quickly, but the changes shown up by the Röntgen rays remain much longer. A typical fact is that only this one bone is affected. The clinical symptoms are pain in the heel in walking and standing, limping and lifting the heel from the weight of the body, local well-defined tenderness on pressure behind the external malleolus, slight swelling of the soft tissues, occasionally some reddening and slight atrophy of the muscles of the affected leg, with some elevation of temperature.

[1] See further, Bircher : Anomalien des Calcaneus. Schweiz. med. Wchnschr., 1923, p. 251.

[2] Vuillet and Schinz : Lit. s. bei Schinz. Ztrlbl. f. Chir., 1922, No. 48.—Blencke : Ztrlbl. f. Chir., 1923, p. 308.—E. Hain : Die Ossificationsstörungen des Calcaneus als eigenes Krankheitsbild. Ztrlbl. f. Chir., 1923, No. 18.—F. Scheid : Über die sogen. Apophysitis calcanei. M. M. W., 1925, No. 42.

Further, the *contour of the ossified apophysis* towards the yet cartilaginous lines is always irregularly ridged, indented, and wavy in the normal state.

At the *trochlear process* of the calcaneus (therefore on the lateral side of that bone) an *epiphysial formation* is sometimes seen. The process may be absent in two-thirds of the cases, but, on the other hand, it may be so prominent as to appear in some instances like an exostosis. An epiphysis arises when of the two nuclei from which the calcaneus ossifies the lateral one does not unite with the principal nucleus until puberty—instead of in six months. While Pfitzner did not see any distinct epiphysis, but only " extensive deposits," röntgenologists found [1] on one occasion both in the right and left calcaneus a trochlear process as large as a finger-tip, which on one side showed the epiphysial line quite distinctly, and a further case with an accompanying os vesalianum. The tendency to form an independent ossification nucleus might be analogous to the sustentaculum tali, which also forms a kind of epiphysis in the form of an os sustentaculum of Pfitzner.

A *calcaneus with typical severe fracture* may be mistaken in Röntgen picture for a normal calcaneus by the inexpert, for the beginner usually examines the calcaneus only from the frontal direction, and the peculiarity of the typical fracture brings it about that in this projection the bony changes are not very apparent nor easy to recognise. The line of fracture, when one regards the calcaneus from behind, runs as a rule from above and external to below and internal plantarwards ; and that becomes evident in an otherwise little-used projection (Fig. 84), namely, by the patient slightly flexing the knee and standing on the plate, the tube being set behind the calf, and the calcaneus photographed in this way ; or when the patient is in the horizontal position the focus of the tube is set distal to the sole. But it is important that even the beginner should know the slight signs that a calcaneus fracture exhibits in a profile negative. First of all, there is a characteristic interruption in the spongiosa ; the whole interruption runs somewhat in the form of a quarter of a circle from above and behind (most posterior part of the ankle-joint) to the middle of the plantar contour (see Fig. 83, A ⇓). On this plantar side we see a light irregular extra dense spongiosa architecture ; and in addition there is almost always visible a double contour of the anterior and lower calcaneal border (see Fig. 83, A ⇑⇑). If the expert finds these signs—usually the posterior process of the astragalus is broken off at the same time (Fig. 83, A, C, D)—the diagnosis of a typical calcaneus fracture is already certain, if the negative taken with the tube set behind the calf confirms the nature of the break.

For *other kinds of calcaneus fractures* which are relatively frequent, typical illustrations are shown in Fig. 83, B, C, D.

Detachments of the sustentaculum tali are difficult to recognise both in profile negatives and in the above-described posterior vertical exposures.

[1] E. Friedl (and Schinz): Epiphysenbildung am Proc. trochl. D. Ztschr. f. Chir., 188, Bd. 1/2, 1924.—O. Oertel: Beitr. z. Anatomie u. vergleichenden Anat. des Proc. trochl. als Grundlage für seine Pathologie. Virchow's Archiv, Bd. 247.

To recognise them when suspected it is recommended :[1] The patient being in the horizontal position the foot is dorsiflexed as far as possible. The plate is placed behind the lower leg. This permits of a valuable view into the interior of the sustentaculum tali which is not easy to see otherwise ; that enables us easily to demonstrate the sustentaculum tali itself or one associated with a fracture of the body.

One sometimes meets in profile photographs *a plantar corticalis* 4–5 mm. thick, that looks like a pathological condition (like a healed fracture or old

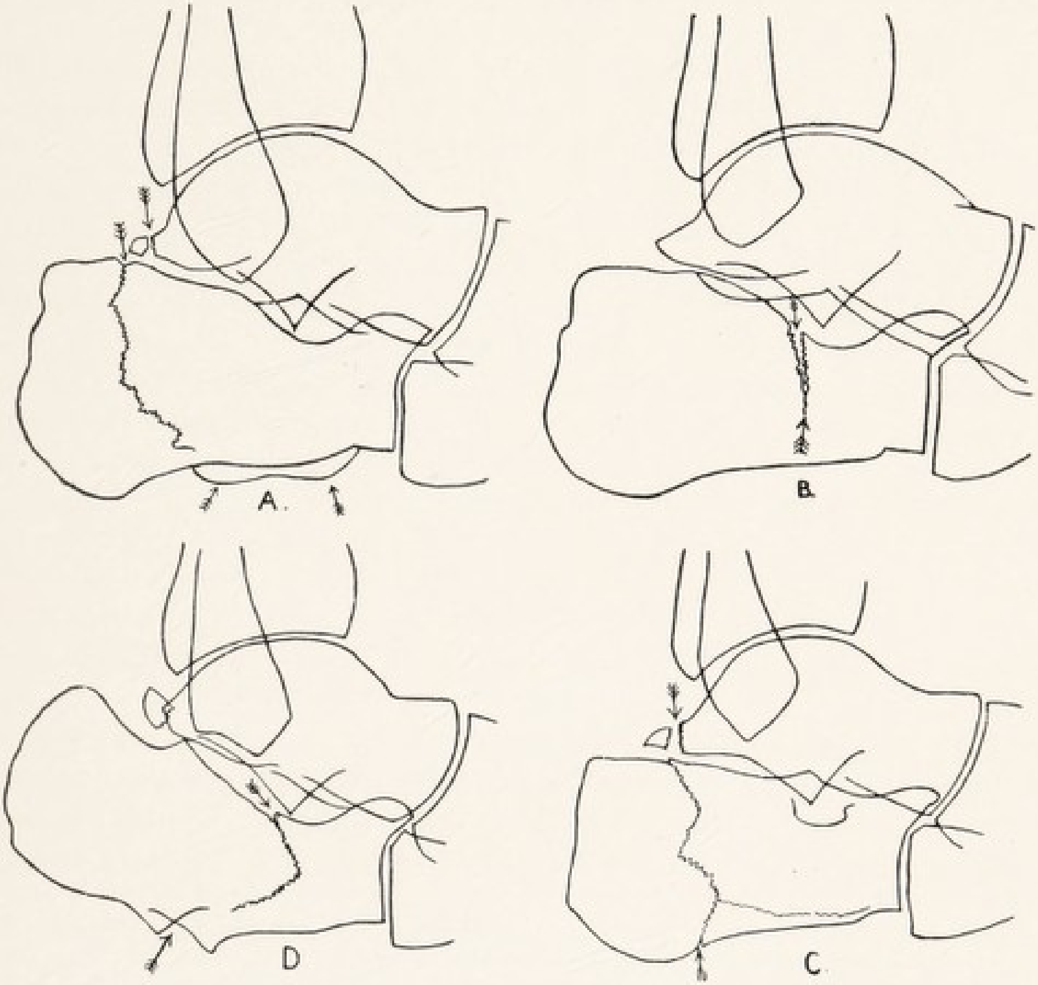


Fig. 83.

osteomyelitis) ; it is, however, quite normal and arises through the confluence of bony trabeculæ, which run from the posterior upper corner of the calcaneus to the middle and anterior half of the plantar contour.

The *posterior upper angle,* usually about 90° in profile pictures, is occasionally drawn out into a joint above ; this is not important.

The calcaneus of the adult is different from that of the child, and *its posterior contour* is normally sharply delimited ; nevertheless, it should not

[1] Baer, Zürich : Beiträge zur Lehre der Fersenbeinbrüche. Physikalisch-medizinische Monatsheft., 1905.—See further : H. R. Conn : Fractures of the Os calcis. Radiology, March, 1926.

be maintained that slight roughnesses causing deposits there are a necessary cause of trouble to the bearer. *Appositional ossifications* select points where powerful tendons are attached; at the calcaneus where the tendo-Achillis is inserted, and behind on the plantar surface where the short flexors of the toes are attached. If they are small and not well developed, say up to 3 mm. in length, we have no reason to regard them as pathological, for we know from other points that ossified tendinous insertions are met with at these points in a certain percentage of healthy people. But if these bony formations have taken on a greater development they cause pain and

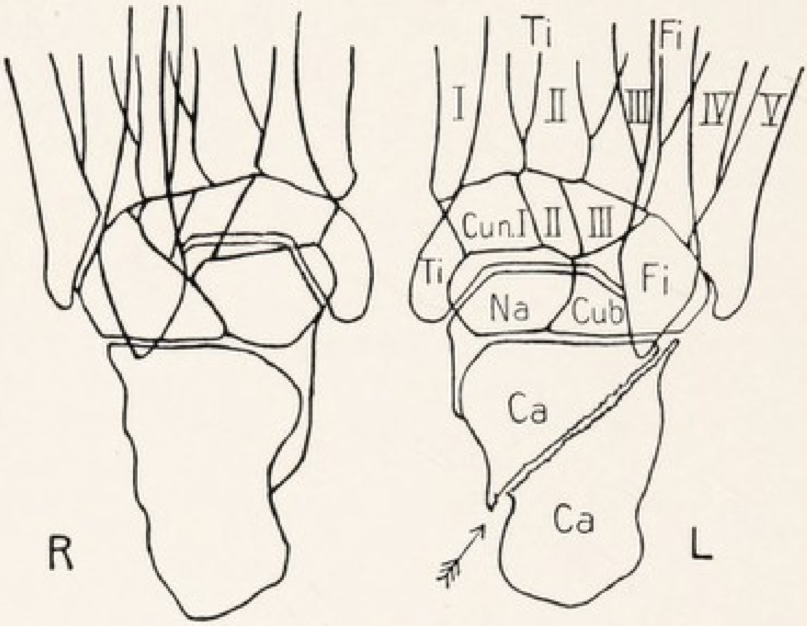


FIG. 84.

functional disturbances, and they must then be looked upon as certainly pathological. Particular attention has been given for some years to the plantar calcaneus spur which is frequent, and regarding the origin of which in spite of many studies there is no clear explanation.[1] *The calcaneus spur*

[1] Blencke: Bemerkungen über den Calcaneussporn. Zeitschr. f. orthopäd. Chir., 1908, Bd. 20.—Jacobsthal: Über Fersenschmerzen. Archiv. f. klin. Chir., 88. Bd., 1908.—Nobl: Über den Fersenschmerz der Blenorrhagiekranken. Zeitschrift für Heilkunde, 1903. Abt. Chirurgie, 24. Bd., p. 273.—Haglund: Über den sogenannten Calcaneussporn. Zeitschr. f. orthop. Chir., 1908, Bd. 19.—Durst: Über Achillodynie. (Reference Zentralbl. f. Chirurgie, 1902, p. 487.)—Kirchner: Zur Frage der juvenilen Fracturen der Tuberositas tibiæ, Tuber, navicul. und des Tub. calc. Archiv. f. klin. Chir., 1907, Bd. 84.—Haglund: Über Fractur des Epiphysenkerns des Calcaneus etc. Archiv f. klin. Chir., 1907, Bd. 82.—Hardiviller: L'ostéite apophysaire de la croissance. Paris, 1907.—Chrysospathis: Die Variationen einiger Skeletteile und die von ihnen ausgehenden Beschwerden. Zeitschr. f. orthop. Chir., Bd. 18.—Plettner: Über die Exostose des Fersenbeins. Jahresbericht d. Gesellsch. f. Natur- u. Heilkunde. Dresden, 1900.—Janowski: Zur Frage von der Calcaneodynie, verursacht durch Hypertrophie des Proc. tub. calcanei. Russkij Wratsch, 1907, No. 15 (see Zentralbl. f. Chir., 1907, p. 1159).—Bradford: Exostosis in the plant. portion of the os calcis. Amer. Journ. of orthop. surg., 1907.—Lehr: Über die plantare Exostose des Fersenbeins. Zeitschr. f. orthop. Chir., 1908, Bd. 19.—Klopfer: Ein Fall von operativ geheilter Calcaneodynie. Fortschritte-Röntgenstrahlen, Bd. 12, 1908.—Ebbinghaus: Ein Beitrag zur Kenntnis der traumat. Fussleiden. Zentralbl. f. Chir., 1906, No. 15.—Wiesinger: Über symptomatische Achillodynie. Deutsche Zeitschr. f. Chir., 1896, Bd. 43.

—it is found in the majority of cases at the internal process of the tuber calcanei—is an appearance which is not so troublesome as to compel the patient to consult the surgeon at once, while, on the other hand, the radiologist hardly ever diagnoses it in other conditions.[1] Very exceptionally one meets it as a pure accident, though in about nine-tenths of the cases complaints are made that point to this part of the calcaneus ; in the rest of the cases there is a complaint of pain above at the insertion of the tendo-Achillis or over the head of the astragalus, where osteophytes may be found In the pre-Röntgen period, on the ground of accidental experiences, it was supposed that the spur of the tendo-Achillis is a disease of the adjacent sac of the deep Achillis bursa.[2] The author was the first to call attention to the fact that exostoses of the calcaneus occur very frequently with associated arteriosclerosis.[3] This opinion was not contradicted, yet in the next years it was ascribed to all possible other causes (constitution expressing itself in osteoarthritis processes ; gonorrhœa ; gout ; tuberculosis ; variations of the skeleton ; originally extra bones, which are wont to occur in the years of development in organisms which for any causes are predisposed thereto ; etc.). More recently the author's opinion has appeared to gain more adherence from the observation of a great number of cases.[4] It should be remembered that arteriosclerosis might be present in a great part of the cases short of a diagnosis in the Röntgen negative, for arteriosclerosis is not always accompanied with calcifications of the vessel walls. Hence, if one finds the arteries calcified in the Röntgen picture in about three-fifths of the cases of calcareous exostosis, and then adds these cases to those where there is no calcifications of the vessels in a definite arteriosclerosis, we may reckon that in about four-fifths of all cases of calcareous exostosis arteriosclerosis is a feature.[5] We have not to understand by this that in an arteriosclerosis the calcaneus spur must come of itself ; no, a trauma is necessary thereto ; but in arteriosclerosis and other affections of the blood nutrition, a much smaller trauma is sufficient, a simple slip that in a healthy person remains without result. This accounts for the bilateral occurrence of the affection in the great majority of cases. After these explanations it is no wonder that we encounter the spur and ossification of the insertion of the tendo-Achillis in osteoarthritis deformans of the surrounding tissues, after severe gonorrhœas, in gout, and years after fractures of the bones of

p. 603.—Selka : Calcaneusexostosen. Fortschritte-Röntgenstrahlen, Bd. 13, 1909, p. 101.—Pantoli : Calcaneusexostose bein Gonorrhöe. Archivio di ortopedia, 1919, No. 3.—Chrysospathis : Calcaneussporn. Zeitschr. f. orthop. Chir., 23. Bd.—A short monography by E. Rumpf : Über den Calcaneussporn. I.-Diss. Berlin, May, 1916.

[1] It could thus happen that a surgeon with a great number of hospital patients in a large city has found such a spur in the Röntgen picture only twice or thrice within ten years and declared it to be a great rarity, while the author could produce several dozen of such pictures. That was about twenty-five years ago.

[2] Rössler : Zur Kenntnis der Achillodynie. Deutsche Zeitschr. f. Chirurgie, 1896, Bd. 42.

[3] Köhler : Lues-Arteriosklerose. Fortschritte, Bd. 6, 1903, footnote.

[4] See Blencke, *l.c.*, p. 132.

[5] K. Staunig now adopts an almost similar point of view : Über den fracturverdächtigen posttraumatischen arthritischen Anfall. Fortschritte, Bd. 35, p. 1254.

the leg and foot (only on one side). In these diseases we find considerable appositional deformity even in the plantar surface of the calcaneus, sometimes more than one spur, also at the insertion of the tendo-Achillis, further at the astragalus and at the scaphoid.[1]

If all these conditions can be grouped under the one category, those cases are an exception in which in young people between the fifteenth and twentieth year the calcaneus spur was demonstrated on both sides. Here the findings appear to be really purely accidental and do not represent a pathological condition, rather only abnormalities, in which the ossification of the cartilage between the body of the calcaneus and the apophysis has overshot itself. With the first light trauma there is complaint of pain. The last word has not yet been spoken on the subject, and further studies on it are desirable.

A recent work[2] distinguishes between two different groups: (1) The spur is already laid down in the developmental period. Following upon trauma or infection there are produced bursitis, periostitis, ostitis; the Röntgen picture exhibits a cloudy etched shadow. (2) Patients of over forty years. The calcaneus sinks down into the atrophying soft tissues, and the process goes on to bursitis, periostitis, formation of exostoses, and ossifications of the soft parts. The exostoses are markedly different in the spongiosa and the compacta.

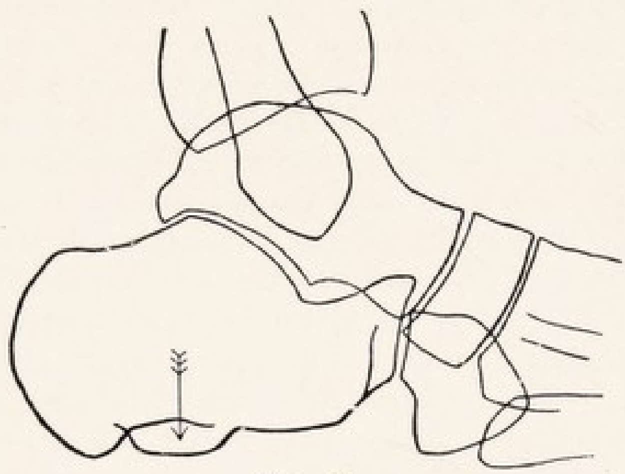


FIG. 85.

Regarding treatment one should warn against surgical interference in these cases for—as Röntgen pictures show[3]—a few months after operation a new spur usually appears (which is quite understandable after the above explanations). The best method is relief of the spur from pressure by well-fitting boots both in front and behind it.

It should also be mentioned that the spur is usually situated on the internal tuberosity.

Another exostosis is met with more rarely at the calcaneus. It is illustrated in Fig. 85, and has been recorded only once in the literature;[4] the author has only two cases of the sort.

[1] It should be specially mentioned that surgical works are not authoritative on the statistics of the causes of calcaneus spur; as mentioned, these typical cases are seldom sent to the surgeon, but rather the difficult and nearly always complicated cases, which are suffering considerable trouble.

[2] Fr. Kirschner: Zur Frage des Calcaneussporns. Arch. f. orthop. u. Unf.-Chir., 23, 1, p. 125.

[3] See Janowsky, *l.c.*, note 1, p. 132.

[4] Gulat-Wellenburg: Calcaneusexostose. I. D. Kiel, 1903.

If the *shadow of the lateral process* of the tuberosity is absent, that arises from pronation of the calcaneus (a sign of flat foot).

The half of all isolated *tuberculoses* of the bones of the foot occur in the calcaneus. While in other bones (*e.g.* end of the fibula) the process has to be pretty far advanced before it is diagnosed by the Röntgen rays, the conditions for Röntgen diagnosis in the calcaneus are more favourable. In a suspected condition it is usual to look to the middle of the bone, the area of the tuber and the anterior process. Larger foci are easy to recognise; it is to be remembered, however, that in the posterior third enchondromata occur, which give similar translucent appearances.

In the calcaneus, both in its anterior and posterior half but not in the middle, *compact-islands* not infrequently occur, p. 3.

Regarding the variety *calcaneus secondarius*, see above.

A true finger formed behind the calcaneus—an extremely rare occurrence—has been reported.[1] It does not belong to the province of this work, but is mentioned because such a formation is occasionally indicated to a very slight extent, and might give rise to mistakes in diagnosis and subsequent inquiry.

A small sugar-loaf shadow (9 mm. long and 6 mm. broad), at the site where the epiphysial nucleus was originally observed in a man of thirty years, and designated an os tuberis calcanei by the finder.[2] It was a chance finding after trauma, and is illustrated in his paper.

Tarsomegaly: enlargement of the child's calcaneus and neighbouring bones.[3]

Soft Tissues at the Ankle-Joint

In front of the ankle-joint in the midst of the tendons there is present on the Röntgen plate in about half to a third of all cases a *round shadow of pea size*, somewhat thicker than the tendon-shadow. This debatable shadow is not particularly noticeable, and usually receives attention only when there are complaints exactly at this point of the foot. This is not pathological, but is the connecting branch from the anterior tibial artery to the perforating branch of the peroneal artery, or the bayonet-shaped anterior articular artery (or vein ?). That a normal vessel contrary to the usual experience appears at all in the shadows of the soft tissues is due simply to the fact that it runs for centimetres exactly in the path of the rays. It is due also to the surrounding layers of fat. In arteriosclerosis the point appears denser. If the artery does not run exactly in the path of the rays, then there is naturally no small circle, but a more or less extended oval or irregular shadow.

Behind the ankle-joint there stands out from the rest of the soft tissues

[1] D. G. Rochlin, Leningrad: Zum Problem der Hyperdaktylie. Ztschr. f. Anatomie u. Entwickelungsgeschichte, 78. Bd., Heft 1/2.

[2] A. Heimerzheim: Über einen seltsamen Knochenbefund am Calcaneus. D. Ztschr. f. Chir., 187. Bd., 1924.

[3] Mouchet and Belot: J. de Rad., 1926, p. 289.

a translucent triangle about 10–20 cm. high, 2–4 cm. broad, with the upper calcaneus contour as basis,=normal, corresponding to the fatty cushion between the tendo-Achillis and the flexors of the toes.

In every profile negative of an adult we look above the calcaneus and behind the bones of the leg for indications (*calcifications*) *of the posterior tibial artery.* According to the author's experience, if arterial calcification is present in a patient, the whole process can be best demonstrated in the posterior tibial artery, and less so in the radial artery. But one sometimes finds upon the calcaneus dense strand-like shadows (but without any double contour) which are apparently not calcified vessels; these are dense connective tissue septa, produced as is well known, as *the crinkled soft tissues* behind and under the calcaneus are produced, by connective tissue septa in the subcutis.

LOWER LEG

Distal Ends of the Bones

General

The *osseous nucleus* of the distal fibular epiphysis is visible at $1\frac{1}{4}$–$1\frac{1}{2}$ years, and unites with the diaphysis between the sixteenth and twenty-second years of life. The osseus nucleus of the distal tibial epiphysis

Fig. 86.

appears about the same time as that of the fibula or earlier between 1 and $1\frac{1}{2}$ years, and unites at the same time as the fibular epiphysis. (The first ossification point of the fibular- and tibial-diaphysis appears between the fortieth to the fiftieth day of fœtal life.)

The *cartilaginous lines* have normally a fairly irregular appearance, especially that of the tibia. The bony contours enclosing them are indented, fringed, and arranged in fork-like fashion both in dorsal and profile view. In examining for rhachitis one ought also to röntgenograph the radius and ulna, which usually exhibit a fairly sharp straight band of cartilage (see the same).

Fractures in the epiphysial lines, which are mostly very rare, can be diagnosed only when the epiphysis is dislocated and rotated about its axis.

For general periosteal deposits at the diaphyses of the long bones, *generalised periostitis hyperplastica,* see pp. 4 and 5.

Fibula

For the appearance of the *epiphysial nucleus,* see above.

A typical *fracture of the end of the fibula* in adults can escape the examiner both in dorsal pictures and in profile views when the shadow of the fibula is completely in the shadow of the tibia. This fracture or almost complete infraction begins about 5 cm. behind the ankle-joint, and runs downwards and forwards. It cannot stay hidden in profile negatives if it is possible to project the shadow of the fibula beside that of the tibia (see Fig. 86). The fibula, as is well known, is normally situated somewhat more dorsally than the tibia. Therefore in lateral profile negatives of the lower leg the tube should be set more dorsally (in medial profile photographs more ventrally) in order to represent the fibula as far as possible free from shadow.

The *articular surface of the fibula* opposed to tibia and astragalus forms usually a double contour (anterior and posterior edge). The osseous laminæ passing from the corticalis into the spongiosa shows a more or less spiral-like shadow.

The end of the fibula is frequently the seat of commencing *tuberculosis.* Unfortunately it is difficult to recognise this in Röntgen view when it starts at this part of the bone; nevertheless, in well-marked atrophy of bone and apparent periostitis ossificans we may with reason suspect it. The focus is usually at the outer side of the malleolus, purely epiphysial, or overstepping the epiphysial line. Well-marked round or spindle-shaped translucent areas at the same part are more suggestive of sarcoma and enchondroma than of tuberculosis, but they are rare.

In the spongiosa of the external malleolus *a compact-island* may occur; see "General," p. 3.

A few weeks after accidents of the lower leg and foot one finds in dorsal pictures below the end of the fibula, partly separate from it, partly connected with it, more or less thick shadows, =*post-traumatic ossifications* of the calcaneo-fibular ligament (or of the peronei tendons ?).

We sometimes see at the end of the fibula a shadow picture showing from below upwards a deep fissure, =normal, due to projection.

Tibia

For the appearance of the epiphysial nucleus, see above : " Distal end of the bones. General."

One observer found an independent osseus nucleus at the tip of the internal malleolus twenty-one times out of 150 children, and twice as often in boys as in girls, and most frequently between the years of eight and nine. The size of the nucleus varied from the head of a needle up to the size of a lentil.[1]

The outermost end of the bone—it is situate more frontal—frequently fractures off (sometimes in common with the whole malleolus fibulæ). It is usually displaced 2–4 mm., the fracture is readily seen, and can be rendered difficult of diagnosis only by a faulty setting of the tube. In profile pictures it is difficult to see.

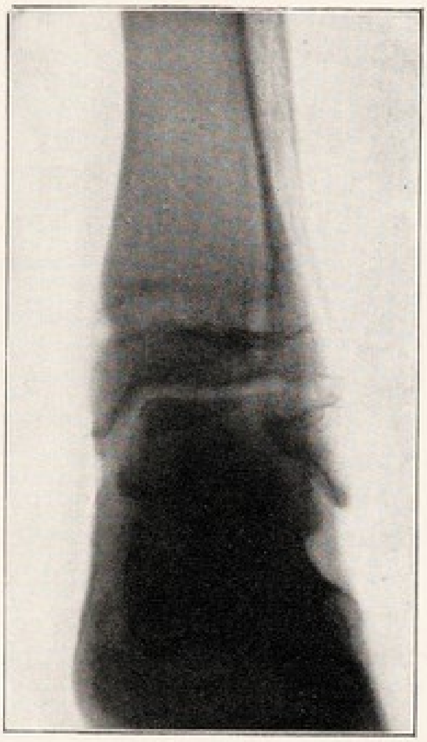


Fig. 87.

Pictures like Fig. 87 in the growing period with a broad transparent zone in the region of the epiphysial line might attract the attention of the beginner and be mistaken by him for a fracture. The condition is really one of rhachitis tarda. Photograph other long bones and compare.

Even the expert may experience difficulty in the Röntgen diagnosis of *suspected fractures* in the following quite normal conditions : The most distal part of the tibial malleolus has a much smaller sagittal diameter than its proximal part ; consequently, in *dorsal pictures* the paler shadow of the former contrasts with the strong shadow of the upper portion ; further, when the inner border of the foot in the photograph is not quite vertical to the table the contour of the most distal end does not pass evenly into that of the upper part, but in a bayonet-form line, it appears somewhat pressed inwards towards the ankle-joint. Naturally it is not possible to see in this a gaping fracture-fissure, for the conditions are really not abnormal.

Similarly *in profile pictures* for identical reasons a like mistake may be made when the conditions are quite normal, as illustrated in Fig. 88. One might believe that a fracture is present.

As in the fibula various shadows are met with in dorsal pictures below the end of the tibia several weeks after injuries, close beside or separate from the malleolus, which are due to *ossifications* of the torn calcaneo-tibial

[1] Hoed, Groningen : Brit. J. of Rad., February, 1925.—Fairbank : A separate centre of ossification for the tip of the internal malleolus Arch. of Rad. and Electr., 1923, Vol. 27, p. 238.

(and talo-tibial) ligaments (or from arteriosclerosis of the posterior tibial artery). Appearing without any previous trauma there is seen at times a piece of bone about 1 cm. long and 8 mm. broad, 2–3 mm. distant from the malleolus, and bilateral. Anatomical reports are lacking on this, and it has been considered an independent sesamoid of the calcaneo-tibial ligament and entitled the " *os subtibiale*." [1]

In the dorsal pictures of adults one sometimes meets with *an arched shadow* about half the size of a bean at the fibular contour of the tibia about 4–6 cm. above the fissure of the ankle-joint. This is devoid of pathological significance.

Tuberculosis is not such a frequent occurrence as at the end of the

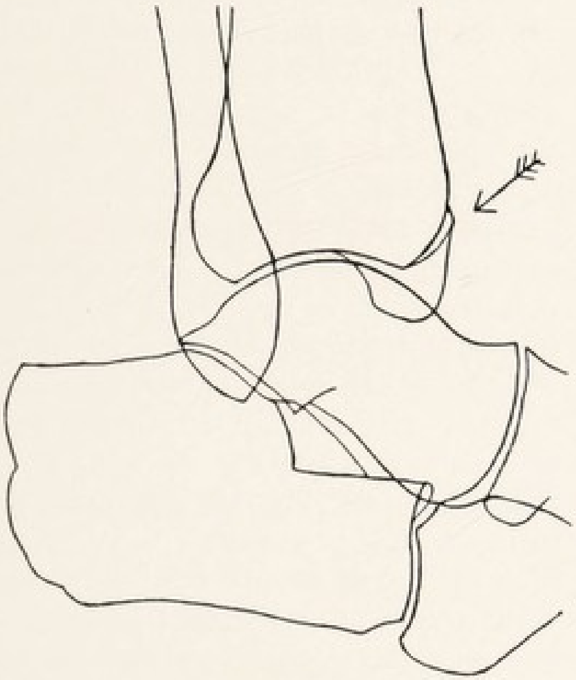


Fig. 88.

Fig. 89.

fibula, it is confined more to the metaphysis. Acute infectious osteomyelitis has frequently been observed here by the author.

In dorsal pictures there sometimes runs from above downwards through the distal end of the tibia, especially of the malleolus, a long shadow, several centimetres broad, limited towards the outside almost by a straight line (see Fig. 90). These are normal conditions, produced by the shadow of the tendo-Achillis.

When the end of the tibia is strikingly different from the normal one should inquire whether severe *rhachitis* was present in childhood. One would have also to consider in addition the occurrence of multiple cartilaginous exostoses (see under " Proximal end of tibia ").

[1] Bircher: Neue Fälle von Varietäten der Handwurzel und des Fussgelenks. Fortschritte, Bd. 26, 1918.

Findings as in Fig. 89 appear on first view as scale-like fractures behind the distal end of the tibia. Fractures do undoubtedly occur at this point, and have been described,[1] yet everything does not yet appear to be explained. The author has pictures in which the particular shadow had practically the same size and situation, but in its finer details bore little resemblance to a fractured piece of bone; the shadow is not so dense as the shadow of the corticalis, there is no defect apparent on the tibial surface opposite, and the shadow is also not sharp enough at its dorsal edge, and at its ventral edge does not appear indented and broken. The shadow picture reminds one in many particulars of the shadows of subacromial and subdeltoid bursa. But at this point there are no bursal sacs. One might think, perhaps, of calcifications in the upper part of the peroneal sheath. One might also consider a calcification of the posterior malleolar ligament in consequence of trauma. The author believes after a thorough study of his own Röntgen findings in this region and of similar shadows occurring at the inner condyle of the femur, and already often discussed in the literature (see at the appropriate place in this book) that in findings such as Fig. 89 we are dealing really with a tearing off of the posterior malleolar ligament together with the periosteum proximal to it, with subsequent ossification. The author recently found the shadow in question small and narrow in a soldier, nineteen days after an accident. In slighter cases one finds the shadow, when there is no intersection due to projection, directly resting upon the bone.

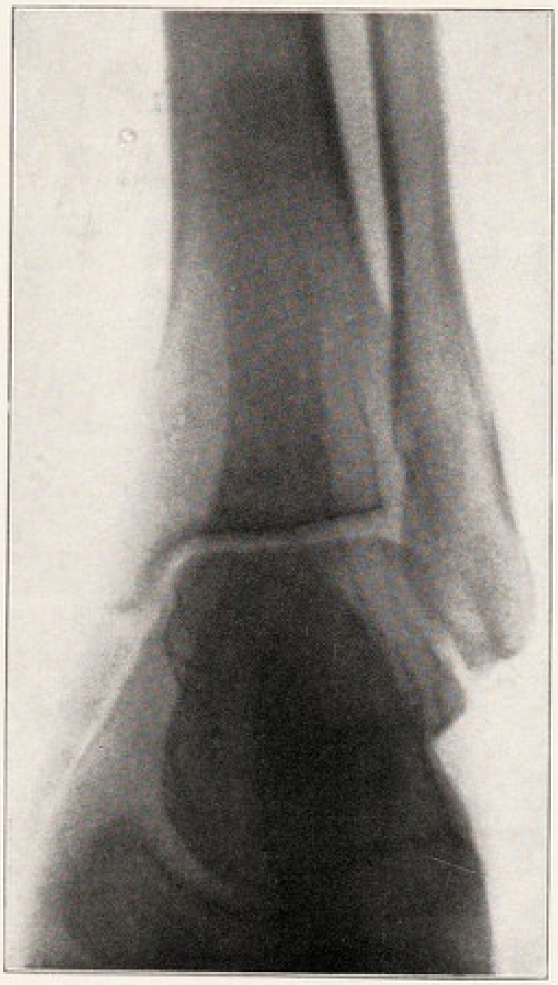


Fig. 90.

Light transverse lines parallel to one another in the shadow of the spongiosa of the distal end of the tibia (Fig. 91) have no particular pathological importance. The description "Annual rings," which has been used here, declares nothing about their origin; it has really nothing to do with years at all; it is used only as a simile and for the sake of abbreviation. We are dealing with an irregular intermittent ossification, dating from youth

[1] Eugen Bircher: Abrissfractur am Malleolus lateralis tibiæ posterior. Zentralbl. f. Chir., 1912, No. 6.

and caused by various forms of chronic disease. Naturally these lines appear also at the ends of other bones, although certainly not so definitely as here.

Detachment of the posterior distal edge of the tibia, as shown in Fig. 92,[1] can be easily overlooked, because the dislocation is usually slight and the line of fracture is completely covered by the shadow of the fibula.

Shafts of Both Bones of the Leg

Fibula

For the appearance of the first *osseous nucleus* of the diaphysis, see above in "General." The shaft is not always straight: this, however, need not be pathological. In the middle of the shaft of the fibula, on its tibial side, one meets a long shadow, resembling a periostitis; this is normal and corre-

Fig. 91.

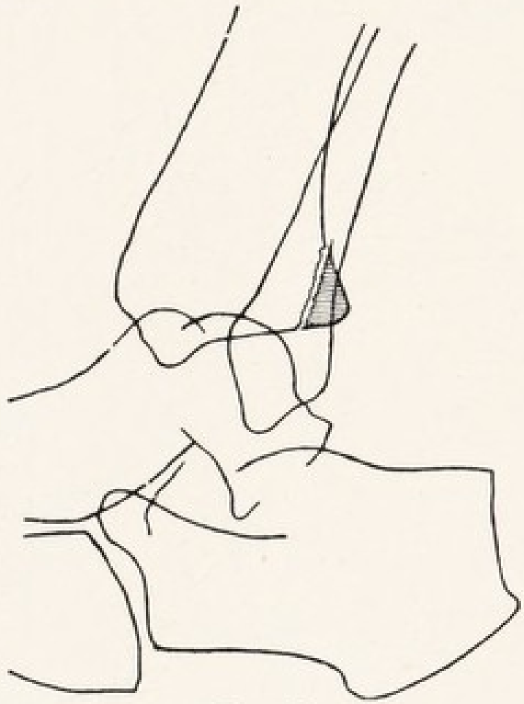


Fig. 92.

sponds to the *interosseous crest;* also at the outer side away from the tibia one sometimes observes similar shadows resembling a periostitis or an old callus.

At the juncture of the proximal and middle third of the fibular shaft *indirect fractures* have sometimes been observed in soldiers owing to the pull of muscles (Recruit's disease);[2] they are often severe, and sometimes can be established only by the subsequent formation of callus. The most

[1] After Grashey in Rieder-Rosenthal's text-book, Vol. 1.

[2] From a private communication by Dr. Glogau, who in the course of a few years has seen about thirty of these cases; see also Hopfengärtner: Militärärztliche Zeitschrift, Vol. 3, 1907, and Thöle, *ibid.*, Vol. 8, 1910.

remarkable thing is their gradual origin without definite trauma. The first Röntgen examination may prove completely negative, only by repeating after two to three months does one then see ring-like evidences of callus. These fractures are transverse. Also small oblique infractions, to be recognised at once, occur at the tibial side of the bone.

Tibia

Fractures should not escape observation, except perhaps such longitudinal fissures as occur in the tibial shaft and are recognised by an almost hair-thin line of light, visible only in one direction of the rays.

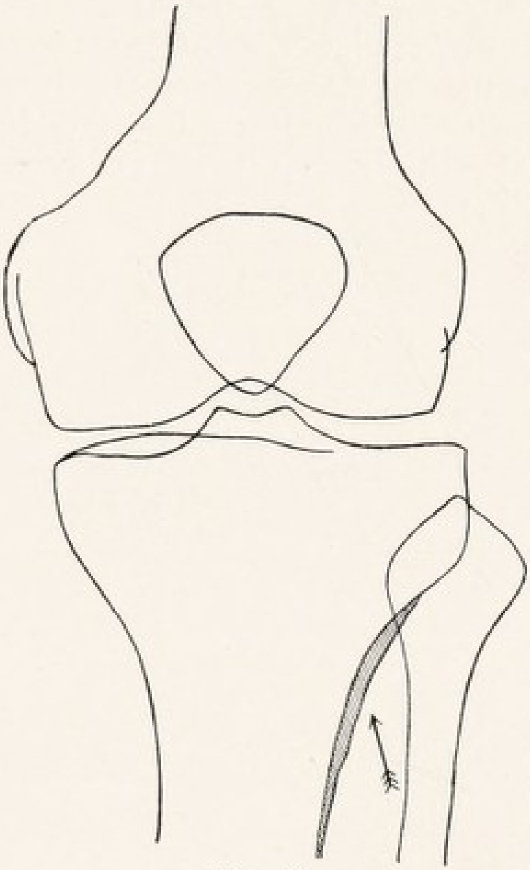


Fig. 93.

Nicks in the tibial shaft a few centimetres below the upper tibial epiphysis and *spontaneous fractures,* also in the femur, with translucency of the epiphysial regions, broadening of the epiphysial lines and evident spotted atrophy of bone in young people have been described since 1918, as a new disease, " hunger-malacia." [1] It is a kind of late rickets with transition into osteomalacia. The gait is waddling, and climbing of steps finally impossible (see also p. 8).

A slight *periostitis ossificans* in front of the tibia is very suspicious of commencing gumma; also a simple traumatic periostitis can naturally be situated at this point. The clinical history must decide. If the ossifying periostitis is of extreme degree and combined with extensive rarefying process of the corticalis, then one has the typical picture of a periosteal gumma before one. Sometimes more, sometimes less, pronounced periostites on both sides at the tibial diaphyses were observed in five-day fever and other febrile diseases; more rarely they occurred at the fibular diaphyses, also in the bones of the forearm.[2]

In dorsal photographs of the lower leg one usually finds at *the lateral border of the tibia* a shadow resting on the corticalis which looks extremely like a pathological periostitis ossificans (Fig. 93), but is quite a normal appearance (rough insertion area of the tibialis anticus muscle ?).

[1] Fromme: Über eine endemisch auftretende Erkrankung des Knochensystems. D. Med. Wochenschr., 1919, p. 510.

[2] A. Burchard: Über den Nachweis von Veränderungen an den Schienbeinen beim Fünftagefieber und anderen fieberhaften Erkrankungen. Med. Klinik., 1918, No. 33.

In Röntgen examinations of the bones of the lower leg in adults one should never omit to observe closely for signs of *calcification of the posterior tibial artery.* One sees the calcified artery in dorsal negatives between the two bones, in profile negatives immediately behind the two bones, provided it does not fall in the shadow of the fibula. The artery is not always calcified in its whole course, one often sees a slight indication of small plates of lime only over a distance of a few centimetres, which are easily missed by the student. It should be remarked that the finding of a calcified artery often explains much that is otherwise puzzling. Localised and usually prolonged symptoms following upon slight fracture, infraction or only distortion or contusion, find a not infrequent explanation in the simultaneous occurrence of an arteriosclerosis.

Varices are usually quite plainly seen in Röntgen picture, if they are projected by rays tangential to the limb. The reason why they are so prominent is in the great difference of the absorption coefficient of the blood plus the thickened walls of the veins on the one hand, and the enveloping fatty tissue on the other.

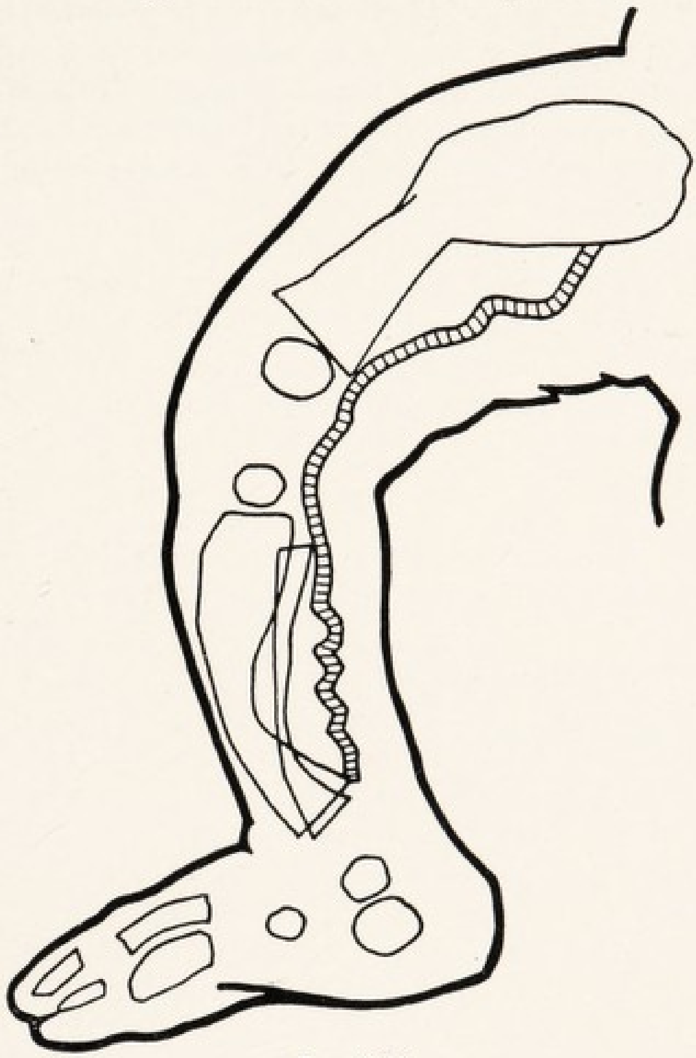


Fig. 94.[1]

In the distal tibial malleolus *a compact-island* has been observed ; see "General," p. 3.

Very occasionally indeed in children in the very earliest months and years of life, the shadow of the coils of the posterior tibial artery can be seen in the Röntgen picture. A picture of this sort in a case of osteogenesis imperfecta occurs in the Swedish Röntgen literature. We are there dealing with a high degree of *arterial calcification,* which could not possibly be missed (see Fig. 94). But one should not fail to observe an arterial calcification even in its earlier stages. The author illustrates such a picture in the forearm (see Fig. 27 and the reference to the literature).

For proximal end of the tibia and fibula, see under "Knee."

[1] Illustration from Sven Johannsson, *l.c.*, note 2, p. 45 of this book.

KNEE [1]

Proximal End of the Fibula

The osseous centre of the proximal epiphysis of the fibula appears between the third and the sixth year.

Few parts of the skeleton are so seldom the site of pathological affections and anomalies as the proximal end of the fibula. Nevertheless, quite a variety of forms are normally seen. If the röntgenogram shows a sharply defined, quite translucent spot in the bone one should think of *sarcoma,* but if the edges be ill-defined from areas poor in calcium one should think of *tuberculosis.*

With the normal amount of lime but an extreme degree of malformation of the proximal end of the fibula, the cause should be sought in an *exostosis,* which is usually multiple. One should then examine the epiphysis of the tibia and femur and also the shafts.

Tibio-fibular synostosis has been observed in genu valgum.[2]

Proximal End of the Tibia

The nucleus of the proximal epiphysis appear shortly before birth and unites with the diaphysis about the twentieth year.

The following points are of importance for forensic, maternity, and other medical purposes : [3] (1) Every child weighing 2700 grams or more, measuring 47 cm. or over, and supplied with two points of ossification (tibial and femoral) in the knee, has reached full time. (2) Every child with tibial and femoral points of ossification which weighs 2600 grams or less and measures 44 cm. and over, also every child that has only one ossification point, the femoral, but weighs more than 2800 grams and measures at least 44 cm., has reached or almost reached full time. (3) Every child with two points of ossification in the knee has been at least $8\frac{1}{2}$ months in utero. (4) A child that weighs less than 2500 grams and shows no points of ossification at the knee, has not reached full time. The only cause of delayed fœtal ossification appears to be syphilis.

In children in the first years of life there sometimes appears in profile pictures at the juncture of the proximal and middle third an oblique fissure in the corticalis up to 3 mm. in breadth ; that is, normal (*nutrient foramen*).

About an average age of from ten to thirteen years there projects from the upper epiphysis, hanging like a tongue in front over the diaphysis, a well-

[1] For the normal Röntgen anatomy of the knee, see Grashey, Atlas I, 4th edition, also the atlas of Wilms and Sick, etc., 1902 ; further : Hasselwander : Die Röntgenstrahlen in der Anatomie, in Rieder-Rosenthal's Text-book, 2nd Vol., 1918.—Sessa and Alberti : see note 1, p. 1.—E. Scott : Röntgenography of the kneejoint. Arch. of Rad. and Electr., London, 1923, p. 304.

[2] H. Rahm : Die tibia-fibulare Synostose. Ztschr. f. orthop. Chir., 43, p. 183.

[3] According to M. Poizier : Etude röntgenographique du genou chez le nouveauné. Soc. franc. de l'électrothér. et de radiol. méd., January 16, 1913.—R. Jardin : J. de Rad., 1927, p. 30.

defined process, the so-called tongue-shaped process of the *upper tibial epiphysis* (Fig. 95, B, C, D). At its distal extremity there then appears an isolated osseous nucleus (so-called *anterior epiphysis*), which forms later the tubercle; it forms a bony union with the tongue-shaped epiphysial process between the thirteenth and the fifteenth year. An anterior tibial epiphysis appears also in the higher mammalia. *In comparative anatomy* it is regarded as the anterior or lower portion of the upper epiphysis which, apparently under the influence of the increased pull of the ligamentum patella, has been separated from the larger posterior or upper part of the upper epiphysis and independently ossified. It can develop in manon both

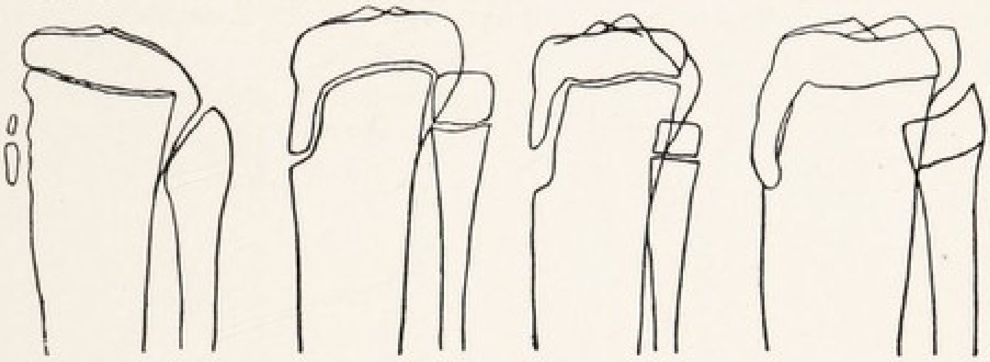


FIG. 95.

sides of the same individual in different directions and to a different extent. The diaphysis can take part in the formation of the tubercle to a different extent on the two sides. The ligamentum patellæ can have a different length of insertion on one side than on the other, and further, the bony nuclei on the one side may appear earlier than on the other. Moreover, an additional second nucleus may appear distal to the anterior epiphysis, and thus the whole area of the tubercle may exhibit quite a different picture on the two sides. As regards *the tibial tubercle of man* in particular, it is usually formed proximally by the anterior epiphysis, but distally by a part of the adjacent diaphysis, more rarely, without particular participation of the diaphysis, by the anterior epiphysis and an inferior nucleus distal to it, which usually exceeds the anterior epiphysis in size in the vertical direction. The ligamentum patellæ is attached to the diaphysis distal to the anterior epiphysis in the erect-walkers, in man, the anthropoid apes, and the old-world monkeys; in the other mammals it is attached at the upper or anterior tibial epiphysis.[1]

Pictures as shown in Fig. 95 (also 111, A) belong all to the realm of the normal. But a good understanding of what constitutes changes from the normal in this region is desirable—for changes especially of traumatic nature are not uncommon in this region. We owe since 1903 the knowledge

[1] A. Kirschner: Die vordere Epiphyse und der untere Tuberositaskern der Tibia beim Menschen und in der Säugetierreihe. Die Tuberositas tibiæ des Menschen. Archiv f. Anatomie und Entwicklungsgeschichte. Anatom. Abteilung. Leipzig, 1908.—See also Decref: Les altérations du noyau osseux de la tuberosité du tibia. Internat. Congress of Radiology and Electricity in Brussels, 1910.—Licini: Verknöcherung der Tuberos. ant. tibiæ. Beitr. z. klin. Chir., Bd. 78, p. 394.

of a new disease to *Schlatter and Osgood* (Fig. 96). A very large number of cases have been published up to date,[1] but many mistakes appear in them, many fractures and traumatic injuries being incorrectly included. The Röntgen finding in well-defined cases shows a marked displacement forwards of the nucleus of the tubercle, the tongue-shaped epiphysial process coming from above having faded translucent contours, its nucleus and that of the tubercle being translucent with little spots and fissures. The finding in question is more frequent in boys than in girls between twelve and fifteen years. The condition is sometimes met with in both tibiæ, but otherwise it is the right tibia that is selected. *Schlatter* took the condition for an incomplete separation of the epiphysial process. According to careful

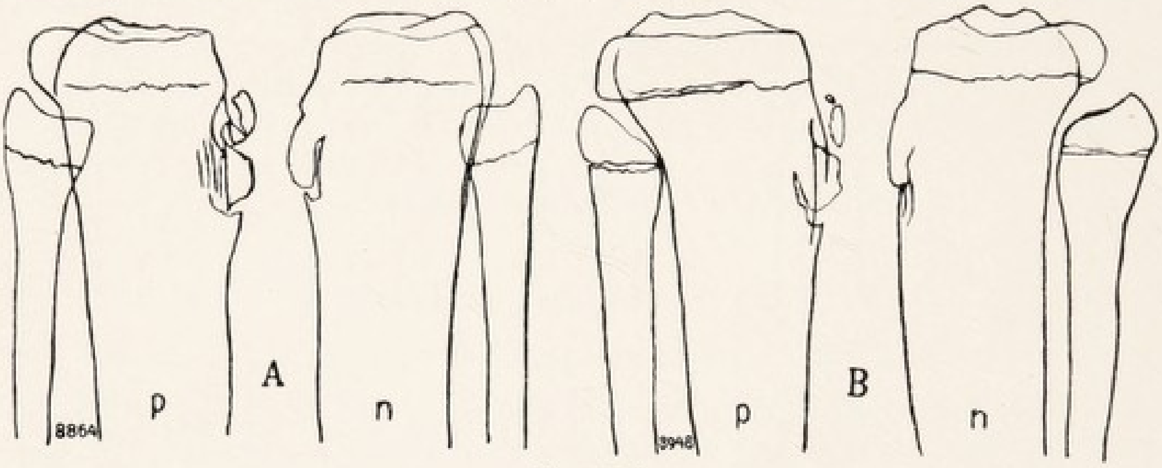


Fig. 96.[2]

researches [3] it appears to be an osteochondritis increased by crushing or tearing, probably of tuberculous nature and possibly accompanied by a primary pretibial bursitis. In 1915 there were in all five different explanations for this singular disease. (For an understanding of the Röntgen picture, see also the previous section.) In one of the more recently published works [4] Schlatter's disease is regarded as of a distinct pathologico-anatomical origin. Late-rickets appears only rarely to be the cause. A traumatic origin is not denied, perhaps associated to some extent with hunger-osteomalacia. One author found in a bilateral case of the disease an elevation or separation of other epiphysis, like the olecranon, the trochanters, the calcaneal epiphysis, but without discovering the ætiology. Late-rickets

[1] The literature on the subject is given in Jacobsthal: Über die in der Adolescenz auftretende Verdickung der Tuberositas tibiæ. Deutsche Zeitschr. f. Chirurgie, Bd. 86. (See also Hohmann: Zeitschr. für orthopäd. Chirurgie, 24. Bd.); see further: E. O. P. Schultze: Zur Schlatterschen Krankheit. Symptom einer Systemerkrankung. Archiv f. klin. Chir., Bd. 100, Heft 2.—Péteri: Schlattersche Krankheit. Fortschritte, Bd. 23, 1915 (with list of the literature).—Altschul: Arch. f. klin. Chir., Bd. 115, Heft 3.—Hinrichs: Ztschr. f. orth. Chir., Bd. 41, Heft 3.—F. Shillington Scales, Cambridge. Two cases of Schlatter's disease. Arch. of Rad. and Elec., May, 1920.—Mandl: Wiener m. Wschr., 1922, p. 1380. 4 bilateral Schlatter's diseases in football-players.—R. Bader: Amer. J. of Röntg., October, 1922.—See also E. Fels, note 2, p. 147.

[2] p = pathological, n = normal.

[3] Über Osteochondritis an der Tuberositas tibiæ und sogenannte Osgood-Schlattersche Krankheit. Kienböck: Fortschritte, Bd. 15, 1910.

[4] W. Rieder: Zur Ätiologie der Schlatterschen Krankheit. Arch. f. klin. Chir., 1922, Bd. 120, Heft 3.

is not accepted as an explanation,[1] but another authority regards it as the main cause, or rather as an important predisposition.[2] Finally, one investigator in a serial examination of healthy young children, found that in many people changes were found in the tibia, which corresponded exactly to Schlatter's disease, but without any clinical symptoms. The cause of Schlatter's disease is thought to be an inflammatory process, which goes on to an interruption of the ossification process.[3]

On account of the singular appearance in the pictures *real fractures* may sometimes be overlooked ; these are : (1) Fracture of a part of the tibial tubercle with complete or incomplete separation of the piece and little or no elevation of the same ; (2) Fracture of the entire tibial tubercle with a marked dislocation or a simple elevation of the fragment ; (3) Fracture of the tubercle with a part of the condyle.[4]

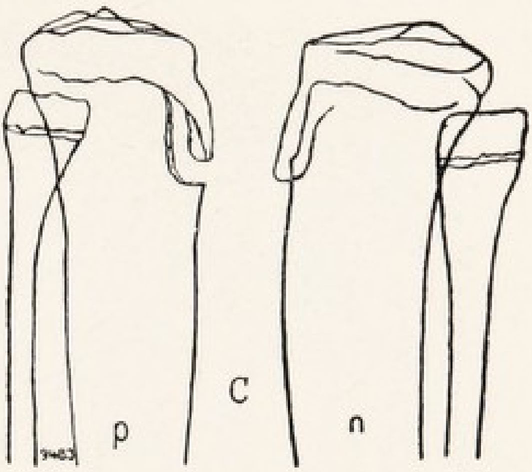


Fig. 97.[5]

The author once obtained a Röntgen finding, as illustrated in Fig. 97, C p, in a case with the clinical signs of Schlatter-Osgood ; the epiphysial process was sharply defined and tongue-shaped, and under it was a transparent area or defect the size of a large almond. Tumefaction and definite fluctuation were present. Without being incised the case healed up after a year. Seeing this case is totally different from the remaining cases of the literature and the author's other cases (Fig. 96, A and B), it may be doubted whether the case should be described as a " Schlatter-Osgood," especially seeing one case is illustrated in the literature in which with similar Röntgen findings [6] thick pus was removed at operation,

[1] F. Mandl : Die " Schlattersche Krankheit " als " Systemerkrankung." Beitr. z. klin. Chir., Bd. 126. Other Röntgen references are found in R. Allessandri. Arch. di Ortopedia, Anno XXVIII, fasc. 6, 1911.—A. Bassetta : *ibidem,* Anno XXX, 1913.—T. Costa : Il Policlinico ; sez. chir., Anno XXIII, fasc. 7, 1916.—C. Lollini : *ibidem,* Anno XXIV, fasc. 7, 1917.—E. Milani : La Rad. Med., Anno VI, fasc. 3/4, 1919.—R. Mosti : La Riforma Medica, 1919, No. 33.—Taparelli : La Rad. Med., Vol. III, fasc. 3, 1916.—Ellis R. Bader : Am. Journ. of Röntg., October, 1922.—v. Mandach, Schaffhausen : Über Störungen der Tuberositas tibiæ des Menschen. J. D. Zürich, 1923.—E. Fels : Über die Entwickelung der Tub. tib. und die Genese der Schlatterschen Krankheit. Arch. f. klin. Chir., 129, 3, p. 552.—Greenleaf, Atlantic : J. of Rad., V, December 12, 1924.—Emmert, Omaha : J. of Rad., VI, July 7, 1925 (operation case).—S. Reinberg, Leningrad : Die Röntgendiagnostik der Osteochondropathien. Reference article. Fortschritte, Bd. 34, p. 406.—F. Giorgo, Bergamo : Breve confronto fra gli aspetti röntgenografici di alcune " epifisiti." La Rad. Med., Bd. XII, 3.

[2] E. Fels : Über die Entwickelung der Tub. tibiæ u. die Genese der Schlatterschen Krankheit. Arch. f. klin. Chir., Bd. 129, Heft 3, 1924.

[3] Durante, Genoa : La Rad. Med., September, 1924.

[4] Kienböck : Abbruch der Tuberositas tibiæ samt Teil des Condylus. Fortschritte, Bd. 15, 1910.

[5] p=pathological, n=normal.

[6] Kienböck, *l.c.* Fortschritte, Bd. 15, p. 139, Table 14, Fig. 6.

tubercle bacilli were found in the evacuated tissue and tuberculosis resulted on injection of the pus into animals.

The next illustration was sent to the author as an exceptionally rare finding: Fig. 98,[1] twenty-three-year-old doctor. Pain only in one leg at the point where the bone is lacking. The growth of bone is already completed, but on both sides the normal ossification is absent below the tuberosity of the tibia. The calcification is apparently absent from the tongue-shaped process that projects down from the upper epiphysis: or rather a portion of the anterior epiphysis is separate from the upper epiphysis, and may ossify independently, or in one of its two nuclei.

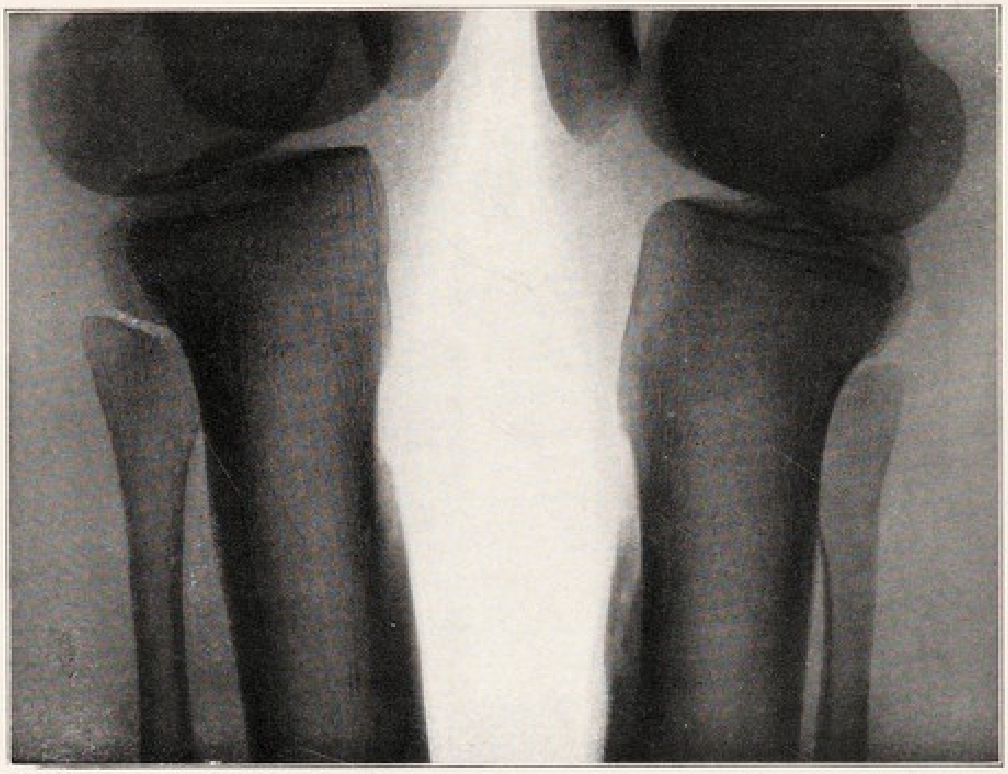


FIG. 98.[1]

In dorsal pictures we usually see the middle of the epiphysis of the tibia, not as a simple narrow band but with translucent spots or in the form of *crossing lines*; this is normal, the appearance being partly due to projection.

If the internal tibial condyle in dorsal pictures shows no rounding at the place where it enters the shaft, but a sharp process directed towards the foot, one has to think primarily of multiple *cartilaginous exostosis*. For certainty of diagnosis one should note whether similar bony projections are present also in the condyles of the femur. If owing to the smallness of the outgrowths any doubt remains as to the picture, one should röntgenograph the *distal end* of the tibula and fibula, or even the distal ends of the bones of the forearm. Occasionally one meets with bony processes which leave no doubt of their nature being real cartilaginous exostoses. Changes in other skeletal parts might perhaps support the diagnosis. The simul-

[1] Sent by Dr. Kaspar Niederecker, Pecs (Hungary). Surgical clinic.

taneous occurrence of sarcoma of bone or of a partial hyperplasia has been several times described in the literature as an accompaniment of multiple cartilaginous exostosis. Furthermore, these exostoses are not situated simply on the bone, but the affected bones are plainly altered in their form, being frequently shorter, and their axes sometimes bent. (Exostoses, on the other hand, proceeding from tendinous or muscular insertions are situated on an intact bone on a closed corticalis.[1])

Ossifications of the insertion of the ligamentum patellæ to the tuberosity of the tibia occur, but are much rarer than at the insertion of the quadriceps tendon to the patellæ.

In dorsal pictures one often finds very dense line shadows in the shaft near the epiphysis and parallel to it ; they are said to be due to the growth of the bone in length being discontinuous and have been termed " annual rings " from the analogy of a tree. (See also the distal end of the tibia, Fig. 91.)

Directly *underneath the intercondyloid tubercles* one sometimes meets areas poor in lime about the size of peas ; this appearance is without pathological importance.

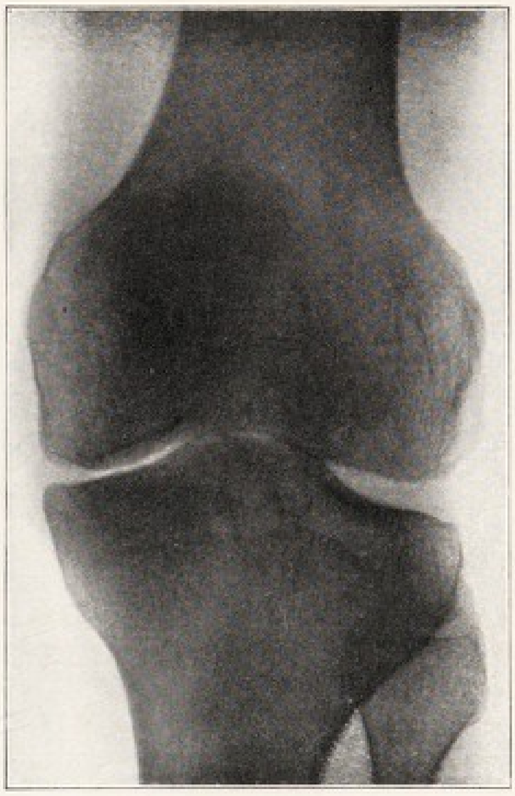


Fig. 99.

Articular Part of the Tibia

The *intercondyloid tubercles* are seldom seen as regular as one might anticipate. The one spine may be pointed, the other blunt, and the hollow between them, apart altogether from accidents of projection, is sometimes deeper, sometimes shallower. Striking irregularities such as bending round of the tip of the tubercle belong usually to the region of the pathological (arthritis chronica levis).

A bare half-dozen times in nearly thirty years' Röntgen practice the author has seen tibial articular ends, as shown in Fig. 99. (The opposite extreme is seen in the knee on Fig. 114.) One need scarcely say that such forms have a constitutional basis. It is not to be wondered at that such joints do not functionate normally. The patients complain usually of weak knees since childhood. One of the author's patients declared that he was always scrophulous as a child.

[1] For a complete orientation of these questions refer to the work of Kienböck : Zur röntgenographischen Anatomie und Klinik der chondralen Dysplasie der Knochen mit multiplen cartilaginären Exostosen. Wiener Medic. Wochenschr., No. 47, 1903.

Fractures of the intercondyloid tubercles occur; although rare, they are sure signs of severe inner torsions. The detachment of one of the tubercles amounts to a proof of the detachment of its accompanying meniscus (which, as is well known, is invisible to the Röntgen rays).[1]

The *two articular edges of the tibial shadow* form normally angles of about 70 to 90°, of which the internal is always a degree or two smaller (see Fig. 100). In commencing simple chronic arthritis these articular edges are surmounted by minute processes (Fig. 103, A, B), which with the

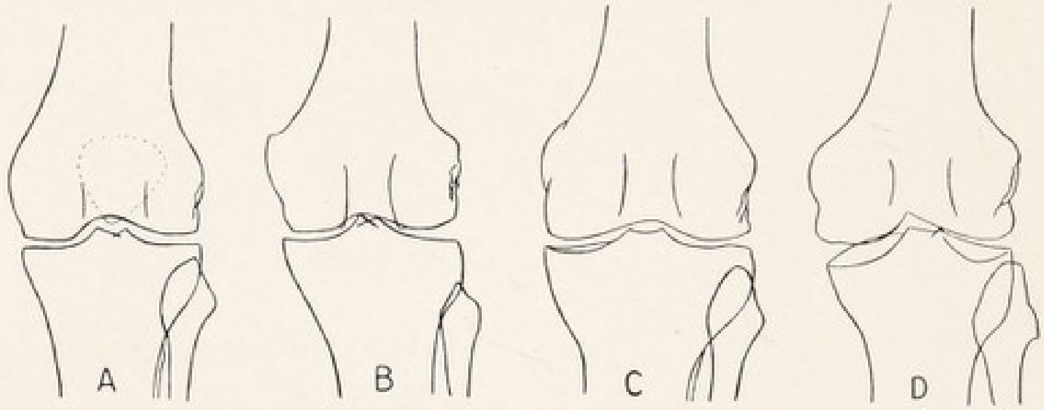


FIG. 100.

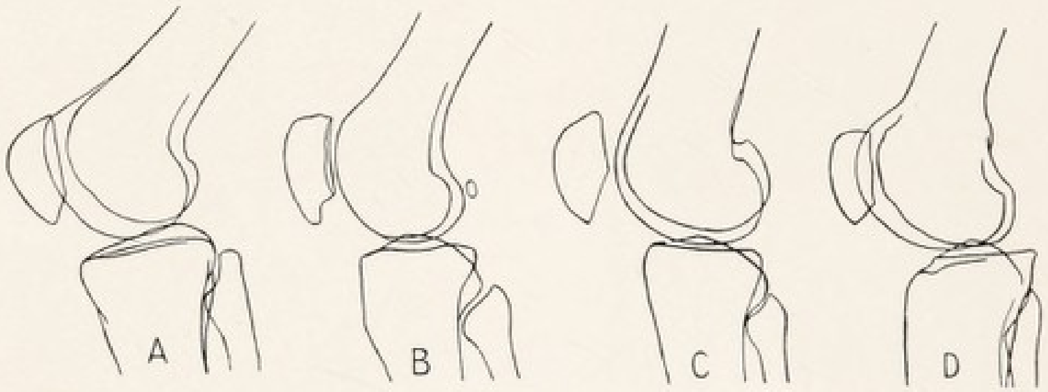


FIG. 101.

further course of the disease are wont to become blunted and broader. In reality these shadow points correspond not to bony processes, but to bony ledges, which run round the greater part of the bone. (Figs. 100 and 101=normal findings.)

Not a very frequent finding, but one occasionally described, is as follows (Fig. 102, a [2]): It is certainly pathological; its ætiology is not very easily explained. The ridges correspond to the lines of insertion of the capsular attachments. The condition is usually found after traumata.[3] There can be little doubt that we have here to deal with ossifications of the capsular attachments.

[1] According to Grashey: Die Röntgenuntersuchung in der Chirurgie; in Rieder-Rosenthal: Lehrbuch der Röntgenkunde, Bd. 1, Abb. 80. Leipzig, J. A. Barth, 1913.

[2] For the importance of the free shadow in Fig. 102, b, at the internal end of the femur, see below under "Distal end of the femur."

[3] A corresponding case is found in the author's book: "Die normale und pathologische Anatomie des Hüftgelenks und Oberschenkels." Hamburg, 1905, Table 7, Fig. 12.

Small *compression fissures* of the proximal end of the tibial joint should not be overlooked, although they are not always very evident.

Regarding the *defect at the internal tibial condyle* with a shadow in the internal condyle of the femur similar to Fig. 116, B, see " Distal end of the femur. Shadow accompanying the internal condyle." The proximal metaphysis of the tibia is most frequently the seat of *tuberculosis.* Regarding its röntgenographic signs what has been stated for " Distal end of the femur " is equally applicable.

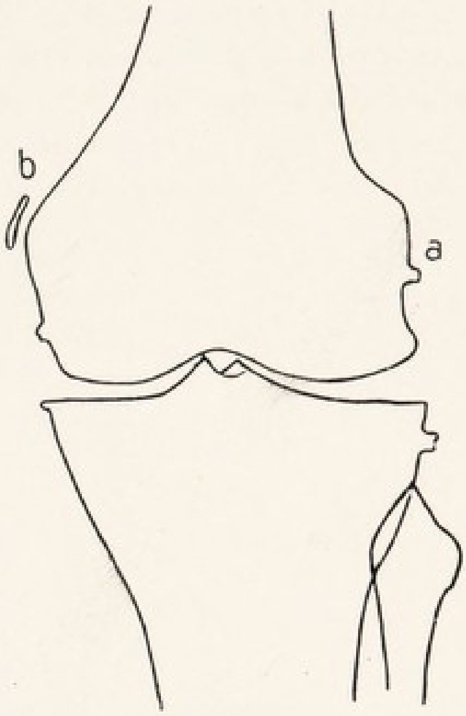


Fig. 102.

Fissure of the Knee-Joint

When all the clinical signs point to the presence of a *foreign body in the joint,* but the Röntgen picture shows no signs of it, one should not allow oneself to be led into a mistaken diagnosis through the negative Röntgen finding. The great majority of all articular bodies are cartilaginous and, as is well known, remain completely hidden to the Röntgen rays (see further below under " Popliteal arteries " and later under " Distal end of the femur ").

The joint fissure in Röntgen picture corresponds, as is well known, to *the articular cartilage.* When the cartilage (*e.g.* in chronic arthritis) is eroded the joint fissure of the röntgenogram is naturally narrower. The normal breadth amounts to about 3 to 5 mm. An exact delimitation of the physiological from the pathological is scarcely possible, still it is an aid to diagnosis to know that the cartilaginous erosions are irregular, *e.g.* in one case the articular cartilage of the internal half of the knee-joint may be more eroded than that of the external half (see Fig. 103, B), and vice versa. If the focus of the tube is not approximately over the joint the conditions are somewhat more difficult to estimate ; the recognition of the erosion of cartilage is still further simplified by the presence of the above-mentioned marginal outgrowths from the articular ends of the bone (Figs. 103 and 104 =cases of commencing and advanced primary chronic arthritis). Bleeder's joints (in hæmophilic cases) have similar Röntgen pictures.[1]

Narrowing of the joint fissure on the injured side in slight subluxation of the tibia towards the sound side is said to be associated with *tearing of a semilunar cartilage* (meniscus) in its whole circumference with dislocation into the interior of the joint.[2] Further, in injuries of the meniscus there is now and then recognisable a slight displacement of the ligamentum patellæ

[1] Engels: Über das Blutergelenk und sein Röntgenbild. Fortschritte, Bd. 25, 1918 (with list of the literature).

[2] After Schwarz: quoted by Schlatter: Meniscusluxation des Kniegelenks. Beitr. z. klin. Chir., 41, 229, 1903.

in profile photographs, but this may be only a secondary consequence of an effusion into the joint.

The *lateral tibial condyle* very frequently projects further outwards than the corresponding condyle of the femur. One should not at once diagnose subluxation in such cases, when the patient has suffered an injury. Knees with such incongruities are doubtless disposed to arthritis deformans.[1]

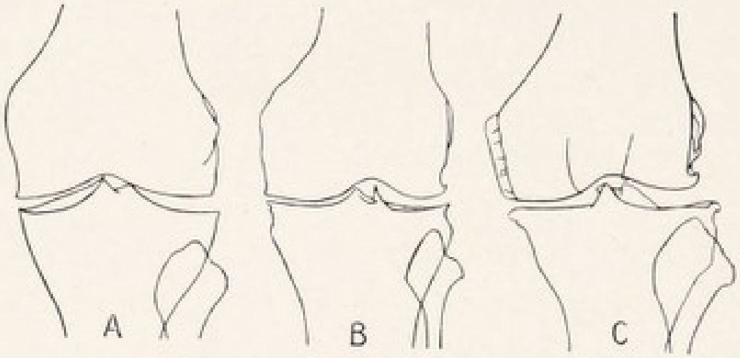


Fig. 103.

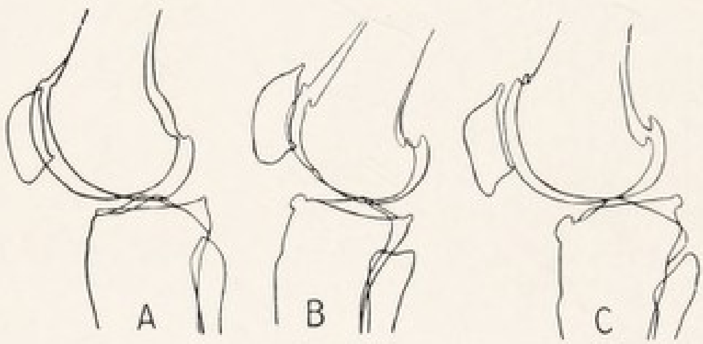


Fig. 104.

If *the popliteal artery* is strongly calcified it can be seen through the joint fissure even in dorsal pictures. If one does not think of this possibility the shadow of the arterial wall in the translucent joint-fissure may be taken for an articular body.

In half of all dorsal photographs of the knee the shadow of the distal point of the patella comes into the clear articular fissure (see Fig. 100, A). Seeing now the patella in consequence of its great distance from the plate disappears almost completely in the shadow of the femur, the inexpert observer may easily overlook that the shadow in the middle of the joint fissure, the size of a pea or small bean, belongs to the patella.

For the sake of completeness it should be mentioned that, since 1905, the introduction of oxygen into the joints has been recommended for the better differentiation of the interior of the joints.[2] The knee-joint is the one best suited for the purpose. The interpretation of the films thus obtained is fraught with considerable difficulties; thus it is scarcely possible by this method to diagnose a displacement or separation of the semilunar cartilage.

[1] Preiser: Über die praktische Bedeutung einer anatomischen und habituell-functionellen Gelenkflächenincongruenz. Fortschritte, Bd. 12, p. 313, 1918, and Bd. 15, p. 45, 1910.

[2] Robinsohn and Werndorff: Über eine neue röntgenologische methode (Sauerstoff-Insufflation) Zur Untersuchung der Gelenke u. Weichteile. 1. Röntgen-Congress, Berlin, 1905 (Proceedings).

The explanations first advanced for the method have not been fulfilled, so that it is only in isolated cases that it is carried out.

Soft Tissues at the Knee

Even when the finding of the bones of the knee permit of a definite diagnosis, a survey of the soft tissues should never be neglected, *e.g.* an associated *calcification of the popliteal artery* explains why it is that symptoms after slighter injuries last many times longer than in cases where no sclerosis of the vessels is present. In general the calcified popliteal artery in spite of its size is as a rule less evident than the posterior tibial artery over the calcaneus; it is therefore an obvious mistake in technique for the röntgenologist in the study of *a profile photograph* of the knee to omit to seek for it along the course of the artery. Its course is illustrated here (Fig. 105).

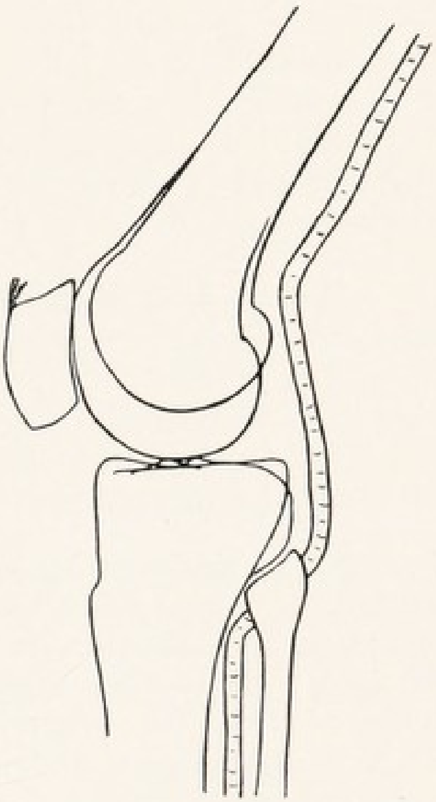


Fig. 105.

There frequently occurs in arteriosclerosis a simultaneous *ossification of the insertion of the quadriceps* muscle at the proximal border of the patella (Fig. 105), an appearance analogous to the ossification of the insertion of the tendo-Achillis at the calcaneus in calcification of the posterior tibial artery and anterior tibial artery (see also under the " Patella ").

The soft tissue area behind the distal end of the femur is about 10 cm. long and up to 3 cm. broad, it is very translucent and corresponds to the physiological *collection of fat* at this point.

The bony shadow from a pea to a hazel nut in size behind the knee-joint or somewhat proximal to it in oblique projections of the knee appears to belong to the joint; this is *the fabella,* the little sesamoid bone that frequently appears in the external tendon of the gastrocnemius muscle: sesamum genu superius laterale. It is seen in about 10 to 15 per cent. of all lateral negatives of the knee, and in about every five cases it is found in both knees. According to the anatomists it is more frequent in women, according to the röntgenologists in men. With increasing years it appears more frequently. In negroes the fabella occurs almost regularly. In spite of its frequent appearance and although attention was drawn to its not being pathological even in the early years after Röntgen's discovery, it was only in the year 1910 that the shadow was described as a free articular body; in that case the mistake was made of seeking for it by operation. In man there is usually only one fabella, extremely rarely two (see Fig. 106).[1] In

[1] According to H. Fischer: Beitrag zur Kenntnis der Skelettvarietäten. Forschritte,

many animals the fabella is quadruple. Whether a sesamoid bone can occur also at the internal head of the gastrocnemius is not yet quite certain. Famous anatomists of past days have described it. Nevertheless, it is now believed that these cases have been instances of a detached muscular process of the inner lip of the femur. In dorsal photographs the fabella is usually not seen, therefore röntgenologists can give little help to deciding this question. If röntgenologists have always spoken of the lateral sesamoid bone, they have done so in reliance on the statement of the anatomists, for it is not apparent from profile pictures whether the structure is medial or lateral. *The form of the fabella* is usually oval or circular, sometimes with a gliding surface ; its length varies between 2·5 to 13·5 mm., its breadth

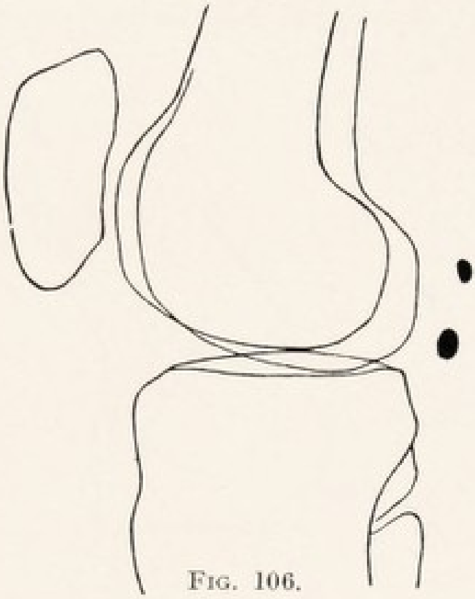


Fig. 106.

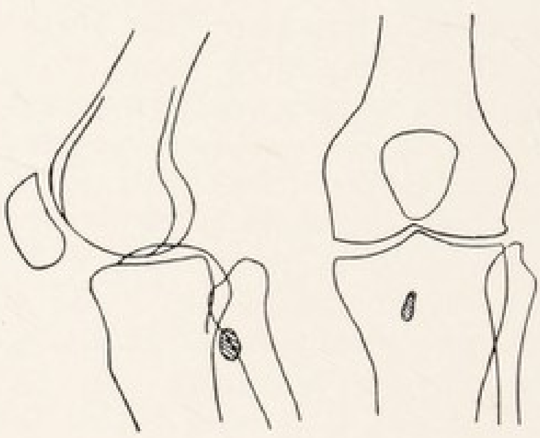


Fig. 107.

from 2·9, its thickness 1·5 to 10 mm. In chronic osteoarthritis or osteoarthritis deformans and other joint affections it is even larger and more or less markedly deformed. It is not usually seen before the twelfth to the fifteenth year of life. With advancing years, and especially under the influence of arthritic changes, there takes place an increase in the percentage of its röntgenological finding and its size. In certain cases there also appears to exist a relation between trauma and fabella ; the meaning of that is, that a stimulus set up by trauma brings about the ossification or calcification of the cartilaginous fabella and brings it into röntgenological view. Its position is always above a horizontal plane imagined as placed in the joint fissure of the standing limb, but not to the inside of the mid-line. The author published a case in which the shadow of the fabella was 4 to 5 cm. distal to the knee-joint and dislocated to the inner side of the mid-line.[1]

Bd. 19, 1912 ; see further : H. K. Pancoast : Radiographic statistics of the sesamoid in the tendon of the gastrocnemius. Univ. of Pennsylvania. Med. Bull., 1909, No. 7.—Karl Pichler : Das Sesambein im Wadenzwillingsmuskel. Tastbefunde am Lebenden. Zeitschrift f. angewandte Anatomie u. Consitutionslehre, Bd. 4, Heft 1/3. Berlin, 1918 (the complete work, which also takes critical account of the pure anatomy of the subject).—B. Ullrichs : Ztrlbl. f. Chirurgie, 1920, 11.

[1] For pictures and descriptions of the case, see A. Köhler : Arrachement tendineux démontré par la röntgenographie. Journ. de Rad., Bd. V, Jahrg. 1911, Brussels.

From the photograph of this case (see Fig. 107), the history and the unusual clinical findings, a detachment of the external head of the gastrocnemius was diagnosed. The fabella could be seen most plainly on the dorsal negative through the shadow of the tibia, which, as mentioned above, is practically never the case in the normal fabella. The reason of this was that in this case it was densely osteosclerotic, this being probably a factor in the accident of the torn tendon. In the normal and pathologically altered fabella we have to consider its differential diagnosis : free bodies, detachments of bone, encrusted synovial fringes, calcified plates in the articular capsule, deposits of lime in the soft tissues, calcifications of the internal and external gastrocnemius bursa, large phleboliths, calcified solitary pustule. The diagnosis is not difficult for one who has photographed the knee a couple of dozen times. It may be noted for the benefit of any one who has to estimate the shadow for the first time that all the above-mentioned affections are wanting in regular sharply-contoured oval or circular form, that phleboliths hardly ever reach the size of the fabella, and that solitary calcified cysticerci are extremely rare. (For multiple cysticerci shadows, see Fig. 108.) Malformed sesamoid bones that might be confused with other bodies are only found when other changes, clinical or röntgenological or both, are present.

A fabella may also sometimes break. One such case has been described [1] : An isolated transverse fracture of the sesamoid bone with torsion of the knee-joint on both sides, produced by indirect violence. A sudden powerful over-extension in the knee-joint, producing an abnormal tension overstepping the limits of elasticity, and finally tearing of the tendinous insertion of the lateral head of the gastrocnemius together with its contained sesamoid bone. Such a fracture may perhaps sometimes be confused in abnormally projected free articular bodies (in oblique views of the knee-joint), detachments from the lateral epicondyle, calcifications in the soft tissues or articular capsule, or in calcareous deposits in the gastrocnemius bursa. But the fabella has almost always a structure ; and always appears symmetrical.

A detached piece of bone similar to the fabella was found in a case of tearing of the insertion of the anterior part of the posterior crucial ligament.[2]

On the anterior side of the knee *the ligamentum patella* is a prominent feature between the antero-inferior edge of the patella and the tibial tuberosity. After severe accidents and after light wrenches with associated disturbances of nutrition (arteriosclerosis, gout, etc.) smaller and larger *ossifications* are met with in the ligament.

Between the ligamentum patella, the tibia, the femur, and the patella there is normally a very translucent, *rhomboid-shaped spot*. That corresponds to the thick *fatty masses and synovial bursæ* which are found here, and it shows a structure readily visible and marbled with a definite regularity. Between this fatty swelling and the femoral condyles one must imagine

[1] H. Reinemer : Fractur der Fabella. Fortschritte, Bd. 33, 1925.
[2] Kaufmann : Schweiz. med. Wochschr., 1922, Nos. 30 and 31.

the articular capsule. In advanced stages of chronic arthritis the translucency of this rhomboid disappears to a great extent in the neighbourhood of the condyles in consequence of the marked thickening and increased visibility of the articular capsule. Also the structure and form of the part remaining still translucent becomes altered more or less.

Above and to the upper posterior aspect of the *patella* there is a translucent part in the soft tissues about 5 cm. long=normal ; synovial sac and fat.

The *tendon of the quadriceps* is usually very evident in the normal condition. If it is ossified at its insertion to the patella, which the röntgenologist sees quite frequently, that is naturally a pathological condition. Such ossifications are met with along with arteriosclerosis (see Fig. 105), in chronic arthritis and arthritis deformans, also in arthropathia tabica and after wrenches of the tendon without other complications.

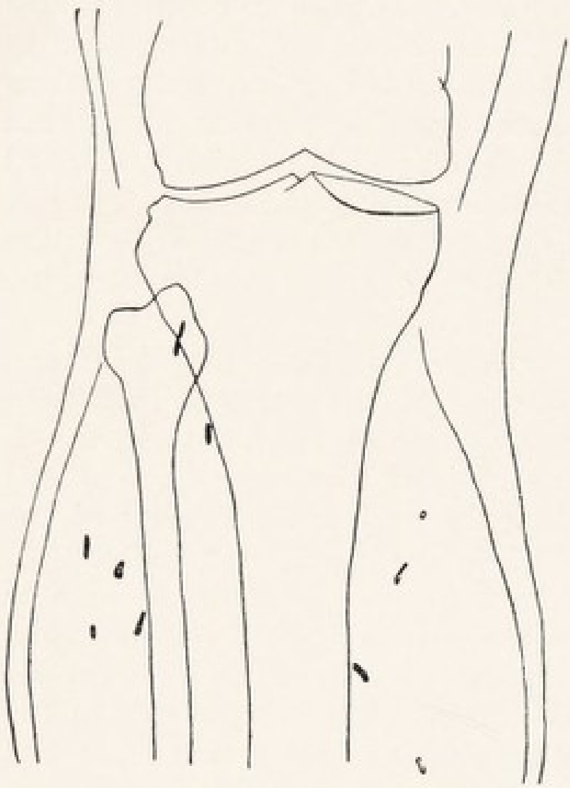


Fig. 108.

Occasionally, though very rarely, in severe chronic or deformative arthritis there are here and there found other larger *deposits of lime* of most striking shapes *in the quadriceps tendon* or its immediate neighbourhood ; this appearance is found also in the dorsal soft tissues of the knee-joint in the neighbourhood of the fabella.

In the shadow of the muscles of the calf and the hollow of the knee the author observed upon one occasion a *shadow of limy density* in form, distribution, and frequency similar to what is shown in Fig. 108.[1] The shadows were homogeneous 2 to 4 mm. broad and 7 to 12 mm. long, the position of their longitudinal axes corresponded roughly to the course of the muscles. These were considered to be calcified parasites, the diagnostic excision confirmed this opinion and the condition was found to be one of calcified cysticeri (Cyst. cellulosæ). (Shadows of calcified *trichinæ* are uniformly round and are only 1 to 2 mm. in diameter.) The marks are characteristic, and if present in sufficient number one ought to avoid making an incorrect diagnosis. Only in the case when we have to deal with a quite solitary shadow would we require to differentiate between osteoma, calcified

[1] A. Köhler : Zur Röntgendiagnostik der Schmarotzer des Menschen (Cysticercus cellulosæ. Distomum pulmonale). Verhandl. d. Deutschen Röntgen-Gesellschaft, 1914, Bd. 10. —See further, Landois : Berl. klin. Wochenschr., 1912, p. 1639.—Küttner and Landois : Die Chirurgie der quergestreiften Muskulatur. Part 25a of " Deutschen Chirurgie," 1913. —Pichler : Wiener klin. Wochenschr., 1911, H. 11 and 12.

small tumour of the skin, and calcified subcutaneous granuloma. That a patient suffering from calcified cysticerci must suffer also from tæniæ is not only not necessary, but such an occurrence is directly denied (by Virchow). But a sufficiency of cases have been described in recent years in which both forms (calcified cysts and mature animals) have been found in the same individual.

Patella

The patella is a large sesamoid bone in the quadriceps tendon and begins its *ossification* within the limits of a very wide space of time, according to anatomical reports from the first (Kolliker) up till the fifteenth year (Munz). In röntgenological works the fifth and sixth years are usually stated. The bony nucleus has often in the first years of ossification a very gross rough contour ; and that appears to be normal.

In defective anomalies of the thigh the *patella* is often absent.

An isolated *interruption of growth* of the patella, consisting in destruction of structure, shrivelling, and sclerosis of the bony nucleus, occurs in combination with the similar process in the navicular bone of the foot. The process heals in a few years with re-establishment of the structure and of the normal size and form (see scaphoid bone of the foot, p. 114, and the literature there given).

Cases of congenital dislocation outwards of the patella (and of the head of the radius) have been observed,[1] also an incomplete ossification of the patella.[2]

In a ten-year-old girl following upon over-exertion the contours of the profile shadow of the patella are seen to be indistinct in front and below.[3]

The patella both of the child and of the adult, in the most comfortable position of flexion of the knee at the femoro-tibial angle of 150° with its proximal end, does not reach much above the edge of the articular cartilage of the femur. *In Little's disease* (congenital rigidity of the limbs) it is situate several centimetres more proximal.[4] Congenital lateral dislocations occur.[5]

In dorsal pictures the patella is difficult to see, in ventral pictures it is seen somewhat better, in profile pictures best of all ; in the latter the shadow of the patella resembles normally a parallelogram with unequal sides and rounded-off corners. In isolated cases the distal third is formed like a beak or tap ; such a form might still belong to the normal. On the average the patella is double as long as it is broad (*i.e.* the breadth in profile pictures). But there also occur very long flat patella=normal.

Transverse fractures and *infractions* are always clearly visible. Linear fractures are very rare, and are sometimes not noticeable in profile pictures,

[1] H. Sieber : Ztschr. f. orthop. Chir., 46/4, p. 555.

[2] J. B. Higgins : Brit. Journ. of Rad., May, 1927.

[3] Sinding-Larsen : Eine bisher unbekannte Affection der Patella bei Kindern. Acta rad., 1, 2. Heft, 1921.—S. Johannsson : Ztschr. f. orthop. Chir., Bd. 43, p. 82.

[4] Peltesohn : Das Verhalten der Kniescheibe bei der Littleschen Krankheit. Inaug.-Diss., Leipzig, 1901.

[5] F. Schultze : Luxatio patellæ lat. congen. 13. Orthop. Kongr.

and even in ventral pictures they have to be carefully sought for; radial fractures or solutions of the bone without special dislocation occur more frequently, and are hardly visible at all in profile pictures. In these cases an oblique projection often affords a good view.

A rare anomaly is the *duplication of the patella*. It is generally present on both sides,[1] and can thus be diagnosed with certainty from transverse fractures or rents in the bone. One such instance with simultaneous Schlatter's lifting of the tibial tubercle was observed in a girl of sixteen years.[2] A similar bilaterality assists us in the equally rare fissure formations

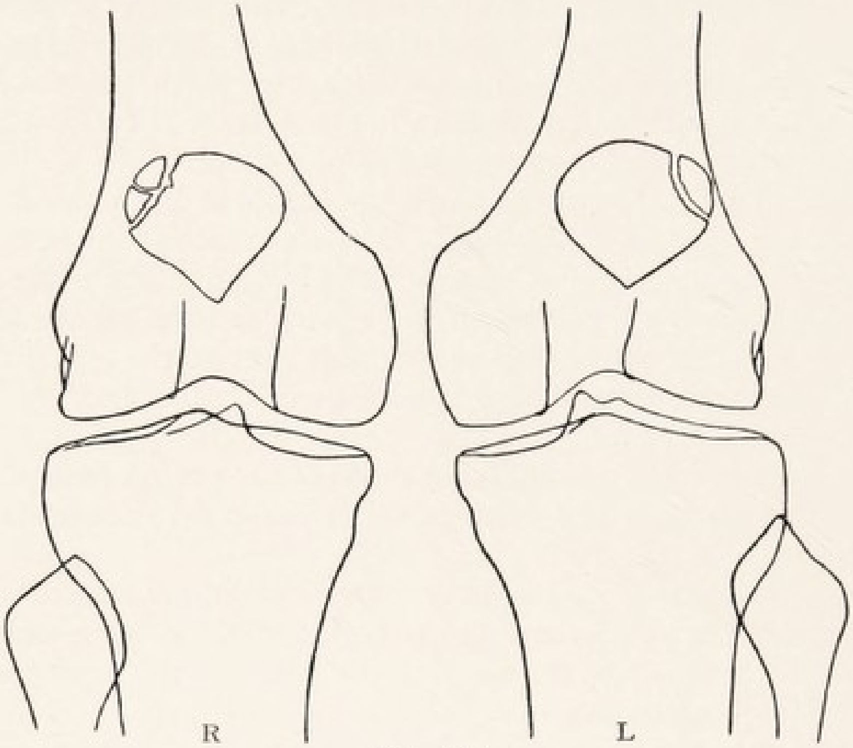


FIG. 109.

of the patella which might be regarded as linear fractures. The author on one occasion saw a bilateral anomaly of the patella (Fig. 109).[3]

One observer describes a case of unilateral patella bipartita with simultaneous Schlatter's disease in the other knee; he therefore classifies patella bipartita along with the picture of osteochondropathia juvenilis.[4]

[1] For röntgenograms of such a case, see Joachimstal: Über Struktur, Lage und Anomalien der menschlichen Kniescheibe. Arch. f. klin. Chir., Bd. 67, Heft 2.—See further: Walther Müller: Über typische accessorische Knochenbildungen an der Patella. Bruns Beitr. z. klin. Chir., Bd. 120, Heft 3.

[2] Hackenbroch: Über einen Fall von congenitaler Contractur der Kniegelenke. Ztschr. f. orthop. Chir., 43, 4, p. 508.

[3] See also H. Blencke: Patella bipartita. Ztschr. f. orthop. Chir., Bd. 42, Heft 5.—Simonett: Schweiz. Ztschr. f. Unfallk., 16, p. 210.

[4] F. Fleischner: Gehört die Patella bipartita zum Kreis der Osteochondropathia juvenilis? Fortschritte, Bd. 31, 1923.—George and Leonard: A congenital anomaly of the patella. Am. J. of Röntg., March, 1925.—A. Hellmer: Patella bipartita. Acta Rad., IV, 2, p. 137.—O. Businco: Geteilte Patella. La Rad. Med., December, 1925.—Walter Müller: Die quergespaltene Patella—eine Umbauzone. M. m. Wchschr., 1924, No. 26.—N. Paus, Tönsberg: A case of patella bipartita. Acta chir. scandin., 1926.

One rather extraordinary alteration was observed by a röntgenologist [1] in an otherwise healthy ten- and eleven-year girl, who complained of pain in the knees after over-exertion at dancing and jumping. The disease was on one side only. The affected patella was painful on percussion; only in one of the two cases were the soft tissues swollen above and below it. The profile views showed the anterior or inferior margins of the patella overgrown with abnormal deposits of lime or bony shadows in the soft tissues (periosteum ?) along and below the base. The author diagnoses periostitis or "epiphysitis" through over-exertion. In one of the two cases the tibia shows signs of Schlatter's disease. The knees appeared clinically to be healthy in both cases, but showed similar abnormalities to a lesser degree. After a rest of six weeks the patellæ were again quite normal four months later.

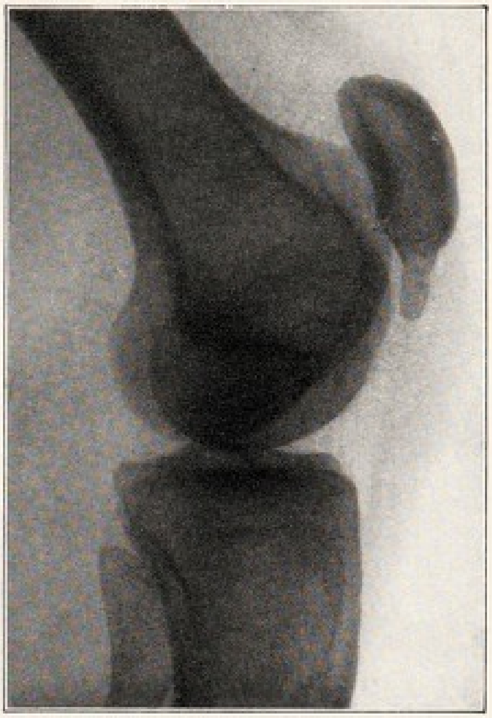


FIG. 110.

If in profile pictures the proximal and distal articular corners of the patellar shadow are not rounded off, but run instead into *sharp processes* (Fig. 104), that is a sign of simple chronic osteoarthritis. In osteoarthritis deformans these points can pass into thick rounded swellings.

We have already spoken of *ossifications at the insertion of the quadriceps* tendon and the ligamentum patella when dealing with the soft tissues; it need only be mentioned here that in isolated cases of these conditions, tendon fibres of periosteum and ossification may form anteriorly in the middle of the convex surface.

Deposits of lime occur frequently in the ligamentum patellæ, but they do not account for the Röntgen finding shown in Fig. 110. The lady, about twenty-five years of age, who was a patient of the author's, had fallen on her knee six months previously. The prepatellar bursæ were distinctly enlarged, and these are not usually affected in deposits of lime in the tissues. There is, however, a deep infrapatellar bursa, situate below the patellar ligament, although usually it is placed further down. The shadow does not appear to arise from this bursal sac, but we are here dealing almost certainly with a "sclerosis of the knee-joint=fatty body" (Hoffa) with calcium deposit. Hoffa operated in six months on forty cases. The condition is often secondary, caused by the irritation of a loose articular body, or of a displaced and torn semilunar cartilage, etc. Also sclerosed fatty bodies that have not calcified give a denser shadow than do the

[1] Sinding-Larsen, Oslo: A hitherto unknown affection of the patella in children. Acta Rad., I, 2, 2, 1921.

normal fatty bodies, the fine structure of which is visible in the Röntgen rays.[1]

Sometimes *tuberculosis* of the bones shows its first foci in the patella. The relation of frequency of incidence in the patella, femur, and tibia, according to numerous statistics, is as 2 : 5 : 6. It is a pity these foci can scarcely ever be seen in the early stages in Röntgen picture. Usually all that is to be seen is a slight atrophy of bone in the whole patella. But if that is not specially marked and all the clinical signs point to tuberculosis of the patella, one should not allow the absence of circumscribed translucent foci in the Röntgen picture to keep us from surgical interference. On the other hand, cases do occur without any atrophy of the patella with quite definite sharply delimited translucent foci (which are naturally best seen in profile pictures). These are cases in which the joint is not affected, and they generally, unless treated, tend to break through to the exterior.

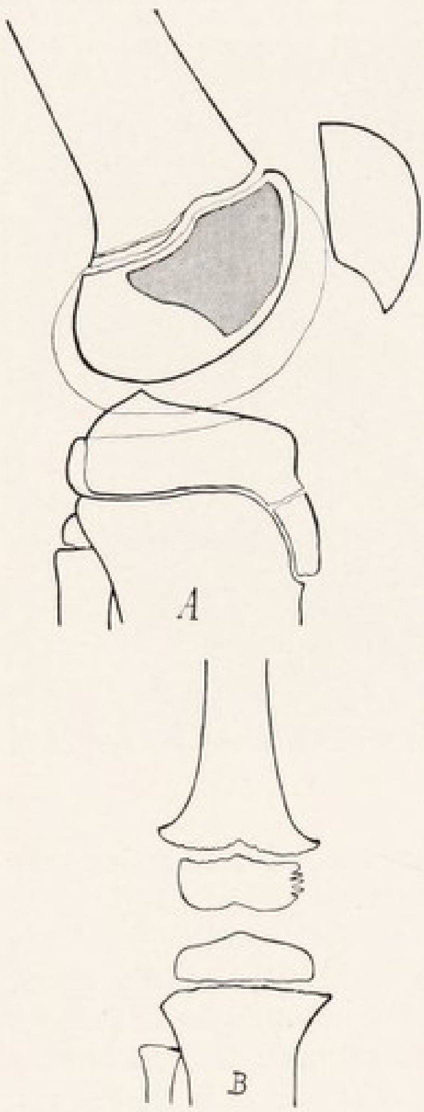


Fig. 111.

Sarcoma of the patella is said to be not uncommon.[2]

In many cases of chronic arthritis or arthritis deformans the patella is covered in its whole periphery with *deposits ;* this appearance is not seen in profile pictures, and in dorsal pictures only when a piece of the edge of the patella projects beyond the shadow of the femur. There is a better prospect of recognising these conditions in ventral pictures.

Distal End of the Femur

The *osseous nucleus* of the lower epiphysis of the femur is generally present in the newly-born child (limits: ninth fœtal month till third month of life). The presence of the osseous nucleus of the distal femoral epiphysis is the surest sign of the maturity of the child. Its diameter amounts normally in the new-born to 5 mm. (see also the remarks, p. 144). The internal and lateral contour of the epiphysial bony nucleus is rough and indented up to about the fifth year and occupied with protuberances.[3]

[1] H. Friedrich: Bruns Beitr. z. klin. Chir., Bd. 136, Heft 1.—Rost: Klin. Wchnschr., 1922.

[2] R. Kienböck: Über die Sarkome der Patella. Fortschritte, Bd. 32, p. 517.

[3] Ludloff: Über Wachstum und Architectur der unteren Femurepiphyse und oberen Tibiaepiphyse. Bruns'sche Beiträge, Bd. 38, Heft 1.

Then the growth of the condyles goes on evenly with smooth margins. Such a dorsal picture of a child of from two to three years (see Fig. 111, B) in spite of its complete normality usually gives the impression to the early röntgenologist of a pathological process; especially the rucked-up corners of the femoral and tibial diaphysis lead to mistakes in diagnosis.

The femur is the largest of the long bones, it is therefore often photographed in suspected *disturbances of growth* in children in cases where the bones of the forearm have not been referred to. For the diagnosis of *Barlow's disease* one chooses with advantage the epiphysial line of the femur. (Regarding other pathological changes of the epiphysial line, see distal end of the bones of the forearm.) Barlow's disease is characterised by a peculiar, very dense, variously broad, slightly wavy, line-like strip, belonging to the most recent zone of the shaft. The Röntgen picture reminds one somewhat of a broad chisel [1] (Fig. 113). It closely resembles that of rickets (Möller regards this particular disease as an acute rickets). Subperiosteal hæmorrhages are present along the shaft of the bone, and accompanying them in Barlow's disease there is an additional shadow around the shaft 1 cm. or over 1 cm. in thickness, which, judging from its density, is not due to the blood alone, but probably also to the ossifying activity or the connective tissue thickening of the raised periosteum or to both.

Even after an interval of years the traces of infantile scurvy are definitely recognisable; the remains of the fragmented-zones are visible as transverse bands with large meshes in the diaphyses three years and more afterwards. The typical peripheral shadow-margin around the rapidly-growing osseous nucleus, corresponding to the fragmented-zones, remains in a severe case of Möller-Barlow's disease as a distinct line for years, around which fresh masses of healthy bone grow out to every side except towards the

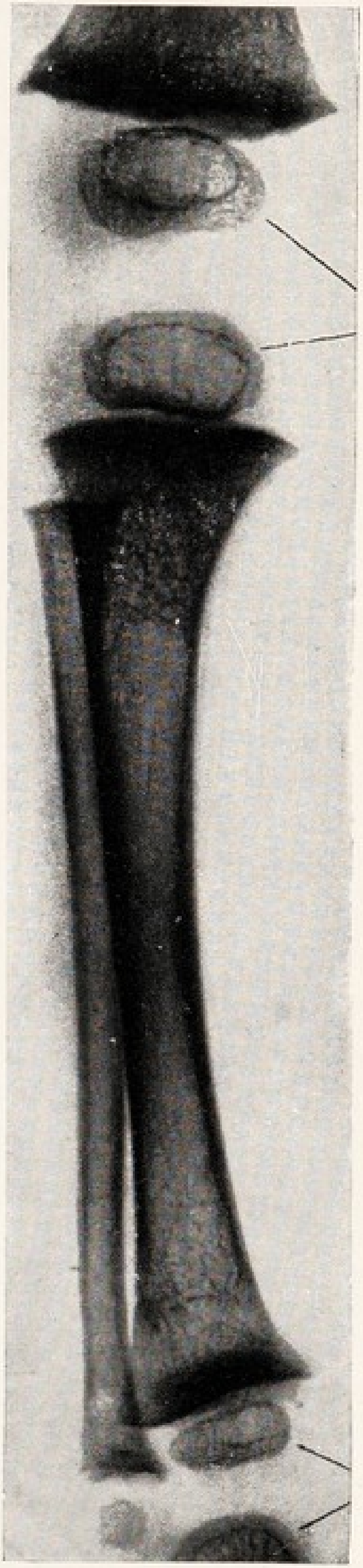


Fig. 112.

[1] Eugen Fraenkel: Die Möller-Barlowsche Krankheit. Hamburg, 1918. See also Grashey, Atlas II, Table 3, Fig. 9.—H. Aron: Alimentäre Anæmie u. Skorbut. Klin. Wochenschrift, 1922, p. 2035.—O. Cozzolino: La fase iniziale del morbo di Barlow. La Pediatria, fasc. 6, 7, 8, vol. 27, 1919.

epiphysial line. Thus the affected epiphysial nuclei give the appearance of a thick-skinned body with a sharply contained transparent nucleus. This picture is typical of a healed scurvy and is pathognomonic for this disease even after the interval of years (Fig. 112).[1] Then stress has to be laid on a sign to which too little attention has been paid, namely, the glassy appearance of the shaft of the bone in consequence of disappearance of the trabeculæ. The three signs, glassy appearance of the bones, broadening of the epiphysial line, and a dense shadow-margin around the ossification-nucleus of the epiphysis, might, taken together, be quite pathognomonic for scurvy. Instead of "fragmented-zone" the term "scorbutic line" has been proposed.[2]

An early ossification of the epiphysial line of the lower epiphysis of the femur has been described in the case of a girl of eight years resulting from a slight trauma on the basis of a previous rickets.[3]

Fig. 113.

To examine *the cartilaginous line in young people* is not easy; for when the focus is not directly over the epiphysial line, the edge of the line near the plate appears distinct and separate from the edge away from the plate. There is a further consideration that here at the femur the epiphysial line is not a plane disc, but is curved in different planes; there arises a confusion of epiphysial lines on the plate, this being naturally more pronounced in profile negatives than in dorsal ones. The greatest confusion, however, is when the patient has turned the knee somewhat—either intentionally or unintentionally—and has been photographed with the knee in an oblique position. In meeting these difficulties in diagnosis we have a fact in our favour, namely, that diseases are extremely rare in the epiphysial line of young people and apart from dislocation injuries hardly ever occur.

In profile negatives of children and adults one should avoid regarding the translucent and approximately sector-shaped area in the shadow of the condyles as pathological (see Fig. 111, A), for instance, mistaking it for a tuberculous focus or the like (so-called epiphysial triangle).[4] This epiphysial spot is quite a normal appearance; it shows in the interior a fine network of bony trabeculæ and is not sharply delimited by a single line, but by the trabeculæ running to its edge being denser. It is said to correspond to the place in both condyles where numerous nutrient vessels enter the condyle and where the reflection of the synovialis is situated. It appears most prominently about the sixteenth year. Thereafter it passes

[1] H. Wimberger: Die Spätdiagnose des Säughlingsskorbutes. Fortschritte, Bd. 32, 1924, p. 17.—V. Nasa, Parma: La Rad. Med., 12, 9, p. 624.

[2] K. F. Pelkan, Boston: Röntgen diagnosis in the early stage of scurvy. Amer. Journ. of Dis. of Children, 1925, 30, 2, p. 174.

[3] H. Jessen: Über einen Fall von traumatischer Störung des Epiphysenwachstums—zugleich ein Beitrag zur Fromme'schen Theorie der Ursache der Wachstumsdeformitäten. D. Ztschr. f. Chir., 182, 5–6, p. 398.

[4] Ludloff: quoted p. 160 of this book.

without any definite dividing line into the transparency of the interior of the diaphysis. Its distal anterior and posterior contour corresponds to the corticalis of the femur between the two condyles.

In the dorsal pictures of adults *the inner condyle* has normally always a distinct form. Its outer margin runs approximately in the form of a flat even arch or a fairly straight line with rounded edges above at its passage into the shaft and below at the edge of the joint. The *lateral condyle* usually shows a lightly ridged irregular outline. The edges are finely rounded

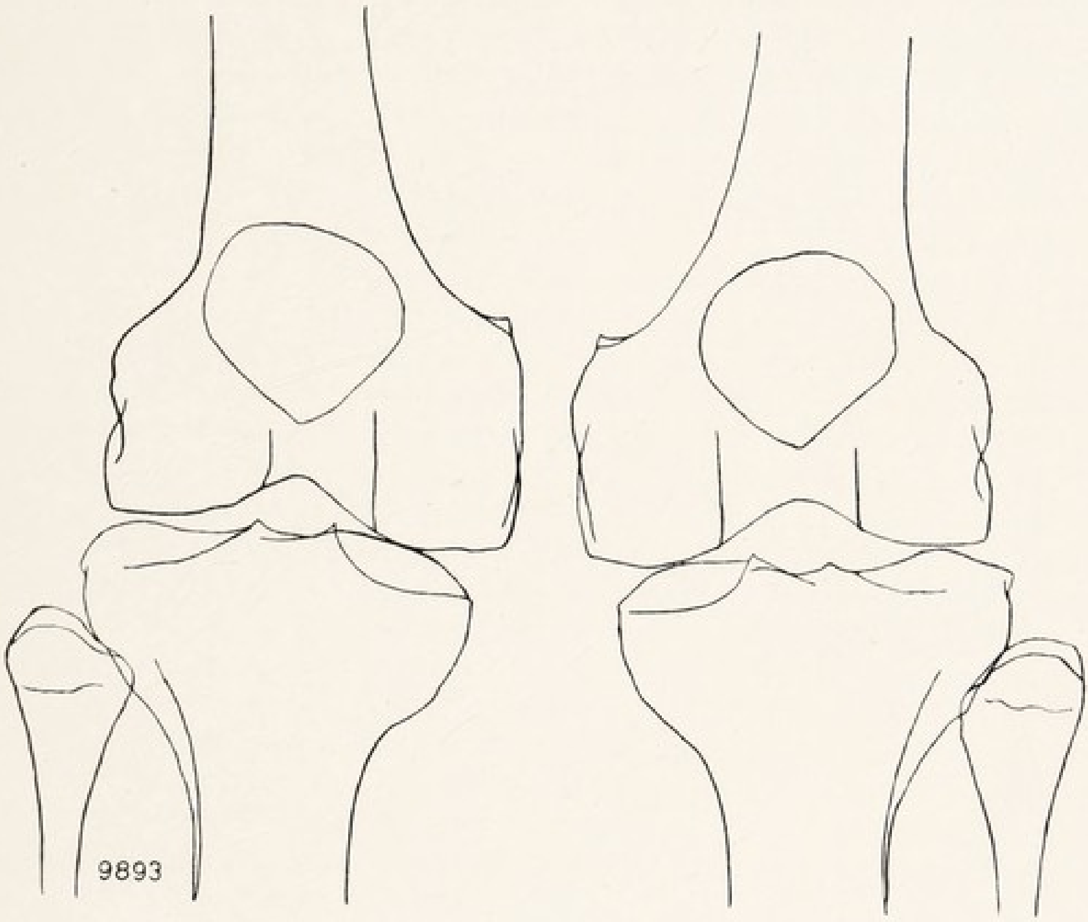


Fig. 114.

towards the joint and become more sharply edged with increase of years, without ever exceeding a right angle.

The epicondyles are only sometimes projected more distinctly out from the condyles.

If little *processes* are situated at the articular edges (as in Fig. 103), that is no longer normal, but a stage or commencement of *chronic arthritis.* In arthritis deformans the excrescences are larger and more rounded. Similar appearances are found in profile negatives and behind, where the condyles begin to pass into the shaft (Fig. 104, C), and, in more advanced stages, above and in front at the trochlea femoris.

The femoral and tibial condyles have unusually regular forms, and *the joint fissure* is strikingly wide in the middle (see Fig. 114, right diagram looking from the reader); such conditions are regarded as accidental findings, and are especially noticeable in negatives taken in the prone position. One thinks first of old rhachitic formations (although indeed the particular patient, in whom the author found the above condition most marked, maintained that his parents had told him he had learnt to walk exceptionally early); compare Fig. 109.

If at *the internal condyle* one perceives an unusual appendage, as Fig. 103, C, illustrates, this is a frequent characteristic of chronic arthritis. This structure can be up to 12 mm. in diameter.

The *planum popliteum* (behind at the passage of the condyles into the shaft) is sometimes seen with a very rough pointed line of demarcation, which is not a pathological appearance (Fig. 115). This is the origin of the gastrocnemius and plantaris muscles. In arthritis deformans the ledge can be especially large. They appear most clearly when the external condyle is projected downwards and forwards.

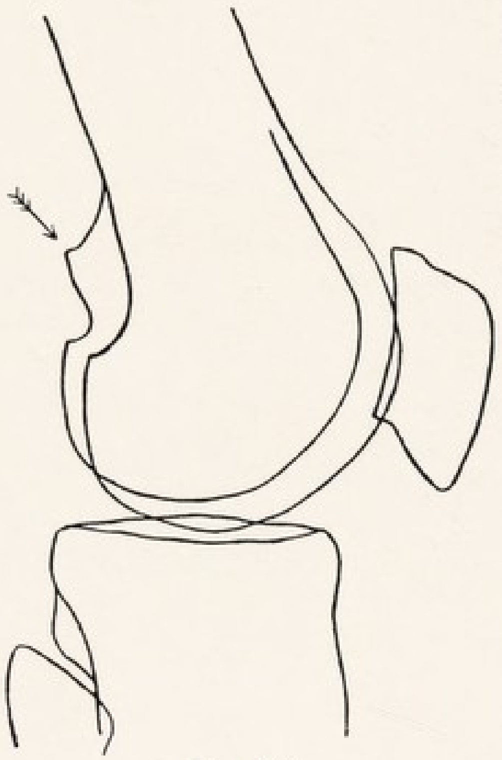


Fig. 115.

The contour of the *femoral condyles in profile* view corresponds normally to a so-called line of evolution, *i.e.* when one divides the marginal curve into short distances, each piece of the arch has a larger radius the more ventral it is. This marginal curve, however, is not always mathematically regular. In individuals who have just attained full growth, especially in those of the female sex, it shows a wonderful mathematical exactness; in men, on the other hand, and in hard-working women, the curves are often interrupted by a flat concavity somewhat ventral to their middle third; this being the spot to which the most anterior point of the articular surface of the tibia reaches in an extreme degree of extension. There are, therefore, found here instead of one large curve, two smaller curves, one on which the tibia glides, the second on which the patella glides.

The *condyle* in immediate opposition to the plate gives always the smaller and more evident shadow.

In the lateral condyle *compact-islands* have been observed; they have no pathological significance, see p. 3.

Primary tuberculous foci are rarely found in the epiphysis, but more frequently in the metaphysis, from which they doubtless easily break through the epiphysial line. Often they cannot be directly seen, but are only indicated by considerable bony atrophy in combination with the clinical history and findings. The articular capsule is then usually already tuberculous. If the latter is not the case then there is usually no atrophy, and the focus can be more or less clearly seen in the röntgenogram. Tuberculous sequestra, in contradistinction to acute osteomyelitic, are not usually recognisable.

A correct interpretation of a very debatable finding in dorsal or frontal negatives must now be discussed in detail. That is the *accompanying shadow of the internal condyle* illustrated in Fig. 116, B. This shadow is observed not uncommonly and appears to be always preceded by trauma ; according to experiments on the subject, whenever the flexed and outwardly rotated leg is abducted at the knee-joint. At the spot indicated there are found the tendon of the adductor magnus, various bursal sacs, the collateral tibial ligament and connective tissue. Calcification of the bursal sac would give other appearances in form, time of occurrence, disappearance, and clinical history (see "Shoulder-joint"). The shadow has been indicated by some as an ossification of connective tissue.[1] We might also have to consider a tear of a bony scale from the epicondyle,[2] although up to date a defect in the bone has never been demonstrated. Further, a tear of the periosteum in consequence of a tearing out of the inferior collateral ligament or a partial tear of the tendon of the adductor magnus with the periosteum belonging to it.[3] Last of all, it has been regarded as a periosteal outgrowth in consequence of a partial tearing of a ligament or tendon.[4] The shadow, apart from detachments of bone, is visible in the röntgenogram at earliest three weeks after the accident. (If one found it immediately after the accident, then it can be only a broken-off piece of bone—provided there has been no previous injury at the affected spot.) The shadow can diminish again in later months and even entirely disappear. The author found it once in a case of quite enormous size (see Fig. 116, C), so that he at once diagnosed a separation of bone—although there was no mention of it at that time in the literature. We have now examined the plate again without finding the slightest defect at that point of the femur. Also small doubled shadows have been observed (see Fig. 116, A). Recently a defect of bone has

[1] At first by the author, see "Hip-joint and Thigh" in röntgenographical representation. Hamburg, 1905, Table 7, Fig. 12. "A small flat dark shadow . . . : which corresponds only to a connective tissue ossification." Later by Pfitzner : contribution to the knowledge of post-traumatic ossifications. Archiv. f. Klin. Chir., Bd. 89, Vol. 4. "A callous formation arising not by a fracture but by a crushing in the tendinous tissue about the bones and in the periosteum." See also König : Ärztl. Verein Hamburg, Münch. Med. Wchnschr. 1903, 23, and *Ibidem :* Ärztl. Verein Marburg, Münch. Med. Wchnschr., 1912, 23.—Ferrarini : La cosi detta lesione tipica dell'epicondoli femorale interno, secondo Stieda. La Riforma medica, 1918, No. 22.—Schüller and Weil : Beitr. z. klin. Chir., 129, p. 71.

[2] Stieda : Über eine typische Verletzung am unteren Femurende. Archiv f. klin. Chir., Bd. 95, Heft 3.—Vogel : Über eine typische Fractur des Epicondylus internus femoris. Arch. f. klin. Chir., Bd. 87, Heft 4.

[3] Preiser : Über posttraumatische Ossificationen. Biological section of the Medical Society of Hamburg. Münchener Medicin. Wochenschr., 1909.—*Ibidem :* Eine typische periostale Callusbildung am Condyl. int. fem. nach Distorsion. Arch. f. klin. Chir., 1910, Bd. 90, 1.

[4] P. Ewald : Kniegelenkverstauchung und Abriss des medialen Seitenbandes. D. Zeitschr. f. Chir., Bd. 117.—See also Günther, Saar : Typische Sportverletzungen. Beitr. z. klin. Chir., Bd. 73, 2. Heft.

been demonstrated in a case with this accompanying shadow at the internal tibial condyle.[1] Although this has not been reported in the other cases, and is not likely to be found often, it is now advisable in all cases to pay particular attention also to the tibia ; for the accompanying shadow has not yet been explained. A recent work [2] is of the opinion that we are here dealing with a new formation of bone—in all likelihood parosteal—within the tendon of the adductor magnus muscle.

Tuberculosis has frequently its site in one of the femoral condyles. The first changes occur in the bone, but do not catch the eye immediately in Röntgen picture ; they occur not in the form of foci, but more in the form of a diffuse translucency of the affected condyle easily recognisable as such ; that is, there can be present a caseous or fungous focus, but the bony

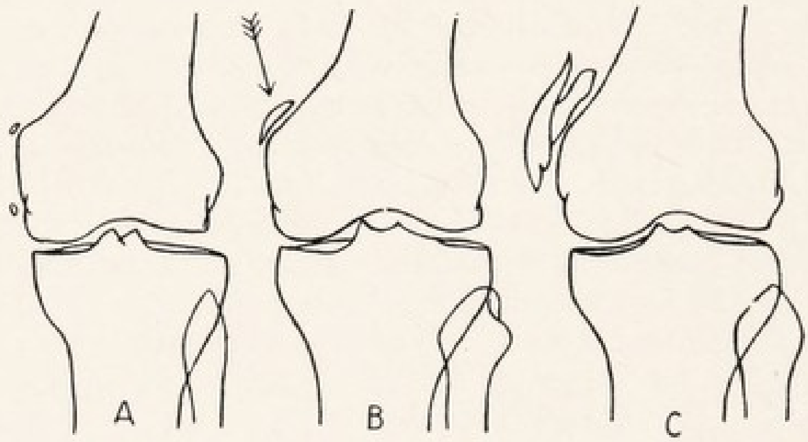


Fig. 116.

trabeculæ enclosed by it, even when they are necrotic, are not completely fused with it ; rather the whole neighbourhood of the lesion and the lesion itself have parted with some of their calcium content (subacute atrophy of bone). A strong clinical suspicion of tuberculosis and an atrophy like this of a condyle entitle the surgeon to operate at once, especially when the corresponding condyle of the tibia contains a normal amount of calcium.

A high degree of atrophy of all the bones forming the joint indicates tuberculosis, in which *the articular capsule* is most extensively affected ; or if tuberculosis is excluded, it indicates gonorrhœa. If the knee is so painful that the patient cannot bear the lightest touch, the gonorrhœic nature of the malady becomes a certainty.

If one finds, with other irregularities in the whole structure of the body, a knee with the bones peculiarly malformed in every part, with a spongiosa structure running differently from the normal and with very large meshes, in which there is still evidence of the original structure, one should think of *ostetitis deformans* (Paget's disease). In this case similar

[1] Kautz: Beitrag zur Kenntnis des Stiedaschen Knochenschattens im Kniegelenk. Fortschritte, Bd. 25, 1918.

[2] P. Schüller and S. Weil: Die Entstehung der Stiedaschen Fractur. Beitr. z. klin. Chir., 129, 1, p. 71.

conditions are naturally present in the entire remaining skeleton, but it is at the knee that they are most pronounced.[1]

The femoral condyles are the favourite site of *myelogenic sarcomata.* Large, sharply defined, translucent, structureless round or oval lesions in the bone are the characteristics of these growths. In profile pictures they are less clear than in dorsal pictures on account of the superjacent shadow of the sound condyle.

Periosteal sarcomata are much more difficult to diagnose, particularly at the beginning, but it is exactly at the beginning that their recognition is of the highest value. Röntgenographically such a tumour is indicated only by a periostitis ossificans; which begins with an acute angle and gradually

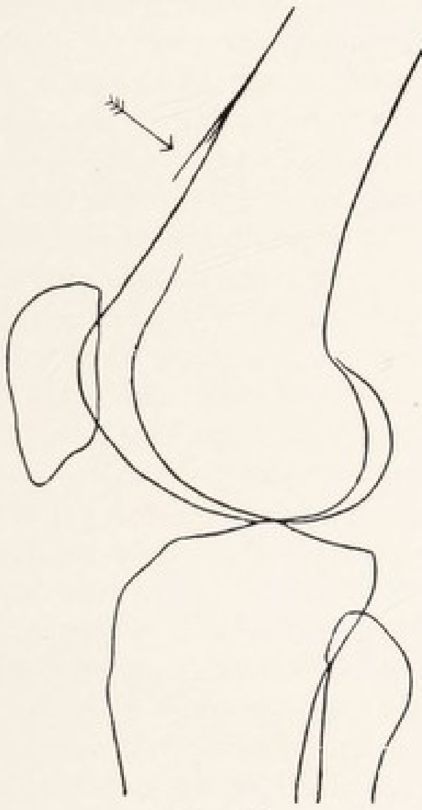


Fig. 117.

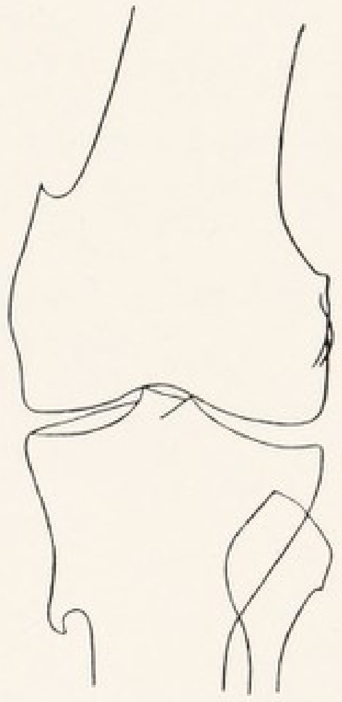


Fig. 118.

fades off into the soft tissues (see Fig. 117), sometimes appearing as if teased up with a sharp spoon. One can only rarely follow the periosteum (extensively ossified in this condition) for any great distance into the soft tissues.

If the proximal ends of the condyles or epicondyles are furnished with sharp directed proximal edges (Fig. 118), then multiple *cartilaginous exostoses*

[1] Röntgenograms with this somewhat rare condition are found in the literature: from the author in Groedel's atlas of Röntgen diagnosis in internal medicine; further, Sonnenburg. Forschritte, Bd. 8, 1915, Table 15, fig. 4.—R. Lawford Knaggs: On osteitis deformans (Paget's disease) and its relation to osteitis fibrosa and osteomalacia. Brit. J. of Surg., October, 1925, XIII, pp. 206–237.—A. Rendle Short: Case of von Recklinghausen's osteitis fibrosa. Brit. J, of Surg., July, 1925, XIII, pp. 170–174. Dawson and Struthers: Osteitis fibrosa. Edinb. Med. J., 1923, 30, 421.—H. C. Cameron: Osteogenesis imperfecta. Proc. Roy. Soc. Med., 1915–16, 9, 43. Section on diseases of children.—D. M. Greig: Osteitis fibrosa. Edinb. Med. J., 1920, XXIV, 324.

are present ; the examination of other long bones of the patient decides the diagnosis.

In a case suspected of *joint-mouse* or in complaints akin to those of an ordinary primary chronic articular rheumatism, there is occasionally found what we see illustrated in Fig. 119. This pathological appearance has always the same form and is always situated at the same spot, namely, at the internal condyle of the femur in the region of the insertion of the posterior crucial ligament (at the head of the radius a similar process is said to have been observed several times). Here there is doubtless the solution of part of the bone (plus cartilage), and we are dealing with quite a definite picture of disease, the so-called *osteochondritis dissecans.*[1] At operation it has been found that the cartilaginous covering of the separated piece of bone remained intact with the rest of the cartilaginous surface of the joint and was marked only by a slight yellow-white discoloration. When the lesion is clear in profile negatives, one sees that it extends pretty far anteroposteriorly. The cause of this circumscribed piece of bone is still quite a mystery ; against trauma there is its frequent bilateral appearance. One should never omit a röntgenogram of the other knee. Young men are chiefly affected. Osteochondritis dissecans doubtless plays the most important rôle in the origin of free articular bodies ; we see in it the commencing stages of joint-mice ; and probably the affection is at first latent for years, without causing the slightest trouble, so that it is perhaps often diagnosed as an accidental discovery. Signs of arthritis deformans are entirely absent in these cases. By far the most probable view is that the affection is first caused by a traumatic injury of the popliteal artery (through small and often repeated wrenches of the knee-joint).[2] One author refuses to recognise osteochondritis disse-

Fig. 119.

[1] First correctly recognised by König. A complete synopsis by Neumann, Baden-Baden : Beitrag zur Kenntnis der Osteochondritis dissecans. Grenzgebiete der Medizin und Chirurgie, Bd. 30, 1. and 2. Heft, 1918 (with complete list of the literature).—R. Sommer : Die Osteoch. diss. König. Eine klinische und pathol.-anat. Studie. Beitr. z. kl. Chir., 129, 1.—Axhausen : Über die Osteochondr. diss. Königs. Kl. Wochenschr., 1924/24, p. 1057.—v. Dittrich, Innsbruck : Zur Frage der O. d. des Kniegelenks. Verh. d. D. Ges. f. Orthop., 19. Kongress, 1924. (Trauma, and in the same category as Köhler-Schlatter-Perthes.)—*Ibidem :* Virchows Archiv, Bd. 258, H. 3.—Löhr : Über Spontanheilung bei Osteoch. diss. des Kniegelenks. M. m. W., p. 1163.—M. S. Henderson, Rochester : Osteocartilaginous joint bodies. Railway Surg. Journ., November, 1918.—Maurice Bernstein : Osteochondritis dissecans. J. Bone and Joint Surg., April, 1925, VI, 319–29.—A. Rendle Short : Case of von Recklinghausen's osteitis fibrosa. Brit. J. Surg., July, 1925, XIII, 170–74.

[2] Ludloff ; see the complete critical work of Nigst : Über Osteochondritis dissecans, mit besonderer Berücksichtigung des Ludloffschen Krankheitsbildes. Münchener Medizin. Wochenschr., 1919, p. 1223.—See further, Kappis : D. Ztschr. f. Chir., Bd. 171, Heft 1, 2, 1922.—Roesner : Beitr. z. klin. Chir., Bd. 127, p. 537.

cans as an independent form of disease, and explains the origin of the articular bodies mechanically, in which the question whether the detachment is sudden or due to a gradual separation is a subordinate one. The matter of what is the cause is really the result of articular and muscular mechanics. In certain unfavourable combinations of joint-setting and muscle contraction very considerable forces can be brought into play : "self-destruction of the motion-mechanism."[1] Another investigator advocates a purely traumatic genesis or an incomplete detachment from the cartilage or from the osteo-cartilaginous bodies.[2] Osteochondritis dissecans and intra-articular fractures may be only different grades. Again, a third observer reports :[3] The articular bodies of the knee-joint and elbow-joint might not have been produced by trauma, but in relation to a local necrosis with the cartilage at first intact and then delimited by a thick connective tissue and fibro-cartilaginous layer (osteochondritis dissecans of König), as in Perthes, Köhler, and Kienböck diseases. The primary change might be an aseptic epiphyseo-necrosis, the causes of which are still unknown (bland mycotic embolisms ?).

The semilunar cartilages are not ordinarily visible in Röntgen picture ; they become partially visible by insufflation of the knee with oxygen. But even then it is not at all easy to diagnose an *injury of the semilunar cartilages*.[4]

In the lateral condyle of the femur *compact-islands* have been encountered, see " General."[5]

Similar to the condition on the proximal end of the humerus (Fig. 53), there is also at the distal end of the femur of adults (in chronic joint diseases) in profile pictures in front at the spot where the *epiphysial line* originally was, a small fissure that gives the impression that there had been an incomplete fusion of the epiphysis with the shaft. At operation there was found a tuberculosis of the capsule.[6]

The fibula affords *the orientation*, which is the external and which the internal condyle. If this is not projected on the plate one recognises the internal femoral condyle because it is larger, runs out further, and because the internal boundary line of the shaft of the thigh attains the condyle in a longer gentler arch.

[1] H. Burckhardt : Über Entstehung der freien Gelenkkorper und über die Mechanik des Kniegelenks. Beitr. z. klin. Chir., 130, 1, p. 163.—See also : v. Dittrich, Innsbruck : Über Osteochondrolysis traumatica. Virch. Arch., 258/3, p. 795.

[2] Häuptli, Aarau : Über Osteochondritis dissecans. Beitr. z. klin. Chir., 131/2, p. 395.

[3] Axhausen : Fortschritte, Bd. 33, p. 306.

[4] Wollenberg : Die normale Anatomie des Kniegelenks im Röntgenbilde nach Aufblasung der Gelenkkapsel.—Wollenberg : Gelenkweichteile im Röntgenbilde nach Sauerstoffeinblasung. Archiv. f. physikal. Medizin und med. Technik, Bd. 2, Heft 3 and 4.

[5] See Grashey, Atlas I, 4th edition.

[6] According to a private communication by Dr. Glogau one need not think the appearance is dependent on a late closure of the epiphysial line (for it is well known that in tuberculosis the opposite is the case) ; we have rather to think of an increased inflammatory absorption at a weak spot.

THE THIGH

Shaft of the Femur and Trochanters

The *ossification* of the *diaphysis* of the femur begins in the eighth fœtal week.

At the juncture of the distal and middle third of the femur typical *fractures* of the severest kind occur ; if these be photographed only in the dorsal position, they can easily be overlooked by the inexpert, especially if the negative is not an exceptionally good one, because (in this break) the fragments do not usually suffer the slightest medial or lateral deviation. In these cases the proximal fragment is dislocated backwards, which only a profile photograph brings into view.

Regarding *inbendings* and *spontaneous fractures* of the shaft of the femur, see " Shaft of the bones of the lower leg. Tibia."

Slight *inequalities* of the contour of the *corticalis* indicate old traumata of slight degree. If in addition the transparency of the *marrow-cavity* has completely or partially disappeared, we have to deal with old osteomyelitic or old syphilitic processes.

Solitary cartilaginous *exostoses* are quite a frequent appearance in the femur. If they are large they cannot be misinterpreted ; if small they can be mistaken for periostitis ossificans traumatica of a severe kind. Very elevated *periostitis* (up to 4 cm. high) may indeed occur after certain traumata (*e.g.* a kick from a horse). In the differential diagnosis it should be noted that the latter have a smooth rounded outline, while the cartilaginous exostoses run out sharply and are sometimes surmounted at their end by a rough cauliflower- or water-lily head.

General periosteal deposits in the long and short tubular bones, with exception of the middle and terminal phalanges, = generalised periostitis hyperplastica, see " General."

Periosteal sarcomata are not at all rare at the femoral shaft, and are in their beginnings very difficult to diagnose with the Röntgen rays. The bone is thereby quite intact, and only a short *periostitis ossificans,* shading off in the direction of the soft tissues, characterises the condition (see Fig. 117).

An *acute infectious osteomyelitis* can offer a similar picture in its first beginnings, long before it comes to sequestration. The clinical condition will easily determine the diagnosis.

Larger irregular shadows found in the vicinity of intact bone or in apposition to it, about the tenth week and onwards after an injury, correspond to *ossifications of torn muscles* or tendons. Several months later one can usually ascertain a reduction in their size.

The *osseous nucleus in the small trochanter* appears about the eighth to the tenth year, its definite union ensues about the eighteenth year, that is, very late ; this should be remembered before incorrectly diagnosing a fracture at this point.

If on one side the region of the small trochanter is altered in a singular way (which cannot be well described or clearly illustrated by diagram) : [1] Broadening of the corticalis with more or less sharply delimited translucent spots in it, and in addition slight curvature of the whole thigh-bone, one has to do with the so-called *Ollier's interruption of growth* (unilateral multiple chondromata) or other multiple chondromatous affections. The rest of the skeleton should be examined röntgenographically.

Fractures occur in the small trochanter ; to diagnose them from an epiphysial line is not difficult ; in the latter case a distinct shadow is all that is visible ; in fracture the shadow is seen always to be dislocated as well.

The contour of the small trochanter, which normally describes a semi-circular-like arch, is sometimes found drawn out into a point proximal and medial months after accidents to the hip. In these cases we have to deal with tearings of the tendon of the ilio-psoas muscle and subsequent ossification of the same.

If the *small trochanter* is not to be seen in the röntgenograms of adults it means that the leg was rotated inwards during the photograph ; on the other hand, if it is projected in its totality, the leg was strongly rotated outwards. It is only in marked deformities of the femur or of the femoral neck alone (coxa vara) that this bony landmark is not clearly distinguishable.

There sometimes appears *at the level of the small trochanter* or somewhat below it in the internal soft tissues of the thigh, a *single focus of bony density* and of varying size (Fig. 120). At the same time there are almost always definite signs of tuberculosis. This picture is visible sometimes on the diseased side, sometimes on the healthy, sometimes bilaterally symmetrical ; it occurs both in young and old, in men and women. An autopsy has never yet been made in any case. Calcified glands are assumed to be the cause, especially the superficial inguinal lymph glands. One should avoid confusing this manifestation with splinters of bone, foreign bodies, myositis ossificans, or the like.[2]

In the *great trochanter* one or several fine *osseous nuclei* appear between the third and ninth year of life, and then unite together. The epiphysial line runs at first in a straight line, inclined at an angle of about 45° ; in definitely rhachitic femora, on the other hand, it runs quite horizontally. The complete bony union is completed by the twentieth year. The part of the epiphysial line that remains visible to the last is at right angles to the shaft when the leg is rotated outwards. As its translucency stops suddenly in the shadow of the bone there is a danger of diagnosing it as an infraction.

In the great trochanter several kinds of *bone diseases* can be distin-

[1] Good illustrations of these peculiar changes are found in A. Köhler : Normale und pathologische Anatomie des Hüftgelenkes und Oberschenkels in röntgenographischer Darstellung. Röntgen-Archiv, Hamburg, 1905 ; further in Burchard : Fortschritte, Bd. 19, 1913, and in Bojesen, *ibid.*, Bd. 24, 1917 ; the latter work with complete list of the literature. —Hackenbroch : Fortschritte, Bd. 30, p. 432.—Johannessen : Mschr. f. Kindhlk., Bd. 25, p. 294.

[2] Levy, Dorn : Beitrag zu den für die Röntgendiagnose wichtiger Weichteilverknöcherungen. Berl. klin. Wochenschr., No. 35, p. 1918.

guished : *tuberculosis* (trochanter indefinitely illuminated, contour not well defined towards the soft tissues, large diffuse dense shadows [1] in the surrounding soft tissues) ; *acute osteomyelitis* (irregular translucency with rough periostitis ossificans) ; *cysts* (transparency with sharply marked edge and now and then dense bony lines through the transparency) ; *sarcoma and carcinoma* (translucency with sharply marked edge).

The most frequent finding is a spine-like *ossification of the tendinous insertions* (Gluteus medius ; occasionally the gluteus minimus, the obturator internus, and the pyriformis muscle).

In estimating the whole form of the shadow cast by the *great* trochanter

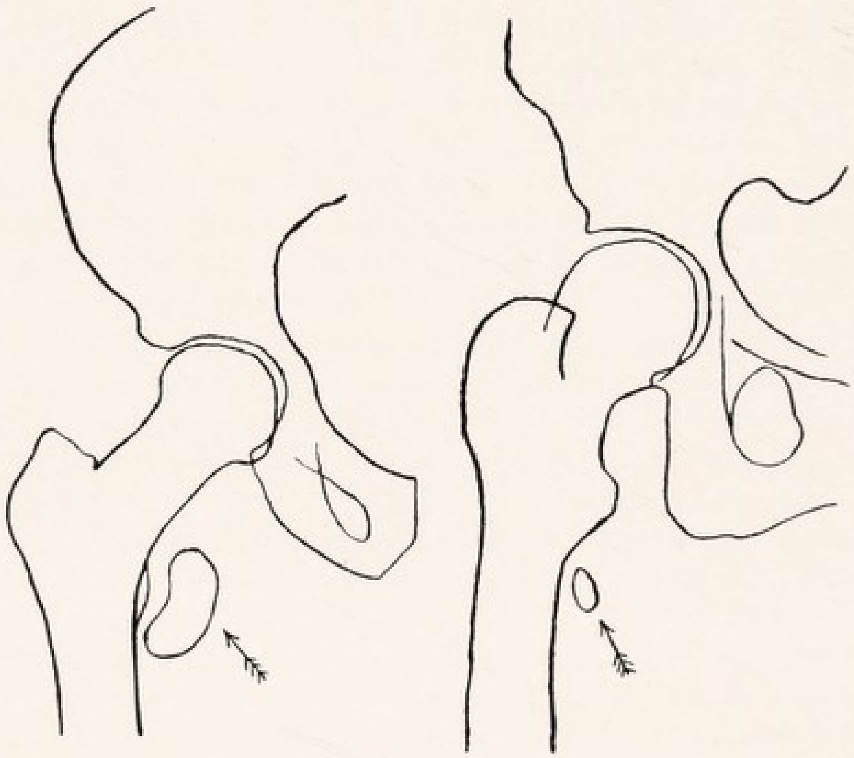


Fig. 120.

we should remember that this trochanter projects quite a different shadow on internal rotation from what it does on external rotation of the leg. The best view is obtained on internal rotation (while the *small* trochanter is best seen on external rotation).

In adults suspected of fracture *the whole trochanter* sometimes appear enlarged and broadened (as in Fig. 121, A and B) with considerable mix-up of corticalis and spongiosa-structure, without any definite line of fracture being seen. And nevertheless a severe fracture with complete solution of continuity is present, the typical *intertrochanteric fracture.* The invisibility of the line of fracture and the fracture-fissures is due to the fact that the break is projected in an oblique plane of about 45° inclination to

[1] See also D. Y. Keith : Tubercular Epiphysitis of the greater Trochanter. Am. Journ. of Röntg., September, 1922.—C. Thurstan Holland : A note of sarcoma of bone. Arch. Rönt. Ray, 9, pp. 187 *et seq.*

the photographic plate in dorsal and ventral exposures. The broadening may be considerable, and is occasioned by the two fragments over-riding at the fracture surfaces by one or several centimetres and staying in this position, being usually impacted. The proximal end of the great trochanter appears to have a special tendency to fracture in a special way and to bend inwards into a horizontal position (Fig. 121, A).

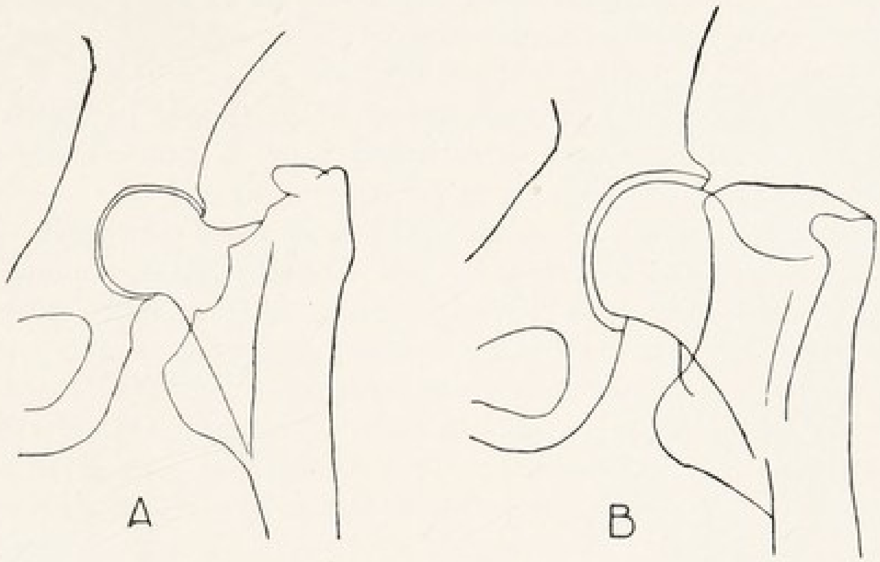


Fig. 121.

The author once saw a *compact-island* the size of a hazel-nut (see "General") in the spongiosa below the great trochanter in otherwise intact bone. The patient complained of the consequences of a slight injury.

Soft Tissues of Thigh and Hip

For estimating the soft tissues, unless it is calcifications that are represented, the negative only is of value.

The lateral part of the *fascia lata* can often be clearly followed from the anterior superior spine to beyond the great trochanter, and in adults better than in younger persons; the density of the fascia opposes a considerable resistance to the Röntgen rays, which is still more evident in contractures of the hip-joint. Almost all the larger *muscles* and *tendons* can be followed to the knee, although to determine single shadows which partly cover each other completely and partly intersect is not in every case easy. In dorsal pictures the external contour of the vastus externus muscle and of the vastus internus are sometimes very plainly marked. The muscle-belly of the rectus femoris is not seen in dorsal pictures, but in profile negatives it appears more clearly in its course; its tendon is most evident above the patella.

In lateral negatives there is always a very translucent area in the form of a high isosceles triangle, behind the femur over the condyles and reaching up to the middle of the thigh; its base is formed by the origin of the gastrocnemius muscle, its anterior limb by a shadow-conglomerate of the insertions of the vastus externus, short head of the biceps and adductor magnus, and its posterior limb by the flexor muscles of the leg. This transparent part corresponds to the *hollow behind the planum popliteum;* it is filled with fat, and in it run the popliteal vessels and nerves.

Between the trochanter minor and the superior ramus of the ischial bone, there sometimes appear more or less circumscribed translucent areas. These may be regarded as *bursæ* (sciatic bursa of the gluteus maximus, bursa of the biceps femoris ?).

Well-marked coiled *varices* show up quite clearly in Röntgen view, because the subcutaneous fat surrounding them is distinctly more translucent than the walls of the veins and their contents.

The *calcified femoral artery* coincides for the most part with the shadow of the bone, while (see Fig. 105) as the popliteal artery it shows up well in the soft tissue-shadow (in profile pictures). According to a recent communication,[1] a calcification of the arteries supplying the hip-joints can usually be seen in the röntgenogram in " arthritis ulcerosa sicca," " malum senile coxæ," while this is extremely rarely the case in arthritis deformans. A marked sclerosis of the superior gluteal, obturator, and external circumflex arteries might in certain conditions be regarded as an early sign in malum coxæ senilis, even in views showing an absence of articular changes.

For *ossification of the tendinous insertions* and muscles, see above in " Shaft of the femur."

HIP[2]

Neck and Head of the Femur

About the sixth fœtal month the centre in the neck begins to ossify. About the tenth month of life the *osseous nucleus* of the head of the femur appears. At three to four years the future semicircular form is already as a rule clearly visible. The cartilaginous line runs obliquely from above lateral to below and within; it is slightly wavy. After the eighteenth year of life the head ossifies up with the neck (regarding the osseous nuclei of the trochanters, see above, " Shaft of the femur and trochanters ").

A few cases in young children have been observed, in which around the relatively small *bony nucleus of the head* there was present at first a semi-

[1] Kimmerle and Laqueur: Wert der Röntgenuntersuchung für die Unterscheidung verschiedener Arthritisformen. Fortschritte, Bd. 34, 1926.

[2] For the normal Röntgen anatomy of the hip, see the Atlas by A. Köhler: Die normale und patholog. Anatomie des Hüftgelenks und Oberschenkels in röntgenographischer Darstellung. Röntgen-Archiv, Hamburg, 1905; further Grashey, Atlas I, 4th edition; further Wilms and Sick: Die Entwicklung der Knochen der Extremitäten von der Geburt bis zum vollendeten Wachstum; further Hauchamps, Klynens, Mahaux: Atlas de Radiologie normale, Brussels, 1908.—Hasselwander: Die Röntgenstrahlen in der Anatomie; Lehrbuch Rieder-Rosenthal, Bd. 2.—Sessa and Alberti, see note 1, p. 1.—Moreau: Stéréoröntgénographie de la hanche normale et pathologique. Arch. d'Electr. méd., January, 1927.

circle relatively poor in calcium, and towards the joint side of that again a semicircular zone rich in lime, Fig. 122. The process was always the same on both sides, and remained like that at least six months. The nature and cause of this are still indefinite. Rickets does not appear to be the cause.[1] Recently one author [2] has drawn attention to the fact that the growth of bone of the head of the femur is completed not only from the epiphysial nucleus but also from the articular cartilage.

For the Röntgen appearance of osteochondritic and *syphilitic separation of epiphysis* which occur often at the proximal end of the femur, and are easily overlooked, see "Forearm. Distal end," pp. 43 and 44.

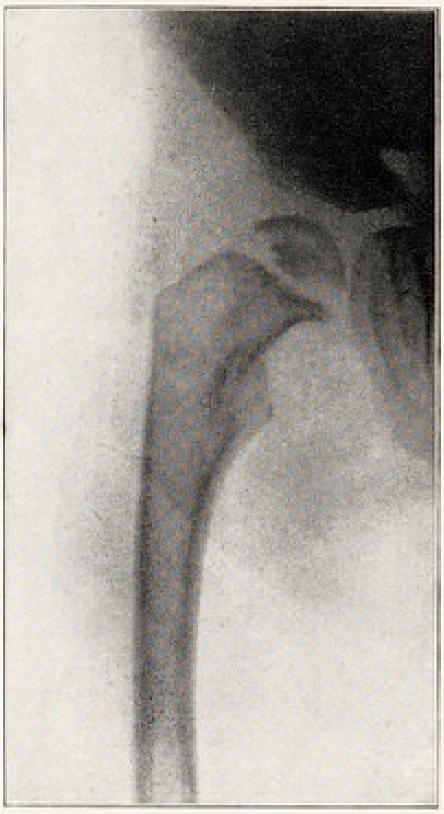


Fig. 122.

The student may find it difficult to determine in *a child's pelvis*, whether a *luxation*, a *subluxation*, or a *normal position* of the femoral head in its socket is present. One should observe that in the röntgenogram the tip of the inner limb of the neck is at the lower border of the acetabulum. Further the prolongation of the visible Y-shaped cartilage, which runs almost at right angles from the linea terminalis, meets the midpoint of the osseous nucleus of the head, when the head is correctly placed in the socket; otherwise not.

We do not mean that this divides the hip-joint into two equal halves. It is true in the normal hip-joint of the newly-born [3] that the acetabular cavity is divided into two equal parts through the direction-line of the Y-shaped cartilage, but as the child grows older the line of the Y-shaped cartilage alters its direction, so that the socket is now divided into an upper half becoming smaller all the time, and a lower half becoming larger all the time. (Also in estimating the situation of the femoral head after replacement of a congenitally dislocated hip, we should give up the old idea that the direction-line of the Y-shaped cartilage divides the femoral head into two equal halves. In the majority of cases the greater part of the nucleus of the head is found below this line.)

The röntgenologist is often asked whether *a coxa vara* is commencing

[1] S. Weil: Ungewöhnlicher Röntgenbefund am kindlichen Oberschenkelkopf. Fortschritte, Bd. 28, 1921.—W. Müller: Über eigenartige Bilder im Hüftgelenk bei rhachit. Kindern. Ztrlbl. f. Chir., 1923, p. 774.—S. R. Löffler: Ein seltener Röntgenbefund an kindlichen Oberschenkelkopf-Epiphysen. Ztrlbl. f. Chir., 1925/8.

[2] Fromme, quoted by Weil.

[3] R. J. Harrenstein, Amsterdam: Beitrag zur röntgenologischen Orientierung bezüglich des Hüftgelenkes beim Kinde. Acta Rad., IV, 4.

or not. Both in children and in adults it is very difficult to decide—unless one takes care in taking the photograph that the foot is vertical to the table or still better slightly rotated inwards—whether the *neck is normal or abnormal.* Thus we cannot tell from B and B_1 in Fig. 123 what the form of the neck is; the leg was here strongly rotated outwards; in A and A_1, on the other hand, with the inner edge of the foot vertically placed on the table,

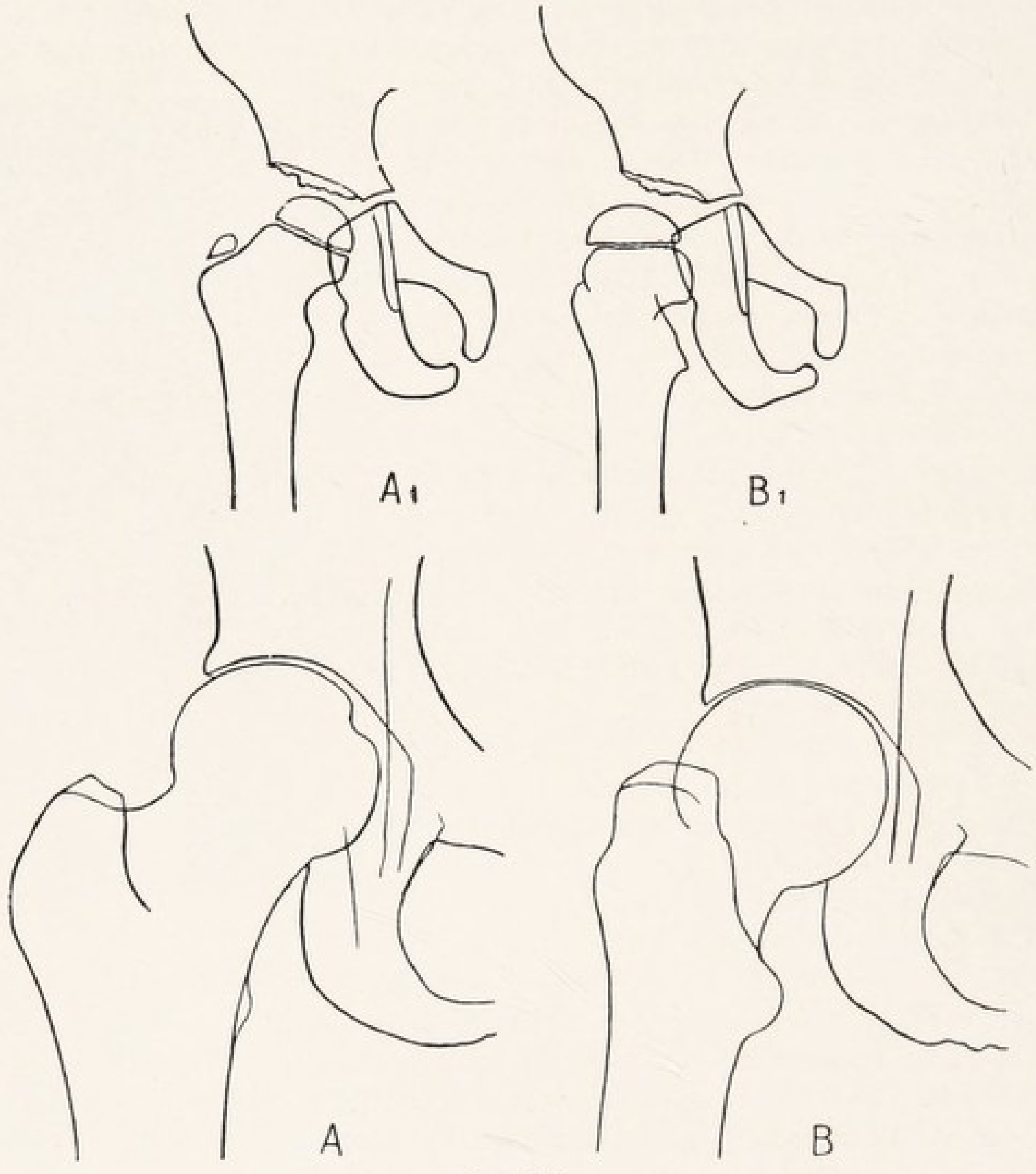


FIG. 123.

or slightly rotated inwards, a good view is obtained of the neck and the head (normal in all four cases). Therefore, one must try in every case to photograph the leg in a slightly inwardly rotated position (Fig. 124, A, coxa vara). Even when the patient can rotate inwards only with the greatest difficulty it is still possible to carry out the photograph, for modern apparatus permits us to secure a good picture of the hip in a second or two. Where the nature of the disease absolutely precludes it, the foot can be rotated inwards as far as it can go, and the tube set as far as possible to the side. One then recognises immediately a part of the upper contour of the neck, even when it is partly overshadowed by the great trochanter. But if this contour be convex or even straight, we are dealing with a fusion-process at the femoral neck (see Fig. 124, B). In more than half the cases a small swelling is placed on the convexity of the arch, which is a very characteristic feature (see Fig. 124, C, arrow).[1] In advanced and extremer cases the expert can make a correct diagnosis even from a photograph with considerable outward rotation, for the picture secured by this projection is quite a typical one, the femoral head especially showing its characteristic features, being evidently displaced downwards partly out of the socket (see Fig. 124, D, and

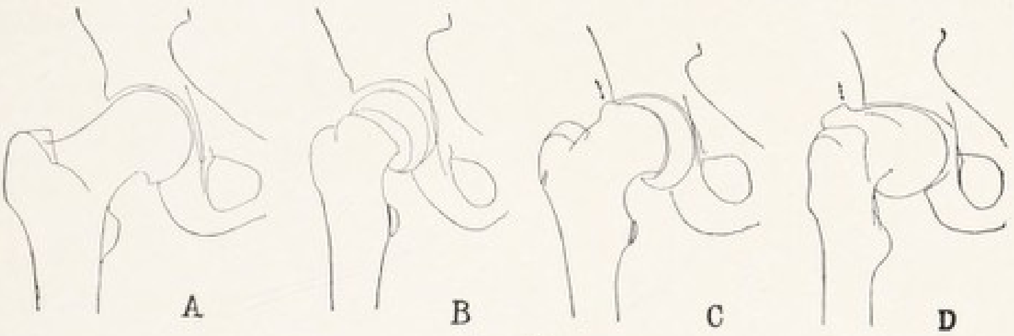


FIG. 124.

A, B, C). If all these measures do not suffice to decide in a case whether the neck is normal or abnormal, for the reason that a view is only securable in a considerable external rotation, there only remains as a last resource the photography of the other healthy femur with exactly the same degree of external rotation. In order to bring into view a simple backward curvature of the neck of the femur it has been advised to photograph the hip-joint with the patient on his back, and the thigh abducted and flexed to 90°.[2]

It is often debated whether coxa vara is a deformity due to the epiphysis of the head being detached or loosened in its connections in consequence of trauma.[3] One should therefore pay particular attention in every case to the epiphysial region.

The abrupt transit of the head into the neck, as shown *e.g.* in Fig. 123, A, disappears gradually in a flattened-off arch, when the same femur has rotated outwards about 20° to 30° (maximal external rotation, on the other hand, as already stated above, yields pictures like B of the same figure).

[1] On the origin of this swelling, see Sudeck: Zur Anatomie und Ätiologie der Coxa vara adolescentium. Archiv. f. klin. Chir., Bd. 59. (The essentials of this work are found briefly summarised in the author's "Atlas of the Hip-Joint and Femur." Hamburg, 1905, p. 25.)

[2] By Lauenstein. For a Röntgen picture of the normal femoral neck prepared by means of this projection, see Grashey, Atlas I, 4th edition.

[3] For an orientation of this subject one may recommend: 1. Fittig: Die Epiphysenlösung des Schenkelhalses und ihre Folgen. (An addition to the subject of Coxa vara and valga adolescentium); 2. Lorenz: Über den Abriss der Kopfklappe, seine Beziehungen zur sogenannten Coxa vara statica seu idiopathica und rationelle Therapie. Verhandlungen d. Deutsch. Gesellsch. f. orthopäd. Chirurgie, 8. Kongress, 1909.—Bibergeil: Gibt es eine Osteoarthritis def. coxæ juvenilis idiopathica? Zeitschr. f. orthopäd. Chir., Bd. 25.

In *coxa valga* of an extreme degree the head of the femur is pressed *upwards* out of the socket. The beginner finds difficulty in recognising the earliest signs of this in the Röntgen picture. Fig. 125 illustrates the condition. The displacement of the head out of the socket upwards and outwards appears in its earliest beginnings as in the figure, and the lower concave contour of the femoral neck forms first a straight line (later a convex line). The cause is said to be a displacement of the epiphyses upwards and outwards.[1]

The *angle of direction* and the *angle of the neck* can be well measured in Röntgen picture when the leg is photographed in a position of internal rotation. The direction-angle [2] varies normally between 25° and 54°. The

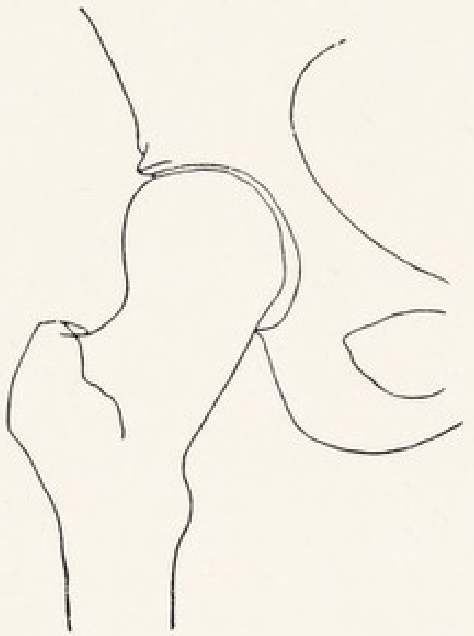


FIG. 125.

FIG. 126

average value of the angle of the neck amounts to 125°.[3] In coxa vara the conditions are expressed better by means of the direction-angle, because it also takes account of the position of the neck to the head. Further, in an arched curved and rhachitic femoral neck the angle of the neck can scarcely be determined, seeing the axis of the neck forms a curved line.

Complete separations in the epiphysial line are not difficult to recognise, for the neck is usually displaced considerably upwards and often directly against the roof of the acetabulum.

A useful criterion of a normal condition of the *head* and *neck* is apparently given by a line drawn vertical to the connecting line between

[1] Walther Müller: Die Entstehung von Coxa valga durch Epiphysenverschiebung. Bruns Beitr. z. kl. Chir., Bd. 137, Heft 1, 1926.

[2] According to Alsberg: "If one unites the two end-points of the cartilage of the femoral cap by means of a line and prolongs this line to where it intersects with the axis of the femur one obtains an angle, which represents what we are seeking." Zeitschr. f. orthopäd. Chirurgie, Bd. 6.

[3] The angle of the axis of the femoral shaft to the axis of the femoral neck.

the upper and the lower terminal points of the femoral neck as seen in the film; this divides into fairly equal parts both the head and the upper portion of the neck.[1]

Röntgenograms, in which the lower acetabular margin, or more correctly the lower contour of the acetabular cavity, is seen in several arches one above the other as in Fig. 126, are indicative of *Acetabular wandering*. If one studies the outline of the femoral head more exactly in these cases, one usually finds more or less marked changes, especially flattening.

Impacted fractures of the femoral neck in adults are easily overlooked, if the photograph has been made with the leg rotated outwards (Fig. 127, A). Sometimes a negative of the same case taken in the prone position gives a better result (Fig. 127, B). The fact that the patient can go about

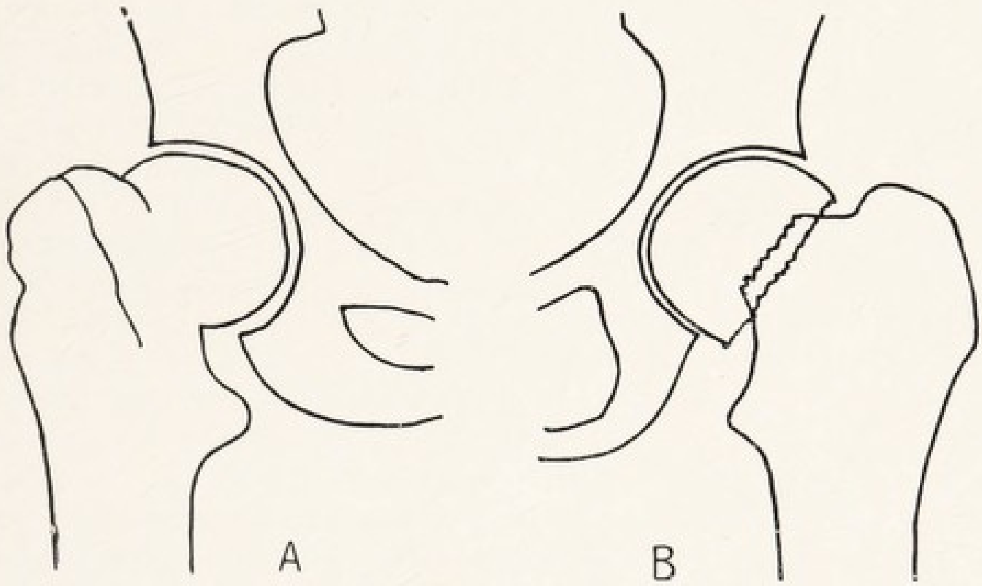


Fig. 127.

for days after the accident does not exclude an impacted fracture of the femoral neck.

One should also remember that *the femoral neck* can be photographed *in cross section:* the patient is in the horizontal position, the healthy leg is bent at a right angle at the hip-joint, and the healthy knee-joint rotated inwards and placed on a high support, the plate lateral to the diseased hip. The Röntgen beam is projected under the healthy thigh.[2]

The form of a normal head of the femur corresponds to about two-thirds of a circle. Its radius amounts in the man to about 2·6 cm., in the woman to about 2·4.[3] In Röntgen pictures it is naturally somewhat larger on projection, according to the distance and the centering of the focus of the tube. If the shadow of the head is not exactly that of a circle, one should not regard it at once as pathological. The closest approach to a circle is found

[1] Grashey, Atlas I, 4th edition.

[2] Lorenz: Die röntgenographische Darstellung des subscapularen Raumes und des Schenkelhalses im Querschnitt. Fortschritte, Bd. 25, 1918.

[3] Fick: Anatomie der Gelenke. Jena, 1904, Bd. I.

in young individuals of both sexes and in women; less often in working men and in older people. In cases which certainly belong to the normal, but in which the form of a head shows a departure from that of a circle, the head remains usually well-marked off below where it joins the neck, while the upper border of the head is more or less flattened.

A very peculiar configuration of the head is shown in Fig. 128. One has here to deal with multiple *cartilaginous exostoses;* the finding is identical on the two sides or at any rate is very similar.[1]

If at the *transition point of the head into the neck* above, or even below, there is a sharp corner, a swelling or a thorn-like pointed *process,* the condition is pathological, and one has then usually to deal with primary chronic osteoarthritis or commencing osteo-arthritis deformans. At the same time one usually finds a swelling at the acetabular margin. This picture is met with quite frequently in riders, who complain of sciatica-like pains and feel unpleasant sensations when trotting.[2]

Fig. 128.

A *translucency* of the *juncture* between head and neck above laterally and below medially is not pathological.

The small concavity in the contour of the head within the joint corresponds to the *fovea capitis;* it is therefore normal, and should not be mistaken for an erosion. It is most evident in the normal joint, when the inner edge of the foot rests vertically on the table.

If the head and neck of the femur together with the neighbouring acetabulum show a *diffuse atrophy of bone* to a moderate or extreme degree, that is, usually—in a case suspected of coxitis—the typical symptom of *tuberculous coxitis,* and particularly its synovial form. It is absolutely necessary to photograph the sound hip on the same plate in order not to overlook the slightest differences in the translucency. If a spot appears isolated in the bone it can often be directly recognised as a translucency, while the calcification in the neighbourhood is normal. As soon as the lesion has broken through into the joint a general atrophy of a marked degree is wont to set in early.

In the early months of *acute osteomyelitis* of the neck the atrophy sets

[1] Köhler: Röntgenbefund der Hüften bei multiplen cartilaginären Exostosen. Fortschritte, Bd. 8, 1905.—See also the view of the Hip in H. Walter: Untersuchungsergebnisse in einer Exostosen-Familie. Arch. f. orth. Chir., Bd. 24, Heft 4, 1927.

[2] König: Bemerkungen zur klinischen Geschichte der Arthritis deformans coxæ auf Grund von Beobachtungen. Archiv f. klin. Chir., Bd. 88, Heft 2.—Amstad: Bruns Beitr. z. klin. Chir., Bd. 102, 3. Heft, 1916.

in rapidly, is very spotty and chequered, usually well defined, and a thick periostitis ossificans is rarely absent.[1]

In a case suspected of commencing tuberculosis of the hip-joint one sometimes obtains *a peculiar shadow picture*, whose type is illustrated in a commencing case (A) and a pronounced case (B), Figs. 129 and 130. There is here a special process of disease whose ætiology is not yet completely explained, the osteochondritis deformans coxae (Perthes), a disease, which has been described also as *pseudo-coxalgia, coxa vara capitalis, Legg-Calvé-Perthes disease.* The first time one sees such a picture one regards the con-

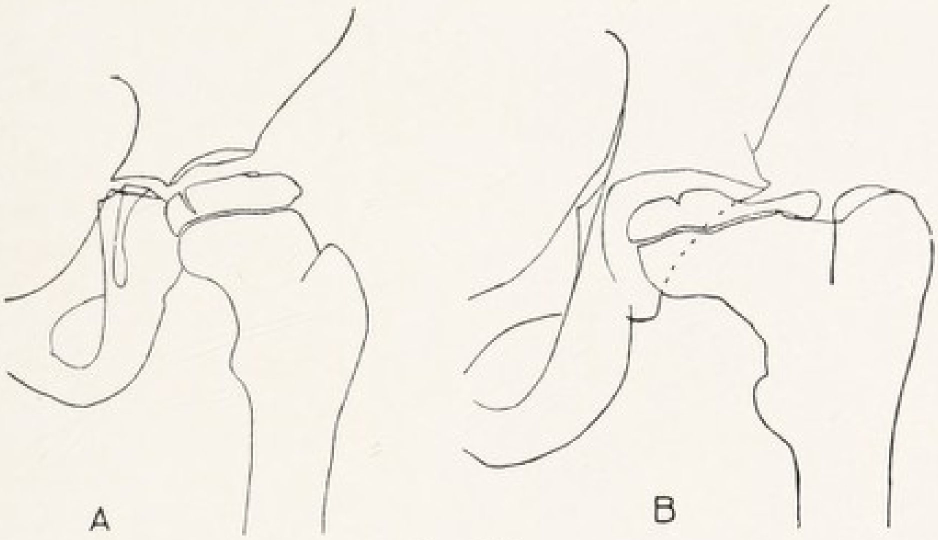


Fig. 129.

dition as a tuberculosis or rickets (this, the author's opinion, being given with all due reserve),[2] although it was regarded as highly remarkable that the disease cleared up completely and without any interference with movement. Clinical findings: a slight halt and temporary pains in the hip and

[1] A very typical example of this and also of tuberculosis coxitis is found in the author's " Atlas of the Hip-joint and Thigh " (Hamburg, 1905, in Table 5, Figs. 6 and 7). For tuberculous coxitis, Figs. 1, 3, and 4 of the same table.

[2] The first Röntgen pictures and technically complete röntgenograms all quite typically formed and commencing cases with a complete description of the clinical findings, were given by me as early as March, 1905, in the " Atlas of the Hip-joint and Thigh," Hamburg, publishers Graefe and Sillem, in Figs. 3, 4, 8, and 9, Table 5, and 3, Table 6, included first in the chapters of " Tuberculosis " and " Rickets." In all my cases attention was drawn to the contradiction of the Röntgen pictures, which appear to show advanced destructive processes, although the clinical findings were slight and the hips rapidly improved after a short rest. I therefore regarded these cases as instances of slight tuberculosis in its earliest stages. Further experience made me certain that it could not really be a tuberculosis; for in the first edition of this book " Limits of the Normal "), which was printed in the first half of the year 1910, that is, in the year in which the first complete work of Perthes-Legg-Calvé and Ludloff appeared, I wrote (pp. 92, 93): " In clinical signs of chronic coxitis it occasionally happens that one finds a coarse flattened femoral-head epiphysis apparently divided into several pieces, associated with bending of the femoral neck in the sense of a coxa vara. After a short fixation in plaster of Paris normal mobility is rapidly restored, but a repeat examination a year later shows to one's surprise the epiphysis again in one complete piece. This is all against the idea that the affection is a tuberculous one. The condition requires further explanation regarding its origin."—Fig. 130, taken in 1904 by the author, is therefore historically the first röntgenogram taken of this interesting pathological condition.

knee, sometimes, though not always, beginning after a slight trauma, Trendelenburg's sign, free flexion and adduction, interference with abduction and certain movements of rotation. Children of from five to twelve years are affected and nearly always boys ; it not uncommonly affects the children of one family and may even appear in two generations. At the beginning of the disease the form of the femoral head may appear quite normal in Röntgen picture even with pronounced clinical symptoms, of which the interference with abduction in free flexion is the most important. After a few months the femoral head becomes flattened out and broadened. In the interior of the head and in the epiphysial part of the neck bordering upon the epiphysial line there appear spots in the normal shadow bone translucent to the rays ; the bone becomes replaced by a fibrous tissue or cartilage poor in calcium and containing giant-cells. In advanced stages, which are outside the limits of the normal, the epiphysis show an apparent disintegration into several parts, usually marked by an increased amount of calcium not unlike certain affections of the scaphoid bone of the foot. The epiphysial line tends to become horizontal, the femoral neck becomes broader, as also does the articular cavity in its middle third. Healing usually follows without the children being sent to bed, in four years on an average. The head of the femur thereby takes on either the form of a circle, which, however, is much more voluminous than the normal (Fig. 131) or a cylindrical—or mushroom—form, which reminds one of an arthritis deformans, especially of the forms found in old age (Fig. 132). In the first case there remains hardly any interference with function. In the cylindrical form, on the other hand, one observes in the final stage a fairly persistent limitation of movement, especially in the sense of abduction, and occasionally a very slight gait, especially when the patient is tired. Perthes' disease can be distinguished from the arthritis deformans of youth by the cartilaginous covering of the joint remaining intact all the time (no crepitation !), by the regular disappearance of the abnormalities visible in the Röntgen plate, and by a clinical cure with a complete, or almost complete, absence of

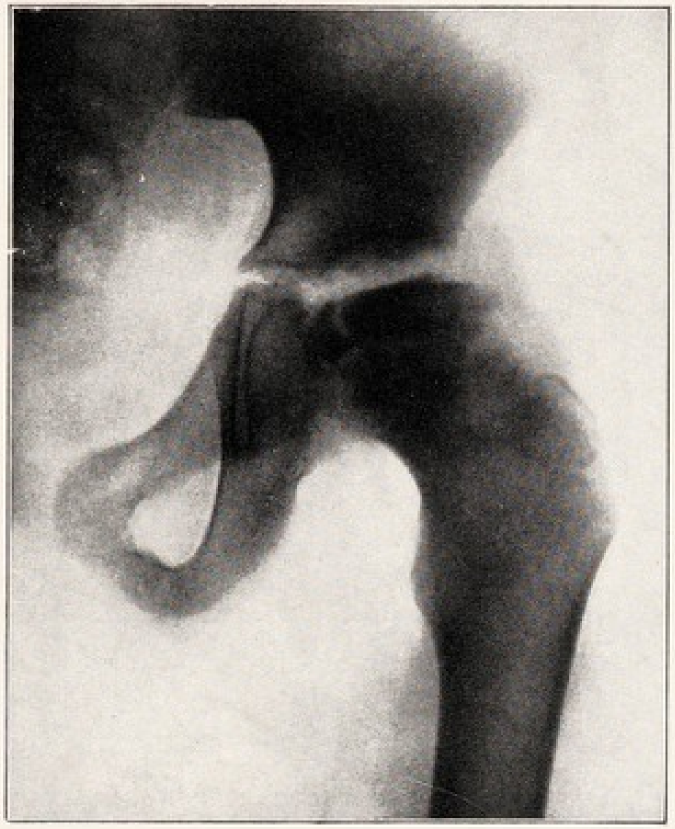


Fig. 130.

symptoms.[1] Another researcher[2] distinguished three forms of the head after healing: (*a*) The head retains a circular form. Head and neck

FIG. 131.[3]

FIG. 132.[3]

can be very well distinguished from each other, and from the great trochanter. (*b*) The upper and frontal part of the enlarged head is near the great trochanter. This part of the head is seen in lateral pictures, much enlarged, situate outside the joint. The upper part of the neck remains

[1] For an earlier complete work with full statement of the literature, see Erwin Schwarz: Eine typische Erkrankung der oberen Femurepiphyse. Beitr. z. klin. Chir., Bd. 93, Heft 1, 1922. There appeared a very thorough work by G. Perthes and G. Welsch: Über Entwicklung und Endausgänge der Osteochondritis deformans des Hüftgelenks, Calvé-Legg-Perthes, sowie über das Verhältnis der Krankheit zur Arthritis deformans. Bruns Beitr. z. klin. Chir., Bd. 127, p. 477 *et seq*, 1922 (with complete list of the literature).—H. Reich: Schweiz. Med. Wschr., 53, No. 50.—Gaugele: Ztrlbl. f. Chir., 1923, p. 1665.—R. G. Giles: The Journ. of Radiol., July, 1922.—Waldenström: Acta Rad., Bd. 1, p. 384.—W. Singer, Basle: Die osteochondritis dissecans juvenilis. Mschr. f. Kindhlk., 1926, Bd. 2, p. 123.—J. Hass, Vienna: Zur Aetiologie der Ost. coxæ juv. Wiener m. W., 1924, Bd. 24, p. 1246.—Büttner, Danzig: Über die Perthes'sche Krankheit. Med. Klin., 1925, Bd. 19, p. 685.—Büttner: Zur Aetiol. u. Pathogenese der Perthes'schen Krankheit. Arch. f. klin. Chir., Bd. 136, Heft 4, p. 703.—Rocher, Bordeaux: L'authenticité et l'autonomie de l'épiphysite fémorale etc. Arch. d'Electr. méd., No. 526, May, 1927.—Moreau, Avignon: Sur un cas d'ostéochondrite déformante infantile de la hanche. *Ibid.*—Kehl, Siegen: Arch. f. klin. Chir., Bd. 138, p. 65.—M. Meyer and D. Sichel: Journ. de Rad. et d'Electr., Tome IX, No. 4, 1925.—Flemming-Moeller: Acta Rad., 1926, No. 23.—Murk Jansen: Platte Hüftpfanne und ihre Folgen. Ztschr. f. orthop. Chir., Bd. 46, 1925.—P. G. K. Bentzon, Copenhagen: Coxa plana. Acta Rad., 1927, No. 41.—H. A. T. Fairbank: Pseudo-coxalgia. Lancet, vol. I, 1921, p. 20, and Brit. J. Surg., January, 1922, p. 366.—J. N. J. Hartley: Osteochondritis deformans juvenalis, Schlatter's disease, and other allied conditions. Edinb. Med. J., 1923, XXX, 254–259.—H. Platt: Pseudo-coxalgia. Brit. J. Surg., 1922, 9, 366.—Abraham Shedlov: Perthes disease, osteochondritis juvenilis. Journal, Lancet, 1923, xliii, 488–494.

[2] Henning Waldenström: The definite form of the coxa plana. Acta Radiologica, Vol. I, 1922.

[3] According to Perthes and Welsch.

invisible. (*c*) The articular surface of the head is uneven and more or less hollowed out. The upper pole of the head is sharp and usually at a lower level than the summit of the great trochanter. Another work [1] in referring to the final stages of the disease says that in bilateral cases the diseases on the two sides are completely independent of each other, appear at quite different periods of time, may heal up on the one side, and not on the other ; on the one side they may appear without trauma, on the other after trauma. The disease develops in hip-joints in whose femoral head-epiphysis no recognisable alterations had previously been seen in reliable negatives. In 20 per cent. the cases went on to cure, clinically and anatomically, in the remainder the clinical course went through the acute stage all right, but left behind considerable changes in form in the femoral head. The final stage of the disease was a short femoral head broadened out on all sides, and mushroom-shaped. The author quoted believes he has established numerous parallels with the so-called malacia of the semilunar bone of the hand. Regarding the ætiology one of the most recent workers [2] inclines to the view that there is no one cause. Among possible causes are congenital and acquired disturbances of development, trauma, and infection ; in general the acquired disturbances are concerned in predisposing, while trauma and infection have to do with the exciting cause. In special cases trauma and infection are the only cause found. A histological examination showed : [3] The cartilage of the mushroom-like head for the most part destroyed, interspersed with bright red granulation tissue and free bone. Connective tissue poor in cells grows from the subchondral marrow which has undergone fibrous change, and undermines the necrotic cartilage. Polynuclear leucoytes, eosinophils, plasma-cells, and round-cells prove the inflammatory nature of the tissue. The wedge-form of the connective tissue foci indicate an embolic origin according to Axhausen's findings. In quite recent cases it has been found [4] that when the Röntgen photograph was taken in the dorsal position with a flexed and abducted hip, the earliest appearances of the disease take place in the anterior quadrant of the femoral head (the patient being thought of as standing), which forms the upper contour in the recommended projection ; and that at first the femoral cap, but soon thereafter the related parts of the epiphysial line and the neighbouring femoral neck are affected in sympathy.

" For soft tissues of the hip," see " Hip," pp. 173 and 174.

It is not within the scope of this work to include the well-marked articular changes of arthritis deformans. But it is the aim and purpose of it to indicate the very earliest and least changes as seen by the specialist. There is naturally no single form of the femoral head and the acetabulum,

[1] Walther Müller : Beobachtungen zur Frage des Verlaufes, der Endausgänge sowie des familiären Auftretens der Osteochondritis deformans coxæ juvenilis. Arch. f. Orthop. u. Unfall-Chir., Bd. 20, Heft 3, 1922.

[2] M. Rehbein : Beiträge zur Perthes'schen Krankheit. Fortschritte, Bd. 31, 1924.

[3] Walter, Würzburg : Zur Histologie der Perthes'schen Krankheit. M. m. W., 1925, 12, p. 499.

[4] W. Müller, *l.c.*

but more or less marked variations peculiar to the different individual constitutions (and in lesser degree to the particular period of life). But over and above this physiological variation there occur trifling differences in form that are always to be considered pathological, and that every beginner must know, if he is to avoid making bad mistakes in diagnosis. Thus, in one or in one of two of the most frequent kinds of arthritis deformans the head adopts a mushroom-like form, so that the height of the head becomes greater than its breadth. Thus in Fig. **133**, A (No. **1693**), the only change present is that the articular fissure is extremely narrow, that is, the articular cartilages are much ground down or shrivelled ; the femoral head does not project laterally from the socket more than three to four mm. beyond the normal. [Eighteen-year girl, with symptoms for three years ; now pains on every movement, even on walking firmly. Knee almost quite stiff. All the joints more or less sympathetically involved.]—B (No. **1625**) : The head above shows a defect, compensating for which there is an increased mass of bone in the acetabular roof ; more rarely there occur typical changes, the origin of which is still completely unknown. Probably the primary change is the defect in the articular head, then follow the changes in the acetabular roof. [Woman ; 1½ years before a very painful acute inflammation. Better at the moment.]—C (No. **6702**) : The articular fissure is above, similar to A, narrowed as thin as a line, and the head turned a little outwards. [Seventy-three-years male ; for three years past complaint of pains and feeling of having to turn the foot inwards on walking.]—D (No. **6605**) : Mushroom deformity of the head in an early stage. Acetabulum above and below with thick projecting margins. Two bony processes above the trochanter minor. [Thirty-nine-year male. Complaints for ten to twelve years ; has done much riding.]—E (No. **2491**) : Joint-fissure (cartilage) well preserved. Earliest lipping deformity above at the transition of the head into the neck of the femur, and at the acetabular roof ; also lipping below at the inferior acetabular margin. [Sixty to seventy-year man. Clinically : commencing senile disease of the hip.] —F (No. **6605**) : Acetabular roof elongated and jutting. In the head very earliest beginnings of mushroom deformity. [Thirty-nine-year man ; rider ; pains in both hips for last ten to twelve years.]—G (No. **1328**) : Head pathologically flattened off above at the transition from the head to the neck, while below the head projects a little from the acetabulum. Joint-fissure of normal width. [Man of about thirty-five years. Similar Röntgen findings at the other hip, but with less pain.]—H (No. **12541**) : Sharp edge at the acetabular roof projecting quite definitely. Joint-fissure above extremely narrow, though broader below. Sharp edges at the transition from the head into the neck above and below, or rather, around it. [Sixty-two-year male ; has ridden much. Rheumatic pains for many years ; he also suffers with gout. Condition worse in the last eighteen months. Impossible to straddle both legs at the hip.]—I (No. —) : Articular fissure narrowed above and to the outside. Transition from the head to the neck is pathologically flattened off. Below, on the other hand, a lipping

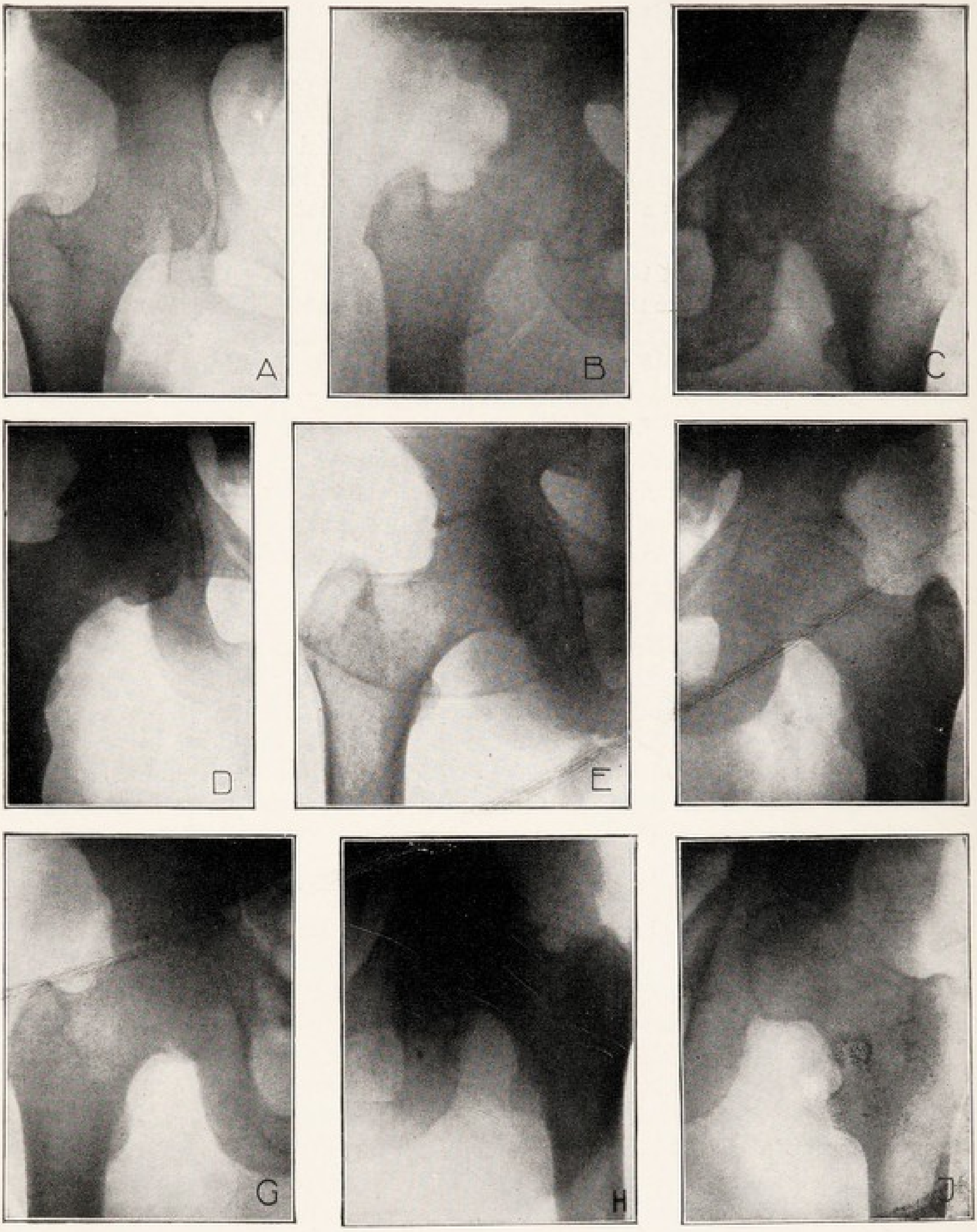


Fig. 133.

at the transition point from the head to the neck. Acetabular roof very little deformed. [History and clinical report are missing.] The bone is certainly pathological, but so slightly so that many beginners might think it normal. It is a pure accident that of these nine views, chosen for illustrative purposes from among hundreds of photographs, four are of men used to much riding. But every rider does not develop changes like this, and the bone must be predisposed, though not to any extent.

Cavity of the Hip-Joint [1]

The articular fissure, which always corresponds to the articular cartilage is in the adult Röntgen view 4 to 7 mm. broad on the average, apart from the region of the fovea capitis, where it may be as broad as 1 cm.

Narrowing of the joint fissure corresponds to an erosion of cartilage and is symptomatic of chronic arthritis (clinically, grating and crackling).

Fig. 134.

Osseous articular bodies in the articular fissure appear to be extremely rare, the author at any rate has never seen any. Also an ossification of the ligamentum teres, which is quite thinkable by analogy, has not yet been reported. When present, it might be diagnosed in the negatives of hips belonging to thin persons. The small round oval or irregularly dense shadows, which we meet sometimes in chronic or deformative arthritis laterally above and internally below at the exit of the articular fissure are not loose articular bodies, but *plates of bone in the capsule.*

If one finds after a short period of disease very numerous and extensive *ossifications of the soft tissues* of the joint capsules, we should strongly suspect a tabetic arthropathy and examine the patient for that disease.

Dense *bean-like shadows* lateral to the upper opening of the hip-joint (Fig. 134) have been observed.[2] The observer had to deal with deposits of lime in a periarthritis coxæ, a disease similar to that in periarthritis scapulo-humeralis. The movement in the joint was not restricted thereby. Pain was the only symptom.

For the introduction of gases (oxygen) into the hip-joint, reference should be made to the section on the knee-joint, p. 152.

Acetabular Cavity

About the date of birth the three *osseous nuclei* of the ischial bone, the pubic bone and the iliac bone (which appeared in the fifth, the sixth,

[1] A complete work with complete literature, see Erwin Schwarz: Eine typische Erkrankung der oberen Femurepiphyse. Beitr. z. klin. Chir., Bd. 93, Heft 1.

[2] Private communication by Dr. Braunschweig of Heidelberg.

and the ninth fœtal month) extend more and more in the floor of the acetabulum, and at a fairly even rate. The line of cartilage between the lateral ends of the ischial and pubic bone is present in every case at the time of birth, but does not appear in the ordinary Röntgen picture, because the ends of the bones mentioned are superimposed in the direction of the rays. In the twelfth year of life in every normal individual the two other epiphysial lines of the acetabulum can be recognised ; they unite by bone in the seventeenth year of life.

The Y-shaped furrow changes its direction with increasing years.

The complete synostosis in the acetabulum to a single os coxæ occupies several years. As a preliminary to this synostosis there appears the ossification nucleus called the *os acetabuli* (Fig. 135) (os cotyloideum, os coxæ quartum, acetabular bone), which is recognisable for some time as an independent piece.[1] Albinus discovered this acetabular bone in 1737, and, according to the views of various anatomists, the synostosis of the hip-socket takes place through intercalated bones, which appear single or multiple, are variable in their size and can be compared with the intercalated bones of the skull and similar islands of ossification (*e.g.* at the glenoid facet of the scapula). The anterior of these bones may be a phylogenetic rudiment, but ontogenetically the acetabular intercalated bones are absolutely homogeneous in form, importance, and variability. As long as there is no persistent os acetabuli, the condition is not dignified with the term pathological. A persistent os may be a purely anatomical variety, occasionally perhaps the symptom of an internal secretory disturbance in ossification. Traumatic, and possibly also tuberculous and osteomyelitic sequestra—all very exceptional—may on occasion be mistaken for an os acetabuli. It appears certain that the os acetabuli, anatomically and röntgenologically very variable, is simply an intercalated bone which appears more or less plainly in the course of every ossification of the hip-joint and disappears soon after by synostosis. Its appearance in Röntgen view is accordingly limited to a very short space of time, about the seventeenth and eighteenth year of life. It is bilateral.[2] Other observers declare the röntgenological os acetabuli is always to be regarded as a pathological formation.[3]

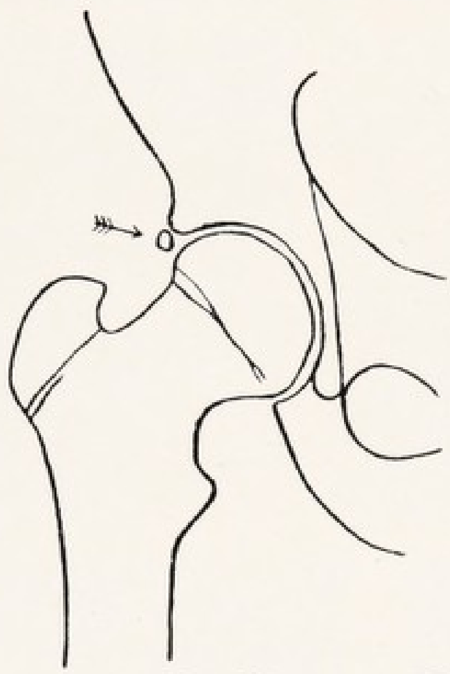


Fig. 135.

[1] H. R. Schinz : Altes und Neues zur Beckenossification. Fortschritte, Bd. 30, 1923 ; see further Nieber : Röntgenolog. Studien über einige Epiphysen-Nebenkerne des Beckens und Schultergürtels. Fortschritte, Bd. 22, 1925.

[2] Almost word for word after Schinz, *l.c.*

[3] Rühle : Arch. f. orthop. u. Unfallchir., 19. Bd., p. 518, 1921.

A good negative of the hip-socket is not obtained by frontal irradiation; during life, and as mentioned already we cannot delineate the line of cartilage between the pubic and ischial bones (the so-called "tear-figure" does not correspond to it; see later). The cartilage between the pubic bone and the iliac bone is all the plainer, and in the normal $1\frac{1}{2}$-year child it is about 1 cm. broad, in the five-year child about 3–4 mm.

In children of seven to twelve years the *superior contour* of the socket is irregularly indented, hillocky, and fringed (Fig. 123, A). That is, normal. One should avoid declaring this condition to be a pathological erosion or an interruption of growth.

The *posterior lower quadrant* of the socket has a sharp contour, and from the fifth to the eighth year forms roughly a right angle at its lateral margin.

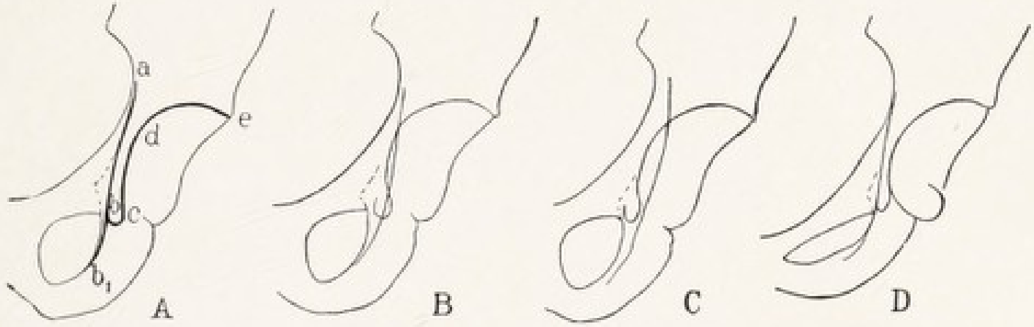


FIG. 136.

The *anterior margin of the socket* is not recognisable in Röntgen pictures, neither in ventral exposures, nor in children, nor in adults.

The *posterior wall of the acetabulum* in adults is always visible and covers normally about three-quarters of the head. In rickety pelvis the head is sometimes completely shadowed by the posterior wall of the acetabulum, for the acetabulum is directed more forwards.[1]

The *roof of the acetabulum* in adults is normally prolonged outwards some 2–5 mm. in length. In simple chronic and deformative arthritis the projecting edge (see Fig. 133, D, F, H) is longer (its substratum is naturally a swelling or edge), sometimes also more irregular, split up, richer in lime or poorer in lime than the normal. At the same time similar changes often take place at the lower margin of the acetabulum or where the head of the femur passes into the neck. Concerning a plate of bone that appears typically in the capsule above the acetabulum, see above under "Hip-joint cavity." One to two centimetres above the spur in the acetabular roof another similar process may appear. That is always pathological, and appears several months after accidents (wrenches). We have here to deal with an ossification of the insertion of the rectus femoris muscle.

The *acetabular cavity* is projected normally as a somewhat flattened

[1] See Preiser: Über die Arthritis deformans coxæ, ihre Beziehungen zur Roser-Nelatonschen Linie und über den Trochanterhochstand Hüftgesunder infolge anormaler Pfannenstellungen. D. Zeitschr. f. Chirurgie, Bd. 89.

semicircle, interrupted in the middle by a depression with a somewhat shorter radius, caused by the deepening of the fossa acetabuli. In addition there are in the depth of the acetabular cavity two other lines, a small curved line and a very long almost straight line. The three lines form elements of a single complete picture in dorsal photographs of the hip, especially when the focus of the tube stands nearer the midline of the body. The resulting figure (see Fig. 136, A) bears a distant resemblance to a tear, and has therefore been called by the author tear-figure, a description that has found general acceptance. The lines mentioned change their position in altered position of the tube, partially intersect, and therefore give the beginner difficulties in diagnosis; the factors to be considered must therefore be referred to briefly. In the *tear-figure* [1] the arch $c\ d\ e$ is the one easiest made out. It is the contour of the acetabular cavity. (When taken exactly it corresponds in every case to a section of the acetabular wall, that would be cut by an imaginary plane laid at right angles to the tangential rays.) The small semicircular arch $b\ c$ corresponds to the part of the bone, where the anterior opening of the acetabular fossa curves round backwards to the wall of the true pelvis, that is, the half-cylindrical corticalis at and over the posterior (or lateral superior) obturator tubercle.[2] The third line $a\ b\ b_1$ is the shadow of the wall of the pelvis running in the direction of the rays. According as the focus of the tube is nearer or further away from the middle of the body, we have to deal with a more ventral surface of this wall or one nearer the spine of the ischium.

FIG. 137A.

[1] These conditions are fully treated in the author's "Atlas of the Hip-joint and Thigh" (Hamburg, 1905), p. 25.

[2] These conditions are best understood by examining the bones. An anatomical atlas is not sufficient.

These three lines do not correspond to borders in the pelvis nor to denser lines in the spongiosa, but to three more or less curved surfaces. If one looks through different röntgenograms of the hip of different persons or of the same person in various projections, one finds the three lines regularly, but their relative positions are very different; but in nearly all the cases the line *b c d e* remains in communication, while *a b* b_1 moves nearer to *c d e* and can intersect it completely, so that the line *b c d* comes to be altogether medial to *a b* b_1. Whatever variations occur in the positions of these lines they can all correspond to perfectly normal conditions, for they are produced by different projections (position of the tube, inclination of the pelvis, rotation of the pelvis). A configuration of lines, as shown in Fig. 136, A, is produced in dorsal pictures, when the focus is over the mid-line of the body (in children also when it is over the joint); Fig. 136, B, arises when the focus is over the joint, and Fig. 136, C, when it is lateral to the joint. (In ventral pictures the conditions are naturally the converse.) Diagrams like Fig. 136, D, are produced, when the half of the pelvis under examination is more inclined and turned to the plate. We meet this picture therefore as a rule in contractures of the hip-joint in a position of flexion. In these cases further the translucent area of the obturator foramen is quite narrow or completely absent, for the shadow of the lower ischial ramus comes to cover the horizontal pubic ramus. The new additional arch open medial and proximal that appears in the lower shadow of the acetabulum, corresponds in the vicinity of C to a small portion of the facies lunata; while the freely curving part corresponds to the thick bony swelling delimited upwards and laterally by the tuber ischii. According to the laborious control-experiments of another radiologist [1] this opinion of the

Fig. 137B.

[1] K. Takagi: A radiographic study of the pelvic outlines. Journal of the Medical Society of Tokio, 1918 (Japanese).

author's is not quite correct, but when the lateral border of the tuber ischii and the posterior cornu of the lunate surface are both completely excluded, the arch in question was still visible. In cases where the convex wall of compact bone of the tubero-glenoid sulcus is absent (*i.e.* the groove extending between the posterior cornu of the lunate surface and the lateral border of the tuber ischii), the arch in question can no longer be demonstrated, although the posterior cornu of the lunate surface and the border of the tuber ischii remain still in position. But when the sawn-out part of the wall is replaced in its original position, the arch in question is brought into view again. Hence the arched shadow opening to the interior in the lower area of the acetabulum is nothing else than the wall of the tubero-glenoid sulcus. This arched shadow may therefore be called the *tubero-glenoid paraboia.*

Fig. 138.

In many röntgenograms in which the tube is centred directly above the joint, the tear-figure becomes still more complicated by the contours of the ischial spine being cast into the tear-figure.

It is obvious that slight *changes* of the acetabular cavity are only visible when they are in the plane of the socket that is determined by the tangential rays. Erosions and perforations have here to be considered.

The eruption of an *inflammatory perforation* of the acetabulum into the pelvis will not be seen at the line A *b,* for here there is a relatively considerable cortical surface running for several centimetres in the path of the rays ; a defect of small or moderate size may not be seen at all on account of its relative smallness to the whole projected surface.

If one finds the tear-figure breaking off suddenly above and dislocated a little into the pelvic lumen, after a history of injury, a *disruption of the floor* of the acetabulum by the head of the femur has occurred. If the above description has been understood there will be no difficulty in seeing that in the shadow-picture these will be three long lines coursing close to each other (see Figs. 137A and B and 138. 137B is the diagram of the case 137A).

Directly over the line of the roof of the acetabulum there sometimes appears a limited brighter area, which might be regarded as a diseased focus (inflammatory transparency), but this is normal.[1]

Tubercular foci are usually clearly seen in the Röntgen rays, being especially plain with a small aperture. One must naturally know the normal appearance of the socket and do a photograph of the sound side in addition. If the capsule is principally attacked there is present diffuse atrophy of all the parts adjoining the joint.

Now and then one finds a condition as shown in Figs. 139 and 140 (arrow). The whole picture leaves no doubt that we are dealing with a

Fig. 139.

Fig. 140.

fore-arching of the floor of the acetabulum (*protrusio acetabuli*). The most remarkable feature is that although the elevation has apparently followed the pressure of the head of the femur, the part does not give one the impression of being soft bone, but, on the contrary, exhibits an *osteosclerotic density*. The author found this appearance after typhoid and in healed tuberculosis of the acetabulum, and without any definite cause. A. W. Otto was the first—in 1924—to describe this intrapelvic arching of the floor of the acetabular cavity; and since then twenty accurately described cases have been recorded. The cause has been ascribed to a variety of ailments, *e.g.* "abnormal gout," tabes, interruption of growth, arthritis deformans, ostitis deformans juvenilis, static factors, while two well-known authors aver that gonorrhœa of the hip-joint is the only cause of the change. The Röntgen-rays after the first communication revealed quite a number of cases. The first röntgenological observer [2] found in his

[1] Grashey: Atlas I, 4th edition.

[2] Kienböck: Über die mit Protrusion des Pfannenbodens einhergenenden Erkrankungen des Hüftgelenks und ihre Beziehungen zur Arthritis gonorrhoica und Arthropathie bei Tabes. Fortschritte, 1912, Bd. 18.

three cases gonorrhœic arthritis and arthropathia tabica. Others found primary chronic polyarthritis, but traumata also appear to be a causative factor ; further explanations were the consequence of a tuberculosis of the hip, streptococcal sepsis and tumour, and even an echinococcus of the hip (discovered on section). There appears to be an acute form, which is usually due to gonorrhœa, and a " chronic form of gradual intrapelvic acetabular displacement." [1] When one examines one's Röntgen views of such cases it becomes more and more surprising how the arching shows a regularity as if produced by a pair of compasses (see Fig. 139) ; moreover, the whole socket is of a similar density of shadow, that is, homogeneous ; the puzzling fact that it is specially dense in lime has been already mentioned above. It is most uncommon for such characteristics to be present in tuberculous, gonorrhœic, and typhoid cases. The only condition that might correspond to this picture is the primary-chronic form of arthritis deformans. According to the author's röntgenological experience there would really seem to be a particular kind of arthritis deformans, which accompanies a general peripheral enlargement of the acetabulum. In these cases the head of the femur is wont to become gradually reduced in size, and may even partly disappear ; in contradistinction to the two to three other types of primary-chronic arthritis deformans. But in this connection there is at the moment no clear agreement.

PELVIS [2]

Iliac Bone

An *ossification centre* appears in the iliac bone at about the ninth week of fœtal life. The nucleus soon assumes a kidney-shaped form.[3] The smaller ossification centres appearing in the tenth week and thirteenth week (corresponding to the posterior inferior iliac spine and the anterior spine) are not visible on röntgen plates because the projection conditions are not favourable to their photography.[4] (Regarding development, see also under " Acetabulum.")

In many pictures of the ilium in young people *the iliac crest* is separated by a translucent strip up to 4 mm. broad from the rest of the shadow of the bone. That is the normal epiphysis of the iliac crest, appearing in the twelfth year and uniting about the twenty-second year.

Some months after an accident we may meet with pointed spur-like

[1] B. Valentin and Hugo Müller : Intrapelvine Pfannenvorwölbung (Pelvis Otto-Chrobak). Arch. f. kl. Chir., Bd. 117, Heft 3, 1921.—R. Loebel : Zur Protrusion der Hüftgelenkspfanne. Fortschritte, Bd. 36, 1917.—J. B. Waller : Ein " Becken von Otto-Chrobak " mit Fractura acetabuli. D. Ztschr. f. klin. Chir., 168, Bd. 1–2, 1922.

[2] For the normal Röntgen anatomy of the pelvis, see A. Köhler : Die normale und pathologische Anatomie des Hüftgelenks und Oberschenkels in röntgenographischer Darstellung. Röntgen-Archiv, Hamburg, 1905 ; further, Grashey's Atlas I, 4th edition.

[3] So that it has even been incorrectly diagnosed as a kidney.

[4] Quoted after Lambertz : Die Entwicklung des menschlichen Knochengerüstes während des fœtalen Lebens. Röntgen-Archiv, Hamburg, 1900.

shadows at the *anterior superior spine.* Cause: tears of the tendinous insertions with subsequent ossification (sartorius muscle and tensor fasciæ latæ).

An independent osseous centre is reported from the anatomical side (Waldeyer) in the *anterior inferior spine.* It is said to arise in the fifteenth to the sixteenth year and unite with the ilium in the sixteenth to the seventeenth year. From the röntgenological side the occurrence of such a centre has been strongly doubted.[1]

The author in 1926, after nearly thirty years' Röntgen practice, saw his first case of fracture-separation of the anterior inferior spine. It seems to be the only case recorded in the literature. A boy of 13½ years, tall for his age, took a running leap at rackets with all his leg-muscles on the stretch. He immediately experienced a pain in the region of the right hip, but this did not last long and was not severe; it did not cause him to fall, and did not stop him from going on with the game. In the next few days the boy complained occasionally, but he was not prevented two days after the accident from making a two-hour walk over fields and roads without particularly complaining. He suffered from some more slight pains; a medical examination eleven days after the accident was negative; externally nothing was found. Active and passive movement in the right hip was equally free on the two sides, but in flexion with the knee extended, pain was felt below the right loin. Tenderness on pressure was complained of a little below Poupart's ligament and to the outer side of the femoral artery. The röntgenogram showed the following conditions, see Fig. 141. A piece of bone about half the size of a walnut, corresponding to the anterior inferior spine, had been broken off and displaced about 4–5 mm. outwards. Therapy: it was too late to recommend rest in bed eleven days from the accident, so a three-months' rest was recommended with massage and without gymnastics, etc. Three months later a röntgenogram showed the

Fig. 141.

[1] Schinz, *l.c.*

earliest signs of a firm bony union. If one sees markedly *translucent spots* in the shadow of the iliac bone, such manifestation is very rarely pathological, for firstly there occurs a very thin (scarcely a millimetre) spot about the size of a crown piece above the middle of the normal iliac bone, and secondly gases in the intestine produce similar striking transparencies. It is usually not difficult to distinguish which of the two it is. Gas bubbles can be displaced by compressing with a lufa sponge and taking a control photograph. Circumscribed transparencies in the bone do, however, betoken malignant tumours. Sarcoma and carcinoma-metastases are not at all uncommon in the pelvic bones ; they usually have very sharp contours towards the intact bone, whereas the normal thin part of the iliac bone gradually fades off into the surrounding bone.

The *posterior inferior spine* shows normally a very varying form ; it is either rectangular or sharply angular. It is partly overshadowed by the sacrum ; complicated shadow conditions are therefore produced, and one is apt to mistake normal projections for something pathological. It need only be noted that pathological processes occur here very rarely. The author has made a definitely positive finding in his practice only in two cases : one a tumour, and one a tuberculous lesion.

Compact bone islets in the spongiosa [1] and *exostoses* [2] above and internal in the ilium have been observed, and have been known to resemble stones in the ureter ; also the shadow of enteroliths of the vermiform appendix [3] and of *calcified mesenteric glands* fall in the shadow of the ilium and resemble ureteral concretions.

For the articular portion of the ilium, see above under " Acetabulum."

In increased pelvic angulation a striking shadow is seen hanging from the spur of the acetabulum roof downwards and inwards, which has been described as the acetabular roof spur.[4] This piece of bone is not often described and is not pathological. It starts at the base of the anterior inferior spine and runs along the body of the iliac bone. One should distinguish this shadow from that of the lateral surface of the anterior inferior spine, which occasionally runs rather more inside the acetabular roof spur, and sometimes merges with it or even continues in the same line with it, so that it appears as a prolongation of the acetabular roof spur. Sometimes the two shadows unite and so form quite a considerable shadow.

Fig. 142 [5] shows an exceptional condition ; below and lateral to the sacro-iliac synchondrosis, at the margin of the iliac bone, an almost completely closed obliquely oval ring of bone is present on the right side ; on the left side only the upper half of a similar one has been formed. The author has gone through his considerable series of röntgenograms, without

[1] See Hänisch : Röntgendiagnostik des uropoëtischen Systems. Hamburg, 1908.

[2] See Köhler : Fortschritte, Bd. 10, p. 295.

[3] Weisflog : Zur röntgenographischen Diagnose der Enterolithen des Processus vermiformis. Fortschritte, Bd. 10, p. 217.

[4] From K. Takagi : On the study of pelvic röntgenography. Proceedings of the Medical Society of Tokio, 1923.

[5] Photograph and report from Dr. Palugyay, of Vienna.

finding a picture like it, except one in which there is an indication like it. We are, therefore, dealing with an uncommonly rare condition. What is the meaning of the appearance? Just above this spot the common iliac artery divides into the internal and external iliac arteries. It may be that in rare conditions a groove or canal is here formed for the external iliac vessels.

Pubic Bone

The first *ossification centre* of the pubic bone is found at earliest towards the end of the fifth or in the sixth fœtal month. It is situate in the horizontal

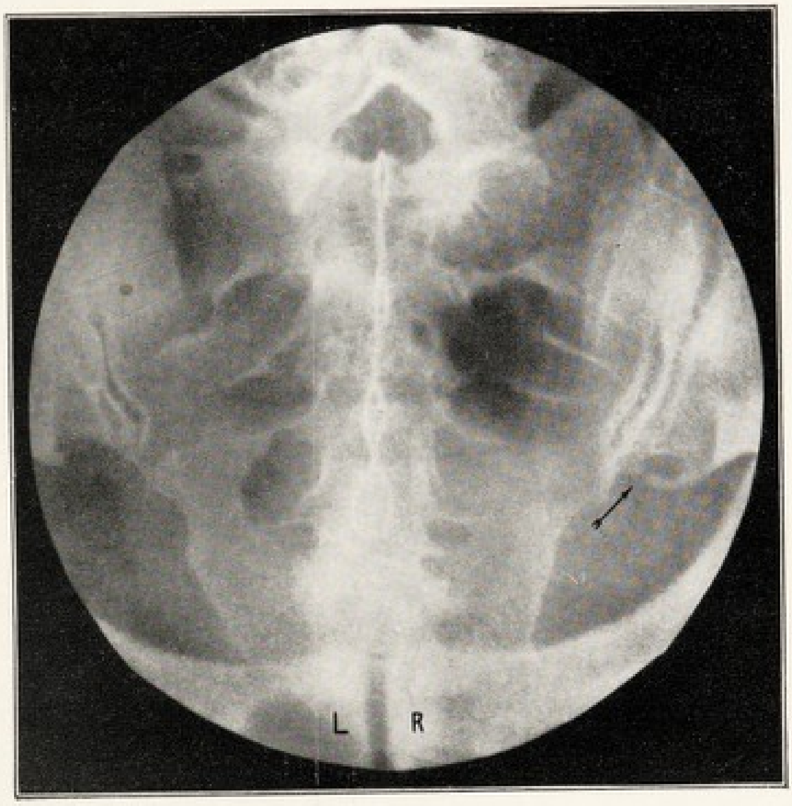


Fig. 142.

ramus near the edge of the obturator foramen. At the date of birth the nucleus of the pubic bone usually surrounds a part of the anterior border of the obturator foramen.[1]

The ossification centres in the pubic spine (eighteenth to twentieth year) and in the pubic angle (the same) had been settled by the anatomists. In the majority of röntgen photographs these nuclei are hidden and do not appear. They would be brought into view in axial negatives (see below).[2]

In the superior ramus of the pubic bone one meets frequently one to three dense closely set pellet-like shadows; these are phleboliths; these have no pathological significance (see later under " Soft tissue lumen of the pelvis ").

[1] According to Lambertz, *l.c.*, note 2, p. 14.
[2] Schinz, *l.c.*

Almost all the *inequalities*, which one encounters at the inner contour of the inferior ramus of the pubic bone, belong to the region of the normal.

Fractures of the pubic bone are usually without much displacement, and may be overlooked if the röntgenogram is not a perfect one. They are usually due to falls from a great height, and it is not, therefore, always possible to photograph the patient in the ventral position, which is the most favourable one for the purpose. The diagnosis is usually secured through an axial photograph. The patient sits upon the plate, leaning a little backwards. The central ray: symphysis of the pubic bone vertical to the plate.[1]

The *symphysis of the pubic bone* is seldom a regular fissure, but normally more or less oblique. A breadth of more than $1\frac{1}{2}$ cm. does not normally appear in men.[2]

In many negatives of the pelvis a thick longitudinal strip appears in the middle of the symphysis transparency; this is due to an accidental projection of normal structures on the dorsal side; nates and hard fascia and ligaments. See further under "Soft tissue lumen of the pelvis."

At the place where the os pubis meets the ischium there have been observed and described upon a few occasions rounded, sharply defined, and conspicuous bodies about the size of a cherry and of a granular appearance. They occur most frequently in children of from eight to twelve years with ill-defined disturbances of gait, simulating hip-joint disease. The picture of disease presented is a special one that may belong to the group of infantile and juvenile interruptions of osseous growth, and has been entitled by van Neck as "osteochondritis ischio-pubica." Cause: Overstrain or slight trauma. Beginning: Atypical pains in the hip or groin, leg easily tired, and slight limping.[3]

For the articular part of the pubic bone, see above under "Acetabulum."

Ischial Bone

The ischial bone commences normally to *ossify* in its superior ramus in the fifth fœtal month. At the date of birth a part of the acetabulum, the ischial spine, the tuber ischii, and the inferior ramus are not yet ossified. Towards the ninth year of life the pubic and ischial bone unite at their distal extremities, while they synostose at the hip cavity only at puberty.

One epiphysial pelvic ossification that is given by all anatomists is the *ossification of the tuber ischii* that encircles both ischial bones, and can be observed in Röntgen view about the same time as the epiphyses of the iliac crest.[4]

The author has not seen any *fractures*, but they do occur, and may be

[1] Lilienfeld: Die axiale Aufnahme der Regio pubica. Fortschritte, Bd. 26, 1919.

[2] For the changes of the symphyseal cartilage during pregnancy refer to the complete statement in Testut: Traité d'anatomie humaine, quoted by Dubois-Trépagne: Un cas de diastase des os pubiens. Journ. de Rad., 1912, p. 668.

[3] M. Wülfing: Über Osteochondritis ischio-pubica. D. Ztschr. f. Chir., 199. Bd., 6. Heft, 1926 (with list of literature).

[4] Schinz, *l.c.*

recognised in a good plate. Displaced fractures of the whole ischial bone have been several times seen in Röntgen view; the dislocation was of such a nature that a proper view could not be obtained.

Malignant tumours are not at all rare in the inferior ramus; their recognition is, however, rendered difficult by the inferior ramus being normally very thin and transparent.

The smaller or larger *inequalities* of the inferior contour without alterations in the calcium-content of the affected spots belong to the region of the normal.

The *ischial spine* is well seen with the tube in the mid-line of the body; it is more or less pointed. Regarding small dense shadows at its tip, see further under "Soft tissue lumen of the pelvis."

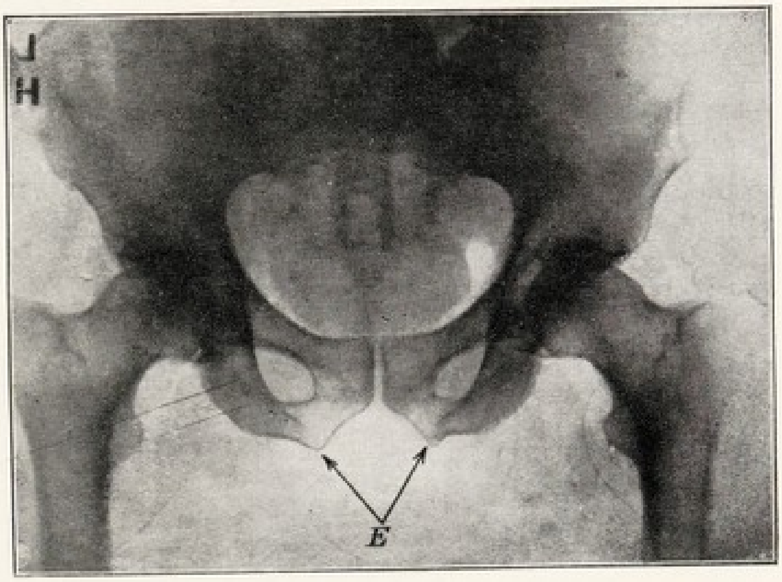


FIG. 143.[1]

For the part of the ischial bone taking part in the acetabulum, see above under "Acetabulum."

The *obturator foramen* appears in Röntgen view smaller and flatter, the greater the inclination of the pelvis. One has to remember the possibility of an arrest in development of the affected half of the pelvis. In ventral pictures (and in dorsal pictures with a proximal setting of the tube) the foramen has more the form of an equilateral triangle with blunted angles.

At the point where the inferior ramus of the pubic bone and ischial bone meet one often finds a slight button-like *thickening of the bone.*

On the inner side of the tuber ischii one often finds a considerable button-like thickening of the bone (Fig. 143). This thickening may sometimes be seen to a strikingly clear degree, see figure. Upon inquiring into the ætiology and course, it was found [1] that: (1) the change is seen only in cases of arthritis deformans; (2) but it is not found in all cases of arthritis

[1] Adolf Scheff: Über eine Veränderung am Ramus inferior ossis ischii bei Arthritis deformans. Ztschr. f. orthop. Chir., 47. Bd.

deformans; (3) the patients with this change had flat feet, external gait, and flat pelvis with "round backs." In purely kyphotic bones without articular changes these particular drawn-out processes were not found. The conclusion was that the site of the change corresponds to the tendinous origin of the gracilis muscle; it was therefore called a "gracilis exostosis." The centre of gravity of the body, is as is well known situate ventrally, owing to a dorsal kyphosis, although it is displaced back again by a corresponding lumbar lordosis. The compensatory action of the lumbar lordosis is, however, within pretty narrow limits. The thickening occurs, therefore, by turning of the pelvis from the inclined position (normal) into the flat position (elevation of the anterior edge of the pelvis). The gracilis muscle is the one specially affected. It is the pronounced changes in statics that then brings about the changes in the hip-joints.

The Whole Pelvis

The estimate of the pelvis *in its entirety*, which is made practically only for gynæcological purposes, is extremely difficult, and not only so for beginners and students. The latter, however, must thoroughly understand that a photograph of the pelvis, as done in other Röntgen examinations—

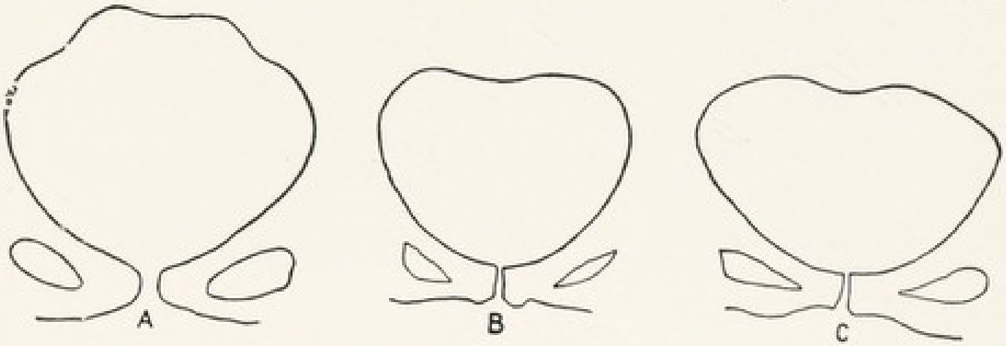


Fig. 144.[1]
A=normal pelvis; B=generally constricted pelvis; C=rhachitic broad pelvis.

that is, in the horizontal position at 60 to 80 cm. tube distance—hardly ever permits a serviceable estimate for gynæcological purposes, whether we are estimating the size of the important diameter or examining rhachitic alterations of the bone. For in horizontal negatives while the patient is horizontal to the plate the entrance to the pelvis is not horizontal to the plate. The latter is, however, absolutely indispensable (if one does not wish to have an astigmatic and distorted projection of the entrance plane of the pelvis). That can be obtained in the sitting or in the half-sitting position. In addition a distance projection is necessary, in order to limit the enlargement caused by the rays from the tube to a minimum. An exactly parallel arrangement of plate and entrance plane of the pelvis cannot be secured

[1] Distance illustrations in the sitting position by H. Martius: Über Beckenmessung mit Röntgenstrahlen: die Fernaufnahmen und der Kehrer-Dessauersche Beckenmessstuhl. Fortschritte, Bd. 22, Heft 6, 1915.—R. E. Roberts: Internal Pelvimetry by Röntgen rays. Brit. Journ. of Rad., 1927.

with absolute certainty. But an approximation thereto can be obtained [1] by photographing the women in such a position that the upper border of the symphysis and the spinous process of the fifth lumbar vertebra are the same distance away from the plate. The distance of the entrance plane from the plate amounts on the average to 10 to 15 cm. At a tube-distance of 200 cm. that gives in the case of the true conjugate an enlargement of projection of about a ½ cm. above the actual size. It is only pictures secured in this way that are of use for midwifery purposes. Regarding the form of the pelvic entrance, several diagrams are given in Fig. 144 of photographs taken in the sitting position (the centering is done in these distance exposures by placing the anticathode of the tube with a plumb-line vertically above the

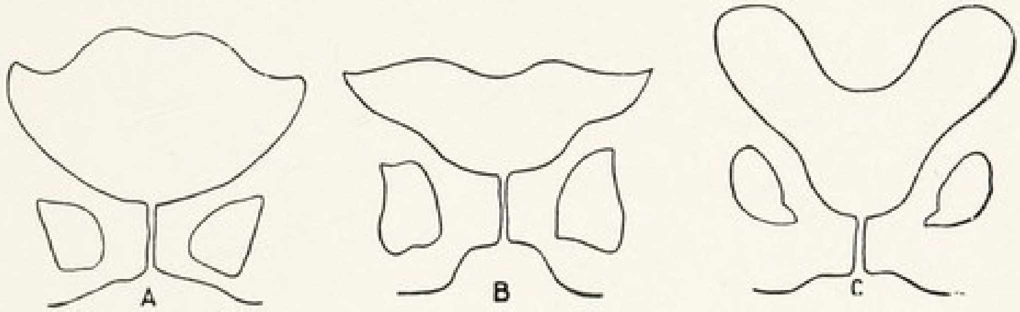


Fig. 145.[2]

A = osteomalacia of moderate degree, photograph in the dorsal decubitus; B = osteomalacia of the severest type, photograph in the dorsal decubitus; C = the same pelvis as B, but photograph in the sitting position.

point of crossing of the mid-line of the body and the line joining the two anterior superior iliac spines).

The röntgenologist is often asked to decide whether commencing *osteomalacia* is present in a patient or not. As the *decalcification* process that sets in is radiologically visible only at a later date, this decision is not always an easy one. One must, therefore, pay special attention to the form of the pelvis, particularly to the point whether the region of the acetabulum is pressed inwards towards the middle of the pelvis. That can often be made out in pictures which are taken in the simple dorsal position, and sometimes relatively early; a better view, however, is generally obtained by making this examination in the sitting or half-sitting position. Above all, the heart-like form of the pelvic entrance is typical and later the strongly projecting promontory and sacrum. Fig. 145 shows good typical photographs of osteomalacic pelves of various degrees.

Pelves similar to the osteomalacic are found in the *osteitis deformans of Paget.*

Soft Tissue Lumen of the Pelvis

Under " Soft tissue lumen of the pelvis " is understood röntgenologically the part of the pelvic picture surrounded by the hip bones, the sacrum, and

[1] After Wormser, quoted by Martius.

[2] Illustrations taken from the work of Leopold and Leisewitz: Geburtshilflicher Röntgenatlas. 1908, Dresden (Zahn and Jaensch).

the coccyx ; it is transparent and sometimes homogeneous. With a short focal distance its lateral limit is formed, not by the linea terminalis, but by the contour of the ischial spines and the contours of the bones which form the ischial notches. In röntgenograms of the pelvis, taken with a soft tube and with a patient at absolute rest, there appear in the lumen of the pelvis a great variety of details in the soft tissues which one must know in order to avoid making diagnostic mistakes.

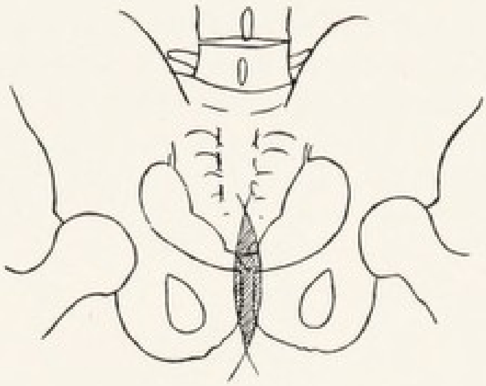


FIG. 146.

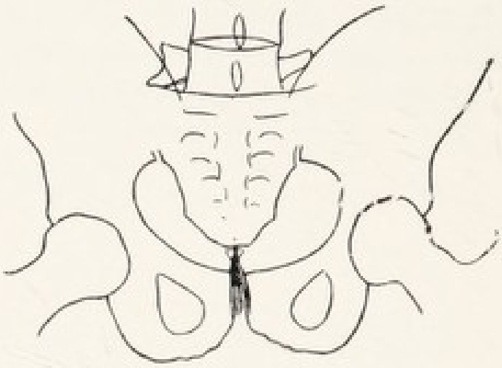


FIG. 147.

Above the symphysis of the pubic bone, sometimes projected also into the line of the symphysis, one sometimes meets a dense shadow several centimetres in length in the mid-line of the body. If this shadow be spindle-shaped it arises from the tissues of the two nates overlapping in the direction of the rays (see Fig. 146).

If the shadow is more *strand-like in form*, extra dense and limited to the line between the coccyx and the anal orifice (Fig. 147), it corresponds to ossified ano-coccygeal ligament. It does not appear to possess any particular pathological significance. It occurs very seldom and only in the adult.

The bladder is scarcely ever to be seen without assistance ; see also under " Bladder." For the determination of stones in the bladder one must know exactly in what part of the plate the bladder is placed. A diagram is given of a röntgenogram with collargol filling of the bladder (see the diagram in the " Bladder " section). Naturally, the conditions vary with the position of the tube to the pelvis. After various suggestions in the course of years it is generally preferred in examining for *calculi* to photograph the bladder region in the dorsal position, with the knees and hips extended, good diaphragming, and the tube pressed obliquely above the symphysis.

A negative Röntgen finding is no proof that no stones are present. If stones of the bladder are visible on the plate, they are usually situated in the shadow of the coccyx or in the lower part of the shadow of the sacrum, and seldom further out.

If one has not much experience in Röntgen-diagnosis, one mistakes for bladder and ureter stones shadow-views that correspond to quite other tissues, for the most part to tissues that, if not quite normal, are of quite innocent nature, and are scarcely the cause of the complaints for which the

Röntgen examination was undertaken. For that reason these slighter shadows may be enumerated and explained at this point.

The most frequent shadow encountered is that of *phleboliths,* which are found almost in every third adult (Fig. 148). Their shadow is circular, without structure, and measures 2–5 mm. in diameter; the older the patient, the larger these stones in the vein; their density corresponds to that of bony cortex; their contour is very sharp, their number usually one to two, but sometimes up to five, and even twelve have been seen near one another.[1] They are arranged usually in a row, rarely in groups. They appear in the lumen of the pelvis along the linea terminalis at the level of the ischial spine or parallel to and near the upper contour of the pubic bone, sometimes covered by its shadow, and sometimes even projected into the obturator foramen. Of all the pelvic spots one finds which are not calculi of the bladder and the ureter, phleboliths form the greater part, about nine-tenths of the total.

Fig. 148.

It is also most interesting to observe that these phleboliths seem to be specially large and dense in cases of severe diseases of the hip-joints (only on the same side ?), and they may even lose their usually well-rounded form, see *e.g.* Fig. 149. This "correlated participation" in the deformative processes of an adjacent joint is also found not so uncommonly in the fabella (of the lateral gastrocnemius tendon) in pronounced arthritis deformans of the knee-joint. The author once saw enlarged "deformed" phleboliths in a case of old-standing severe tuberculous arthritis of the hip-joint.

Next to them in point of frequency come *calcified mesenteric glands.* They are certainly not the cause of the complaint for which the Röntgen examination was made; for they are usually due to old-standing tuberculous processes. They are round or oval shadows of from 10 to 15 mm.

[1] Albers-Schönberg: Die Röntgentechnik. 5. Ed., Hamburg, 1919.—T. Hall-Edwards, Birmingham: The significance of phleboliths. Brit. Med. J., December 13, 1913.

diameter, not sharply edged, of bony density and of roughly granular mulberry-like structure. They generally appear single. The same holds for calcified *retroperitoneal glands*; see also under sources of error in the section on " Kidney."

Small round dense shadows may be due to *stones in the prostate* (Fig. 150, A and B), they are very rare;[1] *bursal stones* might also have to be considered (calcified degenerated tufts of synovial membrane in the obturator bursa, and the bursa of the glutei muscles). Also coproliths may cast a round dense shadow.

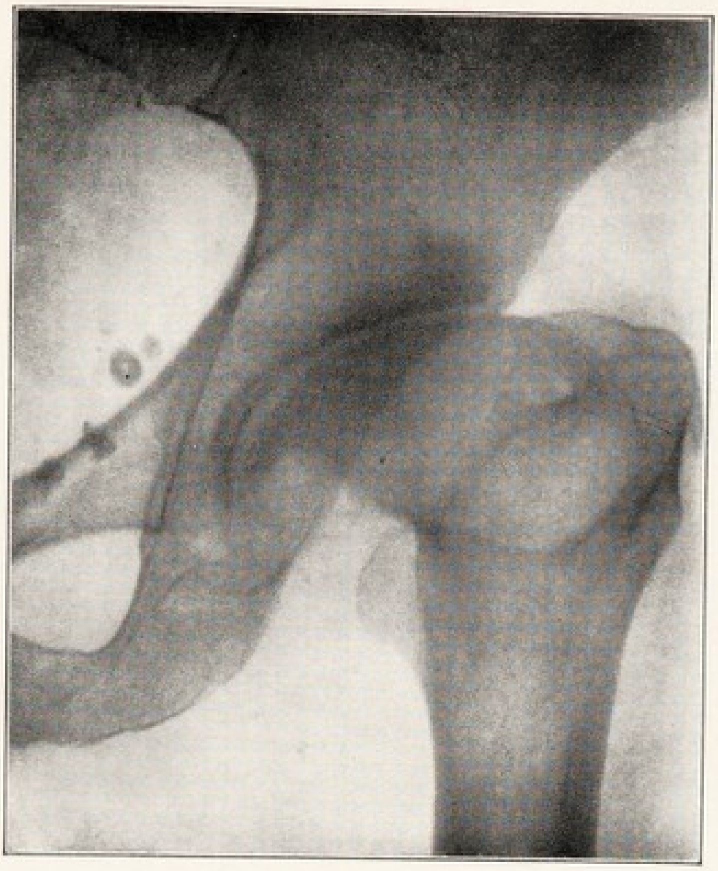


Fig. 149.

For the sake of completeness the other tissues should also be mentioned, that according to the literature have produced spots in the pelvis at least once: *Calcified myoma. extra-uterine pregnancy, dermoid cysts* (dental germ in an ovarian dermoid),[2] *calcifications of the middle coat of the iliac vessel, calcifications of the uterine vessels, stones in the vermiform appendix, remains of bismuth in the bowel, injections of iodipin in the muscles, deposits at the ischial spine, deposits into the sacro-iliac ligaments, calcifications of the tuberculosed mucous membrane of the bladder, sesamoid bones in the tendons of the obturator muscles, calcified appendix epiploica, Blaud's pills.*[3]

A *fœtus* in utero should never be missed or mistaken for anything else (see also the next page, " Pregnancy ").

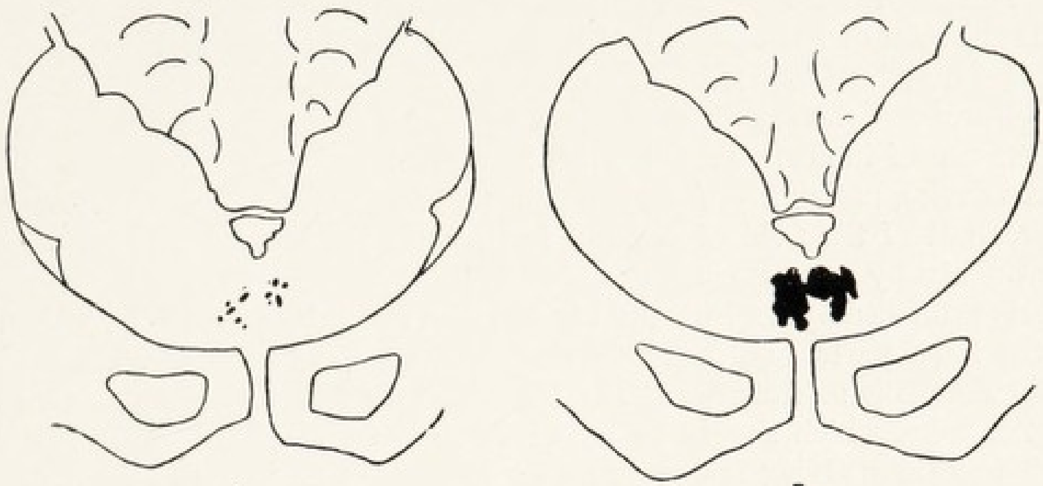
Upon healing and calcification of *a tuberculosis of the Fallopian tubes*, which is not uncommon, definite spots can be seen in the Röntgen picture.

[1] Forssel: Über die Röntgenologie der endogenen Prostataconcremente. Münchener Medizin. Wochenschr., No. 24, 1901. From this work the author's illustration, Fig. 150, A and B, are also taken.

[2] E. Sonntag: Vortäuschung eines Uretersteins im Röntgenbild durch Zahnkeim im Ovarialdermoid. Fortschritte, Bd. 27, 1920.—H. Laurell: Acta radiol., No. 21, 1925.—S. G. Scott, London: The radiographic appearance of calcifying fibroids. Arch. Röntg. Ray, 1913, 18, p. 246.

[3] Quoted from Albers-Schönberg: Röntgen technique, 4th edition, Hamburg, 1910, and from Haenisch, Röntgen diagnosis of the urinary system. Hamburg, 1908.

Apart from small shadows, like the above, there occur normally also *great transparent areas* ; they are produced, as mentioned, by intestinal gases, and often a transparency the size of a pigeon's egg appears above and to the



A. B.

Fig. 150.

left, partly covering the sacral bone ; it corresponds to a collection of gas in the sigmoid flexure. Above the epiphysial line of the symphysis one frequently meets with a very peculiar appearance, not unlike the form of a pair of spectacles (see Fig. 151): the excentric shaded oval shadows are fæcal balls, surrounded by collections of gas. Now and then one sees the terminal part of the rectum, particularly in children. If one has to examine whether these parts of the bowel are normal, the contrast method (high enema) has then to be employed ; for that, see under " Great intestine."

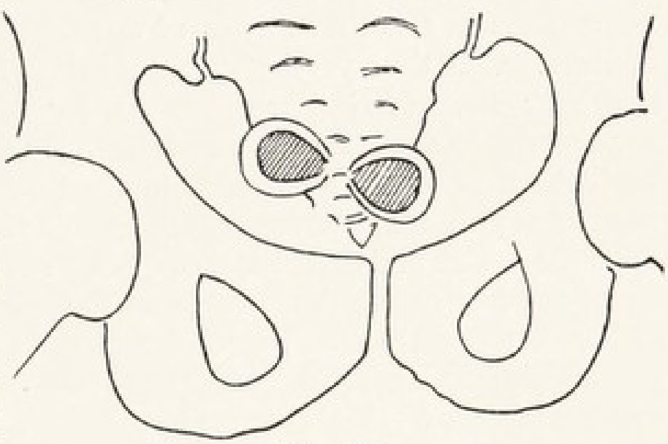


Fig. 151.

The *prostate*, especially if it is enlarged, has been seen by some authors in Röntgen picture (see later under " Prostate ").

Pregnancy [1]

Negative Röntgen findings in the third and fourth months of pregnancy are not uncommon. In the fifth month one receives positive findings—provided the technique is correct. An extramedial position of the fœtus is indicative of *extrauterine pregnancy* only when the skeletal parts of the

[1] Edling, Malmö : Über die Anwendung des Röntgenverfahrens bei der Diagnose der Schwangerschaft. 7. Röntgenkongress, Berlin, 1911.—Ponzio, Turin : La röntgendiagnostica della gravidanza. Radiologia med., 1914, No. 2.—Kayser : Geburtshilfliche Röntgendiagnosen. Fortschritte, 1914, Bd. 22.—Reifferscheid : Die Röntgenuntersuchung in der Gynäkologie und Geburtshilfe, in Rieder-Rosenthal, vol. 2, 1918.—M. Jungmann : Die

child coincide with an isolated palpable tumour near the uterus. In an extrauterine pregnancy that has gone to time the fœtus is placed quite asymmetrical in the pelvis.

Although it is not yet mentioned in the Röntgen literature, it is stated in text-books of pathological anatomy that towards the end of pregnancy *calcium* may be deposited in the placenta.

For a recognition of the earliest signs of osseous shadows the following points are of importance. The bladder must be emptied for photographs taken during pregnancy, for when full it presses the uterus to a considerable degree out of the field of vision ; further, the intestine should be emptied thoroughly by enemata, because fæcoliths or patchy filling with contrast-effects produced by the intestinal gases often render impossible a recognition of the fœtal parts, and it is here that recognition of the very smallest and finest details is so essential. The technique recommended is about 75 ma. on the tube, which should be adequate to carry the load, duplitised film with two intensifying screens, and an exposure of about two seconds. A single exposure ! The contour of the skull and the contour of a part of the adjoining vertebral column are the earliest recognisable parts. If by chance a long (ossified) bone is photographed axially in the direction of its long axis (orthoröntgenographically), that is the most favourable case, and gives an intense circular shadow. These give the densest shadow markings that we can see in the first stages of development, for even the most delicate bones, viewed thus vertically, may attain high degrees of shadow density. Further : rows of similar bones, as, for instance, vertebræ or ribs, produce rows of shadows whose form and arrangement are different according to the projection. Ossification begins in the cervical region and proceeds to the lumbar region, and corresponding to this the shadows of the neural arches decrease in size and density ; the shadows of the vertebræ, on the other hand, increase from above downwards in size and density. For the recognition of the very finest details the best conditions of exposure are naturally hardly good enough. Unfortunately, at the moment we cannot do without intensifying screens, and this is the principal drawback. The period of the eighth to ninth week is stated to be the very earliest time at which a direct röntgenological diagnosis of pregnancy is possible. Pelvic shadows (which see) may give rise to mistakes in diagnosis, but when circular or nearly circular they are very sharply delimited, uniformly dense, and situated usually along the superior pubic ramus and in the vicinity of the spine of the ischium.

Röntgenfrühdiagnose der Schwangerschaft. Fortschritte, 1927, Bd. 35.—T. I. Candy, Newport: Röntgenography of the fœtus in utero. Arch. of Rad. and Electroth., 1923.—Radiography of the fœtus in utero. Proc. Roy. Soc. Med., vol. xvii, No. 4, February, 1924, p. 36. Arch. of Rad. and Elec., October, 1927.—Skiagrams of a case of full-time ovarian pregnancy. Brit. J. of Rad., May, 1927.—G. Fildes, London : Radiography of the fœtus in utero. Proc. Roy. Soc. Med., vol. xvii, No. 4, February, 1924, p. 49.—A. W. McIlroy : X-Ray demonstration of fœtus in utero. Proc. Roy. Soc. Med., vol. xvii., No. 4, February, 1924, p. 50.—W. Edling : Röntgen diagnosis of pregnancy. Radiology, vol. ii, No. 1, January, 1924.—W. A. N. Dorland : Obstetric röntgenography. Radiology, vol. iii, No. 1, July, 1924.—J. F. Stein and R. A. Avens : The interpretation of early fœtal röntgenograms. Radiology, vol. iii, No. 2, August, 1924, p. 110.

Calcified myomata show a usually delimited network of the finest shadow-lines, calcifications of the arteries of the pelvis show the typical signs of chalky deposits in the peripheral vessels. The Röntgen diagnosis of pregnancy is an early diagnosis, and is to be regarded as the first sure sign of pregnancy long in advance of the other definite signs.

VERTEBRAL COLUMN[1]

General

To know the exact details of the *ossification* of the vertebral column is not of much practical value to the röntgenologists; but for the sake of completeness, and because it is sometimes required in forensic cases, we describe it. The ossification begins about the middle of the third fœtal month; that of the arches being independent of that of the bodies. Ossification starts in the neural arches of the atlas and progresses downwards from vertebra to vertebra; ossification of the body commences in the lower dorsal vertebra, and proceeds therefrom somewhat quicker towards the head, somewhat slower towards the coccyx. In the new-born child the vertebræ are ossified in their principal parts including the transverse processes and articular parts of the arches, although the two neural arches are still separate from each other and from the vertebral body by cartilage.[2] For the ossification of the sacrum refer to sacrum.

Fig. 152.

Regarding the *further ossification* of the vertebral column Röntgen examinations have apparently not been published; this want does not make itself felt in practice; even to establish the age of a subject the vertebral column would be the last structure we would take into account. Owing

[1] For the normal Röntgen anatomy of the spine, see Atlas I, Grashey, 4th edition; further Hauchamps, Klynens, Mahaux: Atlas de Radiologie normale, Brussels, 1908.—Hasselwander: Die Röntgenstrahlen in der Anatomie, in Rieder-Rosenthal's text-book, 2. Bd., 1918.—Simon: Röntgenanatomie der Wirbelsäule. Fortschritte, Bd. 14, 1909/10. —R. Balli: Anatomia normale. Ferrara, 1924.

[2] Quoted almost verbally from Lambertz: Die Entwicklung des menschlichen Knochengerüstes während des fötalen Lebens. Hamburg, 1900. These conditions are worked out röntgenographically by Béla Alexander: Die Entwicklung der knöchernen Wirbelsäule. Hamburg, 1906.—See further: M. Delahaye: Ossificatio vertebralis im Röntgenbilde. J. de Rad., April, 1924, p. 167.—R. Hanson, Stockholm: On the development of spinal vertebrae as seen on skiagrams from late fœtal life to the age of fourteen. Acta rad., No. 23, 1926.

to the confusing super-position of shadows of the single sections of the vertebral column photographs on the living subject, limited as they are only to sagittal, frontal, and oblique view, do not much assist in the study of these conditions. A successful study of the ossification of the vertebral column after birth can only be done on dead material by photographs of the separate vertebra, taken especially in the longitudinal direction. There is here a gap in Röntgen literature. It would have a practical value only in the rarest forensic cases, where the only available parts of the body were those of the spine. The author obtained in the profile view of the lower dorsal vertebræ of an eleven-year-old girl (suspected of tuberculosis) the conditions of ossification of the vertebral bodies shown in Fig. 152; these are normal for the age stated and well known to the anatomist, but are not so well known to a röntgenologist. We see here the first formations of the disc-shaped epiphysial plates which are well marked at the margin and become thinner towards the centre, sometimes showing holes there. Little granular deposits of lime appear first in the tenth to the eleventh year of life in the hyaline cartilage covering the upper and lower vertebral surfaces, uniting together in the twelfth and thirteenth years to form calcareous plates which ossify. The union with the body takes place from the twenty-second year to the twenty-fourth, beginning at the cervical vertebræ and ending at the lumbar vertebræ.[1] With the exception of the atlas and the three last coccygeal vertebræ all the vertebræ possess these epiphysial plates, of which those of the lumbar vertebræ are the largest.[2]

Scheuermann of Copenhagen[3] has called our attention to a quite definitely circumscribed picture of disease, appearing from the fifteenth to seventeenth year, a dorsal kyphosis appearing principally in the male sex, which "depends on a fixed curvature of the column and is therefore distinguishable from round-backs, a mistake in carriage, which actively clears up entirely or almost entirely." He refers in his work to the epiphysial discs or plates that have been so neglected by surgeons and orthopædists (in previous paragraph and Fig. 152). He believes that the cause of the picture of disease he describes is to be sought in pathological changes of this epiphysial line and not simply in an insufficiency of the erector spinæ muscles; and he believes it should be brought into line with osteochondritis deformans juvenilis coxæ, and speaks of "O. d. j. dorsi." Another called the condition "kyphosis osteochondropathica." The changes consist of considerable irregularities and deformities of the shadows of the epiphysial discs. The upper and lower surfaces of the vertebra are irregularly defined; this irregularity is especially well marked at the anterior edge of the body of the vertebra in what may be a pronounced cup-like fringing; possibly because the effect of compression is here at a maximum. At the same time one finds a more or less pronounced atrophy of the affected bodies of the

[1] After C. Toldt: "Die Knochen in gerichtsärztlicher Beziehung" in J. Maschka: Handbuch der gerichtlichen Medizin, Bd. 3. (Tübingen, 1882.)

[2] Rambeau and Renault: Origine et développement des os. Text and Atlas with 28 plates. (Paris, 1864.)

[3] Ztschr. f. orth. Chir., Bd. 41, 1921.

vertebræ. The wedge-shaped deformity of the separate bodies may be very different in degree, and extreme cases can arouse the suspicion of a tuberculous destruction of bone. In the final stage, despite advanced deformity of the vertebral bodies, we again encounter fairly even limiting lines and no marked degrees of atrophy. Regarding pathogenesis: If there occurs a disparity between the statical demands and the statical capacity of the vertebral column for any reason, the most important changes

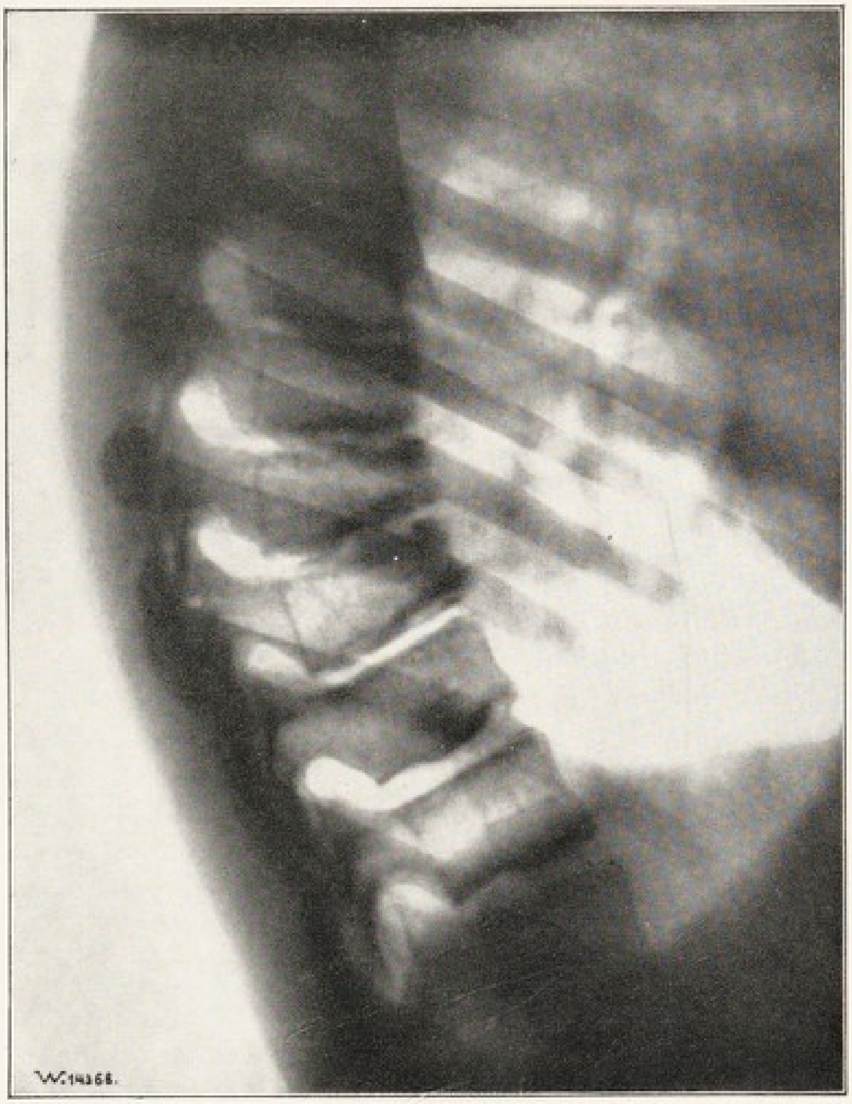


FIG. 153.

produced take place at the growing lines of those vertebræ that are mechanically exposed to the greatest pressure. These changes consist, on the one hand, in a broadening and irregular limitation of the cartilaginous zone of proliferation; on the other hand, in a retardation of ossification and of growth of bone; in severe cases, even possibly in absorption of bone that has already been made. The lower dorsal region is exposed to the greatest compression; it is therefore here that the greatest changes occur. The clinical picture of the whole condition is as follows: Earliest appearance the twelfth year, latest appearance the seventeenth year; the male sex affected about four times as often as the female. Agricultural workers are the ones most frequently attacked: "peasant-back." Heavy bodily work, especially the lifting and carrying of heavy weights, appears to be the chief reason for the disease. But it occurs also in boys at school (thus the author's case illustrated in Fig. 153 is from a girl-pupil of a higher-grade school). The deformity in the back straightens itself in the course of 1–1½ years. The disease is always limited to the lower dorsal region, the seventh to the tenth dorsal vertebra, never appears in the upper dorsal region, nor in the cervical or lumbar regions. The part attacked becomes absolutely and rigidly fixed, even in a complete state of suspension by the whole weight of the body the kyphosis does not lessen to any marked degree. In order to maintain an erect posture of the body the patients force their cervical, upper dorsal, and lumbar spine into a strong lordosis. There is usually an almost entire absence of pain. It is the deformity that brings the patients to the doctor. It is only towards the end of the second decade that the destructive stage is followed by a process of reparation. Regarding ætiology: Only one microscopic examination has been published (Pollosson, Lyon méd., 1885), but the conclusions arrived at were somewhat indefinite. Later, rickets is one of the possibilities suggested. Although, as mentioned, Scheuermann classifies the disease with osteochondritis deformans juvenilis coxæ, others have considered it analogous to coxa vara adolescentium. The one thing certain is that the epiphysial line appears to be the starting-point. Differential diagnosis: the characteristic irregularities in the Röntgen view at the upper and lower corners of several of the neighbouring vertebral bodies prevent one confusing the condition with tuberculosis; its appearance in young people distinguishes the condition from spondylitis deformans, Marie-Strümpell-Bechterew types of disease, and from malacia of the spine. The prognosis is quoad vitam naturally favourable, but is not so favourable as regards the working capacity in advanced cases. For therapy, see the latest works.[1]

If one wishes to obtain survey pictures of the whole vertebral column one never expects to get it running in an exactly straight direction on dorsal (and ventral pictures). (Normal asymmetry! *physiological scolioses!*). Photographs of the vertebral column are nowadays taken with the smallest possible diaphragm, so lateral curvature of the column would not often be seen, although we might have thought it possible from a hasty external view of the patient.[2] Up to about the eighth year of life

[1] This paragraph, with the exception of the illustration, is an excerpt from the work of C. Mau: Die Kyphosis dorsalis adolescentium im Rahmen der Epiphysen und Epiphysen-Erkrankungen des Wachstumsalters. Ztschr. f. orthop. Chir., vol. 46 (with complete list of the literature).—See further G. Valtangoli, Bologna: L'osteocondrite def. giovan. vertebr. (Cifosi dorsale giovanile di Scheuermann). Rif. med., 1925, 35.

[2] Aimé Péré found in 100 anatomical specimens of subjects a straight spinal column only seven times mentioned by Gaupp: Die normalen Asymmetrien des menschlichen Körpers, Jena, 1909.

(the first years of school) the vertebral column does not show any *lateral curvature*. The usual type of spine is one convex to the left in the upper part, convex to the right in the middle part, and again convex to the left in the lower part. *The middle curvature* is the principal and extends from the third to the eighth dorsal vertebra. The inverse type is not so frequent. The röntgenologist must know these facts, in order not to diagnose diseases where none exist; these slight physiological irregularities are increased by the prominent but *physiological irregularities* of the spinous processes.

Regarding the varieties of the vertebral column, we find a large number of most distinct departures from the normal, for the human spine is (according to Rosenberg) in process of transformation, by the boundary between the different regions, being displaced cranialwards in the course of phylogeny and ontogeny. Favourite sites of such processes are the transition regions from the skull to the cervical column (the atlas), from the cervical column to the dorsal region (C VII and Th. I), from the dorsal column to the lumbar region (Th. XII and L. I), and, above all, in the lumbo-sacral region (L. V, S. I and S. II). According to their general directional tendency these variations might be of progressive or retrogressive nature, there may also occur retardation-processes, which are closely akin to the pathological or even partake of the type of malformations.[1]

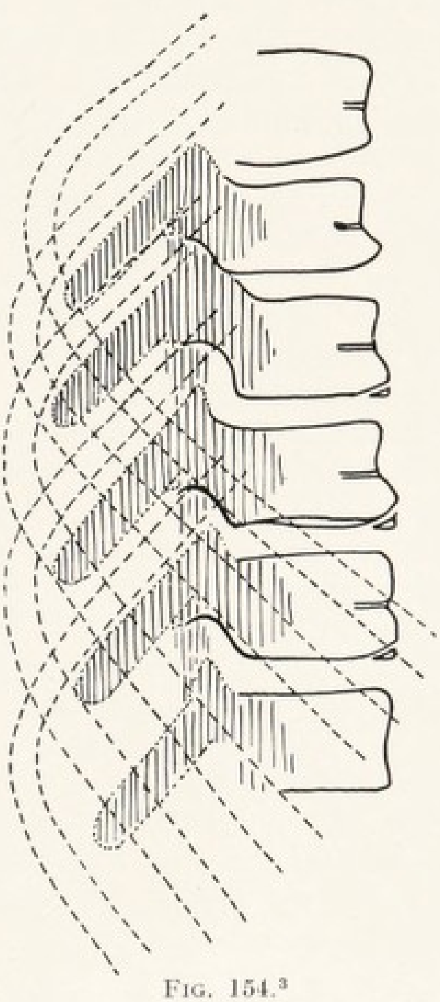


Fig. 154.[3]

In the profile views of young adult spines attention has been drawn to a peculiar appearance, namely, an *apparent splitting up* of the vertebral bodies.[2] See Fig. 154. One sees a clear, band-like, translucent split, about 2 mm. broad, running from the middle of the anterior surface of each vertebral body and extending as far as the middle of the body; in some cases only in one or two vertebræ, in others in all the vertebral bodies. This is not a projection appearance, but due to a number of unusually large

[1] H. R. Schurz, Zürich: Variationen der Halswirbelsäule und der angrenzenden Gebiete. Fortschritte, vol. 31, 1924.—Rosenberg: Die verschiedenen Formen der Wirbelsäule des Menschen und ihre Bedentung. Jena, 1920 (with complete list of the literature).—G. B. Batten, Synostosis of dorsal spine. Brit. J. of Rad., March, 1925.

[2] O. Hahn: Scheinbare Spaltbildung der Wirbelkörper in der Adolescenz. Fortschritte, Bd. 29, 1922.—Sinding-Larsen: A contribution to the diagnosis in diseases of the vertebral column. Acta rad., No. 24, 1926.

[3] O. Hahn, *l.c.*

nutrient foramina which (in anatomical preparation) are so large that one could pass an ordinary probe without trouble a good distance into the bone. The rarity of the appearance of such pictures is explained by the fact that such an exceptionally rich blood supply of the bodies of the vertebræ continues apparently only a short time in adolescence, and appears to take place about the same time as the origin of the epiphysial discs (see above). According to anatomical studies, we are here dealing with venous canals which are usually paired, " stage of paired venous canals," persistent or rudimentary in the higher classes of vertebrates and best developed in the kangaroo.[1]

All the Röntgen pictures of adult vertebral columns are uncommonly complicated owing to the frequent *superposition of shadows* belonging to parts of the most varying form, size, and position which are often difficult to differentiate. We cannot here enter upon a description of the finer details; there are fortunately, however, quite a number of special works on the röntgenography of the vertebral column.[2]

Many lateral curvatures, including torticollis, rest upon congenital anomalies of the vertebræ, especially upon supernumerary rudimentary vertebræ.[3] (Survey photographs desirable !) Unions or absence of single vertebræ may occur.

Spondylitic exostoses at the edges of one or more vertebral bodies, the rest being normal (see Figs. 155 and 156), may be said to indicate tumour of the spinal cord or of its membranes.[4] The relation of this bony change to the tumour is not quite clear. In extramedullary tumours the symptom is more frequent than in the intramedullary. (Naturally a negative Röntgen finding does not contra-indicate a tumour of the spinal cord.) If investigation of the nervous system does not afford any certainty in localising the level of the spinal tumour, the vertebral canal should be opened by the surgeon at the level of the exostosis-formation. If a tumour is not found at this spot, the laminectomy should be extended not upwards, but downwards.

[1] P. Vonwiller, Zürich: Über die Kanäle der Wirbelkörper. Proceedings of the Swiss Naturforschende Gesellschaft, Schaffhausen, 1921.

[2] Kienböck: Wiener klin. Wochenschr., 7, 1901.—Sudeck: Die Darstellung der Wirbelsäulenerkrankungen durch die Röntgenschen Strahlen. Riedingers Archiv f. Orthopädie, Bd. 1, 2. Heft.—Serra, Favini, Ponzio: 1. Italien. Röntgen-Kongress, 1914. (Pavia Mattei.)—Boidi-Trotti: Le fratture latenti della colonna vertebrale. Radiologia med., May, 1914.—Ossig: Untersuchungen über das Röntgenbild der normalen Halswirbelsäule. Monatsschr. f. Unfallheilkunde, 3, 1909.—Grässner: Röntgenuntersuchung der Wirbelsäule. Deutsche Zeitschr. f. Chir., Bd. 94.—Simon: Röntgenanatomie der Wirbelsäule. Fortschritte, Bd. 14, 1909/10.—Eug. Fraenkel: Über Wirbelgeschwülste im Röntgenbilde. Fortschritte, Bd. 16, 1910/11.—R. M. Beath, Belfast: A case of spondylitis deformans. Arch. of Rad. and Elec., May, 1920.

[3] Böhm: Über die Ursachen der jugendlichen, sogen. habituellen Skoliose. Fortschritte, Bd. 11, 1907.—See further also: Ch. G. Sutherland: A röntgenographic Study of developmental Anomalies of the Spine. The Journal of Radiology (Omaha), September, 1922.

[4] M. Sgalitzer and St. Jatrou: Röntgenbefunde bei Tumoren des Rückenmarks. Mitt. Grenzgeb. d. Med. u. Chir., 35. Bd., 5. Heft, 1922.—J. Erdélyi, Budapest: Wirbelveränderungen bei extramedullären Geschwülsten.

In the study of röntgenograms of the *vertebral column* the following points should always be noted :

(1) *General.*—Every successive vertebral body, starting from above, is either higher than the one in front of it, or is at least the same height, it is never lower. If exceptions from this rule are met with, we are dealing with pathological conditions pointing to a loss of firmness in the vertebral body owing to some process of disease, under whose influence a reduction in the height of this vertebra has been produced. It is only for the fifth lumbar vertebra (see the same) that this rule does not apply.

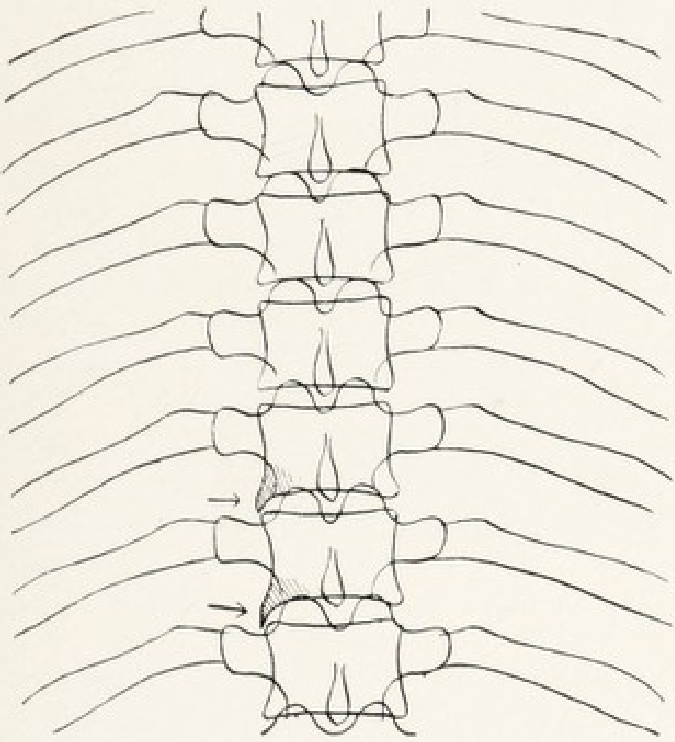


FIG. 155.[1]

FIG. 156.[1]

(2) *Dorsal pictures.*—The shadow of a spinous process seen in the shadow of a vertebral body belongs usually to the preceding vertebra (nearer the head) ; it is only towards the fourth and fifth lumbar vertebræ that the spinous process falls in the shadow of its own vertebral body. As already mentioned, the spinous processes are not often exactly similar in form, direction, and distance apart. The shadow of the spinous process should be displaced about 5 mm. before one is entitled to diagnose a fracture. As in a fracture one sees not only the detached portion of the process, but near it the very similar point of the neural arch from which the spinous process broke off, the student—in cases in which the clinical findings indicate the probability of fracture—is apt to be misled by the double shadow and diagnose at the best a double spinous process. The fractured process is displaced caudally, and displaced more or less to the side, especially the

[1] Sgalitzer and Jatrou, *l.c.*

upper sharp angle of it, while the lower border remains more or less in the middle line of the vertebral column.[1] The projection of the intervertebral disc is naturally quite different according as it is placed exactly in the direction of the rays or obliquely traversed by them. The intervertebral space situated directly under the tube forms a single, straight, broad band or streak; the intervertebral spaces situated at the edge of the picture are projected narrower or doubled and lightly curved. The sharper, more distinct horizontal contour of the vertebral body corresponds to a posterior margin, the less distinct to an anterior margin. In asymmetries gradually increasing from vertebra to vertebra and uniformly graduated, we are simply dealing with a patient whose trunk is somewhat turned upon the body-axis; there need be nothing pathological in that. If the shadows of the spinous processes are closer together at one part than at other parts, that only means that there the vertebral column is curved in a lordosis. If one body is several millimetres shorter from above down than its two neighbours, we have to suspect a fracture, a diagnosis confirmed if the intervertebral-discs on either side of it are narrower and somewhat obliquely set, or if an intervertebral space has completely disappeared. A further feature of fracture is an extensive irregularity in structure. We should also suspect fracture if at one vertebra or between two the axis of the vertebral column makes an angle.

If one finds all the symptoms last mentioned, and in addition a considerable *atrophy of bone,* and if there be no history of injury, we have to think of a tuberculous spondylitis.[2] (Healed spondylitis and healed fracture of the vertebral bodies cannot in many cases be decided by the Röntgen picture alone.) Paravertebral abscess shadows should never be neglected; for they are often the first and only sign of a spondylitis.[3]

Dislocations limited to the sagittal direction usually remain hidden in the dorsal picture. In very stout patients, from whom we cannot obtain a profile picture, gross dislocations can still be interpreted from the dorsal picture, because the ventrally luxated vertebral body casts a greater shadow than the neighbouring vertebræ do.

If one finds a *vertebra broadened* in relation to its neighbouring vertebra, we may suspect a compression-fracture.

(3) *Profile pictures.*—Most of the points mentioned for dorsal pictures apply also to these. Also refer to " Cervical column " and " Dorsal column."

(4) *Oblique exposures.*—It is often very difficult to distinguish the single shadows of many of the imbricating parts of a vertebra. One is only entitled to diagnose a lesion when the similarity which neighbouring vertebral shadows bear to each other is interrupted at a definite point. To decide what kind of pathological change we are dealing with is very

[1] Zollinger, Aarau: Isolierte Fracturen der Dornfortsätze der unteren Hals- und oberen Brustwirbel durch Muskelzug. Fortschritte, Bd. 31, 1923.

[2] For tuberculosis of the vertebræ, see also Serra: Su le ombre paravertrebrali della colonna dorsale. Radiologia med., March, 1914.

[3] S. Hass, Wien: Die paravertebralen Abscessschatten im Röntgenbilde und ihre diagnostische Bedeutung. W. m. W., 1925, vol. 37, p. 2077.

difficult even for the most expert. Tuberculous lesions in the bodies of the vertebræ are sometimes the clearest of all. In interpreting an oblique negative one should recollect that the shadow of the transverse process falls in the shadow of the vertebral body and the spinous process forms the convex margin of the vertebral column.

In difficulties in the diagnosis of *injury to the vertebral column* one should not hesitate to take ten and even more photographs in different positions of the vertebral column and at various focal distances. (Beware of Röntgen-injuries !)

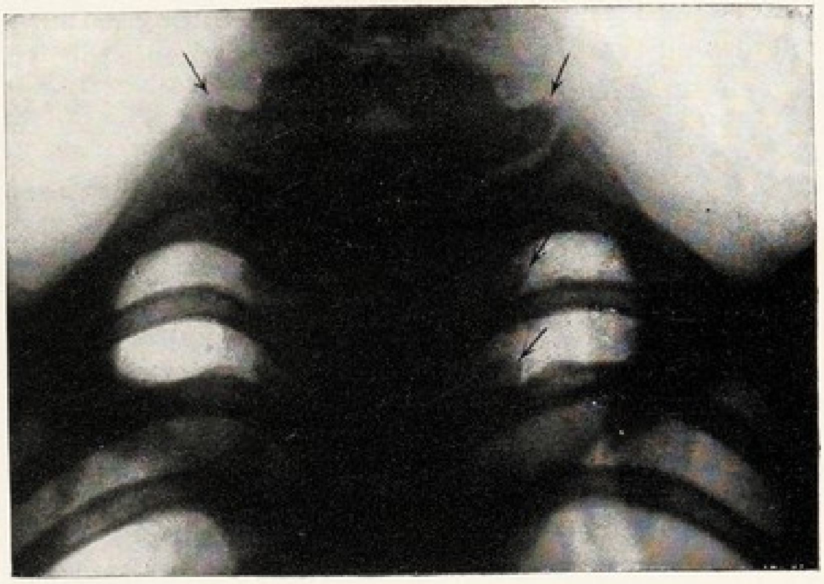


FIG. 157.

One observer had a Röntgen finding as shown in Fig. 157 (see the arrows) ; he first thought of an arthritic change of the tubercles of the ribs. Upon further investigation it transpired that the finding is quite a physiological one, namely, an ossification centre situate separate and distinct from the transverse process of the vertebra.[1]

It was in 1919 that the idea of rendering the subdural space visible by means of insufflation of air was first tested.[2] Ten cubic centimetres of liquor were drawn out and replaced by an equal quantity of air. The application in practice of insufflation with air is regarded to-day as insufficient. Since 1921 [3] iodol has been employed with better results. "Myelography," as the method is called, is best employed for the diagnosis of tumours, and for segmental diagnosis it is nearly perfect. It has become the special field of a few researchers, for it demands much personal experience. This book being specially intended for practitioners, the subject cannot be taken up in these pages.

[1] A. Bernstein : Über Arthritis deformans im Rippenquerfortsatzgelenk. Arch. f. klin. Chir., Bd. 141, Heft 3, 1926.—See also later towards end of the section " Ribs and Sternum."

[2] Dandy.

[3] Sicard. A complete work appeared in 1926 by H. Peiper: Die Myelographie im Dienste der Diagnostik von Erkrankungen des Rückenmarks, in "Ergebnisse der medicin. Strahlenforschung," Bd. 2. Leipzig, 1926; publishers, Thieme.

Cervical Vertebræ

If one does not succeed with dorsal and profile negatives one should take an anterior picture or a dorsal or anterior photograph in such a way that the central ray is 75°–80° to the plate. With this direction of the rays the articular processes are not projected one over the other, as in pure profile negatives, but one behind the other.

Dorsal negatives.—A satisfactory picture of the first and second cervical vertebræ is obtained only by a projection through the widely open mouth, the cervical column being held as straight as possible. With the neck bent backwards (and the photograph taken through the mouth) the atlas rarely comes on the plate, but only the second and third vertebræ.

One surgeon reported [1] upon the maximal *artificial translucent zones* in the vertebræ in photographs taken through the mouth, which might give rise to considerable mistakes in diagnosis. They are said to be due to the air-filled space of the epipharynx. (The author does not recollect having seen an appearance of that kind upon any of his negatives.)

The *band-like translucency* of 2 cm. breadth which runs on dorsal pictures over the middle of the cervical vertebræ, corresponds, not to the spinal canal, but to the larynx from the seventh vertebra downwards to the trachea. A narrowing and unevenness of the articular cavity of one side at the *joint between the atlas and the axis* (in photographs through the mouth) is, when grating and crackling is present, to be regarded as a detachment of the cartilage and as pathological. The strong wavy outline to both sides of the cervical column is formed by the masses of *the articular processes*. These contours appear normally to be fairly regular, while the projecting small shadows of the *transverse processes* (like all transverse processes of the vertebræ) have a very different form and size.

During life the anatomical diagnosis of occipital vertebra has not yet been made, probably because the condition is practically unknown except to the anatomists. We have here to deal with a retrogressive variation. In preparation these are found in the neighbourhood of the foramen magnum osseous formations that remind one of an atlas or of parts of one. A normal atlas is present with this manifestation of an occipital vertebra. In correlation therewith is, for instance, the appearance of a third condyle (an atrophic anterior arch of an occipital process or an indication of a transverse process, supracondyloid process, etc.). One form of condylus tertius can certainly occur by ossification of the apical ligament of the odontoid process. It is not at all easy to distinguish between an assimilation of an atlas and a manifestation of an occipital vertebra.[2]

Between the *occipital bone and the atlas* a complete or partial synostosis may occur, and in such a way, that the compact and spongy bones of the occipital condyles pass directly into the compact and spongy bones of the lateral masses of the atlas.[3]

[1] F. de Quervain: Über eine Irrtumsquelle bei der Röntgenaufnahme der obersten Halswirbel durch den offenen Mund. Fortschritte, Bd. 29, 1922. [2] After Schinz, *l.c.*

[3] Ferrari: Sulla saltadura dell' os occipitis coll' atlas. Imagini röntgenografiche

Associated therewith one often finds important clinical symptoms, such as stoppage of movement in the atlanto-occipital joint, unusual fixation of the head (the head set in a fixed position between the shoulders), the hirsute covering at the back of the neck extending down as far as the dorsum, so that the Röntgen finding is not altogether an accidental one. At the same time changes may be found in the axis (epistropheus).[1] This assimilation of the atlas, also called ankylosis of the atlas or synostosis of the atlas, is regarded as a progressive variation (the manifestation of the occipital vertebra being a retrogressive variation), for the anatomists regard it really as the expression of a caudal displacement of the craniovertebral junction and include it within the normal range of variations One should, however, not explain every case of synostosis of the atlas as a simple variation, for according to anatomical researches specially directed to this, it is found in preparations of the bones that quite similar acquired atlanto-occipital synostoses can be brought about as the end-stages after diseases and injuries, etc. (tuberculosis, syphilis, arthritis, luxations, and fractures).[2]

A clinically important variety receives the name of processus transversus atlantis. It is the lateral mass of the atlas separated off and developed as an independent base.[3]

Fractures of the odontoid process of the axis are usually easily recognisable in technically good negatives through the mouth. Should the technique be deficient in any respect, one can recommend introducing a small film into the nasopharynx and pressing it against the vertebral column, thus conducting the photograph in the dorso-ventral direction. The film is fastened on a lead strip bent at right angles.[4]

The seventh transverse process projects normally about 2 cm. laterally beyond the other shadows of the cervical vertebræ of the first dorsal vertebra below it, and usually forms an acute angle with the transverse process of the first dorsal (Fig. 158). The transverse process of the seventh cervical is often of unequal length on the two sides,[5] and when of exaggerated length can produce disturbances in the areas supplied by the brachial plexus similar to those resulting from cervical ribs.

Memorie della R. Accademia dei Scienze, Lettere e Arti in Modena, Serie III, Vol. X, Parte seconda (Appendice), 1912.—Sick: Virchows Archiv, Bd. 246, p. 448.—E. Heidsiek: A case of Atlas Assimilation. Fusion of the second with the third cervical vertebra and other anomalies of the cranio-cervical skeleton. Ztschr. f. Anatomie und Entw. Gesch., Bd. 76, Heft. 1, 1925.

[1] C. Ch. Sick: Über Synostose des Atlantooccipital-Gelenkes und die dabei beobachteten Veränderungen des Epistropheus. Virchows Archiv, Bd. 246, p. 448.

[2] Rose: Virchows Archiv, 1923, Bd. 241, p. 428, quoted after Schinz, *l.c.*

[3] Greig in Goldhamer and Schüller: Variet¨ten im Bereiche der hinteren Schädelgrube. Fortschritte, Bd. 35, 1927.

[4] E. Fritzsche: Über die Fracturen des Zahnfortsatzes des Epistropheus. Neue röntgenographische Darstellung des Processus odontoideus. Deutsche Zeitschr. f. Chir., Bd. 120.—Kienböck: Über die Verletzungen im Bereiche der obersten Halswirbel und die Form der Kopfverrenkung. Die typische Luxation des Kopfes im unteren Kopfgelenk usw. Fortschritte, Bd. 26, 1919.—O. Alberti: Fratture del dente dell' epistrofeo con e senza lussazione dell' atlante. Congr. Ital. di Rad. Med., 1925.—*Idem:* La Rad. Med., Vol. XIII, Fasc. 2.

[5] See also Sénèque: Formschwankungen des Querfortsatzes des 7. Halswirbels. Journ. de Chir., August 2, 1923.

The costal process of the sixth cervical vertebra (the carotid tubercle) sometimes shows a marked development; as is well known the costal process can grow out into a rib, which consists either wholly of bone or in rarer cases carries at its anterior extremity a costal cartilage (which does not show up in the Röntgen picture). *The cervical rib* is sometimes connected by diarthrosis with the first dorsal rib. One can then see the articular connection in the Röntgen picture. Cervical ribs occur in straight vertebral columns; but also along with the phenomenon of a so-called cervical rib scoliosis. The cervical rib should never be missed, for it is often the cause of considerable symptoms; irritation and paresis symptoms in the region of the brachial plexus, paræsthesias, sensory disturbances and muscle atrophies in the arms and especially in the hand. Further, the cervical rib can always be well palpated; it can be felt to spring back elastically.

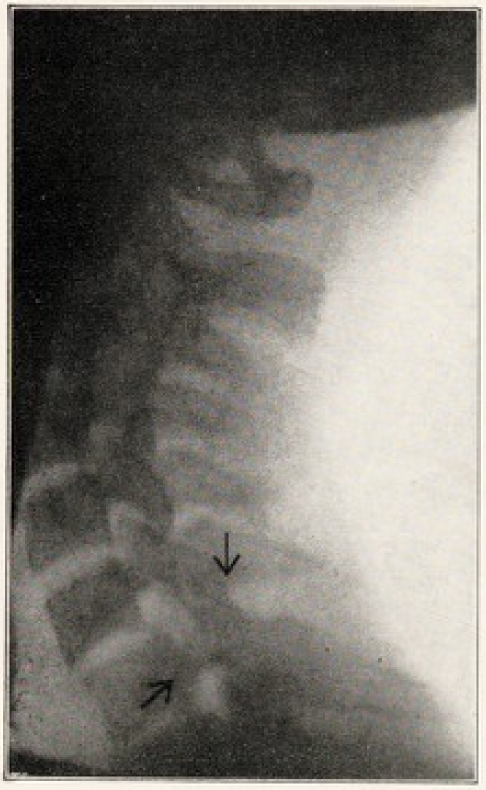


Fig. 157a.

For incomplete first dorsal ribs, see under "Ribs." Associated with cervical ribs, but also without them, one sometimes finds the congenital condition known as *elevation of the shoulder-blade*, together with ossifications of single muscles, exostoses, deformities of the shoulder-blade, defects of the vertebral column, fissure formations, interpolations of wedge-vertebræ (the latter not belonging to normal variations, but being signs of interruption in the course of development). One case is described in which the Röntgen view showed one rib on the right side of the fifth, sixth, and seventh cervical vertebræ.[1] Two or three cases have been noted with cervical ribs on the sixth cervical vertebra. Periostitic formations in the cervical ribs and at the transverse process of the vertebra are said to be not unusual; they usually give rise to the appearance of symptoms.

The *spinous processes* are pretty irregular in the middle cervical vertebræ and frequently bifid.

For how to decide in doubtful cases between the seventh cervical and the first dorsal vertebra, see under "Dorsal vertebral column."

If the patient be placed on the back with the neck extended, the head

[1] From Lechleuchthener, quoted by Max Fischer: Über einen Fall von doppelseitiger Halsrippe. Fortschritte, Bd. 25, 1917; see further Fürnrohr: Die Röntgenuntersuchung in der Neurologie; in Rieder-Rosenthal's text-book, Bd. 2, 1918.—H. R. Schinz, Zürich: Variationen der Halswirbelsäule und der angrenzenden Gebiete. Fortschritte, Bd. 31, 1924.—D. Greig, Edinburgh: On congenital high scapula. Edin. Med. J., March, 1911.—H. Lewis Jones, London: Sprengel's deformity. Arch. Röntg. Ray, 1911, 16, p. 2.—E. F. Peckham: Congenital elevation of the scapula. Boston Med. and Surg. Journ., 1916, 174, 315.—Leonard W. Ely: Sprengel's deformity. Arch. Surg., October, 1925, XI, 598–601.

bent forwards a little and turned a little or completely to one side, and the film given a larger exposure than in lateral cervical views, one usually obtains a good survey view of the atlas and axis.[1]

Profile photographs.—If a vertebral body projects ventrally about two or three millimetres beyond the rest, that does not need to be regarded as pathological.

The *last cervical vertebræ* appear in profile only in long necks (see, for instance, Fig. 157A).

In pure profile negatives both halves of the neural arch of the atlas come plainly into view (see Fig. 157A). One of these halves can be found distinctly more slender than the other, without that being at all a pathological condition. The normal arch of the atlas is always well represented in an approximately correct position of the tube and can be seen uncovered by occiput and axis. The posterior arch of the atlas may also remain quite open (retardation-deformity). The posterior arch of the atlas arises, as is well known, from two ossification centres in the neural arch which are present in the newly-born and remain separate from each other by cartilage till the fourth or fifth year. If the fusion of the two osseous portions does not occur, we find a hiatus atlantis; this is found nearly always in an assimilated atlas, but may also appear independently.

The spinous process of *the axis* is the largest, forms almost a right angle in the picture, and varies much in its form and size.

Synostoses between the anterior arch of the atlas and the odontoid process of the axis have been mentioned by anatomists.

The transparent fissure between the odontoid process of the axis and *the anterior tubercle* of the atlas should not cause us to diagnose a detachment of the tubercle at this point (see also the illustration in the section "Lower jaw," the fissure itself being seen left from "a"); but, though rarely, real diarthroses do take place between the odontoid process and the body of the axis "os odontoideum."

In people with short necks a congenital synostosis of the cervical vertebræ may be the cause; in these cases the second to the sixth vertebral bodies form a single bony mass without any sign of intervertebral discs.[2]

Like the fissure formations in the lumbo-sacral region (which see), such a condition has been observed in the adult at the seventh cervical vertebra, "hiatus cervicalis persistens."[3]

The spinous processes of the third, fourth, and fifth vertebræ are approximately the same in length and form, although showing normally many small irregularities; the fourth is usually nearer to the fifth than to the third.

The spinous processes of the sixth and seventh vertebræ are again longer and also more sharply defined.

[1] Bársony and Koppenstein. Fortschritte, Bd. 35, 1926.

[2] F. Partsch. Arch. f. Orthop. u. Unf.-Chir., Bd. 24, Heft 2, 1926.—Feil, Roland, and Vanbockstael: "Les hommes sans Cou." Révue d'Orthopédie, 1924, p. 281.

[3] Schinz, Zürich, *l.c.*

The *irregularities* in the shadows of the vertebral bodies correspond to the superimposed shadows of the transverse processes. These irregularities should not be regarded as pathological. Not infrequently, too, the shadows of the transverse processes come into the translucent space of an intervertebral disc, and may mislead the observer into diagnosing them as bony deformities.

The beginner may easily and frequently overlook even gross injuries to the cervical spine. The difficulties may be illustrated in Fig. 157A. The patient was struck on the head with some bricks two years before, at the same time being thrown from a scaffolding five feet high. The dorsal view, although quite sharp, showed no certain evidence of pathological change. Upon closer study the displacement of the sixth and seventh spinous processes caught the attention. In the profile photograph (Fig. 157A) a general inspection revealed nothing particular. On a more careful examination of all the details the part indicated with arrows caught the eye. On comparing this with the corresponding point in the three higher vertebræ one recognises that in the seventh neural arch, the part corresponding to the articular processes was rotated about 80° in consequence of the fracture.

Calcified thyroid cartilages can project as vertical shadows right and left and be a trouble, especially at short focal distances and in ventro-dorsal view (pseudocallus).[1]

Dorsal Vertebræ

Only the first *three uppermost vertebræ* can be clearly seen in dorsal view, the others being much masked by the shadows of the sternum, the aorta, and the heart; with long enough exposure through the sternum the form of the vertebræ can be clearly photographed. The shadow of the liver interferes with the lower vertebræ. Therefore the principal projection for five-sixths of the dorsal vertebræ is the oblique one. For the lowest dorsal vertebræ the direct profile view on extreme inspiration is the one most preferred, and a dorsal photograph with two intensifying screens (see also below, "profile negatives").

Dorsal exposures.—The *upper dorsal vertebræ* closely resemble the lower cervical vertebræ in their shadows, and what was said of the latter applies equally to the former.

In *the transverse processes* of the first dorsal vertebra an extra nucleus has been observed on both sides.[2]

The beginner sometimes finds a difficulty in deciding which is *the first dorsal vertebra* and which *the last cervical* vertebra; especially seeing many projections do not indicate the attachment of the first rib. Fig. 158 will illustrate. The first rib articulates usually only with the first dorsal vertebra, but may in addition articulate with the seventh cervical vertebra (see also below).

The second to the ninth or tenth *ribs* are each wedged between two

[1] Grashey, Atlas I, 4th edition. [2] *Ibid.*

vertebræ ; and each vertebral body follows the number of the rib above it ; we can remember that much from our anatomy.

Abnormal development, *multiplication* and *coalescence* of single vertebra, occur in *congenital scoliosis*, further in congenital *elevation of the scapula*. A multiplication of the vertebræ, resembling the normal vertebræ unusually wedged between them, is not easily diagnosed as such. The first thing that catches the eye would be the presence of variation in the shadows of the spinous process, into which we would have to inquire further (see also in vertebral column, General).

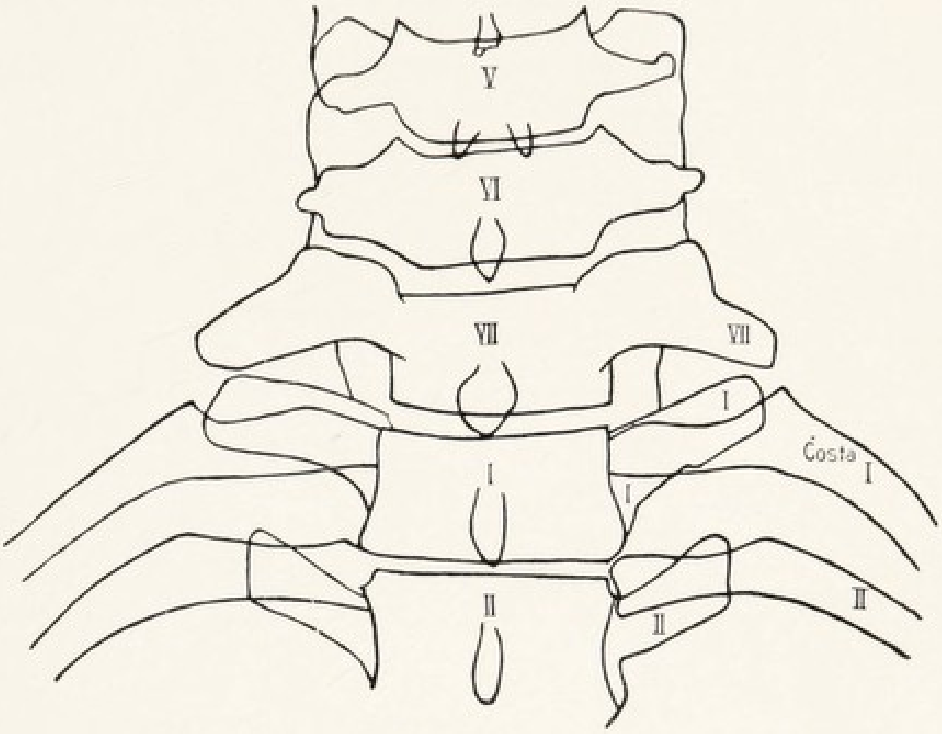


Fig. 158.

In members of various races one finds without any difference of age and sex a not infrequent forking of two to three of the *lower dorsal spinous processes*. This anomaly is probably to be regarded as a process of retrogression, and to be brought into line with the occurrence of the false ribs. The forking sometimes takes place also at the first lumbar vertebra.[1]

Oblique exposures.[2]—These succeed best when the back of the patient is supported by a sand pillow, and is placed at an angle of about 30° to the plate with the focus of the tube about 40 cm. above the right axilla.

The observer who succeeds in taking his first oblique negative will be struck by the marked degree of *scoliotic curvature* of the spine ; a normal

[1] Gundermann : Über eine häufige Anomalie der unteren Brustwirbelsäule. Münchener Medicin. Wochenschr., 1913, No. 34, p. 1878.

[2] Wilms was the first to recognise and recommend the great value of oblique exposures of the vertebral column.

appearance, which, however, has given rise to mistakes. (Seeing the vertebræ are at different distances from the plate owing to the normal kyphosis, the ones nearest the plate are projected almost in the middle line, the others deviating laterally according to their distance from the plate.)

The various superimposed shadows correspond to the following structures (Fig. 159) : a=the spinous process of the vertebra above ; b=the left transverse process ; c=the right transverse process ; d=superior articular process ; e=inferior articular process : C.V.d=fifth right rib.

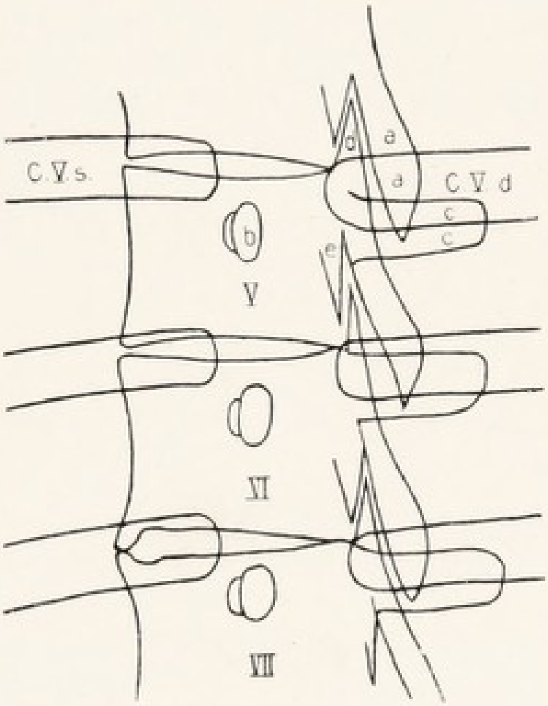


Fig. 159.

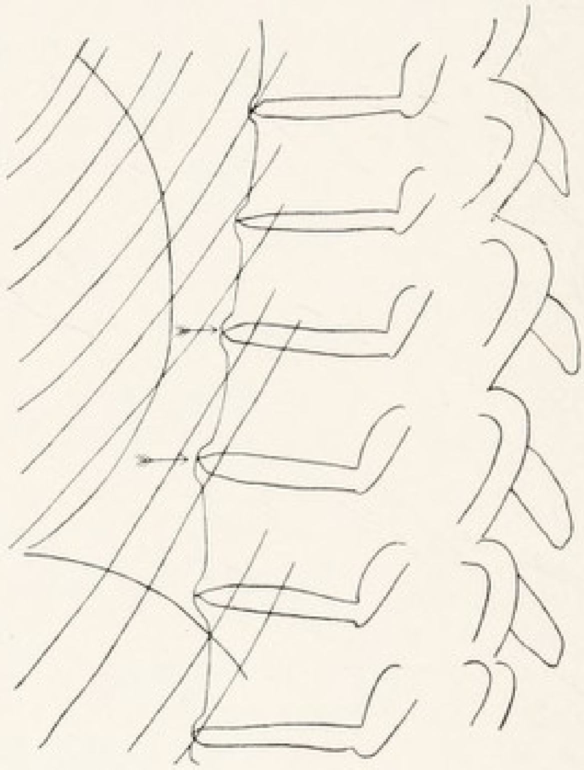


Fig. 160.

If the margins of the vertebral bodies do not form an angle of 60°–80°, but run out in sharp angles, points or processes in people over fifty years of age, that is simply a sign of old age (see Fig. 159, left, between the sixth and seventh vertebral body). If these *marginal processes* are larger (Fig. 160) or present in young people, then the finding is to be regarded as analogous to chronic arthritis (regarding the intervertebral space as the joint) and as a commencing chronic spondylitis.

In fractures similar marginal processes are formed at the vertebral bodies of the injured and especially the neighbouring vertebræ ; they are favourable, and are to be regarded as *compensatory processes.*

In numbering the vertebræ one should note that the twelfth rib is not merely subject to very great variations, but is sometimes absent altogether (see " Ribs ").

Profile pictures.—In these one obtains a good view from the fifth to the tenth or eleventh vertebræ, for they come into the clear pulmonary fields. Fractures, especially compression fractures, one sees clearest of all. The photographs can be taken well only in the horizontal position. The tube should be placed over the tenth spinous process; if it is placed more proximal, the half of the diaphragm on the side next the plate covers over two whole vertebræ and more. The three single vertebræ which are difficult to represent in profile, are the three uppermost dorsal vertebræ. On the other hand, one can obtain a good view in profile of the two last dorsal vertebræ, although they do not come into the pulmonary field, and also of

Fig. 161.—Sketch of the lateral view of a normal vertebral column.

(*a*) Eleventh rib distant from the plate (left).
(*b*) Eleventh rib near the plate (right).
(*c*) Inferior articular process of the eleventh D.V.
(*d*) Superior articular process of twelfth D.V.

Intervertebral space between.

The articular cavities between the twelfth dorsal and first lumbar vertebræ are not visible, for they are nearly sagittal.

(*w*) Width of the spinal canal in sagittal direction.
(*Qu*) Transverse process (next to plate) of the third L.V.
(*B*) Vertebral arch.
(*f*) Intervertebral foramen.
(*Z*) Diaphragm.

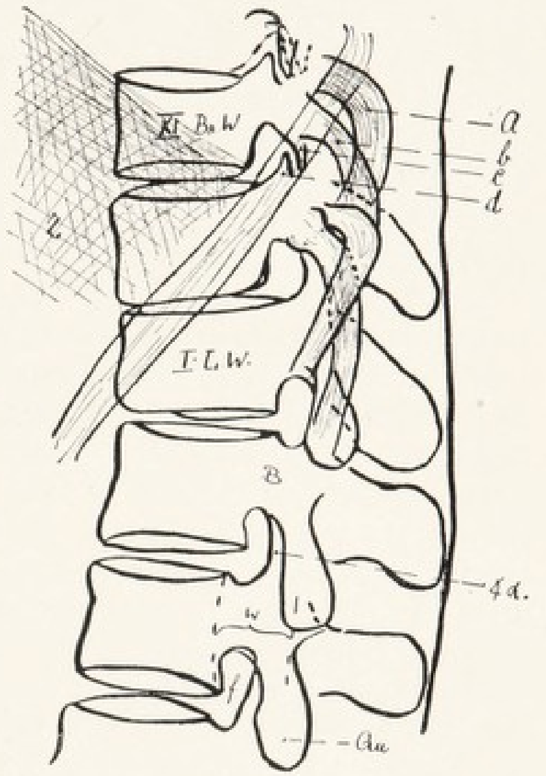


Fig. 161.[1]

all the lumbar vertebræ when the technique is adequate; satisfactory views being obtained even in stout adults. A new method affords an excellent view of the upper three dorsal vertebræ,[2] by projecting the shoulder outside the vertebral shadow. The radiograph must be taken in sitting or standing, the arms being stretched far forwards and downwards, and the hands clasping a knee. The neck is hyper-extended. The original work should be consulted for the details.

The circumstance that *the twelfth dorsal vertebra* marks the limit of a series in regard also to the articular surfaces so that its superior articular processes are in the frontal plane, while its lower articular processes are in an oblique plane, enables this vertebra to be used in frontal negatives for many a difficult identification. One should guard against considering the

[1] After Hammes, *l.c.*

[2] Bársony and Koppenstein: Eine neue Methode zur Röntgenunters. der oberen Brustwirbelsäule (frontal exposure). Fortschritte, Bd. 36, 1926.

angle between the shadow of the transverse process and the posterior margin of the intervertebral foramen of a lumbar vertebra as a frontally placed articular process. Compare the sketch of the lateral picture of a normal articular cavity, Fig. 161.[1]

A lesion only of a single vertebra, but otherwise simulating Pott's disease, has been observed a few times.[2] The intervertebral discs were unaffected, new formation appearances were seen in the cartilage, condensation areas in the bone, and signs of new bone formation. The disease might be brought into parallel with Köhler's disease of the scaphoid bone of the foot and with coxa plana.

After inflammation and following upon trauma cases of deposit of calcium have been reported in some of the intervertebral discs. This hitherto unknown disease has been called Chondritis intervertebralis calcarea or Calcinosis intervertebralis. First case: Twelve-year child, that fell ill with acute symptoms of fever and with partial fixation of the vertebræ. On the eighteenth day of the disease the Röntgen examination revealed a partial calcification of two of the intervertebral discs, at the juncture of the dorsal and lumbar vertebræ, the twelfth dorsal to the second lumbar: at the same time the upper and lower surfaces of the vertebræ were hollowed out in concave fashion. After a year the deposit of calcium disappeared again, only the concavity of the vertebræ being left. Second case: A man of forty-seven years: an accidental finding. Upon inquiry it transpired that he had fallen on the soles of his feet at the age of twenty-eight years while working on a second storey. Ten days in hospital: after two months his health was restored. During the preceding twenty-six years there had been no recrudescence of the pain. A dorsal röntgenogram shows between each of the seventh and eighth dorsal vertebral, as also between the ninth and tenth dorsal vertebræ, a linear and very intense shadow-band, which does not fill the whole intervertebral disc. The deposit of lime is insular, the islands flow in radiate manner to form larger patches, and are always well distinguishable from the bodies of the vertebræ. Probably a necrobiosis started in the cartilage in consequence of the accident and the deposit of lime followed later in the necrotised tissue.[3] Further cases were at once reported: one a condensation area between the ninth and tenth dorsal vertebræ, which corresponded in form and position with the nucleus pulposus, in a woman of seventy-two years with stiffness of the back and pain; one between the twelfth dorsal and first lumbar vertebræ and between the first and second lumbar vertebræ in a boy of twelve years, who was acutely ill with high fever (metastatic disease of the two intervertebral discs with secondary deposit of lime); one between the seventh and eighth

[1] Hammes: Über die Technik und den Wert seitlicher Wirbelaufnahmen. Fortschritte, Bd. 25, 1917.

[2] Jacques Calvé: Sur une affection particulière de la colonne vertébrale chez un enfant simulant le Mal de Pott. J. d. Rad., 1925, Tome IX, January, 1925.—See also Sicard, Haguenau, and Lichtwitz. Revue neurol., 1926.

[3] Baron: Über eine neue Erkrankung der Wirbelsäule. Ztschr. f. Kinderheilk, 104.—Bársony and Polgár: Calcinosis intervertebralis. Klin. Wchnschr., 4. Jahrg., No. 16.

and between the ninth and tenth dorsal vertebræ in a man of forty-seven, who had suffered from a severe trauma twenty-six years before. Vertebral bodies notched (accidental finding); once between the eleventh and twelfth dorsal vertebræ, especially in the nucleus pulposus owing to an ankylosing spondylitis and spondylarthritis.[1]

For further details of deformities, see under "Lumbar vertebræ."

Lumbar Vertebræ

These are usually viewed in *dorsal negatives*, occasionally too an oblique negative is helpful, and in children even a profile negative; even in the adult satisfactory profile negatives can often be secured.

The shadow of the vertebral bodies of *children* and *young people* have blunted edges.

Since the beginner and the inexpert can only differentiate with difficulty the superimposed shadows of the parts of the vertebræ, a diagram is given in which the arches with their articular processes are the most obvious structures (Fig. 162). The most important areas, including the articular cavities of the superior and inferior articular processes, cannot be clearly recognised in röntgenograms that are only moderate in quality (see Fig. 162). In *fractures of the articular processes* [2] changes are found, obliquity of the joint cavity, etc., which are recognisable only in the very best diaphragm negatives, and even then not in every case. In most of the pictures such fractures are best diagnosed from the angulation of the vertebral bodies or a break in the line connecting up the spinous processes. One can see these articular cavities more easily in cases suspected of spondylitis deformans or Marie-Strümpell-Bechterew's disease. For while in fractures only one or two joints are concerned, in the diseases mentioned the whole spine or great parts of it are affected; and although we cannot get a view of all the joints on account of the complicated cross-cuttings of the shadows, we can usually see one, and that usually suffices. One then finds complete disappearance of the joint cavity, that is, ankyloses, or it may be only irregularities, narrowing, and deformity of the articular ends. The best view of these conditions is obtained at a point where two articular cavities are projected directly on to an intervertebral space (crossing) or in negatives, in which the focus of the tube is not centred over the middle of the spine, but right or left from it, as evident in many kidney photographs. The changes of the vertebræ themselves, their marginal processes and bridges, are much more easily recognisable (see the remarks in the next figure, Fig. 163).

The *transverse processes* vary much in their form and length. The breadth is the most constant feature. Forms as in Fig. 147, left, are occasion-

[1] V. Horenstein: Kasuistischer Beitrag zur Verkalkung des Nucleus pulposus der Zwischenwirbelscheibe. Fortschritte, Bd. 35, 1927 (with list of the literature).—Baron, Budapest: Neue Wirbelsäulenerkrankung. Chondritis intervertebralis acuta calcarea. Ztrlbl. f. Chir., 1924, Heft 6, p. 250.

[2] See further also K. Koch, D. Ztschr. f. Chir., 180, 4–6.

ally met with on one side.[1] Unilateral lumbo-sacral vertebra. Upon one occasion the author found a peculiar *triple transverse-process* on both sides of the fourth lumbar vertebra.

The *superior articular processes* of the fourth and fifth lumbar vertebræ are sometimes met with slightly but distinctly curved. The author has not yet been able to determine whether that is a normal condition or not.

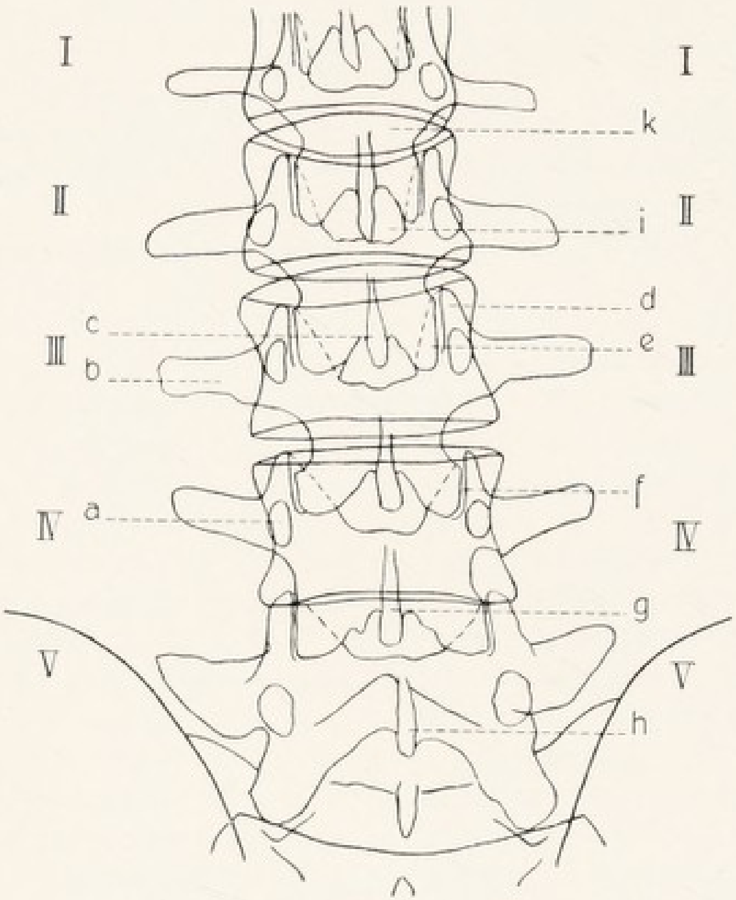


FIG. 162.

a=Root of the vertebral arch (fourth lumbar vertebra); *b*=Transverse process (third lumbar vertebra); *c*=Spinous process (second lumbar vertebra); *d*=Superior articular process (third lumbar vertebra); *e*=Inferior articular process (second lumbar vertebra); *f*=Joint between third and fourth lumbar vertebral arch; *g*=Spinous process (fourth lumbar vertebra); *h*=Spinous process (fifth lumbar vertebra); *i*=Translucent parts, where no part of the vertebral arch shadows the vertebral body or the intervertebral space in the direction of the rays; *k*=Intervertebral space and overshadowing of the same by the obliquely-rayed bodies of the first and second lumbar vertebræ.

If between normal broad transverse processes one meets a *narrow shadow of the transverse process* on both sides, and if the patient has had an injury, that indicates an injury to the affected vertebra and its displacement out of position; so that the transverse processes are no longer placed with

[1] A similar observation is illustratively described by Calvé: Sur un cas d'anomalie d'une des apophyses transverses de la 5. vertèbre lombaire. Orthopédie et tuberculose chirurgicale, 1. Jg., 1914, 1. Heft. From the literature given there it appears that the author of this book in the 1910 edition was the first to draw attention to this anomaly.

their broad surface in the frontal plane, but are rotated more or less about a transverse axis.

Isolated fractures of the transverse processes occur and are usually well seen in Röntgen pictures ; but in the transverse processes of the first lumbar vertebra a fracture can sometimes be simulated, where there is none, especially if the edge of the psoas (or still more, the intervening space between psoas and kidney) produces *a transparent line* in the shadow of the transverse process.[1]

It is seldom that a patient keeps his spine quite straight during the taking of a Röntgen negative. Small *asymmetries* are therefore always appearing, and one should avoid diagnosing these as pathological. Frequently, moreover, the patient holds his spine slightly rotated, especially towards the upper lumbar vertebræ. While *e.g.* the sacrum and the fifth lumbar vertebra are projected in the desired way, the other vertebral shadows towards the head increase in obliquity and want of clearness. At the level where the rotation is greatest an incorrect diagnosis is rare, because the rotation cannot be missed ; but in the vertebra at which it starts there are produced shadows which may well lead to a faulty diagnosis. While the intervertebral space on the one side is quite free, on the other side it appears closed, because a shadow with a convex contour covers it laterally. We have here to deal with the articular processes, which are projected by a slight rotation out from the shadow of the vertebral bodies.

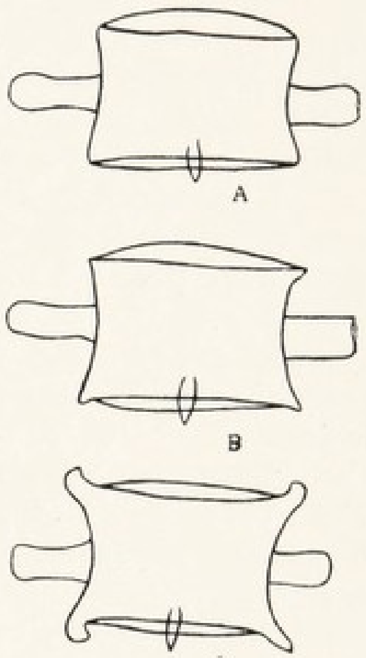


FIG. 163.

Sometimes one finds at the first lumbar vertebra in place of the transverse processes, which are quite absent, rib-like structures articulating with the vertebræ, and not much longer than the transverse processes of other lumbar vertebræ. We have here to deal with *lumbar ribs*. The twelfth rib is usually abnormally long in such cases. This anomaly of the lumbar rib—which is a constant feature in the hylobates, gorilla and chimpanzee—is usually found in individuals having still other peculiarities of growth.

Reduction in size of the second lumbar vertebra has been observed in congenital kyphosis. The mother and sister of the patient showed the same findings.[2]

The shadow edges of the vertebral bodies form normally in the röntgenogram an angle of about 60°–80°, and are always somewhat rounded at the summit (Fig. 163). With advancing years this rounding disappears

[1] See also Biermann : Am. Journ. of Röntg., June, 1923.—W. Niedlich : Isolierte Querfortsatzfracturen der Lendenwirbelsäule. Beitr. z. kl. Chir., 132/3, p. 655.

[2] Wollenberg in Gerhartz' Leitfaden.—See also Wehner : Ztschr. f. orthop. Chir., Bd. 43.

and the angle becomes more a geometrical right angle. Smaller appositional processes also make their appearance, without there being any more than this one sign of advancing years present (Fig. 163, B), but if these slight changes build out into long marginal processes of several millimetres, and if the patient complains of pain and grating upon movements, then we are concerned with definite pathological processes (*chronic rigidity of the spine*), Fig. 163, C.[1] Seeing such marginal outgrowths are to be regarded in the last resort as compensatory processes, one need not wonder to see them developing in the later stages of fractures, and luxations, that is, after accidents which affect the stability of the vertebral column (see also pp. 184 *et seq.*).

In prostatic carcinomata *metastases* appear in the skeleton, and under their influence similar *new bony formations* appear in the bodies of the vertebræ, often of considerable size. And it is well known that it is not only in prostatic carcinomata that osseous formations occur in the secondary metastases into the bony system—a condition peculiar to prostatic cancer—but similar changes can sometimes ensue in carcinoma arising from other organs (*e.g.* mammary carcinoma, thyroid gland carcinomata). In the bony metastases developing after sarcomata and malignant hypernephromata osteoplastic processes of that kind are never found. These metastases are usually encountered in the lowest dorsal and upper lumbar vertebræ.[2] It would not be necessary to mention these conditions in the pages of this book, if these carcinomatous metastases in the vertebral body were radiologically easy to recognise. That is unfortunately seldom the case. Certainly it is the fresh osseous formations that are easiest to recognise, while the majority of tumours only mask the structure of the vertebral bodies and appear to diminish the shadow-intensity only to a moderate extent. Others maintain [3] that in tumour metastases we can speak of an " abnormal porosity " of the affected lumbar vertebræ. In these cases clinical symptoms were present without the primary lesion being known or local pain being felt : unilateral sciatica with marked remissions, that simulated complete health, and even prolonged periods of freedom from sickness. Then the clinical picture of a bilateral sciatica sets in gradually. It was only very late, shortly before death, that neurological symptoms appeared. In a slight lesion-like transparency in a vertebral body, with pain felt at the corresponding point, one should not forget to inquire into a possible occurrence of enteric, which sometimes produces lesions in the

[1] A good survey of these changes is found in Plate : Über die Anfangsstadien der Spondylitis deformans. Fortschritte, Bd. 16, 1910, and in Bertolotti : Über die Nosologie der chronischen Ankylose der Wirbelsäule. Archiv f. phys. Med. und med. Technik, Bd. 7, 1913.—W. Schwanke : Wirbelsäulen-Versteifung. Fortschritte, Bd. 33, 1925, p. 1.

[2] Recklinghausen's " Osteoplastische Karzinose," quoted after Eugen Fraenkel. Fortschritte, Bd. 16, 1910.

[3] Th. Scholz : Röntgenbefund in 2 Fällen von metastatischem Karzinom der Wirbelsäule usw. Fortschritte, Bd. 28, 1922.—Siccard, Coste, Belot, and Gastaud : The representation of the vertical column in Röntgen view. J. de Rad., August, 1925, p. 353.

bone which do not give rise to complaints till several months from the incidence of the disease.[1]

If one sees *the cavity of the articular processes* exceptionally clearly (Fig. 162, *f*), and clinical complaints point to an extreme affection of the vertebral column, such a condition can arise from transparent areas of tumour being present in the vertebral bodies in the path of the rays in front of articular cavities possessing a normal density of calcium ; the author observed this in a very interesting case of multiple myeloma, but it can only be recognised in absolutely perfect negatives and with exact study.

In *fractures* the above description general to all the vertebræ is specially applicable to the lumbar column. The conditions are very difficult, particularly in the fifth lumbar vertebra. This vertebra even in exceptionally well-marked lumbar lordosis is so projected that it seems to be lower. In fractures its shadow almost completely disappears,[2] even if it is only the articular processes on both sides of the fifth vertebra that are fractured. Such take place in severe over-flexion or over-extension of the lumbar vertebral column. The fifth lumbar vertebra then usually slides forwards on to the promontory of the sacrum.

The surest way to photograph *the fifth lumbar vertebra* with a small and vertical diaphragm is to centre the tube where the median line of the body intersects with the line connecting the two anterior superior spines. This view, however, does not afford the best survey. A better is got by projecting the tube-diaphragm on to the vertebral bodies by pressing obliquely from distal to proximal. The neural arches, on the other hand, are best secured by setting the tube obliquely from proximal to distal.[3] In patients that are not too stout, one should try to obtain a profile view of the fifth lumbar vertebra through the iliac bones ; [4] moreover, one should endeavour to arrange that the tube is directed from above proximal to below distal, and is pressed firmly into the soft tissues. This enables us to avoid the upper aspect of the iliac bone. A distorted picture is naturally obtained.

If after severe trauma the shadow of *the body of the fifth lumbar vertebra* is very oblique on the sacrum, then the affected articular processes are broken only on one side. It is only seldom and under specially favourable circumstances that one can see the break itself—one should accordingly express one's opinion all the more carefully—but it is described as frequent and typical, and corresponding bony preparations are found in the anatomical collections.[5] If the oblique position of the fifth vertebra on the sacrum is compensated by the third and fourth lumbar vertebræ, whose body shadows

[1] H. Gallus : Über Spondylitis typhosa. Fortschritte, Bd. 28, 1921.—A. Lorey : Über Spondylitis typhosa. *Ibid.*

[2] See Delorme : Beitrag zur Kenntnis des Verhebungsbruches am 5. Lendenwirbel, Münchener Medizin. Wochenschr., No. 10, 1910.

[3] Serra : Anatomia e patologia röntgenografica della Va lombare. Radiologia med., 1914.

[4] Hammes, *l.c.*

[5] See Ludloff : Verletzungen der Lendenwirbelsäule und des Kreuzbeins. Fortschritte, 1906, Bd. 9, 1905/06.

show a compensating wedge formation, there is probably present a congenital anomaly without any trauma. An oblique positioning of the shadow of the fifth lumbar vertebra on the sacrum in Röntgen pictures may also occasionally be physiological.[1] The clinical findings must then decide.

The shadow of the spinous process of the fifth lumbar vertebra (sometimes also of the fourth) is sometimes projected in the shadow of its own vertebral body, in consequence of physiological movement of the vertebra around a frontal axis. Consequently, it appears also shorter, often only as a spot ;

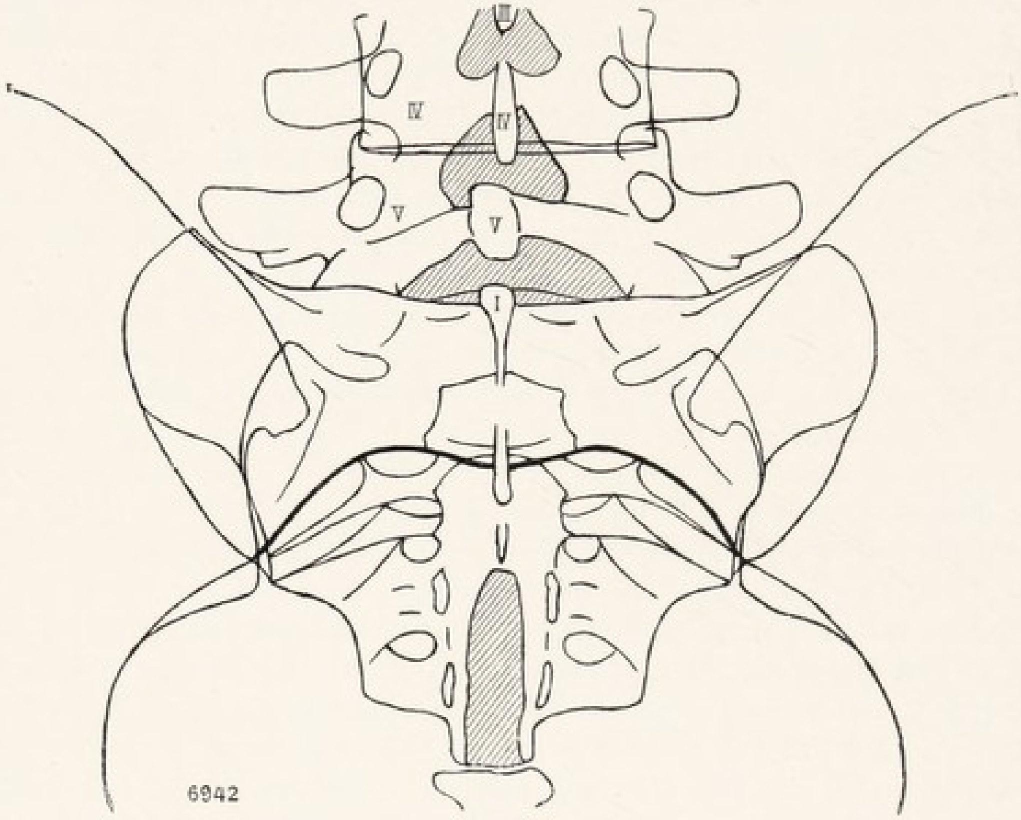


Fig. 164.

occasionally the first spinous process of the sacrum with its arch open below may fall in the shadow of its vertebral body. Occasionally also an extremely long fifth spinous process occurs, as shown in Fig. 167, F. Further, when it appears short in projection, it can be regarded as being in reality longer than it seems. The author once saw a shadow of a fifth spinous process 5 cm. in length. Regarding the asymmetry or *obliquity* of the arch of the fifth lumbar vertebra and the first sacral vertebra, see the summary given under " Sacrum."

A case of synostosis of the posterior neural arches of the fourth and fifth lumbar vertebræ with bilateral symmetrical sacralisation of the fifth lumbar vertebra and patency of the posterior neural arch of the fifth lumbar vertebra has also been reported.[2]

[1] Schede : Der fünfte Lendenwirbel im Röntgenbilde. Fortschritte, Bd. 17, 1911.

[2] G. Cola, Palermo : A duplicate skeletal anomaly in the lumbo-sacral region. La Rad. Med., March, 1924.

The fifth lumbar vertebra, joined by bone with the sacrum, assimilated to it, a so-called "*sacralised fifth lumbar vertebra,*" is met with in about 1 per cent. of Röntgen photographs of this region;[1] see also "Sacrum"

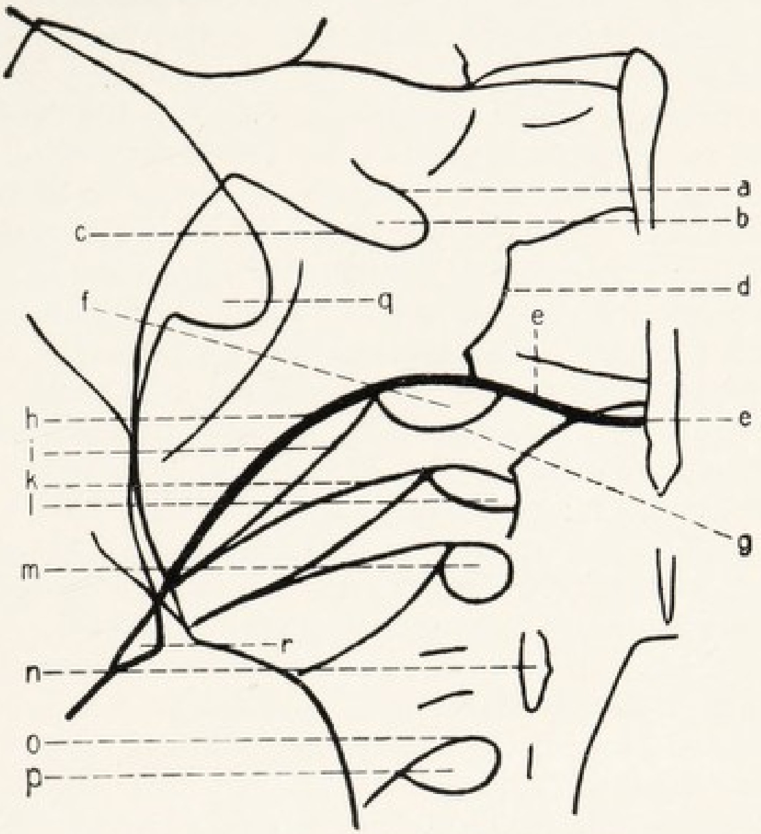


FIG. 165 (=left inferior part of Fig. 164).

a, b, c=opening of the first foramen to the dorsal surface of the sacrum; *b*=lumen, *a*=upper medial margin, *c*=lower lateral margin of the foramen with exit to the dorsum of the pars lateralis; *d* (and continuation inwards and upwards)=the part of vertebral body running in the direction of the rays, which is surrounded by the first sacral foramen, the corresponding intervertebral foramen and the sacral canal; *e*=promontory; *f*=opening of the first foramen to the pelvic aspect, *i.e.* anterior opening; *g*=lower margin of opening; *h*=upper part of anterolateral wall, into which the promontory runs; *i*=corticalis of the groove of the first foramen running laterally; *k*=anterior upper margin of the second foramen with lateral exit of the same; *l*=anterior opening of the second foramen; *m*=foramen II; *p*=foramen IV; *o*=upper margin of foramen IV and lateral exit; *n*=part of the articular sacrum crest; *q*=posterior superior spine; and *r*=posterior inferior spine.

and Fig. 169. About half the cases give clinical symptoms: Limping, sciatica, stiffness, scoliosis, contracture of the lumbar musculature, hypertrichosis in the lumbar region, local tenderness on pressure, muscular

[1] Dürr: Assimilation des letzten Bauchwirbels. Zeitschr. für rationelle Medizin, 3. R, Bd. 8.—See also Coleschi: Sacralizzazione simmetrica della V. vertebra lombare.—Considerazione roentgenodiagnostiche ed infortunistiche. Rassegna Sociale.—Rivista della Cassa Nazionale infortuni, 1918, No. 3.—A. Rossi: Sciatiche di orgine scheletrica da anomalia vertebrale e la sindrome del Bertolotti. Chirurgia degli organi di movimento, December, 1918.—L. Coleschi: Contributo allo studio röntgenologico delle anomalie congenite del tratto lombo-sacrale del rachide. Radiol. med., July–August, 1919.—Japiot: Journ. de Rad., 1921.—G. Turini: Revue méd. de la Suisse rom., 1922, No. 2.

atrophy. The symptoms very often do not appear till later on in life.[1]

The interpretation of the grosser and finer *details of the fifth lumbar vertebra* is one of the most difficult chapters of röntgenology, first on account of its form differing considerably from the neighbouring vertebræ ; further on account of its oblique position in the usual dorsal projection to the recipient photographic plate ; finally, because it is the favourite site of morphological anomalies.[2] Every one must have noticed in his films that in contradistinction to the fourth and the preceding vertebral bodies the fifth lumbar vertebra is neither so well-defined above and below nor shows such strong lateral contours. The want of definition is due to the wedge-shaped form peculiar to this vertebra—it is deeper in front than behind—and to its oblique position, whereby its upper and under surface is obliquely met by the projecting rays and the inferior surface also is overshadowed for the most part by the sacrum. Consequently, this vertebra appears as a rule exceptionally low in position. The lateral contours are not so clear for the following reason : the upper lumbar vertebræ have a pronounced neural root, the bodies are sharply delimited from the arches and the transverse processes. Their lateral walls are almost sagittal walls in a certain distance in the path of the rays. In the fifth lumbar vertebra, however, which forms in a way a transition to the sacrum, the arch is no longer so sharply delimited ; the neural root disappears, the transverse processes are moderate in size, and the gradual merging of the body into them begins quite ventrally.

Mention should here be made of one form of disease, which—as long as the profile röntgenograms are not yet perfect— can be easily missed in the sagittal view even by men of some experience ; this is spondylolisthesis. What is understood by that according to Killian is a slowly completing displacement of the last lumbar vertebra on the first sacral vertebra forwards, or rather forwards and downwards. The condition is very rare, but has long been well known to the gynæcologists, for it is of practical importance for them. (The spondylolisthetic pelvis has now been distinguished from kyphotic pelvis, with which it was formerly included.) In the text-books of practical surgery they speak of a total dislocation of the fifth lumbar vertebra ; that is, however, inexact, for in most cases the posterior part of the arch with the inferior articular processes does not undergo dislocation. Spondylolisthesis appears to occur far more frequently than was formerly believed. Certainly the disposition for the vertebral bodies to glide appears to be present in a comparatively large number of people. As mentioned, the whole of the last lumbar vertebra is not usually displaced,

[1] Casolo, Milan : Clinical and röntgenological contribution to the study of sacralisation of the fifth lumbar vertebra. La Rad. Med., June, 1924, p. 357.

[2] There are a number of special works on the subject : Putti : Die angeborenen Deformitäten der Wirbelsäule. Fortschritte, Bd. 15, 1910.—Schede, see footnote 1, p. 230.—Fischer : Der letzte Lendenwirbel. Fortschritte, Bd. 18, 1911/12.—Garcin : Journ. de Rad. et d'Electr., Bd. B, No. 9.—Emil Rosenberg : Die versch. Formen der Wirbelsäule des Menschen u. ihre Bedeutung, 1920, Jena, Fischer.

but the posterior half of the arch carrying the inferior articular processes and the spinous process does not undergo any displacement. Such a fifth lumbar vertebra shows clearly an elongation of the neural arch, especially the interarticular portion, which in sagittal view appears to enlarge the spinal canal very considerably. The articular processes, usually so near, can be separated as far apart as 1–2 cm. It has been proven (by Neugebauer) that the origin of this elongation is to be sought in a congenital ossification anomaly of the neural arch, the so-called spondylolysis interarticularis congenita; in these cases each neural half arises abnormally from two ossification nuclei, and at their place of contact there is an absence of fusion, so that a pseudarthrosis or simply a ligamentous union is produced. In addition to this developmental anomaly of the arch there are doubtless other causes to be considered: anomalies of the articular processes and fractures of the articular processes, or rather of the portio interarticularis. At the moment findings upon early cases are lacking. The lumbo-sacral junction does certainly seem to be a locus minoris resistentiæ. This spondylolysis is decidedly more frequent than the anatomists report, but does not exceed more than 5 per cent. of all lumbar vertebræ, and—as mentioned—a whole series of causes must be admitted. Clinically, the disproportion between the length of the lumbo-sacrum and the length of the leg is characteristic of well-marked cases; the lumbo-sacrum appears to have sunk into the pelvis, the abdomen is distinctly shortened; the upper part of the sacrum projects forwards and above the sacrum is a lordotic bend; but it is only seldom that this lordosis attains any considerable degree. There is also a peculiar gait described for spondylolisthesis, "rope-dancer's gait," narrow gait with very short pace but equal on the two sides. The symptoms of the patient are not typical for the condition: pains in the sacrum, as have been observed frequently in many other complaints, sometimes radiating into the thigh. The attacks of pain may be very severe, or there may be only a feeling of weakness or tension. There is little reference to Röntgen findings in the German literature, but much more in the American and Russian (see footnote). The principal and most reliable Röntgen symptom of spondylolisthesis is said to be the inclusion of the shadow of the vertebral bodies in that of the sacrum. The fourth lumbar vertebra also, and sometimes even the third lumbar vertebra, appear in unusual projection; of the fourth there is at times very little to be seen. For commencing cases the lateral view is the only determining one. The malady is also found in men, and according to one investigator's report comparatively often after trauma to the back. In such a case it might be possible by early diagnosis to arrest the progress of the disease. For rendering the Röntgen picture clearer it might be advisable to fill the colon with air.[1]

[1] W. Jaroschy: Spondylolisthesis lumbosacralis. Bruns Beitr. z. kl. Chir., Bd. 138, Heft 3 (with complete list of the literature).—Darling, Palmer, Bowman: Amer. Journ. of Röntg., 1918, 1922, and 1924.—Desfausses and Collin: Rev. d'orth., 1925.—Els: Beitr. z. kl. Chir., 1915.—Michael: Neederl. tijdschr. v. verlosk en gyn., 1924, Bd. 29.—Neugebauer:

It has recently been asserted[1] that spondylolisthesis is not a rare disease. It sometimes arises quite gradually, and sometimes also in correlation

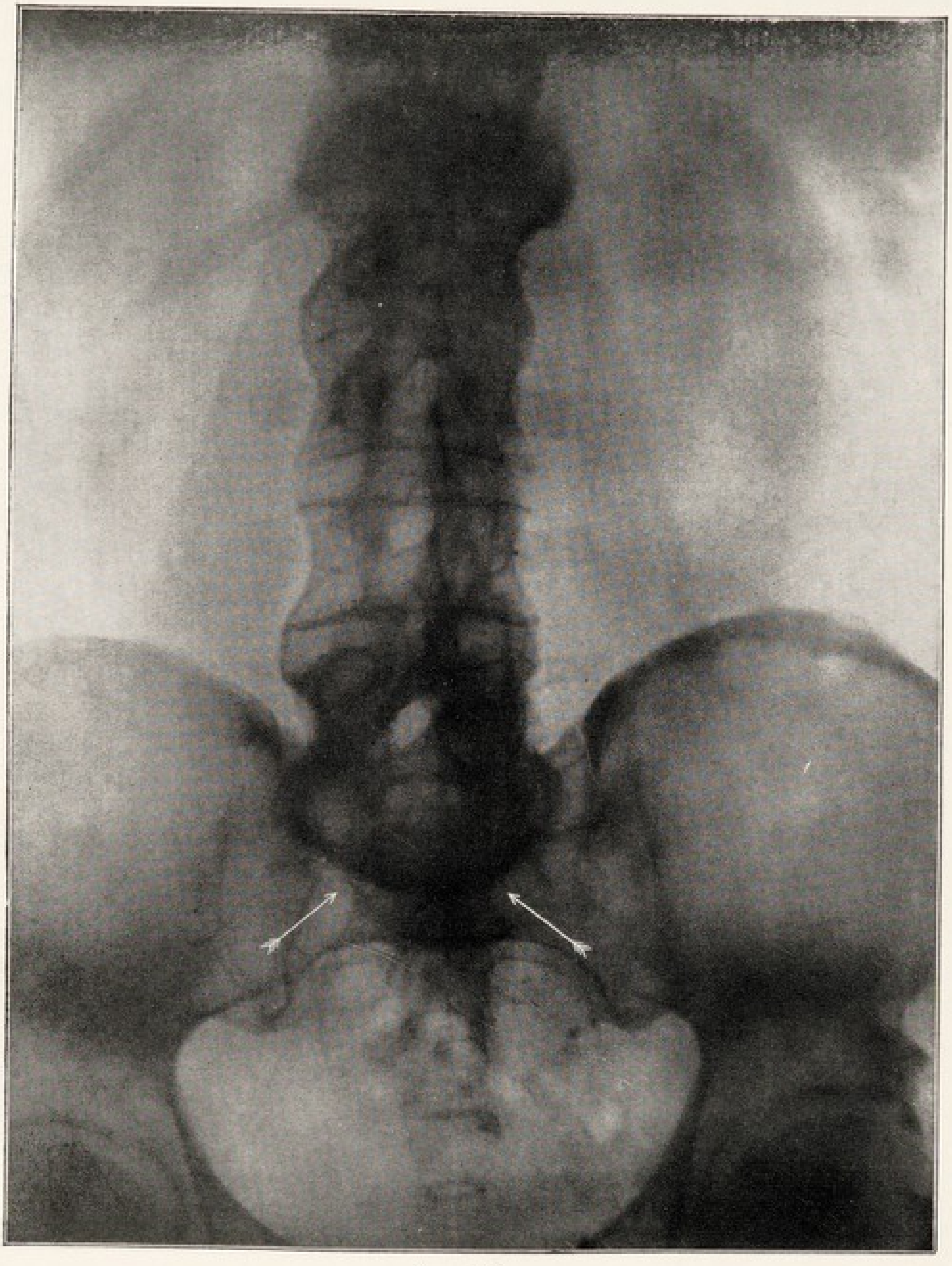


Fig. 166a.

with fractures or congenital anomalies of the fifth lumbar vertebra and

Arch. f. Gyn., Bd. 35.—Wiemers: Arch. f. Orthop., 1913, Bd. 12.—E. L. Meisels, Lemberg: Fortschritte, Bd. 35, 1927.

[1] Bowman, Los-Angeles: Spondylolisthesis a common lumbosacral lesion. Am. J. of Röntg., March, 1924, p. 223.—B. C. Darling: Spondylolisthesis, or Lumbosacral dislocation. Am. J. of Röntg., January, 1918, p. 16.—H. Turner and N. Tchirkia: Spondylolisthesis. J. Bone and Joint Surg., 1925, VII, 763–86.

first sacral vertebra. Many of the injuries hitherto regarded as dislocations of the sacro-iliac synchondrosis may be spondylolisthesis. Then still another observer [1] maintains that spondylolisthesis can be very easily mistaken, especially in dorsal negatives, particularly when the angle between the anterior margin of the last lumbar vertebra and of the first sacral vertebra is an unusually large one. The profile view is then to be preferred, but even then the possibility of mistakes can still occur. Where the profile view is not successful one should try an oblique - lateral projection. The author of this book can agree with this finding only as far as the point that spondylolisthesis can very easily be mistaken; he cannot agree with the view that spondylolisthesis is not at all a rare disease. I cannot recollect in about thirty years' Röntgen practice having seen an absolutely certain case. A single case which, following upon a dorsal view, was regarded as a spondylolisthesis (Fig. 166A) was röntgenographed nine years later, this time with the addition of a profile view. The latter (Fig. 166B) showed conclusively that there was no loosening and no sliding downwards of the fifth lumbar vertebra, but that only the lumbo-sacral angle had been considerably enlarged, thus producing a confusing projection in the dorsal picture. The semicircular shadow here seen so clearly above in the shadow of the sacrum corresponds therefore simply to a fifth lumbar vertebra inclined to a maximum; but as already stated it is not subluxated even in the slightest degree, and still less therefore could it have slipped forwards. That the particular semicircular shadow corresponds to the fifth lumbar is revealed by the fact that there are only four lumbar vertebræ present above it, and it is not a sacralised vertebra. The ossified capsular bands

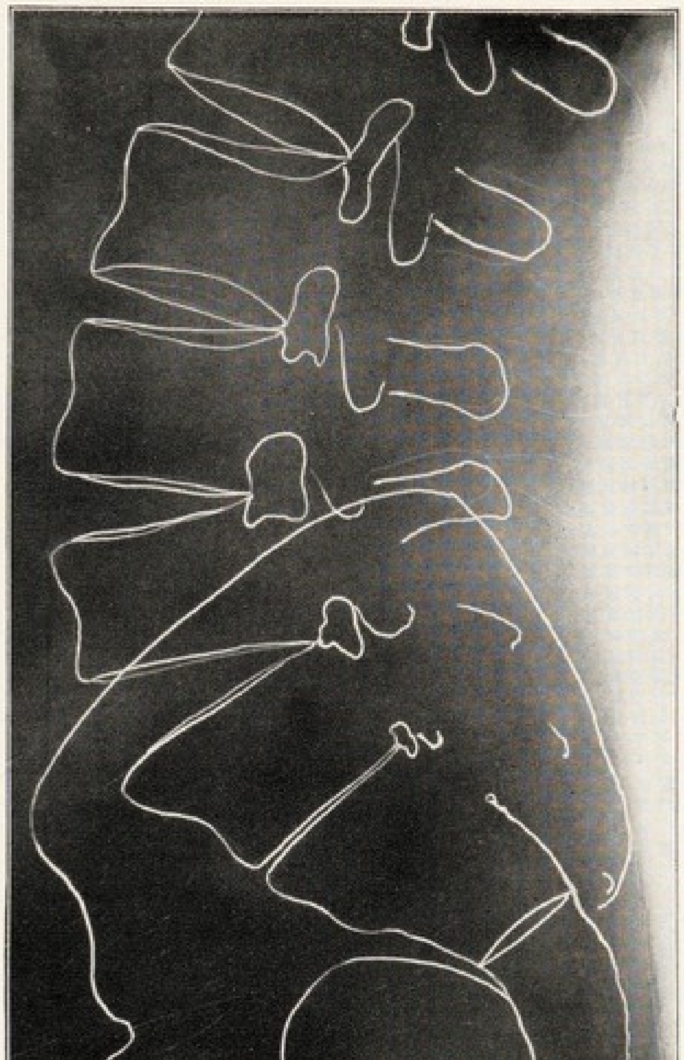


FIG. 166B.

[1] Lewald, New York: Lateral röntgenography of the lumbosacral region. Am. J. of Röntg., October, 1924.

(bridges) in the upper vertebræ were, moreover, not yet indicated in the negative nine years before. They are probably to be explained as compensatory processes, which purpose they carry out completely, for the patient, a man of seventy years, has quite a fresh and active appearance and declares that his only worry is that he cannot bend as well as he could fifteen years ago. There are many radiograms of the back to be found in the literature of spondylolisthetic patients, they show a strongly projecting and strongly curved sacrum, and immediately above a narrow groove or depression extending upwards, and large transverse folds of the skin on either side along the inferior costal margin. Our patient showed only a slightly prominent os sacrum, otherwise nothing much was to be seen in the röntgenogram.[1]

It has not yet been explained how in some adults vertebral bodies occur with central depressions. This peculiar pathological change can be regarded as an isolated deformity or as a concomitant of cranio-caudal shortening or wedge-formation.[2] This depression can probably arise only through a comparatively too strong pressure, in which there occur in the intervertebral discs not only pressure, but also pulling, torsion, and shearing tensions. The condition is regarded as " a reciprocal modelling of the impressed vertebræ and the impressed intervertebral discs." Whether the change in the intervertebral discs is primary or secondary to " the formation of a large intervertebral disc, by which the cranio-caudal diameter of the lateral surfaces is increased," has not yet been settled. One large intervertebral disc was demonstrated in the röntgenogram, and that might be the first stage. The reciprocal modelling of the vertebral bodies and the intervertebral discs, apart from the structure or rather the mechanics of the intervertebral discs, would doubtless be favoured by the fact that the surfaces of the superior and inferior corticalis of the vertebral bodies might give way to cranio-caudal pressures more readily than the osseous cylinder of the body itself formed of lateral, anterior, and posterior surfaces, and with its edge to a certain extent in constant action. In the one case treated the success of the therapy indicated that the condition was due to lues; one neurologist diagnosed the case as a tabes, another as a lues cerebrospinalis. The pathologist Schmorl showed preparations at the German orthopædic congress of 1927, in which enlarged intervertebral discs had pressed into the vertebral bodies or had indeed grown right through them " by diffuse enlargement of the intervertebral discs caused by degenerative processes " and a formation of " pearls of cartilage."

That one vertebra can cast a deeper shadow than the one above it or below it is a fact, although it is exceedingly rare; it occurs especially in osteoplastic processes in the sense of reactive new formation of bone in

[1] For the further literature, see also J. F. Brailsford: Röntgenography of the Spine. Am. J. of Röntg., August, 1927.—G. J. Turner, Leningrad: Veränderungen der Statik des Körpers bei Spondylolyse. 17. Russ. Chir. Kongress, Leningrad, 1925. Reference: Fortschritte, Bd. 35, p. 826.

[2] A. Baron and Th. Bársony: Central eingedellte Wirbelkörper. Fortschritte, Bd. 36, 1927.

central sarcomata. In such cases it is not possible to recognise any structure in the particular vertebra, the condensation appears to be quite homogeneous. In the case published the vertebral body showed a normal size in its external outlines, upon closer investigation a certain roughness of the superior contour of the body was noticeable. The condensation of the tissue-structure was so well marked that the vertebral body in frontal view was plainly visible even through the two iliac bones. Microscopic examination: Typical spindle-cell sarcoma.[1] In metastatic carcinoma on the other hand, osteoplastic processes as is well known are not infrequent.

Remarkable large semicircular sharp defects at the anterior surface of some of the bodies of the lumbar vertebræ were found in the Röntgen view in a case of aneurism of the abdominal aorta. Confirmed at autopsy. This picture is one of the most unusual that has ever been seen in the Röntgen literature of skeletal changes.[2]

In contradistinction to the joints of the other lumbar vertebræ the *superior articular processes of the fifth vertebra* are seldom visible in Röntgen view as a clear fissure, sometimes only a little, sometimes not at all. The position of the upper articular surfaces of the fifth lumbar vertebra is indeed not sagittal, but an intermediate position between sagittal and frontal; the sacro-lumbar or *inferior articular processes* are placed almost exactly frontal. Short vertical transparencies corresponding to the mere beginnings or ends of the joint fissure are nevertheless sometimes seen. One may also notice on one side, in spite of the vertebræ being practically symmetrically projected, a definite articular cleft evident on one side and not on the other. One should not at first view make an absolute diagnosis of a pathological change from the absence of an articular cavity, more especially in the lower joints. If the joint is absent on both sides, which is the rule in lumbo-sacral articulations, we are not tempted to make such a diagnosis. But if one sees only the one lumbo-sacral articular cavity, one is apt to declare the other one "obliterated" and to declare it due to a traumatic injury. Moreover, even in the most exact symmetrical projection, the region of one *sacro-lumbar articulation* is sometimes denser than that of the other. That may very well be normal, for experience proves that one joint, especially the right, is more strongly developed than the other.

For oblique, distorted, bayonet-shaped *form of the arch of the fifth lumbar vertebra,* finally separated by a fissure on the right or left from the spinous process and similar malformations or major defects, see below under "Sacrum. Spina bifida occulta."

A bellying out of the line of the psoas shadow to the side is often the sign of a psoas abscess. In other cases the shadow of calcium granules lateral to the vertebral column, along the psoas, is the only symptom of a psoas abscess.[3]

[1] Breitländer: Centrales osteoplastisches Sarkom eines Wirbels im Röntgenbilde. Fortschritte, Bd. 34, 1926.

[2] J. F. Brailsford: Röntgenography of the spine. Am. J. of Röntg., August, 1927.

[3] Bársony and Polgar: Ein Röntgensymptom der Psoasabscesse. Fortschritte, Bd. 34, 1926.

If a marked *concretion-like shadow* appears in the shadow of a lumbar vertebra, one should think—apart from calcified lymph glands, which, however, have not yet been described at this spot—also on the possibility of a concretion in a horse-shoe kidney (see also under "Kidney").

A rare finding is a calcification of the ilio-lumbar ligament. The ligament runs from the transverse process of the fifth and partly also from the fourth vertebra to the posterior part of the crest of the ilium, the inner surface of the iliac fossa and the posterior surface of the lateral part of the sacrum.[1]

Sacrum

In the third month of fœtal life *three osseous centres* appear in the first sacral vertebra, just as if there were a sixth lumbar vertebra.

In the newly-born child the bodies of the first to the fifth vertebræ and the costal elements of the first to the second vertebræ are ossified.

The *osseous union of the bodies* begins about the sixteenth year of life in the two lowest vertebræ and advances upwards, so that the synostosis between the first and the second sacral vertebræ is delayed until the twenty-fifth to the thirtieth year. The vertebral arches and their processes unite in like manner. Regarding the age and sex differences of the sacrum, see under "Sacro-iliac synchondrosis."

Translucent spots in the shadow of the sacral bone equal to crown pieces or more in size are a quite normal appearance. They are due to collections of gas in the intestines, and ought not to be regarded as tuberculous lesions or tumours infiltrating the bone. In differential diagnosis the beginner should note that when the transparency widely exceeds the contour of the bones we are certainly handling gas-bubbles. If that is not the case one should endeavour to displace the gases by compression of a lufa-sponge. If that gives no result, then photograph again in a day or two. In gas-bubbles one then obtains quite a different picture (unless perhaps when intestinal adhesions are present); in affections of the bone, on the other hand, it is the same appearances that are found. Finally, one may take another profile view of the sacrum.

In pictures of the sacrum *the iliac artery* when it is calcified is visible against the surrounding soft tissues.

Fifth sacral-foramina are met with only rarely, usually there are only four; but there occur numerous transitional forms (belonging to fusion-vertebræ), so that often a foramen is not shut, but opens out broadly to the side.

Normally the sacrum has three to four rudimentary spinous processes, see *e.g.* Fig. 164 and Fig. 167, A, B, E, F.

Fractures usually issue from a foramen and demand often an exact study of the plate before they are found.

[1] H. B. Doub: The rôle of ligamentous calcification in lower back pain. Am. J. of Röntg., August, 1924.

If when the patient is resting quite straight and the focus of the tube is exactly over the middle line of the body, one obtains a marked *asymmetry of the shadows of the iliac bones,* we may entertain a strong suspicion of a

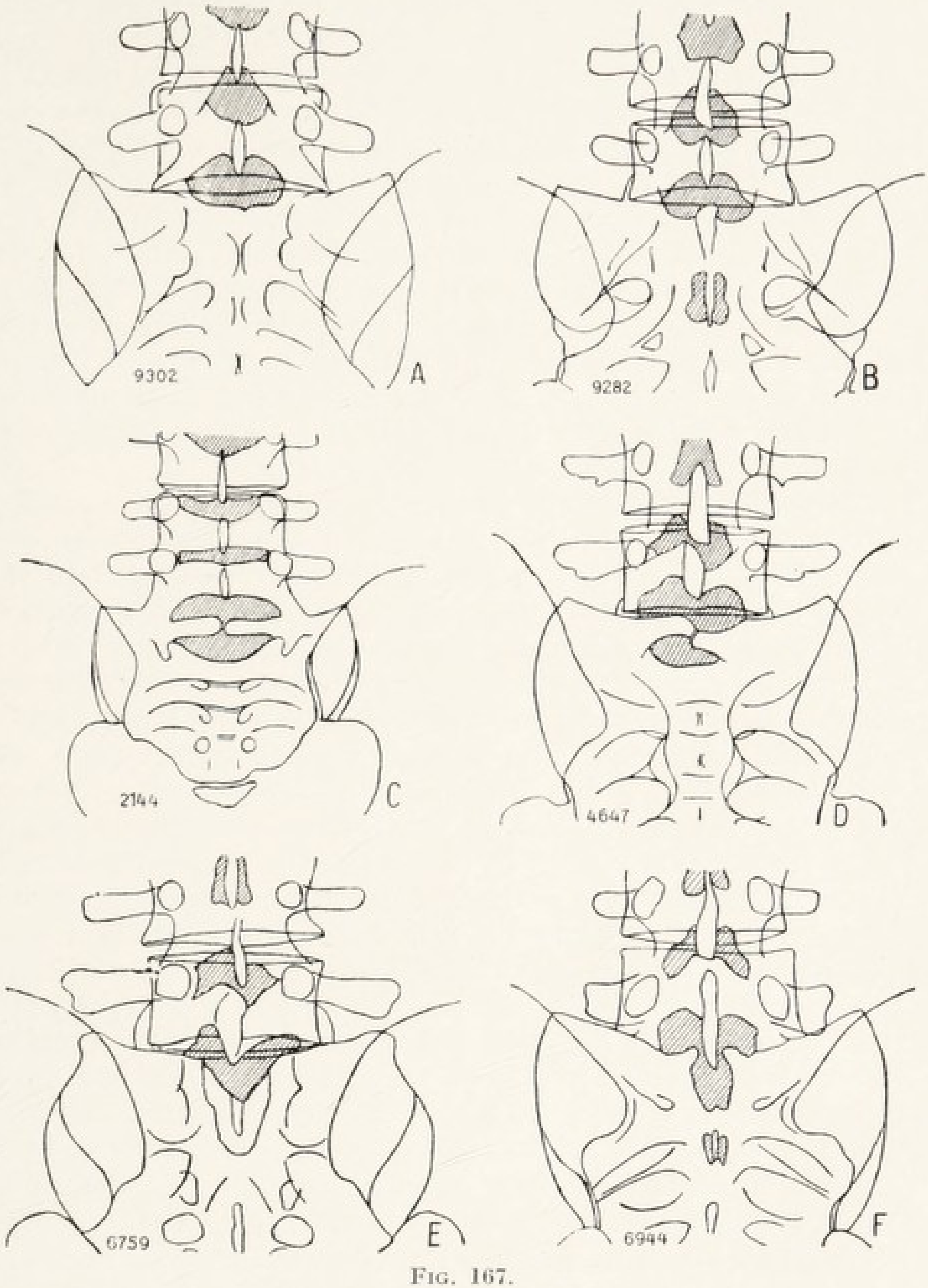


FIG. 167.

vertical fracture of the sacrum in cases with corresponding history and clinical findings.[1] One does not expect to see a clear line of fracture.

According to the position of the tube and the form of the promontory, *the first arch of the sacral vertebræ,* when such is well marked, is projected in

[1] See Ludloff: Die Röntgendiagnostik der Kreuzbeinverletzungen. Fortschritte, Bd. 10, 1906/07.

the shadow of its own body or in that of the fifth lumbar vertebra (as *e.g.* in Fig. 168). It frequently happens to the early worker that he mistakes the first arch of the sacrum for the last arch of the lumbar vertebræ. An exact orientation is therefore necessary ; in the most urgent cases one makes also a survey photograph from the twelfth dorsal vertebræ to the middle of the sacrum. But if one reads the foregoing statement exactly, one ought to dispense with such an expensive negative. In cases that are not clear to the beginner the shadows of two spinous processes are usually seen in the shadow of the body of the fourth lumbar. Of these the upper one belongs to the third, the lower one to the fourth vertebral body ; from there one can count further and can hardly make a mistake.

If one finds a very *fore-shortened shadow of the sacrum*, as, for instance, in Fig. 164, that simply means that the sacrum of the affected patient is inclined more strongly forwards. At the same time the promontory is delimited more sharply by a thick, occasionally double, contour from the pelvis. Regarding the promontory, see also the statements and illustrations 164 and 165.

The *interpretation of the details*, even only of the most important details, of the röntgenogram of the sacrum is not at all so simple as it appears at first sight. The first reason for this is that the details of form of the anterior and posterior surface of the sacrum are superimposed with the same distinctness, so that one cannot say without special study which is anterior (distant from the plate) and what posterior (near the plate) ; the second reason is that the sacrum (and the last lumbar vertebra) is not parallel to the photographic plate, but is considerably inclined to it, being a curved bone ; the third reason is that in projection of bones at an incline to the plate every small displacement of the focus of the tube produces distorted and very different views. Even in compensated cases of lumbar lordosis the pictures are not any more distinct. The rudimentary spinous processes are clear enough in such a picture (Fig. 164), the articular sacral crest, the sacral hiatus, and the foramina of which usually only the fourth foramina come clearly into view. What one expects to see in every case, but sees only very occasionally on the plate and then by chance, is the surface of the body of the first sacral vertebra. (The inferior surface of the fifth lumbar body usually remains invisible, see under " Lumbar vertebræ.") It is projected as an oblong between and above the first foramina, Fig. 168.[1] But it is usually sought for in vain, or only traces of it appear. In many good views there appears a six- to eight-sided figure abutting upon the promontory (Fig. 164 and Fig. 165, *d*) ; this is the corticalis of the lower half of the first and the upper half of the second body of the sacral vertebræ in its whole circumference at the level of the first sacral foramen, running about 2 cm. in the direction of the rays. (Only with a preparation of the sacrum in our hand, that has been sawn through the mid-sagittal plane, can we understand these statements.) In sacra which are not much inclined, the shadow figure referred to cannot, for an easily explainable

[1] Strongly marked lumbar lordosis.

reason appear. Even the shadow line of the promontory does not show up well in a slightly inclined sacrum, because the part of the corticalis under observation is traversed obliquely by the rays, while with a strongly inclined sacrum it projects forward very plainly; not so much because the promontory is met with by the tangential rays, but rather because at this point the anterior surface of the whole first sacral vertebra-segment, whose curvature is almost nil, runs in the direction of the rays to a depth of about 3 cm. It should finally be mentioned that while one can usually look through the fourth foramen, in marked inclination of the pelvis one can look through the first foramen from below (or from above), the opening running almost vertical to the direction of the rays; in the shadow picture there is projected therefore not only the ventral, but also the dorsal, opening of the first foramen (see *b*, Fig. 165, and the survey picture, Fig. 164). The dorsal openings of the other foramina usually appear only indistinctly, and have been omitted from the diagrams. Regarding the meaning of the other lines, reference should be made to Fig. 165.

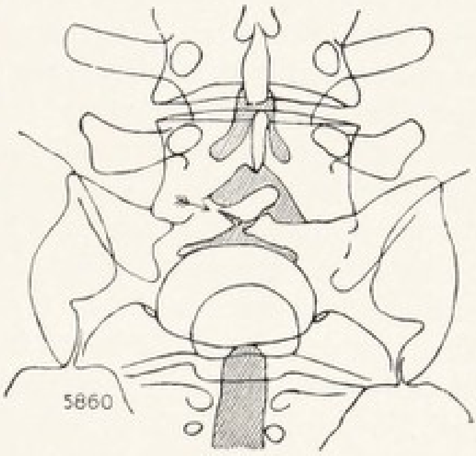


FIG. 168.

The first arch of the sacral vertebræ shows frequently a variation; its spinous process stands obliquely or the whole arch sits obliquely, its shadow is asymmetrical, one half of the arch runs higher or lower than that of the other side; the whole arch thus forms a (transverse) bayonet-formed shadow (as in Fig. 167, D, in which in addition to the arch there is also a fissure to the right of the mid-line). One must be aware of these facts, if one is to avoid diagnosing fractures where no such indicatior is present. Real fractures do, indeed, occur, and sometimes one can perceive the zigzag contour of the solution of continuity (*e.g.* Fig. 168, arrow); in a difficult case the other clinical findings would have to give the decision. But not only the first arch of the sacral vertebræ, but almost more frequently the last arch of the lumbar vertebræ shows this obliquity (see *e.g.* Figs. 164 and 167, D and E), and more rarely a fissure formation. Usually it is only the arch of one of the two vertebræ that is oblique, more rarely the arches of both. In the latter case still further changes are found in the sacrum. These anomalies may all occur, without them being the cause of the complaints for which the Röntgen photograph was taken. The lower end of the spine canal shows a tremendous variety of pictures, and one finds it impossible to say where the pathological conditions begin. "The sacrolumbar part of the spine is a favourite site for morphological anomalies and defects in differentiation."[1] A brief survey of anomalies of the fifth lumbar vertebral arch and of the sacrum is shown in Fig. 167.

[1] Putti, *l.c.*, footnote 2, p. 232.—A. Turnbull: Case of patency of the spinous processes simulating appendicitis. Glasg. Med. J., June, 1927.

While in Fig. 164 only the spinous process of the fifth lumbar vertebral arch stands a little obliquely, in Fig. 167, A, there is no sign of a spinous process of the first sacral vertebra (in contradistinction to B of the same figure); in its place there is an increased space or defect between the fifth lumbar and the first sacrum. Such defects take on often a large triangular (Fig. 167, E) or oval (Fig. 167, F) extension (in F there projects also a specially long spinous process of the fifth vertebra over the defect). In estimating the size of the defect it is to be noted that the part with the defect is inclined to the photographic plate, and is almost in the direction of the rays; that, therefore, these defects are larger in their extent upwards, indeed much larger than their outline. (One can understand this only by making use of the dried sacrum.) In occasional cases smaller openings of the spinal canal are found between the first and second sacral segment (B and F, Fig. 167). In B, as in the sacrum of the child, the first vertebral segment is not united laterally by bone with the second. In children (Fig. 167, C) one must naturally be very careful with the diagnosis " fissure formation," for the two osseous centres which build their neural arches do not unite by bone before the eighth year of life. But permanent generally oblique fissure formations in adults, as illustrated in Fig. 167, D, are, nevertheless, an extremely frequent finding in negatives of this region; and there are an extremely great variety of different forms of this fissure formation; see also Fig. 168 (in addition to the fracture of one-half of the arch). The majority of these findings were obtained as chance discoveries in investigating for fracture, for spondylitis, for tumour, for tuberculosis, in intestinal, pelvic, ureter, and bladder photographs. Although these anomalies gave rise to complaints only in the rarest cases, one thing is still certain: that the more pronounced they are the more they represent a locus minoris resistentiæ. Hence occasional fractures of these ununited halves of the vertebral arches might certainly occur (Fig. 168). The author in twenty-five years' practice saw only one case of fracture; also a spondylolisthesis has, perhaps, been found here, judging by the oblique shadow contours. Between the cases illustrated in Fig. 167 and Fig. 168 there are naturally a great number of intermediate stages, and also more or less diverse forms up to a complete patency of the whole vertebral canal in the sacrum. These various distortions of the spinous processes, the asymmetries, and the more simpler linear and transverse fissures, are reckoned to belong to the realm of *spina bifida occulta*, in which are naturally included the major structural defects. The most remarkable fact, however—as röntgenologists found [1]—is that every tenth man exhibits a more or less marked fissure formation. Occasionally external marks like nævi, scarring, indrawing of the skin, and teleangiectases indicate the anomaly. Those affected in this way may be quite healthy as children and develop in ten to twenty years

[1] Grässner: Der röntgenologische Nachweis der Spina bifida occulta. 10. Röntgen-Kongress, Berlin, 1914.—Altschul: Röntgenbefunde bei Myelodysplasie. *Ibid.*—The same: Ist die Spina bifida occulta als pathol. Befund anzusehen? Med. Klin., 1924, No. 45.

of age without any external cause trophoneurotic disturbances, chronic ulcerations of the feet, paræsthesias, thermhypæsthesias, analgesias, slowly developing changes in the bones of the feet, which gradually go on to claw-feet and griffin-toes. The remarkable fact was also found [1] that spina bifida occulta can be demonstrated with the Röntgen rays in about 60 to 70 per cent. of the cases of *nocturnal enuresis.* (For the manifestation of the diseases of enuresis or of club-foot a releasing stimulus is in addition necessary. Thus enuresis occurred in one man after a prolonged sojourn in the trenches, a spina bifida occulta being demonstrated by the Röntgen rays; it also occurred in a boy of eleven years after recovery from a severe attack of whooping-cough.) [2] There even occur fissure formations in the front of the vertebral bodies, *spina bifida anterior,* which often give rise to most confusing Röntgen pictures.[3] The question how far one can reckon defects in the ossification of the neural arches of the lumbo-sacral vertebræ as normal, and where exactly the pathological sets in, has finally been summarised thus: [4] the definitely pathological ossification defects show an unusual extension of the defects towards the upper lumbar vertebræ—in the adult an implication of the fourth, in the child of the third, lumbar vertebræ is pathological, as is also an exceptional lateral asymmetry. A characteristic pathological feature is in every case the abnormal distribution of bone, represented as an outgrowth of large irregular processes either below or above the defect and usually extending even to the vertebral bodies. Spina bifida occulta is said to be the cause of most orthopædic deformities of the lower extremities, even in those cases where a secondary closure has taken place later on. A certain retardation of the ossification in the lumbo-sacral arches is quite a normal stage of development in the child, a kind of "lumbo-sacral fontanelle"; and such openings remain in quite a considerable percentage of adults also as a variation, without producing any pathological symptoms indicative of an interruption of development at the lower end of the spinal column.

Thus we may reckon as *belonging to the normal* those narrow, median, and symmetrical ossification-defects, affecting the first sacral arch or the one next to it, or affecting it and the arches above and below, also variations of the halves of the arches in the order of their appearance and variations of the processes from the sagittal plane. In myelodysplasia the Röntgen findings might be just within the limits of the normal, in certain cases of meningocele they might be negative. A complete sacral hiatus even of con-

[1] 1909 by Fuchs and Mattauschek, Vienna.—Latest summary, see Willy Hofmann: Über den Röntgenbefund bei Enuresis nocturna (Spina bifida occulta). (With reports of the literature.) Fortschritte, Bd. 26, 1919.—O. Cozzolino: Enuresi essenziale, dismorfismo della colonna lombo-sacrale e mielodisplasia di Fuchs. La Pediatria, Vol. 31, fasc. 3, 1923.

[2] Altschul: Fortschritte, Bd. 30. I. Kongressheft, 1922, p. 95. Discussion.

[3] W. Altschul: Spina bif. anterior und andere Missbildungen der Wirbelsäule. Fortschritte, Bd. 27, 1921.

[4] A. Hintze: Die pathologischen Formen der Verknöcherungslücken an den Verschlussbögen der lumbo-sacralen Wirbel. Fortschritte, Bd. 30. I. Kongressheft, 1922.—O. E. Schulz, Prague: Über symmetrische Contracturen aller Extremitätengelenke. Ztschr. f. orthop. Chir., 45, 3/4, p. 560.

siderable width and even in the case of an adult is not *per se* pathological. Somewhat surprising Röntgen pictures are obtained in young individuals, if the opening is filled up by the ossified tip of the spinous process.[1]

Attention has recently been directed to the fact that the numerous differences of Röntgen views of the lumbo-sacral region are due not so much to morphological differences of the particular vertebræ and segments as to the different degree of inclination of the iliac bones to the base of the sacrum, further, to the different elevation of the fifth lumbar vertebra between the two iliac bones, as also to the different degree of inclination of the fifth lumbar vertebra to its frontal axis. The variations in form may be quite considerable, and are always related one to another.[2]

The first vertebra of the sacrum is in exceptional cases united laterally with the pars lateralis only in the one half, possessing on the other half a similar form to that of the lumbar vertebræ (Fig. 169); these intermediate forms are generally described as *lumbo-sacral vertebræ*. (The sacrum obtains its first vertebra only in course of ontogenesis, this vertebra may be a sacralised lumbar vertebra or a lumbarised sacral vertebra.) Which of the two it is does not appear from a first view of the vertebra, because it is impossible to count the vertebræ in diaphragm exposures of this region. The determination of the number of the particular vertebra becomes still more complicated when the number of the pre-sacral vertebra is altered. Fig. 169 and Fig. 167, B, are probably sacralised lumbar vertebræ. There is said to be some relation between numerical variation of the lumbo-sacral region and "flat-back."[3]

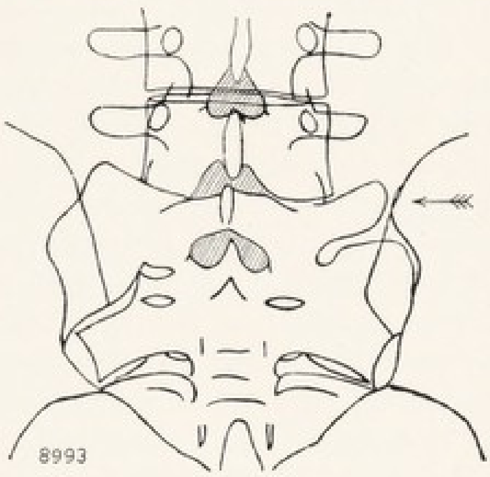


FIG. 169.

Tumours of the sacral bone are relatively frequent; they appear to occur usually more in the neighbourhood of the sacro-iliac synchondrosis than in the middle of the bone. They are sharply delimited from the healthy bone tissue in contradistinction to *tuberculosis destructions*, which usually tail off into the surrounding tissues. For a good representation of

[1] Almost verbally after A. Hintze, *l.c.*—For further contributions to the anomalies of this region, see Ch. G. Sutherland: A röntgenographic study of developmental anomalies of the Spine. The Journal of Radiology, Vol. III, September, 1922.—M. P. Schüller: Die Sacralisation des 5. Lendenwirbels mit bes. Berücksichtigung ihrer klinischen Bewertung. Beitr. z. kl. Chir., 131/2, p. 281.—Meyer, Göttingen: Die Bedeutung der Spaltbildung im knöchernen Wirbelkanal in der Aetiologie orthop. Leiden. 19. Kongress der D. Orthop. Ges., 1924.—D. Schamburow, Moscow: Zur Symptomatologie und Therapie der Sp. bif. occ. bei Erwachsenen. D. Ztschr. f. Nervenheilkde, 85, 5/6, p. 257.

[2] E. Bracaloni, Firenze: Röntgenograph. Variationen der Lumbo-Sacralgegend. La Rad. Med., November, 1924.—See also H. Merz, Paris: Röntgenological study of the morphological variations of the lumbo-sacral vertebræ in normal adults. Presse méd., 1926/27, p. 423.

[3] Böhm, quoted by Wallenberg, in Gerhartz' Leitfaden.

the minuter changes one should not take a hard tube, but one of such quality as is used for photographing the hands of adults. Good diaphragming, emptying of the bowel, and compression are indispensable to the production of a satisfactory röntgenogram.

The lower ends of the *articular sacral crests* often cast a very dense shadow which might be regarded as pathological (sclerosis) if it were not completely symmetrical.

A partial *ossification of the sacro-spinous ligament* and the great sacro-sciatic ligament are not uncommon, in which bony processes are found running out from the tuber ischii or from the ischial spine sometimes quite a way into the ligament. A complete ossification of the sacro-spinous ligament has been observed in a Röntgen picture.[1]

Sacro-iliac Synchondrosis

In the first year of life one finds a wide gaping of the articular fissures, marked divergence of them below and rapid *changes in growth*. In the next four years the joint surfaces appear at first parallel, and then converge in a downward direction, owing to the processes of growth and curvature in the sacral and iliac bones. The anterior and the posterior articular fissure are still superimposed in the Röntgen picture. From the sixth to tenth year of life the articular surfaces are visible from the front ; the posterior articular line appears. At the same time the processes of growth, and above all of curvature, increase, being seen in the deepening of the convexity produced by the base of the sacrum at the anterior articular line. In the sacrum slight *sexual differences* can already be made out. The sacrum of the woman begins to be broader in the horizontal and shorter in the vertical than that of the male. From the eleventh to the twentieth year of life in addition to increases in growth these sexual differences become more prominent. In the female sex the differentiation begins earlier than in the male, namely, in the eleventh year of life. The superior part (anatomically the dorsal) of the base of the sacrum increases markedly in breadth, so that in Röntgen pictures the greatest convexity of the anterior articular line comes to be situated in the upper part of the bone. In the male pelvis the differentiation appears first at about the twelfth to the fourteenth year. The most marked convexity is developed by increase of breadth in the base of the sacrum in the inferior portion of the anterior articular lines. Simultaneously with this sexual differentiation the posterior articular line becomes more evident. Both articular lines become narrower towards the end of the period. With the twentieth year of life the typical stage of maturity is reached for both sexes. After this time appear two further typical appearances : in the pictures of many women the posterior articular lines are strikingly broad (especially in the inferior part of the bone). Whether this is to be regarded as a sign of a previous pregnancy it is difficult to say. In the photographs

[1] Schönfeld and Delena : Röntgenologie des unteren Kreuzbeinendes und der Steisswirbel. Fortschritte, Bd. 23, 1915/16.

of male pelves after the forty-fifth year one observes an alteration in the form of the anterior articular line resembling the form of this line in middle-aged female pelves.[1]

In order to diagnose the pathological process in one of the synchondroses a correct photograph is essential with precise centering of the tube and reproducing both synchondroses. One should not pay too much attention to small irregularities of the anterior articular contour (lateral in the plate) and of the posterior articular contour (medial in the plate). But there do occur severe affections, which the commencing röntgenologist might miss, if he were not aware of the possibility of these lesions. There are said to be four different forms of tuberculosis[2]: (1) Small initial foci in the vicinity of the synchondrosis; (2) Chronic caries (larger circumscribed focus in the joint fissure with sclerosed edge); (3) Mild chronic form with abscess formation and small sequestra; (4) Synovial type of other joints, without sclerosis. Instead of sacrocoxalgia and sacrocoxitis one should call the condition "Sacro-ileitis." Syphilis and pyogenic osteomyelitis may also occur at the synchondrosis. Syphilis is said to be characterised by bilaterality.

According to the statements of anatomists[3] there sometimes occurs a partial *fusion of the articular fissure* in elderly people, especially in males.

Small irregular hillocks along the articular contours are really signs of old age.

Small dense shadows in the articular lines or in their neighbourhood may be due to *stones in the ureter*.

It is normal when the articular surface of the ilium is a couple of millimetres larger in all directions than the articular surface of the sacrum (= proof of the movement of the sacro-iliac synchondrosis).

The normal conditions of the röntgenogram of the synchondrosis, particularly the great variety in the configuration of its inferior aspect, are illustrated in the various diagrams in this book.[4]

Primary chronic arthritic changes, especially at the lower end of the synchondrosis, are not uncommonly seen, especially in "sacral pains," and are easily overlooked by the beginner, because they are not usually particularly obvious. Most frequently they occur in the form of one or two large processes or sharp edges. The cause of the condition is usually a deep lumbar scoliosis. It can also arise from trauma in consequence of loosening of the ligaments.[5]

[1] Almost verbally from P. Happel: Das Sacroiliacal-Gelenk im Röntgenbild. I. Mitt. Die Alters- und Geschlechtsverschiedenheiten des Sacroiliacalgelenks im Röntgenbild. Arch. f. Orthop. u. Unfall-Chir., Bd. 20, Heft 4, 1922.

[2] P. Pincherle: La Sacro-Ileite. La Rad. Med., 1927.

[3] Quoted from Fick: Anatomie der Gelenke, I, pp. 289 and 290.

[4] See further also: Myron B. Palmer: The lumbar spine and sacroiliac joints. Am. Journ. of Röntg., January, 1922.—Edward S. Blaine: Sacroiliac Arthrosis obliterans. Am. Journ. of Röntg., March, 1923.—Smith-Petersen, Boston: Clinical diagnosis of common sacro-iliac diseases. Am. J. of Röntg., December, 1924.—Darling: The sacro-iliac joint. Radiology, December, 1924.

[5] Joachimovits. Wiener kl. Wschr., 1925, 36.

Coccyx

The first vertebra of the coccyx becomes ossified about birth.

The number of the coccygeal vertebræ (maximum = 6) and the *size* of the coccyx are extremely various; usually four vertebræ are present.

The *lowest vertebræ* usually unite by bone, the upper ones are, on the other hand, usually loosely connected; most frequently an articular connection can be established between the first and the second coccygeal vertebræ. Further, the first coccygeal vertebra is in males frequently joined by bone with the sacrum. Oblique projection may interfere with a complete view of the foramina and the connections (synchondrosis and synostosis), or make it impossible to see them.

According to the statements of anatomists an *ossification of the ligaments* between the sacral cornua and the coccygeal cornua is a frequent occurrence. It should be possible to demonstrate that on the plate.

The coccyx can if necessary be rendered plainer than usual by the introduction of air into the rectum.[1]

In a searching for stones in the bladder the author found as an accidental discovery a coccygeal bone resting obliquely on the sacrum. Its axis was turned about 45° to the left from the axis of the sacrum.

RIBS AND STERNUM[2]

Ribs

The *dorsal ribs* receive their *first ossifications* at the end of the second fœtal month commencing at their dorsal ends; already at the beginning of the third month they surround the greater part of the thoracic wall as delicate bone strips. From the eighth year of life and on, epiphysial nuclei are developed in the capitulum and tubercle.[3]

Malformations are not uncommon; they are almost always associated with malformations of the corresponding vertebræ; occasionally elevation of the scapula is present at the same time.[4] Extensive malformations which modify the elasticity of the thoracic walls produce an alteration in the movement of the diaphragm; the cupola which normally remains even on deepest inspiration becomes then flattened out more or less into a straight line (see "Diaphragm"). If one finds upon complaints a slight malformation of single ribs, the latter is not always necessarily the reason for the

[1] Kaïsin: Un perfectionnement technique dans l'examen röntgénographique de la région sacro-coccygienne. Journ. de Rad., July 31, 1909, Vol. 3.

[2] For the normal anatomy of ribs and sternum, see Grashey, Atlas I, 5th edition. See also Hasselwander, *l.c.* (p. 2 of this book).

[3] Quoted verbally from the complete description by Lambertz: Entwicklung des menschlichen Knochengerüstes während des fötalen Lebens. Hamburg, 1910.

[4] A complete list of the literature (up to 1911) upon elevation of the scapula is found in Hayashi and Matsuoka. Deutsche Zeitschr. f. Chirurgie, Bd. 113, 1912.

trouble complained of. The most common forms of rib-anomalies are: Fusion and forking of several ribs with each other with simultaneous elevation of one scapula. Defects of the anterior parts of the second to the fifth ribs or of one of the same (so-called lateral fissure of the thorax). Intermediate bony bridge between the fourth and the fifth rib. Simple forking of the ribs. A rudimentary first rib is sometimes not shortened, but only narrowed, and at the same time more vertically placed than normal. In these cases the lower bony end of the first rib often fails to reach the level of the clavicle. Unusual pictures are then obtained, if at the same time in elderly individuals the costal cartilage is ossified on both sides, or as sometimes happens, on one only. Another observation made was: Shortening of the first rib on both sides with fusion of the anterior end of the first rib on one side with the somewhat elevated second rib to form a broad plate of bone.[1] The author observed a thin third right rib broadened out above and below in this way.

For *cervical ribs*, see under "Cervical column." Incompletely developed cervical ribs can be united in half their extent with the first rib (doubled-headed first rib).

Sometimes the *ribs of the first dorsal vertebra* do not reach the sternum.[2] One should not mistake these ribs for cervical ribs.

Ossification of the costal cartilages.[3]—In individuals of twenty-five years and upwards one nearly always meets with more or less complete ossifications of the first costal cartilage; and in the first rib this process takes place in lamellæ vertical to the course of the ribs.[4] The lower margin of the completely ossified first costal cartilage is usually peculiarly notched or indented: further, there remains quite uncalcified a fine vertical translucent fissure at the insertion of the original cartilage to the bony ribs and to the manubrium sterni; one should know that, in order not to mistake this fissure for a fracture. According to recent researches[5] the early ossification of the upper costal cartilages and congenital obliquity of the first rib is favourable to the occurrence of tuberculosis in the upper lobe of the lung. "That the ossification of the costal cartilages is not the consequence of the tuberculosis is seen from the fact that there are many cases, which show no sign of calcification of the costal cartilages, and that when the tuberculous process starts in the lower parts of the lung no calcification is found at that point." The other costal cartilages show, at least in males and as early as the twenty-

[1] Kienböck: Über angeborene Rippenanomalien. Fortschritte, Bd. 13, p. 269 (most complete and with all the literature).

[2] Quoted from Grashey, Atlas I.

[3] See also Groedel: Der röntgenologische Nachweis der Rippenknorpelverknöcherung. Münch. Med. Wschr., No. 14, 1908.—Käding. Röntgenkongress, 1923.—A complete anatomico-pathological work is that by W. H. Schulze, Brunswick: Über die Verknöcherung des I. Rippenknorpels. Ztrlbl. f. allg. Path., Appendix to Vol. 33, p. 260.—B. Maggi, Firenze. La Rad. Med., February, 1925.

[4] The work of Sato, quoted under "Sternum."

[5] F. Jessen: Röntgenolog. Studien über die Beziehungen zwischen Rippenknorpelverknöcherung und Lungentuberculose. Verh. des Deutsch. Kongresses f. Innere Medizin, Wiesbaden, 1914.

fifth year, signs of commencing calcification, and in the experience of the writer of this work the degree of calcification increases towards the lower costal cartilages, so that the sixth rib is more calcified than the second, and the twelfth rib more than the sixth ; and often quite independently of the ossification of the first rib. Cases are in fact frequently found in which the first rib is calcified completely, the second almost not at all, the third only slightly, the fourth more so, and so on till the twelfth rib, which is again completely calcified. The start of calcification in the second to the twelfth ribs is usually seen in Röntgen view at the juncture of the bony ribs and cartilages in the form of a narrow dense oval shadow, that is usually overlooked ; soon, however, there appears a thick strip along the lower border of the cartilage, which is very noticeable ; then the upper margin ossifies along a narrow strip, and finally the part between the margins, the process beginning laterally and below and spreading upwards and towards the sternum. Apart from a few cases, to which we shall refer later, we are dealing in the calcification of the costal cartilages with a physiological process analogous to what takes place in the cartilages of the larynx. After going through hundreds of plates of people who were suffering from lungs or heart, or in whom there was only a slight suspicion of these diseases, the author came to the following conclusion : up to the end of the nineteenth year of life there does not appear to be the slightest sign of any calcification in any of the ribs, even in patients with a marked degree of pulmonary tuberculosis. Also up to the end of the twenty-fourth year there is in the majority of cases no trace of calcareous shadow to be seen in the costal cartilages, one finds only quite occasionally commencing calcification in the cartilages of the first rib, indicated now and then in the other ribs also by a vertical strip at the rib-end of the costal cartilages. Extensive calcification of the first costal cartilage does not appear earlier than the twenty-fifth year, and seldom as early as that. Also up to the twenty-ninth year the costal cartilages remain in quite a large number of cases (more than the half ?) without any calcification (even in the most extensive pulmonary tuberculosis there may be an entire absence of calcification). From the thirtieth to the thirty-fifth years the first costal cartilages (*i.e.* the first costal cartilage on either side) are usually more or less calcified in about 95–99 per cent. of the cases, all the other cartilages being marked with vertical streaks at the juncture of the ribs ; extremely rare cases (apparently always associated with tuberculosis of the lungs) occur about the thirty-fifth year with a high degree of calcification of all the ribs. About the fortieth to the fiftieth year the first costal cartilage is completely calcified in the majority of cases, in all the other ribs commencing calcification is present, increasing from the second to the twelfth rib. Occasionally all the costal cartilages, including—and this is striking—the first costal cartilage, show merely uniform narrow linear calcification lines. At this period of life one also finds cases with dense calcification of all the costal cartilages in advanced pulmonary tuberculosis, although, on the other hand, there are cases of advanced pulmonary tuberculosis with quite moderate calcification of all ribs, including the first.

From the fiftieth year on the calcification naturally increases, but one occasionally finds cases, even at sixty years of age, in which only the first rib is markedly calcified, the others exhibiting only thin lines; and even in one male of seventy years (an arteriosclerotic and man of the world) the author found only slight indications of calcification in all the costal cartilages. The author, as stated, made a study of two hundred plates of patients who were suspected of having disease of the lungs or certainly had it, and further of two hundred plates which were taken on account of heart-complaints, and we did not gain the impression that calcification of the ribs occurred more frequently in pulmonary than in cardiac patients. One point emerged clearly from the photographs, however, as indicated above, the process of calcification in women sets in distinctly later than in men and also advances more slowly forwards. That is all the more extraordinary, as in the female sex certain processes, like that of ossification of the osseous centres in the growing individual, precede those of the male sex. It may be that the type of breathing causes the earlier rigidity of calcification of the chest wall in the man. Just as (see above) a small percentage of cases in men and women are found, in which the calcification of the costal cartilages is almost completely absent until advanced years, there also occur isolated cases, in which at a strikingly early period all the costal cartilages are calcified in their whole extent; thus the author has one case of twenty years, another of twenty-six years, a third of thirty-four years, and two of thirty-seven years, and several between forty and fifty. The history is of importance in these cases; in some—before I saw the Röntgen plate—the statement was made " coughing ever since childhood "; one patient suffered for twenty years with malaria; another was prisoner of war for a year or two; one, according to the report of his doctor, suffered for twenty-seven years with chronic pneumonic and pleuritic processes; one for twenty-one years with pulmonary tuberculosis; one with an apparently slowly growing tumour of the lung; one with an aneurism of the aorta; two patients appear cachectic without any reason being found; one patient suffers with a marked degree of diaphragmatic eventration (or hernia of the diaphragm); one has lost 70 pounds of weight in the course of recent years; three were syphilitics since the age of twenty years; one suffers with inflammation of the kidneys. I found the highest degree of calcification of the ribs in a twenty-two-year-old woman of the upper class suffering from her stomach (ulcer also suspected); as a child she had had many stomach complaints, always a very bad appetite, and considerable hyperacidity. Finally, from among four hundred cases I have made a special note of all with a high degree of calcification of all the costal cartilages. It transpires that conditions that have prevented people from receiving adequate nourishment for many years are the principal if not the only causes for an accelerated high degree of calcification of the costal cartilages. That pulmonary tuberculosis is one of the most important of these causes is understandable. Whether and in what way mechanical factors also act is at the moment not yet clear. That such do act can be concluded from the delayed appearance and progress of the calcification in women, in which the type of breathing would appear to be the principal ætiological factor. A few cases on the other hand appear not to fall into this hypothesis. There does not seem to be any parallel with arteriosclerosis. It is true there is one case with aneurism in the above list; yet the author is aware of another case of a seventy-year-old man with arteriosclerosis and aneurism, in whom only the most minimal amount of calcification is present in the costal cartilages. Such an absence of calcification in old people is a great rarity; in one hundred cases one finds scarcely five. It deserves to be noted, however, regarding ætiology—that the few cases of people of advanced age without calcification of the costal cartilages affected those individuals that had always been used to the best conditions of life. In contradiction to this one of the text-books maintains: "With increasing years and probably in relation to conditions productive of arteriosclerosis we find calcification of the cartilages as in the ribs and trachea, which usually are clear of this material (chalk)." The whole theory of calcification of the costal cartilages is certainly very interesting and far from being explained yet. But the good view afforded by Röntgen views gives hope that a better solution of these puzzling processes will soon be found. One observer has recently been occupied with "Inquiries into the problem of the correlation of the costal cartilages and the vascular calcifications (arteriosclerosis)." [1] A very thorough macroscopic, histological, and röntgenological examination was carried out on fifty bodies, especially the costal cartilages, coronary arteries, valves of the heart, aorta, carotid, subclavian, innominate, cerebral arteries, iliac and femoral arteries. Although the result was not a conclusive one, it nevertheless showed, apart from the first costal cartilage on the two sides, certain parallels between arteriosclerotic and costal cartilaginous calcifications; patients with arterial calcifications showed much greater C-(calcification-degree) values than others of their age. With a certain degree of C, one may be in a position to diagnose arteriosclerosis. The degree of calcification is greater in males than in females (which confirms the author's experience). With age the degree of calcification increases progressively both in arteriosclerotic and non-arteriosclerotic cases. Arteriosclerotics of similar age and sex show great C-differences. Individual tendency to calcification is in these cases an important factor according to the circumstances. Up to the twenty-second year the non-arteriosclerotics show $C = 0$, but in the subsequent years calcification of the costal cartilages are found to a small extent. Patients with chronic disease of the lungs and pleura, as also patients with nephritis, have a tendency to calcify furthest. Of the male arteriosclerotics of the coronary arteries, seven showed a high degree of C, one average C, four lesser C, than the average of their age; in the female cases four showed a high degree of C, one approximately average C, one lesser C, than the average of their age. Confirmed by the results of these inquiries one may answer the question asked in a positive sense, but only with a certain reserve, in relation

[1] Ch. A. Huyssen, London: Schweiz. Med. Wchschr., No. 44, p. 1010, 1924 (in German).

to other diseases and ages, which might equally be the cause of calcifications of the costal cartilages! It is also thinkable that in certain cases in which several of these ætiological factors are united one might make a mistaken diagnosis of commencing arteriosclerosis upon grounds of the high C. Among the cases after the fortieth year not a single one was noted with a normal state of the vessels.

The whole subject deserves further attention. Further thorough studies in thousands of cases might well be carried out. Especially inquiries might also be directed to the extent of calcification of the larynx in these cases. Emphysema and senile rigidity of the thorax are also said to be a cause for calcification of the costal cartilages.

A condition well known to surgeons is a general porotic atrophy of bone, earliest and best marked in the ribs, which is wont to supervene in long-standing biliary fistulæ. The consequence is increased flexibility of the bone and fractures. Following upon experiments upon animals we have to deal with combinations of porosis and formation of broad osteoid seams similar to what is found in senile osteomalacia.[1]

Seeing *the thoracic opening* in the röntgenogram is always projected obliquely to the photographic plate, it is naturally difficult to say whether the aperture is more a straight oval or a transverse oval (the latter appearing to be typical in phthisis); for the opening is always represented as a transverse oval in Röntgen view for the above reason.

Fractures of the ribs are difficult to exhibit when they fall in the shadow of the liver, also on the left side when they are below the diaphragm. Naturally when there is marked break in the continuity and the photograph is a good one they can be seen, but these cases are rare; the more frequent cases are the kinkings, which are never visible when they occur in the costal cartilages, and very seldom even in the bony portion of the ribs, because the kinking almost always takes place in the horizontal plane, and this gives the most unfavourable conditions for the projection. Small lateral displacements appear best in pictures with tangential direction of the rays. Though we are dealing only with examinations of bone in fractures of the ribs, we should nevertheless carry out in every case a preliminary screening, in order not to miss associated injuries of the lung (hæmothorax) and of the diaphragm (hernia of the abdominal organs into the pleura). Peculiar transparencies in the shadows of the soft tissues near fractures of the ribs are produced by emphysema of the soft tissues.

In healed fractures with callus formation one should not get confused with the following appearance: in the middle of their dorsal halves the lower borders of the ribs show a 6 to 10 cm. *long superposed shadow* with a more or less definite edge, which might simulate a callus or a periostitis ossificans. These are quite normal borders, corresponding to the sharp overhanging edge of the intercostal groove.

In pictures of the whole or half of the chest mistakes are not likely,

[1] H. Dieterich: Die porotische Malacie nach Gallenfisteln. Beitr. z. klin. Chir., Bd. 134, Heft 4, p. 530.

because the shadow of *each rib* is plain. But in small exposures in which only one rib can be seen, while the others are covered by the shadow of the liver, the beginner might easily be led to an incorrect diagnosis.

For *the orientation* of which rib it is we are looking at, the following may serve: the first rib usually articulates only with the first dorsal vertebra, but it can also articulate with it and with the seventh cervical vertebra. The second to the ninth or tenth ribs are inserted with their articular surfaces between alternate vertebral bodies. Each of these ribs, therefore, belongs to the number of the vertebra, at whose upper edge the rib is applied (and conversely, to each vertebra there corresponds the number of the particular rib articulating with its upper part). At the angle of the scapula there is always placed the seventh or eighth rib. The tenth rib is usually in articulation with the ninth, occasionally only with the tenth dorsal vertebra. The eleventh and twelfth rib articulate only with the vertebra belonging to them.

FIG. 170.

Regarding *cervical ribs* and orientation at the lower end of the cervical column, see under "Cervical vertebræ" and "Dorsal vertebræ."[1]

For *lumbar ribs*, see "Lumbar vertebral column" and also under "Kidneys."

In pathological processes of the vertebral column and as manifestations of old age, small excrescences occur at the vertebral end of the ribs.

At the tip of the twelfth rib there occurs *an independent calcium shadow* (see Fig. 170 [2]), which should not be confused with a stone in the kidney. It is said to be not uncommon, it may also articulate with the end of the rib, and be found double instead of single.

In a twelfth rib of normal length the one on the other side of the body was found much shortened.[3]

[1] See also Falk: Zur Genese der Halsrippen. 10. Röntgen-Kongress, 1914.

[2] Quoted from Grashey, Atlas I, 5th edition.

[3] Frommhold: Über Intercostal-Neuritis infolge Missbildung einer Rippe. Fortschritte, Bd. 25, 1918.

One variety was observed in the sixth rib :[1] at the neck of the rib bony cylindrical processes were found directed upwards, which articulated with the neck of the fifth rib or rather the transverse process of the fifth rib. Frequently also short projections were seen at the necks of the sixth to the tenth rib. There occurs directly here a joint-system disease, which can give rise to a mistaken diagnosis of an apical lung process : The deformative arthritis of the joints between the ribs and the transverse processes gives a shadow-picture, which was upon one occasion confused with the formation of intrapulmonary lesions. The process is usually associated with cervical pain.[2] Fig. 171 illustrates a case of a parti-

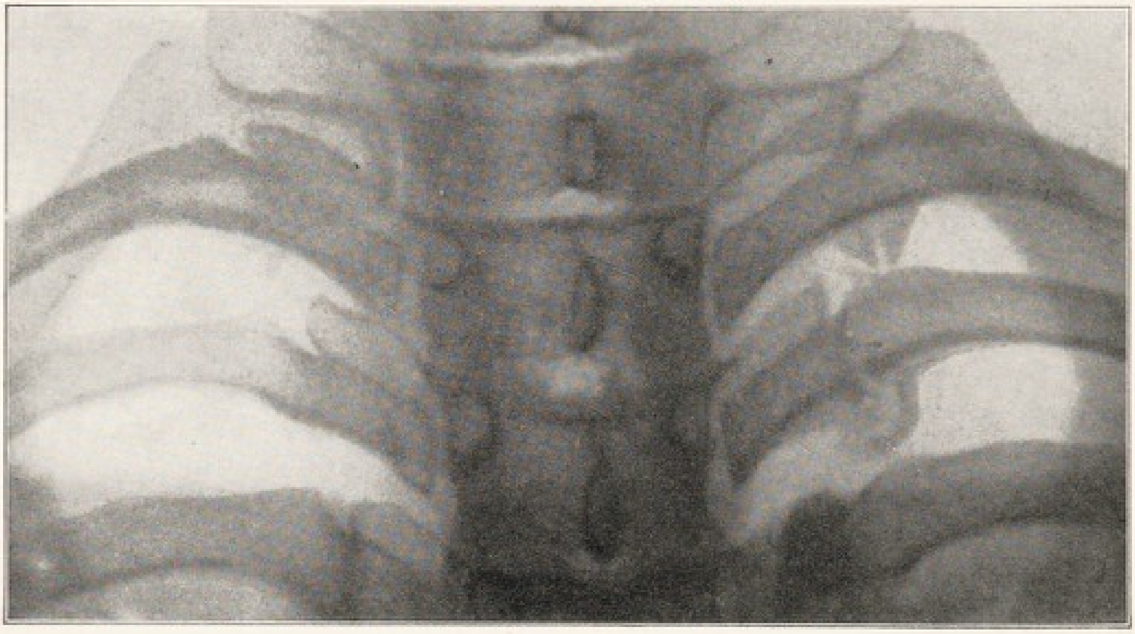


Fig. 171.[2]

cularly advanced deformity in the second and third rib. For the differential diagnosis, see also footnote, p. 215, and the text relating to the illustration.

Sternum

The *first signs of ossification* are seen in the sixth fœtal month, and first of all in the manubrium ; several more soon develop in the body ; sometimes, however, the first ossification centre makes its appearance in the upper part of the body between the second and third costal cartilage. In the newly born the nuclei (six to thirteen in number) are usually separate from each other. The particular segments of the sternum are already ossified by the twelfth year of life, and are separated from each other only by narrow strips of cartilage ; they then synostose with each other, and

[1] Schwegel : Zeitschr. f. rat. Mediz., 3. Reihe, Bd. 5, quoted after Atlas I, Grashey, 5th edition.

[2] F. Polgar, Budapest : Über Arthritis deformans im Bereiche der Lungenspitze. Fortschritte, Bd. 32, 1924, p. 243.—See further : A. Bernstein : Über Arthritis deformans im Rippenquerfortsatzgelenk. Arch. f. klin. Chirurgie, Bd. 141, Heft 3.

later the body synostoses also with the manubrium, unless instead of a synostosis a syndesmosis developes (Angulus Ludovici). The ensiform process, whose ossification begins in childhood at an irregular period, does not ossify completely till advanced age and then becomes united with the body through synostosis.[1]

The form of the *manubrium* is longitudinal up to the twentieth year, then broadens out gradually into a transverse form. The average length of the sternum in the male is 16·7 cm., in the female 14·6. The articular line between the manubrium and the body of the sternum runs sometimes oblique, sometimes curved, more rarely horizontal.[2] It is an anomaly for the joint between the manubrium and the body to be absent; whether there is any relation between pulmonary tuberculosis and absence of the sternal articulation has not been yet decided.

It is obvious *the sternum* cannot easily be photographed. The conditions of projection have to be carefully considered and the sternum irradiated obliquely, the best way being from the right and behind to the left and in front, so that the shadow of the vertebral column is projected away to the left of the sternum. Weight has here been laid upon the value of stereoscopic photographs. But one may often get conclusive pictures from left and behind to right and in front, unless the arch of the aorta and the heart shadows the part of the plate which it is wished to examine. A larger view of the sternum is obtained on the plate by placing the patient on the left side, so that the heart and aortic arch sink to the left and leave a broader clear space. But even this projection does not give a complete view over the whole sternum. The photograph is best taken with the breath held. The sternoclavicular articulation usually comes into view on the same plate. In modern technique profile negatives may often be quite successful. The patient in this view does not hold the arms above the head, but places them behind the back. Occasionally the ensiform process can even be manifested in profile pictures. The main point is to see that both shoulders are pressed backwards. Occasionally even the ensiform process can be represented in profile views.[3]

In technically complete negatives the structure of the bone can be seen beautifully; it is therefore not too difficult to make a right diagnosis of *tumours*, which often show here absorption of the bone without sharp demarcation, and without signs of regeneration. In tuberculosis we find absorption of bone with associated absorption. In pressure necrosis due to aneurism one finds homogeneous decalcification;[4] a differential

[1] With abbreviations almost verbally quoted from Lambertz: Die Entwicklung des menschlichen Knochengerüstes während des foetalen Lebens. Hamburg, 1900.

[2] Mendelssohn: Rippenknorpelanomalien und Lungentuberculose. Archiv f. Kinderheilkunde, 1904, Bd. 38, *vide ibidem*, 1906, Bd. 44.—Seichiro Sato: Zur Lehre vom Thorax phthisicus und den Operationen der Lungenspitzentuberculose. Deutsche Zeitschr. für Chir., 1913, Bd. 126.

[3] Drüner: Über die Röntgenologie des Brustbeins. Fortschritte, Bd. 27, 1919.

[4] Pfahler, Philadelphia: The study of the sternum by the Röntgen-Rays. Am. J. of Röntg., 1924, p. 311.

diagnosis might have to be made from gummata. This remark applies also in these photographs to the sternal end of the clavicle, which in these views are specially well seen.

The projection conditions in these oblique exposures often brings it about that the *sternal end of the clavicle* appears luxated or subluxated, without any pathological process being present. This striking appearance is said only to occur in depressed shoulders.

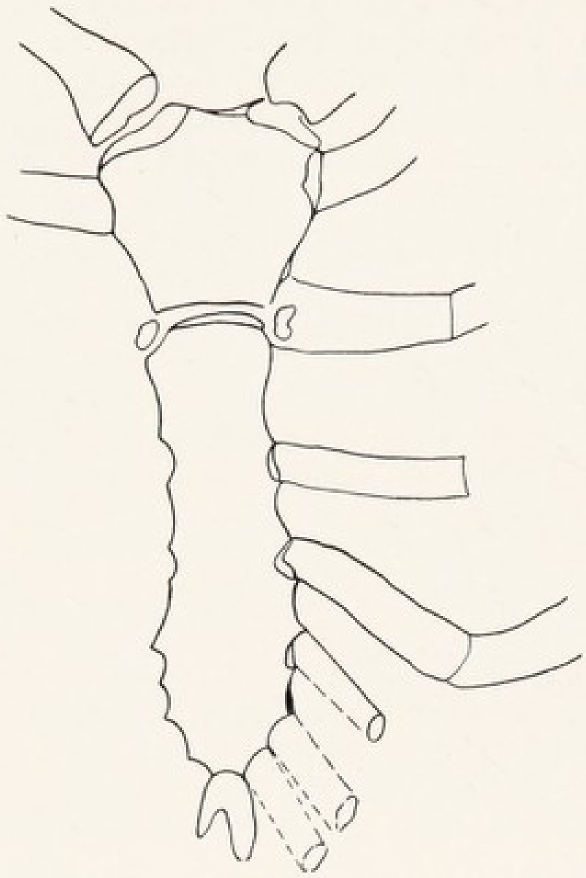


Fig. 172.[1]

The anatomical literature describes as *varieties:* suprasternal ossicles immediately internal to the sternoclavicular joint, occasionally resting against the upper border of the manubrium. Congenital fissure of the sternum. Articular connection between first rib and clavicle. Further small bony nuclei are described at the insertion of the second ribs near the articulation between manubrium and body; see Fig. 172. See also under "Clavicle."

In the region of the attachment of the first rib, both right and left, one occasionally observes calcareous shadows about the size of a pea and roughly triangular, separated from the manubrium only by a narrow fissure 1 mm. thick, which perhaps might be confused with the suprasternal ossicles. These are possibly just the commencing calcifications of the costal cartilages.[2]

[1] L. Drüner: Über die Röntgenologie des Brustbeins. Fortschritte, Bd. 27, p. 58.
[2] Private communication from H. R. Schinz, Zürich.

HEAD[1]

Development

The *first centres of ossification* in the head occur in the seventh week of intrauterine gestation, in the jaw; in the eighth week another appears in the squamous portion of the occipital bone; in the third month follow ossifications in the sphenoid, ethmoid, frontal and parietal bones, in the nasal conchæ and in the malar bone, also in the squamous and tympanic parts of the temporal bones; the petrous part does not begin to ossify until the fifth fœtal month, the styloid process remaining cartilaginous till birth. The incus ossifies in the fourth fœtal month, the stapes in the fifth.[2]

Of all the synchondroses of the child's skull, the *spheno-occipital synchondrosis* remains open the longest (Fig. 173); it commences to fuse in the thirteenth to fourteenth year of life, and is completed by the eighteenth to twentieth year.[3] A premature synostosis is, according to Virchow,[4] typical of cretinism, others affirm[5] that it is sufficient to find arrested development of the tribasilar bone (clivus, sella turcica, and the planum sphenoidale). A recent examination of fifteen cretins, all of adult age, showed a persistent spheno-occipital synchondrosis in 60 per cent. of them.[6] Premature synostoses of the sutures occur.[7]

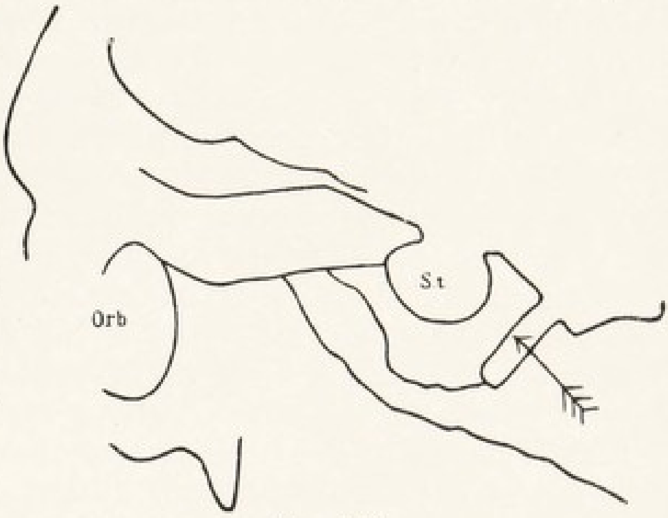


FIG. 173.

The pneumatic cavities, the frontal sinuses, sphenoidal sinuses, maxillary antra and mastoid cells, are absent normally in the newly born.

Congenital defects of ossification have been described for the parietal bone.[8]

[1] For the normal Röntgen anatomy of the head, see Grashey, Atlas I, 5th edition; further, Schüller, in Schittenhelm's text-book, 1924.—Albers-Schönberg: Die Röntgentechnik, 5th edition, 1919. (Hamburg, Sillem.)—Balli and Frasetto: Anatomia röntgenografico dello scheletro. Part I. Il cranio. Modena, 1921. (Edit. Orlandini.) With list of the literature.—Weinnoldt: Beitr. z. pathol. Anat., 70, pp. 311 and 345.

[2] For complete particulars refer to Lambertz (*l.c.*, p. 14), and Hasselwander, "The ossification of the Bones of the Skull," in Rieder-Rosenthal's text-book, Bd. 2, pp. 200 ff.

[3] Arthur Schüller: Die Schädelbasis im Röntgenbilde. Hamburg, 1905 (Sillem).

[4] Virchow: Knochenwachstum und Schädelform. Virchows Archiv, Bd. 5.

[5] Bircher: Entwicklung und Bau des Cretinenskeletts. Hamburg, 1919 (Gräfe and Sillem).

[6] Stoccada: Untersuchungen über die Synchondr. spheno-occip. und den Ossificationsprozess bei Cretinismus und Athyreosis. Zieglers Beiträge, Bd. 6, 1915.

[7] Böhm: Über das angeb. synostot. Caput obstipum. Orthop. Kongress, 1914.—See also R. Thoma: Über die praematuren Synostosen der Schädelnähte und über das Wachstum, die Senescenz und die Hyperostose des Schädels. Beitr. z. path. Anat., Bd. 72, Heft, 1, p. 207.

[8] R. Neurath: Zschr. f. Kinderhlk., Bd. 32, Heft 1/2, p. 121.

General

In lateral negatives of the head the side of the head next the plate is always overshadowed and its clearness diminished by the image of parts of the other side. The beginner should therefore know that this difficulty can be partially overcome by bringing the anticathode of the tube as close as possible to the patient. The conditions would get worse were the anticathode to be removed to a distance; for the result might be that one could not distinguish on the negative which is the side of the head next the plate and which the side away from it. If we are dealing with parts in the middle of the head (sella turcica, etc.), then the anticathode should be set at a far distance. The physics of these conditions is simple.

Negatives of the head are taken with most advantage in the horizontal position, in order to avoid movements of the head. For separate projection of the two halves of the lower jaw, see below under " Lower jaw."

Sometimes puzzling round shadows are found in larger or smaller number in the region of the ear; these are *parotid stones,* and they occur very seldom. One published negative [1] shows about forty scattered concretions ranging in size from a pin's head to a lentil, containing little lime, but with more of it round the periphery.

One should avoid mistaking simple sutures, which are sometimes prominent in diaphragmed negatives, for fractures or fissures. Also the furrows of the *middle meningeal artery* and of *the lateral and sigmoid sinus* stand out distinctly in perfect negatives and should not cause error.

The changes of the venous vascular-canals of the skull occurring in pathological alterations of the skull and its contents can be registered röntgenographically, and diagnosed at their proper value; more especially we have to deal in chronic increase in cerebral pressure with a general enlargement and increased number of the vascular canals, and local changes in the vascular canals arising out of tumours of the brain. The diseases of the bones produced by syphilis are of interest, they bring about changes (unrecognised except in the Röntgen rays) in the venous channels of the diploë and occasionally in the Röntgen findings obtained in sinus pericranii. The knowledge of the Röntgen views of the venous canals of the skull facilitates their differentiation from pictures of other changes in the bone, *e.g.* defects in the skull, fissures in the skull, and arterial grooves in aneurysma arteriale racemosum.[2]

Fissures of the base of the skull, as can be easily understood, may remain completely hidden in the röntgenogram; it has even been found impossible to render them visible with negatives of dried skulls. Nor can one obtain clear results in the case of infants whose skulls have been injured in childbirth by forceps, etc.

[1] E. Rabloczky: Über Parotissteine und über die Röntgenuntersuchung der Speicheldrüsen. Fortschritte, Bd. 27, 1920 (with list of the literature).

[2] Yoshihide Nishikawa: Über die röntgenographische Darstellung der Venenkanäle des Schädels. Fortschritte, Bd. 31, 1924. (Complete work with many sketches and a copious list of the literature.)—L. T. Le Wald: Dilatation of diploic veins and other anatomical variations in the skull. Am. J. of Röntg., December, 1924.

The auricular muscle on the side next the plate is often clearly demarcated ; a misinterpretation would be possible only when a portion of it appears. For calcification, see later under " Ear."

The part of the head which is pressed against the negative is often less transparent (apparently), while the surrounding parts, especially the upper and posterior, which are always situate further away from the plate, appear to be more transparent than one might expect. That arises from the *secondary radiation* of the air-space between the plates and the more distant parts of the head ; we have here similar conditions to what is described at p. 12 under " Large survey exposures." These conditions are quite normal, but unfortunately innumerable mistakes have been made in diagnosing them : the middle portion, which is nearly oval and not darkened by the secondary radiation, being mistaken for a tumour of the base of the skull. These conditions relate primarily to the years before the Potter-Bucky diaphragm was brought into use.

In marked *enlargement of the pneumatic cavities* one should think of the possibility of acromegaly. The prognathism of the lower jaw can scarcely be overlooked. If that is absent or not yet present, then one usually finds the lower jaw coarse and without recognisable structure. For tumour of the hypophysis, see under " Sella turcica."

A rough process of bone about 1 cm. in length at the occipital bone, 6 to 8 cm. behind the posterior process of the atlas, is not a pathological process, but only corresponds to a strongly marked *occipital protuberance,* which process is usually strongly developed also in the dog. This projection in man has been spoken of as belonging to the congenital family skeletal-anomalies,[1] for the same affection has been found present in several families of children. The process is said to originate independently of the pull of the ligamentum nuchæ, which influences especially its later growth (see also " Olecranon-spur ").

An extremely striking, almost rectangular bending of the occipital bone as viewed in profile was seen in one family of children with the three clinical symptoms of blue sclerotic, fragility of the bones, and difficulty of hearing. (For particulars and literature, see the last paragraph of the section : " Mastoid process and ear.")

Where there is suspicion of fractured skull one should avoid regarding as pathological 2 or 3 cm. long transparent fissure-like zig-zag lines seen in profile near the middle of the vertex of the cranium. These are the normal sutures between the frontals and parietals, which often show up very clearly at this point. In hereditary insanity, the frontal suture and intercalated bones, especially in the lambdoid suture, are said to persist.

On the lateral wall of the orbit *the fronto-zygomatic suture* is usually clearly marked ; it should not be confused with a fracture.

Of *sutural varieties* there are a great number : occipito-mastoid s., parieto-occipital s., spheno-occipital synchondrosis, inter-occipital syn-

[1] Esau : Bemerkungen zu den Spornbildungen (Olekranon- u. Occiputsporn). Deutsche Zeitschr. f. Chir., Bd. 117.—Chrysospathes : Der Occipitumdorn, ein Beitrag zum Calcaneussporn. Deutsche Zeitschr. f. Chir., Bd. 110, p. 313.

chondrosis, squamo-condyloid suture, sut. transversa squamæ occipitalis, occasionally observed sutures with median-sagittal or paramedian-sagittal course in the region of the occipital squama.[1]

As the paramastoid process, a process of the occipital squama, is described, it serves as an attachment for the rectus capitis lateralis muscle, but is not always present ; it can form a joint with the transverse process of the atlas.

One should be on the outlook for *sutural bones*, usually symmetrical (frequent in the lambdoidal suture ; rarer between the parietal bone and the great wing of the sphenoid, between the parietal bones, the squamous and mastoid parts of the temporal bones) ; [2] one should also watch for the Wormian bones ; any of these can simulate fracture depressions.

A Röntgen examination of the skull in *epileptics* gives usually a negative result. Still there are already a number of positive findings reported ; one has consequently to pay particular attention to the affected areas and the variations that may be found in them. There have been found : [3] Basal hyperostosis of the anterior fossa of the skull, deepening of the digital impressions, deepening of the Pacchionian cavities, enlargement of the veins of the diploë (Brechet's canals), thinning of the wall of the cranium over the parietal and alterations in the sella turcica (see the same). Others [4] report as Röntgen findings in epilepsy : Fissures, impressions, defects of bone, anomalies in form and size of the skull, diffuse and circumscribed hyperostoses of the cranial wall, luetic diseases of bone (osteoporosis, osteosclerosis), localised lesions of the brain (calcified encephalitic lesions, calcified cysticerci, calcified tumours of the brain, alterations in the sella turcica in non-calcified tumours of the base of the brain.

Synostoses between the occipital bone and the atlas occur.[5] They may be complete or partial (for particulars, see under " Cervical vertebral," also under " Manifestation of the occipital vertebra "). In the skulls of the *elderly* the sutures are more or less obliterated and ossified.

In *frontal negatives*—that is, where forehead and face are laid against the plate—one should remember that the head is normally asymmetrical. The left half of the cranium is often larger than the right, and the nasal cavity of one side may be narrower than that of the other. The *orbits* also are not usually of identical shape. The septum of the *frontal sinuses* is hardly ever exactly in the mid-line, and the two frontal sinuses are almost always different in appearance.

The bright areas between the orbits correspond to the anterior and

[1] Goldhamer and Schüller : Variations in the region of the posterior fossa of the skull (with special reference to the operations employed in this area). Fortschritte, Bd. 35, 1927.—A schematic representation of the sutures of the occipital squama is found in Rauber-Kopsch, Text-book of Anatomy, Leipzig, 1911 ; a collection of the most frequent varieties of the occipital area in Hori : On the anomalies of the occipital bone. Folia anatom. jap., 1925/III/6 (quoted from Goldhamer and Schüller).

[2] Rauber, quoted from Grashey, Atlas I, 4th edition.

[3] Sabat, *l.c.*, footnote 4, p. 261, of this book.

[4] Schüller and Redlich : Fortschritte, Bd. 14, 1909/10.

[5] See G. Ferrari : Sulla saldatura dell' os occipitis coll' atlas. Modena, 1912.

middle *ethmoidal cells* (see later); in the nose one sees clearly the inferior and middle turbinates and the inferior and middle meatus. The frontal sinuses, the orbits, and the two maxillary antra are occasionally hardly recognisable. The cause is their overshadowing by the shadow of the base of the skull (see also later). One or two separate wavy-lines in the middle of the summit of the frontal bone are normal. As is well known *the nasal septum* is frequently oblique or bent without this being pathological.

Pacchionian cavities should be difficult to recognise in a Röntgen negative.[1] If they appear to be clearly recognisable, one should consider whether a gumma or myeloma is not present.

In the body of the adult *occipital bone* a transverse fissure may occur, if the anterior and posterior osseous nuclei of the main part of the occipital bone fail to unite.[2] Also fissures of the squamous bone, sutural bones, and intercalated bones are mentioned by the anatomists.

Brain

In a case suspected of having *a tumour* of the brain one need not expect to arrive at a conclusion by means of the Röntgen rays. Apart from tumours of the hypophysis (see below) only a few cases of tumour can be demonstrated, those in which calcification or ossification has occurred, psammomata and such other tumours as have invaded the bones, *e.g.* hypophysial tumours; that is, the tumour itself in the latter case one does not see, but only the erosion of the bone brought about by it. The same is true of abscesses and gummata. In certain cases a tumour of the brain produces an enlargement of the veins of the diploë, or rather causes their osseous canals to appear more distinct in the Röntgen view, sometimes only on one side, sometimes on both. But they may appear even in normal cases. Therefore the appearance of venous canals is only then a sure sign of a tumour of the brain, if it increases steadily. The same applies to the intensifying of the digital depressions. One should also remember the Pacchionian corpuscles, the intensifying of the arterial grooves and sutures, and certain deposits of calcium in the falx and glands of the brain.[3]

Intracranial calcifications often cast shadows which appear very like defects in the plate. Further, even very extensive calcifications do not show up at all clearly upon poorly finished plates. Moreover, such unusual and little understood appearances are easily overlooked or interpreted as some sort of artifact. Care in diagnosis and repeated negatives are therefore always necessary. Systematic examinations on large numbers of cases have shown that these calcifications are not at all so uncommon.[4] They can be of very different origin, and are not necessarily of a pathological nature.

[1] A good Röntgen picture with Pacchionian depressions, seen in the macerated cranial vertex, is found in Grashey, Atlas I, 5th edition.

[2] Observed twice by Schwegel; see Grashey, *l.c.*

[3] Le Wald, New York: Dilatation of diploic veins and other anatomical variations in the skull. Am. J. of Röntg., December, 1924, Vol. 12, p. 536.

[4] See Sabat: Röntgendiagnostik der Erkrankungen des Kopfes und der Wirbelsäule. Verhandlungen der Deutschen Röntgen-Gesellschaft, Bd. 9, 1913.—S. Ström: Über die

(1) *Physiological* intracranial calcifications occur in the *pineal gland*, in the choroid plexus, in the falx cerebri, and in the Pacchionian granulations; the first of these are the most numerous; they are round or oval, very small up to 4–5 mm. diameter and 1·5–2·5 cm. above the pars petrosa. Calcifications in the *choroid plexus* have been seen in the lateral choroid plexuses in the descending horns of the lateral ventricles. In the frontal pictures they were placed symmetrically on each side of the middle line; almost exactly above the orbits, but a little nearer the mid-line; while in

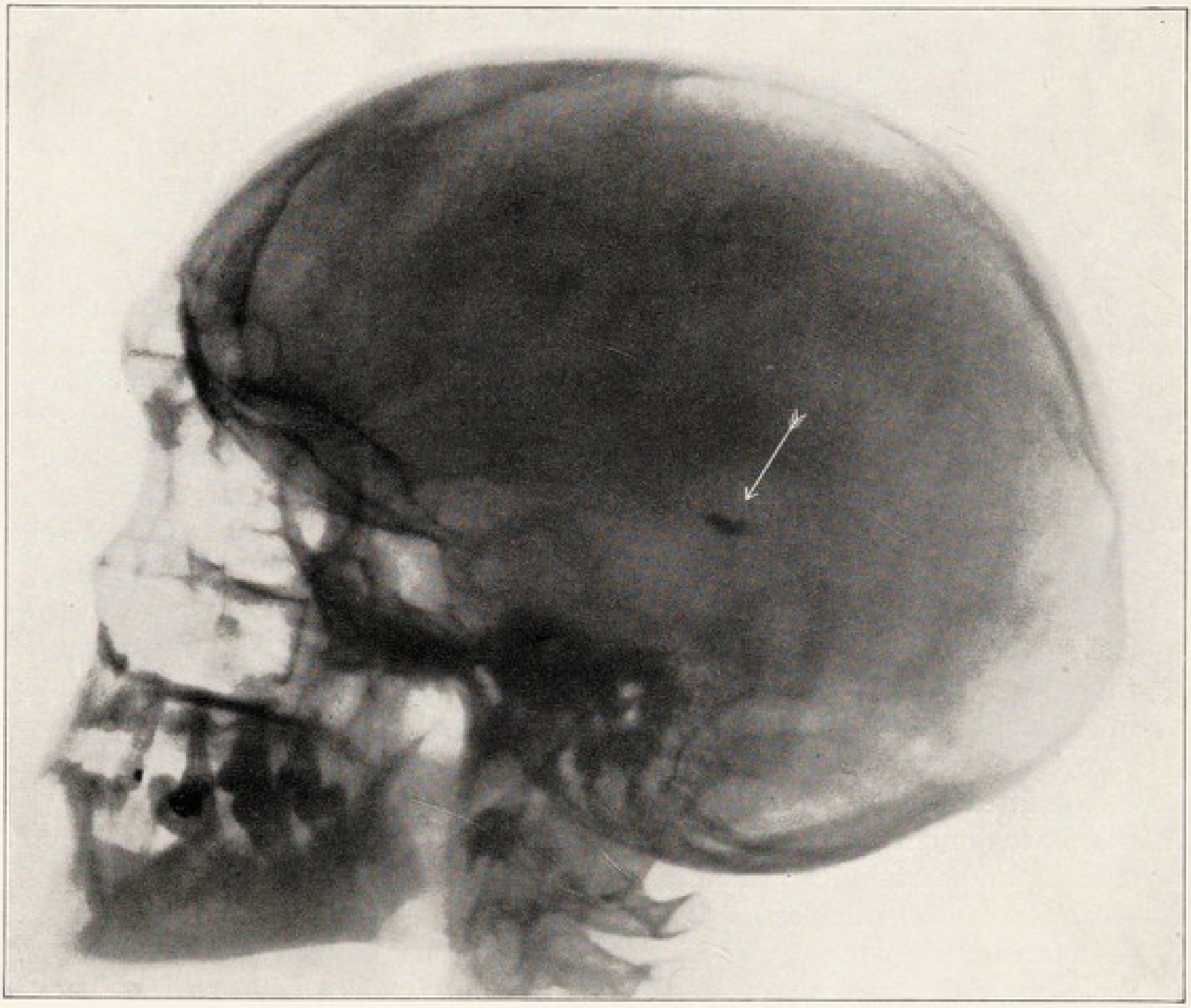


Fig. 174.

profile view they appear above the posterior edge of the pars petrosa; another author saw them in a frontal view at the upper and inner corner of each orbit, measuring about 1 cm. Osseous new formations in the *falx cerebri* appear as linear or buttonhole shadows in the middle line along the course of the falx cerebri. Concretions of lime in the *Pacchionian granulations* are readily distinguishable as lentil-like spots appearing lateral to the vertex of the cranium in one of the Pacchionian depressions.

Röntgendiagnostik intrakranieller Verkalkungen. Fortschritte, Bd. 27, 1921 (with complete list of the literature).—See further: O. Sullivan: Some rarer intracranial calcifications and ossifications. Brit. J. of Rad., 30, No. 301, August 1925.

(2) *Pathological* intracranial deposits of lime.

Calcified *psammomata* are close against the inner surface of the cranium, seldom in the interior of the cranium itself. They show a fairly uniformly dense structure. *Endothelioma and sarcoma* arise usually from the dura, more rarely from the blood-vessels in the brain, and they therefore show their calcifications within the area of the dura, their ramifications extending to a greater or less depth into the intracranial space; there is often too a well-marked local hypertrophy of the cranial vault over the area of the tumour. *Tumours of the hypophysial tract;* typical situation with spread in the immediate neighbourhood of the sella, occasionally even intrasellar.

Calcified *gliomata* and *cysts* give shadows of a ring-like or spherical form. Calcified *solitary tubercle* can attain the size of a goose egg, and exhibit well-defined lime-shadows circular in form; in the three Röntgen-ray cases described to date the site of the condition was pretty much the same, the anterior and inferior surface of the hemisphere. (Solitary tubercles can also occur in the cerebellum, the pons and the basal ganglia.)

Calcification in aneurisms: Aneurisms arise principally on the basal arteries of the brain, the internal carotid, the basilar artery, and the arteries of the Sylvian fissure, usually originating from where the vessels start to branch. They can be as large as a hen's egg. Those arising from the internal carotid artery can destroy the sella and break through into the orbit. Three cases have been published and exhibited quite a characteristic Röntgen picture, "striped shadows semicircular in form," "thin arc-shaped shadows in the middle fossa of the skull and the posterior part of the anterior fossa." Calcification in *encephalitic lesions* after injuries and hæmorrhages (the clinical symptoms in such calcifications being mostly epilepsy, infantile hemiplegia, or various pareses). The Röntgen shadows were from small up to the size of a hazelnut, without characteristic structure or site. One cannot always infer the size of the new formation on the strength of the size of the calcareous shadow. Calcified cysticerci have also been found in the brain.[1]

In a former paragraph it was mentioned that physiological intracranial calcifications are met with in the pineal gland, and this not infrequently. The picture is a pretty typical one, see Fig. 174. The natural size of the shadow in one case was about that of a bean. The position the limy shadow normally occupies can be seen from the illustration. It is interesting to note in the Röntgen literature that the existence of a cerebral tumour has been diagnosed from the displacement of the lime-shadow cast by the pineal gland.[2] One must, however, be very careful with such conclusions. The pineal gland is normally situated in a central position in the interior of the cranium, it therefore is placed a considerable distance from the film and can very easily be projected to the one or other side and appear

[1] After S. Ström, *ibid.*—See also O. Kingreen: Verkalkte Gehirn-Conglomerat-Tuberkeln im Röntgenbilde. Fortschritte, Bd. 32, p. 55, 1924.

[2] I. H. Vastine and Kenneth K. Kinney: The pineal shadow as an aid in the localisation of brain tumors. Am. J. of Röntg., March, 1927.

in a false position.[1] The pineal body (epiphysis) is situate about 5–6 cm. behind, and a little above the sella turcica; this much is visible to the röntgenologist in searching for a calcified pineal. (The origin of the epiphysis is derived from a formation in which this process reached up to the surface of the head, and formed here an unpaired organ, that was regarded as an unpaired eye. Such an organ, definitely constructed on the lines of an organ of vision, is found in the petromyzon, and in many reptiles in the parietal region [the parietal eye], and appears at one time to have had a much wider distribution. The pineal body is the last remains of this tissue, which—Gegenbaur, 1890—arises from an organ that became rudimentary.)

For the sake of completeness, especially for students, it should be remarked that since 1919 attempts have been made to represent the cerebral ventricles and cortex by the Röntgen rays, the cerebrospinal fluid being partially replaced by air or oxygen prior to examination. The method has been called "Ventriculography" or "Encephalography" or "Pneumocranion." It affords evidence on the size, position, and form of the cerebral ventricles, on the relations of these to the subarachnoid space, and upon any changes in the subarachnoid space. The method is employed in the diagnosis of the hydrocephalus; in cerebral tumours; following upon cerebral trauma; in postmeningeal or postcephalitic conditions; and in epilepsy.[2]

This book is intended for practitioners, who cannot be expected to use ventriculography, and it need not therefore be gone into in detail.

Base of the Skull

Profile photographs are here the rule.[3] On the frontal aspect are visible the posterior wall of the frontal sinuses, *the floor of the anterior fossa of the skull* and the roof of the orbit; they appear as a well-marked shadow, a few centimetres in length. Behind that there comes the sella turcica, which calls for special description.

Sella turcica

The röntgenologist is asked in acromegaly, in Raynaud's disease, etc., to decide whether the sella turcica is enlarged or not, from which we can infer the condition of the hypophysis—itself not visible in the Röngten negative. That is a difficult business, because the size of the normal sella turcica

[1] See also Heinrich Reich: Über die normale Lage der Zirbeldrüse nebst einer Bemerkung zu ihrer Funktion. Ztschr. f. d. ges. Neurologie u. Psych., 104/4, p. 818.

[2] W. E. Dandy, Baltimore: Röntgenography of the brain after the injection of air into the spinal cord. Annals of Surgery, 1919, p. 397.—Ventriculography following the injection of air into the cerebral ventricles. Amer. J. of Röntg., vol. vi, No. 1, p. 26, January, 1919. —A. Bingel: Enkephalographie, eine Methode zur röntgenographischen Darstellung des Gehirns. Fortschritte-Röntgenstrahlen, 1921, p. 205.

[3] See among others P. Brown: The diagnostic evidence obtained by Röntgen-Rays from the lateral aspect of the skull, with especial reference to the base and its adnexa. Boston Medical and Chirurgical Journal, June 12, 1913.—W. F. Manges: The Röntgenfindings in obscure head lesions. Amer. Journal of Röntg., August, 1914 (with American literature). —Crouse (El Paso): Am. J. of Röntg., June, 1923.—McKinney: *Ibid.*, October, 1923. —W. S. Stewart: Skull fractures, röntgenologically considered. B. Hoeber, 1925.

varies between wide limits, namely, between 8 and 16 mm. longitudinal diameter. (Average measurement of 500 Röntgen negatives: anteroposterior 1·06 cm., depth 0·81 cm., [0·4 cm.–1·2 cm.], in agreement with the anatomical values; in children 70 per cent. are round, in adults 58 per cent. are oval sellæ, 24·4 per cent. round, 17·2 per cent. flat.) Uniform circular enlargement of the sella, erosion and thinning of the dorsum sellæ, blunting of the anterior clinoid processes, extension and erosion of the floor, lack of symptoms of cerebral pressure (except in the late stage) are indicative of intrasellar tumour. Signs of cerebral pressure, flattening of the sella from above, sharpening and thinning out of the anterior clinoid processes, flattening by pressure on the tubercle and the anterior wall, are characteristic of extrasellar tumours. Hypophysial disturbances with deposit of lime over the sella indicate a tumour of the hypophysial canal.[1] As the lateral boundaries of the hypophysis (optic tract, cavernous sinus, and carotid artery) offer only a slight resistance compared with the osseous wall of the sella, growing hypophysial tumours are able at first to broaden out laterally and also upwards. Accordingly a negative Röntgen finding does not preclude the possibility of a moderately enlarged hypophysis. (Reductions of the hypophysis—atrophy, sclerosis—are not followed by reduction of the sella itself.)[2]

But the estimation and measurement of the Röntgen negative is not at all easy, for in doing so we have to deal with a number of complicated conditions; the sella is situated in the middle of the skull and in the adult cannot be brought nearer to the plate than about 7 cm.; therefore in any event it is an enlarged shadow which is projected on to the plate; yet, seeing its size and distance from the plate is relatively very small in comparison to the customary focal distance of from 50 to 60 cm., we can in practice neglect the slight focal distortion.

In cases of psoriasis, in addition to an acromegalic form of the bones of the hand, the hypophysis is often affected as well, so that the sella almost always appears at the highest limits of the normal.[3]

[1] Camp, Rochester: The normal and pathological anatomy of the sella turcica as revealed by Röntgenograms. Am. J. of Röntg., August, 1924, p. 143.

[2] L. Haas, Budapest: Erfahrungen auf dem Gebiete der röntgenologischen Selladiagnostik. Fortschritte, Bd. 33, 1925 (extremely complete work with 60 original röntgenograms and list of the literature).—F. Jaugeas, Paris: The X-Ray diagnosis of tumours of the Hypophysis. Arch. Röntg. Ray, 1910, 15, p. 87.—S. G. Scott, London: The radiographic appearances of the sella turcica, in diseases of the pituitary gland. Arch. Röntg. Ray, 1914, 18, p. 458.—G. C. Johnston, Pittsburgh: The radiography of the pituitary gland in its relation to epilepsy. Amer. J. of Röntg., vol. i, No. 4, p. 172, February, 1914.—R. Knox: The Röntgenography of the Sella Turcica. Arch. of Rad. and Electroth., 1923, Vol. 28.—J. van Assen: Zur Röntgenologie der Sella turcica, zugleich eine Mitteilung über eine einfache Methode zur Anfertigung congruenter Bilder. Arch. f. Augenheilkunde, Bd. 94, 1/2, 1924.—Argelin, Lyons: Les altérnatives de la selle turcique, etc. Journ. de radiol. belge, 1924, p. 125.—Goldhamer and Schüller: Die Varietäten der Sella turcica. Fortschritte, Bd. 33, 1925, p. 894.—R. W. Knaggs: Leontiasis ossea. Brit. J. Surg., 1924, 10, 347.—Norman M. Dott and Percival Bailey: Consideration of the hypophysial adenomata. Brit. J. Surg., October, 1925, XIII, 314–366.

[3] Rochlin, Schrimunsky, and Kotschneff: Über einige Eigentümlichkeiten der constitutionellen Beschaffenheit der mit Schuppenflechte behafteten Kranken. Fortschritte, Bd. 33, 1925.

It is practically impossible to set the focus with mathematical accuracy immediately over the sella, and therefore the following projections (diagrammatic) are produced (Fig. 175, *a*, *b*, *c*). View *a* is obtained when the tube happens to be centred vertically over the centre of the sellar space: view *b* when it is further forwards or backwards: view *c* when it is more towards the vertex or towards the chin or when the median sagittal plane of the head does not lie parallel to the plate. One naturally endeavours to secure the projection that approximates most nearly to the view *a*. That is best secured by centering the anticathode vertically above the mid-

Fig. 175.

point of a line connecting the external canthus of the eye with the external auditory meatus. It is evident that in views like *b* one is measuring not the profile width, but one of the oblique diameters. In the work of a Japanese an endeavour is made to prove that a double-contour is impossible in the shadow of the sella. The author cannot agree with that. And our opinion is confirmed from another side:[1] "In a projection that is not

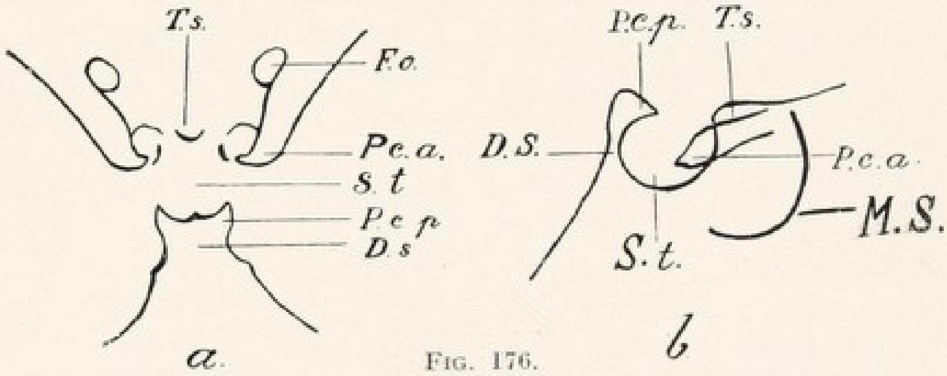


Fig. 176.

Seen from above.	Seen from the side
S.t. = Sella turcica.	*P.c.a.* = Anterior clinoid process.
T.s. = Tuberculum sellæ.	*P.c.p.* = Posterior clinoid.
F.o. = Foramen opticum.	*M.S.* = Anterior wall of the middle fossa.

quite exact the contour near the plate and the contour away from the plate appear to be separate, a double contour might therefore be normal." In reference to the accompanying illustrations. "More than two contours are always pathological, they mean an asymmetrical, unilateral excavation. Three cases, etc."

The physiological limits being so wide it is, on the one hand, difficult to decide whether a sella is still normal or pathologically enlarged; on the other hand, there is an additional factor, which removes or lessens these

[1] L. Haas, *l.c.*, and others.

difficulties, namely, the circumstance that *a tumour* does not simply enlarge the sella turcica (in the geometrical sense), but that it destroys definite parts of the sella in quite a typical manner: first the posterior clinoid processes, then the dorsum, and last of all the anterior part of the sella. Also an aneurism of the internal carotid artery has been known to hollow out the sella turcica.[1] In illustration, the anatomical conditions are shown in two diagrams (Figs. 176, *a* and *b*). In infantilism specially small sellas have been observed;[2] in mongolism only slight alterations in the sella are visible.

If the conditions cannot be clearly seen, one or two extra films can be taken; the smallest size of film is all that is wanted. Avoid mistaking the curve of *the anterior wall of the middle cranial fossa* for the enlarged sella turcica (*M.S.*, Fig. 176, *b*). A diagnosis can be obtained only from an absolutely faultless negative. But if the plate be a sharp one—it need not be rich in contrast—even small erosions of the process or of the dorsum can be clearly seen.[3]

Cases occur where the anterior clinoid processes are fused with the posterior clinoid processes or appear to be so, and some believe this to be pathognomonic for *epilepsy*, an opinion which others deny. Faint pictures of the sella are indicative rather of gumma. It is further stated on important authority[4] that the multiple osseous formations, which for the greater part are taken as osseous formations in the preformed strands of dura in the region of the sella, are not due to any pathological cause, any more than the so-called dorsum sellæ elongatum; rather, all these conditions might speak for the view that we are dealing with a normal picture. The view of several authors that an injury of the neighbouring soft tissue can be produced by the osseous formations of the region of the sella, has not yet been proven as conclusive.

Fig. 177.

In suspect cases of tumour of the hypophysis, with practically the normal contour of the sella turcica, but distinctly more opaque contents than the ordinary hypophysis, *i.e.* less transparent hypophysis, one should think of *deposits of lime within the hypophysis*. The beginner easily misses the salient points of such a picture; but a röntgenologist experienced in views of the sella turcica who meets such a condition for the first time,

[1] Cases of Schüller, Spiess, and Pfeiffer, quoted by Pincherle (see later under "Orbits").

[2] O. v. Dehn: Zur Casuistik des hypophysären Zwergwuchses. Fortschritte, Bd. 29, 1922.—W. Clift: Am. Journ. of Röntg., July, 1922.

[3] See also Luger: Hypophysengangsgeschwülste. Fortschritte, Bd. 21, 1914.

[4] Goldhamer and Schüller, *ibid*.

recognises it immediately, although he may not find the right diagnosis. These deposits of lime, taken alone, are not abnormal.

If the anterior clinoid processes are eroded or destroyed and surmounted by granular limy shadows, that speaks for Rathke's (suprasellar) tumour. As these are congenital they are found very early.[1]

The dorsum sellæ appears normal in its inner spongy osseous tissue. But it happens now and then that in a very broad dorsum sellæ there is an entire absence of spongiosa, the dorsum is not delimited at all, but forms an air-space with the sphenoidal sinuses, which can be seen very clearly in the röntgenogram (see Fig. 177).

Foramina

The *foramen ovale* varies in its size within considerable limits. In the intracranial injection treatment of trigeminal neuralgia the röntgenologist is asked to determine the situation and size of the foramen ovale, to render puncture a more certain procedure, and to diagnose anomalies that would interfere with puncture. The course of the axis of the foramen ovale corresponds to the "trigeminal axis,"[2] which passes in front of the trigeminal impression of the petrous bone through the foramen ovale, following the direction of the third division of the trigeminal nerve, and meets the cheek between the maxillary tuberosity and the ascending ramus of the jaw. At the other end this line cuts the roof of the cranium at a point about 4 cm. in front of the tip of the lambdoidal suture and about 2 cm. from the mid-line towards the opposite side. The photograph is taken in the prone position, the head is bent a little backwards at the neck, and lies with the cheek obliquely on the plate ; the latter is horizontal. The rays are directed at the point of the cranial vault mentioned above. The central ray is so arranged that seen from the side it passes through the pupil. The mouth is held wide open by a cork.

To represent the exact size of the other foramina is naturally only possible, when we succeed in directing the central beam into the axis of the osseous canal examined. Thus the axis of the *optic foramen* passes horizontally from behind and within forwards and outwards ; that of the *foramen rotundum* sagittal, that of the foramen lacerum runs from within, in front and above to outside, behind and below ; that of the *jugular foramen* horizontal from behind and within forwards and outwards. The *canals of the carotid artery and of the facial nerve* cannot be exhibited at all on account of their curved course.

Pneumatic Cavities[3]

General

Contrasts in the cranial picture of *children* do not appear so sharp as in the adult, because the differences in density between the soft bones

[1] Mackenzie and Sosman : The röntgenological diagnosis of cranio-pharyngeal pouch tumours. Am. J. of Röntg., February, 1924.

[2] Fr. Härtel : Röntgenographische Darstellung des Foramen ovale des Schädels. Fortschritte, Bd. 27, 1921 (with list of the literature).

[3] J. Macintyre, Glasgow : The Röntgen rays in diseases of the nose, throat and neighbouring organs. Brit. Laryng. Rhin. and Otol. Soc., 1900.—Rhese : Die Diagnostik der

and the soft tissues of the skull are less. That is the more unfavourable, because diseases of the accessory sinuses are not so rare and simple as would appear from the literature on the subject.

Darkening, opacity, and obliteration of the contours of a pneumatic cavity of *one side* can be normal in a few cases, when the osseous wall of the cavity on one side is thicker in the direction of the rays than that on the other ; or when the one cavity does not run so far in the direction of the rays (which is often the case in the frontal sinuses) ; or when processes casting shadows are outside, in front of or behind one of the cavities in the direction of the rays. But as a rule an opacity means *disease* in the affected cavity. The cause of the opacity may be pus, tumour, a very œdematous swollen mucous lining, collections of mucus, polyps, and scar tissue (in healed processes).[1] For comparison with the other side only photographs taken in the sagittal direction are of any use. The estimate of the Röntgen plate is rendered difficult, when the comparison with the cavity of the other side is made impossible through accompanying disease or absence of the cavity. (For frontal and sphenoidal sinus might be absent in children in the first years of life, but also now and again in adults in one or both sides ; while the maxillary sinuses and the ethmoidal cells can be seen at every period of life.) One then relies on the condition of the boundaries of the sinuses. The latter as a rule appear erased. That is settled by the condition of the margins of the cavities, which as a rule appear indistinct in disease.

If after irrigation of a cavity it still appears *opaque* in the Röntgen negative, the condition is ascribable to changes of the mucous membrane, the periosteum, or of the surrounding bony parts. If the cavity after irrigation becomes considerably clearer we can exclude any marked alteration in the mucous membrane, and if there be an entire absence of opacity a pyosinus is indicated.[2] That an opacity clears up after lavage is denied by one authority.

On the matter of the fluid-mirror it may be noted : In the first years of the röntgenology of the accessory sinuses all these examinations

Erkrankungen des Siebbeinlabyrinths und der Keilbeinhöhle durch das Röntgenverfahren. Deutsche Med. Wochenschr., 1910, No. 38.—Brunslow : Die Darstellung der Nasennebenhöhlen und ihrer Erkrankungen im Röntgenbilde. Fortschritte, Bd. 17, Heft 1, 1911.—Sonnenkalb : Röntgendiagnostik des Nasen- und Ohrenarztes. Jena, 1914, Publishers Fischer (with list of the literature).—See further P. Brown, *l.c.* (note 2, p. 264, of this book).—J. Neumayer : Die Röntgenuntersuchung in der Rhino-Laryngologie.—B. Heine : Die Röntgenuntersuchung des Ohres. Both works in Rieder - Rosenthal's text - book, 2. Bd., 1925.—Dag B. Carlsten : Zur Röntgenologie der Nasennebenhöhlen. Stockholm, 1917.—F. M. Law : Amer. Journ. of Röntg., April, 1923.—v. Sonnenkalb and E. Beyer : Die Röntgendiagnostik von Ohr, Nase und Nebenhöhlen, Kehlkopf, Mund und Zähnen. 1923, Leipzig. Publishers Klinkhardt.—A. Thost : Die Erkrankungen der Nebenhöhlen der Nase im Röntgenbilde. Schittenhelm, Lehrbuch der Röntgendiagnostik, 1924.—Tondorf : Zur Erklärung des Röntgenbildes bei Nebenhöhlen-Erkrankungen. Verh. d. Ges. dsch. Hals-, Nasen- u. Ohrenärzte, 1923.—Uffenorde : Das Röntgenbild bei Nasennebenhöhlen-Entzündungen. *Ibidem,* 1922.—Passow and Graupner : Röntgenuntersuchung der Nase und d. Nasennebenhöhlen. I Bd. des Handb. d. Hals-, Nasen-, Ohrenheilkunde. Berlin, Springer, 1925.—W. W. Wasson : A developmental study of the nasal accessory sinuses. Radiology, 1927.

[1] " If a cavity is hazy or confused, the first thing I think of is that the bony wall has been altered." A. Thost, *ibid.*

[2] Neumayer, *l.c.*

were carried out on the sitting patient, just to illustrate the fluidity mirror. But at that time the mirror was hardly ever seen, this being attributed to defective technique, confusion of the pictures by prolonged exposure. Then—as far as the author recollects—it was stated from some authoritative source that a fluidity-mirror was never seen in the accessory sinuses without there being also a valid physical explanation for it. But the consequence was—at least, the author did this—that from that time on the accessory sinuses sagittal exposures (apart from the sphenoidal sinuses) were always taken with the patient in the prone position, a method which also possessed other advantages. Recently, in 1925–26, the possibility of representing fluidity-mirrors has again been indicated.[1] The smaller the amount of mucus in the secretion, the less the surface tension, and the more evident the fluidity-mirror, represented by a concave line, which might speak for an acute inflammation with a secretion generally serous, more rarely purulent. A convex fluidity, on the other hand, indicates a more or less mucous, partly muco-purulent secretion, and enables one to infer the existence of a subacute or chronic inflammation. The convex line is also sometimes found when a cystic polyp is placed on the floor of the maxillary sinus. Puncture by the trocar might then reveal a copious clear fluid. Also fluidity-shadow lines might occur in recurrences of disease in the maxillary sinuses. The secretion generally follows the change in posture of the patient. If the secretion is too tough and viscous, it does not get displaced on the patient changing position.

Occasionally in an air cavity there is not a homogeneous darkening, but clear and dark parts alternate so that a kind of *mottling* is produced. These changes, seen so far only in the maxillary antra, are regarded as typical of previous disease of these cavities; it is believed that this appearance is produced through fibrous thickenings of the mucous membrane and simultaneous development of osteophytes, for upon lavage of these sinuses they are generally found free of secretion.[2]

In *children* one finds even more frequently than in the completely developed cavities of adults partial opacities and indistinct margins in a perfectly healthy sinus, because the sinuses attain no depth at first, and their diameter in the path of the rays is not always the same on the right and left sides.

Reduction in the size of many cavities occurs with remarkable frequency in cases of *ozaena,* together with atrophy of the nasal turbinates, very wide nasal passages, and opacity of the accessory sinuses (especially of the ethmoid base).

Apart from the method of showing the accessory sinuses illustrated in Fig. 180, there is a second way, in which, however, the ethmoidal cells are not brought sufficiently into view.[3]

[1] G. Claus: Über die Gestalt der Flüssigkeitslinien auf Röntgenplatten erkrankter Nasennebenhöhlen. Fortschritte, Bd. 24, 1926.

[2] Brunslow, *l.c.*

[3] H. Tschebull: Eine neue Darstellung der Nebenhöhlen. Fortschritte, Bd. 28, 1921 (with list of the literature).

To decide whether the central ray has been exactly in the mid-plane of the head in a sagittal-röntgenogram of the accessory sinuses or of the whole head, the best way is to see that each horizontal ramus of the lower jaw is placed symmetrically to the superior maxillæ.

Frontal Sinuses

It is exceptional to see the frontal sinuses before the fifth year; in the sixth to seventh year they are about the size of peas; from the eighth year onwards their presence becomes more apparent; and in the twelfth year they are seldom otherwise than quite distinct; but they do not reach their full development till the beginning of the twentieth year.

In the last year of childhood it may be found that *one cavity is well developed* while the other is still in the first stages.

In children *small cavities* at the level of the superior orbital margin as also highly placed ethmoidal cells may be *frontal sinuses* in early development. Profile photographs usually clear up which of these two conditions it is; on the other hand, occasional cases occur in which the frontal sinus extends into the superior nasal spine.[1]

In adults *absence* of one or both of the frontal sinuses is not at all rare. Before, however, such an absence of both frontal sinuses can be affirmed, we must make certain that the negative is technically a good one; *i.e.* the frontal sinuses should not be hidden by very dense shadows cast by the base of the skull and the occiput. The focus of the tube should not be below or in the same plane as the base of the skull, but above it, and, best of all, well above it. The uncommonly large differences of form and size and arrangement of the frontal sinuses may be used as a certain aid in the identification of skulls.[2]

One frontal sinus can quite easily be less illuminated than the other side without the condition being a pathological one. The explanation is simple enough: the clearness of a normal frontal sinus in a Röntgen negative is proportionate to the diameter of the air-space in the path of the rays. Now especially in the frontal sinuses the two sides are often different in size, and consequently of different depth in the path of the rays. The shallower sinus will therefore be less transparent. (See in addition the further statement under " Pneumatic Cavities. General.")

When the *opacities occur equally* on the two sides, difficulties in diagnosis may occur. A profile photograph should then be taken. If the sinus then remains quite opaque, it is not normal, for a normal frontal sinus is clear in profile view. At the same time we can see the thickness of the anterior cranial wall, which in the sagittal view not infrequently simulates an opacity.[3]

[1] H. Haike: Die Röntgenuntersuchung der Nasennebenhöhlen der Kinder und ihre Ergebnisse für Entwicklungsgeschichte, Diagnostik und Pathologie. Archiv f. Laryngologie, 23. Bd., 2. Heft. This work includes several quotations from the author.

[2] Proposed by Schüller.

[3] Brunslow, *l.c.*

To prove whether the anterior or posterior wall of the frontal sinuses has been destroyed, the profile negative should always be performed.

One should also read the general description given above under " Pneumatic sinuses."

Ethmoidal Cells

The ethmoidal cells of the *child* can be recognised as early as 1½–2 years in a Röntgen view.

In the *adult* what correspond to the ethmoidal cells are the numerous honeycomb clear spaces between the orbits; of cherry stone to hazelnut size they run downwards and laterally around the orbits.

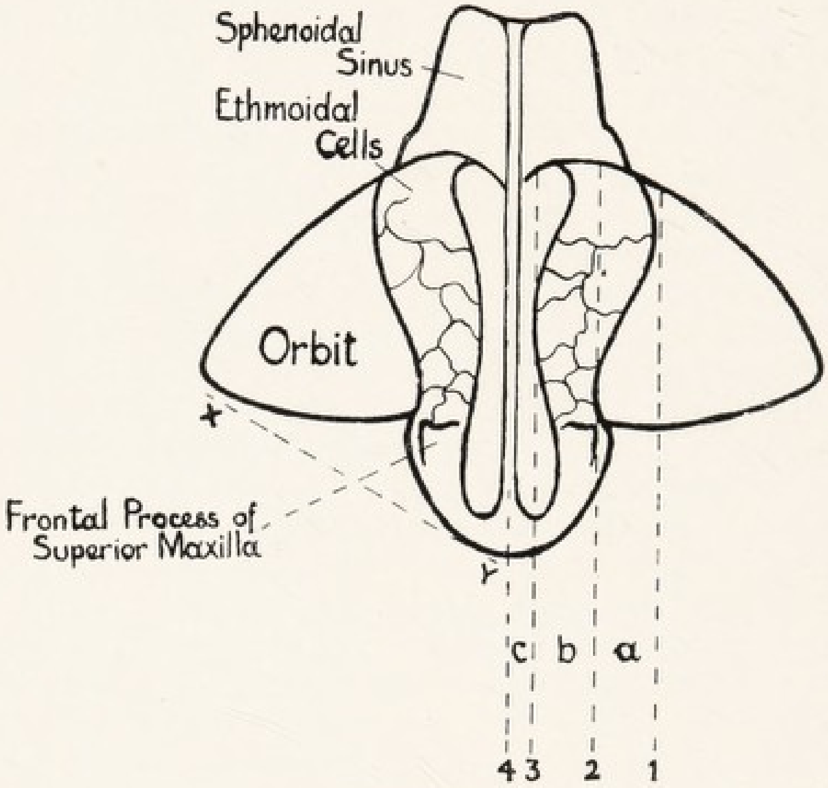


FIG. 178.[1]

Horizontal section through orbits, ethmoidal labyrinth, and sphenoidal sinus. In the section *b* between the parallel lines 2 to 3 there are placed the anterior, middle, and posterior ethmoidal cells, while in the section *a* between 1 and 2 the posterior ethmoid region is free and is situated almost by itself at the orbital margin. In the section *c* a part of the anterior wall of the sphenoidal sinus is seen uncovered by the ethmoid.

Slightly marked opacities of the one side can arise when the head is held somewhat obliquely during the taking of the photograph. *Definite opacities* of the one side when the head is held straight are always extremely suspicious. Rhinologists of great experience assert that in regard to the anterior ethmoidal region they can always rely upon the Röntgen view, whether in the living subject or at the autopsy.[2] The projection con-

[1] After Rhese.

[2] Goldmann-Killian: Über Verwend. d. Röntgen-Str. f. d. Bestimmung d. nasalen Nebenhöhlen und ihrer Erkrankungen. Beitr. z. klin. Chir., 54. Heft, I. 07, and Albrecht:

ditions in the case of the ethmoid cells are naturally extremely complicated ones.

As shown in Fig. 178 [1] the ethmoid surrounds a considerable part of the orbit from behind, the anterior and middle cells, with the innermost part of the ethmoid, being situate behind the frontal process of the superior maxilla ; a considerable part of the posterior ethmoid is placed laterally to the frontal process and the inner wall of the orbit, and projects into the

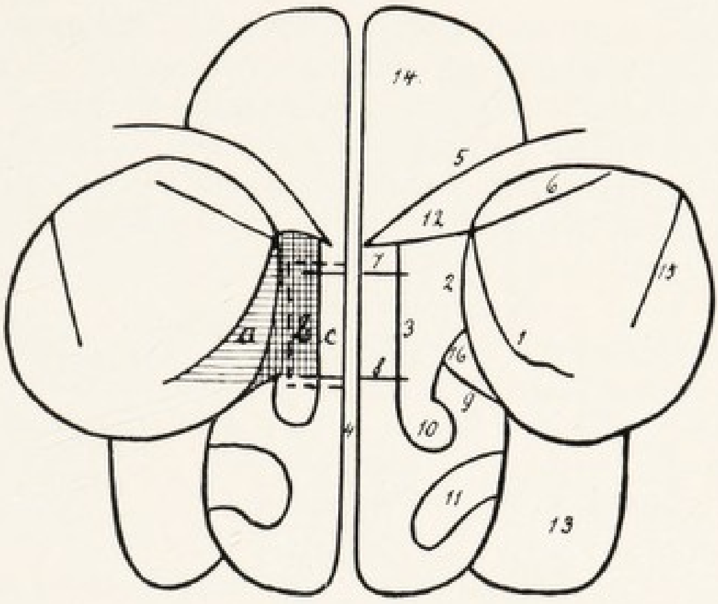


Fig. 179.[2]

Fig. 179 shows the relations represented in Fig. 178 as seen in a sagittal Röntgen view. We find the anterior and middle ethmoidal cells in the double-shaded section *b* between the lines 2 and 3 ; the posterior ethmoidal cells in the single-shaded portion *a* between lines 1 and 2 ; the region of the sphenoidal sinus is bordered by a dotted line.

a (between lines 1 and 2) corresponds to *a* in Fig. 178
b (between lines 2 and 3) corresponds to *b* in Fig. 178
c (between lines 3 and 4) corresponds to *c* in Fig. 178

(1) Inner edge of the inferior orbital fissure ; (2) inner margin of the orbit; (3) inner border of the ethmoid ; (4) septum ; (5) superciliary ridge ; (6) upper border of the superior orbital fissure ; (7) suture between the nasal bone and the frontal process of the upper jaw on the one side, and the frontal bone on the other side ; (8) roof of the superior meatus (floor of the sphenoidal sinus) ; (9) uncinate process ; (10) middle turbinate ; (11) inferior turbinate ; (12) projection inwards of the superior orbital margin ; (13) antrum of Highmore ; (14) frontal sinus ; (15) suture between malar bone and great wing of sphenoid ; (16) bulla ethmoidalis ; - - - - - region of sphenoidal sinus.

orbit from behind, for it forms not only the side but also part of the posterior wall of the orbit.

If we suspect disease of *the anterior ethmoid cells* with the frontal cells, and cannot arrive at any decision from a sagittal exposure, an oblique exposure with the plate in the position *x y* in Fig. 178 can be recommended. Rays vertical or almost vertical to a plate so arranged would bring into

Die Bedeutung der Röntgenographie für die Diagnose der Nasenhöhlenerkrankungen. Archiv f. Laryngol., XX, p. 175, 07.

[1] After Rhese, *l.c.* (footnote 2, p. 268, of this book).

[2] After Rhese.

relief the anterior ethmoidal cells of the (in this case) left side and avoid interference caused by superimposed shadows.

Diseases of the posterior ethmoidal cells can certainly be best recognised by sagittal exposures, owing partly to the anatomical peculiarities of the posterior ethmoidal labyrinth illustrated in Fig. 178 and partly because the line 1 (Fig. 179) appears in sagittal exposures. This line is sharp and clearly visible in the great majority of sound posterior ethmoidal cells, but when these cells are diseased the line is either vague or entirely absent. Accordingly, in a sagittal negative, disease of the posterior ethmoidal region can be deduced from a lateral broadening of the opacity, especially laterally from the medial orbital wall and between it and the medial margin of the ascending part of the inferior orbital fissure (line 1 in Fig. 179). If line 1 is not obliterated, the section between lines 1 and 2 clear, and that between lines 2 and 3 opaque, we may conclude the disease is localised to the anterior and middle ethmoidal cells.[1]

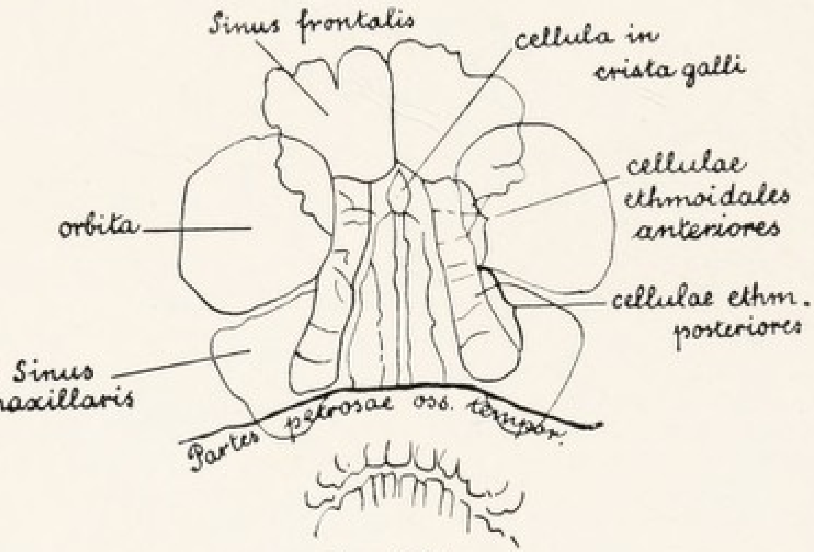


Fig. 180.[2]

An *ethmoidal cell disease* alone should produce a deep intense shadow, but is usually *combined with disease of the sphenoidal sinus*, the combination being frequently observed.

A little lateral turning of the head on sagittal exposure may simulate *an enlarged ethmoid of one side*.

When a sufficient view of the ethmoidal cells cannot be obtained, we can utilise *a special projection* recently devised.[3] The patient presses his chin on to the photographic plate, while the end of the nose is lifted 1–1·5 cm. from the plate ; the forehead is therefore about 5 cm. from the plate. The focus of the tube is vertical over the middle of the plate. One obtains then an exceptionally comprehensive view of all the ethmoidal cells, with the frontal sinuses and maxillary sinuses as well (see Fig. 180), so that this method of projection is useful for these sinuses too.

[1] This and the two previous paragraphs verbally from Rhese, *l.c.*
[2] After Waters and Waldron.
[3] After Waters and Waldron : Am. J. of Röntg., February, 1915.

Those who are not expert rhinologists should be aware that "nasal stones" also occur, which being structures rich in lime are sharply demarcated and often contain nuclei, which are more transparent than their periphery.

Exceptionally dark shadows in the ethmoidal cell area are indicative of osteomata.

Maxillary Antra

The maxillary antrum becomes visible about the second year; at the age of 2½–3 years the antrum in sagittal exposures gives usually the picture of a triangle. Very similar conditions are found here as occur in the anterior ethmoidal cells. A *maxillary antrum divided* by a sagittal wall is not pathological. The antra should be projected in such a way that the focus is placed below a plane running through the base of the skull, so that cranial base and occipital shadow do not interfere with the path of the rays (see also above).

Small maxillary antra are usually correlated with high gums.

Marked *asymmetries* of the two halves of the skull, especially of the base, can cause a darkening of the antrum on one side by a shortening of the cranial base pressing the temporal bone upwards, without any certain evidence of this being visible from the outside of the skull.

Large strong teeth with long roots often project with their apices far into the maxillary antrum and are covered only with a thin layer of bone. An inflammation of the roots of the teeth can thus extend inside the maxillary antrum.[1] But the röntgenologist should always remember that in consequence of its projection an invasion of the root-apex into the cavity of the maxillary antrum can be simulated.

Sphenoidal Sinuses

The sphenoidal sinuses can be recognised by the Röntgen rays in the child between the third and fourth years. In the sixth year they are about the size of a bean. The space situate under the sella turcica is fairly large, and is transparent to light in profile negatives and corresponds to the sphenoidal sinuses superimposed in the path of the rays. In *height* and *extent* the sinuses vary in wide limits. Specially directed investigations[2] have proven that in the adult the form of the sphenoidal sinus is independent of the age of the individual, the form of the skull and the sella turcica, and the presence and form of the clinoid processes. The sphenoidal sinuses are superjacent in lateral photographs; the profile exposure is therefore valueless in catarrhs, etc., however well the united contour is seen, for the two sides cannot be compared. In sagittal views the sphenoidal sinuses are difficult to demonstrate, but still possible (Fig. 181). The dotted line 1,

[1] A. Thost, *ibid.*

[2] Bertini: Osservazioni di Anatomia röntgenographica sui Seni sfenoidali de Cranic umano. Turin, 1911.

Fig. 181, has attained great importance, and thorough researches have been made upon it.[1] It is called abroad the Granger-line. It corresponds to the part of the roof of the sphenoid bone called the optic sulcus. The dotted line 3, Fig. 181, corresponds to the floor of the sella turcica. The slightly bent line which joins line 1 on both sides, near to and parallel to the supra-orbital margin, does not correspond to the small wing of the sphenoid, as was thought for long by röntgenologists, but to the cerebral or inner edge of the orbital or horizontal portion of the frontal bone.

The contours of the sphenoidal sinuses *on sagittal-views* are explained as

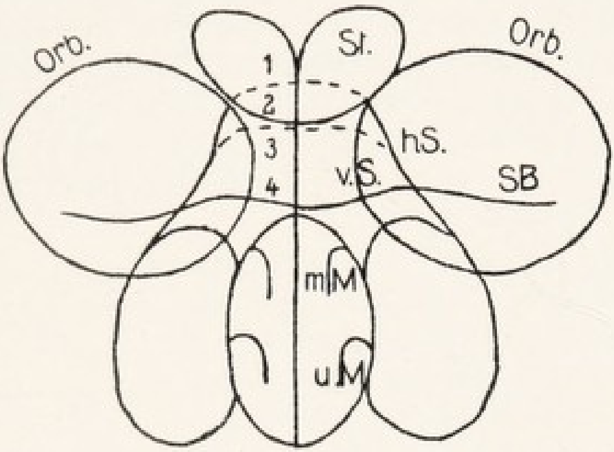


Fig. 181.[2]

Orb = orbital margin.
St = frontal sinus.
SB = cranial bone.
hS = lateral margin of the posterior ethmoidal cells.
vS = lateral margin of the anterior ethmoidal cells.
2 = lamina cribrosa.
1, 3, 4 = upper and lower margin.
mM = middle turbinate.
uM = inferior turbinate.

follows: Line 4 corresponds to the inferior wall of the sphenoidal sinus, the dotted line 1 to the upper wall. The sphenoidal sinus, however, in consequence of the depression of the sella turcica, is composed of two portions at different levels; and line 1 corresponds to the upper wall of the anterio-superior part, line 3, to that of the postero-inferior.

The possibility has recently been advanced in the literature [3] to render *sagittal irradiation* still more successful for the sphenoidal sinus, by placing the plate under the chin, or even a good-sized film in the mouth, and setting the focus of the tube in the median sagittal plane over the vertex; axial exposure with vertico-submental direction of rays (Fig. 182). In this way a most comprehensive view is obtained of the two sphenoidal sinuses, the two ethmoidal labyrinths, and the orbital recesses of the frontal sinuses. The patient is best examined in the prone position. The cervical spine is put on the stretch and the chin laid on the photographic plate. Further, the following technique has been recommended: The mouth is opened wide and the chin and the nose rest on the plate, which is placed on

[1] In the last years especially by Granger: A new technique for the positive identification of the sphenoid sinus and the ethmoidal cells. Radiol., April, 1923. Further, Jour. Am. Med. Assoc., October, 1923, and Radiology, September, 1923, and September, 1924.

[2] From Brunslow: Die Darstellung der Nasennebenhöhlen und ihrer Erkrankungen im Röntgenbilde. Fortschritte, Bd. 17, Heft 1, 1911.

[3] An interesting piece of work with very good illustrations is that of D. R. Bowen: Röntgen-Examination of the sphenoidal sinus, presenting a vertical technique. Amer. Journ. Röntg., October, 1914.

a wedge-support of 30° angulation. The central ray enters at the skull and proceeds at right angles to the plane of the table. The view thus obtained of the maxillary, frontal, and sphenoidal sinuses is extra good when the upper canine teeth are absent.[1] The projection can be done in the reverse direction: submento-vertical (see Fig. 183). The head is hung over the table with the cranial vertex on a plate placed on a chair. For the relations of the parts, see Figs. 182 and 183. In fine focus tubes with small

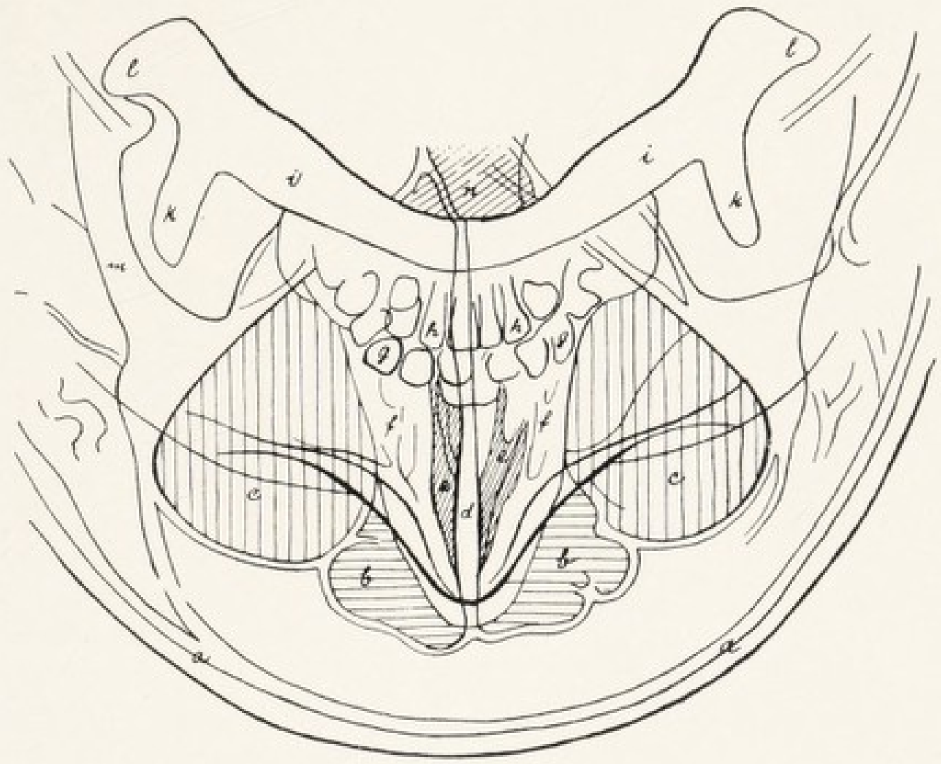


FIG. 182.[2]

Vertical (vertico-submental) photograph. (*a*) Frontal bone; (*b*) frontal sinus; (*c*) orbit; (*d*) nasal septum; (*e*) meatus of the nose; (*f*) ethmoidal region; (*g*) upper teeth; (*h*) lower teeth; (*i*) lower jaw; (*k*) coronoid process; (*l*) articular process; (*m*) zygoma; (*n*) sphenoidal sinus.

aperture and short exposure one obtains quite useful pictures in thin skulls, but it is only occasionally that a thickening of the sphenoidal sinus can be diagnosed with certainty; the reason of this is the relatively greater distance of the sphenoidal sinuses from the photographic plate and the resulting superposed secondary radiation between it and the sinus. The shape of the septum and the breadth and extent of the sinuses, for probing and other purposes, can be seen well in this vertical method.

Although difficult it is occasionally advantageous to take *oblique photographs of the sphenoidal sinuses*, projecting the sinuses to the orbital space of one or other side.[3]

[1] After Tschebull, quoted by H. Neumayer, *l.c.*

[2] Illustration by Neumayer of Münich (vol. 2 of Rieder-Rosenthal's text-book).

[3] See Skillern and Pfahler: The Röntgen-Ray as an aid to the diagnosis of diseases of the sphenoidal sinus. Annals of Otology, Rhinology and Laryngology, December, 1912.

The *form of the air-space* of the normal sphenoidal sinuses is very various. A in Fig. 184 ↑ is the usual form, but occasionally B ↑ is met with. Possibly the latter form is met with in certain forms of skull.

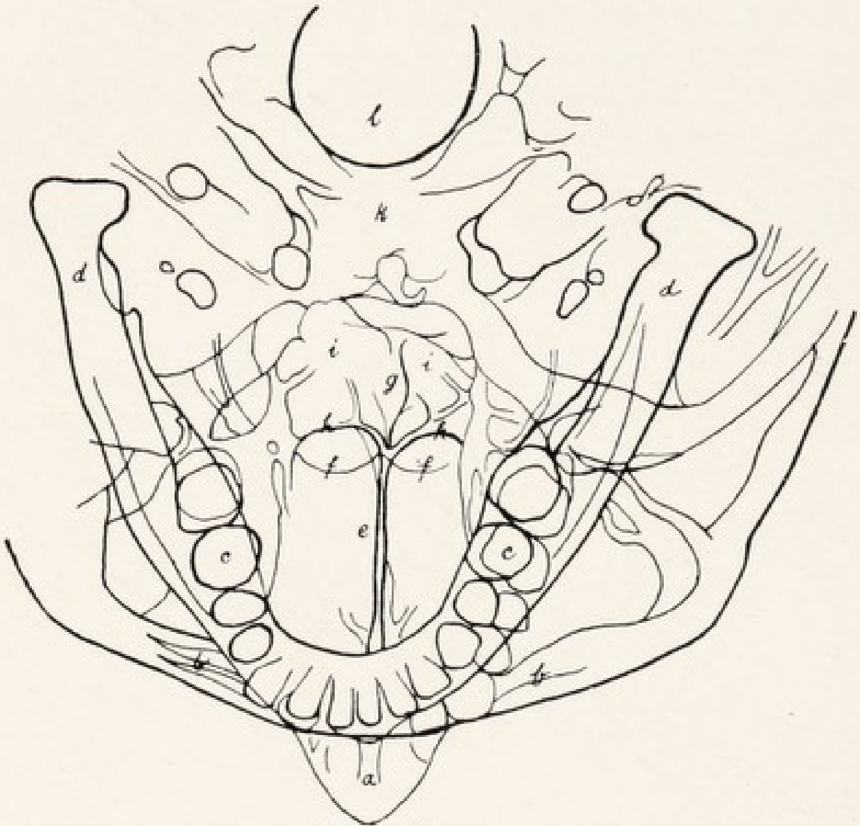


FIG. 183.[1]

Vertical (submento-vertical) photograph. (*a*) Outer nose with septum; (*b*) frontal bone; (*c*) lower and upper teeth, superjacent; (*d*) lower jaw; (*e*) hard palate with the nasal crest and the nasal septum covered; (*f*) posterior margin of the hard palate; (*g*) sphenoidal septum; (*h*) anterior wall of sphenoidal sinus; (*i*) the two halves of the sphenoidal sinus; (*k*) clivus; (*l*) foramen magnum.

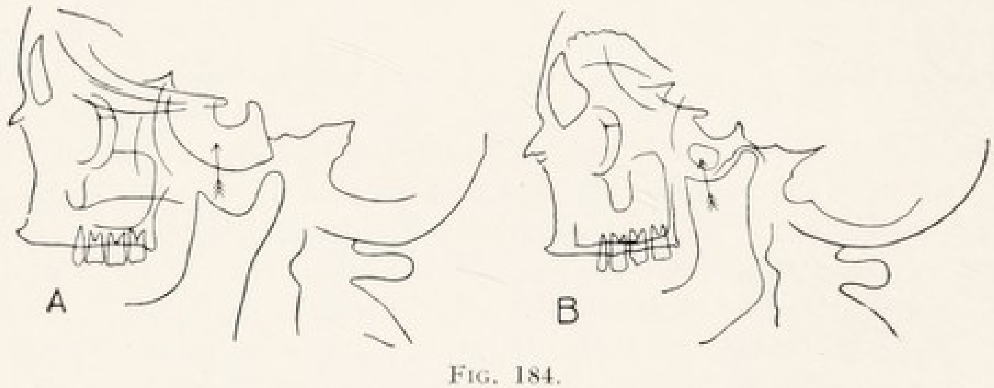


FIG. 184.

In views of the face the roof of the sphenoidal sinuses shows up, as is well known, as a fine line convex upwards. In disease processes in the sphenoidal sinus the above-mentioned line may become indistinguishable from the overshadowed sphenoidal sinus.[2]

[1] Illustration by Neumayer of Munich (2nd vol. of Rieder-Rosenthal's text-book).

[2] Granger, New Orleans: The value of the Granger-Line, etc. Radiology, III, 3, September, 1924.

By introducing a larger film into the mouth and projecting from above one secures little tangible result, unless in order to avoid the fifth reflex one renders the posterior wall of the pharynx, the arch of the gums, and the base of the tongue insensitive with cocaine and adrenalin. After that both sphenoidal sinuses can usually be very well seen and examined (Fig. 185).[1] There are also aluminium-cassettes for the purpose with double intensifying screens and water-tight compartments. The tube is placed over the skull and has a diaphragm-tube; the central ray passes axially through the skull somewhat in front of the ear at the level of the mandibular joints. One thus secures nearly complete pictures of the sphenoidal sinus with all its boundaries. If the projection be too vertical one can easily fail to obtain the posterior wall of the sinus on the plate. The orientation is facilitated by securing a view usually of the whole series of teeth. The site of the sphenoidal sinus is then always medial, and behind the last molar tooth, and should be sought for medial to the characteristic outline of the pterygoid process; the diagnosis is somewhat more difficult in patients who have no teeth, when one does not find the pterygoid process. Medial and in relation to the latter is the sphenoidal sinus, while in front of it the maxillary antrum can be well seen, especially in those who have lost their teeth. When the sphenoid bone is highly pneumatised the picture becomes often very confused and protean, for the sphenoidal sinuses are frequently not only subdivided and loculated by sub-septa and lamellæ, but both lateral to and above the sphenoidal sinus there are a number of larger and smaller ethmoidal cells. The study of the relations of the sphenoidal sinus to neighbouring ethmoidal cells is extremely important for Röntgen diagnosis. But this method of taking exposures is also quite suitable for the representation of diseases of the posterior ethmoidal cells. Diseases of the posterior ethmoidal cells without implication of the sphenoidal sinus can be shown. That occasionally superjacent and adjacent ethmoidal cells cannot always be distinguished with certainty from the cavities of the sphenoidal sinus, cannot diminish the value of the method. (Similarly, in the sagittal view high-reaching, frontal ethmoidal cells are difficult to diagnose from cavities of the frontal sinus.

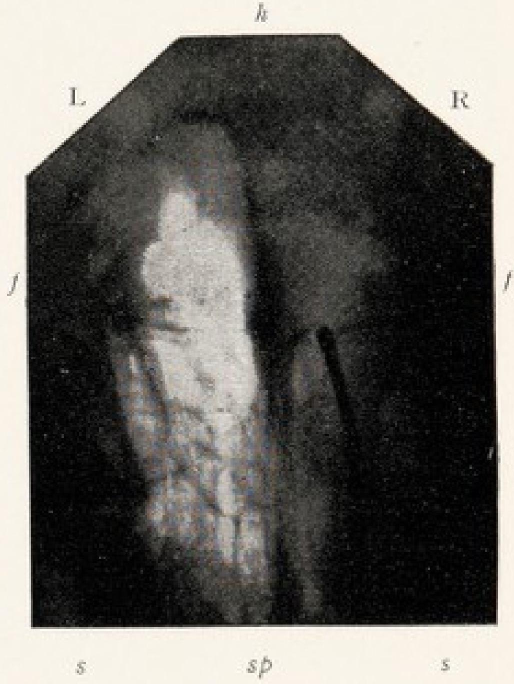


Fig. 185.[2]

[1] Knick, Leipzig: Zur Röntgendiagnostik der Keilbeinhöhlen-Erkrankungen. Ztschr. f. Hals-, Nasen- und Ohrenheilkunde. Report of Congress, Bd. VI, 1923.

[2] From Ztschr. für Hals-, Nasenheilkunde. Fig. 9, p. 106. Knick. Bd. VI, 1923, Report of Congress.

Yet the Röntgen view might retain its value in diagnosis of the frontal sinus.) The application of this method is to be specially recommended, when it is of importance to establish or to exclude the implication of the posterior ethmoid, in multiple empyema, in retrobulbar neuritis, in optic atrophy, in periostitis of the orbit, or in intracranial complications. Fig. 185 (from Knick) is from a girl aged eighteen. L are the sphenoidal sinuses and ethmoid cells translucent and sharp. R are sphenoidal sinus and ethmoidal cells markedly opaque. Probe in the ostium of the sphenoidal sinus. Right-sided suppuration of the sphenoidal and ethmoidal sinuses. h=posterior fossa of the skull ; f=pterygoid process ; s=ethmoidal cells, opaque on the right side ; sp=septum ; k=sphenoidal sinus, opaque on the right side. Still another special way to photograph the sphenoidal sinuses has been recorded, arranging the head of the patient and the tube in such a manner that the film-cassette is placed vertically at the convexity of the skull and the central ray enters through the middle of the mouth held open by a cork.[1]

The Orbits [2]

In *children* the orbits are relatively large in proportion to other parts of the body. Regarding their normal *asymmetry*, see under " Head. General."

If the endeavour is in *profile views* to obtain a picture of *one orbit*, as little as possible complicated by the shadow of the other side, then the focal distance should be as small as possible.

Anomalies in the form of the orbits are usually one of the signs of deformity of the whole skull, more rarely it is due to congenital or early acquired anomalies of the orbital contents. Atrophic and absorptive changes of the orbital walls, like diffuse and circumscribed hyperostosis of the same, are brought about by inflammatory processes or tumours.[3]

Commencing *malignant tumours*, as may be readily understood, which have invaded the thin walls of the bony orbits, can be recognised only in specially favourable conditions ; osteomata, on the other hand, can be seen owing to their density. Such a case (12089) is shown in Fig. 185, L. As the particular bony tumour adheres at first more or less to the normal contours of the bones, the inexpert at the first glance will be likely to overlook it. The patient, forty-three years old, suffered for seven years from a gradually increasing protrusion of the bulb. He was treated in the University eye-clinic, and was for three years apparently blind. At the

[1] H. Richter : Beitrag zur Röntgenographie der Nasennebenhöhlen. Ztschr. f. Hals-, Nasen- und Ohrenheilkunde, Bd. 13, Heft. 2, 1925.—*Ibidem* : Münch. Med. Wochenschr., 1926, No. 23.

[2] Engelbrecht : Röntgenologie in der Ophthalmologie ; in Grashey : Röntgenologie, 1922.—Salzer : Röntgenologie in der Augenheilkunde, in Rieder-Rosenthal's text-book, vol. 2, 1924.—Wagemann : Verletzungen des Auges ; in Graefe-Saemisch's manual, 1910–13.—Szily : Pathologie der Tränenorgane in Röntgenbild. Klin. Monatsschr. f. Augenheilkunde, 1914.

[3] A. Schüller : Röntgendiagnostik der Erkrankungen des Kopfes, in Schittenhelm's text-book, Berlin, 1924.

time when these Röntgen views were taken the patient was under the care of the eye-specialists for a painful inflammation of the left eye (ulcer of the cornea in consequence of incomplete closure of the lids). The optic nerve was quite pale, in correlation with which there was only slight sensitivity to light. The patient is still alive, $5\frac{3}{4}$ years from the time of taking Fig. 185A, therefore twelve to thirteen years from the commencement of the complaint. The tumour has now extended to the antrum of Highmore, the patient writing that his local doctor had diagnosed it so. Fig. 185A shows that rather more than the lateral half of the left orbit is rendered opaque with a mass of dense bone. The shadow on its medial side is not quite sharply defined. The roof of the orbit is thickened, mostly it would seem in its posterior part, medially 1 cm., laterally $1\frac{1}{2}$ cm. thick at the maximum. The tumour extends laterally and above, roughly along the orbital wing of the sphenoid, to run more or less to a point laterally and above. Further, both sphenoidal sinuses appear apparently completely full of solid masses of bone. In the frontal-röntgenogram one has succeeded in obtaining a view of the entire sphenoidal sinuses (*i.e.* the space between the lines 1 and 4 in Fig. 181). In addition and in approximation thereto the upper anterior and middle ethmoidal cells are markedly opaque, although not so dense as the other tumour-areas. The superior orbital fissure is also still free for a half of its lumen. (The author has no longer by him the profile negative belonging to it.)

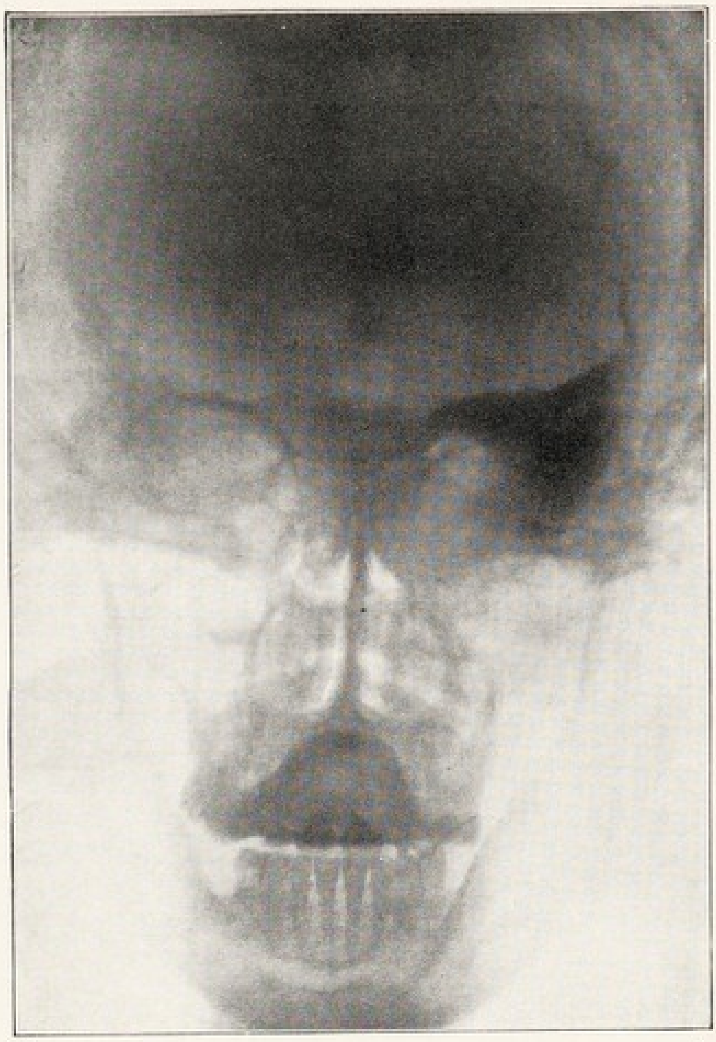


FIG. 185A.

A couple of unusual Röntgen pictures of the orbits are published,[1] in which *dense shadows of lime* are seen in coil-like or horseshoe form (or in

[1] Schüller, quoted by Pincherle.—P. Pincherle: Über die röntgenographische Darstellung verkalkter Hirnarterien. Fortschritte, Bd. 29, 1922.

indistinct lines), which remained unaltered for years. These are really parts of the *calcified internal carotid artery*, which were projected in sagittal exposures in the middle of the orbital space. On photographing such a case in profile the shadows appear even more distinctly in the sella turcica space. Seeing arteriosclerosis affects chiefly middle-aged people, *e.g.* in consequence of the misuse of alcohol and tobacco, in lead workers, in people suffering with auto-intoxications of liver and kidneys, and especially in luetic cases, its early discovery by the Röntgen rays cannot be over-estimated in diagnostic importance.

Good negatives are requisite to the examination of *fractures and infractions of the orbital margins*. Avoid mistaking the *fronto-zygomatic suture* for a fracture or a fissure. In a possible fracture of the *optic foramen* do not omit to take a special photograph of it. The plate should abut as far as possible against the whole orbital area ; the head is therefore turned towards the sound side, and the focus of the tube is set vertically over the centre of the plate. There should not be the slightest difficulty in recognising whether the foramen is intact or not.[1] The physiological size of the foramen was examined by White, who found an average size of 5·35 mm., with only slight differences.

A normal-sized optic foramen does not exclude the possibility of a tumour of the optic nerve, but a foramen that is definitely too large in a suspected case makes it probable that the tumour has penetrated into the optic canal. A foramen that is definitely too small or markedly deformed can be regarded as suspicious in atrophy of the optic nerve, in inflammation and disease of the nerve, and in elevation of the skull, etc., as a predisposing factor.[2]

In examining for *minute metallic splinters* in the eyeball the beginner and the inexpert are apt too easily to mistake small particles of bone in the orbital walls for foreign bodies. It should therefore be remarked that metallic bodies are five to ten times as dense as bones, and in at least nine out of every ten cases give an absolute reliable picture, even though they are not larger than a $\frac{1}{4}$ mm. The author found in one case on a technically absolutely faultless negative only one shadow $\frac{1}{4}$ mm. in size. The enucleated bulb brought directly on to the plate showed, however, a total of four minute metal splinters. It is to be noted that the Röntgen representation of very small splinters depends not so much on their size and distance from the photographic plate, but rather on the size, *i.e.* the diameter of the focus of the tube. The finer the focus of the tube, the smaller the splinters that can be seen. It is naturally important for the bulb to be held still during the exposure. Exposures in which the eyes are not fixed upon a definite point are valueless.

It is only a vivid imagination that can discover the *bulbus oculi* in a

[1] Complete works on the subject are those of A. de Kleyn and H. W. Stenvers of Utrecht in Graefe's Archiv für Ophthalmologie 19.—H. A. Goalwin, New York : Die exakte röntgenographische Darstellung des Canalis opticus. Fortschritte, Bd. 32, 1924, p. 218.

[2] Van der Hoeve, Leyden : Röntgenography of the optic foramen in tumours and diseases of the optic nerve. Arch. f. ophthalm. 115/2, p. 355.—D. J. Steenhuis : On the Röntgen examination of the petrous bone and the optic foramen. Fortschritte, Bd. 34, 1926.

Röntgen picture. If one wishes to determine the exact situation of *a foreign body*, whether inside or outside the bulb, a profile negative should be taken with change in the direction of the eye. During the first half of the exposure the patient is asked to fix his gaze to a definite point opposite him (marked in chalk or stamp-paper), during the second half he is told to look at a second mark some way off the first, changing his gaze without moving his head. If the foreign body is inside the bulb, two shadows of foreign bodies are then cast on the plate; if it is outside the bulb only one, with a few exceptions.[1] This method can be combined with other means of localisation. It may be recommended not to direct the gaze to two points widely apart, on account of the accompanying movement of the fat masses in which the eyeball is embedded. "The bulb of the eye is held in a tendinous circular compartment, and it is taught that it moves inside that like the femoral head in its socket. The comparison is not quite applicable, for the two are connected by many loose connective-tissue fibres. In strong movements the ring is therefore drawn upon, and perhaps the retrobulbar fatty masses moved a little also. The fatty tissue situate lateral to the bulb is connected by loose connective tissue with the tendons and the anterior ends of the orbital muscles, and may upon strong contractions be moved with them, probably to a greater extent than the retrobulbar fat."[2] Therefore one separates the two points that the patient has to look at one after the other not too far apart, best at a distance of 40 cm. and then at a distance of about 150 cm. from the eyes to the points. This method does not displace a foreign body in connective tissue outside and quite near to the bulb, when the direction of gaze is being changed, so as to produce a double image.

Despite the aid of Wessely's lead capsules one is unable in many cases to decide whether the foreign body is in the bulb or behind it—especially when the foreign body is far back in the orbit. But the Wessely capsule is indispensable when the foreign body is situate far forward in the bulb. One can then reckon almost to a millimetre how far from the anterior surface of the eyeball it is to be sought at the operation.

Mastoid Process and Ear

Up to the end of the fifth year the whole mastoid process is usually filled with air-cells, but the process of pneumatisation under really normal conditions is never brought to a completion the whole life through, either interstitially or at the periphery.

In the first years of the Röntgen era one was confined, so far as the temporal bone was concerned, to an examination of the mastoid processes.

[1] Köhler: Zur röntgenologischen Differencierung intra- oder extrabulbär sitzender Geschosssplitter. (Results and further extension of the procedure of changing direction of vision.) Münchener Mediz. Wochenschr., 1918, No. 15, p. 399.—W. Altschul: Localisation intraocularer Fremdkörper. Fortschritte, Bd. 29, 1922.—The other methods are more difficult and are summarised by Salzer, *l.c.*

[2] Private communication from Dr. Roux-Halle.

Sagittal exposures were the ones primarily considered, for in profile views an adequate comparison of the two sides is impossible. In sagittal exposures it is convenient to place the face on the plate or to photograph with the occiput on the plate ; one should note, however, that in every case a portion of the air-cells of the mastoid process, especially those placed medially and above, are covered almost to invisibility by the temporo-mandibular joint and the zygomatic process. In order to obviate this overshadowing as much as possible, in the first case (with the face on the plate) the focal distance should be as small as possible (40–50 cm.), in the second case as large as possible (70–80 cm.). The first of these is preferable.

It was about the year 1905 that they made these inquiries. With more experience and improvements in the Röntgen technic, greater and greater endeavours were made to bring the finer details of the parts of the inner ear into the region of Röntgen diagnosis. The technical measures naturally became ever more complicated, and the specialist for röntgenology as a whole perhaps could not always succeed in controlling the technical and diagnostic details as could the aurist at a large ear clinic, who had devoted himself for years to the study and Röntgen diagnosis of his particular line. Thus in the course of time there arose about seven different typical exposure methods for the temporal bones, probably every one of which had its own advantages. One or other was more or less successful, but each had its definite advantages for certain questions set in particular cases. These projections are : [1]

(1) Axial comparison exposure of the pyramids. The patient is prone, the chin in extreme extension on the film. The central ray runs in the intersecting line of the mid-sagittal plane with one perpendicular to the horizontal through the two external auditory canals. The view obtained is similar to Fig. 182, but extending further to the dorsum. It is applied in suspected fractures of the base of the skull, to determine the size of the two petrous bones, *e.g.* in osseous atresia of the external auditory canal.

(2) Antero-posterior comparison exposure of the pyramids. The patient is on the back. The central ray runs in the intersecting line of the mid-sagittal plane with the horizontal. It is used in suspected tumours in the region of the tip of the pyramid and in carious processes in the petrous bone.

(3) Comparison exposure of the mastoid processes. The patient lies prone, with the forehead and nose pressed against the plate, a wedge-pillow under the face. The central ray runs in the intersecting line of the mid-sagittal plane with a plane set parallel to the horizontal through the superior orbital margin. Tube focal distance 35 cm. It is applied for estimating the extent of air in the mastoid cells.

(4) Schüller's projection. The patient rests on the side, median plane

[1] According to Ernst G. Mayer's classification : Ergebnisse der röntgenologischen Untersuchung des Schläfenbeins bei Erkrankungen des Ohres. Fortschritte, Bd. 32, 1924. *Ibidem :* Röntgenographic examination of the base of the cranium in the presence of basal tumours. Radiology, April, 1928. The "horizontal" here referred to is the plane through the two infraorbital margins and the highest points of the two external auditory meatuses.

parallel to the plane of the plate. The central ray runs in a plane perpendicular to the horizontal, passing through the two external auditory canals. It is directed to the auditory meatus of the side to be examined, and forms with the horizontal an angle open towards the vertex by about 30°. This projection affords the best survey of the topographical relations. Further, it yields an excellent view of the inner ear.

(5) Sonnenkalb's projection. The patient rests on the side, median plane parallel to the plane of the plate. The central ray runs in a plane laid through the two external auditory meatuses, forming with the horizontal an angle open towards the vertex of 60°. It is directed from the region of the parietal eminence to the external auditory meatus of the side to be examined, and forms with the sagittal plane an angle open towards the vertex of 60°. In consequence of the inclination of the central ray from behind and above to in front and below one receives a better view (as in Schüller's method) of the pneumatic system, but no very exact verdict on the topographical relations is possible.

(6) Stenvers projection. The patient rests prone, the head turned about 45° towards the sound side, with the nose, the forehead, and the zygoma of the affected side towards the plate. The central ray passes in a plane perpendicular to the horizontal through the mid-point of a line uniting the external auditory meatus with the outer margin of the orbit, which plane forms an angle of 45° with the sagittal line. It is directed from the region of the external occipital protuberance to this point, and forms with the horizontal a dorso-caudal open angle of 12°. This arrangement brings the petrous bone in the best projection with the least distortion, and represents it as we see it when looking from the front, perpendicular to its long axis. It is applied in all suspected tumours, both of the mastoid part and at the tip of the pyramid, further for fractures and for caries of the petrous bone.

(7) Mayer's projection. The patient rests on the back, the head turned about 45° towards the side to be examined. External ear turned forwards. The central ray runs in a plane perpendicular to the horizontal through the external auditory meatus of the side to be examined and the opposite external frontal process. It is directed from the vicinity of the bregma to the external auditory meatus, and forms with the horizontal a cranial open angle of 45°. It is applied in cases suspected of disease in the region of the antrum, attic, and external auditory meatus. For the best localisation of a pathological process it is advisable to combine the projections (4), (6), and (7).

When the orientation on the two sides of mastoid process, antrum, aditus ad antrum, tympanic ossicles, labyrinth and middle fossa of the skull, arouse special interest, stereoscopic views may with advantage be taken, for which there are a number of methods.[1]

A *difference in the translucency* of the two sides is always very suspicious, indeed usually pathological, for it is proven by thorough examination that

[1] H. Richter: Fortschritte, Bd. 34, 1926.

the mastoid processes, whether composed of solid bone or of air-cells, are approximately the same in appearance on the two sides in the same person and in a normal condition, and are of the same density.[1] If the mastoid process of one side be distinctly opaque, uniformly structureless compared with the other side, and if the patient's symptoms do not point to the mastoid process or the external ear, it is not unlikely that we have to deal with a chronic otitis media, which has healed and given an osteosclerosis.

In a typical profile picture of the head the two petrous bones are superjacent, which often (although not always) renders the picture useless for otological purposes. If the osseous tissues of one side have to be photographed in detail, an *oblique view* is essential; the diseased side of the head then rests against the plate as in a regular profile exposure, the focus of the tube, however, is not perpendicular over the ear, but is set perpendicular to the frontal profile (in this way the rays having only the thin cranial wall of the temporal region of the sound side to traverse) or over the parietal eminence.

If a satisfactory view of the mastoid process be not obtained with the usual ray directions, an oblique photograph should be tried with the patient keeping his mouth open.

Still another oblique projection of the mastoid process is from in front above and lateral, to behind, below, and inside.[2] This encounters the petrous pyramid and the air-cells vertical to its axis, the pyramid being exhibited in its whole length. The mastoid process is represented in finest detail; towards the inner part of the pyramid the sharpness of the picture decreases evenly with the increasing thickness of the bone, the increased distance from the plate, and the decreased number of air-cells.

For a better survey of the petrous bone it is also advised to project the petrous into the orbit.[3]

Cholesteatomata as such give no shadow in the Röntgen negative. The clinical history and a large antrum in Röntgen view affords a probable diagnosis. A large round or oval structureless field in the mastoid process, more transparent than bone, is indicative of choleastomatous masses.[4] In cholesteatoma the antrum and its neighbourhood, and the epitympanic recess is usually destroyed, even the whole mastoid process may be destroyed, and the sigmoid sinus and the dura in the middle fossa of the skull. For the differential diagnosis from abscess, which can give a similar

[1] Kühne and Plagemann: Röntgenuntersuchung des Proc. mastoideus bei Otitis media. Fortschritte, Bd. 12, 1907.—Sidney Lange: Die Pathologie der Mastoiditis im Lichte der Röntgenstrahlen. Fortschritte, Bd. 17, Heft 2, and further Bd. 15, Heft 2, and references Bd. 15, Heft 1, p. 57, and Heft 4, p. 208.—S. Tglauer, Cincinnati: The clinical value of radiography of the mastoid region. J. Amer. Med. Assoc., Vol. liii, No. 13, p. 1005, September, 1909.—Wm. A. Evans: Amer. Journ. of Röntg., May, 1923.

[2] Staunig and Gatscher: Eine neue röntgenologische Darstellung des Schläfenbeins. Fortschritte, Bd. 26, 1919.

[3] Steenhuis, Leyden: Über die Untersuchung des Os petrosum u. Canalis opticus. Fortschritte, Bd. 34, 1926.

[4] See also S. Asai: Über Röntgenbefunde am Schläfenbeim bei Tumoren. Fortschritte, Bd. 29, 1922 (with list of the literature).

picture, the anamnesis and clinical findings give the decision. The differential diagnosis from abscess, which gives a like picture, is afforded by the history and clinical signs.

For *localising the external auditory meatus* it is recommended that a metal pellet be wrapped in gauze and placed in the ear. It is only seldom that this method is required.

In orientation the following relations should be remembered—vertically below the internal auditory meatus there is the jugular foramen with its two apartments for nerves and vein, and in front of it the carotid canal, which appears fragmented. In the upper edge of the pyramid the eminentia arcuata projects, and from it there runs an extremely fine line, the tegmen tympani et antri, into the air-cell shadow; sometimes the line appears doubled. The cells above it belong to the squamous part of the temporal.

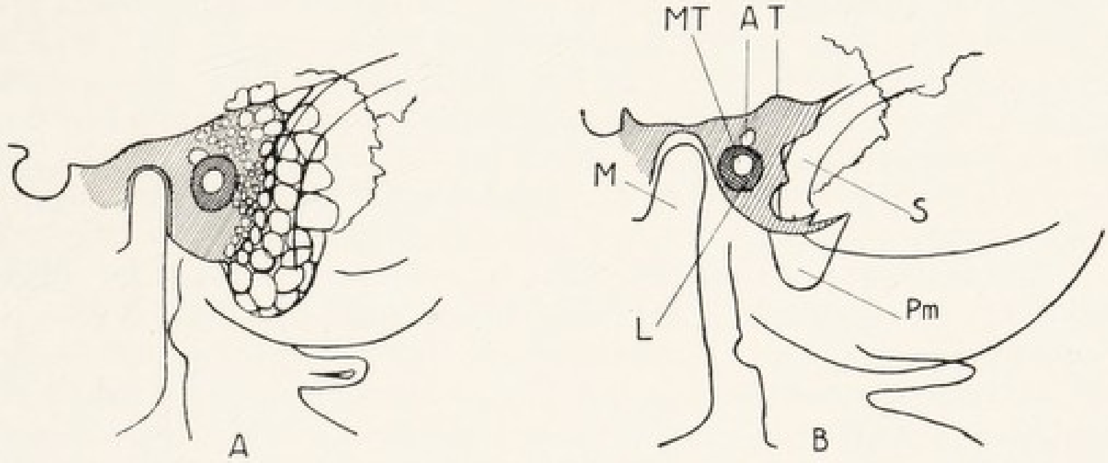


FIG. 186.

MT = Internal auditory meatus with tympanum; T = Tegmentum; A = Antrum; L = Osseous labyrinth; S = Sinus; M = Lower jaw; Pm = Mastoid process.

The antrum, which is situated above and behind the tympanic cavity under the tegmen, cannot be seen in vivo among the air-cells of the mastoid process. In a total sclerosis of the mastoid it appears in triangular form above and behind the tympanum, but its outline even then is not too distinct.[1]

The sinus appears in a Röntgen negative more clearly when the mastoid process is sclerosed. It shows up dark in the negative, and in a mastoid rich in air-cells its course is not readily distinguishable from the dark air-cells themselves, only its two edges being visible as fine lines.

In a *mastoid process rich in air* the cells increase in size from the centre, *i.e.* the antrum region, to the periphery, and their linear walls are arranged radially, they radiate fan-wise from the centre (see Fig. 186, A).

[1] Taken almost verbally from Sonnenkalb: Die Röntgendiagnostik des Nasen- und Ohrenarztes. Jena, 1914 (Fischer); a few other sentences of this paragraph are taken from the same book.—Sonnenkalb and Beyer: Die Röntgendiagnose von Ohr, Nase und Nebenhöhlen, Kehlkopf, Mund und Zähnen. Leipzig, 1923. Published by Klinkhardt.—Further, see also Wittmack: Verhandlungen der Deutschen Otolog. Gesellschaft, 1913 (Stuttgart), p. 342; further the works of E. G. Mayer, see note above; further L. Deutsch, Vienna: Zur Röntgendiagnostik der chronischen Otitis. 4. Kongress der Hals-, Nasen- und Ohrenärzte, 1924, 10. Bd.

Broad white bands running above the tip of the mastoid are due to the thick parts of the base of the skull on the inner side of the process.

A certain diagnosis regarding *the normal or pathological state of the antrum* is not easily secured ; in these oblique views it is mostly obliterated on the negative ; it is only its size that we can be at all certain about.

The number of the air-cells is uncommonly variable. Two extremes, but which both represent normal views, are shown in Fig. 186—at any rate they are the photographs of patients unsuspected of having ear trouble. In the right figure, B, no air-cells are to be seen, only a compact mass. In the case of a mixed compact-pneumatic process the pneumatic part is central, the compact peripheral ; the cellular formation is then usually less in size and arrangement. The compact and mixed mastoid processes are supposed to predispose to abscess formations and recurrences ; in strongly pneumatised processes, however, the inflammation—once it gets a hold—takes a more acute and unfavourable course.

Atypical displaced cells are frequently found in the zygoma, but occasionally also further back, when there has occurred an early fusion of the occipito-mastoid suture. In the anterior of the pyramid also cells in a few cases may be displaced forwards as far as the apex, and these in cases of a suppuration may provoke meningeal symptoms.[1]

In acute otitis media the cells that are invaded by the process are more indistinct in their outlines ; there may even be no sign of them at all. (It is essential to compare a picture taken of the sound side.) A marked inflammation in a pneumatic system always reveals itself as an opacity on the Röntgen negative. As in the larger air cavities so also in the small cells it is almost impossible to decide whether the cause of the trouble is an œdematous mucous membrane, a collection of pus, or a granuloma. In general a diminished amount of air is indicative of an infiltration of the mucous membrane, indistinctness of structure a decalcification of the bone (commencing osteitis), disappearance of structure a necrosis of bone.

A large *internal auditory canal* is indicative of an *acoustic-tumour*.[2] Other investigations have contradicted this[3]—the author has had no personal experience of that point—a third investigator has confirmed it.[4] The principal difficulty of diagnosing is the fact that the width of the canal exhibits great individual differences.

Large *abscess cavities* in the compact bone give a circular or oval translucency, which, however, does not reach the degree of clearness given by the pneumatic space itself. Smaller abscesses can remain quite invisible. In any case one should be very chary of the diagnosis—abscess-cavity—

[1] After E. G. Mayer.

[2] Henschen : Die Acusticus-Tumoren, eine neue Gruppe röntgenographisch darstellbarer Hirntumoren. Fortschritte, Bd. 18, 1911–12.

[3] Otto Strauss : Medizin. Klinik., 1916, p. 399, in a reference of the 2nd edition of this book, etc.

[4] S. Fraenkel : Die Röntgendiagnostik der Acusticus-Tumoren. Moskowski Medizinski Journal, Jhrg. 2, Nos. 5–6, 1922.

simply on the support of the Röntgen plate. The surest way is to repeat the Röntgen examination at a greater focal distance.

In *mucous inflammations* one should refrain from advising antrotomy as long as the pneumatic system of cells appears sharp, well defined, and rich in contrast on the plate.[1]

Abnormal bilateral copious *deposits of lime* occur around the labyrinth in a peculiar and recently discovered hereditary ailment, manifested by difficulty of hearing, fragility of the bones, and blueness of the sclerotic.[2] One should proceed to inquire if any other congenital lesions are present. The entire train of symptoms was first recognised and described by Eddowes in 1900.

The spheno-temporal suture may in Stenvers' projection be mistaken for a fracture.

Changes in the region of *the temporal bone* may be produced in a number of ways. Next in frequency to the diseases already mentioned come the following: carcinoma metastases, multiple defects in consequence of intracranial cysts, acoustic tumours in the region of the internal auditory meatus, aneurisms of the basilar artery in the region of the petrous bones, also large tumours of the hypophysis and endotheliomata of the dura mater, osteomata, osteosarcomata, and hyperostitis changes brought about by osteitis deformans.[3]

It was mentioned above that occasionally the whole cartilaginous auricle interferes in profile negatives. Yet in order to avoid possible mistakes we should also bear in mind that *calcifications* and *ossifications* of *the external auricle* are not at all uncommon,[4] especially in the upper edge of the helix, and nearly always in people over forty years of age. In more elderly people, of sixty years and over, such calcifications occur in about 20 per cent. The ætiology is not yet known, a large percentage occur at the site of former frost-bites and hæmatomata of the ear.

In perichondritis of the external ear röntgenography has also been utilised; it shows clearly the form and alterations in size of the concha and the cartilage, not merely in the acute stage of inflammatory conditions but also in the post-inflammatory phase. Abscess formations are plainly visible in the negative, and the extension of the destructive process in the vicinity of the cartilaginous framework of the external ear can be seen without any difficulty.[5]

[1] Sonnenkalb, *l.c.* (footnote 1, p. 287, of this book).

[2] van der Hoeve, de Kleyn and Stenvers: Blaue Sklera, Knochenbrüchigkeit und Schwerhörigkeit. Archiv für Ophthalmologie, 95. Bd., 1. Heft, 1918.—S. Singer: Zschr. f. klin. Med., 97, 1–3, p. 43.—Blencke: Ztschr. f. orthop. Chir., Bd. 45, 3–4, p. 406.—F. Schwarz, Prague: Beitr. zur idiopathischen Osteopsathyrose. Med. Klin., 1925, 49.

[3] Enumerated by Asai, *l.c.*

[4] Eugen Fraenkel: Über Verkalkung und Verknöcherung der Ohrmuschel. Fortschritte, Bd. 27, 1920.

[5] Helm. Richter: Die Perichondritis der Ohrmuschel im Röntgenbilde. Ztschr. f. Hals-, Nasen- und Ohrenheilk., Bd. 17, H. 4.

Lower Jaw

Fractures and *infractions* are not always clearly distinguishable, and it is sometimes only a close study of the plate that reveals them ; and only then when the negative is a first-class one ; for the amount of dislocation is frequently quite a minimal one.

A semilunar piece of bone, 1 to 2 cm. in diameter, appears often behind the angle of the jaw, and it can be mistaken for a piece of bone detached from the jaw. That is not an abnormality, however, but the anterior tubercle of the first cervical vertebra (see that and A, Fig. 187).

Tumours of the mandible are no rarity, and are usually clearly demarcated in the röntgenogram. One should not in profile view mistake a sharply defined clear space at the angle of the jaw for a tumour. This is due to the air in the pharynx. It can be recognised as such by tracing it on to the soft tissues of the neck and by its form, which is that of a broad straight or slightly curved band (P, P, Fig. 187).

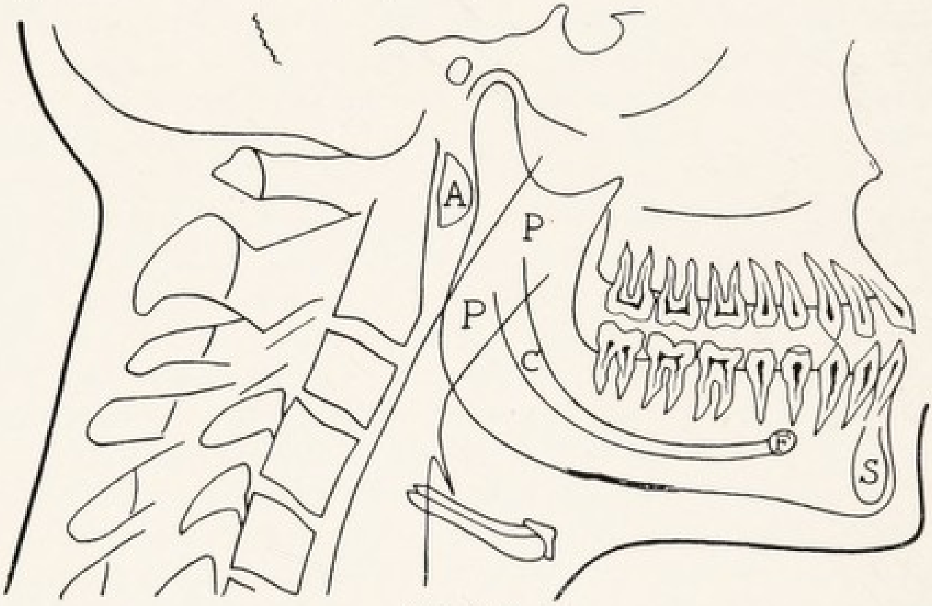


Fig. 187.

The *alveolar spongy tissue* in profile view is strikingly translucent anteriorly in the mid-line, and the beginner might be misled into diagnosing a tumour of this region upon the patient complaining of it (see Fig. 187).

A 1 to 3 mm. broad transparent gutter in the horizontal and ascending parts of the jaw is due to the *canal of the mandibular nerve : the mental foramen* is also always clearly visible and should not, in complaints about this region, be pronounced to be a lesion in the bone (see Fig. 187 ; F=Foramen ; C=Canal).

If a satisfactory *view of the lower jaw* is not obtainable owing to the superjacent shadow of the other side, one then endeavours to secure an isolated view in as wide an extent as possible : [1] place the patient in the

[1] This projection was introduced very late into the photographic technique and about the same time by the author (Grenzen des Normalen, 1st edition), Haenisch and Quiring Fortschritte, Bd. 16, p. 56) ; it was rediscovered by the dentists.

lateral position and let him bend his head with the side of the jaw to be examined as far towards the shoulder and his head bent backwards as far as he can himself manage, and place the focus of the tube over the opposite shoulder in such a way that the central rays run tangential to the shoulder on the tube side. The jaw of the side next to the tube then covers the jaw to be examined only at the front of the jaw and at the crowns of the front teeth; the whole of the canine tooth, bicuspids and molars, and the whole architecture of the horizontal ramus of the jaw, can be surveyed. The half of the jaw to be examined is overshadowed less and less, the closer one can bring the Röntgen tube to the shoulder and neck of the opposite side. This method also affords a view of *the temporo-maxillary joint,* which, as is well known, is unfavourably placed for Röntgen exploration. This projection usually gives satisfactory results, but is sometimes not easy to carry out, for instance in patients with short necks, and above all in defective children. In these latter cases one can usually manage with the so-called percranial projection, that is, the patient is fixed exactly as for a profile photograph of the head, the focus being placed in a horizontal plane 10–15 cm. above the cranial vertex, and best in a frontal plane laid through the suture between the frontal bone and the parietal bones (or rather more frontal or more occipital, according as the wisdom or the canine tooth is the point aimed at). The tube position, however, does not require to be calculated so exactly.[1] A summary of all the available methods of demonstrating the temporo-mandibular joint has been published, together with an excellent new suggestion.[2] In nearly all the previous measures, at least in those with the anticathode placed over the opposite side of the neck, the joint is over-shaded by the sphenoidal spine, occasionally also by the styloid process of the temporal and the crista basalaris of the occipital bone. That can all be avoided by directing the central ray roughly through the middle of the base of the coronoid process of the sound side towards the affected temporo-mandibular joint. " The patient is placed in the lateral position, which brings the temporo-mandibular joint in the middle of a small plate (a 9 by 12 cm. suffices). A diaphragm of 5 cm. diameter and 8 cm. length is then placed with its centre on the basis of the coronoid process of the opposite side, so that the central ray is directed towards the joint to be photographed. The diaphragm has to be tilted about 25° cranio-caudally and about 20° fronto-occipitally. It is easy for one to find the right spot for directing the central ray; it is the point of the crossing of a horizontal drawn through the attachment of the lobule of the ear and the line connecting the angle of the jaw with the most inferior point of the anterior edge of the hair."

[1] See Köhler: Zur Vereinfachung der Röntgenographie ganzer Kieferhälften. Fortschritte, Bd. 17, 1910–11.

[2] Altschul: Die röntgenologische Darstellung des Kiefergelenkes. Fortschritte, Bd. 27, 1919.

TEETH [1]

Development and Eruption

The *first formation of bone* begins in the fifth month in the crowns of the teeth and rapidly progresses, so that by the seventh month almost all the twenty milk-teeth have entered the stage of ossification. Of the permanent teeth the first molar is the first to ossify, a short time before birth, the other remaining teeth, excepting the wisdom teeth, ossify from the first and second year onwards. In the sixth year, therefore, the two jaws of the child contain fifty-two teeth, of which the four wisdom teeth are not yet ossified, and therefore not recognisable in a Röntgen plate, while the remaining twenty-eight teeth of the permanent dentition are ossified in the crowns and situated internal to the roots of the milk-teeth inside their dental sacs.[2]

For forensic purposes it should be mentioned that an approximate determination of any one's age up to about the twentieth year can be made from the width of the pulp cavity, the stages of development, the degree of eruption of the teeth, and the absorption of the roots of the milk-teeth.[3]

There is a perfect array of *anomalies in the teeth of children*, and we have not space to describe all of them. The diagnosis of teeth, even though only two be visible on the film, is usually easy—even for the röntgenologist who is not a dentist ; in the adult we can usually determine the majority of cases from the fillings.

Milk-teeth that show no intention to erupt have usually no early formation of a permanent tooth in the jaw. A fact well known to the dentist.

In uncivilised races the teeth form somewhat earlier and erupt sooner than in the more civilised peoples.

The *persistence of milk-teeth* occurs most frequently in the upper canine, then the second lower milk molar, and thirdly the upper lateral incisor and lower central incisor.

Reduction of the number of the teeth is not very uncommon. The most frequent defect is the upper lateral incisors, then the lower second

[1] Hauptmeyer and Albers-Schönberg : Die Untersuchung der Zähne und Kiefer ; in Albers-Schönberg : Röntgen-Technik. 5th edition. Hamburg, 1919 (Publishers, Sillem.)—Balli and Frasetto : Anatomia röntgenografica dello scheletro. Part I. Il cranio. 1921. Modena (Edit. Orlandini).—Weski : Vjsch. f. Zahnhlk., 38, 1, p. 1.—Shearer and Tyler : Misplaced, unerupted and impacted teeth. J. of Rad., February, 1924, p. 37.—Lurie : The interpretation of dental röntgenographic shadow changes. J. of Rad., July, 1924.—B. Simon : Zahnärztliche Röntgendiagnostik. Budapest, 1923. Publishers, H. Mai.—A. Cieszyński : Die Röntgenuntersuchung der Zähne u. der Kiefer, in Rieder-Rosenthal's text-book, vol. 2, 1925.—Hermann A. Osgood : Teeth and Jaws. Annals of Röntgenology, vol. 5. Publishers, Paul B. Hoeber, New York.

[2] Quoted from Lambertz : Die Entwicklung des menschlichen Knochengerüsts während des fötalen Lebens. Hamburg, 1900 (Gräfe and Sillem).—See further F. G. Riha : Röntgenstudien über die Entwicklung des menschlichen Eckzahnes. Ztschr. f. Stomatologie, Heft 6, 1922 ; further Riha : *Ibidem*, Heft 11, 1922.

[3] The most complete work is the atlas of W. Dieck : Anatomie und Pathologie der Zähne und Kiefer im Röntgenbilde, Hamburg, 1911 (Sillem), from which many extracts of the 2nd and following editions have been taken.

bicuspid, then the wisdom teeth, then the lower central incisors. A greater rarity is the congenital absence of the upper canine, the upper bicuspids and the second molars; the rarest of all is for the first permanent molar to be absent.

Double teeth may be observed in the upper lateral incisors; fourth molars may also be formed, and a pair of additional bicuspids have been seen. The canine hardly ever shows this anomaly.

A Röntgen negative in region of the canine may show *three teeth* above each other (*i.e.* two neighbouring teeth). In the majority of cases that is only an appearance. The first of these teeth occupying the jaw belongs to the tooth in front or behind. Also malformed teeth can be simulated in certain projections. But there also occur really malformed teeth, most frequently (although even these extremely rarely) in the molars.

The root-canals under normal conditions became increasingly narrower with advancing years. If, therefore, one finds in an elderly person an

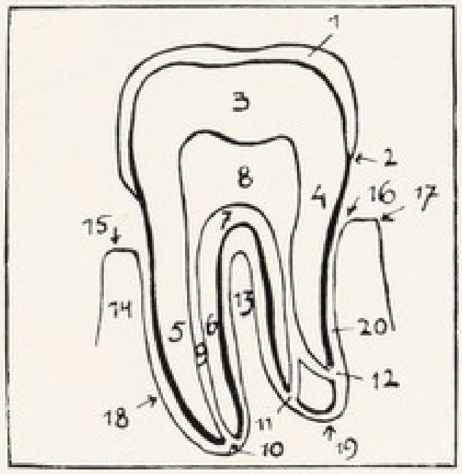


FIG. 188.[1]

1. Enamel.
2. Enamel margin.
3. Dentine of the crown
4. Neck.
5 and 6. Root.
7. "Root-bridge."
8. Pulp cavity.
9. Root canals.
10, 11, 12. Apical foramen.
13. Interradicular septum.
14. Alveolar septum.
15. Septal crest.
16, 17. Alveolar limbus.
18. Lateral wall of alveolus.
19. Apical alveolus.
20. Periodontal space.

unusually wide pulp cavity and the root-canal, it means that in youth the pulp was for some reason (usually trauma) attacked by necrosis.

Total root-absorption of the permanent teeth takes place occasionally.

In complaints of young people or adults in the region of the *wisdom tooth*, it is not enough to establish that the tooth is about to erupt. We have also to consider the direction of the tooth, because the pain is often due to pressure against the molar in front.

Sometimes a milk-tooth is retained and the tooth to take its place never appears, and remains enclosed in the jaw in a varying stage of formation. The *persistence of a single milk-tooth* can cause the permanent tooth to break through at other parts of the alveolar process, outside or inside.

[1] Illustration by Robinson, Vienna: Fortschritte, Bd. 22, p. 346

Supernumerary teeth are rare. In rare instances a pair of teeth are found behind the upper incisors (gum-teeth) ; if it be a single tooth, its crown is usually conical.[1]

Anatomy and Nomenclature

The illustration of what is to be made out in a single tooth is given in Fig. 188.

Early Pathology

A negative Röntgen finding in a tooth is no proof that the tooth is not infected.[2]

The *alveolar cancellous tissue* around the roots is normally uniformly dense and of regular meshy structure. Transparent parts of irregular form are usually due to pathological processes of old standing.

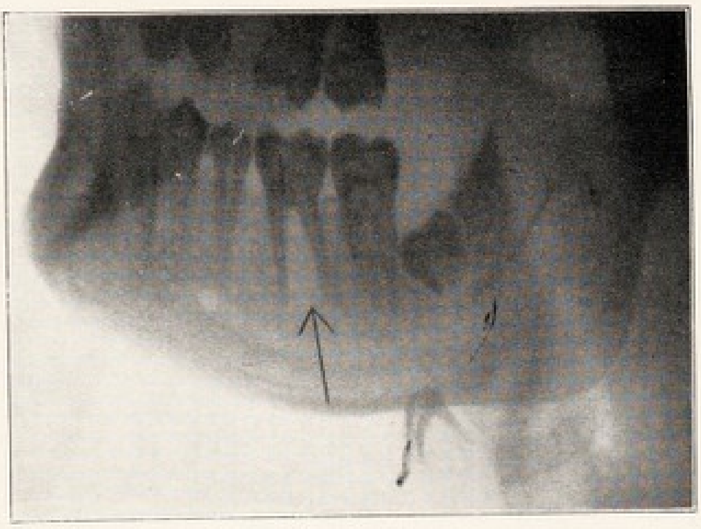


Fig. 189.

If the apical alveoli of the two upper central incisor teeth are not visible, that can be normal. The cause is unknown.

Circular or oval transparent areas sharply delimited from the surrounding parts, and placed concentrically around a root that appears somewhat blunt, are always pathological : root abscess or granuloma. The transparency is not due to pus (which indeed is never visible), but to the spongiosa having been eroded or absorbed by the pus or the granulations. Root abscesses appear frequently in teeth that are apparently sound. If the transparent cavity is surrounded by a narrow dense sclerotic margin about 1 mm. thick, the granuloma or abscess has begun to heal or is already healed—an unusual contingency.

A very unusual finding is sometimes met with, although it occurs very seldom (Fig. 189). In apical-root-granulomata a transparency is found around the root-apex, and one sees here such a transparency as corresponds to an inflammatory reduction in calcium, exactly between the two roots of the first molar, occupying the interradicular space and tailing off downwards quite gradually. We have here probably a locally produced chronically prevalent absorption-process of the interradicular alveolar

[1] Gegenbauer : Anatomie.—See Peter H. Abercrombie : Eruption of a Canine Tooth into the Nasal Fossa attended by Rhinitis Caseosa. J. of Laryng. and Otol., September, 1925.

[2] See also R. L. Heden : The röntgenographic diagnosis of periapical dental infection in the light of bacteriologic findings. Rad., April, 1925.

septum arising almost certainly from infective causes. The origin of the infection is either one of the two root-apices of the first molar, or both of them, particularly when the pulp of the tooth has been rendered dead and putrid, or the gum-margin on the lingual or buccal side. If the pulp is still alive the alternative path of infection from the edge of the gum is the probable one, and is explainable by the passage of a foreign body like a tooth-bristle, fish-bone, or such-like under the margin of the gum in the region of the branching of the roots. One might understand the ætiology of this remarkable Röntgen finding if one knew whether penetrating caries from the lingual side of the first molar is present, or whether now or earlier a periodentitis had affected the tooth with swelling of the gum or of the jaw, or whether a fistula can be demonstrated at the lingual or buccal side of the gum.[1]

Teeth carrying extra strain, *e.g.* teeth used as bridgings or supplied with an artificial crown, may show a broadening of the whole periodontal fissure and a sclerosis of the surrounding compact bone of the alveolus. There are no signs of absorption in the periodontal tissues or in the roots. Symptoms are usually absent.[2]

In film-negatives, which reach well beyond the roots of the teeth, one sees 2–5 mm. above the roots large tongue-like or patchy uniformly clear areas, which could be mistaken for root abscesses in certain clinical conditions. The condition is not a pathological one, but due to extensions of the *antrum of Highmore.* The size of the clear areas, their regular form, and especially their thick limiting wall next to the alveolus, indicate what they really are (see the paragraphs above and below).

The *communication of the dental roots* with the maxillary antrum in cases of empyema of the antrum is easily distinguishable; on the other hand, it should be remembered that a root that appears on the film to project into the maxillary cavity may not project into it at all, but may be due to the focus of the tube being tilted too far obliquely upwards. To decide whether a root is in the cavity or not consider these points: A sound root appears enclosed by a narrow transparent line corresponding to the space occupied by the pericementum, then comes an opaque line which represents dense osseous substance of the alveolar wall. If both these limiting lines are intact, the apex of the root does not enter the antrum, although it appears to do so in the film. Likewise it does not project into the antrum, when it is surrounded by a circular or oval clear space (granuloma or abscess).

An *elevation on the floor* of the antrum by the root of a tooth is sometimes found, especially in wide antral cavities.

The apex of a sound tooth is pointed or a little rounded and sharply delimited from its surroundings. Roots therefore that are round, fringed, or poor in calcium are or have been diseased. The roots of many teeth that have been filled with stoppings are like that.

Roots that have broken off and lain in the jaw for years usually undergo

[1] Private communication from Professor Dieck, Berlin. The case is ten years back, and unfortunately neither the patient (fifteen years old) nor the dentist are available.

[2] Pordes: Die Periodontitis im Röntgenbild. Ztschr. f. Stomat., 1920.

marked atrophy and partial absorption. They therefore do not always show up in the Röntgen picture as clearly as one might wish. We should be acquainted with this fact, in order not to make a mistaken diagnosis.

In injury and suspected *fracture of a root* do not miss the latter. If there has been no displacement of the fragments, the only sign of fracture is an oval line of light in the shadow of the root, as thin as a hair and just recognisable.

In photographs of the two upper central incisors there usually appears a small very transparent spot between the roots, that to one seeing it for the first time looks like a fusion patch. That is, however, a perfectly normal picture of *the incisor foramen*. In an incorrect oblique projection it can be projected in to the root of a tooth and be then mistaken for a granuloma or root abscess.

The same holds for the *mental foramen*. It is situated in the lower jaw between the two bicuspids and below the ends of the roots.

A large *apical foramen* in a young and not fully formed tooth together with the loose connective tissue pad below or above it can be mistaken for a granuloma.

In many cases *the nasal bones* and *the nasal septum* are projected also on to the film, occasionally even *the malar bones*. The possibility of these should always be reckoned with in estimating difficult and complicated views.

In patients complaining of earache who are referred to the dentist owing to nothing being found in the ears, the cause of the earache is almost always the teeth of the lower jaw, even if the patient is of opinion that it is the upper jaw that is the trouble.

The answer to the question of two superjacent or crossing shadows is really part of the film, and which is to be rejected can in many instances be determined only by stereoscopic examination or by other complicated technique with the help of several photographs. In the retained canines of the upper jaw, which are fairly common, one should note that these are usually situated on the palatal side of the neighbouring teeth.

The röntgenologist who is not an odontologist should never neglect to make a close inspection of the pulp cavity and its degree of transparency. A frequent cause of *trigeminal neuralgia* is formation of dentine or complete calcification of the pulp. The beginner can quite easily overlook that. Old roots may also be productive of trigeminal neuralgia (see also under " Lower jaw ").

SOFT TISSUES OF THE NECK [1]

General

In no other part of the body can there be radiologically distinguished so many and various soft tissues as in the neck. It is true Röntgen inquiry is not so often made into diseases of the neck, because ordinary clinical

[1] See footnote 1, p. 297.

methods are usually sufficient. Yet to avoid mistakes in diagnosis we have to realise the shadow configuration of these soft tissues.

In young *children* and in the profile photograph usually taken there is scarcely any differentiation seen in the cervical organs. The first signs of the *thyroid cartilage* appears about the seventh year of life, the *cricoid cartilage* about the eleventh year.

Mulberry-like thick shadows in any part of the neck indicate the presence of calcified glands.

The *hyoid bone* is well seen and serves to localise the shadows of the cervical organs. It is usually visible in the first few years of life, its body at any rate. The cornua appear between the sixth and the tenth year, at first separate, then without an interval between them.

Exceptional instances have been recorded of an ossified *styloid process* longer than the usual. It is extremely rare, however, for one to reach the length shown in Fig. 190. We are here dealing with a styloid process about 10 cm. in length, or rather with an ossified stylo-hyoid ligament. As is well known the visceral skeleton (gill arches) are very well developed in fishes, and much reduced in men. There remains of it long rods of cartilage in the first and second gill arch, and a shorter piece of cartilage in the third gill arch. From the cartilage of the first gill arch (Meckel's cartilage) there arises the malleus and the incus, and in relation to it there develops the lower jaw. From the cartilage of the second gill arch (Reichert's cartilage) there is formed the stapes, the styloid process, the stylo-hyoid ligament, the lesser cornu of the hyoid bone and a part of the body of the hyoid bone. The styloid process ossifies from two nuclei, of which the upper appears shortly before birth, the other after birth; the upper soon unites with the petrous and tympanic parts of the temporal bone, but does not unite with the inferior nucleus till middle age. The nucleus in the lesser cornu first appears after birth, the nucleus in the body appears earlier. Defective ossification of the styloid process, or rather of its two portions, are frequent. It is not so uncommon for the stylo-hyoid ligament to be ossified for a longer or shorter distance; this usually occurs as an addition to the styloid process, so that the process appears very long. There also occurs complete ossification of the stylo-hyoid ligament. Such an ossified stylo-hyoid ligament has often been mistaken by surgeons for a swallowed denture or the like, and been the occasion of the operative removal of "the foreign body."[1]

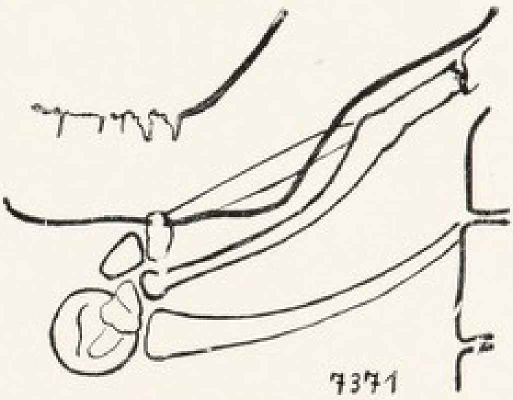


FIG. 190.

[1] For the developmental stages, see Broman, Bonnet, etc. Further Thomas Dwight: Stylo-hyoid ossification. Annals of Surgery, November, 1907. The first mention of this anomaly is found in the "Anatomia" of de Marchettis. Patavii, 1652, Cap. XIII, p. 205. "Observavi tamen aliquando processum styloideum usque ad cornua ossis hyoidei pervenire,

When unusual shadows of calcareous density appear at the level of the clavicles, and above in the central portion of the cervical field, we have to consider carefully the possibility of *deposits of lime in the colloid tissue of the thyroid* (Struma ossea).[1]

Larnyx and Pharynx

The long transparent tube in front of the vertebral column corresponds to the *pharynx* and *larynx*, or rather to the air they contain. The epiglottis can be seen in its whole length in nearly every good adult negative ; at this level the Röntgen picture is complicated by the superposed angles of the jaws and the anterior portion of the atlas. *Tumours of the pharynx and larynx*, especially on the anterior and posterior wall, project shadows—if

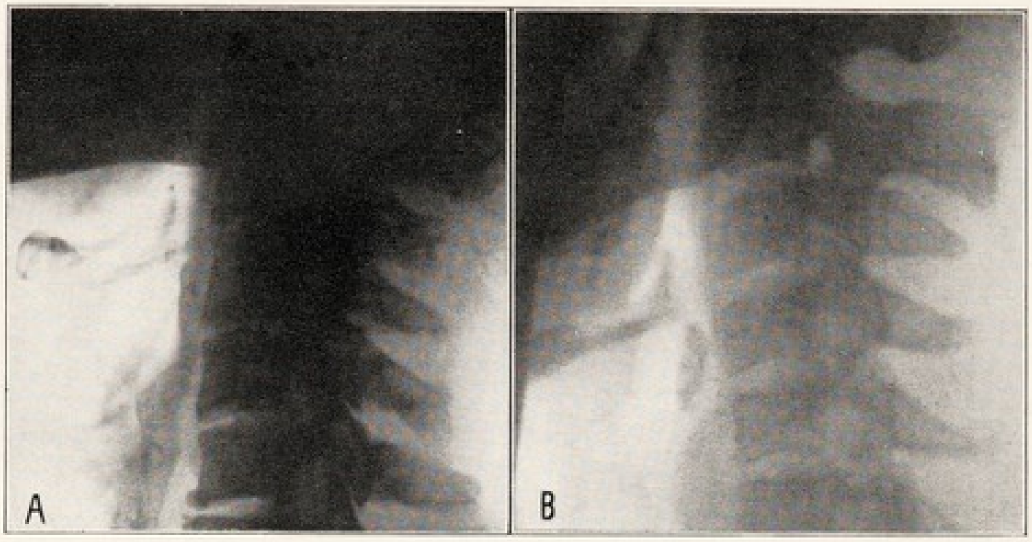


Fig. 191.

they be of sufficient size—against the transparency of the air ; yet laryngoscopy and pharyngoscopy afford easier and clearer results, and therefore we need not spend more time over that. Nevertheless, certain cases of malignant tumour at the root of the tongue and floor of the mouth that prevent examination by the mirror can be examined with benefit by the Röntgen rays. And this has been actually done in certain cases.

In the first years of life *the epiglottis* is not yet distinguishable by the Röntgen rays.

The larynx moves not only on swallowing but also with *respiration*. Therefore to secure a radiogram, in which one wants the image of the larynx, the patient should be taken holding his breath.

The difference between the *male* and the *female* larynx is not so marked in a radiograph as in the laryngeal mirror. At puberty in the male when

ipsisque valido nexu devinci."—Robert Knox : An unusual development of the hyoid apparatus. Acta Radiologica, vol. VII, Fasc. 1–6, Nos. 35–40.

[1] See also Levy-Dorn : Beitrag zu den für die Röntgendiagnose wichtigen Weichteilverknöcherungen. Berl. klin. Wochenschr., 1918, p. 829.

the voice is wont to break the relative proportions of the parts change very rapidly.

Calcified laryngeal cartilages are easily recognisable as such and can hardly be mistaken for anything else even by beginners. For long there was a tendency to regard the calcifications in individuals in the prime of life as pathological. That is not the case. The Röntgen rays have proved that the calcification of the laryngeal cartilages is a *physiological* process, that sets in about the end of the period of growth, in several instances as early as the fifteenth year. (Microscopically the cartilage is at first free of blood-vessels, at puberty, however, a complicated series of tissue changes supervene, vessels and spaces filled with blood appear, and calcareous deposits form therein as a prelude to calcification.) Calcification becomes more pronounced with advancing years, although one cannot determine the age from the degree of calcification. The senile retrogressive metamorphoses that occur from fifty to fifty-five years (including transformation of the red bone marrow) are scarcely visible in a Röntgen picture. The three larger laryngeal cartilages consist of and retain their form by means of a thin scale of bone, that encloses a fatty structure containing a few blood-vessels.[1] In Fig. 191, A, one sees immediately in front of the vertebral bodies an extreme calcification of the thyroid cartilage ; in B, on the other hand, the shadow in front of the third vertebral body (reckoning from below) is due not to deposits of calcium in the laryngeal cartilage but to a calcified cervical gland.

A senile eburnation occurs, which is explainable not so much as a new formation as by a want of absorption of the bony tissue already present. The author does not recollect ever having seen the condition in a Röntgen film. Thost says it is very rare.

The *process of calcification and ossification* commences earlier in the female, according to some authors ; while others hold that it takes place earlier in the male.

In *osteomalacia* the laryngeal cartilages are strikingly devoid of osseous tissue.[2]

The *epiglottis*, the *cartilages* of Santorini and of Wrisberg appear never to ossify. Only once, and in a woman of 102 years, have spots of calcium been reported in the cartilages of Santorini.

The *thyroid cartilage* is the first to calcify, beginning at the postero-inferior margin of the lateral plate. The calcification process proceeds

[1] The greater part of this section is taken from the following important Röntgen works : A. Thost : Der normale und kranke Kehlkopf des Lebenden im Röntgenbild. Hamburg, 1913 (Gräfe and Sillem) ; see further E. Fraenkel : Über Verknöcherung des Kehlkopfes und Luftröhre. Fortschritte, Bd. 12 and 21. The first röntgenological works are by J. Macintyre : Röntgen rays in larygenal surgery. Brit. Med. J., 1896 (i), p. 1094. Also Med. Press and Circular, January–June, 1896, p. 470.—M. Schreier : Weitere Mitteilungen über die Anwendung der Röntgenstrahlen in der Rhino- und Laryngologie. *Ibidem*, Bd. 1 ; further *ibidem* : Über die Ossification des Kehlkopfes. Archiv f. mikroskop. Anatomie und Entwicklungsgeschichte, Bd. 59.—Mignon : L'examen anatomo-topographique et physiologique du larynx par la röntgenoskopie. Arch. internat. de Laryngologie, 1901.

[2] Siebenmann : Demonstration der Kehlköpfe zweier osteomalazischer Frauen. Verh, des Vereins süddeutscher Laryngologen, 1905.

slowly forwards and does not extend over the whole thyroid cartilage until the forties.

About the same time (towards the end of the growing period), or a little later, *the cricoid cartilage* also calcifies, first of all in the plate. The cricoid further does not ossify completely till the forties.

The calcification of *the arytenoid cartilages* does not commence earlier than the twentieth year. It begins in the basal part of the cartilage, more rarely at the tip of the pyramid. It does not ossify completely before the forties. Some individuals show not a trace of calcareous deposit in the arytenoid up to the thirtieth year.

The *points of ossification* correspond especially to the muscular attachments.

Ossifications are usually preceded by a diffuse calcification process, which gives a less dense shadow.

In phthisis cases the calcareous deposits are said to be specially extensive, whereas there is less tendency to ossification.

In local *syphilis* of the larynx the contours of the larynx appear sharply delimited, in contrast to the dull tone of tuberculous larynxes. The ossification points appear especially sharp and exhibit a typically jagged form.

The horizontal, spindle-shaped, intensely clear area in the laryngeal lumen 2–3 cm. below the hyoid bone is due to the *ventricle of Morgagni*. The clear area in the picture corresponds for the most part to the half of the ventricle abutting upon the plate. In distinct alterations in one side of the larynx a profile photograph should, for clearness sake, be made on both sides.

In *tuberculosis of the vocal cords* the illuminated area of the ventricle of Morgagni is absent, provided always that the Röntgen film is technically a flawless one, secured during a cessation of the breathing.

Even small *tumours of the vocal cords* interrupt the clear area of the ventricle by a larger or smaller circular shadow.

Trachea [1]

In *early childhood* the trachea is placed to the right of the middle line, after the fifth or sixth year it is situate in the mid-line. The bifurcation in the first three years of life is situated in front of the fourth dorsal vertebra, afterwards reaching the level of the sixth dorsal vertebra. Some of the anatomists appear to doubt that statement.[2]

The *calcification* of the tracheal rings commences on the average about the middle of the fourth decade of life, the formation of bone about ten years later. Some maintain there is no regularity in the ossification and

[1] Eugen Fraenkel: Anatom. röntgenol. Untersuchungen über die Luftröhre. Fortschritte, Bd. 21, 1915.—A. Thost in Schittenhelm's text-book, 1924.—Blake: The relation of the trachea and bronchi to the thoracic walls. Am. J. of Med. Sc., March, 1899.

[2] St. Engel: Form, Lage und Lageveränderungen des Bronchialbaumes im Kindesalter. Arch. f. Kinderheilkunde, Bd. 60 and 61.—A. Hasselwander: Die Bedeutung des Röntgenbildes für die Anatomie.

calcification process. Early ossifications are observed in pulmonary phthisis and in other cachectic conditions.

The trachea attains *its widest point* about the middle. At the level of the thyroid it is somewhat narrower. Hence, in addition to the photographic plates, one should never omit to screen in all directions.

In profile the trachea can be followed down a greater or less distance according to the length of the neck. The posterior outline is fairly straight, the anterior one somewhat wavy.

Even small *tumours* springing from anterior or posterior wall of the trachea—such as strumata or endotracheal gummata—can be seen projecting into the lumen. Erosions or ulcerations of the mucous membrane are not visible in a Röntgen plate.

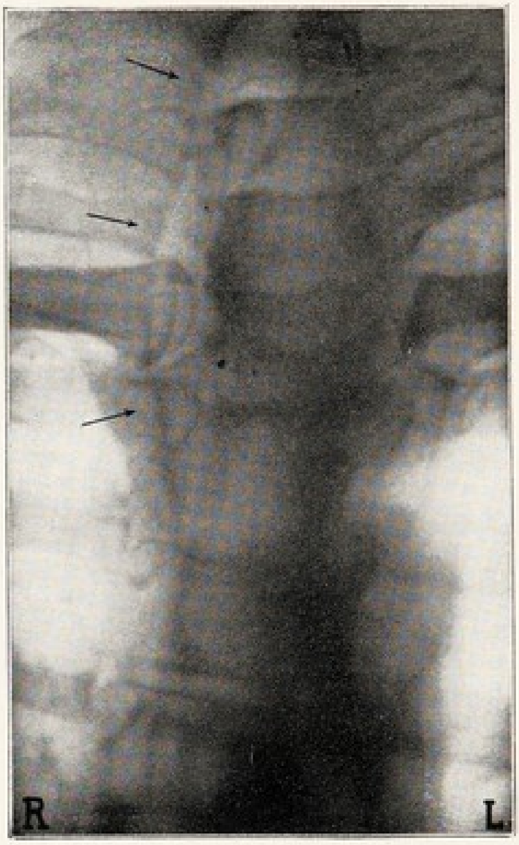


FIG. 192.

Negatives taken *in the sagittal direction* (prone or supine positions) are just as valuable as profile pictures, in spite of the vertebral column being in the way. It is indispensable for a proper estimate of such a view, however, for the focus of the tube to be exactly in the extended sagittal plane of the neck. The normal trachea is then centred in the middle of the vertebral column or at least shows up clear opposite the intervertebral discs.

Deflections of the trachea below, especially towards the left side, and if associated with narrowing, arouse suspicion of an aneurism of the aortic arch. Deflections and narrowing can also be brought about by tumours of the lymph glands, strumata (see Fig. 192), enlargement of the thymus, mediastinal tumours, tumours and diverticula of the œsophagus, tumours of the spine, tubercular abscesses, tumours of the lung, etc.; also in emphysema of the lungs, sabre-scabbard form of the trachea is observed.[1] In this last the trachea is bent into the form of a bow or S, or bent sharply at an angle. *Sabre-scabbard form* of the trachea sometimes appears apart from the above conditions, especially in males of advancing years, and more rarely between twenty and fifty years of age (idiopathic sabre-scabbard trachea). It appears quite independently of the ossification process in the tracheal rings.

The *shadows of the spinous processes* of the vertebræ, we may add,

[1] Kahler: Säbelscheidentrachea und Lungenemphysem. Verhand. d. Ver. Deutscher Laryngologen, 1913.

appear as prominent spines or knobs in the shadow cast by the intervertebral discs and the tracheal clear spaces, each spine belonging to the vertebra immediately below it (see also " Cervical column ").

Various

In *gout* of the crico-arytenoid joint diffuse calcareous shadows are seen in the neighbourhood of the diseased arytenoid cartilage. In such cases one should never omit inquiring regarding the condition of the cervical vertebræ and arthritic changes.

Clumpy shadows immediately under the angle of the jaw are due to stone or *stones in the submaxillary gland.*[1]

The *sternal prolongation of an enlarged thyroid* is sometimes seen in goitres that appear external. In these a radiological examination should never be neglected, which gives also a better view of the form, degree of bending, and lateral displacement of the trachea.

The author upon one occasion found the stylo-hyoid ligament completely ossified (it has even been mistaken by surgeons for a swallowed denture).

LUNGS AND PLEURÆ [2]

In the Fœtus and the Infant

The *thorax in the fœtus* is pear- or bell-shaped, as is also that of a newly-born dead child. The lateral contours run in a line concave inwards.

[1] Conrad: Volumineux calcul de la glande sousmaxillaire. Journ de Rad., 1910.

[2] For the normal Röntgen anatomy of the lungs, see A. Köhler: Zur Röntgendiagnostik der kindlichen Lungendrüsentuberkulose. Hamburg, 1906; further Munk: Grundriss der Röntgendiagnostik innerer Krankheiten. Leipzig, 1922; further Rieder: Die Röntgenuntersuchung der Lungen und der Bronchien, in Rieder and Rosenthal's text-book. Leipzig, 1913.—Klare-Harms: Beiträge zur Lungentuberkulose im Kindesalter. Rotes Kreuz. Hohenlychen, 1918.—Assmann: Die Röntgendiagnostik der inneren Krankheiten. 1924 (Leipzig, Vogel).—W. M. A. Evans: Röntgenstudies of the Thoraces of the Stillborn and Newborn. Am. Journ. of Röntg., October, 1922.—Dietlen: Das pathologische Lungenbild, etc. Atlas Groedel, 1924.—Brauer: Pleura-Erkrankungen. *Ibid.*—Siciliano: La Rad. med., 1918.—Coppola: Annali di Elettr. med. e Ter. fis., 1914.—Kaestle: in Schittenhelm's text-book, 1924.—Dietlen: Die Bedeutung der Röntgenuntersuch. der Lungen u. des Mediastinum für die innere Medicin. Verh. d. D. Röntgen-Gesellsch., 1927, Wiesbaden.—Assmann. *Ibid.*—Haenisch. *Ibid.*—Graefe and Küpferle: Die Lungenphthise. Atlas, Berlin, 1923. Publishers, Springer.—H. Kennon Dunham and J. H. Skavlem: A comparative study of the pathology and Röntgen-ray densities of tuberculous lung lesions. Americ. Review of Tuberc., June, 1921.—H. Alexander and A. Beekmann: Röntgenatlas der Lungentub. des Erwachsenen. 1927 (J. A. Barth).—H. Assmann: Fortschritte, Bd. 36, 3. 1927.—Haudeck: Röntgen-Kongress. Wiesbaden, 1927.—H. Walsham and G. H. Orton, London: Röntgen rays in diagnosing diseases of the chest. 1906.—G. A. Pirie, Dundee: Routine examination of the chest. Arch. Röntg. Ray, 1907, 12, p. 260.—C. Thurstan Holland: Diagnosis of pulmonary tuberculosis by means of the X-Rays. Liverpool Med. Chir. Journ, July, 1908.—*Ibid.*: X-Ray examination of the thorax. Arch. Röntg. Ray, 1909, 14, p. 205.—*Ibid.*: Patches of healed tuberculosis. Arch. Röntg. Ray, 1912, 17, Pl. cccxcviii. —G. H. Orton: Some points in the X-Ray diagnosis of early pulmonary tuberculosis. Arch. Röntg. Ray, 1911, 15, p. 323.—A. W. Crane, Kalamazoo: The inverted comma sign in pulmonary röntgenology. Amer. J. of Röntg., vol. v, No. 3, p. 124, March, 1918.—Percy

The *newly-born child*, on the other hand, has an egg- or barrel-shaped form of thorax (cf. Fig. 193); infants a cylindrical form.[1]

The thoracic viscera do not grow at an equal rate in the first years of life. The lungs grow the quickest. Between birth and completion of the first year they increase their weight threefold and their volume sixfold; in contradistinction to the heart (see the same), which increases comparatively little in the same period.[2]

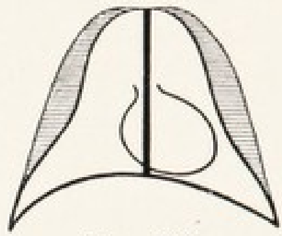


Fig. 193.

In the Adult

The pulmonary picture *in immature and newly-born infants* are produced by the arterial system of the lungs.[3]

The breadth and thickness of the lungs increases from above downwards, hence in lungs *that are normal* the pulmonary tissue is contrasted all the more from the soft tissues and ribs the further down the level of the lungs examined. *Exceptions* from this rule take place without the condition being pathological:

(*a*) Thick scapulæ prevent the penetration of the lungs by Röntgen rays in the upper lateral part of the middle third.

(*b*) Well-formed pectoral muscles diminish the translucency of the lungs. Occasionally one even sees the lower border of the muscle.

(*c*) The mamma prevents the translucency of the lung to the outer and lower side according to the degree of its development.

(*d*) In children an unusually large thorax affects the translucency of the upper and inner parts of the lungs.

(*e*) On the shadow differences between the right and the left apex, see later.

A negative Röntgen finding when a pulmonary disease is really present is possible in extremely rare cases, even with the best technique; *e.g.* in bronchiectasies or recent pneumonic or exsudative tuberculous foci, with a far focal-distance view of a deeply situated small focus in a strongly translucent surrounding emphysema.[4]

The *estimation* of small changes in the apices of the lungs is involved in considerable difficulties, and the radiologist must know of these, for his decision upon the existence or non-existence of *catarrh in the apices* is frequently a final one.[5] Screening alone is insufficient. Early lesions are

Brown, Boston: The recognition of pleural disorders by X-Rays. Boston Med. and Surg. J., vol. clxxiii, No. 22, p. 25, November, 1925.—S. Melville, London: Diagnosis of hilum tuberculosis in the adult by means of X-Rays. Arch. of Rad. and Elec., November, 1921, and June, 1923; Brit. J. of Rad., December, 1925.—D. Campbell Suttie, Glasgow: Pulmonary Tuberculosis in Childhood. Section Diseases of Children. B.M.A. Annual Meeting, Bradford, 1924.—H. Morriston Davies: The importance of radiology in connection with intrathoracic surgery. Brit. J. of Rad., October, 1926.

[1] After E. Vogt; see later under "Heart of the Newly Born."

[2] Scammon: Growth and structure of infant thorax. Radiology, August, 1927.

[3] E. Vogt: Fortsetzung der Röntgenuntersuchung der inneren Organe des Neugeborenen. Fortschritte, Bd. 29, 1922.

[4] Dietlen, *l.c.*

[5] A complete orientation regarding these points is found in the proceedings of the Deutsche

not distinguishable by it. In every case, however, screening should be followed by at least one photographic exposure. On suspicion of tubercle or other inflammation of the lungs never use the intensifying screen, that is an ineradicable error on the part of those doctors who are not experts in röntgenology. Radiologists are always making that mistake. The intensifying screen is a useful adjunct in the case of children, who have not learnt to hold their breath, and also for exposures of the lung in large, broad, fat men. The negative film and not the positive print is taken as the standard ; a simple and regular diminution of the translucency on one side, gradually

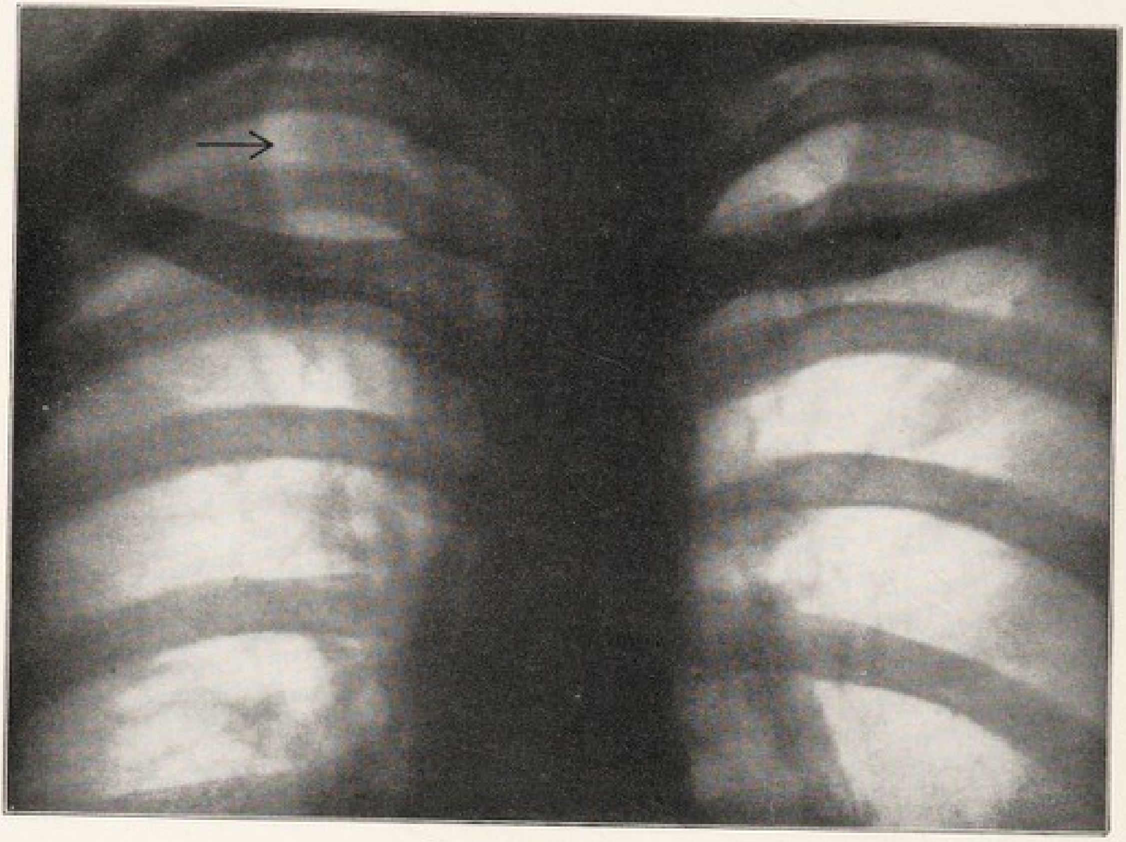


FIG. 194A.

lessening from above down, signifies nothing. That can be produced by a number of conditions : (1) by a stoutly developed formation of the shoulder musculature on that side ; (2) by an involuntary contraction of the shoulder muscles during exposure of the plate ; (3) in an asymmetrical position of the patient or from a badly centred tube. A diffuse opacity in one or both pulmonary apices is to be considered a pathological one only when in an absolutely sharp and clear negative the apical thickening contains minute granular shadows or the intercostal spaces on the affected side are definitely narrowed or the ribs are very drooping. In these last two instances the

Röntgen Gesellschaft, 4th Congress, 1908, in the addresses of Rieder, Krause, Albers-Schönberg, Groedel, Stürtz, Klieneberger, Schlayer, Schellenberg ; further in the short work of Assmann appearing in 1913 : Röntgen examination of the lungs with special regard to anatomical controls (Jena, Fischer).—Assmann, *l.c.*, footnote 2, p. 303.—The same : Fortschritte, vol. 36, 1927.

opacity must be present not only in ventro-dorsal but also in dorso-ventral irradiation.

The very first indications of a commencing tuberculosis in the apices can hardly be reproduced in illustrations, they can be recognised only in the original film ; and even in films they are only evident when no intensifying screen has been used in taking the picture. An attempt may be made selecting from several thousand exposures to adduce two photographs of the apices, which are just beyond the limits of the normal : Fig. 194A and Fig. 194B. In the first instance if the diffuse opacity were a little fainter and passed laterally with less sharpness of definition than it actually does,

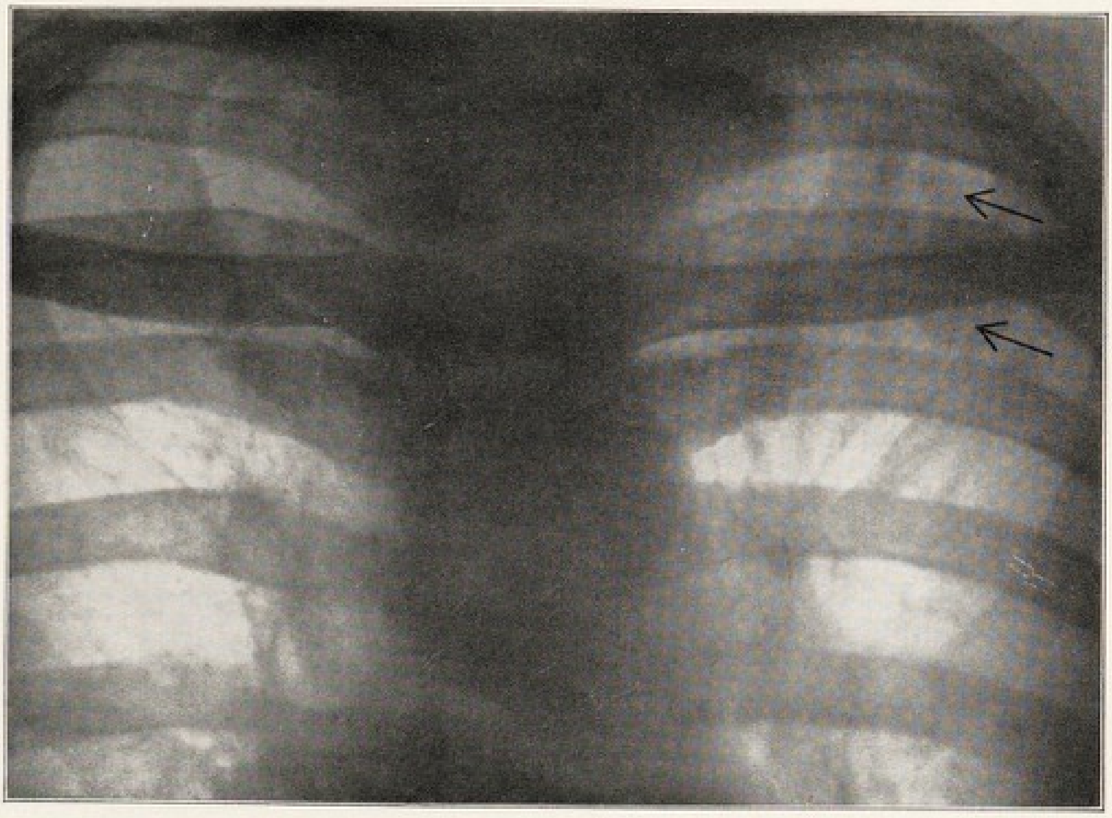


FIG. 194B.

it might be described as being within physiological limits. But as actually depicted it is certainly pathological. The second case shows likewise an early delicate pathological shadowing, extending some way, though without sharply defined limits (no fibrous shadow-strands !), and here the diagnosis is assisted by the evidently enlarged and thickened gland at the upper border of the hilus, towards which the various shadows point. We have here a type of commencing tuberculosis before us (as far as I am aware not yet recognised as such), which is not uncommon. The most remarkable thing about it is the regular way in which the condensations run parallel to the upper anterior ribs. That probably indicates that the tuberculous process is just under the pleura.[1]

[1] Assmann, *l.c.*

It is pointed out in the literature that in strumas one often finds a darkening of the apices of the lungs, especially in their central aspects, the conditions of the lungs in other respects being quite normal, and occasionally a demarcating arched line contrasting with the clear lung-field corresponding to the course of the subclavian artery. The shadow of the struma itself can also form the border of this.

In corpulent persons and in people with a low thorax the apices of the lungs always appear more opaque. Moreover, in these patients it is extremely difficult to form an estimate of the röntgenogram of the apices, the upper posterior intercostal spaces being usually very narrow. All the same tuberculous lesions of the lungs can be clearly seen through the shadows of the ribs.

It is important to know the changes in the lungs in *scoliotic and kyphoscoliotic cases.*[1] In severe kyphoscoliosis tubercle of the lungs is rare, for the venous congestion of the lungs acts like a Bier's congestion; on the other hand, less marked scolioses exhibit tuberculosis more frequently. The interpretation of the Röntgen findings at the apices is therefore all the more difficult. In mild cases of scoliosis an apex can be opaque, without there being any tubercle present. A scoliosis which is slight and hardly evident to the observer on external examination can evoke damping at the apex and changes in the breath sounds. In advanced cases of kyphoscoliosis there is naturally considerable opacity of the lung on the convex side of the vertebral column. On the other hand, it is averred [2] that an opacity of the left apex can be occasioned in a right-convex scoliosis by an unduly prominent shadow of the subclavian artery, a statement not yet verified, however.

In the usual Röntgen projections *the first interspace* at the back hardly ever appears, for the first and the second ribs are projected either in contact or superimposed. If it is desired to bring the first intercostal space into view in all circumstances, the arms should be raised above the head and the focus of the tube set almost vertically over the clavicle. We have to recollect, however that when the first intercostal space is photographed in this way, it is related not to lung but to the soft tissues of the neck, and it is only by its contrast with the shadows of the ribs that it appears translucent and simulates the lung tissue.

Occasionally too the *nipples* appear in a technically perfect photograph of the lung. It is scarcely possible to mistake them for a lesion in the lung-tissue.

For ossification of the *first costal cartilage*, see under "Ribs."

A slight homogeneous darkening of the right apex of the lung is to be considered quite physiological. Exact investigations [3] have shown that *the right apex* of the lung is a little lower than the left: see also above.

[1] Amelung, quoted in the section on the heart.

[2] Assmann, quoted by Amelung.

[3] By Seufferheld and König, quoted by Krause and Friedrich: Beiträge zur Röntgendiagnostik von Lungenkranken. Zeitschr. f. Elektrologie und Röntgenkunde, Leipzig, 1908, p. 65.

The line seen clearly 4–6 mm. above the clavicle and running parallel with it in its outer half corresponds to the skin over the clavicle, where it is reflected over into the supraclavicular fossa (Fig. 195, H).

To secure a proper *survey of the apices* the best technique is the following: dorsal position of the patient (for tubercle appears first in the posterior upper bronchus), the upper part of the body being raised about 30°; the tube of a hardness similar to that used for exposures of the hand. Setting of the tube opposite the patient's mouth; short exposure with the breath held. Although in all other examinations of the lungs the exposure is taken on deepest inspiration, that interferes with apical exposures, because on inspiration the clavicles are strongly raised and cover too much of the apices. The diaphragm should be employed. Intensifying screens should never under any circumstances be used. Usually, however, the apices with their details can be better seen with the patient in the standing position, with the breast pressing against the film-holder, so that a survey negative with the film in front on the breast is usually sufficient. But if there be the slightest doubt regarding the apical-findings of the survey negative, a well-diaphragmed dorsal exposure of the apices should be added.

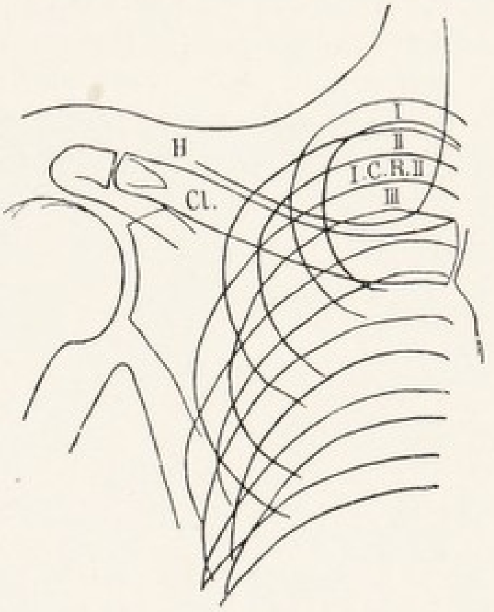


Fig. 195.

Between the right and the left apices *shadow differences* occur, without any apical tubercle being present: cervical ribs, kyphoscolioses (see above), fractures of the ribs, fractures of the clavicle, lobes of the thyroid, lymphomata colli, excessive development of the erector spinæ on one side (especially in powerful manual labourers), voluntary or involuntary contraction of the shoulder muscles, and in aneurism of the innominate artery.

The picture of *the lungs in children and adults, i.e.* the marbling of the lung fields by a thicker shadow running out like fingers from the hilus and becoming more delicate the further they pass towards the periphery, is produced, in the case of a sound lung, by the vessels and bronchioles at the hilus,[1] and without any sharp transition by the vessels alone in all other parts of the lung! Normal pulmonary glands, from their small size, composition, and distance from the plate, are as good as invisible, therefore a normal picture of the lung never contains circular or oval shadows, not even in the roots of the lungs. The small isolated circular shadows of

[1] The often-repeated assertion that the walls even of the great bronchi do not cast any trace of shadow is certainly a mistake because it contradicts physical laws. Experiments carried out upon the subject, however exact they may be, are not suited for the clearing up of this problem.—Among recent works, see Frank Salomon: Ein Beitrag zur Lungenzeichnung. Fortschritte, Bd. 28, 1922.

3 mm. diameter or less in the immediate vicinity of the hilus are exceptions to this, they are of average opacity and correspond to blood vessels that run a part of their course in the direction of the rays. One usually sees the branching of these at once. In a congestion of the lung they may be rather thicker. Very occasionally one finds in the vicinity of the hilus a fairly large rounded shadow with a translucent lumen ; this corresponds to one of the larger bronchi running in the path of the rays. Small rhomboid shadows are frequently seen, consequent upon the crossing of the shadows of two vessels. Larger circular or oval shadows, whether in the thickness of the hilus or in portions of the lung further out, are always pathological. In children—especially when they have a packet-like appearance—they arouse the suspicion of tuberculous glands, markedly swollen, caseated or calcareous according to the intensity of the shadow ; or they represent condensed glands following whooping-cough, pneumonia, measles, and influenza. If the lungs in an adult show nothing more striking than a couple of dense round shadows, we are usually dealing with anthracotic lymph glands or indurated fibrous glands. The discovery is only doubtful in adults when striated shadows, or other signs characteristic of tubercle, exist in the immediate neighbourhood of these glandular swellings and run into them. (Every gland showing signs of anthracosis may have been previously infected with tubercle.)[1] According to others,[2] soft anthracotic glands do not generally show up in the röntgenogram, unless they reach a certain size. Of greater importance, on the other hand, would appear to be the degree of connective tissue induration usually, though not always, associated with anthracosis. Markedly fibrous indurated glands might give a clear shadow, defined more or less sharply.

One worker [3] has noted that in the vicinity of the hilus and the supraclavicular fossæ in people with healthy lungs and also in tuberculous cases, certain *circular transparent areas* clearly defined may be mistaken for cavities, although there may be no clinical signs of cavity. These are either islands of sound lung tissue, surrounded by sclerotic pulmonary tissue, or emphysematous parts of the lungs near thickenings or around

[1] Completer details on the normal and pathological dealings of the lungs is found in Köhler: Röntgendiagnostik der kindlichen Lungendrüsentuberkulose. Hamburg, 1906; see further Engel: Die anatom. und röntgenolog. Grundlagen für die Diagnostik der Bronchialdrüsentuberkulose beim Kinde. Ergebnisse der Inneren Med. und Kinderheilkunde, Bd. 11, 1913.—Albert-Weil: La röntgénographie des adénopathies thoraciques. Journ. de Rad. et d'Electr., April, 1914.—Cerdeiras: Die Bronchialdrüsen im Röntgenbilde. Fortschritte, Bd. 25, 1918.—Alfons Foerster: Ein Beitrag zur Frage der Lungenzeichnung im Röntgen-Bilde. Fortschritte, Bd. 27, 1920.—Kretschmer: Röntgendiagnose der kindlichen Bronchialdrüsentuberkulose. Fortschritte, Bd. 28, 1921 (with reports of the literature).—R. Holitsch: Röntgenbefunde bei tuberculin-negativen Erwachsenen. Wiener klin. Wochenschr., 1918, No. 1. The author found similar conditions in a number of definitely tuberculosis-negative adults.—L. Delherm and R. Chaperon: Comment doit-on interpréter les ombres hilaires normales ? Journ. de Rad. et d'Electr., VII, 1923.

[2] Assmann, *l.c.*

[3] v. Maragliano: False cavities in the lungs. La Rad. Med., January, 1922. See also H. Erbsen: Cavernen und cavernähnliche Ringschatten im Röntgenbilde. Beitr. zur Klin. d. Tbc., Bd. 65, 4/5, 1927.

a circumscribed pneumo-thorax. Cavities are often incorrectly diagnosed in the apices, " Pseudo-cavities," while other round contours, of neck, ribs, etc., combined with a bit of round shadow of a vessel or of a tuberculous thickening, to form a circle or oval shadow, have been diagnosed as " cavities."

A certain type of picture is not unusual : clearness of the whole lung picture, but above on the left side immediately below the shadow of the clavicle and somewhat laterally quite a well-marked circular or oval shadow about the size of a bean. We are then dealing with an *isolated tuberculous gland* or *Ghon's* primary infection (see later).

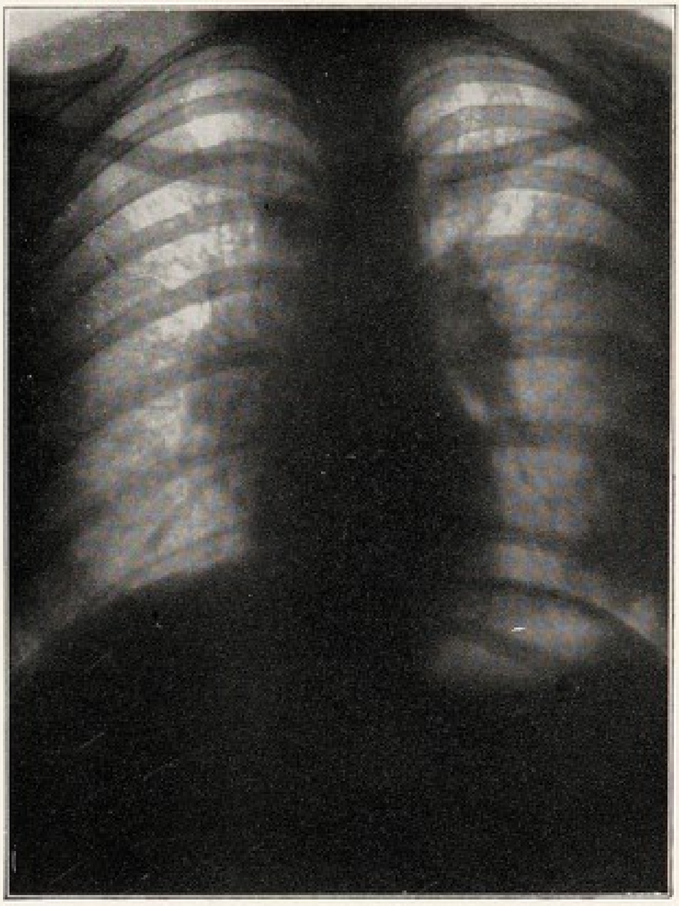


FIG. 196.

The shadow picture of *the roots of the lungs* can be very pronounced without any other change in the configuration of the lungs. Causes are age of the individual (ossification of the bronchial cartilages), emphysematous people (by contrast), workers subject to the inhalation of dust. A pronounced increase of all the lung markings is produced by congestion of blood in the pulmonary vessels; especially in mitral disease and congenital defects of the heart that accompany an enlargement of the pulmonary artery, but also in myocarditis and other conditions of debility principally of the left ventricle. As a typical example of increased hilus-marking in congestion in the lesser circulation following kyphosis the reader should refer to Fig. 196. That röntgenogram might have led very easily to the diagnosis of " tuberculosis," more particularly the peripheral vessel-marking being strikingly dense and reminding one of extensive peribronchial miliary foci. In screening such congestions one can occasionally observe an independent pulsation of the hilus shadow. (A condition that sometimes takes place under normal conditions with nervous action of the heart.)

Fig. 197 illustrates a case with caseated glands, that are arranged in packets of same size, and appear most prominently at the right hilus. Calcified glands in the neck had already been removed by operation (in

1905); a brother had died of phthisis. The patient was examined later in the pathology room, and the calcified glands were found at the hilus and tubercular processes in the right apex.

Quite different hilus shadows are seen in Fig. 198. We are here dealing with a typical case of pseudoleukæmic tumours. This röntgenogram can leave even the beginner in no doubt that it is certainly a pathological finding. It is introduced as a typical finding, that may appear even less marked to the eyes of the observer, and as a comparison with the other hilus changes mentioned above.

Findings as in Fig. 199 are very rare. The cause of the remarkable shadow-picture at the level of the left apex of the lung is outside the lung;

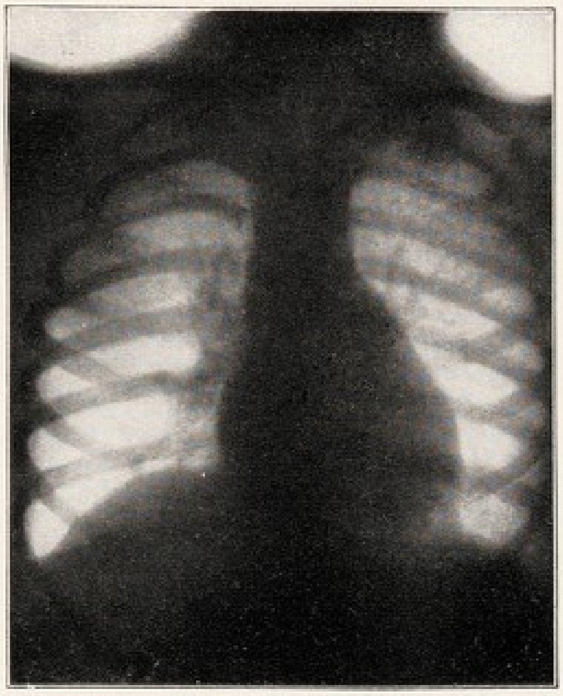


FIG. 197.

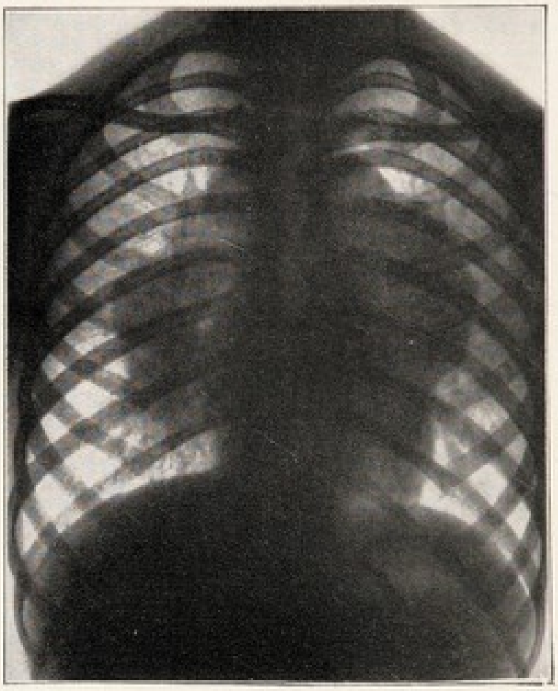


FIG. 198.

it is due to calcified tuberculous cervical glands. One should avoid confusing congested hilus with so-called hilus-tuberculosis, a mistake made all too frequently.

Simple cases of bronchitis do not cast any Röntgen picture, which is therefore quite a negative one. The text-books are not informative on the subject. But it has been recently stated [1] that outside the shadow of the hilus glands the strands running from the hilus are specially well marked, a broad leash of strands reaching out usually to the periphery, those running downwards being the most marked. Signs of adhesions were present where they reached the periphery of the lungs at the diaphragm. This would seem to contradict the vascular theory of the pulmonary picture, and it is therefore believed that they arise from the inflammatory infiltration of the bronchial mucous membrane and of the peribronchial tissue with congestion

[1] M. v. Falkenhausen: Das Röntgenbild der akuten und chronischen Bronchitis. Fortschritte, Bd. 29, 1922.

of the lymphatics ; indeed such strands appear even at the periphery where no vessels of sufficient calibre are normally present. The scars produced by these bronchitic inflammations, moreover, are generally visible for years.

The bronchi (apart from the region of the hilus) cast a shadow only in the following pathological conditions : (*a*) Bronchi filled with secretion. *Bronchi filled with secretion* in the best röntgenograms give cylindrical-shaped shadows, solid shadow bands. If these be suspected attention will naturally be directed to the shadow-picture of the inferior lobes. These shadows are broader and coarser than the neighbouring vascular shadows. Further, a bronchial shadow retains its breadth unaltered for some distance up to the next point of branching, whereas vessels gradually tail off into the surrounding tissues. At the place where such a bronchus filled with

FIG. 199.

secretion runs a short distance in the direction of the rays (" orthoröntgenographically "), one sees dense circular spots ; these also are larger and denser in shadow than in the blood vessels examined orthoröntgenographically. One has to decide from the breadth of the shadows whether one has to deal with normal bronchi or with enlarged bronchi filled with secretion. (Larger cylindrical and sacculated bronchiectases exhibit shadows that are much beyond the limits of the normal.) (*b*) Non-tubercular bronchiectases. Empty bronchiectases are recognised on the Röntgen film as a double-contoured strand with a transparent central lumen ; bronchioles filled with secretion give more solid shadows. A photograph taken early in the morning before expectoration and another taken after expectoration confirm the diagnosis. A favourite site is the left lower lobe. Eighty per cent. of these bronchiectases are recognised as of congenital origin. (*c*) Tubercular bronchiectases, bronchiectases supervening upon old fibrotic tubercular processes, or secondary development of a tubercle in bronchiectatic cavities.[1] Small circular or elliptical shadows are indicative of empty bronchiectases.

[1] Enumerated from R. H. Schinz : Die Begutachtung der Lungentuberkulose auf Grund der Röntgenuntersuchung. Fortschritte, Bd. 28, 1921.

The illustration, Fig. 200, shows extensive bronchiectases (not tuberculous) in the right lower lobe, with pleurodiaphragmatic adhesions. The picture is a thoroughly typical one, although many details do not appear in the printing owing to reduction in size. The patient died a few weeks later of typhoid and autoptic confirmation was made of the diagnosis. A bronchopneumonia had extended outwards from the bronchiectases.

Honeycomb shadows are produced in bronchiectases, when they are set close together inside an indurated shrunken lung-tissue, so that only septa intervene between the bronchiectatic cavities.

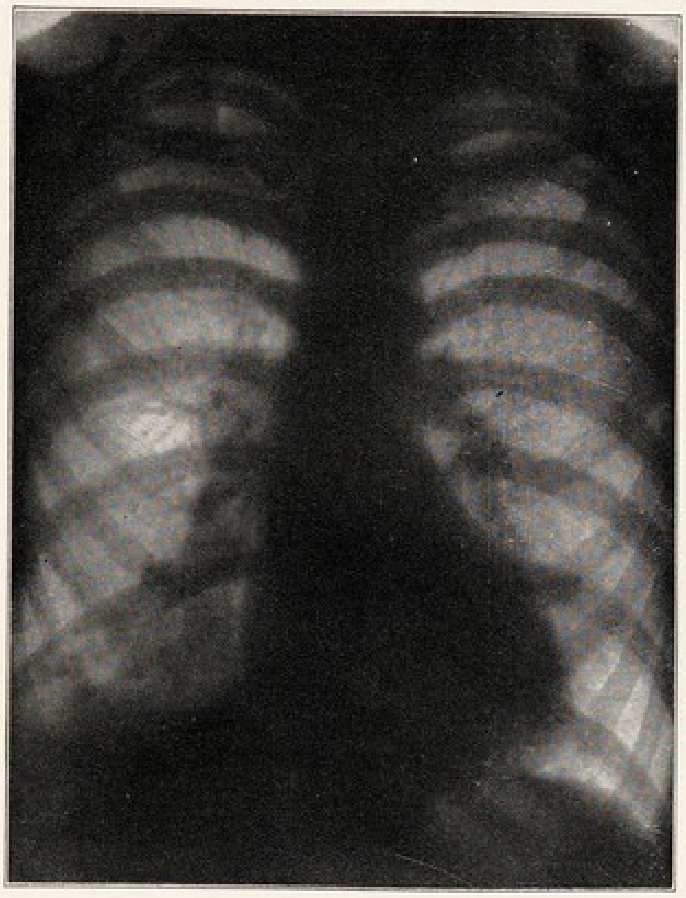


Fig. 200.

In sharply delimited round or oval stones, that differ in appearance from vessels, glands, or bronchi filled with secretion, seen orthoröntgenographically, we have to think of *bronchial stones* (corpora amylacea).

Very small to medium circular structures with markedly thick but usually regular external contours in great number in the immediate neighbourhood of the hilus has been frequently observed after pertussis. We are manifestly dealing with distended and gaping small and very small bronchial lumina, whose walls are hypertrophied by the repeated prolonged bursts of coughing. According to the stage or rather the duration of the disease, the number of the little circles is greater or less and their walls are more or less developed. At autopsy: strongly catarrhal inflamed medium and small bronchi, which are enlarged.[1]

The most various affections of the lungs may—a point to be borne in mind—show under certain conditions very similar Röntgen pictures. If that holds good for the finished pathological conditions, all the more for their earliest commencing stages; thus, for example, croupous lobar pneumonia can be mistaken in the Röntgen picture for a carcinoma of a lobe, or (röntgenologically speaking) a Hodgkin's disease of the lungs with a bronchopneumonia or with certain forms of tuberculosis, or an influenza-pneumonia with a lobular-exsudative tuberculosis. On the other hand

[1] Pino Pincherle: Röntgenbefunde u. Röntgentherapie der Pertussis. Fortschritte, Bd. 33, 1925.

again, large circular shadows in the region of the lungs can be produced by any different causes: Sarcoma, carcinoma, intrathoracic struma, echinococcus, interlobar empyema, abscess, actinomycosis, infarct.[1] Primary-like secondary tumour, benign and malign processes, may take their course under strikingly similar Röntgen findings.

For syphilis of the lung there is as yet no typical Röntgen picture. Its favourite site is said to be the right middle lobe.

Branching calcification in the lung has been much described and discussed in pathological anatomy; it occurs invariably in elderly men and seems to cause no special clinical signs. The process is perfectly visible in the röntgenogram,[2] but appears to be extremely rare (at least the writer of this book does not remember having ever seen it).

Attention has been already drawn to a 2-mm. broad band in relation

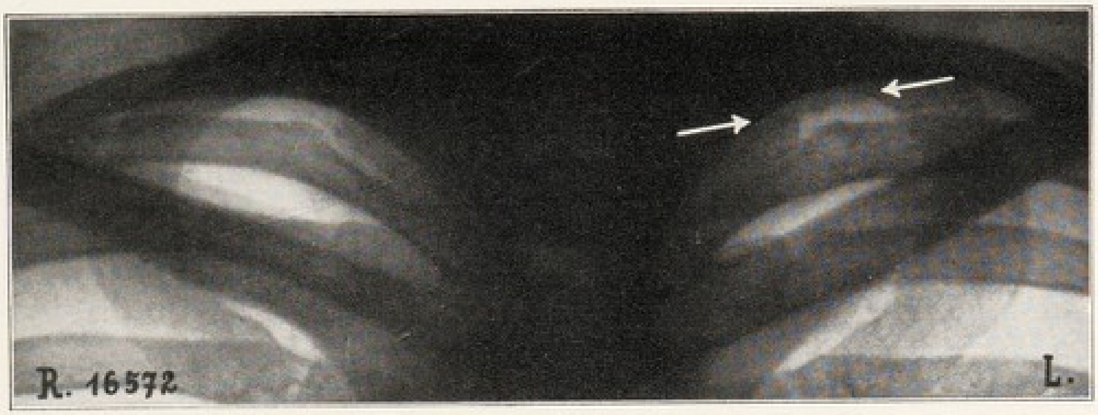


FIG. 200A.

to the lower border of the second rib. That indicates a *depression of the apex of the lung* on that side and is therefore the shadow of the soft tissues covering the apex; it is met with frequently in people whose lungs are perfectly sound.[3]

Occasionally the upper third of the apex of the lung contains a limited opaque area sharply delimited below, although the part of the lung below it with the shadow of the blood vessels is clearly visible. "Companion-shadow of the second rib." The picture has been compared with a half-dropped *curtain* and is referable to an infiltration process well known to the pathologists, definitely flattened off below.[4] Similar shadows have been described,[5] and called the first and second intercostal shadows. These are considered normal, and are ascribed to bands of muscle or large blood vessels in the upper part of the thorax.[6]

[1] M. Lüdin, Basel: Der solitäre, umschriebene, rundliche Schatten im Lungenröntgenogramm. Forschritte, Bd. 34, 1926.

[2] Simmonds: Über verästelte Knochenbildungen der Lunge (Pneumopathia osteoplastica racemosa). Fortschritte, Bd. 25, 1918.

[3] Albers-Schönberg: 4. Röntgen-Kongress, 1908.

[4] The same, *ibid.*

[5] Levy-Dorn and Cornet: Das Röntgenbild des normalen Thorax mit Rücksicht auf die Diagnose der Phthisis incipiens. Berl. Kl. Wochenschr., 1908, No. 21.

[6] The author ventured on the opinion in the 1st edition of this book that this appearance was produced by larger vessels and indicated as proof thereof the picture of the injected vessels,

By autoptic controls it has now been established that this companion-shadow is really formed by the upper boundary of the apex of the lung. If the otherwise regular curved line shows spots and indented contours, there are corresponding to them in the subject small pleural fibrous thickenings at the uppermost boundary of the apex.[1] Such pleural thickenings and apical thickenings are isolated resting or extremely slow progressing processes. They have nothing to do with the more extensive parenchymatous diseases of the apices of the lungs. Above all, they should not be classified as an "apicitis," and confused with the true phthisis that does not begin in the outermost part of the apex.[2]

The normal pleura is not visible. It must have attained a high degree of uniform thickening before a definite shadow can be differentiated from the sound half of the chest. A still further difficulty has then to be decided, whether the diffuse opacity is produced by the pleura or by the lung.

Quite a slight darkening of the apex in pleuritic exsudate is said to indicate a tuberculous disease of the apices, only if separate focal shadows are at the same time present in the apex. This simple opaqueness is explained on the one hand as due to a reduction of the air-space of the deficiently expanded lung ; on the other hand, as very small masses of exsudate that can reach up that height.

A distinct thick broad line, running transversely or slightly obliquely across the lung (usually the right), which appears, however, only with one position of the Röntgen tube and when the tube is set higher or lower broadens and gets less distinct until it disappears and is not noticeable, is typical of *the interlobar line*.[3] These are found twelve to thirteen times as often on the right side as on the left.[4] It has been recently remarked [5] that many interlobar lines would never appear in the Röntgen picture of the lungs of children, because then the shadow they cast is only a fine linear one, situate usually in the third right intercostal space, and traversing the lung more or less horizontally at a higher or lower level. Their typography is so typical that one should have no difficulty in spotting them. They may appear as simple lines or as double lines running parallel to each other or obliquely, or they may be of forked shape. These findings are of importance, for though they are occasionally the result of metapneumonic exsudates they can be related nearly always to a positive Pirquet. The question whether the normal pleura can show up as a fine linear shadow in a favourable negative has not yet been settled.

Table 196 of the ninth year of the Archives of the Röntgen-ray. Recently Assmann has also adhered to this view, upon the score of a larger number of cases.

[1] Assmann, *l.c.*

[2] F. Fleischner: Lungenspitzenbefunde im Röntgenbilde. Fortschritte, Bd. 35, 1927.

[3] One of the most recent works with a list of the literature is F. Helm: Zur Röntgendiagnostik interlobärer Processe. Fortschritte, Bd. 25, 1918.

[4] A. E. Uspensky: Röntgenbild der verschiedenen Formen der Pleuritiden. Fortschritte, Bd. 36, 1927.

[5] A. Hotz: Zur Kenntnis der interlobären Schwarten im Röntgenbilde der kindlichen Lungen. Fortschritte, Bd. 27, 1920.—See further: F. Fleischner: Lobäre u. interlobäre Lungenprozesse. Fortschritte, Bd. 30, 1923.—Kreuzfuchs and Schuhmacher. Acta Radiolog., V, 1, H. 2.

Vertical shadows between adjacent transverse processes (*intertransverse shadows*)[1] are normal, and are due to parts of the central shadow of the vessels, or above, to the soft tissues of the neck (Fig. 195).

In the angle between the diaphragm and the right auricle there not infrequently appears a dense shadow about the size of a bean, not unlike a gland in appearance, especially when the picture is not absolutely sharp and clear; that is due to the right transverse process of one of the mid-dorsal vertebræ, and it can only be the occasion of mistake, when the transverse process above it is covered by the right auricle and the one below it by the shadow of the liver.

The strands that pass from the hila to the apices of the lungs are in suspected cases of tubercle said to be the expression of *lymphangitic tubercular processes*. The diagnosis is clarified by the finding of glandular shadows in the hilus of the same side.

Chronic fibrous condensations of the hilus are apparently the precursors of primary-chronic pneumonias. The latter, on the other hand, may take their course under the general picture of carcinoma of the lung.[2]

Thromboses of the pulmonary vessels elicit a specially marked depth of shadow in the area affected.

To diagnose *an infarct of the lung* radiologically is a really difficult matter. It usually selects the lower and middle lobes of the lungs and is seen mostly at the outer margin of the lobe. If the axis of the infarct is at right angles to the Röntgen rays its sharp triangular shadow is then a characteristic one. If its axis is in the direction of the Röntgen rays, its shadow is then circular or oval, and can be mistaken for echinococcus, tumour, abscess, gumma, interlobar effusion, central pneumonia, and actinomycosis.[3]

A localised rounded *enlargement of the central shadow* of the vessels above and to the right has usually nothing to do with the vessels, but arises from caseated paratracheal glands.

If the hila of the lungs are specially well marked, we should not too readily ascribe that to calcification of the arteries. *Arteriosclerosis* of the pulmonary vessels, not simply a few plaques in the intima, but a real thickening of the vessel-wall, is a very rare occurrence, and extensive calcifications sufficient to mark a plate are not at all common.

Not only the beginner, but almost all röntgenologists, have overlooked the primary infection, which Ghon was the first to call attention to; being missed not so much on account of its frequent inconspicuousness (hemp-seed to a pea, less frequently small hazel-nut size), but on account of its position. It is never visible in the apices, nor in the hilus region, nor in the middle of the lungs, but almost invariably in quite a lateral part of the lungs, not far

[1] Levy-Dorn and Cornet, *l.c.*

[2] Dietlen, *l.c.*

[3] Kohlmann: Zur Frage des Lungeninfarctes. Fortschritte, Bd. 30, 1. Kongressheft. 1922.—G. Böhm and O. Kühne: Über den Lungeninfarct im Röntgenbilde. Fortschritte, Bd. 34, 1926.

removed from the lateral wall of the thorax; it is encountered at a level of from the second to the sixth intercostal space. Why these areas of the lungs are particularly selected, we do not yet know. The pathologists think it may occur anywhere but in the apices. But this is scarcely correct either. In a post-mortem examination of the lungs it is not every square millimetre of pulmonary tissue that is sectioned, while the röntgenologist obtains a survey view of the whole of the lungs, and is not in the habit of missing even the smallest caseous and calcium foci, least of all at the hilus and in the middle areas of the lungs. And röntgenologists meet with the Ghon's primary infection almost always in the most lateral parts, and usually more to the frontal plane of the thorax. Fig. 201 shows not only such a focus of caseous density situate quite laterally at the level of the second intercostal space, but—what one sees so seldom in conjunction with it—the whole tissue-path leading to it. From the infected focus, which usually is nearly circular or oval, there runs medially a strand of tissue at first the thickness of a quill, then gradually becoming broader and diminishing in shadow intensity, similar to an interlobar line, as far as the hilus, where four to five glandular enlargements of caseous density are visible. At post-mortem it is always caseous foci that have been found to form the substratum of the solitary Ghon's primary infection, not lymph glands. It usually heals up by calcification.

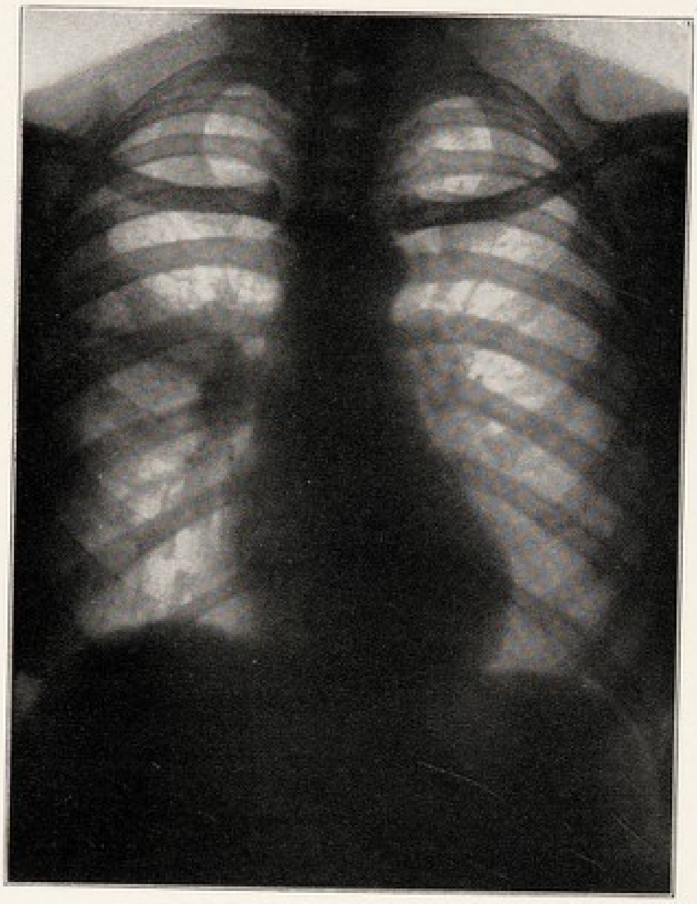


Fig. 201.

Regarding the extension of commencing tumours of the hilus refer to Fig. 202; to the right of that illustration is a normal left hilus. In this case the author in 1903 arrived at the diagnosis: "Tumour, extending into the two left main-bronchi," this in spite of the continuous temperature of the patient. Death occurred four weeks later. Upon section (by Herxheimer): "Soft tumour of the left bronchial glands, passing over to the great bronchi; in addition bronchial catarrh, and right-sided bronchiectasis. Œdema and hypostasis of the lungs. Histological report: "Round-celled sarcoma of the bronchial glands and bronchi (only the cartilages of these being relatively intact." [1]

In a lung untouched by tubercle there were found multiple calcareous foci in a female patient with the symptom triad: fragility of the bones, blue sclerotics and difficulty of hearing (Eddowes' disease; see also above, under "Mastoid process" and "Ear"). The bones of the hand were deficient in calcium in this case.[2]

A *conspicuous hilus shadow*, larger and more marked, without evidence of round or oval shadows, can be produced by soft recently enlarged glands (not caseated, calcified, or indurated), a point established on the post-mortem table.

A uniform sprinkling of the pulmonary field with barely recognisable

A FIG. 202. B

minute shadows speaks for *miliary tuberculosis* (even in a healed case); [3] if the shadows are larger and less sharply defined, they are probably due to *stone-hewer's lung*. The calcareous deposits themselves do not appear in the film, but the well-developed scar formations surrounding them do and are densest around the hila. For the differential diagnosis from a simple chronic pulmonary tuberculosis of the lungs it should be remarked that in pneumokonioses both halves of the lungs are usually symmetrically affected, and apparently to an equal degree, and principally the middle and inferior parts of the pulmonary fields, and that the distribution, size, and form of the individual spots is more even, with a marked

[1] A. Köhler: Zur Röntgendiagnostik der intrathoracischen Tumoren. Fortschritte, Bd. 7, 1903.

[2] E. Wiechmann and H. Pall: Zur Klinik der blauen Skleren. Münch. m. Wochschr., 1925/6, p. 213.

[3] Lorey: Über einen Fall von geheilter Miliartuberculose. Fortschritte, Bd. 30, 1. Kongressheft, 1922. In the subsequent discussion considerable doubt was expressed regarding these cures. Autoptic after-findings are naturally not available. See also Assmann.

reduction of the mobility of the lower margins of the lungs. A very characteristic sign for the diagnosis of pneumoconiosis is the want of relation between the evident röntgenological and the slight clinical appearances. The patient gives a history of never having interrupted work and of difficulty of breathing upon the slightest physical exertion; further of frequent transient and inconsiderable hæmoptyses, which clear up without any trace being left. The temperature remains normal even in severe cases, sometimes subfebrile, the precipitation test of the erythrocytes shows constantly high figures, 3½ hours on the average. Regarding the density of the different foci, it is stated that deposits of silicate (siderosis) are the densest, then follow deposits of lime, the most delicate of all being miliary tubercle. To distinguish from miliary tuberculosis the foci in the pneumokonioses are connected up by strands, which lends the koniotic lung a peculiar netlike appearance. As regards pneumokoniosis associated with tuberculosis: changes which exhibit a well-marked apico-caudal process of development are very suspicious of tubercle. (According to some other authors the apices may even be considerably affected in pure pneumokonioses, which is usually explained by the fact that in poorly ventilated parts inhaled foreign bodies are eliminated with all the greater difficulty.)[1] As regards the size of the lesions the limy deposits show the greatest amount of variation.[2] In cases difficult of diagnosis we have also to think of disseminated actinomycosis of the lungs, multiple miliary pulmonary abscesses, the miliary form of influenza-pneumonia (rapid altering of the Röntgen picture within a few days), the miliary lesions of leukæmia, the scattered lesions of syphilis (extremely rare), and bronchiolitis obliterans.[3] The lymphogenic carcinomata of the lung are almost always secondary to cancer of the stomach. They show a pretty evenly arranged and finely distributed network, corresponding to the cancer infiltration extending out in the lymph-spaces; set upon this network are numerous very fine round spots, which, however, are not little cancer nodules, but—as can be histologically proven—cross-running lymph-spaces filled with cancer cells. The process is limited usually to the lower two-thirds of the lungs (an important point differentiating it from peribronchitic tuberculosis). The fine network connecting the spots is pathognomonic of lymphogenic carcinoma.[4]

[1] Abramowitsch, Warschawsky, and Scheinin: Die Röntgendiagnostik der Pneumokoniose (der Chalikose u. Siderose). Fortschritte, 1927, Bd. 35.—H. K. Pancoast and E. F. Pendergass: Pneumoconiosis (Silicosis). Paul Hoeber, New York.

[2] Alfred Weil: Die Siderosis der Lunge im Röntgenbilde. Fortschritte, Bd. 24, 1916. —Netusek: Diagnose der Miliartuberculose. Fortschritte, Bd. 15, 1918 (with complete list of the literature).—Alfred Weil: Die Miliarkarzinose der Lunge im Röntgenbilde. Fortschritte, Bd. 25, 1918.—See above all the exhaustive monograph by O. Strauss: Röntgenologische Feststellbarkeit der Staublunge. Fortschritte, Bd. 30, 1. Kongressheft, 1922.—Abramowitsch, Warschawsky, and Scheinin: Die Röntgendiagnostik der Pneumokoniose (der Chalikose u. Siderose). Fortschritte, 1927, Bd. 35.—Lars Edling: Pulmonary anthracosis. Acta Rad., Vol. VI, 29–34.

[3] Enumerated after Schinz, *l.c.*

[4] H. Lorenz: Lymphogene Lungenkarzinose. Fortschritte, 1921, Bd. 28.

A *thick strip at the apex of the heart* running out to the diaphragm and particularly evident in forced inspiration corresponds to the pericardium.

Insufficient inspiratory depression of the diaphragm from a normal state of expiration (Williams' sign) is always to be looked upon as pathological. In commencing phthisis it is not so often encountered as was formerly thought, it is often the remains of a simple pleurisy.

The costo-phrenic spaces should always be well lit up and sharply delimited. When that is not the case, we have to think of a small pleural exsudate (provided always that such comes within the clinical findings). Large pleural exsudates are not sharply defined above, but their shadows which produce an opacity of the lower lobes of the lungs diminish gradually from below upwards and laterally.

A *spindle-shaped intense lighting* that is related to the parietal thoracic wall and shows not the slightest shadow of a structure, is characteristic of pneumothorax; and a straight horizontal limiting shadow below it is significant of the presence of a sero- or pyopneumothorax.

If *in profile irradiation* one finds a wide space between sternum and heart both in inspiration and in expiration, we are dealing with an emphysema. Normally, the heart upon inspiration touches the sternum only in its lower third, while in expiration its anterior wall abuts almost completely against the sternum. That applies especially to younger people. In older persons only the lower part of the anterior shadow of the heart abuts against the sternum in inspiration and expiration; that is to say, even on expiration there is a greater air-space visible between the sternum and the anterior contour of the heart-shadow. That is due probably to differences in the respiratory mobility of the sternum. As that is greater in young people, the position of the heart is not fixed; but when the thorax is sufficiently rigid, with immobility of the sternum, the position of the heart stays constant both in inspiration and expiration.[1]

In profile views of the thorax one sometimes sees the angle that the diaphragm makes with the postero-inferior outline of the heart occupied by a shadow with a vertical border. That is produced by the vena cava inferior.

Occasionally cases are met with in which the sagittal view appears perfectly normal, while in profile view *the posterior pleural sinus* where the pleura extends further down is filled with fluid; the lateral part of the sinus being still free. The reverse of that is also possible.[2] (The author is of opinion that in such cases of a small effusion the action of the diaphragm is affected on the particular side.)

With the tube a good distance from the observer a perfectly *uniform opacity* of larger or smaller areas of the lungs without sharp delimitation from the sound tissues can be due to the following causes: (1) Infiltration. (2) Atelectasis. (3) In the partial collapse of the lung in bronchial stenosis.

[1] Zehbe: Über Frontaluntersuchung. Fortschritte, Bd. 25, 1917.

[2] Zehbe, *l.c.*

(4) After pneumonia due to the same. (5) Œdema. (6) Commencing hypostatic pneumonia. (7) Thin pleural thickening. (8) Pleuritis sicca. Differential diagnosis in the absence of definite clinical symptoms are often difficult.

Darkening of one pulmonary field in ventro-dorsal illumination, and normal clearness in dorsal-ventral illumination (or vice versa) is found in large pleuritic thickenings.

In one instance in an elderly woman peculiar dense round shadow markings were found beside the vertebral column at the level of the diaphragm of from pea to hazel-nut size. A few days later section revealed rounded, flat, and perfectly hard knots of tissue on the left diaphragm, which could be recognised at once as containing calcium. The knots lay partly

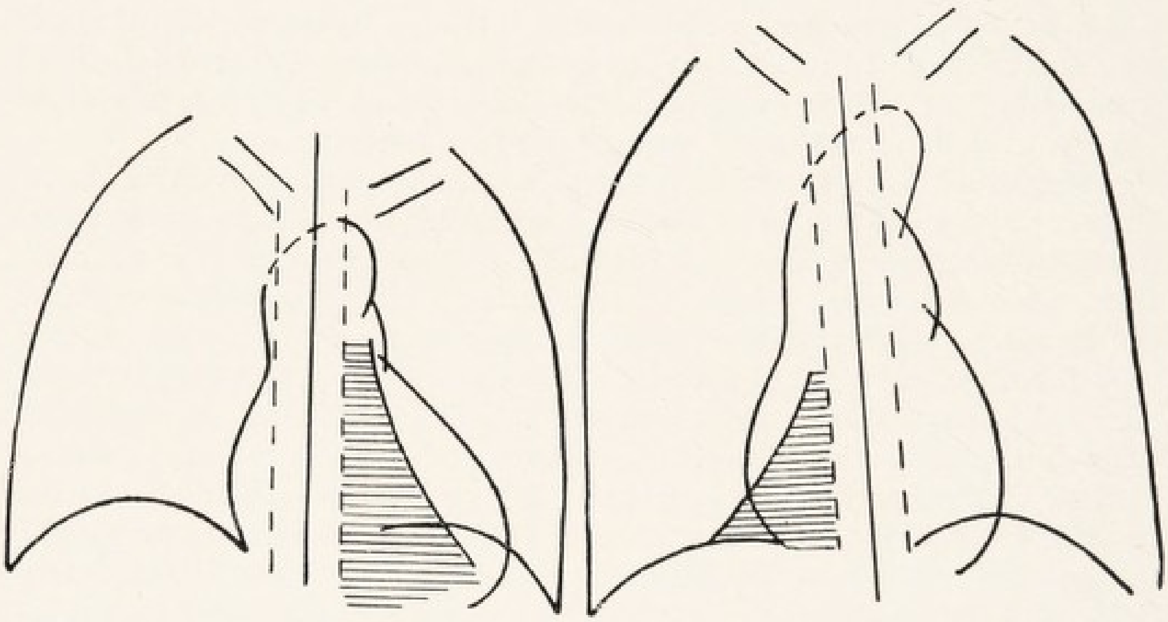


Fig. 203.[1]

in tough fibrous tissue, and partly were closely adherent with one of their broad surfaces to the diaphragm, or were connected with a stalk to it and were movable. According to the histological examination, these proved to be organised and calcified fibrous remains of exsudate.[2]

Shadows well down in the thorax and placed to right or left of the shadow of the heart, on the right side free or on the right partly concealed, and on the left wholly or partly concealed, these arise from so-called " mediastinal pleuritis." [1] These exsudates are purulent or serous or (in most cases)

[1] After Assmann, *l.c.*; the illustration (203) is drawn after Herrnheiser: Hintere Costomediastinale Schwarte. Fortschritte, Bd. 30 (Kongressheft, 1922).—The same. Fortschritte, Bd. 31, 1923.—Savy: Les pleurésies médiastines. Progrès médicale, 1910.—Dietlen. Erg. d. Inn. Med. u. Kindhlkde, Bd. 12.—Rehberg. Med. Klin., 1920, No. 40.—Groedel. Fortschritte, Bd. 28.

[2] G. Hammer: Ein eigenartiger Befund von Kalkablagerungen in der Pleura. Fortschritte, Bd. 36, 1927.

fibrinous and occupy the pleural space, not the mediastinum. In an anterior mediastinal pleuritis a doubling of the cardiac shadow is occasionally produced, and sometimes too an aneurism of the aorta is simulated. Band-like shadows running parallel to the vertebral column are met with in the posterior mediastinal form. In all diameters of the thorax good diaphragming is desirable. The shadows are usually due to fibrinous deposits which are found accessory to tuberculosis ; more rarely it is one of the signs following upon pneumonia. The boundary line on the outer side is usually concave (see the above illustration). One speaks of costomediastinal thickenings, when the larger shadow extends to the wall of the thorax. Pure mediastinal thickenings are situate in the space between the pulmonary and mediastinal pleura ; they cannot be easily differentiated from within the mediastinal shadow, and they appear only in the form of fine-ridged processes along the border of the heart. Fluid exudates are rare, usually metapneumonic empyemata. Clinical symptoms are sometimes negative, sometimes non-characteristic, sometimes very painful.

In case there has been no mention made of certain appearances in röntgenograms of the lungs, see under " Diaphragm " or under " Ribs."

DIAPHRAGM [1]

The right and left halves of the diaphragm form both in ventral and dorsal view a beautiful arch or cupola, exhibiting nearly the same costo-phrenic angle in inspiration and expiration. Both fixation of the summit and enlargement of the costo-phrenic angle on inspiration are pathological, and being found in obliteration of the pleural cavity, in emphysema, and in rigid thorax (malformation of the ribs, advanced calcification of all the costal cartilages).

An extreme case of roof-like flattening of both halves of the diaphragm in inspiration—while it shows normal arched cupolæ in expiration—is represented in Fig. 205. The patient had very great deformities of the ribs, as one also clearly recognises in the photograph, and in consequence of that the thorax was completely immobile in breathing, so the diaphragm had to secure room for the extension of the lungs by stretching out straight.

On quiet breathing the diaphragm rises and falls regularly about 1–2 cm., on deep breathing 2–4 cm. *On forced respirations* the variations can be very marked. Estimating the elevation of the diaphragm from the ends of the ribs the right cupola of the diaphragm in a few selected males reached

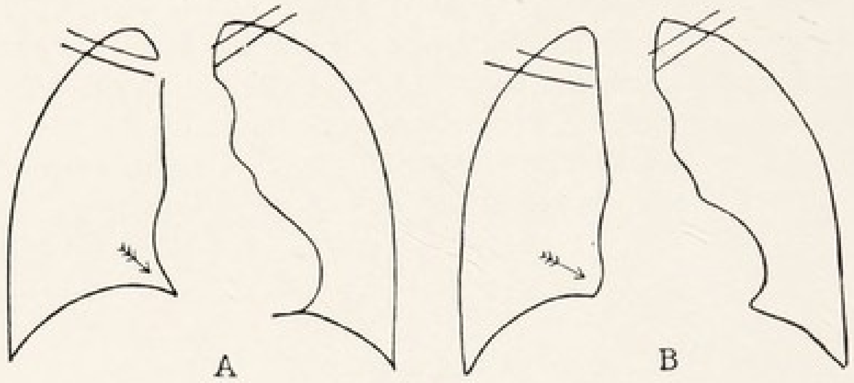
[1] For the normal Röntgen anatomy of the diaphragm, see the works mentioned under " Lungs " and Kraus : Die Röntgenuntersuchung von Pleura und Zwerchfell, in Rieder and Rosenthal : Lehrbuch der Röntgenkunde. München, 1913.—Jamin : Zwerchfell und Atmung ; in Groedel's atlas.—S. Lange, Cincinnati : The relations of the diaphragm as revealed in lungs by the Röntgen ray. J. Amer. Med. Assoc., Vol. 50, No. 9, February, 1908.—G. W. Holmes : Observations upon the respiratory movements of the heart and diaphragm. Am. J. of Röntg. Vol. III, May, 1916.—A. Hasselwander : Die Bedeutung des Röntgenbildes für die Anatomie. Erg. der Anat. und Entwicklungsgeschichte, Bd. 23, 1921.—Rieder, im Lehrbuch Schittenhelm, pp. 478 ff.—Thomas : Fortschritte, Bd. 31, 1923 (Congress Report).—L. Jenkinson : Lesions of the diaphragm. Am. J. of Röntg., July, 1925.—Assmann, *l.c.*

the end of the fourth rib on expiration and the end of the seventh rib or even the seventh interspace on inspiration ; in other instances the variation in quite normal cases varied about the sixth to the seventh rib.[1] The left cupola behaved similarly. (In screening with the focus of the tube only a short distance away the variation naturally appears greater.)

Fixation and elevation of the diaphragm on one side has been observed in some cases of acute diaphragmatic pleurisy, before ever an exudate formed.[2]

Flattening of the two halves of the diaphragm, with little excursion on breathing, indicate emphysema.

Low fixation of the diaphragm in the erect posture, with considerable reduction of the respiratory movements, but with complete respiratory



A B

Fig. 204.

movements of the same individual in the dorsal decubitus, is a sign of enteroptosis.

Insufficient inspiratory downward movement of the affected side of a diaphragm normal upon expiration is *Williams' sign* in commencing tuberculosis.

A low diaphragm with marked flattening and a diminution in the inspiratory downward movement is one of the signs of *old age*.

An absolute low fixation of the diaphragm is present in *laryngeal and tracheal stenosis*.

If there be no sign of diaphragm or of hepatic cupola, if the dense abdominal shadow passes over gradually into the lung space, or if similar conditions are present in the left side above the saccule of the stomach, the Röntgen signs are those of *pleural effusion*.

In unilateral *pleuro-diaphragmatic adhesions* the line between the lung and the diaphragmatic abdominal opacity on the affected side is not even, but is composed of a number of pointed fringes, while the sound side displays a sharp and clean-cut arching contour (provided the negative be a sharp one).

Many pleuro-diaphragmatic adhesions appear only on deepest inspiration.

[1] A. Hasselwander, *l.c.*

[2] Ohm : Beitrag zur Klinik der Zwerchfell-Lähmungen. Zeitschr. f. klin. Med., 59. Bd., Heft 5 and 6.—Kraus : Die Röntgenuntersuchung von Pleura und Zwerchfell, in Rieder and Rosenthal : Lehrbuch der Röntgenkunde. München, 1924.

Instead of there being one cupola one meets sometimes with two, especially on the right side. Though this cannot be called normal the condition is a relatively harmless one, due to the *sagittal furrow of the liver.* They can be observed in post-mortem sections of the liver. They are also frequently met with in pulmonary tubercle.

Spasmodic jerking of the diaphragm is present in chorea.[1]

The shadow of *the right side* of the diaphragm usually forms a sharp angle with the inferior aspect of the right auricle ; but not infrequently the transition from auricle to diaphragm is gradual and wave-like, as in

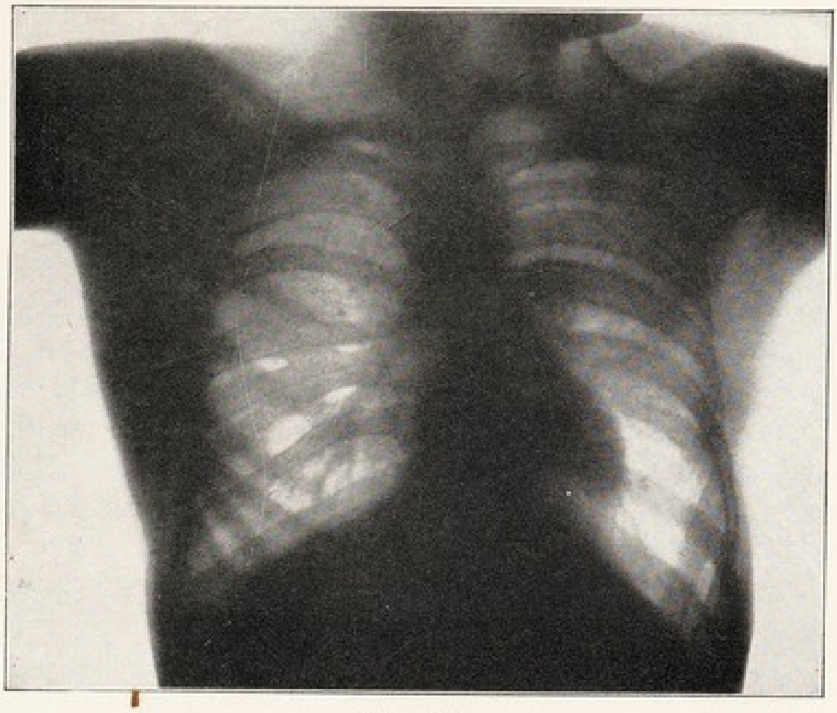


Fig. 205.

Fig. 204, B, or even more gradual ; that is rather an accidental finding than a cause of complaint, and is due to an anomalous attachment of the pericardium to the diaphragm. When the right auricle runs vertically down or a little obliquely downwards, the short straight bit almost always corresponds to the *vena cava inferior.*

Elevation and fixation, with atrophy, of the left cupola of the diaphragm is not uncommon, being always associated with considerable collection of gas in the stomach or splenic flexure of the colon. It is a departure from the physiological.[2] A well-marked case is usually termed *a hernia dia-*

[1] Rieder and Rosenthal : Lehrbuch der Röntgenkunde, 2. Bd. (Fürnrohr).

[2] See also Lorey : Eventratio diaphragmatica, 8. Röntgen-Kongress, 1912.—Scheidemantel : Zur Röntgendiagnostik der Eventratio diaphragmatica. Münch. Med. Wochenschr., 1912.—Ohm : Beitrag zur Klinik der Zwerchfellähmung. Zeitschr. f. klin. Medizin, Bd. 59.—Otto Frank : Über Zwerchfellinsuffizienz (Eventratio diaphragmatica). Beiträge zur Chirurgie, 74. Bd., Heft 2.—Bergmann : Über Relaxatio diaphragmatica. Ergebnisse der Inneren Medizin und Kinderheilkunde, XII, p. 327, 1923.—Glässner : Über Eventratio diaphragmatica. Fortschritte, Bd. 24, 1916 (with complete list of the literature).—H. Schlecht

phragmatica, a less-marked one *an eventration* or *relaxation*. Some, indeed, doubted the possibility of diaphragmatic hernia and described every case as an eventration. We are now aware that atrophy of one-half of the diaphragm, enlargement of the gastric saccule, eventratio, and many of the cases described as diaphragmatic hernia, represent different degrees of the same trouble. There are certainly real diaphragmatic herniæ, but to differentiate them from the more pronounced degrees of eventration may be uncommonly difficult. An examination of the patient in profile should enable us to decide. A constant Röntgen finding speaks rather for an eventration, a variable condition more for a hernia. *Eventration of the right half* of the diaphragm has only been described a few times up to date, and seems therefore to be very rare. In its ætiology it may be regarded as a congenital defect in the majority of instances.[1] Ætiologically eventration is regarded in the majority of cases as a congenital deformity, which, however, is not sufficient to elicit this disease. It is necessary in addition to have a corresponding pressure from below on the diaphragm. According to others, a weakness of the lung is said to be the cause; in the opinion of a third the diaphragm may have lost tension and been lifted up by the stomach distended with air swallowed into it. The last theory might also explain why almost all the cases of relaxation described up to date have been on the left side. In a certain number the condition occurs only in later years. *Anatomically* the side of the diaphragm implicated is extraordinarily thinned out in its muscular fibres, converted into a sac of connective tissue and lifted high up towards the chest-cavity (in distinction to a pure elevation of the diaphragm where the diaphragm is raised without any alteration in the muscle). There does not appear to be such a thing as an idiopathic elevation of the diaphragm. For the right-sided cases that have been described the cause is considered to be an atrophy of the phrenic nerve.[2] *Clinically*, eventrations are usually first noticed in examining for valvular lesions.[3] Every elevation of the diaphragm modifies the position

and P. Weis: Zur Röntgendiagnose der Hernia diaphragmatica. Fortschritte, Bd. 27, 1921.—J. Dillon: Ein Beitrag zur Klinik der Diaphragma-Erkrankungen. Fortschritte, Bd. 34, 5, 1926.—A large list of literature is found in Assmann, *l.c.*—M. J. Biermann: Diaphragmatic hernia, non-traumatic. Radiology, September, 1924.—R. D. Carman and S. Fineman: The röntgenologic diagnosis of diaphragmatic hernia, with a report of seventeen cases. Radiology, 1924, VIII, p. 26.—Thomas R. Healey: Symptoms observed in fifty-three cases of non-traumatic diaphragmatic hernia. Am. J. of Röntg., March, 1925, p. 266.—Donald P. Abbott: The early diagnosis of true hernia of the diaphragm. J. Am. Med. Assoc., December 13, 1924, lxxxiii, 1898–99.—L. T. Le Wald: Some normal variations and pathological conditions of the diaphragm. Am. J. of Röntg., May, 1925, p. 447.—Also Le Wald: Thoracic stomach: Differentiation from eventration and hernia of the diaphragm. Radiology, Vol. III, No. 2, August, 1924, p. 91.—P. Bailey: Thoracic stomach. Anat. Record, October, 1919, XVII, No. 2, pp. 107–9.—R. E. Roberts: A case of thoracic stomach. Brit. J. of Rad., January, 1927.

[1] J. M. Woodburn Morison, Edinburgh: A contribution to the study of diaphragmatic hernia of the eventration type. Acta radiol., Vol. VII, Nos. 35–40.—Elevation of the diaphragm. Unilateral phrenic paralysis. A radiological study, with special reference to the differential diagnosis. Arch. of Rad. and Elec., May, August, 1923.

[2] E. Andersen: Über rechtsseitigen Zwerchfellhochstand. Fortschritte, Bd. 34, 3, 1926.—See also L. Reich: Fortschritte, Bd. 34 (Traumat. Hernia).

[3] Alfred Weil: Über die röntgenologische Bedeutung normaler und abnormer Gas-

of the heart, which is thrust either more horizontally or to the right. A most voluminous literature has arisen on the differential diagnosis between relaxatio and hernia, because the difference is often very difficult to determine. The most recent opinions [1] are quite agreed that screening is often the only way to determine whether the upper limiting shadow is formed by the diaphragm or by the stomach. Expiratory acceleration of diaphragmatic movement speaks for relaxation and against hernia. Of some differential diagnostic value is the so-called paradoxical movement (inspiratory elevation) of the doubtful shadow, which is observed in hernia but never yet in an eventration. In a recent case the diagnosis was established by forming a pneumo-peritoneum.[2] For *temporary elevation of the diaphragm*, see above.

In broad cylindrical chests the diaphragm relative to the ribs is usually lower than in the long narrow thorax with descending ribs.[3] If necessary the level of the diaphragm to the ribs can be determined. According to orthodiagraph findings the right cupola attains on the average the upper border of the fifth rib, the left cupola the lower border of the fifth rib. In relaxed abdominal walls and enteroptosis the diaphragm does not reach so high.

Paradoxical action of the diaphragm. In the standing position the cupola after first sinking immediately rises. That occurs even in normal conditions, and is therefore only apparently a paradoxical action. On long deep respiration it appears on drawing in the abdominal walls. Frontal screening shows that the dorsal portion of the diaphragm really does fall, but that the anterior ventral parts are elevated by the powerful uplift of the thorax to such an extent that the marginal portions came to stand higher than the cupola raised in expiration.[4] Inspiratory aspiration of a paralysed diaphragm is a pathological condition, and on frontal screening gives quite a different appearance.

Elevation of the two halves of the diaphragm is found in every unusual increase in the contents of the abdomen (tumours, cysts, ascites, enlarge-

ansammlung im Abdomen. Fortschritte, Bd. 24, 1916.—Fr. Rosenfeld: Über einseitigen Zwerchfellhochstand. 31. Kongress f. Innere Medizin, Wiesbaden, 1914.—Weinberger: Zur Klinik der rechtsseitigen Zwerchfellhernien. Fortschritte, Bd. 25, 1918 (with complete list of the literature).—Assmann: Hernia und Eventratio diaphragmatica. Fortschritte, Bd. 26, 1918 (with complete list of the literature).—Samaia-Palmieri: Bullett. di Scienze Mediche. Bologna, 1920.

[1] H. Schlecht and P. Wels, *l.c.*

[2] Wels: Untersuchungen zur Diagnose und zum Entstehungsmechanismus des idiopathischen Zwerchfell-Hochstandes. Fortschritte, Bd. 28, 1921 (with complete survey of the literature).

[3] Particulars regarding examination of the diaphragm with the Röntgen-rays are found in Jamin: Zwerchfell and Atmung; in Groedel's Atlas (4th edition, 1924, with complete list of the literature). Further also de la Camp: Beiträge zur Physiologie und Pathologie der Zwerchfellatmung, etc. Zeitschr. f. klin. Medizin, 1903, Vol. 49. From these works single sentences and paragraphs have been almost verbally taken.

[4] Thorough examinations into its appearance have been made by Holzknecht and Hofbauer: Zur Physiologie und Pathologie der Atmung. Holzknechts. Mitteilungen, II. Heft, Jena, 1907; see further for pathological paradoxical movement of the diaphragm the work of Bittorf: Über die paradoxe Zwerchfellbewegung. Münchener Med. Wochenschr., 1910, No. 23.—See also László Frigyér: Paradoxe Zwerchfellbewegung. Fortschritte, Bd. 36, 3, 1927.

ments of liver and spleen, pregnancy, and obesity), also in chlorotic, exophthalmic, and anæmic cases, and in pyriform thorax. In the dorsal decubitus the elevation is still more in evidence.

In *tubercular peritonitis* one finds [1] a general pressing upwards of the diaphragm with the same level on the two sides, flattening of the two cupolæ, and obliteration of the costo-phrenic sinus. On quiet respiration only a very slight excursion of the diaphragm occurs, while even on deepest inspiration the diaphragm is depressed and the sinus opened out only to a moderate degree. Viewed obliquely the two sinuses are narrower than usual, although otherwise quite free. After disappearance of the clinical symptoms the two halves of the diaphragm behaved quite as usual. In paranephritis a similar condition is seen on one side, but is not seen in cholecystitis, pyelitis, and appendicitis.

A unilateral displacement upwards of the cupola of the diaphragm upon the diseased side without alteration in the shape of the arch, with cessation of movement on respiration, speaks for a subphrenic abscess. In contradistinction to paralysis the diaphragm is not drawn towards the chest on inspiration. The movements of the sound side appear all the more marked.

A one-sided increase of the respiratory displacements of the diaphragm is always an indication of a disturbance by disease on the other side, for a one-sided active increase of diaphragmatic activity is unknown.

Stoppage of the inspiratory downward movement of the central tendon of the diaphragm is usually produced by *pericardial adhesions*, and is often found in tuberculosis. The picture is different from that seen in Fig. 204, B, and should not be confused therewith.

Diminution of respiratory movement of the diaphragm shadow, with the diaphragm lower than normal on both sides, is a sign of *emphysema*, and is due to an increase in the volume of the lungs.

Unilateral depression of the diaphragm and *displacement of the heart and aorta* to the affected side are the signs of a one-sided broncho-stenosis.

In profile view of the chest the contour of the lumbar portion of the diaphragm forms in the erect position of the body a very sharp angle with the vertebral column. In nephroptosis and enteroptosis an enlargement of this angle takes place with diminution of the respiratory movements, these being especially well marked at this point.[2]

In perforated gastric ulcer *air* is apt to collect in the left cupola of the diaphragm. This displacement of the liver with air enables us to understand how occasionally coils of intestine find their way between the liver and the cupola of the diaphragm. A dilated piece of intestine, usually the colon, can thus be found *above* the liver, and so give occasion to errors in diagnosis.

[1] A. Foerster: Über röntgenoskopisch feststellbare Zwerchfellbewegungsstörungen bei Bauchfelltuberculose und Paranephritis. Münch. Med. Wochenschrift, No. 2, 1920. See also C. Thurstan Holland, Liverpool: The X-Ray diagnosis of subphrenic abscess. Arch. Röntg. Ray, 1911, 15, p. 451.

[2] Schürmayer: Die normale und pathologische Zwerchfellbewegung im Röntgenbild. I. Deutscher Röntgen-Kongress, 1905.

HEART[1]

The remark in the preface is specially applicable for this section on the heart: In no single case should the Röntgen finding be considered the only one. Behind every statement one should bear in mind the proviso: "Provided the history and clinical findings favour, or at least do not oppose."

General

There is even less hard-and-fast lines *between normal and pathological* in the case of the heart and aorta than in the other organs. This remark applies to the size as well as the form of the radiographic shadow. The size and form of the heart are as different in different individuals as the size and form of the nose. Every heart is the product of the anatomy, physiology, and pathology of its bearer and of his ancestors.

The *form, position, and size* of the heart can be radiologically estimated either by a teleröntgenogram (with focal distance of not less than 1·5 metres), or by an *orthodiagram*. Naturally the teleröntgenogram or orthodiagram must be adequate and to the purpose, *i.e.* in accord with the right lines and instructions. Photographs or drawings that fail to come into that category are quite useless. At the same time the breadth and height of the thorax should be observed in the photograph or drawing.

Teleröntgenography[2]

Teleröntgenography was the method given in 1904–5 by the author for obtaining an exact determination of the size and form of the heart. It excludes the personal factor of the examiner that obtains in orthodia-

[1] Complete works on the Röntgen examination of the heart are: Groedel: Die Röntgendiagnostik der Herz- und Gefässerkrankungen. Berlin, 1912 (Meusser).—Vaquez and Bordet: Le cœur et l'aorte. Etudes de Röntgénologie clinique. Paris, 1913 (Baillière).—Munk: Grundriss der gesamten Röntgendiagnostik innerer Krankheiten. Leipzig, 1922 (Thieme).—Dietlen: Rieder-Rosenthal's text-book, 1924.—Lebon and Aubourg: Examen röntgénologique du cœur. La Presse médicale, 1913.—Kienböck: Zür Röntgenologie des Herzens. Zeitschr. f. klin. Medizin, July, 1918, Bd. 86.—Haudeck: Eine Revision der Methodik der röntgenologischen Herzgrössenbestimmung. Jahreskurse für ärztl. Fortbildung. August, 1918.—A. Hoffmann: Krankheiten der Kreislauforgane. Leipzig, 1919 (Publishers, Thieme).—Wenckebach: Kongress für Innere Medizin in Warschau.—H. Gerhartz: Leitfaden der Röntgenologie. 1922 (Urban and Schwarzenberg).—H. Dietlen: Herz u. Gefässe im Röntgenbilde. 1923 (Leipzig, Barth).—Assmann: Röntgendiagnostik innerer Krankheiten. Leipzig, 1924 (Vogel).—P. Schrumpf: Klinische Herzdiagnostik. Berlin, 1919 (Springer).—M. Zehbe: Beobachtungen am Herzen u. an der Aorta. Dtsche. M. Wschr., 1916, No. 11.—The same: Fortschritte, 1917, Bd. 25 and Bd. 26.—Groedel: Atlas Groedel.—Delherm and Chaperon: Les contours de l'ombre médiane cardio-vasculaire röntgénologique. Vus de face. La Presse Médicale, April 26, 1922.—The same: Journ. de Radiol. et d'Electrol., No. 1, January, 1923.—F. Perussia: La röntgenologia dell' apparato circolatorio. Trattato italiano di diagnostica radiologica, 1924 (Ferrara).—G. E. Knappenberger: The Röntgen-ray in cardiac diagnosis. Radiology, October, 1926.—F. J. Hodges: Röntgenological examination of the heart. Radiology, August, 1926.—The first cardiograph was taken by John Macintyre, Glasgow: Arch. Röntg. Ray, 1–3, p. 30.

[2] For particulars on this method, see Köhler: Technik der Herstellung fast orthoröntgenographischer Herzphotogramme vermittelst Röntgeninstrumentarien mit kleiner Electricitätsquelle. Wiener klin. Rundschau, 1905, No. 16.—Köhler: Teleröntgenographie

graphic methods, and it preserves the eye and body of the examiner from the danger of the rays. An unavoidable disadvantage is that the patient can be photographed only in the erect posture. Orthodiagraphy permits of both vertical and horizontal examinations.

The margin or error is stated by experienced röntgenologists, with a thorough understanding both of teleröntgenography and orthodiagraphy, to be 1–2 cm. in orthodiagraphy, but "it is only by the skilled observer that even this considerable margin of error is not overstepped, while in judging distance exposures the difference from the objective findings is inconsiderable even when the radiographer is inexpert."[1] In teleröntgenography the error (see the following tables) is scarcely 5 mm. in very large hearts at 2 metres distance, and scarcely 3 mm. in normal or slightly enlarged hearts. Whereas in orthodiagraphy we have always to bear in mind possible margins of error to the outside or the inside, the 3–5 mm. margin in distance photographs are not "errors" at all, but the calculable consequence of projection. Physical laws make no mistake! The 3–5 mm. are therefore always an enlargement, never a diminution; they are therefore always to be deducted from the diameter of the shadow. In the orthodiagram, on the other hand, every point can be drawn towards the outside or the inside of the true heart-wall, even when one carries the pencil

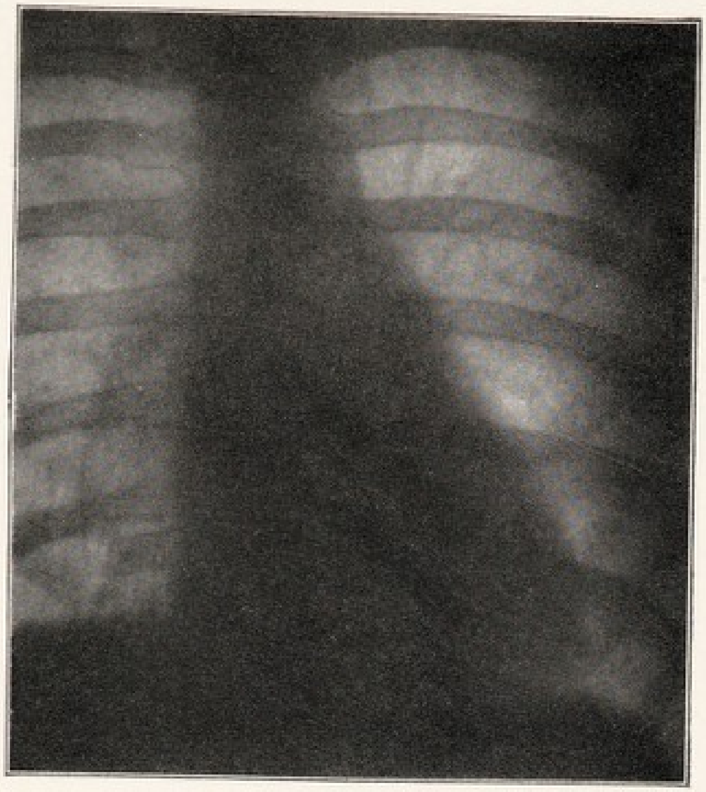


Fig. 206.

des Herzens. Deutsche Med. Wochenschr., 1908, No. 5.—Köhler: Röntgentaschenbuch, 2. Bd., 1909.—Köhler: Teleröntgenograph und Universalgestell. Münchener Med. Wochenschrift, 1911, No. 3.—Vaquez and Bordet: Le cœur et l'aorte. Etudes de Radiologie clinique. Paris, 1913 (Baillière).—Josué, Delherm and Laquerrière: Note sur l'instrumentation et la technique de la téléröntgénographie du cœur et de l'aorte. Journ. de Rad. et d'Electr., Tome 1, No. 6, 1914.—Alfred Weil: Die röntgenologischen Methoden der Herzgrössenbestimmung und ihr Einfluss auf die Entwicklung der Herzpercussion. Strassburger med. Zeitung, 1916, 8. Heft.—Köhler: Archives of the Röntgen Ray, Bd. 18, pp. 311 ff.—Huismans: Telekardiographische Studien über Herzkonturen. Fortschritte, Bd. 24, 1917.—The same: Die Telekardiographie. Ztschr. f. klin. Medizin, 25. Bd.—H. Dietlen: Herz u. Gefässe im Röntgenbild. 1923 (Leipzig, Barth).—Groedel: Atlas, 1924, and Lehrbuch Schittenhelm.—A. Kriser: Eine neue Fernaufnahme-Vorrichtung. Fortschritte, Bd. 35, 6, 1927.

[1] Alfred Weil, *l.c.*

from the lung tissue. Real errors and mistaken curves are therefore apt to arise. Tele-sketches and drawings at a distance are not a bit better!

Fig. 206 is historically the first teleröntgenogram, taken by the author in 1903. In this trial photograph we were dealing with a healthy twenty-year female case. The photograph was taken in the prone position in from 20–25 seconds with the breath held in inspiration, this length of exposure being required on account of the weak electrical current: from 24-volt accumulators with a 45 cm. induction coil and a mercury interrupter by Hirschmann of Berlin. The plate has been intensified, but not touched up.

The author has for years made his distance exposures with a focal distance of 2 metres in $1\frac{1}{2}$–2 seconds and after a good but not forced inspiration. The heart is thus seen in the position of diastole (as in orthodiagraphy), not diminished by straining and without injury, however sick the patient may be. The patient is instructed in advance to make one inspiration deeper than normal, but quietly and without effort from the call "Begin now" until 3 is counted (until 3 seconds); the exposure is then made on the 3rd to the 5th second. Different patients make little differences in the depth of their breathing, the same patient understands the directions each time in the same way, and in control photographs always takes up the same position of inspiration, as experience shows. Exceptions that amount to a margin of error of from 4 to 5 mm. occur extremely rarely. We can recollect only one really difficult case, and that was that of a colleague.

We should rejoice that there exist two classical röntgen methods of determining the size of the heart and the form of the heart, we ought not to play off the one method against the other. If only account is taken in every case under what conditions the size of the heart has to be estimated, orthodiagraphy and distance plates may be said to give equally good and equally objective results. It is common to both of these methods that when carried out they permit of the size of the heart being determined to a millimetre, and provided they be conducted under the same conditions they lead to identical conclusions.[1]

The focal aberration (*i.e.* the amount to be deducted from the heart shadow on the left side, in order to obtain the true size of the heart) amounts to the following values at the distances stated:

ABERRATION OF THE LEFT CONTOUR OF THE HEART IN MILLIMETRES.

At 1·5 metres focal distance.

Distance of the apex of the heart from the mid-sagittal plane of the body in cms.	Distance of the photographic plate from the apex of the heart in cms.				
	4	5	6	7	8
7	1·9	2·4	2·9	3·4	3·9
8	2·1	2·7	3·3	3·9	4·5
9	2·4	3·1	3·7	4·4	5·0
10	2·7	3·4	4·1	4·8	5·6
11	3·0	3·7	4·5	5·3	6·1

At 2 metres focal distance.

Distance of the apex of the heart from the mid-sagittal plane of the body in cms.	Distance of the photographic plate from the apex of the heart in cms.				
	4	5	6	7	8
7	1·4	1·7	2·1	2·5	2·9
8	1·6	2·0	2·4	2·9	3·3
9	1·8	2·3	2·7	3·2	3·7
10	2·0	2·5	3·0	3·6	4·1
11	2·2	2·8	3·4	3·9	4·5

[1] A. Weil, *l.c.*

At 2·5 metres focal distance.

Distance of the apex of the heart from the mid-sagittal plane of the body in cms.	Distance of the photographic plate from the apex of the heart in cms.				
	4	5	6	7	8
7	1·1	1·4	1·7	2·0	2·3
8	1·3	1·6	1·9	2·3	2·6
9	1·4	1·8	2·2	2·6	3·0
10	1·6	2·0	2·4	2·8	3·3
11	1·8	2·2	2·7	3·2	3·6

At 3 metres focal distance.

Distance of the apex of the heart from the mid-sagittal plane of the body in cms.	Distance of the photographic plate from the apex of the heart in cms.				
	4	5	6	7	8
7	0·9	1·2	1·4	1·6	1·9
8	1·1	1 3	1·6	1·9	2·2
9	1·2	1·5	1·8	2·1	2·4
10	1·3	1·7	2·0	2·2	2·7
11	1·5	1·8	2·2	2·6	3·0

On the right side of the heart shadow the aberration for self-evident reasons (smaller distance from the median sagittal plane of the body) can be taken as nothing and therefore neglected.

The above tables are to be read as follows : When, for example, the apex of the heart was distant about 7 cm. from the mid-sagittal plane of the body and about 4 cm. from the photographic plate (or the screen), then at 1·5 metres focal distance 1·9 mm. have to be deducted from the left border of the heart shadow, in order to obtain the true size of the heart, etc.

Seeing the estimate of the heart has to be carried out in comparison to the width of the thorax, one should draw that in also or photograph the whole thorax or the greater part of it. To take a 30×40 cm. plate would be a needless expense, a 24×30 cm. one should do ; it is placed excentrically, so that the whole of the left thorax and the median vertical third of the right thorax is projected on the plate.[1] Naturally the aberration at the thoracic margin is greater than at the border of the heart, in teleröntgenograms (not in orthodiagrams). But that does not amount to more than 1·5 cm. on the average, so it can be neglected or—in exact studies of the heart—entered in the notes.

Orthodiagraphy [2]

The essentials of this method, in addition to what appears in the foregoing statements, are already known to röntgenologists and Röntgen workers. Reference can also be made to the short summaries in the text-books and the works on cardiac-röntgenology given in the footnotes.

[1] In the author's teleröntgenographic apparatus the space for the plate is therefore placed excentrically. The apparatus was built by the makers, Philipp Berghäuser, Wiesbaden, Wellritzstrasse 32.

[2] F. Mortiz : Eine Methode, um beim Röntgenverfahren aus dem Schattenbilde eines Gegenstandes dessen wahre Grösse zu ermitteln (Orthodiagraphie) und die exacte Bestimmung der Herzgrösse nach diesem Verfahren. Münch. Med. Wochenschrift, 1902, No. 1. Further the other works of Moritz (see Dietlen's text-book and Gocht's Röntgen literature), also the reference works of Levy-Dorn, Groedel, Aug. Hoffmann, etc., also Alfred Weil : Die röntgenologischen Methoden der Herzgrössenbestimmung und ihr Einfluss auf d. Entwicklung der Herzpercussion. Strassburger mediz. Zeitung, August, 1926.

Composition of the Normal Heart-shadow, Fig. 207

In sagittal röntgenograms *the right auricle* (R. A.) exhibits a nearly circular arch with a large radius, and on it is seen a very open angle or shallow incurving, where it is met by a much flatter shorter arch, which is nearer the median line and formed by the great vessels, the *ascending aorta* and the *superior vena cava*, the so-called *right vascular arch* (A. A.). In the standing position it is the aorta, in the horizontal rather the vena cava, that forms the margin. In addition there is a third arch or linear shadow-border visible, which is due to the innominate vein. The right inferior arch is normally never formed by the right ventricle.

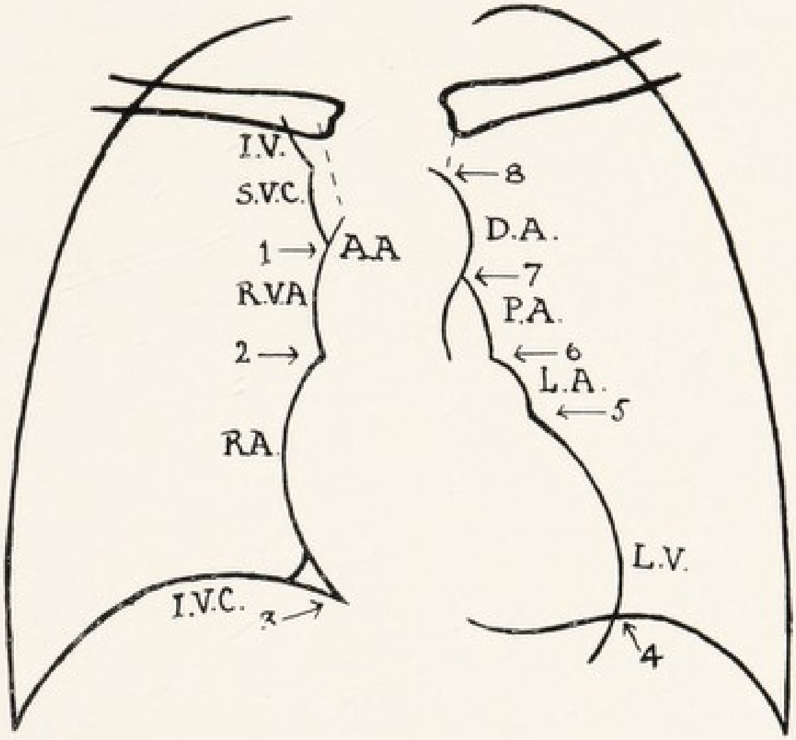


Fig. 207.[1]—Normal Antero-Posterior View of the Heart (near view).
1–8 indicate the notches between the various arches.

R. A. = Right auricle.
R. V. A. = Right vascular arch.
A. A. = Ascending aorta.
L. V. = Left ventricle.
L. A. = Left auricle.
P. A. = Pulmonary artery.
D. A. = Descending aorta.
I. V. = Innominate vein.
S. V. C. = Superior vena cava.
I. V. C. = Inferior vena cava.
3 and 4 = The Cardio-phrenic angles.

The left border shows always at least three definite arches. The inferior corresponds to *the left ventricle* (L. V.), and possibly in its uppermost part also to the conus arteriosus of the right ventricle.

The middle arch is much shorter and usually flat. It is formed by the conus arteriosus and the pulmonary artery. It appears more arched in

[1] According to Dietlen, *l.c.*, and the statements thereon by Groedel, Dietlen and Assmann, *l.c.* See further: Delherm and Chaperon: L'hombre médiane cardio-vasculaire vue de face. Journ. de Rad. et d'Electr., January, 1923.

the horizontal than in the standing position. It is called *the pulmonary arch*.

The superior arch is usually strongly curved and clearly delimited from the pulmonary arch by a specially marked angle. It is formed by the aorta : *the aortic arch* (D. A.).

Occasionally—but only in orthodiagrams in the horizontal position—there occurs a fourth arch between the pulmonary arch and the left ventricle, at the so-called " heart-taille." It appears to be doubtful whether it can occur in the perfectly normal heart. It is clearly delimited from the pulmonary arch, it is not clearly defined from the left ventricular arch. It pulsates a little or not at all. This small arch is said to be due to the left auricle, at any rate it is only the left auricle that takes part in the shadow. It is better seen in screening than in the photographic plate. (The author in distance views of the normal taken in the standing position has seen it only occasionally, see, for instance, Fig. 211, Plate 7448, further in enlarged hearts, Fig. 212, Plates 8908, 9571 ; further in the figures of the aorta, Fig. 225, Plates 8092, 9413, Fig. 226, Plate 9601, Fig. 227, Plate 8906, 5163.)

In order to represent the heart of fat patients and to secure a bird's-eye view, it is recommended [1] to set the focus of the tube not at the level of the sixth or seventh rib, but much deeper at the level of the eleventh rib, in order to separate the heart-shadow better from the cupola of the diaphragm, seeing that in the usual projection of such fat subjects the heart falls partly into the shadow of the diaphragm. This can only be attained when the patient is asked to breathe deeply and hold the breath. It is true the cardiac shadow does not appear quite correct, but appears elevated above the diaphragm. The apex of the heart in this method is said to form a clear contrast. It is best to test the best position on the screen. In slender patients one should retain the older methods of projection.

On the meaning of the details of the posterior border of the heart in frontal and oblique illumination there are still some points to be cleared up. Examination by deep inspiration usually gives the best view. In this view, in profile, the lower half of the posterior border of the heart is formed roughly by the left ventricle. The upper part according to the general opinion is formed by the left auricle. It is stated by one observer [2] that this part is formed by a connective tissue space enveloping the left auricle in its posterior and upper aspects, that contains the large pulmonary vessels, the bronchi, lymph-glands, etc., and runs out laterally to the hilus of the lung. These great vessels are met with orthoröntgenographically in a part of their course ; hence also the formation of intense shadows and their demarcation. The pulmonary artery forms a definite line in every

[1] Paul Eisen : A rational method for demonstrating the heart. Radiology, September, 1924.

[2] E. Attinger : Die Interpretation des hinteren Herzrandes in frontaler u. schräger Durchleuchtung. Fortschritte, Bd. 31, 1, 1923.

case in the upper part of the outward-curving posterior border of the heart ; it even shows the form of the curved margin. The intervening portion between the upper part of the line and the lower half (ventricular part) forms roughly less than a third of the whole posterior border, being formed by the left ventricle itself ; this can also be recognised from the auricular contractions. (It is only rarely that a slight indentation is present between the auricle and the ventricle.) An almost straight course of the posterior border of the heart is said to occur in normal hearts of elderly individuals with emphysema or arteriosclerosis. If one finds the convexity of the posterior cardiac margin increased, that is not ascribable—as has been hitherto assumed—to an enlargement of the left auricle, but is usually due to the antero-posterior broadening of the ventricles (left or right), *i.e.* to an enlargement of the cardiac diameter in the sagittal plane.

Pulsation [1]

As regards *the difference* between *the diastolic* and the *systolic shadow* of the heart, "*the size of the contraction*," there are still considerable contradictions between the results of different investigators. It is best seen at the left ventricular margin. It is certainly not as large as one might suppose from the screening examination. The results of the normal heart vary between 2 and 7 mm., the smaller figures, however, being still in doubt ; it is, however, certain that differences occur in the normal that are conditioned by the frequency of the pulse (the duration of diastole), and also by the type of pulsation and the form of the heart. In the diseased heart one finds the greatest difference in extreme bradycardia and in dilated left ventricles, and increased volume of the heart consequent upon aortic insufficiency, and above all in exophthalmic goitre ; in the diseases mentioned excursions from 7 up to 20 mm. have been observed by authoritative cardiologists. The greatest excursion in healthy and diseased hearts are found in maximal inspiration, the smallest in maximal expiration.

The greatest extent of movement is found near the apex, not only in the normal heart, but also in hypertrophy consequent upon mitral insufficiency, while large movements of the base of the heart, near to the annulus fibrosus, are indicative of aortic insufficiency.

A powerful action-type of heart is found in all diseases of the heart, which accompany an increase in the volume of the ventricular pulsation, in hearts with aortic lesions (the pulsation movement of the left ventricle is powerful in aortic insufficiency), patients with contracted kidneys, and in hypertrophied hearts. *An irritable type of heart* is found in the fluttering exaggerated exophthalmic disease, in paroxysmal tachycardia, in cardiac neuroses of the heart, in war neuroses, also in patients who are frightened of röntgen examination, also after severe athletic exercises and after hot baths.

The weak action-type of heart occurs almost only in enlarged hearts ;

[1] Almost verbally from Dietlen

thus one finds strikingly weak slow contractions in the old-standing insufficiency of chronic myocarditis; as generally in enlarged hearts, the weak action-type appears to point to a threatened cessation of the heart's action.

The normal type of pulsation is intermediate between powerful and weak types, and is met with best in adult men of from thirty to fifty years.

Heart of the Infant and Child

The *heart of the newly born* has the form of a ball, both in children who have breathed and in still-born children. Premature children are said to exhibit this form of the heart in a still more pronounced measure. In the new-born child the left half of the heart has a rounded form which

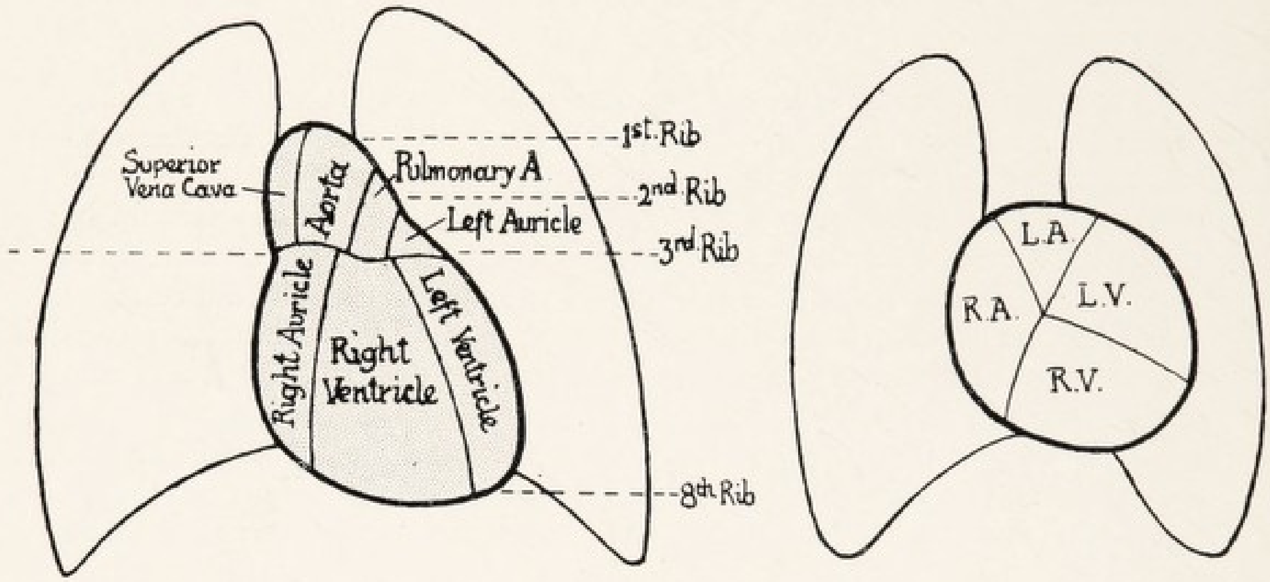


Fig. 208.

indicates that this form—assuming that the heart of the newly born stops in diastole—is produced not simply by muscular contractions but also in morphology. In contradistinction to the adult heart where the surface of the heart in relation to the anterior chest wall is formed mostly by the right ventricle (Fig. 208, left), in the newly born the anterior surface of the heart is formed almost equally by the right and left ventricles (see Fig. 208 on right).[1]

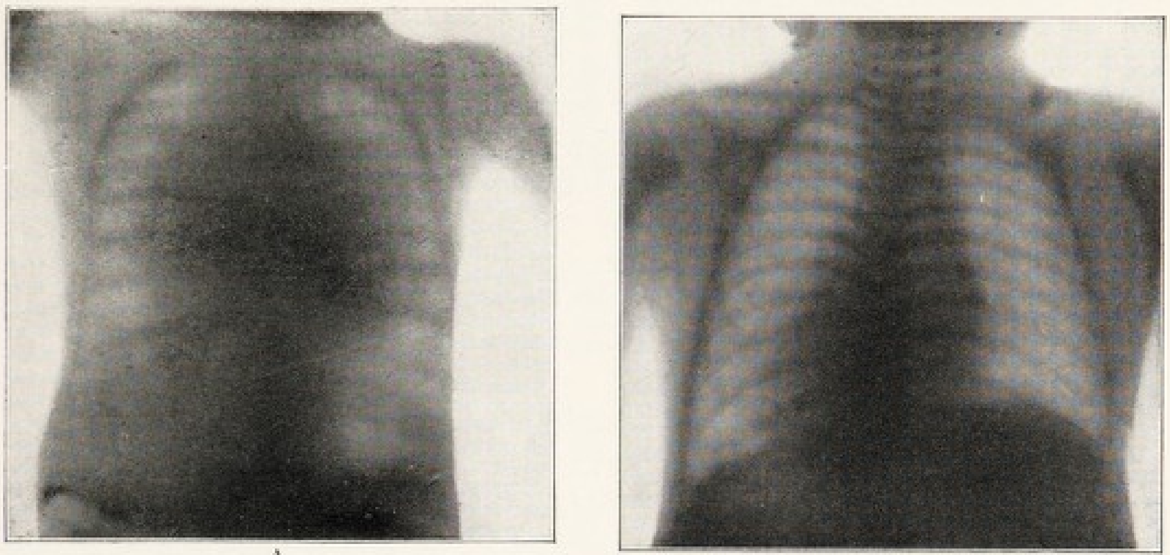
The *composition of the left margin* of the heart is generally less marked; in infants usually only two arches, aorta and ventricle, are seen, in the child three arches—aortic, pulmonary and ventricular arches.[2] Others deny this,

[1] E. Vogt: Der Nabelschnurkreislauf im Röntgenbilde, zugleich ein Beitrag zur Lehre vom Verschluss des Ductus arteriosus Botalli. Fortschritte, Bd. 28, 1921; continued in Bd. 29, 1922. Fig. 208 is taken from that work.

[2] Bamberg-Pützig: Herzgrösse im Säuglingsalter. Z. f. Kinderheilkunde, 1919.—Reyher: Über den Wert orthod. Herzunters. bei Kindern. Jahrbuch f. Kinderheilkunde, 1906, 14.

saying that it is only the more rapid action of the heart that renders it difficult to make out the arches.[1]

The heart of the child is larger in relation to the thoracic cavity than in an adult. It is uncommonly difficult to decide in a child's heart whether it is larger than the normal; nevertheless, in Fig. 209, A, in a child seven months old, there is no doubt that we are dealing with an extremely enlarged heart; Fig. 209, B, is a heart of a child of eight months. The form is generally the more useful criterion to deciding whether pathological conditions are present. (For congenital lesions of the heart, see later.)



A B

Fig. 209.

A strikingly *broad base of the heart* (vascular part) in children is remarked upon by various observers,[2] and has often been incorrectly diagnosed as a shadow of the thymus; it is due to a superior vena cava engorged by forced expiration. In children one may even obtain an unexpected view of the sinuses of Valsalva and regular changes in the fullness of the heart, corresponding to the successive respirations.[3]

For normal dimensions of a child's heart, see below.

The growth of the heart in the first year of life is relatively small, mainly owing to a period in the first four months when the growth is arrested, subsequent to separation of the placenta at birth. The left ventricle increases much more quickly in weight and thickness than the right. The relative conditions of weight of the arteries, compared with the two ventricles, undergo no particular alteration in the first year.[4]

[1] Groedel: Röntgenolog. Untersuchung des kindl. Herzens. Zeitschrift f. Kinderheilkunde, 1921.

[2] Gött: Die Röntgen-Untersuchung in der Kinderheilkunde. Rieder-Rosenthal's textbook. Leipzig, 1914 (Barth).—Vogt, *l.c.*—Bamberg-Pützig, *l.c.*

[3] Dietlen, *l.c.*

[4] R. E. Scammon: Studies on the growth and structure of the infant thorax. Radiology, August, 1927.

Adult Heart

Form and Position of the Heart as a Whole

While the *forms* of the healthy child's heart do not appear to vary very much in different individuals, the Röntgen picture of perfectly healthy adults shows us, as already mentioned, a wonderful variety in the form and size of the heart (see Figs. 210 and 211). Yet it is not so much the heart alone as the varying positions of the heart and the thoracic cavity that produces the manifold differences in the shadow picture. For a heart even of the self-same size and form will give in a narrow thorax quite a different picture from what it gives in a squat thorax, a different picture in inspiration from that in expiration, in the vertical from that in the horizontal, a different picture in the prone position from that in the dorsal decubitus, quite apart from the different amount of filling by the blood; for the heart is suspended above by the vessels and rests upon the diaphragm. In *kyphoscolioses and scolioses* it is almost impossible to make an accurate estimate of the shadow of the heart. That is all the more unfortunate, as in thoracic deformities, hypertrophies and dilatations of one or both ventricles are usually present, auscultation and percussion are usually insufficient in these cases, and the decision is usually left to the röntgenologist. One is too easily inclined, in a scoliotic or kyphoscoliotic case, to regard as within normal limits a heart that extends far to the left, upon the ground that its horizontal position and its overstepping of the mamillary line is simply due to a higher level of the diaphragm than normal.[1] Further, the form of the chest is quite different in the standing and in the horizontal positions, and this exerts a very special influence upon the size and position of the heart-shadow. The height of the thorax diminishes in the horizontal position, becoming at the same time broader;[2] its depth diminishes in the upper part, increases in the lower part. The heart becomes correspondingly broader. " The size of the heart depends not only on the weight and size of the body, on the constitution, on the age and sex, but also on the pulse, respiratory phase, on the muscular activity, etc."[3] The following points have first of all to be thought of in every estimate of the heart shadow:

(*a*) In individuals of *a short broad stature* and also in elderly people the axis of the heart is more horizontal, the left apex of the heart is more lateral, " oblique heart."

(*b*) In thin individuals with *a high thorax*, in young people as also in adults suffering from enteroptosis, the axis of the heart is more vertical, the contour of the left ventricle is situated medial to the mamillary line, " vertical heart."

[1] Brugsch: Über das Verhalten des Herzens bei Skoliose. Münch. M. W., 1910, No. 33. —W. Amelung: Die Veränderungen des Röntgenbildes der Brustorgane bei Kyphoskoliosen und Skoliosen. With review of the literature. Fortschritte, Bd. 28, Heft 3, 1921.

[2] Rumpf: Orthodiagraphie des Herzens und Thoraxverschiebung. 26. Kongress für innere Medizin, 1909.

[3] Kraus, *l.c.* later.

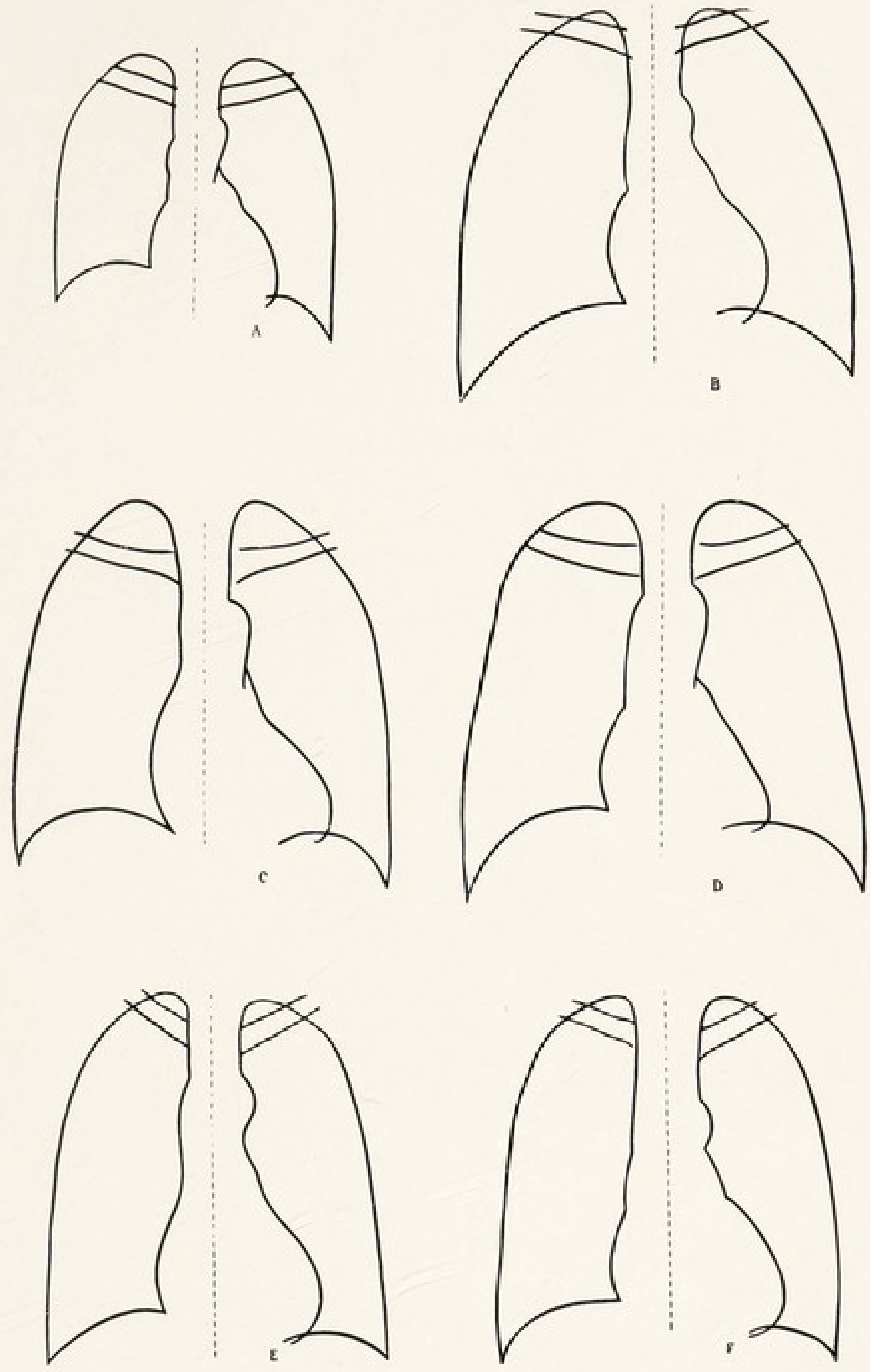


Fig. 210.—Forms of the Normal Heart in Inspiration.

A = fifteen-year-old girl of average size in the standing position; B = seventeen-year-old youth of average stature in the prone position; C = forty-year-old woman in the standing position; D = thirty-six-year-old male in the standing position; E = twenty-three-year-old male in the standing position; F = the same in the prone position.

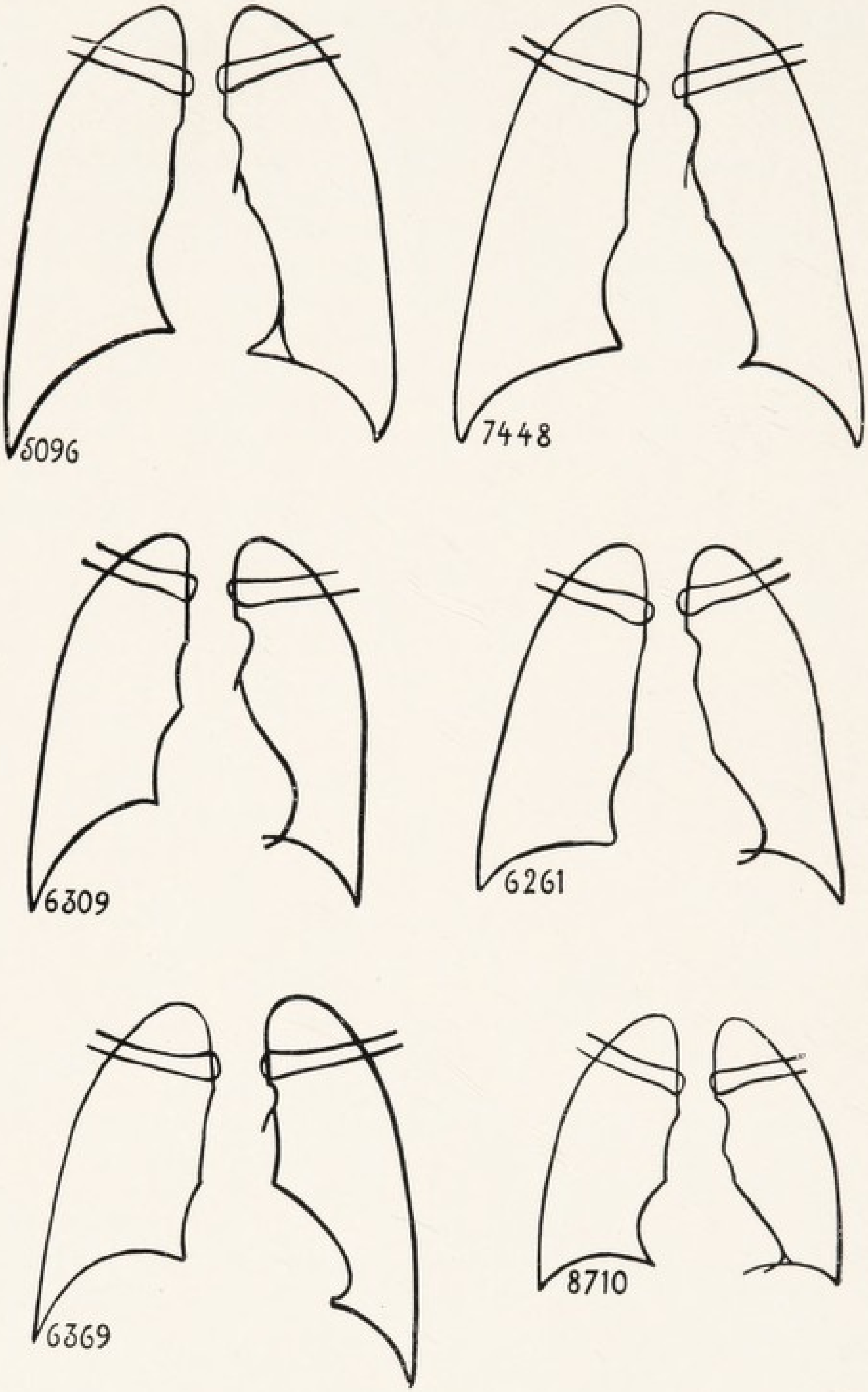


FIG. 211.—Normally-sized Hearts.

Inspiration, upright position, 2 metres focus distance.

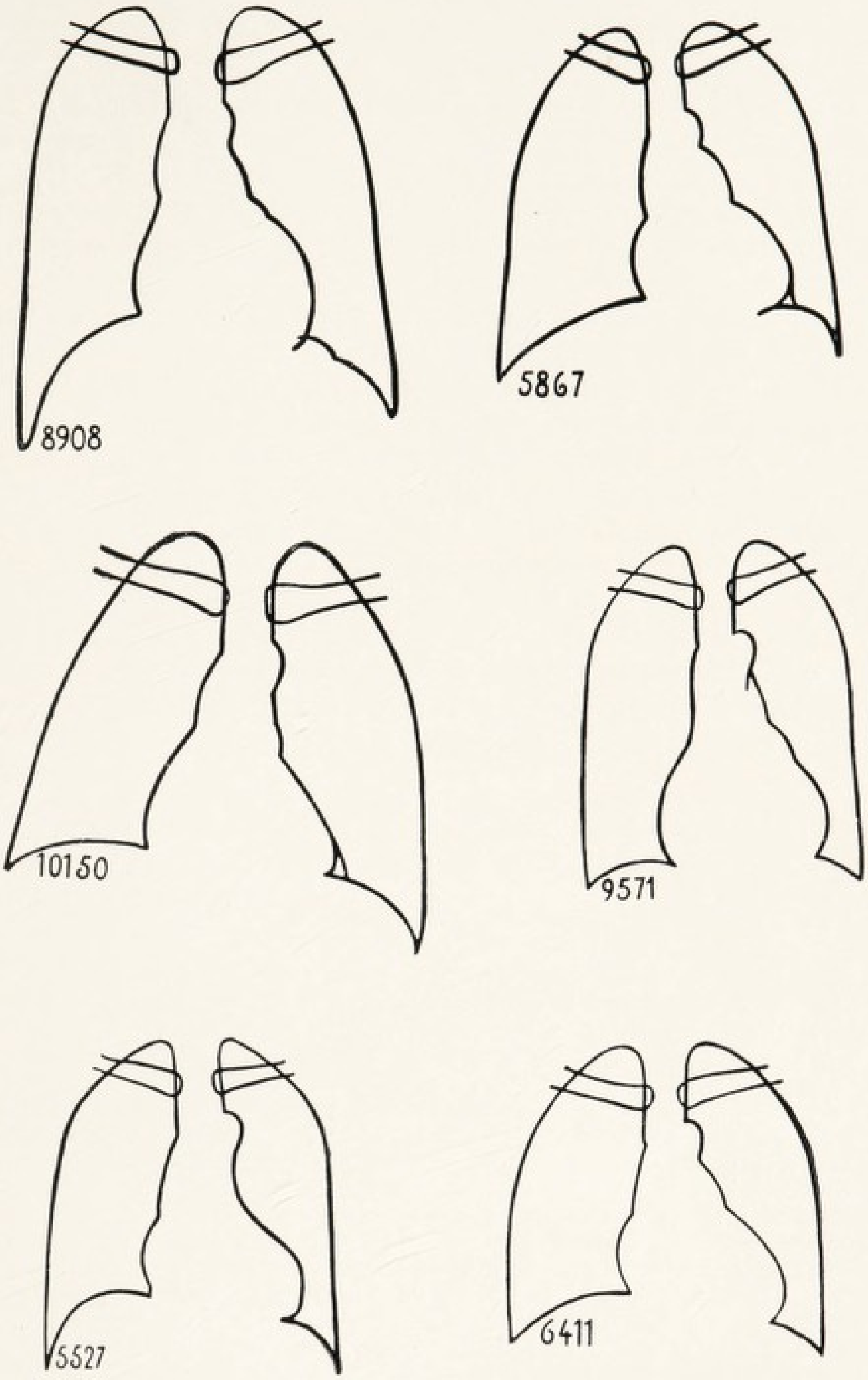


FIG. 212.—Hearts of Slight to Moderate Enlargement.
Inspiration, upright position, 2 metres focus distance.

(*c*) In pictures or diagrams of the heart obtained in the horizontal position, the apex of the heart becomes raised, and the left margin extends somewhat further out than in the same individual in the standing position.

The axis of the heart in people of normal size and form is more horizontal than the normal, in the presence of tumours of the liver, meteorism, ascites, subphrenic abscess, hernia of the diaphragm, hernia or eventration of the diaphragm, commencing eventration (strongly dilated air-sac of the stomach), tumours of the hypochondrium, etc., in short, in all cases in which an elevation of the diaphragm is produced.

The *mamillary and parasternal lines* vary, as is well known, in their distance from the middle line of the body within wide limits. To estimate the size of the heart from them has therefore only a limited value. In every case one should always mark the left mamilla (in men) with a small piece of lead, noting, however, that a heart which reaches to the mamillary line does not need to be enlarged (for the mamilla may be situated relatively near the mid-line) ; further, that a heart whose apex is situated two finger-breadths inside the mamillary line can still be enlarged (when the mamilla is unusually displaced from the middle line of the body).[1]

It may sometimes happen that the right and left distance of the heart from the mid-line may be incorrectly regarded as increased by a centimetre, owing to the contours of the heart being covered by the ribs or the angles of the heart being filled up by the same.[2]

Brief Remarks on the Röntgen Anatomy of Heart Pictures, Figs. 211 *and* 212.

These various types of hearts were taken from a series of 1,128 photographic plates ; screening was done in every case ; they were carefully selected from numerous screening and plates of other hearts. In inspiration and the upright position the left middle arch (pulmonary and left auricular) did not project so distinctly as in photographs in the prone position or orthodiagrams in the dorsal decubitus. That is not altogether a disadvantage. Rather one could say in general that it is not until one of these arches projects very distinctly in inspiration and in the standing position (more than about 5 mm. beyond the cardiac margin) that it is to be considered a pathological feature. The diagnosis is thereby simplified.

In the making of these diagrams the shadow contours are exactly reproduced. Only perfectly clear sharp photographs were selected. Seeing the cases were healthy or practically healthy there was naturally no autoptic control. The principal purpose of these diagrams is to show how a pathological process can be diagnosed from the shadow form alone—that is, without conducting set measurements. Even a moderately enlarged heart is quite different in appearance from the normal heart.

We have intentionally avoided enlarging the lower and the upper margins of the heart, for although this is apparently quite easy it can be done only with a greater or less degree of imagination. The author finds in the literature a diagram of the heart with enlargements of the upper and lower margins, which could not possibly be correct.

Attention should be paid even in normal hearts to the extremely different contours of both halves of the diaphragm and the phrenico-costal angles, a theme that deserves more extended research.

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[1] See also Ed. Müller : Röntgenologische Beobachtungen über Fehlerquellen der klin. Herzgrössenbestimmung. Münch. Med. Wochenschr., 1914, No. 23.

[2] With illustration by Huismans, *l.c.*

Normally-sized Hearts

Fig. 211. No. 5096: Thin woman of twenty-six years. Mother died from lung trouble. Patient had hæmoptysis twice in the last 1½ years. Heart placed somewhat sagittal, at the lower border of the normal, but is not atrophic and shows no diminution in size.

No. 7448: Thin man of twenty-three years of healthy family. Bronchial catarrh frequent; influenza shortly before. Heart of the average size of the normal and in the normal position.

No. 6309: Twenty-year male of average build and proportions; suffers much from bronchial catarrh. Heart near the upper limit of the normal, resting firmly on the diaphragm, situated somewhat posterior to the normal; middle left arch not visible.

No. 6261: About thirty-five-year male, broad and heavy build, opera singer. No complaints. Purely scientific photograph. The heart near the upper limit of the normal resting firmly on the diaphragm.

No. 6369: Forty-year male, heavy build; twice hæmoptysis in six weeks. Right diaphragm distinctly elevated, left diaphragm distinctly depressed. Heart within the normal size, broad attachment to the diaphragm, but placed obliquely and tilted far backwards.

No. 8710: Thirty-five male, small size, well-proportioned build. Complaint of "nervous" heart. Heart corresponding to the size of the body, situate obliquely through elevation of the left diaphragm and clearly displaced to the right. See in addition the diagram, Fig. 210.

Enlarged Hearts

Fig. 212. No. 8908: Thirty-five-year male, thin and very tall. Vague complaints in his chest. Heart sounds normal. Position of heart normal. Moderate enlargement of the left ventricle (with blunt hypertrophied apex).

No. 5867: 22½-year male, large build; heart complaint for last four years. No murmurs present! Myasthenia? Left ventricle moderately enlarged, left middle arch very pronounced; cardiac axis more horizontal than the normal.

No. 10150: Forty-year male, large broad build. Professional wrestler. Stature very similar to patient No. 6261. (Seen on the left.) No complaints. Athletic heart. Moderate enlargement of the left ventricle and the left auricle, moderate degree of enlargement of the right ventricle and auricle.

No. 9571: Sixty-seven-year thin woman. No cardiac complaints. Finding accidental. Röntgen plate taken for contusion of the chest. Quite an exceptional picture of a heart certainly enlarged (medium degree), elevated and rotated at the apex by elevation of the left diaphragm. All four chambers of the heart are enlarged and hypertrophied.

No. 5527: Sixty-year woman, average size, somewhat stoutly built (husband luetic). For many years heart complaints, the previous year an apoplectic attack of a slight nature. Grating murmurs at all the valves. Left ventricle dilated downwards and outwards, middle left arch not visible, heart turned over backwards, "duck-form." Type of aortic insufficiency. Aortic arch still within the normal limits.

No. 6411: Thirty-five-year woman of average size; heart complaints for 1½ years. Arteriosclerosis. Second heart sound clearly accentuated, somewhat ringing, no murmurs over the valves. Blood pressure 160 Riva Rocci. Pulse, strong, regular quickening. Knots palpable in the epigastric veins; left leg œdematous. Heart: left ventricle shows a medium degree of enlargement; left middle arch more prominent than normal.

Size of the Whole Heart

Normal size of the heart.[1] The most reliable of the cardiac measurements is the transverse dimension (the so-called "basal breadth"). That

[1] Further particulars are found in the works of Moritz, Dietlen and Veith: in Deutschen Archiv für klin. Medizin, Bd. 81 and ff; Münch. Med. Wochenschr.; Fortschritte; Deutsche Klinik, Bd. 4, Abt. 2, and Jahrbuch f. Kinderheilkunde, 1908, from which the following measurements are taken; see further Groedel: The Röntgen diagnostic of diseases of the heart and blood vessels. Berlin, 1912 (Meusser); also Dietlen: Ergebnisse des med. Röntgenverfahrens für die Physiologie. Ergebnisse der Physiologie, 10. Jahrg., pp. 597 to 639.—Wenckebach: Kongress für Innere Medizin in Warschau, 1916.—Also Monograph by H. Dietlen: Herz und Gefässe im Röntgenbilde. 1923, Leipzig (Barth).—Groedel, in Atlas Groedel, 1924.—Th. Ziskin, Minneapolis: Development and size of the child's heart after measurements on teleröntgenograms. Am. J. of dis. of children, 1925.

is obtained by dropping a vertical from the extreme right point of the heart silhouette to the extreme left point (or by adding the MR = median distance right and the ML). The following represent average measurements :

A. Size of heart in the mid-breathing position and in the dorsal decubitus.

Children.

Height.	Transverse-dimension.
111 to 120 cm.	9·25 cm.
121 ,, 130 ,,	9·9 ,,
131 ,, 140 ,,	10·2 ,,

Men.

Height.	Transverse-dimension.
145 to 154 cm.	11·4 cm.
155 ,, 164 ,,	12·8 ,,
165 ,, 174 ,,	13·0 ,,
175 ,, 184 ,,	13·5 ,,

Women.

Height.	Transverse-dimension.
145 to 154 cm.	11·6 cm.
155 ,, 164 ,,	11·9 ,,
165 ,, 174 ,,	12·3 ,,

B. Size of heart in the mid-breathing position and in the erect position.

Adult men	13 cm.
Under-developed men	12 ,,
Adult women	12 ,,
Under-developed women	11 ,,

These last measurements apply to persons of medium bodily size.

C. In shadows of the heart obtained during strong inspiration these values are to be reduced by about 6 mm.

Table after Dietlen for Practical Use.

Average values (not minimal or maximal sizes).

Males.

Weight-groups.	Average size.	Tr.	L.
40–49·9 kg.	150–160 cm.	11. **12**. 13 cm.	12. **13**. 14 cm.
50–74·9 ,,	160–180 ,,	13. **13**. 15 ,,	13. **14**. 15 ,,
75– ,,	180– ,,	14. **14**. 15 ,,	14. **15**. 16 ,,

Females.

Weight-groups.	Average size.	Tr.	L.
40–44·9 kg.	145–154 cm.	10·5. **11**. 11·5 cm.	12. **12**. 13 cm.
45–59·9 ,,	155–164 ,,	11·5. **12**. 13·5 ,,	12. **13**. 14 ,,
60– ,,	165– ,,	12·0. **13**. 14·0 ,,	13. **14**. 15 ,,

The relation Tr (= Transverse-diameter) to L (= Longitudinal diameter) amounts in the normal heart on the average to 1·0 : 1·1 or as 10 : 11 ; that is, the dimension Tr = L or Transverse-D greater than Longitudinal-D almost always points to a pathological condition being present.

While looking for an *Index-method* for the normal size of the heart one röntgenologist [1] arrived at the idea of including the measurement of the shoulders in the reckoning. Experience shows that a healthy broad-shouldered man is the possessor of a broad heart. Heart and clavicles should first be measured in the teleröntgenogram, yet mistakes arise thereby because both are projected in a different way by the rays. A better idea was to measure the heart in the telecardiogram, but to measure the length of the clavicles directly on the shoulders of the patient. Finally, it was found that the best way was to measure the shoulders themselves. The breadth of the shoulders, measured from the one acromion to the other, gives the numerator, the figure for the breadth of the heart being taken as the divisor. The resulting index-series ranges from 35 to 22. The number 35 betokens the smallest heart, the number 22 the largest one. The narrowest shoulders were 33·1 cm., the broadest 42·3 cm. A healthy adult of normal weight may have the average value 30–29. The breadth of the heart might in these limits vary between 11 and 14·7 cm. The comparison-value of the " small heart " varies between 35 and 33, the breadth of heart being 10·1–12·5 cm. In evident endocarditis and myocarditis the index might be from 27 and under. The comparison-value of the broadest heart (18·8 cm.) was 22.

The author usually takes all his heart photographs at 2 metres tube distance (see " Teleröntgenography ") in the standing position of the patient and in good but no forced inspiration of the chest. The patient is allowed to take a deeper breath than usual, but *without any strain*. The normal transverse-dimension, *i.e.* the basal breadth, is thereby 11–13 cm. according to the size and stature of the adult patient. This measurement has been tested in many years of practice. (See, however, the next paragraph.)

Manual workers have their bodily musculature well developed, and in them the heart musculature is more developed than usual.[2] Their transverse-dimension may exceed that of the normal measurement by 2 cm. The same is the case in sportsmen in constant training. Such hearts which appear in the majority as perfectly healthy form therefore an exception (training heart, workman's heart). Also in soldiers at the end of their military service one finds sometimes exceptionally large although healthy hearts. For athletic hearts, see Fig. 212, No. 10150 (champion wrestler), and Fig. 225, No. 2811 (tennis player, mountain climber, and ski-runner). Although these hearts are enlarged one would describe them as pathological

[1] Lauri Taipale : Über einen neuen röntgenologischen Index der Herzgrösse. Temporary report, Journal of the Soc. of Finnish Medicine. Duodecim No. 1, 1927 (in Finnish : sent to the author in the form of a translation).

[2] Schieffer : Über den Einfluss der Berufsarbeit auf die Herzgrösse. Deutsches Arch. f. klin. Medizin, 92, Heft 5/6.—Buschan : Sport und Herz. Munich, 1910 (Publishers Reinhard).—R. Ackermann : Einfluss sportlicher Arbeit auf d. Herz. M. m. W., 1926.

only if they were accompanied with complaints. Naturally the limit between simple compensation and the pathological consequence of heart strain are temporary and difficult to recognise. Whether these enlargements are dependent upon hypertrophy or dilatation, there is considerable disagreement among the first authorities.[1]

The weight of the heart accompanies the weight of the body, the size of the body, and especially the development of the musculature.

Cyclists constantly show larger cardiac dimension than non-cyclists. Cycling is in fact the sport that is most injurious to the heart. One must, therefore, be careful not to permit such hearts to pass as normal. The same remarks apply also to rowers.

Enlarged hearts are, as already mentioned above, never geometrically similar to normal hearts. With the enlargement there is always an accompanying change of form. The most characteristic forms are produced by valvular defects (see later).

In any *considerable enlargement of one chamber* of the heart the other three chambers are also affected, by pressure and drag of the enlarged part upon the neighbouring part. Thus, *e.g.*, the enlarged chamber may produce on the neighbouring parts an enlargement of form, the neighbouring wall of the heart being drawn out with it. Further, the enlargement of one ventricle produces an enlargement of the auricle belonging to it and of the other ventricle. In enlargement of the part to the left of the middle line (and conversely) the heart is usually displaced a little to the right, yet not so strongly that the one-sided origin of the enlargement cannot be recognised. An enlarged and therefore heavier heart sinks in the standing position of the trunk deeper into the abdomen, generally retaining its oblique position in the chest. Moreover, an enlarged heart rotates in the thoracic cavity through inability to move freely, through lack of space, around its vertical axis (parallel to the axis of the trunk), in a counter-clockwise direction regarded from above; it now rests with its longitudinal axis more frontal in the chest, and therefore looks with its apex not so much forward as usual, but more to the side.[2]

Acute enlargement of the heart is sometimes associated with incomplete degeneration and occurs in infectious diseases, such as diphtheria, scarlet fever, acute rheumatic polyarthritis, and sepsis, a fact already well-known to the clinicians.

The point at which the left middle arch passes with a niche into the inferior arch, is a point of considerable diagnostic importance,[3] for it corresponds to the upper limiting point of the left ventricle. In the erect position of the patient this point is placed a little below the upper terminal point of the arch of the right auricle on the other side; but in diseased conditions these points alter their relative positions; thus, for instance, the left limiting point in mitral stenosis is considerably lower than the right.

[1] Dietlen and Kaufmann, *l.c.*

[2] Almost verbally after Kienböck, *l.c.*

[3] Gerhartz: Leitfaden der Röntgenologie. Urban u. Schwarzenberg, 1922.

If one finds in a patient of advanced years *an oblique heart* of fairly normal size, which has not been displaced upwards into the chest, but rather is much lower than usual or is slung in relation to an accompanying depression of the diaphragm, we have to deal with a typical *old-age heart*. Old-age hearts are nearly always somewhat dilated.[1]

The normal proportion between the right and the left median-distance (= distance of the most lateral point of the right and left shadow of the heart from the middle sagittal plane of the body) amounts in adult men in a horizontal position to 1 : 2·1 ; in young women to 1 : 2·4 ; in children 1 : 2·2 (the striking figure 2·4 for the left portion of the heart shadow in women is a consequence of the form of the chest and costal breathing and the associated high position of the diaphragm, which is specially pronounced on the right half of the diaphragm. Moreover, in women the inspiratory movement of the diaphragm is less and the heart is placed somewhat higher in the thorax, and as is a general rule in elevation of the diaphragm is pressed more to the left side). In standing and sitting the proportion for men is 1 : 1·9. *In old people* the heart is more frequently displaced to the left than in the young. The reason : loss of elasticity of the suspensory ligaments and old-age hypertrophy of the left ventricle.

A moderate displacement of the heart upwards and to the left, simulating an enlargement, takes place in *pregnancy*.

A strikingly narrow, small, vertically placed heart (cor pendulum) is met with very frequently in tuberculous patients or in the children of tuberculous people, without any particular complaints being made of the heart (in peace-time). Such hearts are regarded as a consequent expression of a general under-nutrition, although there are many points about them still to be cleared up. To this group belongs Fig. 211, No. 5096 ; woman with tuberculosis of the lungs, whose mother died of tuberculosis. It is not so centrally placed, but on account of its narrowness belongs to the same group as the heart in Fig. 213, No. 5364 : twenty-year-old apparently healthy maiden, whose father died of galloping consumption two years after her birth, and who already at the age of twelve showed a very large calcified bronchial gland below the left hilus. A good example of the pathologically small heart, of the hypoplastic or drop-heart, the constitutional cardiac debility (of Kraus, 1905) is given in Fig. 213, No. 3042.[2] It is usually associated with a want of development of the rest of the body, especially of the sexual apparatus of the body. Narrowing of the aorta is usually present at the same time (although not in this case). Even in the mid-position the heart does not rest against the diaphragm. Depression of the diaphragm is therefore not the cause of the vertical position of the drop-heart (in contradistinction to the typical cor pendulum, which is united with an extreme depression of the diaphragm and whose affinity to drop-

[1] Dietlen, *l.c.*—Kraus : Über constitutionelle Schwäche des Herzens. Deutsche Medizin, Wochenschr., 1917, No. 37.—Staub : Über das " kleine Herz." Münchener Med. Wochenschr., 1917, p. 1442. After Staub, *l.c.*

[2] Moritz ; see Groedel, *l.c.*, p. 57.

heart has been contested). In the drop-heart we have to deal not with an exaggerated "long-chest" but with a specially depressed diaphragm. In our case it is not a question of a long-chestedness or of a paralytic thorax; regarding the position of the diaphragm it should be noted that the photograph was taken in deep inspiration. Others reckon that there are four types of röntgenological shadows of "small hearts": (1) Narrow hearts with normal arched contours; (2) normally configurated hearts, but with a narrow vascular band above it; (3) heart with a well-marked usually strongly pulsating left middle arch; (4) the drop-heart; in it the details of the normal heart picture are lacking, the right and the left margin of the heart being almost parallel. The heart shadow scarcely touches the diaphragm and is centrally placed. These forms of heart are rare and are not to be confused with a vertical or obliquely placed small heart, that has

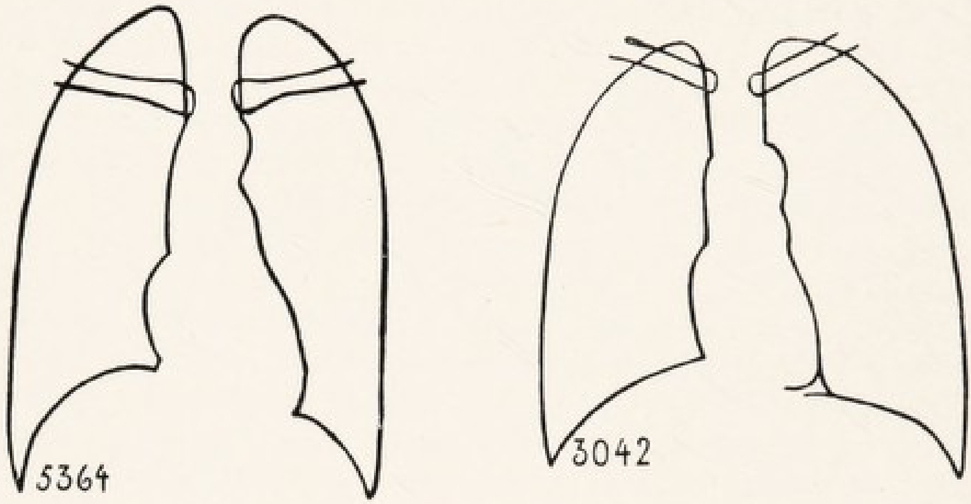


FIG. 213.

been generally described as drop-heart, but in which the arch contours are normal and the heart rests upon the diaphragm to an extent corresponding to its size. These drop-hearts are found exclusively in severe cases of tuberculosis. The reader perceives that there is little clearness or unity concerning the idea of the drop-heart, pendulum heart, and hypoplastic heart. Seeing the description "drop-heart" is now always associated with the idea of a constitutional heart weakness and more recently also with the idea of a hypoplasia, it has been suggested for the other forms of a similar shape the term "narrow vertical heart" should be employed, especially seeing there are many narrow hearts of drop-form which have nothing to do with either of the above groups.[1] The transverse-dimension is usually under twelve, and cases of under ten, at least when the patient is standing, are not rare. A narrow and vertically placed heart is, generally speaking, not at all an under-value or hypoplastic heart, estimated according to the size only, but in most cases is only one manifestation of a generally constitutional anomaly. To sum up: one should draw no strict dividing line between drop-heart, pendulum heart, asthenic heart, hanging heart,

[1] Dietlen, A. Hoffmann, Wenckebach, quoted by Dietlen.

median-placed vertical heart, as far at any rate as the Röntgen picture is concerned. In no case should one group these different forms of heart under the term " small heart." The clinical findings are the decisive factor in any single case. The description " small heart " contains the idea and estimate of a small and hypoplastic heart. This term should be reserved for cases in which a disproportion between the volume of the heart and the size of the body can be certainly accepted or proven. At that rate we would not find many small hearts. Further, it is not every drop-heart that is a small heart, while, on the other hand, small hearts can appear not only in the form of a drop-heart, but under any form. In war the ordinary drop —pendulum—etc., hearts proved quite serviceable, and often proved capable of the demands made upon them.[1]

A small heart is frequently found in patients suffering from carcinoma, and it is said to occur also in Addison's disease.

Temporary reduction in the size of a heart after hard and long-continued exertions speaks for a normal heart. In Boston Marathon-runners there was no sign of dilatation of the heart. In the majority the heart immediately after the race was found somewhat smaller, becoming normal again within a few hours.[2] It is also now established that *an enlargement of the heart* is certainly present during work.[3] The heart becomes smaller on the acceleration of the pulse and enlarges on slowing of the pulse.

Temporary diminution of the heart also takes place in hysterical stenocardia and in bronchial asthma, and for a short time after severe losses of blood.[4]

The diagnosis of " sclerosis of the coronary arteries " from the röntgenogram has not yet been achieved in the living subject, although it has been done in one or two subjects. Firstly, the smallness of the vessels and their distance from the photographic plate makes it practically impossible ; secondly, researches on the subject have shown that sclerosis of the coronary vessels is but seldom accompanied by *calcification*. Sclerosis without calcification can hardly ever be represented röntgenographically in the coronary vessels. Recently in one case, taken with the Potter-Bucky grid, two parallel shadow-lines have been reported in a branch of the left coronary artery, or rather of its horizontal branch.[5]

If a heart which shows quite a normal form on inspiration rests upon the diaphragm in expiration in the form of a badly filled purse, a formless mass, a lump of dough (" sign of expiratory flattening "), we have to deal with a relaxed atonic heart. Its longitudinal axis has moved from its earlier

[1] The last paragraph is almost verbally from Dietlen, *l.c.*

[2] Burgess Gordon : The effect of effort on the size of the heart. Observations on animals and Marathon-runners. Am. J. of Röntg., November, 1925.

[3] Nicolai and Zuntz : Füllung und Entleerung des Herzens bei Ruhe und Arbeit. Berl. klin. Wochenschr., 1914, No. 18.

[4] Dietlen, *l.c.*

[5] R. Lenk : Röntgendiagnose der Coronar-Sklerose in vivo. Fortschritte, Bd. 35, 6, 1927.

more vertical position into an almost horizontal one, the cardio-diaphragmatic angle is therefore smaller in expiration and has moved more to the right. The form of the heart is completely altered, it appears, so to speak, broken up, broadens out to the right and to the left, and it takes on the form of the cupola of the diaphragm.[1] The muscle-fibres of the heart have lost some of their tone and are no longer able to resist the elevation of the diaphragm. The sign is a very useful one, it points to an organic foundation for the complaint, Fig. 214. It confirms directly the diagnosis of reduced mechanical power secured from the clinical examination. The condition

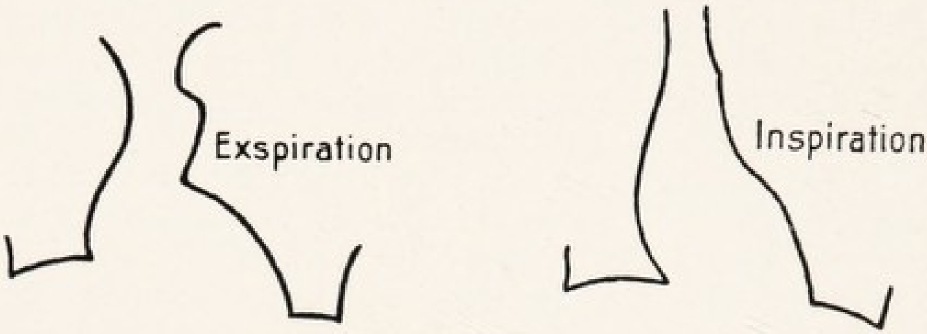


FIG. 214.[2]

has been repeatedly found in the case of soldiers, who have been exposed to any influences injurious to the heart (deprivations, punishments, injections). The term "cordatony"[3] is sometimes given to these hearts, but is best reserved for the autoptic findings of those bodies which have died of wasting diseases or of conditions specially deleterious to the heart muscle. Such a heart in contradistinction to a good contracted heart muscle does not retain its form when laid upon the table or when placed upon the hand; it falls much more apart, takes the shape of what it is laid on, exactly like the exhausted muscle of a suddenly paralysed limb.[4] The phenomenon of the relaxed heart can be brought into view from forced expiration and also by gaseous distension of the stomach; it can often be better made out in the second oblique diameter than in the sagittal view.

The author is in a position to illustrate two cases similar in stature, similar in height and width of chest, and of like size and tone of the heart, of similar position in respiration, but of quite different condition of the diaphragm, Fig. 215. In the first case (No. 1615; same case as Fig. 205) we are dealing with a rigid thorax owing to malformations of the ribs, with a roof-shaped condition of diaphragm (only on inspiration!), in the other case (No. 8618) we are dealing with an elevation of the left half of the diaphragm of moderate degree, which one sees fairly often. The different appearance of the heart shadow is of interest.

[1] Zehbe: Beobachtungen am Herzen und der Aorta. Deutsche Mediz. Wochenschr., 1916, No. 11.—C. Plaut: Über schlaffe Herzen im Röntgenbilde (zugleich zur Beurteilung des Zehbeschen Phänomens). Fortschritte, Bd. 26, 1918.

[2] After Plaut, *l.c.*

[3] A. Hoffmann.

[4] C. Plaut, *l.c.*

Broad, plump, slightly differentiated hearts resting broadly on the diaphragm indicate a generalised dilatation.

Rounded hearts are common in *goitre* subjects.[1]

Duplication of the contours of the heart shadow may occur, *e.g.* in mediastinal pleurisy (see above), in extreme enlargement of the left auricle, in retrocardial aneurism, in cold abscess of the dorsal vertebral column (see later), in spondylarthritis deformans, in parœsophageal diaphragmatic hernia, in dilatation of the œsophagus, in cardiospasm, in scoliosis, and in fatty heart.[2]

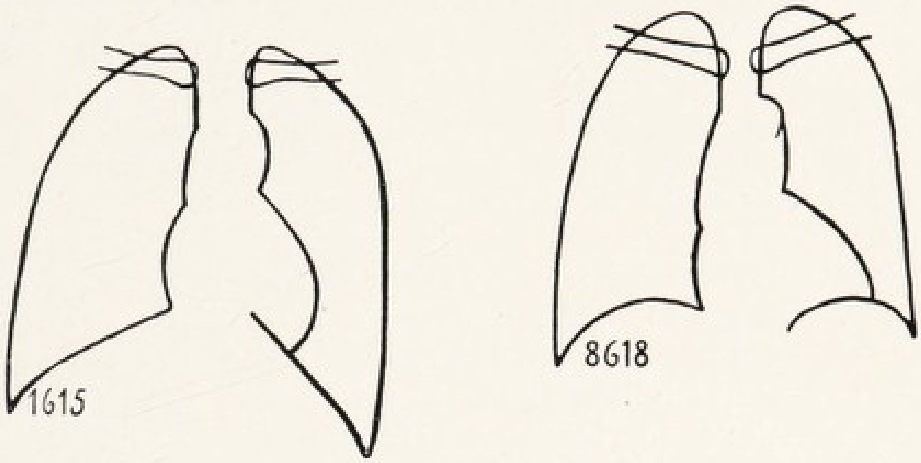


FIG. 215.

Alterations of Particular Chambers of the Heart

Large and considerable changes in one part of the outline of the heart, as appear especially in valvular lesions, need not be included in the scope of this work ; usually ausculatation is employed at the commencement of the pathological process and gives us the diagnosis.[3] Nevertheless, in view of the slighter degrees of enlargement and the diminution of the various parts of the heart, we are bound to describe what the radiologist is wont to miss, what he exaggerates, and what he is in practice apt to misinterpret. One should especially note : In murmurs over the apex of the heart and the aorta, and in lack of other definite signs a more or less circular shadow of the heart widened from the right below to the left above points to mitral insufficiency, a heart enlarged longitudinally towards the left and below indicate an aortic insufficiency. For details, see the next paragraphs.

[1] M. Otten : Die Bedeutung der Orthodiagraphie für die Erkennung der beginnenden Herzerweiterung. D. Arch. f. kl. Med., 1912, p. 370.

[2] L. J. van der Mandele : Über einen Fall von Pleuritis mediastinalis u. über den Doppelkontur des Herzschattens im Röntgenbild. Fortschritte, Bd. 34, 1/2, 1926.

[3] Thorough particulars on the pronounced variations of the several chambers of the heart appear in the aforementioned books of Dietlen, Groedel, also Vaquez and Bordet. The first pictures are probably those in Santiard : L'air de projection du Cœur. Thesis, Paris, 1900 ; and by the author in Manual of Clinical Examination Methods, by Eulenberg, Kolle, and Weintraud, 1903. Edition by Urban and Schwarzenberg (see the bromide silver table accompanying text).

Left Side of the Heart

The apex of the heart is rounder in the horizontal than in the standing position, reaches further outwards, and often also further upwards, relatively to the arch of the diaphragm.

Sometimes *the apical impulse* appears outside the border of the heart (cause : oblique direction of action of the apical impulse).[1] Hence the apparent displacement is all the greater, the thicker the chest wall and the stronger the pulsation. So that in a broad or strongly pulsatile apical impulse it is easy to make a mistake in percussing the cardiac dulness of the heart.

If on photographing the heart in the standing position, in spite of an absolutely sharp clear-cut picture, the apex of the heart is seen covered with a kind of *veil of light*, that should not be regarded in any way pathological. The appearance is produced by the rich secondary radiation from the air-sac of the stomach, causing a want of definition at the apex.

If in the heart shadow of corpulent people *the apex of the heart* is not well-rounded but appears pointed and drawn-out downwards and outwards, the cause is likely to be the masses of fat situated upon the pericardial surface.[2] Sometimes in the ascending pulmonary part the cardiac margin appears indentated, which is also due to the pericardial collection of fat. Caution : confusion with pericarditis ! This pericardial collection of fat often occurs in tuberculous patients and not only in those who are particularly well fed.[3] Further, when the margin of the heart shadow appears somewhat dull (in instantaneous photographs), especially at the upper part of the left inferior arch, we can diagnose a pericardial collection of fat at the point.[4]

In the normal heart the cardiac apex becomes elevated on deep inspiration in its whole extent from the left half of the diaphragm ; if movement upwards to the apex does not occur, *hypertrophy of the ventricle*, and especially of the left ventricle, is present.[5] Thus a strikingly broad, plump, almost circular-formed cardiac apex, which does not merge into the shadow of the diaphragm, but is placed above the cupola of the diaphragm—often in the horizontal position, frequently in the standing position, and almost always on deep inspiration—is *typical of the heart of aortic insufficiency*. At the same time the shadow of the aortic arch appears to be broadened (duck form of the heart !). In *pure aortic stenosis* the apex is neither plump nor circular.[6]

[1] Moritz ; see Groedel, *l.c.*, p. 57.

[2] G. Schwarz : Über einen typischen Röntgenbefund am Herzen Fettleibiger. Wiener kl. Wochschr., 1910, No. 51.—Roemheld : D. Arch. f. kiln. Med., 1913, No. 3.

[3] Dietlen.

[4] Munk, *l.c.*

[5] J. M. Woodburn Morison and L. White : A radioscopic method of estimating hypertrophy of the left ventricle. Arch. of Rad. and Elec., February, 1919.—P. Schrumpf : Klinische Herzdiagnostik. Berlin, 1919 (Springer).

[6] Dietlen, *l.c.*

Hearts of the aortic insufficiency type occur also in the early stages of *granular kidney*. The heart picture in commencing *hypertony* is similar.

In röntgenograms, especially in men, when taken upon deep inspiration, the *left ventricular contour* exhibits not a well-curved line, but a very flat arch that is almost a straight line. The beginner may mistake this for a relaxed heart. The opposite is more like the case. Such plates prove only that the cardiac musculature is good, normal, and elastic, and yields to the pericardium stretched taut on deep inspiration ; the heart in these cases is rotated somewhat backwards. In hypertrophy of the left ventricle this stretching of the arch is not found.

In hearts very considerably enlarged to the left the *exact Röntgen examination* indicates a smaller heart than does *percussion*. Although apparently paradoxical this interpretation can be explained by simple physical laws.[1]

A more *parabolic* delimitation corresponds to a normal ventricle, a more *hyperbolic* to a dilated one, a more *elliptic* to a hypertrophied left ventricle.[2] This, however, is not generally admitted. Only this much appears certain, that a marked curving, especially of the lower part of the left ventricular margin, indicates hypertrophy. The cardiac dimension in the other diameters may remain quite normal.[3]

A small enlargement of the left chamber of the heart may be doubtful in anterior view, while in the second oblique diameter (from the right posterior to the left anterior) it may be quite plain, for the left ventricle belongs in general to the dorsal part of the heart.[4]

Marked curving of the arch of the left ventricle, greater plumpness of the cardiac apex, strengthened cardiac action, with often a distinct break between auricle and ventricle, speaks more for *hypertrophy* than for *dilatation*. Retrogression of the enlargement in successful therapy is a proof that it is dilatation we are dealing with.[5]

Enlargement of the heart to the left can be simulated in a normally-sized heart, in an oblique-set heart, and when an enlarged right chamber presses the left margin of the heart backwards and outwards, thereby causing an apparent enlargement of the left chamber.[6] To decide examine the patient in the profile position.

If the left ventricular margin is curved more in *the basal part* of the chamber than in the apical part, this indicates a mitral insufficiency.

The left chamber while normal may appear diminished by the heart rotating about a vertical axis (vertical heart, drop-heart).

If the transverse diameter approximates to (or exceeds) the longi-

[1] See the explanation in Groedel's atlas.

[2] G. Schwarz: Über röntgenoskopische Messungen und Analyse der Herzkammer-Pulsationen. Med. Klin., 1920, No. 32.

[3] Dietlen, *l.c.*

[4] Vaquez and Bordet.

[5] Haudek, *l.c.*, and Dietlen, *l.c.*

[6] Dietlen and Vaquez and Bordet.

tudinal diameter, that is typical of mitral insufficiency ; in enlargement of the left ventricle from other causes this relationship does not obtain.[1]

In spite of a normal anterior picture *an isolated enlargement of the left auricle* may be present—which though rare does sometimes occur in slowly developed mitral stenosis. The auricle becomes enlarged at first, especially in the ventro-dorsal direction. Therefore the enlargement is best recognised in the left profile view and in the first oblique diameter.[2]

Circumscribed rounded projections of the heart's shadow are found in *aneurism of the heart ;* this is a very rare occurrence. They appear at the cardiac apex and its anterior surface, and may easily be missed.[3]

An almost constant feature *in mitral stenosis* is the definite enlargement of the volume of the left auricle with an ovoid form of the heart shadow and without any marked enlargement of the heart shadow. Dilatations of the left auricle with marked systolic pulsation and rounded from the heart with evident enlargement of the cardiac shadow, are almost certainly ascribable to *mitral insufficiency*.[4]

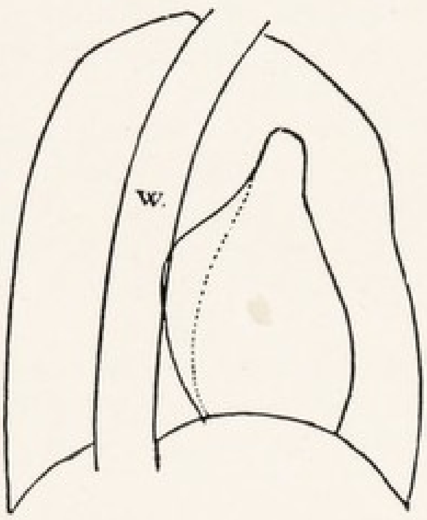


Fig. 216.[5]

The point at which the left middle arch passes with a break into the inferior arch is *a point of remarkable diagnostic importance,* for it corresponds to the upper limiting point of the left ventricle. In the erect position of the patient the point is placed a little inferior to the upper terminal point of the arch of the right auricle on the other side ; but in disease the relation between these three fixed points becomes altered, so that in mitral stenosis, for instance, the left limiting point is considerably lower than the right one.[6]

A marked darkening of the middle third in the first oblique diameter (right side of chest on plate, body turned about 50°, left side of chest away from the plate) is due to an arching out (enlargement) of the left auricle (in mitral insufficiency ; it is found especially in mitral stenosis, in patency of the Ductus Botalli, see Fig. 216, in congenital aortic stenosis, in goitrous hearts, and in slighter degrees of drop-heart).

A frequent type of pulmonary tubercle starts in the left upper lobe (see Fig. 217). The author has quite a number of almost identical pictures. In these the heart shadow moves out to the left and the pulmonary arch projects markedly outwards, probably owing to pleural adhesions.

The enlargement of the pulmonary arch was formerly regarded by German authors as typical of *a patent Ductus Botalli,* while French radiologists con-

[1] Dietlen, *l.c.* [2] *Ibid.*

[3] Kienböck, Kraus, Christian, and Frick, Assmann, quoted by Dietlen.

[4] Translated from Pesci : L'aumento di volume della arecchietta sinistra del cuore nel quadro röntgenologico. La radiologia medica, 1914, No. 3.

[5] From H. Gerhartz : see previous footnote.

[6] Gerhartz : Leitfaden der Röntgenologie, 1922 (Urban and Schwarzenberg).

sidered it to be typical of *pulmonary stenosis*. This diagnostic dispute has not yet been settled. Certainly the Röntgen pictures of pulmonary dilatation do occur in such different conditions as persistent Ductus Botalli and pulmonary stenosis. Pulmonary dilatation appears in congestion and heightening of pressure in the lesser circulation (mitral defects, especially mitral stenosis, contraction processes, especially in the hilus-glands and in pulmonary tuberculosis, and also in other pulmonary affections leading to heightening of pressure in the lesser circulation, also in emphysematous heart and severe cases of scoliosis). Pulmonary dilatation following pulmonary aneurism, or in consequence of rupture of an aortic aneurism into the

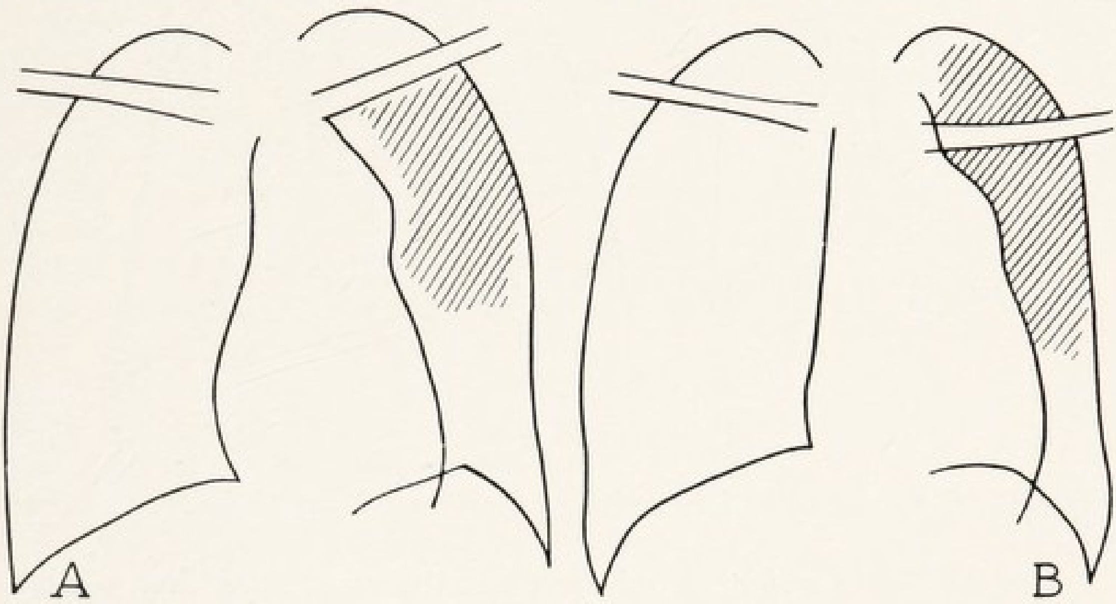


Fig. 217.

pulmonary artery or through endocarditic pulmonary-insufficiency, is very rare. The dilatation is most prominent in the first oblique diameter and shows increased pulsation, and in addition a broadened, abnormally dark, and strongly self-pulsatile hilus-shadow. Patent Ductus Botalli should only be diagnosed in an accentuation of the second pulmonic sound and conduction of the characteristic murmur in the second and third intercostal space, to the vessels of the neck and to the back ; other clinical signs are also present. Pulmonary stenosis does produce considerable dilatation, but is seldom seen alone. In an accompanying *defect of the ventricular septum* (frequently a congenital defect) the dilatation of the pulmonary is entirely absent.[1]

The diagram of the author shown in Fig. 218, A, shows us a dilated pulmonary arch. The picture of another congenital cardiac lesion is given in Fig. 218, B. In a marked case of morbus cœruleus the author could discover not the slightest alteration of the figure of the heart ;[2] see also Fig. 209 and its text.

[1] Assmann and Dietlen, *l.c.*

[2] In this section one should refer to a short communication by R. Gassul : Über einen offenen Ductus Botalli mit Beteiligung des linken Herzens (ohne autoptische Kontrolle). Fortschritte, Bd. 28, 1921.

A subdivided pulmonary arch takes place in enlargement of the right ventricle. The lower part of the arch is then formed by the conus arteriosus being cranially displaced. In general, in quite normal hearts and in normal pulmonary artery, the arching of the shadow-contour is somewhat increased in the first oblique diameter, which brings the conus arteriosus into better view.[1] A slight degree of dilatation, especially if associated with accentuation of the second pulmonic sound, has been observed in young powerful males who have gone in much for sport, and in soldiers ; probably also in

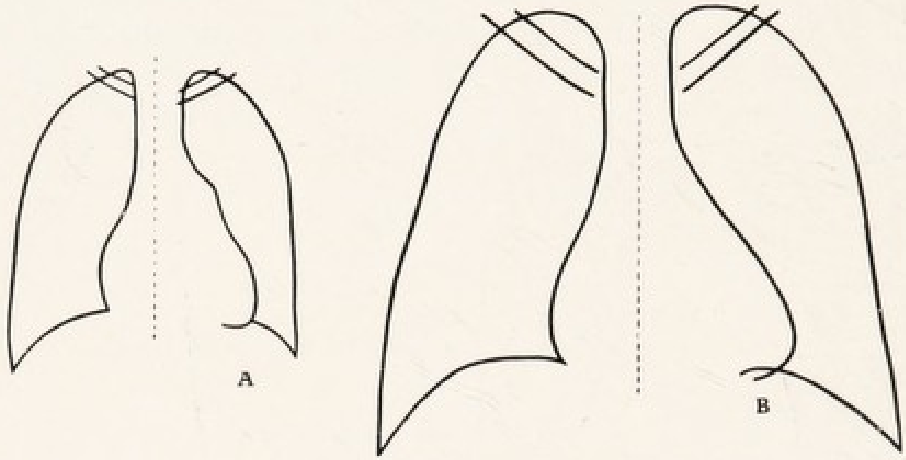


FIG. 218.

emphysema, as an expression of the marked congestion of the lesser circulation.

For *the highest arch of the left heart* and the vascular shadow, see later under " Aortic arch and associated vessels."

Right Half of the Heart

If the *right auricular arch* appears divided, it usually indicates congestion of the chambers. The upper part then corresponds to the right auricle (?), the lower part to the right ventricle.

If the *right auricular margin* cannot be recognised, *i.e.* if it does not project to the right beyond the shadow of the vertebral column, in many cases the cause of this is a drawing of the heart to the left (in consequence of pleuro-pericardial adhesions) ; in narrower hearts quite a moderate scoliosis of the dorsal vertebrae to the right suffices to conceal the contour of the auricle completely.

If a definite arch oversteps the right auricular contour (*i.e.* joins it above) more than 2 cm. beyond the right margin of the vertebral column, we have to deal as a rule with *dilatation of the aortic arch* (see later " Aortic arch"). In spite of 4 cm. (perhaps 5 cm.) projection the aortic arch can still be normal, especially in all cases in which the heart through any cause reaches or has been displaced more to the right, *e.g.* in low broad thorax, in

[1] Dietlen, *l.c.*

elevation of the left half of the diaphragm by a large gastric air-sac or a rudimentary eventration, in right pleuro-pericardial adhesions, and in enlargement of the right heart.

When in the cardiac pictures of *thin* persons free from pleuro-pericardial adhesions the shadow of *the right auricle* projects further than 2–2½ cm. beyond the right margin of the vertebral column, we might diagnose a pathological change in the size of the heart.

The most marked dilatation and heightening of the right auricle is met with in consequence of failure of the mitral valve in *tricuspid insufficiency*.[1]

If *the inferior contour of the right auricle* does not form a sharp angle with the right diaphragm, but passes over with a convex arch into the contour of the diaphragm (as above in Fig. 204, B), we have to deal with a rare, but innocent, condition. It is perhaps just an abnormal insertion of the pericardium. Further, the inferior vena cava occupies and fills out the angle in about half the cases.

Moreover, *in profile pictures* the sharp angle which the postero-inferior contour of the heart forms with the diaphragm is filled up by a small triangular shadow, which is distinguishable as the inferior vena cava.

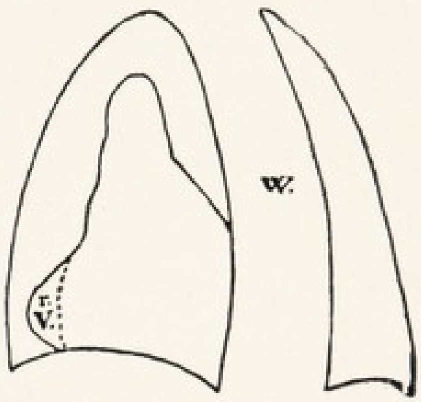


Fig. 219.[2]

The enlargement of the right ventricle is best recognised by raying in the second oblique diameter (see Fig. 219), in which the left chest is resting against the screen, the body is turned about 50°, and the right side of the chest is turned away from the screen (remember that one finds enlargement of the right ventricle especially in mitral defects, in pulmonary stenosis, and in defects of the ventricular septum ; enlargement of the left ventricle following upon aortic stenosis, aortic insufficiency, a general sclerosis, in chronic nephritis, and lead poisoning).

Displacement of the whole heart to the right (" *centrally situated* "), especially of the right auricle through the enlargement of the right chamber and the enlargement of the left auricle pressing against the spine, is for the most part an expression of the rotation of the heart ; it is in a large measure due to the smallness of the left ventricle, and is found especially in the heart of mitral stenosis.

In *hypertrophy of the right chamber* and a consequent increase in the pressure and enlargement of the pulmonary arteries, *i.e.* in mitral lesions, one usually sees on the screen " *dark lungs*," the röntgenological sign of increased fluid in the lungs through congestion and *brown induration*.[3]

[1] Dietlen, *l.c.*

[2] According to Vaquez and Bordet, *l.c.* " r. V."=right ventricle. Le cœur et l'aorte. Abb. 34, 1913. Paris (Baillière).

[3] Assmann, *l.c.*

PERICARDIUM [1]

The pericardium cannot be seen in the majority of Röntgen pictures; it is only in deep inspiration that a shadow, string-like or band-like in appearance, appears on many films running outwards and down from the apex of the heart to the diaphragm; this is neither more nor less than the stretched left lateral wall of the pericardium. The right lateral wall has been already discussed.

If in an otherwise sharp thoracic picture the shadow of the heart fails to appear sharp in contour, but with its margins obliterated, the complementary spaces of the heart filled out, and the hollows between the several parts of the heart elevated, the whole cardiac shadow being roughly triangular, that is the typical appearance seen in an acute exudative *pericarditis* (and often too in subacute pericarditis). Many even declare that they have seen the heart shadow like a denser nucleus in the lighter shadow of the exudate. In screening hardly any pulsation is visible. If a very small effusion be suspected the stomach can be blown up with an effervescent mixture and the lower margin of the heart examined, whose pulsation is obliterated even with small effusions.[2] The tobacco-pouch form is also typical of pericarditis. It has recently been discussed in the literature [3] whether the heart can be differentiated from a pericardial effusion by the Röntgen rays. The author's opinion is that while that is theoretically possible it is a practical impossibility.

The possibility of the formation of a cardiac-nucleus shadow in the exact meaning of the term has therefore to be definitely rejected. A central denser shadow can occur occasionally in mediastinal pleuritis (see above), posterior mediastinitis, gravitation abscess, and fibrous formations in the pleura and pericardium, but this is never identical with the shadow-view of the heart. The author of this work is strongly of opinion that the heart is not visible in the pericardial sac.

In marked lateral displacement to right and left in serous pericarditis a displacement and change in the form of the heart shadow has been observed, *i.e.* a curving out due to the displacement of fluid.[4]

A *daily enlargement of the cardiac shadow* is the natural result of an increasing exudate; the increase being seen most clearly towards the right.

[1] Römheld: Das Röntgenbild des Perikards. Deutsches Arch f. klin. Med., Bd. 106, Heft 1 and 2.—Brauer: Erkrankungen des Perikards, in Atlas Groedel, 4th edition.—Dietlen: Röntgendiagnostik bei Erkrankungen des Perikards, in Rieder-Rosenthal, Lehrbuch für Röntgenkunde (Leipzig, 1913, Barth).—The same: Herz und Gefässe im Röntgenbild. 1923. (Leipzig, Barth).

[2] Maragliano: Nuovo segno röntgenologico dei versamenti pericardiaci. La Riforma medica, 1912, Nos. 40 and 42.

[3] H. Kloiber and H. Hochschild: Zur Frage des röntgenologischen Sichtbarwerdens des Herzens im Perikardialerguss. Fortschritte, Bd. 27, 1921.—W. Amelung: Zur Frage der doppelten Konturierung des Herzschattens im Röntgenbilde bei Pericarditis. Fortschritte, Bd. 28, 1922.—Walter Schmidt: Experimentelle Untersuchungen zur Kernschattenfrage bei Perikarditis exsudativa. Fortschritte, Bd. 35, 1927.

[4] Kamenetzky and Rabinowitsch: Zur Symptomatologie der Pericarditis exsudativa. M. m. W., 1926, 12, p. 478.

Projections and jagged elevations in cardiac edges not sharply defined, in a negative that is otherwise absolutely sharp and perfect, indicates the after result of a *pericarditis* (adhesions). (On the other hand, adhesions can be seen at the autopsy which are not visible on radiation.) It has not hitherto been found possible to distinguish purely intra-pericardial from purely extra-pericardial adhesions. The favourite sites for adhesions are the pulmonary artery, the apex of the heart, and the angle between the heart and the diaphragm, and sometimes the whole left side of the heart can take on the appearance of a mitral-stenosis through mediastino-pericardial adhesions, as seen, for example, in Fig. 220.[1] In addition, it is to be noted that parts of the lung-fields, pathologically denser patches, that have nothing to do with pericardial adhesions, may be mistaken for such when projected into the diaphragmatic angle. The notching or crumpling of the cardiac margins is best seen on deep inspiration. The movements of the pericardium on respiration are naturally either diminished or stopped.

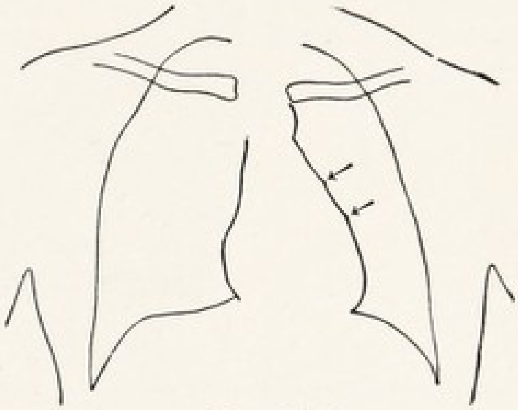


Fig. 220.[1]

If in profile irradiation the heart does not move downwards on inspiration or even moves upwards, the heart may be diagnosed as adherent to the sternum, provided there be no other condition present.[2]

Clasp-like shadows of bony density may surround the heart shadow or be deposited against it (and these are often missed in spite of their density on soft under-illuminated negatives and also in screening); several cases of the sort have been described; they are due to deposits of lime in old pericardial scars. The left side of the heart is the favourite site for these deposits, yet both ventricles may be affected and surrounded by a thick framework ("*armour-heart*"), the auricles usually remaining free. According to other authors, the pericardial calcification begins at the outer or anterior side of the right ventricle, where it doubtless is often concealed by the shadow of the diaphragm. If one sees calcareous deposits in the left side in the pericardium the diseased process is probably already relatively advanced.[3] A recent case carefully studied clinically and by the Röntgen rays[4] (see Fig. 221) is specially remarkable, for its discovery was one of pure accident and made during a radiation of the thorax preceding a gastric examination. Subjectively the man, a cartwright of thirty years, felt perfectly well, and used

[1] From Dietlen, "Heart and Vessels," *l.c.*

[2] Achelis: Über adhaesive Pericarditis. D. Arch. f. kl. Med., 1914, 115, p. 419.

[3] Alfred Weil: Panzerherz und Picksche Leberzirrhose. Fortschritte, Bd. 23, 1915/16 (with list of the literature).—Ernst Friedrich Müller: Perikarditische Verkalkungen. Fortschritte, Bd. 15, 1918 (with list of the literature).

[4] M. Zehbe: Ein Fall von Panzerherz. Fortschritte, Bd. 30, 1923.—Possibly certain miraculous manifestations can be explained in this way, *e.g.* that of Joan of Arc: "Her heart would not burn." Bernard Shaw: "Joan of Arc."

to cycle to his work four times daily. Objectively: a small heart, a low blood-pressure, delayed recuperation power in the heart, congestion in the pulmonary circulation, all symptomatic of commencing insufficiency in the heart. Röntgenological findings: a rich deposit of lime on the posterior and under surface of the right heart (both of the ventricle and of the auricle), also a ring of lime surrounding the heart at the coronary sulcus, the left heart taking little part in the process. Another investigator[1] found the under surface of the heart to be th- site of predilection for peri cardial calcifications. He found them divided up or forming a net or ring round the heart close under the coronary sulcus, or in lines radiating out from a centre. A calcification within the annulus fibrosus was sharply delimited and without outgrowths. A colleague[2] describes a case where the condition must have been present for at least twenty years. The course of the disease must always be regarded as extremely chronic. The coronary sulcus is believed to be the commencing point of the calcification. The apex of the heart can be included in the calcification, while the conus arteriosus (infundibulum) as the place of the strongest movement in the heart may remain free from it.

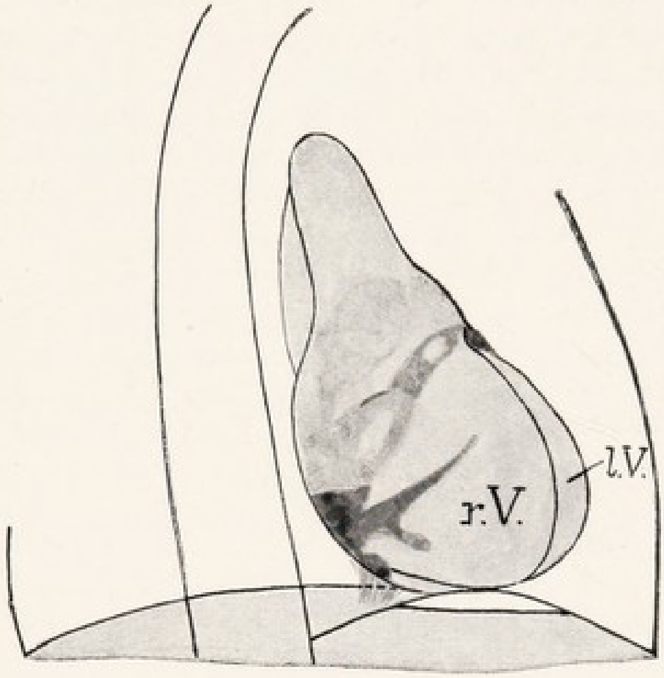


Fig. 221.[3]

THE AORTIC ARCH AND ASSOCIATED VESSELS[4]

General

For the avoidance of repetitions refer to the chapter on " Heart " and more particularly the parts " General," " Teleradiography," " Orthodia-

[1] T. Klason: Pericarditis calculosa und Herzverkalkungen. Acta Radiologica, Vol. I, 1921.

[2] Friedländer: Über Panzerherz. Fortschritte, Bd. 34, 1/2, 1926.

[3] See footnote 4, p. 357.

[4] For literature see the section on " The Heart "; further Stadler and Albrecht: Über Sklerose u. Erweiterung des Truncus anonymus. D. Arch. f. kl. Med., 1911.—P. Schrumpf: Die Syphilis des Herzens und der Gefässe. Ztschr. f. phys. u. diät. Therapie, 1918, p. 22.—E. Romberg: Krankheiten des Herzens. 3rd ed. 1921. (Enke, Stuttgart.)—G. Hubert: Deutsch. Arch. f. klin. Med., 1919; and Münch. Med. Wschr., 1919.—M. Zehbe: Beobachtungen am Herzen und der Aorta. Deutsche M. Wschr., 1916, No. 11.—Schittenhelm:

graphy," "Composition of the normal cardiac shadow," "Pulsation," "Heart of the infant and child," and the various drawings in that section.

In the aorta as in the heart there is no sharp line between *the normal* and the *pathological*.

Remarkable differences occur in the size of the different parts of the thoracic aorta in *infancy* and in *childhood*. The ascending aorta especially grows greatly and compensates for certain changes during the fœtal circulation. The vena cava superior grows comparatively slowly in childhood, and at the age of one year is relatively smaller than at birth. The pulmonary trunk (conus arteriosus) also grows slowly in the first year of life.[1]

In *little children* one should always remember that the shadow of the thymus (see also later under "Thymus") may make it difficult to see the Röntgen view.[2]

After thorough examinations of the subject [3] the following guides were taken to the visibility of the aorta, or rather the parts of the central shadow forming its outlines: Right. At the highest point one sees the outer border of the right truncus venosus traversing the sterno-clavicular angle, and running usually obliquely downwards and inwards. Below that comes the superior vena cava, sometimes vertical, but more often somewhat convex outwards. A small indentation below shows the place it enters the heart. Below that the right auricle arches convexly to the right, and a very evident indentation marks its lower end. Below that again is a very short shadow, the outer border of the inferior vena cava passing to the diaphragm. Left. The upper end varies much in length and changes with the age and height of the aortic arch, it forms most frequently a short vertical line, the border of the sterno-vertebral shadow, the subclavian artery also assisting to form the border. The aortic arch comes next, to the left of the vertebral column; then a vertical portion, sometimes running somewhat obliquely, the first part

Aortitis luica. Münch. m. Wschr., 1921; and Deutsche M. Wschr., 1922.—A. Heuser: Die schräge Durchleuchtung des Thorax mit Röntgenstrahlen. J. Diss. Leipzig, 1910.—Lippmann and Quiring: Die Röntgenunters. der Aortenerkrankungen mit spez. Berücksichtigung d. Aortenlues. Fortschritte, 1912, Bd. 19.—Weiss and Landa: Die Kreuzfuchssche Methode der Aortenmessung. Deutsche M. Wschr., 1921.—Kreuzfuchs and Eisler: Die Röntgendiagnose der Aortensyphilis. Fortschritte, Bd. 21, p. 488.—K. Frik: Zur Deutung des Röntgenbildes im I. schrägen Durchmesser. 13. Tag. d. Deutsch. Röntgen-Gesellsch., 1922. —Groedel, in Schittenhelm's text-book.—Bonnamour, Badolle and Beaupère: J. de Radiology, 1926.—R. Kienböck: Zur röntgenologischen Differentialdiagnose der Aortenaneurysmen und Mediastinal-Tumoren. Fortschritte, Bd. 34, 1926.—J. Erdélyi: Die Bedeutung der Röntgen-Untersuchung der Aorta in der klinischen Diagnostik. Fortschritte, Bd. 35, 5, 1927.—F. M. Groedel: Die Röntgenuntersuchung des Circulationsapparates. Schittenhelm's text-book, 1924, I. Band.—B. H. Nichols: Some observations from a röntgenological study of the aorta. Radiology, August, 1927.—Deneke: Die pathol. Aorta im Röntgenbilde. 16. Röntgenkongress, 1925.—G. Huber: Aortensyphilis. Klin. Wchnschr., 1924, 3.—R. D. Carman and C. G. Sutherland: Aneurysm of the aorta and abscess of the tracheobronchial lymph glands. Am. J. of Röntg., 1921, VIII, p. 269.

[1] R. E. Scammon: Studies on the growth and structure of the infant thorax. Radiology, August, 1927.

[2] For the thymus see Klose: Chirurgie der Thymusdrüse. Ergebn. d. Chir. und Orthopädie, 8. Bd., Berlin, 1914 (Springer); further Rieder-Rosenthal's text-book.

[3] Delherm and Chaperon: Etude anatomo-röntgénologique de l'ombre médiane cardiovasculaire vue de face. J. de Rad. et d'Electr., January, 1923.

of the descending thoracic aorta, usually 1–2 cm. long, but up to 5 cm. long in senile aorta. Abutting on that next is the pulmonary aorta; it is only in "transverse" hearts that the enlarged left auricular appendix oversteps the border of the pulmonary. The left ventricle then joins the line of the pulmonary aorta from below. It follows from this that the *superior vena cava* is visible in almost every case, after the thirty-fifth year usually in its whole length, and also *the brachio-cephalic venous trunk. In no case has the aorta overstepped the right margin of the superior vena cava.* One measures, therefore, in anterior sagittal views, not the shadow of the aorta, but rather the entire pedicle.

According to others, it is only in the horizontal position that the shadow of the well-filled *superior vena cava* projects in a straight line beyond the border of the aorta; but that is exceptional, and it is more frequent for the aorta to be defined within the shadow of the vena cava.

The length of the aorta increases with *the age* of the individual. Further, the aortic arch is longer and narrower in a long narrow thorax, and shorter and broader in a squat thorax. If in a long thorax and correspondingly long aorta the arching of the aorta is more than usual—in which case the arch of the right auricle is usually pressed downwards—and if the arch curves out to the left, we have to do with a (pathologically) enlarged aorta, with an "*elongation.*"

The aorta is broad and strongly developed, without being pathological, in people who do heavy physical labour.

The shadow of the normal aortic arch *in sagittal views* exhibits a marked projection to either side of the central vertebral shadow only on the left side above and less distinctly on the right side below. With the patient in the horizontal position, the shadow of the better-filled *vena cava superior* always projects in a straight line beyond the edge of the aorta, the outline of which can generally be seen within the superior cava shadow.

In oblique photographs from the left posterior to the right anterior position it was formerly believed that the heart shadow, which is triangular or oval, is continued above directly into a shadow-band with parallel edges or one wedge-shaped from below upwards; this being usually called the "aortic shadow" or the "vascular shadow," ending above freely in the pulmonary field, being demarcated in front sharply from the left pulmonary field, and behind being separated from the vertebral column by a clear space, the "retrovascular space." Careful study [1] has shown that these views are incorrect, that at any rate one should not speak of an "aortic shadow," and that measurements of the aorta in the first oblique diameter have been incorrectly done. In frozen sections (by Braune) it was seen that with a central beam which forms a clear shadow of the descending and ascending aorta (see R_1, Fig. 222), the spine is always covered and (partially at least) the right heart. A free central field can never be got in this way. But on turning the patient in such a way that the central beam traverses the space between the vertebral column and the heart (see R_2), one obtains

[1] K. Frik, *l.c.*

on the screen a clear space between the shadows of these two organs ; the consequence is that the ascending aorta and the descending aorta are separated by a clear space, so that on further turning of the patient to the left the descending aorta is brought into the central field, the " retrovascular and retrocardial space." The frozen section shows a further important point that in the production of the " *aortic shadow* " (in first oblique diameter) not only the aorta but also the *superior vena cava* takes part; this is important because it contains a column of blood and is nearer the plate than the ascending

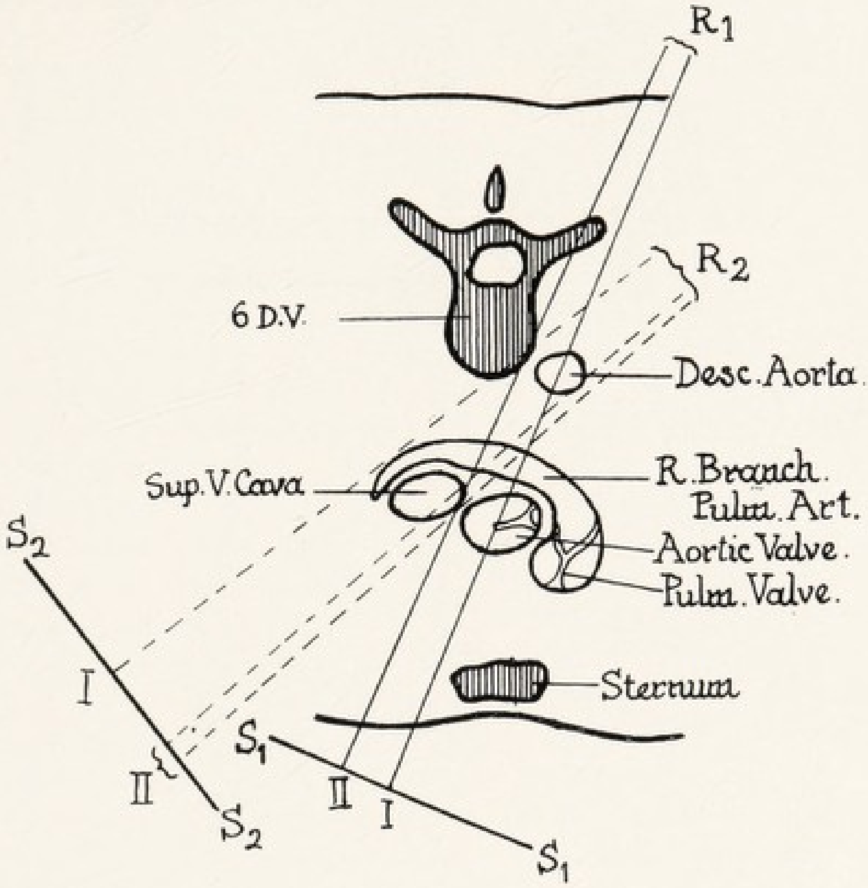


FIG. 222.[1]—Transverse section of the level of the sixth dorsal vertebra ; after Braune.

R_1=Path of rays ; S_1=screen in the first screening position. The central beam I traverses the descending aorta and the ascending aorta ; the beam II tangential to the vertebral column traverses the heart ; there is no free central space.
R_2=Path of rays ; S_2=screen in the second screening position. The central beam I passes between vertebral column and heart ; central space beginning to appear ; the II beam passes freely through between descending and ascending aorta, their shadows being divided. The heart itself is not shown, being at a deeper level.

aorta. Without entering further into all the details and points of contention, let us introduce an illustrative sketch in oblique diameter (Fig. 223) that exhibits the broadest possible space on screen or plate between the heart and the vertebral shadow—at 45° to 80° from the frontal position. This sketch should be carefully studied. At the highest part of the heart-shadow we see the point of division of the pulmonary artery, and this appears so

[1] After Frik, *l.c.*

markedly dense in all good pictures because the branches of the pulmonary artery are photographed in part in the direction of their long axis. This darker shadow has been often mistaken for a tracheo-bronchial collection of glands. Further, the anatomical structures forming the shadow above the base of the heart are the ascending aorta and the vena cava superior ; further

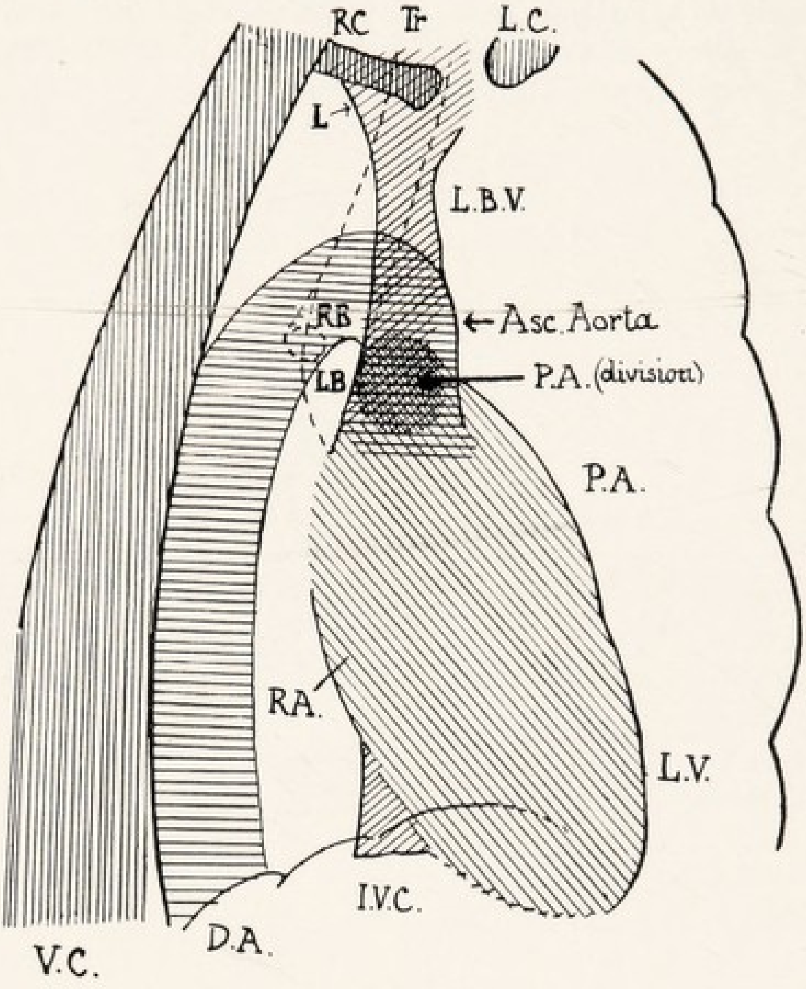


FIG. 223.[1]

From a photograph of a thirty-two-year emphysema case with normal aorta. Turning about 70°. Somewhat diagrammatic. Deep thorax. Broad retrovascular and retrocardial space, so that the whole course of the thoracic aorta can be clearly seen.

R.C.=Right clavicle ; Tr=trachea ; L.C.=left clavicle ; L=edge of the shadow of the right brachio-cephalic vascular stem (serves as guide-line to finding the posterior border of the superior vena cava shadow) ; L.B.V.=edge of the shadow of the left brachio-cephalic vessels ; RB=right bronchus ; LB=left bronchus ; Asc. Aorta=ascending aorta ; P.A.=pulmonary artery, with pulmonary conus ; RA.=right auricle ; L.V.=left ventricle ; V.C.=vertebral column ; D.A.=descending aorta ; I.V.C.=inferior vena cava.

up where the edges of the shadow diverge, there are the brachio-cephalic arterial and venous stems. The posterior margin of the right brachio-cephalic vessels is clearly visible and forms a guide-line (L in the sketch) ; if this be followed from above downwards it indicates how far backwards the posterior

[1] After Frik, *l.c.*

edge of the superior vena cava may be taken to go. In other words, *the posterior border of the so-called "Aortic shadow" is always formed either by the vena cava superior or the vena cava projects a little way behind it.* Further, the superior vena cava being anatomically narrower than the ascending aorta, and nearer to the plate, the shadow of the vein can never reach the anterior border of the so-called "Aortic shadow." Moreover, it is not possible to see the anterior edge of the shadow of the superior vena cava, nor the posterior border of the ascending aorta. The latter disappears completely in the shadow of the superior vena cava, or is covered by its posterior border, or is occluded by the clear space of the trachea. We should therefore use the term "*Vascular shadow*" instead of "Aortic shadow." We cannot measure the breadth of the ascending aorta; what one has measured with this idea is really the distance of the anterior border of the ascending aorta from the posterior border of the superior vena cava! A further difficulty in diagnosis is the intense clear space of the trachea and main bronchi. Even as dense a shadow as the aorta and the superior vena cava can be eclipsed thereby completely or almost completely. In many cases a recognition of the guide-line (see above) is helpful, where actually the posterior edge of the vascular shadow is to be sought; it usually proves impossible to determine the posterior border of the ascending aorta. Further, *the whole arch and the descending aorta* are normally visible as far as the diaphragm. The clear visibility of the descending aorta does not require to be regarded as a sign of arteriosclerosis or dilatation, as hitherto believed. But in order to obtain a good screening or plate for all these conditions, it is essential that *the left scapula* should be quite excluded from the field of vision. One holds the left forearm of the patient immediately above the wrist with the right hand, abducts the upper arm horizontal, bends the elbow at a right angle, and uses it as a handle to draw the upper arm gently forwards, and to rotate it as strongly as possible towards pronation; at the same time one pulls with the left hand on the patient's clothing and turns him into the most favourable position. The right arm of the patient can be slightly withdrawn and allowed to hang down loosely.[1]

In an examination and test of this method[2] it was found that the measurement of the ascending aorta in the first oblique diameter can be rendered of real value. The superior vena cava may be placed at most entirely lateral to the aorta, but is never situated in front of it. That being so the right posterior wall of the vena cava superior can only form the right contour of the vascular stalk, when the patient is photographed in a nearly frontal direction, that is, strictly speaking, when he is no longer in the right anterior oblique position. That the posterior walls of the superior vena cava and the ascending aorta can still cover each other in the first oblique diameter is quite unthinkable. The conditions are really such that the

[1] Almost word for word, but much condensed, after Frik, *l.c.*

[2] Leo Reich: Das Röntgenbild und die orthodiagraphische Messung der Aorta im 2. schrägen Durchmesser. Fortschritte, Bd. 34, 3. and 4. Heft, 1926.

shadow of the vascular stalk is limited to the right and posteriorly by the trachea or rather by the left main bronchus, whose translucency cuts off a varying amount from the vena cava superior alone or even from the ascending aorta. The condition requisite to the breadth of the vascular stalk giving in this position the breadth of the ascending aorta would be that the left border of the trachea or rather of the left main bronchus would coincide with the right border of the aorta. While that would not take place always, it is very often the case, for it is found in 70 per cent. of cases. The method is therefore practically useful, although not exact. It might perhaps be better to employ the second oblique diameter for aortic diagnosis. The view one secures is doubtless a more complex one. But the ascending aorta can in that case be measured only in quite a small part of its course below the bifurcation of the trachea. The correctness of the measurement of the ascending aorta in the second diameter is proven, but the method used for doing so is not suited for practice. (Reference should be made to the original article.)

The breadth of the shadow of the aortic arch *in sagittal view* increases clearly with advancing years and uniformly, so that every decade manifests a fairly constant measurement, which varies somewhat according to the size and weight of the patient.[1] For healthy men the average widths of the aortic arch are: up to 25 years, 4·6–4·9 cm.; 26–35 years, 5–5·4 cm.; 36–40 years, 5·5–5·9 cm.

The first part of the aorta projects normally both in ventral and dorsal view to the right of the vertebral shadow a distance of not more than 1½ to at most 2 cm. If it projects further and above the right auricle, the condition may be regarded as pathological; nevertheless, it should be remembered that upon elevation or displacement of the heart, for whatever cause, it can project out to the right without being enlarged. According to other observers, the ascending aorta is never normally visible at the right border of the central shadow. That is, if a pulsating convex arching be seen, that is pathological. The author cannot agree with that view. For exact measurements of the normal aortic arch have been carried out on a large number of people,[2] especially in soldiers, and represented by Groedel in the accompanying sketch (Fig. 224), in which AMr and AMl are the aortic median distances to the right and left, AT=AMr+AMl, and AL the length of the aortic arch. The average dimensions are found to be:

AMr=2·5 cm.
AMl=3·1 ,,
AT=5·6 ,,
AL=7·3 ,,

These average values must be taken with caution, and fairly large differences above and below need not be regarded as pathological. Seeing

[1] Zehbe, *l.c.*

[2] F. M. Groedel: Die Dimensionen des normalen Aorten-Orthodiagramms. Berliner klin. Wochenschr., 1918, No. 14.

the aortic arch has to adapt itself to the spatial conditions of the thoracic cavity as does the heart, *the breadth of the normal aortic shadow* varies in anterior view within pretty wide limits, from about 4·0–8·5 cm.

Some again measure the aortic arch at the root of the vessels, others by a horizontal at the point where the aortic arch passes into the shadow of the pulmonary artery (a point that unfortunately cannot always be exactly localised).[1] The last measurement has an average value of 4·6 cm. For the determination of the longitudinal diameter the length of the ascending aorta was chosen = the line joining the point where the right auricle with the auricular appendix passes into the right vascular arch, with the point at which the left aortic arch reaches its highest point. (These two latter measurements should not be related to the above-mentioned AT and AL, for they apply to different measurements.) Naturally all the measurements should be made by teleröntgenogram or by orthodiagram.

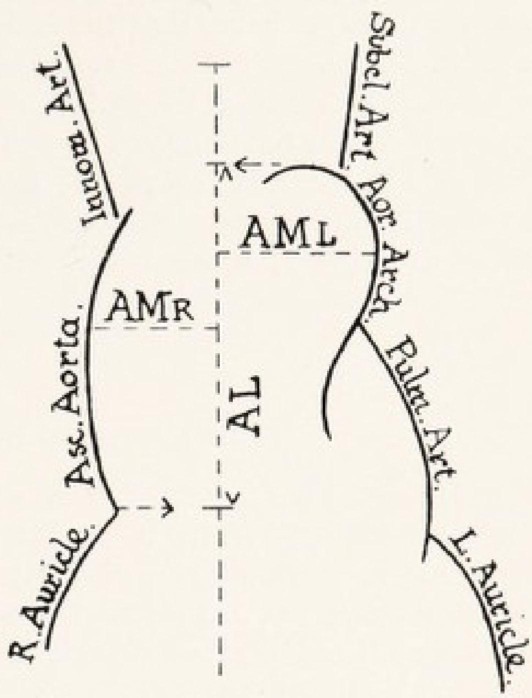


FIG. 224.

Pathological elevation of the diaphragm separates the two limbs of the aorta and drives the summit of it up into the root of the neck. In a low fixation of the diaphragm and in the emphysema of old age one generally sees a narrow and downward displaced aortic shadow.[2]

It is mentioned in the literature that the normal aortic arch shows the same density in every part (which is undeniable), and that the shadow of the diseased aortic arch exhibits an irregular or even spotted shadow, and that this difference arises less from the width of the vascular lumen than from the structure of the vessel-wall; hence the earliest Röntgen sign of *aortic sclerosis* is the darkening of the aorta (not yet dilated) in comparatively young people.[3] The author is obliged to reject that opinion. In the customary short momentary exposures when the Röntgen tube is not very hard the aortic arch is not penetrated by the rays, the shadow is one of equal density in every case. If the rays traverse the aortic arch, then at the point of the aortic lumen where the diameter is widest, the shadow cast is denser than at the adjacent narrow parts; provided other physical factors do not come into consideration. Not an infrequent occurrence, however, is for a strongly dilated descending aorta to appear

[1] v. Teubern: Orthodiagraphische Messungen des Herzens und des Aortenbogens bei Herzgesunden. Fortschritte, Bd. 24, 1917.—Zehbe: Beobachtungen am Herzen und an der Aorta. D. med. Wochenschr., 1916, No. 11.

[2] Dietlen, *l.c.*

[3] See also Nichols, *l.c.*

quite markedly translucent. The reason of that in my opinion is the wide distance of the descending aorta from the plate (in breast exposures), and the resulting secondary radiation in the antejacent pulmonary tissue. The way to test this is by screening or photography in the dorsal position, which brings the pars descendens near the plate. If this test prove negative, it is always more probable that the lesser opacity opposite the pars ascendens is caused by a very flat although large vessel-lumen than by purely arterio-sclerotic changes. It is quite another matter, when deposits of lime are present. That the oblique views of the thorax in elderly people are so sharp and rich in contrast is probably due to the diminished pulsation movement in sclerosis of the aorta and especially conditioned by the emphysema of the lungs in old age ; it is not due to the theoretically greater Röntgen-shadow-density of the vessel wall.

The Divisions of the Aortic Arch

It has been asserted that a stronger fore-arching, " an increased convex bending," of the ascending aorta is typical of syphilitic atheroma, but this is certainly not the case ; but it does occur in atheromatous aortæ (elongated, rigid-walled, and somewhat broadened) and in aortæ working with high blood pressures (enlarged and elongated) ; it also occurs in insufficiency of the aortic valves.[1]

Certain very *long aortæ* bend sharply out to the left, that is, they exhibit a projecting " aortic-head," yet we should not infer from that alone that the aorta is dilated. Long aortæ usually bend out well to the left. Screening in the other directions decides the matter.

If the *outer edge of the descending aorta* can be seen as a line running parallel to the vertebral column a little way out into pulmonary tissue and the left ventricular shadow, that is without clinical significance. It is usually seen in elderly persons upon sharp negatives.

The aortic shadow, as we have seen, corresponds to the overlapping ascending and descending parts of the aorta and the vena cava, and if it is so broad that scarcely any narrow clear space is left between it and the shadow of the spine, then we have an even *enlargement* (usually with lengthening) *of the aortic arch.*[2] If the shadow be club-shaped, it is more likely to be an aneurism. A definitely outlined tumour interfering with the parallelism of the aortic margins is always indicative of aneurism.

The highest point of the aortic arch is at an average of 2 to 3 cm. below the level of the sterno-clavicular joints. But this measurement varies with circumstances that are independent of the aorta, such as the form of the thorax, the curvature of the spine, the position of the diaphragm, the

[1] Erdélyi, *l.c.*

[2] A complete work of all the literature is that of Binet : Les Rayons de Röntgen et les Aneurysmes de l'Aorte thoracique. Thèse de Paris, 1909 ; see further Vaquez and Bordet : Le cœur et l'aorte. Paris, 1913 (Baillière).

situation of the heart, the condition of the respiration, and displacements due to tumours and adhesions. Further, the distance varies with the length and breadth of the aorta. These factors influence the level of the summit of the aorta to a lesser or greater degree. The increased prominence of the latter does not always betoken, as already mentioned, a change in the wall of the aorta.[1]

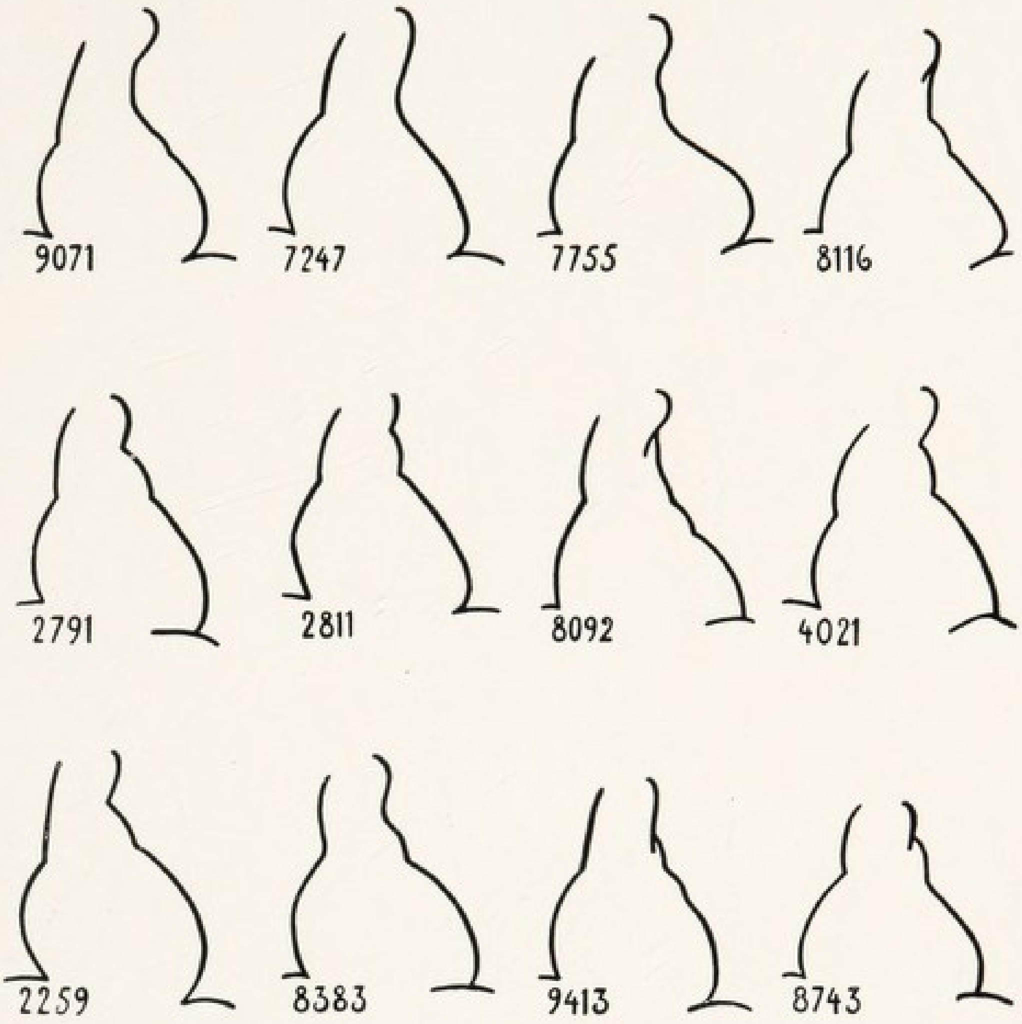


FIG. 225 (Minified 7 : 1).—Aortic arch not enlarged (normal or moderately enlarged hearts).

(Inspiration, erect position, 2 metres focal distance.)

In order to place as many pictures as possible on the one page the thorax and clavicles have been omitted ; it is useful, however, to know how far the uppermost margin of the aortic arch shadow reaches. To make up for this defect, one may say that in cases 7755, 8116, and 4021 it reaches to the clavicular line ; in cases 9071, 2791, 2811, and 9413 one finger's breadth ; in the cases 7247, 8092, 2259, 8383, and 8743 two finger breadths below that level.

If the descending aorta is visible through the shadow of the heart, as it may be perhaps as far as the diaphragm, that does not prove in the least the occurrence of pathological conditions. It only signifies that fairly hard rays have been used in the screening or photography. In the spondylitis

[1] Erdélyi, *l.c.*

of children such a descending aorta has been taken for a paravertebral abscess.

If in antero-posterior view *the descending part of the aortic arch* (using parallel rays) projects further than $2\frac{1}{2}$ cm. beyond the left edge of the vertebral shadow, we should think of a diffuse dilatation or aneurism. If

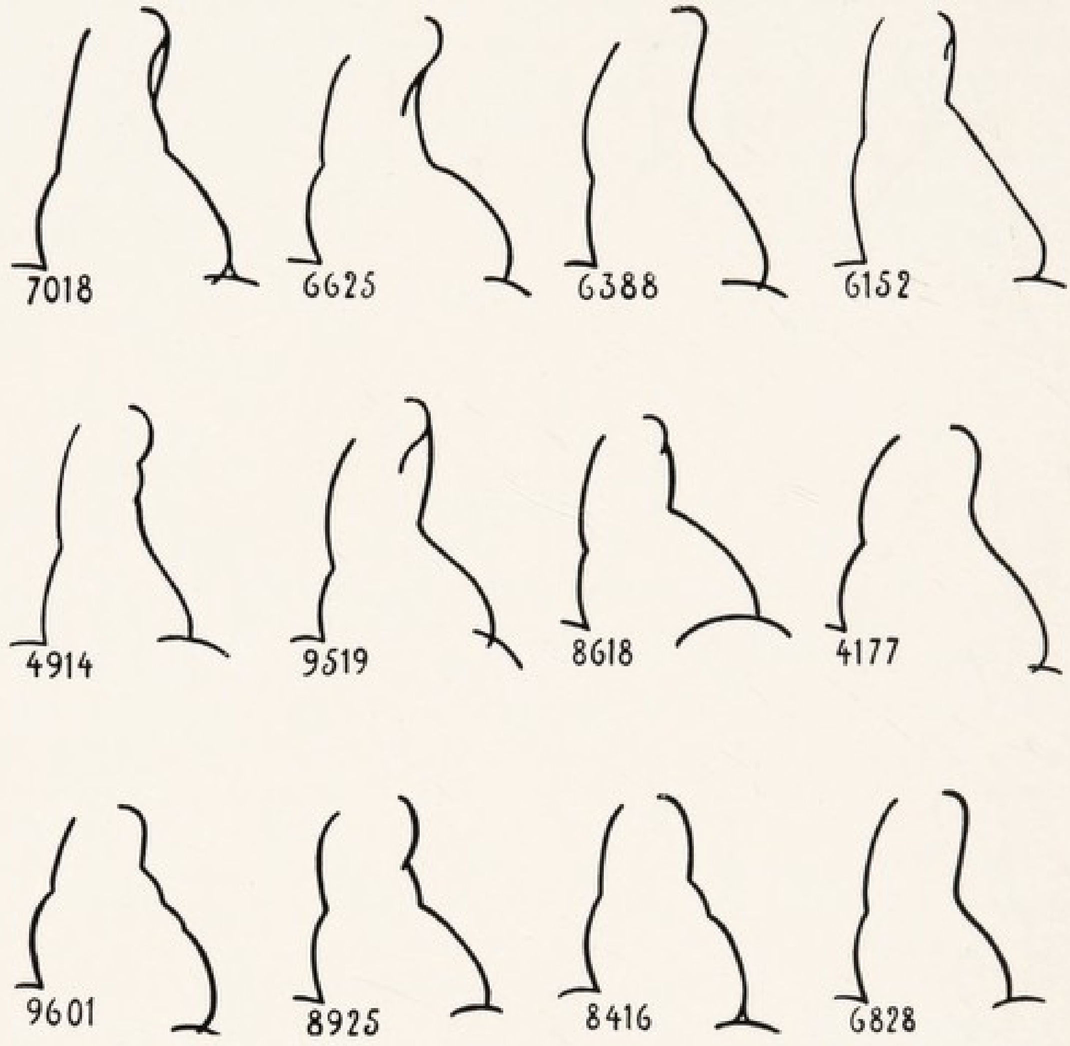


FIG. 226 (Minified 7 : 1).—Enlarged aortic arches not of luetic origin.

(Inspiration, erect position, 2 metres focal distance.)

When one compares these aortic arches, which are probably of arteriosclerotic nature, with those of luetic infection (Fig. 227), one recognises that a distinct luetic type of aortic arch does not appear to exist. It is worthy of mention that the form of the aortic shadow which is often considered to be typical of pure arteriosclerosis appears also in younger patients, and the author has found it as early as thirty years. The most extreme and sacculated aneurisms are not mentioned here, for they do not belong to the theme of this work. The alteration of the aorta brought about by chronic nephritis is often quite similar to that of an aortic sclerosis.

the descending part is more to the back, it is always advisable to examine the case by dorsal irradiation ; pulsation can best be observed in this way and even with a short focal distance mistakes are not likely to occur (see also Fig. 231.

A *scoliosis* or kyphosis sometimes simulates an aneurismal enlargement of the aorta. In doubtful cases a dorsal photograph should be taken. This will enable the spine to be distinguished from the aortic arch shadow, which cannot always be made out from a ventral negative.

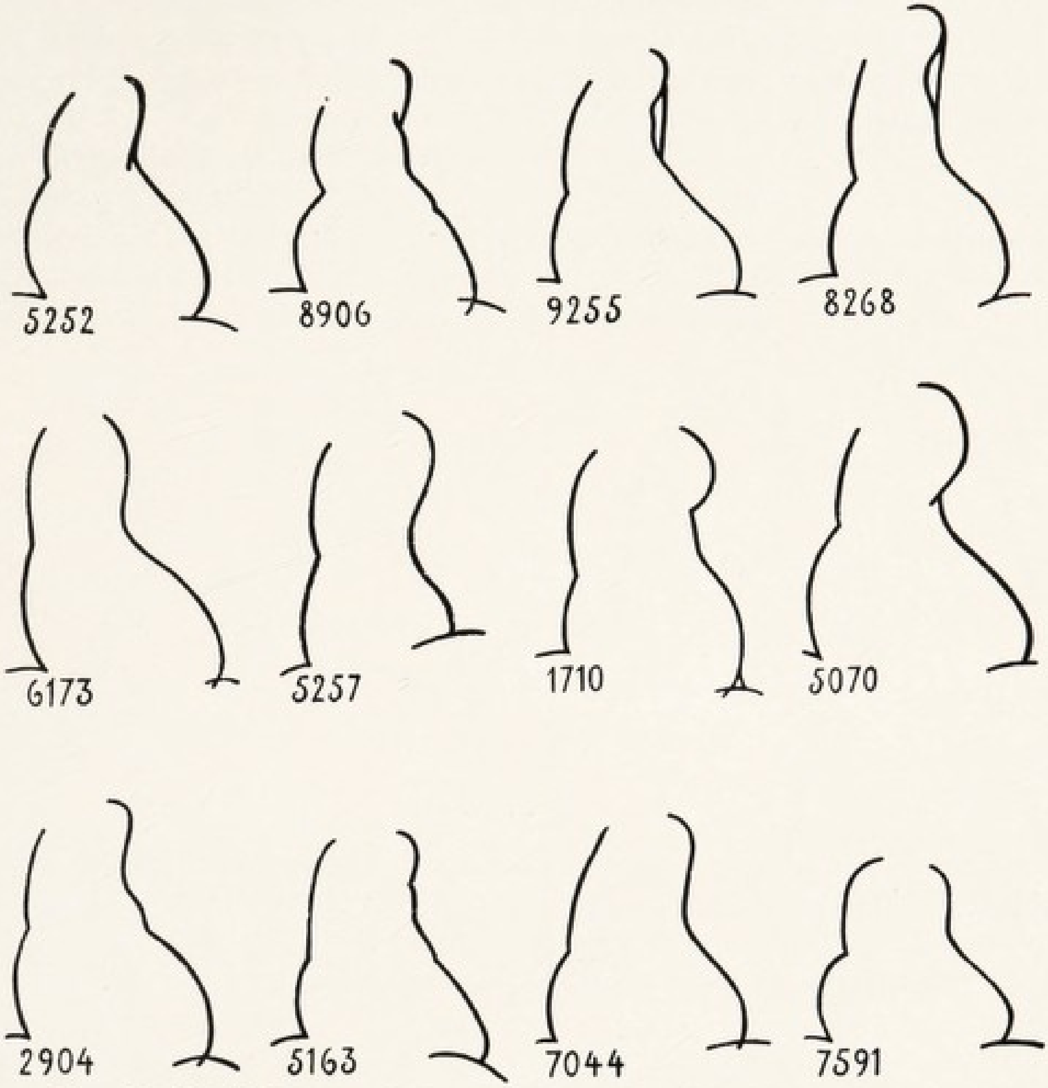


Fig. 227 (Minified 7 : 1).—Enlarged aortic arches with a history of previous luetic infection.

(Inspiration, erect position, 2 metres focal distance.)

The luetic infection in the different cases had taken place from 14 to 40 years before; there is of course no relation between the amount of aortic enlargement in the cases and the date of infection. All the cases are men: No. 5252, about 60 years, infection 25 years before; No. 8906, 37 years, infection 14 years before; No. 9255, 45 years, infection 18 years before; No. 8268, 44 years, time of infection uncertain (rapidly progressing tabes); No. 6173, 42 years, infection 14–15 years before; No. 5257, 68 years, infection 30 years before; No. 1710, 48 years, infection 24 years before; No. 5070, 45 years, infection 25 years before; No. 2904, about 60 years, infection 40 years before; No. 5163, infection 34 years before; No. 7044, age not known, infection 25 years before; No. 7591, 49 years, infection 20–25 years.

The absence of pulsation of a shadow projection above and to the left does not exclude aneurism; this contour is specially sharp on the negatives of typical aneurisms, even in negatives in which the patient has been breathing.

One of the most difficult tasks in röntgenology is to determine in fat and thick-set individuals *whether the aorta is dilated or not.* In the oblique diameter the view is usually so imperfect that nothing certain can be made out; and in sagittal views one does not know how far one can estimate the normal conditions in such individuals. To give some idea two thoracic findings are here given, the one man (Fig. 228, A) with a normal aortic arch, the other (B) with a certainly enlarged aortic arch (confirmed at autopsy); for aneurisms, see later.

It should be remarked that *large lymphomata in the mediastinal space* can produce an exactly similar Röntgen picture (like Fig. 228, B) to a diffuse or aneurismal enlargement of the aortic arch. The clinical findings decide the one condition from the other (also paravertebral abscesses have sometimes a very similar appearance). In tumours the suspected shadow shows

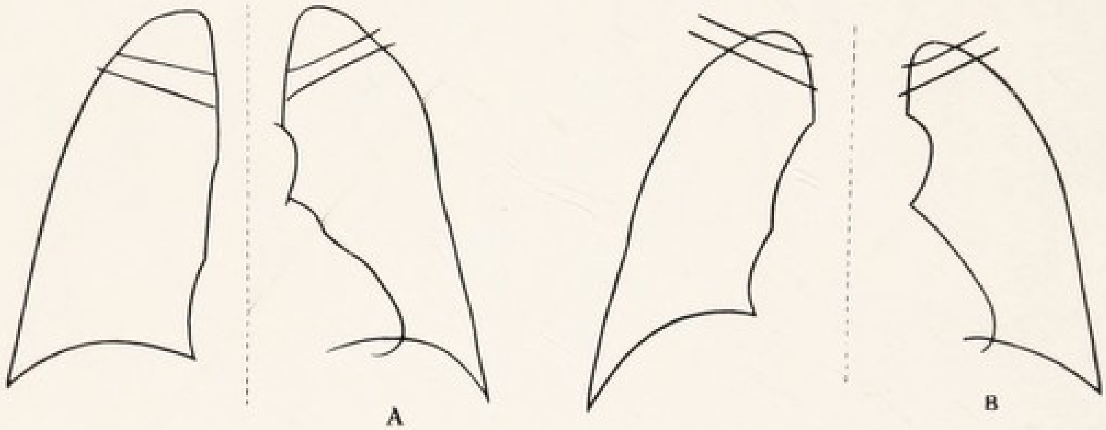


Fig. 228.

very sharp edges in which indentation is not uncommon; other signs are metastases into the hilus, palpable cervical glands, and rapidity of growth. An energetic test irradiation usually clears up the diagnosis.

A remarkably *small aortic arch* is frequently encountered in mitral insufficiency.

If the arch projects far to the right (a diffuse aortic arch or, more rarely, an arch with aneurismal dilatation) and a second shadow runs upwards and outwards under the clavicle, we have probably to deal with a simultaneous *enlargement of the innominate artery.* Similar shadows filling up the angle between the clavicular and spinal shadows can arise from retrosternal struma and from lymphoma. It is a general, though not invariable, rule that in the latter cases the external shadow contour turns back above towards the mid-line.

Large strumata of the thyroid gland depress *the aortic arch shadow downwards,* and a large right lobe presses the arch down and to the left: a left lobe to the right. At the same time one has to recollect that a diffuse dilated aorta may accompany a struma. Naturally this makes it more difficult to estimate a Röntgen negative.

In well and sharply defined negatives one may see on the contour of the aortic arch (especially on the left) narrow crescentic shadows of great density, as in Fig. 229; these are *calcareous plates in the wall of the vessel.* One should, however, recollect that immediately adjacent to this region calcareous plates may be found in the pleura.[1] The history and the clinical findings must decide in difficult cases.

The author discovered the following unusual condition in a patient severely ill and with puzzling symptoms. The autopsy showed that the projecting shadow on the right side was due to an aneurism of the descending aorta. A similar picture with a similar diagnosis has been published in the Röntgen literature recently.

The differential diagnosis of aneurisms of the aortic arch from mediastinal tumours is often very difficult, particularly to begin with. If the clinical

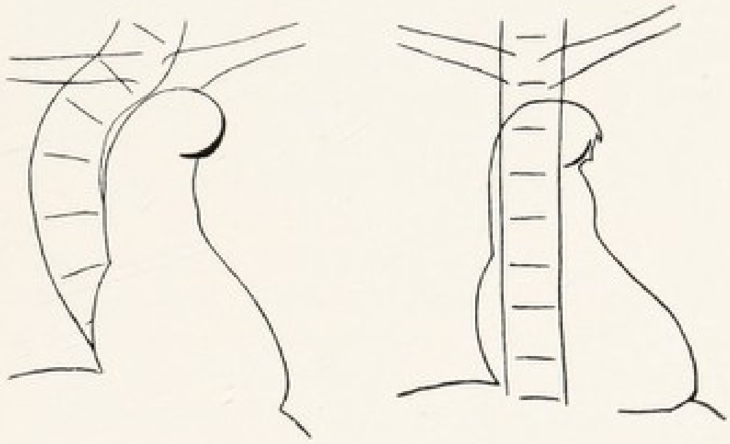


Fig. 229.

findings fail to give a sure diagnosis, the following points should be noted, the "Thoma-Kienböck rule":[2] a localised aneurismal enlargement hardly ever occurs in an aorta that is otherwise free of disease. Therefore, if one finds an aneurismal-like projection at any part of the aortic arch shadow, and at the same time a dilatation of the remainder of the aortic arch shadow, that speaks for aneurism; on the other hand, if apart from the evident projection itself the rest of the aortic shadow is normal, that is probably a tumour (lymphoma, substernal struma, etc.). Simple lateral displacements of the aorta, especially to the left, occur frequently in mediastinal tumours, and they can be diagnosed by the fact that the radius of the semi-circle projecting to the left is not enlarged (see also p. 370).

For the differentiation of an aneurism from a mediastinal tumour the "Aortic-Asymmetry Rule" (of Kienböck) is of value and is applicable to (1), almost all atherosclerotic, widely dilated, homogeneous, diffuse, cylindrical dilatations of the aorta; (2) the usual and most frequent forms of syphilitic aneurisms (it is not applicable for the dilata-

[1] Köhler: Röntgenographischer Nachweis von Kalkplatten im Aortenbogen Lebender Fortschritte, Bd. 18, 1911, 1912.—Boden: Über den Nachweis von Kalkeinlagerung in der Aorta. Münch. M. Wschr., 1921, p. 1451.—Keyth T. Meyer: Radiology, 1924.

[2] Kienböck: Zur Differentialdiagnose der Aneurysmen und Mediastinaltumoren. 8. Röntgen-Kongress, 1912, p. 137.—The same: Fortschritte, Bd. 34, 1926

tions and aneurisms of the descending aorta). More particularly, when one views the enlarged *supracardiac field*, and especially when one compares the right and left portion with each other, a *peculiar inequality* of the two sides, a projection exists on the right side below, similarly one on the left side above. The two projections can be connected above and below by an arch, when there is produced a characteristic, albeit artificial oval picture, the "aortic oval." It is always placed obliquely in a perfectly definite direction, the axis running from right and below to left and above.

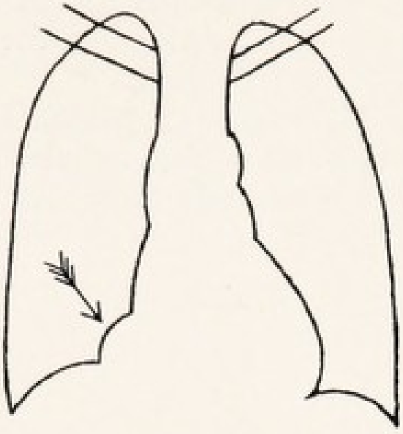


Fig. 230.

A marked projection of the upper left arch in ventral or dorsal view, the "head of the aorta" (similar to I in Fig. 231) betokens a *lengthening of the arch* of the aorta. (Just as a sclerotic radial artery lengthens and coils, so does the aortic arch.) In consequence of its fixation and curvature the arch projects to the left and not to the right. If the lengthening be an extreme one, the summit of the aortic arch becomes elevated and the ascending aorta projects out to the right. But in that case there is usually an *enlargement* present as well (somewhat like II and III, Fig. 231). Nevertheless, in a purely sclerotic enlargement the swelling is a regular cylinder and not spindle-shaped, and the aortic margins remain parallel in oblique diameters.

Systolic displacement of the entire aorta to the left outwards and upwards, "passive pulsation," is a sign of especially strong thickening and rigidity of the vessel wall.[1]

In aortic sclerosis a rounding off of the apex of the heart is usually present as the earliest sign of hypertrophy of the left ventricle.[2]

It appears that in sclerotic disease of the aorta the ascending aorta is principally affected: in lues the ascending aorta, especially the part immediately above the aortic valves (aortitis suprasigmoidea), and the descending aorta (with stretching of the arch) with abrupt stoppage of the dilatation at the diaphragm—best recognised in the second oblique diameter. In mesaortitis luetica (anatomically a patchy destruction of the media and adventitia, and replacement of the elastic tissue by non-elastic, inflammatory, and scar tissue) the aortic arch does not reach up so far into the neck as in sclerotic disease of the aorta.[3] On the other hand, the diffuse form of aortic disease is declared by some authors to affect practically only the ascending aorta.[4] A cylindrical dilatation confined to the ascending

[1] Vaquez and Bordet, *l.c.*, and Dietlen, *l.c.*

[2] M. Zehbe: Beobachtungen am Herzen und der Aorta. Deutsche Med. Wschr., 1916, No. 11.

[3] Extremely important is the work of F. Kraus: Über die Aortenerweiterung bei der Heller-Doehleschen Aortitis. Deutsche Med. Wochenschr., 1914, No. 12.—G. E. Brown: Syphilitic aortitis and its early recognition. Am. J. of the Med. Sc., January, 1919, p. 41.

[4] Zehbe, *l.c.*, and Dietlen, *l.c.*

aorta and a moderate opacity of the aortic shadow would indicate a luetic aortitis, especially when there is evidence of an insufficiency of the aortic valve, as is practically always the case. If the projecting margin of the ascending aorta shows an irregular or indented contour instead of a uniformly sharp curvature, that indicates almost certainly a lues. Calcareous deposits are not usually present in negatives of aortitis, but may sometimes occur in company with arteriosclerosis.

Some moderate enlargements of the aortic arch are sketched in Fig. 231 and deserve attention.[1]

Small calcareous deposits in the *innominate artery* have been observed. These are apt to be confused with minute tubercular deposits.

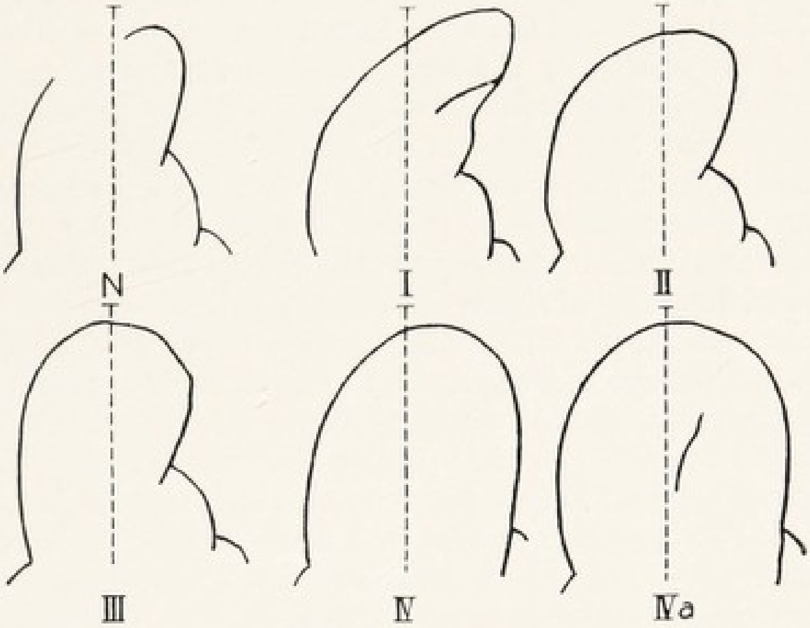


FIG. 231.

N=Normal; I=Sclerosis of tho aorta; II=Dilatation of the ascending aorta; III=Dilatation of the arch; IV=Dilatation of the descending aorta; IVa=Diffuse dilatation.

In cardiac insufficiency the *innominate artery and vein* are seen as shadows of varying density and varying direction.

For high anchoring of the aorta to the right, or rather of the aortic arch, dysphagia illusoria, and situs inversus aortæ, see in " Œsophagus."

ŒSOPHAGUS[2]

The œsophagus cannot be demonstrated with the Röntgen rays alone. To follow its course it is not necessary to use a tube filled with metal ; the

[1] According to Groedel: Die Röntgendiagnostik der Herz- und Gefässerkrankungen. Berlin, 1912 (Meusser).

[2] From Groedel's Atlas, 3rd ed., chapter on " The Röntgen Examination of the Œsophagus " by Steyrer. Some paragraphs are taken almost verbally. A larger and more recent monograph is that of Faulhaber: Die Röntgendiagnostik der Speiseröhrenerkrankungen. 1916.—S. Lange, Cincinnati: The Röntgen examination of the esophagus. Arch. Röntg. Ray, vol. xiii, No. 103, p. 231, 1908.—G. E. Pfahler, Philadelphia: Diagnosis

ordinary stomach tube is sufficient although it does not stand out in particularly strong relief. It has the advantage that it does not distort the course of the œsophagus by its weight and stiffness. The examination should be carried out in the oblique position ; the right side of the breast rests against the plate or the screen, the tube is set behind the left shoulder ; or vice versa, the shoulder or postero-lateral aspect of the thorax abuts against the plate or screen and the tube is set in front of the right shoulder. The cervical part of the œsophagus can be best brought into view by turning the head sharply to the left, the lower half of the œsophagus is best seen on left profile projection. The clearest way of recognising all the various points is to let the patient take a deep inspiration.

The *physiological narrowings* are at the entrance of the œsophagus (opposite the lower edge of the cricoid cartilage), at the arch of the aorta, at the point of crossing of the left bronchus, at the œsophageal hiatus (where the œsophagus traverses the diaphragm), and at the cardiac opening. One author, Mehnert, has described thirteen (!) different narrow points. Also the entire subdiaphragmatic part is narrower than the rest of the œsophagus.

Peristalsis is very difficult to observe, indeed almost impossible.

There are some recent studies from the purely anatomical side concerning the form of the *lumen* of the œsophagus and the *distance* of the latter from the spine (in the living person).[1] Two opinions have held the field hitherto : (1) The œsophagus apart from the act of swallowing is more or less contracted, its lumen is almost closed, the mucous membrane laid in longitudinal folds. (2) In the cervical portion the walls are very likely in close contact with each other, but the thoracic portion is represented by a widely gaping tube. Röntgenograms show that it is usually closed in the cervical part with the walls in close approximation. Upon transition to the thoracic part the mucous membrane is in longitudinal folds. But even at the level of the second and third dorsal vertebra there is a considerable dilatation, the œsophagus has quite an open lumen, which, however, is flattened in the sagittal or frontal direction. The principal dilatation is at the level of the fourth to the ninth thoracic vertebræ ; it is in the transverse direction, while shortly before its passage through the diaphragm the lumen turns again into a sagittal direction. In expiration it has a different appearance,

carcinoma of the esophagus by means of the Röntgen rays. Archives of Diagnosis. New York, January, 1909.—Seth Hirsch : The Röntgen-Ray Study of the Esophagus. St. Louis. Interstate Medical Journal, Vol. 23, No. 4, 1916.—A complete chapter with numerous illustrations, also list of the literature, is found in R. D. Carman : The Röntgen-Diagnosis of diseases of the alimentary canal. 1921 (Philadelphia and London, Saunders).—H. Chaoul : Röntgenologie der Speiseröhre, im Leitfaden der Röntgenologie by H. Gerhartz. 1922 (Urban and Schwarzenberg).—Kerley and Lewald : Digestive Disturbances in Infants and Children. 1923. New York (P. Hoeber) in English, French, and Japanese.—G. Schwarz : Pharynx u. Speiseröhre ; in Schittenhelm's text-book.—A. Pratje : Zur Topographie des Mediastinum am Lebenden. Verh. d. anat. Gesellsch., Erg.-Hft. z. anat. Anz., Bd. 58, 1924 (with Röntgen examinations).—Porter P. Vinson : The value of the Röntgen-ray in the diagnosis and treatment of diseases of the esophagus. Radiology, August, 1924.—Santoro : Stenosi esofagee. Arch. di rad., 1925.—W. Manges : Right-oblique-prone posture for study of the œsophagus. Am. J. of Röntg., 1926, p. 374.

[1] Pratje, *l.c.*

it loses its band-like appearance, the lumen is opened wide and is more cylindrical. For the distance of the œsophagus from the spine: Nearly all the anatomical text-books teach that the œsophagus is closely applied to the anterior vertebral bodies as far as the eighth thoracic vertebra, is then somewhat displaced from it by the descending aorta, and at the œsophageal hiatus through the diaphragm is 2–3 cm. removed from the vertebral column. Röntgen examination tells a different story. The œsophagus of the living person is much further removed from the spine: in its lower portion, at the level of the ninth to the eleventh dorsal vertebræ, the distance may be 5–6½ cm., with individual differences up to about 2 cm. In inspiration the distance is naturally larger than in expiration. It is probable the position of the body—back, prone, or oblique, standing or sitting—exerts an influence.

The *lowest part of the œsophagus* cannot be easily seen in oblique screenings either on the screen or in the plate, as it is projected into the shadow of the diaphragm when the tube is not set properly. For the point of entrance of the œsophagus through the diaphragm is not situated at the summit of the cupola but on its posterior declivity. Consequently the Röntgen tube should be lowered when it is behind, and raised when it is in front of the patient; and for the diagnosis of distinct lesions that has proved sufficient in many cases. Another or better plan should be adopted in the search for the very finest changes (*e.g.* in carcinoma of the cardia in its earliest stages), when it is a question of the end-portion of the œsophagus, of its *subdiaphragmatic portion*, the so-called *epicardia*, which is 3–5 cm. long, or of the cardia itself. We may then arrive at a clear picture by the following method (see Figs. 232A and B).[1] In the erect posture only the part above the hiatal level is clearly visible; in the horizontal position and with the central beam of rays vertical to the axis of the body, the œsophagus would be visible in its whole length, but the cardia with its contraction ring would be completely overshadowed by the highest cupola of the fundus of the stomach (Fig. 232A). It is different, however, in very oblique irradiation, which is best obtained by putting the patient in the Trendelenberg position [2] (see Fig. 232B). (It is indifferent whether the screen or the plate is placed ventral or dorsal.) The whole cardia mechanism can then be studied in all its phases. It should be remarked that the passage of the contrast-meal with the patient in the Trendelenberg position takes considerably longer than when he is standing. On the contrast-meal reaching the cardia, it remains considerably longer than in the vertical position before reaching the stomach proper, which is not indeed to be wondered at. The passage of the meal takes place as follows: the lowest part of the œsophagus sends out a very thin continuation of its contour on the side adjoining the fundus of the stomach; the point of that looks towards the stomach. At

[1] J. Palugyay: Die Diagnose des beginnenden Kardiakarzinoms mittels Durchleuchtung in Beckenhochlagerung u. über die Röntgenologie der Kardia überhaupt. Fortschritte, Bd. 30, 1. Krongressheft, 1922.

[2] First proposed by Strauss.

the same time a similar continuation of the ordinary stomach contour makes its appearance. These two shadow processes approach till their tips meet, whereupon the lateral walls of these processes separate till a parallel continuous canal is formed. After a fraction of a second the canal returns to the picture of the two processes meeting at their tips, which then resolves itself into a silhouette of the stomach on the one hand and the œsophagus on the other. This method sends with each opening of the cardia only small quantities of contrast-meal, which are held up at the lower end of the

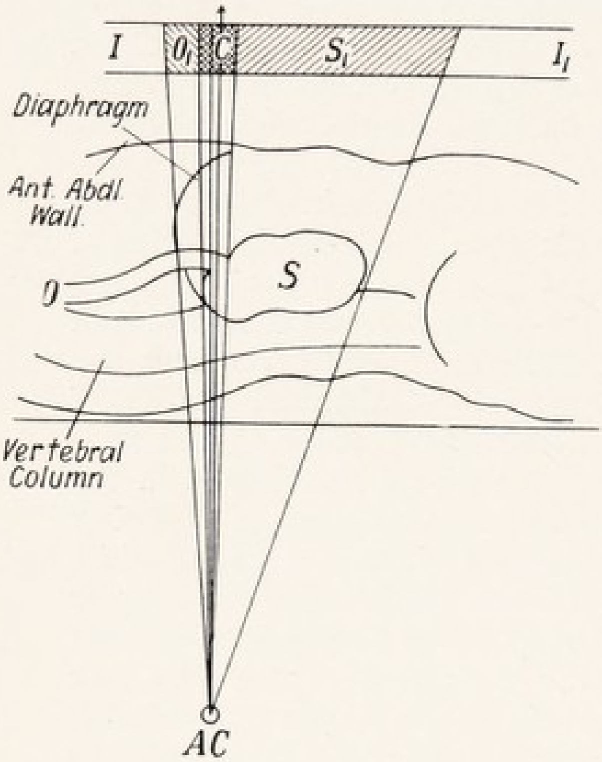


FIG. 232A.[1]

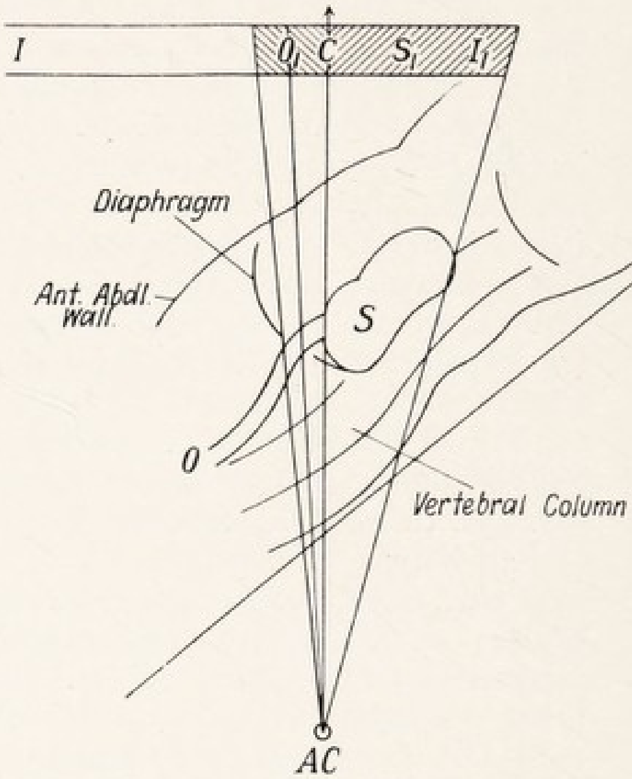


FIG. 232B.[1]

FIG. 232A: Horizontal position. FIG. 232B: Trendelenberg position. S=Stomach. O=Œsophagus. S_1=Shadow of the stomach. O_1=Shadow of the œsophagus on screen. I—I_1=Irradiation screen. AC=Anticathode. C=Central ray.

œsophagus. The cardia opens successively at distinct intervals, and the fuller the stomach already is, the slower does the œsophagus open and empty. The quantities of contrast-meal getting into the stomach at each time of opening diminish with each successive addition to the stomach. In this way röntgenologists can examine the function of the cardia just like that of the pylorus. On account of the marked delay in the emptying of the œsophagus it is possible to watch the passage of the meal more easily in this way.[2]

A fluid meal (with bismuth or other salts) will in a *normally functioning œsophagus*—depending on the consistency, taste, and temperature—be ushered into the stomach in from 2 to 10 seconds after it has entered the opening of the œsophagus ; delays, however, of seconds' duration may occur

[1] See footnote 1, p. 375.

[2] Much abbreviated, but almost verbally after Palugyay.

normally at the points of physiological narrowing (see above). Pulpy mouthfuls are of cylindrical appearance and of finger-length. A brief stoppage at certain points with a little regurgitation is not at all pathological, but is rather the rule. Nevertheless, delays of longer periods than the above always denote pathological conditions, even in an entire absence of stenosis of the gullet. At the cardia the mouthfuls are arrested for a little, and one sees a very thin shadow at the lower end of the œsophagus, which becomes reduced after a few seconds, and finally disappears through the cardia, which opens reflexly.

In certain difficulties of swallowing thin fluid meals form fine lines that run right along the whole œsophagus ; these remain for many minutes, even although larger boli pass normally. They betoken atony of the œsophagus.[1]

Seeing that in every case good salivation is required for the act of swallowing, one should avoid giving very dry bismuth capsules or meals. Unless these are followed by some liquid, they are seen to remain in the normal œsophagus for several minutes ; compressed tablets of bismuth of 1·0 gram have been seen to remain for nearly a quarter of an hour.[2]

In organic narrowing, autogenous in character, the mouthful remains resting a half or even a whole minute, and despite active swallowing movements, goes no further. The narrower the passage the longer it stays, although the patient has the feeling that the mouthful has already got into the stomach. A mouthful of water is generally sufficient to move the mouthful on further. An enlargement above the narrowing is usually present. Moreover, one can often observe on the screen in stenosis a retrostaltic movement of the contents, that is an apparent antiperistalsis, in which the fluid content is again displaced upwards through the effect of the waves of contraction coursing downwards and pressing as far as the stenotic narrowing at the diaphragm.[3] Even fairly large tumours of the œsophagus are not as a rule recognisable in screening without the aid of a contrast-meal.

Stenotic appearances are found in *abnormal enlargement of the heart*, especially of the auricles, more rarely in pneumothorax, pleuritis, pericardial effusions, and more often in mediastinal or pulmonic tumours and in aneurisms. In the latter the observation of pulsation and of the other clinical symptoms yield us a correct diagnosis.

There occurs an important anomaly in the course of the œsophagus, of which several cases have been published, and as it occasions no symptoms it is now described : These are the cases of *aorta running behind the œsophagus*, known clinically as Bayford-Autenrieth *Dysphagia lusoria* (for the dystopic aorta presses upon the œsophagus and causes difficulty in swallowing). In Röntgen examination the aortic impression of the œsophagus is found at the right posterior aspect of the œsophagus, which appears displaced forwards and to the left. In the differential diagnosis

[1] Olbert-Holzknecht : Oesophagus-Atonie (pseudo-oesophagism). Proceedings of the 6th Röntgen Congress, 1910 ; nevertheless, see Faulhaber, *l.c.*, pp. 27 and 28.

[2] Faulhaber, *l.c.*

[3] After Rieder. Fortschritte, Bd. 35, 5.—See further : Osmond. Radiology, 1925.

we have to consider tumour-formations in the posterior mediastinum, gravitation abscesses, vertebral exostoses, and tumours of the spine. In this particular anomaly one therefore sees the shadow of the œsophagus displaced distinctly forwards in the hollow of the aortic arch and indented and constricted from behind, with perfectly smooth contours of the œsophagus at this point. The arch of the aorta does not therefore run, as normally, in an arching over the left main bronchus in front of the left side of the trachea, but in the angle between the trachea and the right main bronchus. It gives off the right carotid artery and the right subclavian, and therefore does not give off any innominate artery; it then proceeds on behind the œsophagus; see Fig. 233 on this.

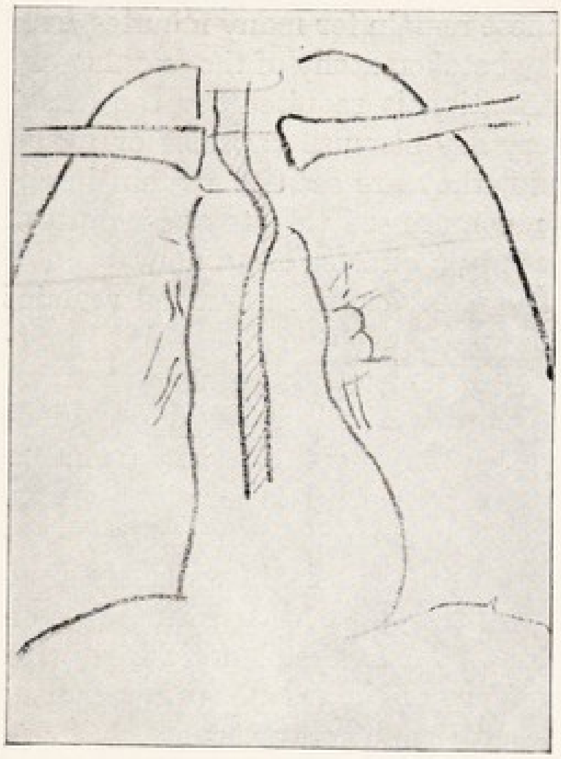


FIG. 233.[1]

In a sagittal röntgenogram of the thorax, while the pulmonary artery and left ventricle are distinguishable in the usual way from the pulmonary field, the aortic summit (on the left) is wanting; on the other hand, on the right side, above the right auricle, two arches are visible, the upper being the "right aortic summit" and belonging to the aortic arch, the lower being the descending aorta, see Fig. 234, "Sagittal diameter with filled œsophagus." The descending aorta runs out below far to the right into the right pulmonary field. This lower arch can be absent in "*High right-sided aorta*, or rather aortic arch" or "Situs inversus aortæ,"[1] also "Transposition of the arch of the aorta." The impression in the œsophagus is here produced not by the aortic arch running behind it, but by the left subclavian artery in its course behind the œsophagus. A displacement of the aorta to the right can occur without the heart being diseased, although the latter is a fairly frequent concomitant, and it is found in clinically healthy and quite serviceable hearts. Symptoms of dysphagia may occur, if the descending aorta or one of the subclavian arteries with an abnormal origin crosses the œsophagus, displacing and compressing it.[2]

When we are dealing with a *stenosis in consequence of mere displacement and lengthening of the œsophagus*, a mercury sound should be introduced

[1] After Saupe. Fortschritte, Bd. 33, p. 760, 1924.

[2] M. Löweneck: Einige seltene Beobachtungen aus der Oesophaguspathologie. Fortschritte, Bd. 35, 1927.—F. Herzog and E. Firnbacher: Beitrag zu den Anomalien der Aorta und des Oesophagus. The same (with literature).—Hammer: Situs inversus arcus aortae. Fortschritte, Bd. 34, 1926. (With literature.)—A. Renander: Acta Rad., 35–40.

and the patient turned in various directions; this will elucidate that the sound is external to the supposed tumour in every screening direction. Instead of the sound contrast-milk or porridge can be used.

If the mouthful or the greater part of it sticks at the level of the manubrium sterni, and if its position is not altered by drinking of water, but tends to rotate transversely, that indicates a *diverticulum.*[1] (The diagnosis of "diverticulum" becomes a certainty, if a sound be introduced and seen outside the shadow of the contrast-meal in every screening position.) The size of a diverticulum varies from 5 mm. to 8 cm. Small diverticula are occasionally seen as accidental findings. In one such case the diverticulum was present along with an ulcus duodeni.[2] The floor of small and medium-sized diverticula does not appear half-circular, as one might think, but rather resembles a flat shell, as if the diverticulum were not hanging down, but was sessile. Irregularities of the Röntgen shadow are due to old remains of food. Only recently deeply situated œsophageal diverticula have been described.[3] A diverticulum often fills better in the horizontal than in the standing position. One often finds calcified glands in the neighbourhood of a diverticulum (traction-diverticulum).

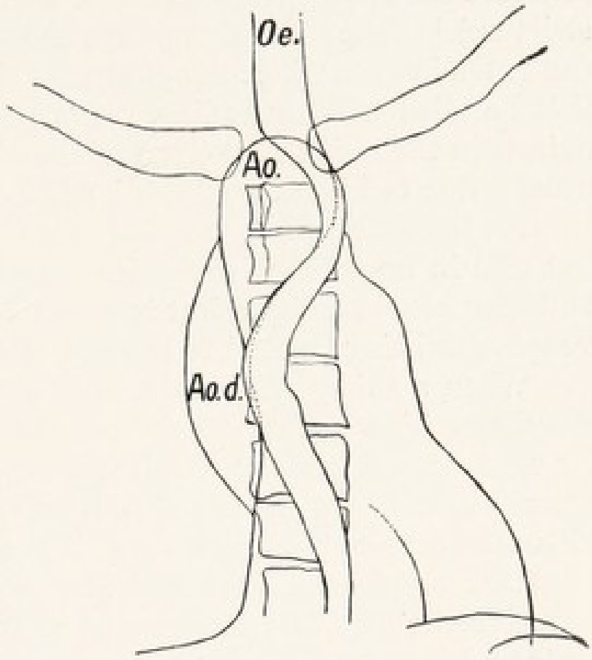


FIG. 234.[4]

A Röntgen picture almost identical with the usual anatomical one can be got even in extensive malignant disease of the œsophagus, in the case of a *rigid carcinomatous infiltration.*

Regular fusiform enlargement of the œsophagus speaks for conditions of degeneration, atrophy of the musculature, or irritation of the vagus nerve. In irritations of the vagus nerve the symptoms are those of a cardiospasm. A differential diagnosis between atony and spasm can be determined with fair certainty from the above observations, if after giving atropin we find the stenoses promptly vanish.

Spastic narrowing is characterised by the change from rapid contrac-

[1] A thorough study of diseases of the œsophagus is that by Kienböck and Kaufmann: Wiener Klin. Wochenschr., 22, pp. 35–38.—See further, M. Haudek: Zur Röntgendiagnostik der Speiseröhren-Divertikel. Fortschritte, Bd. 32, p. 556, 1924.—F. Peltasohn: Fortschritte, Bd. 33.—Morley: Brit. Med. Journ., 1926, 3414.

[2] G. A. Bokor: Fortschritte, Bd. 34, 1926.

[3] J. Freud: Zur Röntgendiagnose des seltenen tiefsitzenden Oesophagus-Divertikels. Fortschritte, Bd. 28, 1922.

[4] After Herzog and Firnbacher, *l.c.*

tions to relaxations of stenoses. The diagnosis is rendered more difficult by the fact that commencing carcinoma may give rise to spasm.

The *differentiation of spasm and tumour* at the entrance of the œsophagus into the stomach is very difficult in Röntgen view, and sometimes quite impossible. Funnel-shaped enlargement is indicative rather of carcinoma, a round, sausage-like, wide, symmetrical dilatation, of spasm. The presence of a neoplasm is suspected, when the shadow above the stricture shows jagged defects (see Fig. 235, A=spastic, B=carcinomatous stricture).[1] The dilatation above the spasm is also very considerable, and can extend to the whole œsophagus, which may even be visible in such cases, if it be filled with an ordinary fluid (without bismuth or barium). Small defects in the filling of the end of the œsophagus in spasm of the cardia are usually due to bits of food left behind.[2]

A *spastically dilated œsophagus* is frequently enlarged not only in length but also in breadth, whereby its course becomes twisted. The twisting is best seen, not in oblique, but in directly sagittal view; the upper half of the œsophagus being twisted to the left, the lower half to the right.[3]

When a thin *foreign body*, such as a needle, which ought to be in the œsophagus, does not appear on screening, it may be sticking in the œsophagus for all that. A plate is absolutely necessary, and it should be an oblique dorsal view. That usually elucidates the foreign body, and a clear picture of it would be got in every case, if every tube had a small focus. Seeing, however, the focus in the majority of tubes is one of 4 to 5 mm., it does not give a sharp and sufficiently clear image of a needle. Even dental plates with several teeth attached, especially when situated in the supra-clavicular fossa, are looked for in vain in the screen, while in photographs they can be seen clearly enough in the shadow of the vertebral column. Fish bones have never been seen; equally rarely small pieces of bone, although it is not impossible that upon odd occasions they may be so favourably placed as to be found in the negative (see further the next paragraph).

When *a foreign body has been swallowed and is not visible*, it is said a contrast mouthful will show a permanent or temporary hold-up opposite it; or the patient may feel pain at the instant the mouthful passes over the foreign body. In this way it is feasible to determine the level of a foreign body in the œsophagus in favourable cases.

Displacements of the œsophagus are not uncommon. Where the whole mediastinum or parts of it are displaced (contraction processes, pleural effusions, tumours and aneurisms of the aorta, substernal strumata, spinal diseases and deformities), and in enlargement of the left auricle, *i.e.* in

[1] A. Stein (Papaverin zur Differentialdiagnose zwischen Oesophagospasmus und Oesophagostenose. Fortschritte, Bd. 23) recommends here injections of the papaverin used in spasmus pylori, 0·03 gr.

[2] See also W. Drügg: Beitrag zur Frage des sog. Kardiospasmus und der idiopathischen Oesophagusdilatation. Fortschritte, Bd. 32, p. 12, 1924.—Breitländer. Fortschritte, Bd. 33, 1925.—H. Stark. The same.—J. M. Woodburn Morison, Edinburgh: Röntgen-Rays and cancer diagnosis. Brit. J. of Rad., November, 1927.

[3] Faulhaber, *l.c.*

mitral stenoses, the œsophagus takes part in the displacement to a greater or less degree. The œsophagus when filled with contrast-meal affords a certain important guide-line for the posterior border of the heart, and in cardiac enlargements it is gradually displaced, and is therefore of some importance for estimating the degree of enlargement of the auricle. The compression between the enlarged left auricle and the spine is manifested in the œsophagus by an anterior and posterior flattening. The time of passage of the food is thereby naturally delayed. This gives rise clinically to little or no complaints.[1] The discovery of a deviation of the œsophagus can point directly to a mediastinal tumour, which can sometimes itself be seen. In such a displacement there usually takes place a compression-stenosis to a

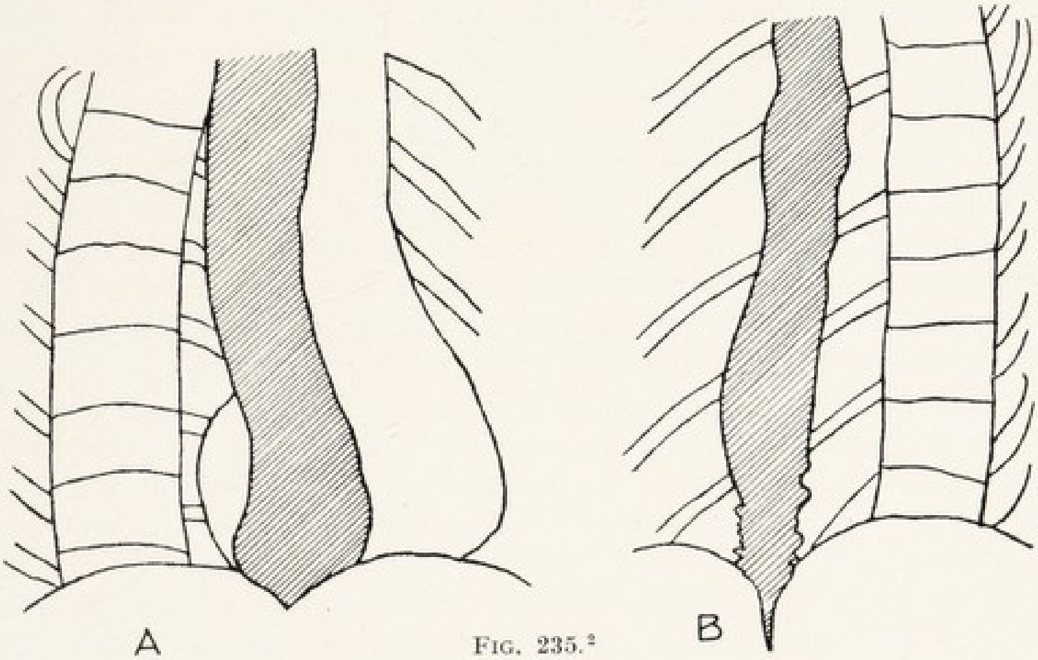


FIG. 235.[2]

greater or less degree. The contrast-meal therefore in such deviations passes more slowly at the spot where the œsophagus is most stretched.[3]

In patients with *kyphoscoliosis* the œsophagus aims at taking the direct path from the neck to the hiatus of the diaphragm, to run like a string to the bow formed by the vertebral column, in contrast to the aorta, which is fixed by the intercostal arteries to the spine and must therefore follow its curves.[4]

It is important that even *extreme departures from the normal course* of the œsophagus can be quite devoid of symptoms to the patient. Hence deviations of the œsophagus possess no particular clinical importance, and are usually discovered incidentally in obstructions.[5]

[1] E. Gäbert: Der hintere Herzrand in normalen u. kranken Fällen etc. Fortschritte, Bd. 32, 1924.

[2] After Steyrer, *l.c.*

[3] See also the comprehensive work of Eisenstein: Beitrag zur Röntgenologie der Speiseröhre. Fortschritte, Bd. 21 (with list of the literature).

[4] A. Bittorf and L. Hübner: Der Oesophagus bei Kyphoskoliosen im Röntgenbilde. Fortschritte, Bd. 33, p. 59, 1925.

[5] Faulhaber, *l.c.*

Increased peristalsis and *anti-peristalsis* are extremely rarely seen above organic and spastic stenoses.

THYMUS

In *enlargements of the upper parts of the central shadow of the thorax*, the so-called " heart-neck," one should consider the possibility of its being due to an enlarged thymus. In the first decade after Röntgen enlargement of the thymus was far too frequently diagnosed, the striking breadth of the upper part of the central shadow being due to the tube being brought too near, in order to take a more rapid picture of small unruly children; the picture of the thoracic cavity being consequently also much enlarged. As far as the question of a shadow being due to the thymus is concerned, there are one or two points to be noted.[1] The normal thymus is not visible in a Röntgen view of the young infant. Its shadow passes over into that of the vascular shadow, and can hardly be said to project into the fields of the lungs. That the pathologically enlarged thymus can be represented radiologically, is very probable. It may be expected to increase both the upper part of the central shadow and the heart shadow to the two sides, perhaps more to the left than to the right, and being an air-free organ be sharply delimited from the air-containing lung tissues. In thymuses enlarged apparently to the right side, we are usually only dealing with the shadow of the vena cava superior, which is distinguished by its position on the right side, its amplitude in respiratory movement, and by the circumstance that it bends outwards at its upper end (origin of the innominate and subclavian vessels). That is found well marked especially in those infants whose pasty state of the body would suggest an enlargement of the thymus. The possibility of the röntgenological proof of an enlarged thymus is in no way invalidated through this discovery; one should take care not to regard every enlargement of the " heart-neck " in a small child as an expression of a hyperplasia of the thymus, as is nearly always done. An enlarged thymus projects more into the left pulmonary field,[2] and so frequently produces together with the heart the shadow picture of a Jacobin cap. The principal forms of thymus to be distinguished in Röntgen view are the bulbous and stalked form, also the club form; the asymmetrical forms and the appearance of thymoptosis are said to be rarer.[3]

There is no doubt that—although Röngten diagnosis has made strides—there still exists much ignorance about the thymus. With our present technique a systematic investigation in a large children's clinic offers a very promising field for inquiry. The work done from 1900 to 1910 is in-

[1] Abbreviated almost word for word from " Röntgen examination in the diseases of childhood " by Th. Goett. 2nd vol. of Rieder-Rosenthal's text-book, 1918.

[2] d'Oelsnitz and Paschetta: Bullet. de la Soc. de Pédiatrie, p. 457. Paris, 1911.—Ferrand and Chatelin, p. 164, *ibid.*

[3] E. Vogt: Zur Kritik der Röntgendiagnostik des Herzens und des Thymus in der ersten Lebenszeit.

sufficient. Yet from that one or two points emerge clear: A thymus at the height of its development resembles the picture of a large pericardial effusion. In enlargement of the thymus its shadow can be the breadth of the heart or even broader. For the differential diagnosis from mediastinal tumour: The thymus descends on inspiration and rises on expiration, that is, it accompanies the respiratory movements. In oblique view the retrocardial field is filled up according to the enlargement of the thymus gland.[1]

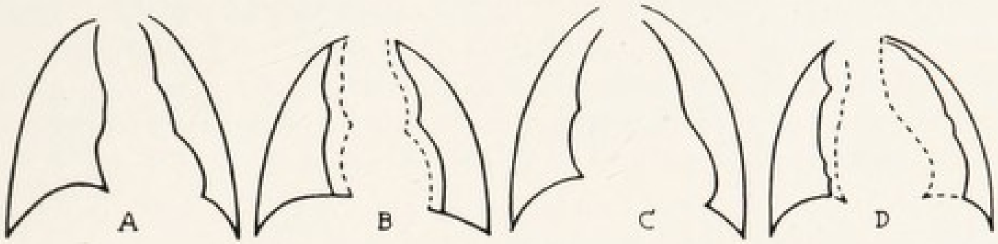


FIG. 236.[2]

A. Normal vascular shadow in the newly born child. B. Hyperplasia of the thymus in a seven-weeks' child. C. Hyperplasia of the thymus in a newly born child. D. Hyperplasia of the thymus in a newly born child.

In young children, especially in premature children, one should always think of an enlarged thymus, when they have any difficulty in breathing. When the child cries, the thymus increases still more.[3]

LIVER [4]

General

The *upper border of the liver* is easily distinguishable from the clear lung spaces even in technically poor pictures, provided they are taken with

[1] Rheu: Thymusstenose u. Thymustod. Arch. f. klin. Med., Bd. 80, 1906.

[2] In rough drawings from M. Bürger and H. Schlecht: Erkrankungen der endokrinen Drüsen; in Schittenhelm, Lehrbuch der Röntgen-Diagnostik. 1924 (Springer, Berlin).—See further: H. Assmann: Die klin. Röntg.-Diagnostik der inneren Krankheiten. Leipzig, 1924.—G. J. Noback: The Thymus in the Newborn and early Infancy. Radiology, November, 1926.—C. W. Perkins: Röntgen-study of 500 children for Thymic enlargement. Am. J. of Röntg., March, 1926.—O. Coe: A method for estimating the size of the thymus. *Ibid.*—I. Cash King: Thymic enlargement in children. Radiology, August, 1927.—A. Lorey, in Schwalbes "Irrtümer der Diagnostik, etc." 4. Heft, p. 165.—G. W. Grier: The diagnosis and treatment of enlarged thymus. Am. J. of Röntg., February, 1924.

[3] G. W. Grier: The diagnosis and treatment of enlarged thymus. Am. J. of Röntg., February, 1924.

[4] Faulhaber: Die Röntgenuntersuchung der Leber; in Rieder-Rosenthal, Lehrbuch der Röntgenkunde. Leipzig, 1913.—Immelmann: Die Röntgenuntersuchung der Leber und der Gallenblase; in Groedel's atlas, 3rd ed.—Desternes and Baudon: L'exploration röntgénologique du foie. Journ. de Rad. et d'Electrol., July, 1914.—O. Goetze: Röntgenologie des Bauches, in Leitfaden der Röntgenologie by H. Gerhartz, 1922.—F. M. Groedel: Die Gallenblase im Röntgenbilde. XI. Deutscher Röntgen-Kongress, 1920.—F. Perussia: Appunti di röntgenologia del fegato e delle vie biliari. Atti II Congr. d. Soc. Ital. di Rat. Med., Genoa, 1919.—Parola: L'esplorazione röntgenologica del fegato. L'Ospedale maggiore, Milan, 1915, Fasc. 11.—Schittenhelm and Wels: Untersuchung der Bauchhöhle, in Schittenhelm's Lehrbuch der Röntgendiagnostik. Berlin, 1924.—Haenisch, in 2nd ed. of Rieder-Rosenthal, 1924.—R. Knox: Röntgenography of the Gall-Bladder. Acta Rad., No. 14.—*Ibidem*: Radiography in the examination of the liver, gall bladder, and bile ducts (W. Heinemann, London).

the breath held. Usually it forms a cupola with a contour of the third of a circle without any interruption, and preserves its form unaltered both in inspiration and expiration, appearing flattened only when the lungs are of larger volume than normal.

A liver surface, which shows one or two indentations, is very frequently seen by the radiologist. Whether this phenomenon be normal or otherwise, the furrows observed are seldom the cause of complaints. These furrows are simple sagittal ones, they occur in a large percentage of adult sections, and are regarded by the pathologists as quite a normal appearance.

Enlargement of *the size and volume* of the liver does not alter the appearance and level of the upper contour of the liver. It is otherwise in solid tumours, abscess, and hydatid cyst; these can form a special small arching and prominence on the cupola of the liver. One should never neglect to do a right-lateral profile screening or photograph.

For other appearances at the upper margin of the liver, see under "Diaphragm."

The inferior margin of the liver with the gall-bladder (spleen, urinary bladder, perhaps other organs and tissues also) may sometimes show up in the ordinary röntgenogram, because the mesenteric fat and gas in the small intestine offer the best conditions for taking it.[1] In infants the inferior border of the liver is clearly defined from the gas-containing coils of intestine below it.

The lower border of the liver cannot generally be distinguished in a röntgenogram either in the normal or in the pathological condition. In a number of cases, on the other hand, the lower border can be reproduced on the plate; by setting the focus of the Röntgen tube not directly dorso-ventral over the liver as in Fig. 237, A, but much nearer the head, at the level of the fifth or sixth spinous process of the thoracic vertebræ. Then the lower rays running tangential to the edge of the liver traverse the liver in its whole extent from above and behind to below and in front, and so one gets a better contrast as against the other soft tissue shadows of the abdomen[2]; that is shown diagrammatically in Fig. 237, *b*, with the Spalteholz-Braune anatomical atlas used as a background for the path of the rays drawn by the author. The right lobe of the liver shows up best under these conditions. The left lobe of the liver is covered by the shadow of the vertebræ; in order to distinguish the left lobe and a part of the right one, it has been advised to photograph the patient in the left lateral position, with the plate resting on the abdomen, and the tube at the back over the middle of the plate.[3] In this left lateral position the gastric sac

[1] Pordes. Fortschritte, Bd. 33, 1925.

[2] Köhler: Totalröntgenogramme der Leber. Fortschritte, Bd. 1, and (without illustrations) in the Proceedings of the 4th International Congress for Electrology and Radiology (Amsterdam, 1908). The projection recommended by the author has been taken up again recently by A. Hensselmann (see below in the chapter "Spleen"). The author's illustrations are therefore not accidental findings.

[3] Béclère, H.: La röntgénographie du foie. Congrès de Dijon, 1911; see also Ledoux-Lebard: L'examen röntgénologique du bord inférieur du foie. Journ. de Rad. et d'Electrol., July, 1914.

moves up to the right and produces the best contrast with the liver; the small quantity of air in the gastric sac very seldom suffices, so an effervescing powder is usually given before the examination.

In a marked arching upward of the right cupola of the diaphragm an echinococcus cyst was diagnosed, and afterwards found.[1] (Calcification of such cysts have also been observed, and even intrahepatic abscess with gas contents and fluidity mirror.)

Almost complete immobility of the right elevated contour of the diaphragm with active enhancement of the action of the left one is characteristic of subphrenic abscess on the right side. In gas-containing subphrenic abscess there is in addition a fluidity mirror. (A sickle-shaped transparency between the liver and the diaphragm occurs in entrance of air into

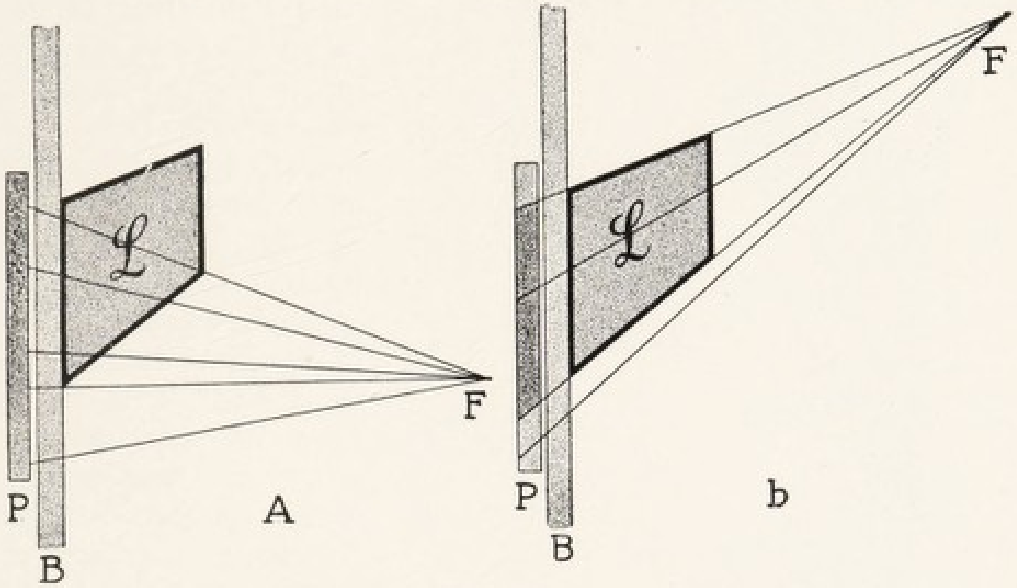


Fig. 237.

P = Photographic plate. L = Liver.
B = Abdominal parietes. F = Focus of Röntgen tube.

the peritoneal cavity in consequence of perforated gastric or intestinal ulcer, in pneumoperitoneum after laparotomy, etc.)[2]

About 1914 more attention began to be paid to Röntgen representation of the liver.[3] Introductions of gas were made not only into the stomach but also into the colon. After clearing the bowel with an enema 1–1½ litres of atmospheric air (oxygen, nitrogen) were introduced per rectum (later also with the aid of the duodenal tube air was introduced into the duodenum and the proximal part of the intestine). Contra-indications: severe inflammatory appearances in the abdominal viscera. The introduction of the gas and the examination itself is best conducted by means of screening. If the gas be too little the liver does not stand out sufficiently from its

[1] Kienböck. Fortschritte, Bd. 21, p. 77.

[2] F. Haenisch, *l.c.*

[3] Löffler: Leber und Milz im Röntgenbild. Münchener Med. Wochenschr., 1914, No. 14.—Meyer-Betz: Methode und klinische Bedeutung der Darstellung der Leber im Röntgenbilde. Münchener Med. Wochenschr., 1914, No. 15.—E. Rautenberg: Röntgenphotographie der Leber, der Milz und des Zwerchfells. Deutsche med. Wochenschr., 1914, No. 24.

surroundings; if one blows in too much, then displacement occurs, and this is undesirable. It is advisable to do palpation during screening, especially if an abdominal tumour be suspected. A view of the left lobe of the liver is obtained by filling the stomach moderately with gas so as to smooth out its creases. A soft tube is desirable.

About the same time another method was recommended, namely, *the introduction of gas (oxygen) into the peritoneal cavity.*[1] The liver and the region of the gall-bladder are thus brought well into view, also tumours, and especially good results were got with the aid of Rieder's bismuth meal. The method was first attempted on a patient with ascites. The ascitic fluid was drawn off and the abdomen insufflated with from 2–6 litres of oxygen. In the course of a decade the technique and diagnosis of *pneumoperitoneum* has attained a stage promising much for the future. As far as the liver in pneumoperitoneum is concerned, it becomes lifted from the diaphragm and from the abdominal wall, it is suspended from its attachments and alters in standing, in the horizontal and in the lateral position to a greater or less degree. One can recognise not only the limits of the right and left lobe of the liver and its adjacent ligaments, but also the characteristic form of the normal, congested, cirrhotic, the coarse-lobed luetic, the rough carcinomatous, and the round studded echinococcus-liver; further, there can be recognised various forms of the thick, tongue-like, or apparently freely pendulous "corset-lobe." Delimitations of solitary tumours of the liver from pancreatic cysts or tumours of the stomach are rendered possible. But pneumoperitoneal diagnosis should stop short at all recent inflammatory processes, for there is a danger of spreading an abscess.

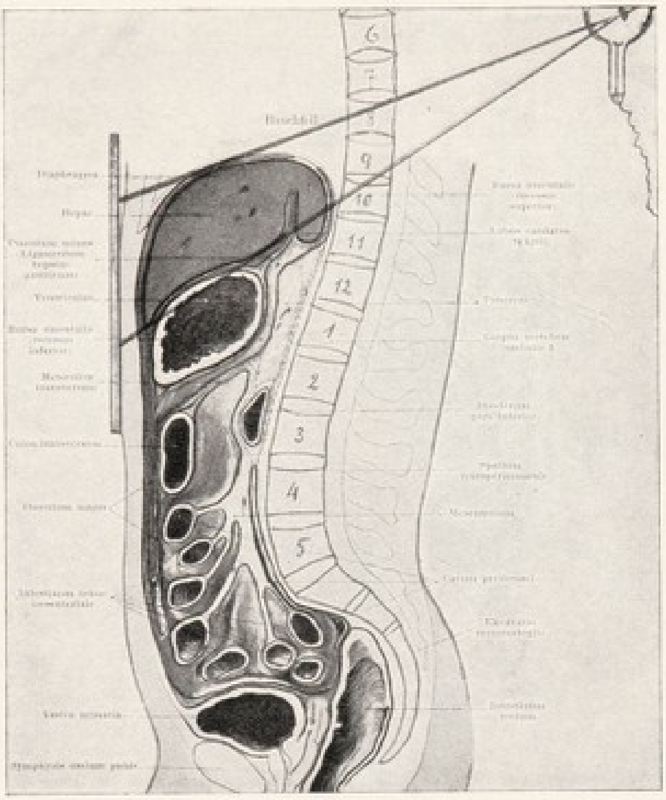


Fig. 238.

[1] Meyer-Betz and Rautenberg, *l.c.* after Jacobaeus: Über Laparoskopie und Thorakoskopie. Würzburg, 1913; further Weber: Über die Bedeutung der Einführung von Sauerstoff resp. Luft, etc. Fortschritte, Bd. 20, 1913.—E. Rautenberg: Sechsjährige Erfahrungen mit pneumoperitonealer Röntgendiagnostik. Verhdl. d. Deutschen Röntgen-Gesellsch., Bd. XI, 1921.—O. Goetze: Pneumo-peritoneal Röntgen diagnosis. *Ibid.* Quite a good short summary, from which the second half of this paragraph has been taken, is found in Gerhartz's Röntgenology, by O. Goetze. There is now an extensive literature dealing with pneumoperitoneum. The latest summary is from Schittenhelm and Wels, *l.c.*

A *clear zone between liver and diaphragm* (without pneumoperitoneal examination) is present in very mobile livers, without the patient necessarily complaining about it; "hepatoptosis," "interposition-ptosis" (Hasselwander). The gas-filled colon has pressed into the space. The condition can disappear from day to day and reappear again. The colon is recognisable from its haustra; if these be absent, we have to think of a subphrenic

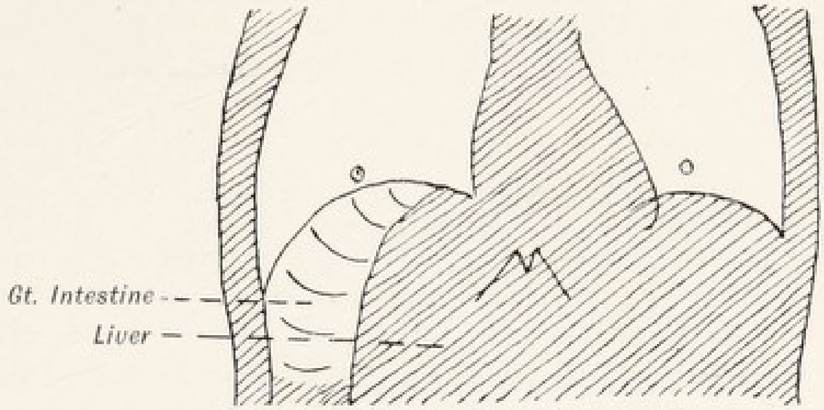


Fig. 239a.[1]

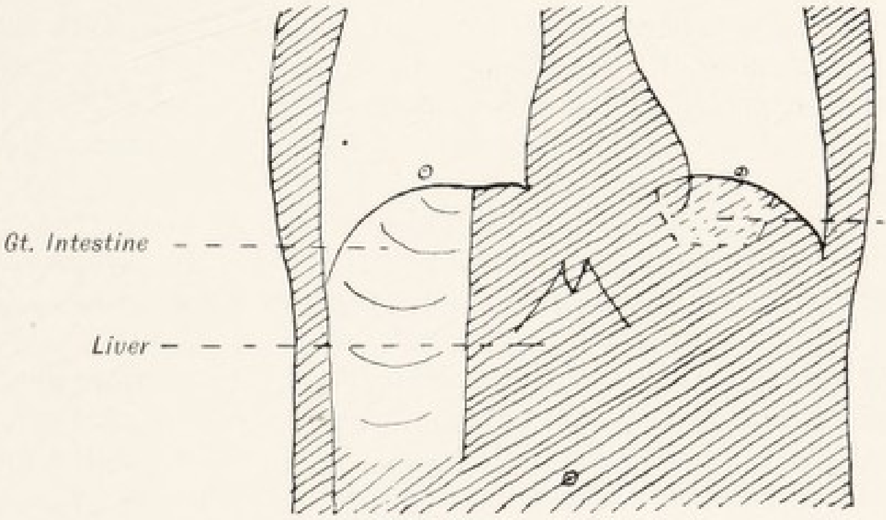


Fig. 239b.[1]

abscess with gas in it. A picture of fluid may also be seen in hepatoptosis, for the ballooned coils of colon may contain considerable quantities of fluid contents.

If one cares to examine his photographs of the large intestine, one finds the liver tolerably well shown in about one in every four pictures.

It has also been sought to measure the size of the liver on röntgenograms taken with the Potter-Bucky diaphragm,[2] and the average length

[1] Demetrius Chilaiditi: Zur Frage der Hepatoptose und Ptose im Allgemeinen im Anschluss an drei Fälle von temporärer, partieller Leberverlagerung. Fortschritte, Bd. 16, 1910. The two figures are taken from that work.—F. Perussia: La epatoptosi parziale da interposizione. La Riforma Med., 1916, 3.—Boidi-Trotti: Considerazioni sopra un caso di interposizione dell'intestino fra il fegato e il diaframma. R. Accad. di Med. di Torino, Gennaio, 1918.

[2] G. E. Pfahler: The measurement of the liver by means of Röntgen-rays based upon a study of 502 subjects. Am. J. of Röntg., December, 1926.

of the right lobe is 21·3 cm., and the average thickness 12·8 cm. Sex, age, size, weight, and stoutness of the body do not really make very much difference.

GALL-BLADDER

The indirect method of examination, cholecystography, we shall refrain from describing in detail. The method was first employed by Graham, Cole, and Copher,[1] and it depends upon combining phenolphthalein, a means of testing the function of the liver, which is expelled with the bile, with elements of a higher atomic weight (chlorine or iodine). The most suitable substances proved to be the sodium salt of tetrabromphenolphthalein and tetraiodophenolphthalein. These substances were injected intravenously or given by the mouth, the injection method being the more reliable; the peroral method is less risky. The technical details of the procedure need not here be described. After the injection it takes about 8 hours, after peroral administration 12–18 hours, before the gall-bladder becomes visible in the röntgenogram. It exhibits normally a shadow 4–10 cm. in length, pear-like or fig-like in form. Its position is subject to extraordinary variations. Stones if present give negative shadows. If the gall-bladder does not exhibit any contrast shadow, the passages leading to it may be blocked, or the concentration-capacity of the gall-bladder has been reduced, or its walls are inflamed. A very large shadow of a gall-bladder indicates a dilated gall-bladder.

For a considerable time great promises were held out for rendering the gall-bladder visible by means of pneumoperitoneum. In *pneumoperitoneum* a normal gall-bladder shows up distinctly from its surroundings; it swings a little to and fro on one striking the region of the trochanter. The elastic delicacy of its wall is betrayed by a fine vibration. Apart from the varieties of form which are usually easily recognisable one can estimate the degree of thickening of the walls, extent of adhesions, and even the finer pericholecystitic adhesions.[2] Since the further introduction of cholecystography the examination of the gall-bladder with the pneumoperitoneum method has been almost entirely abandoned, especially as gall-stones were hardly ever recognised by it.

Without pneumoperitoneum the *normal* gall-bladder can scarcely ever be seen. The *pathological*, enlarged, or stone-containing bladder can occasionally be seen, but only in a very small percentage of the total cases, of which every röntgenologist can convince himself by examining a hundred or two gastro-intestinal photographs. (For aids to diagnosis, see below.) In these exceptional cases the conditions are particularly favourable, owing to the presence of gas in the adjacent coils of intestine. It is quite possible, however, that in the future a more frequent view of the gall-bladder will be

[1] Graham, Cole, and Copher: Visualisation of the gall-bladder by the sodium salt of tetrabromphenolphthalein. Journ. of Amer. Med. Assoc., 1924, 82, p. 1777.—Graham and Cole: *ibidem*. 1924, lxxxii, p. 63.—Graham, Cole, and Copher: *ibidem*. 1925, lxxxiv, p. 14.

[2] For literature on pneumoperitoneum, see above.

obtained with the aid of the Potter-Bucky diaphragm, in cases where that is desirable, in addition to cholecystography with tetrabrom- or tetraoidol-phenolphthalein. One investigator mentions that a gall-bladder with thick inspissated contents is generally visible. Exposures taken for the gall-bladder alone should be done on an empty stomach, for a duodenal cap filled with ordinary contents can simulate a gall-bladder. Very much enlarged gall-bladders have even been mistaken for shadows of the kidney. We may summarise as follows: if a gall-bladder is recognisable on a Röntgen film we must be dealing with a diseased gall-bladder. In well-nourished, stout people the shadow should be sought for high up and more lateral; in thin individuals, on the other hand, and cases with general ptosis, it can come much lower, and be found even below the crest of the ileum. The lower pole is always the clearest part of the shadow. The size of the gall-bladder can vary from that of a walnut to one 20 cm. in length.

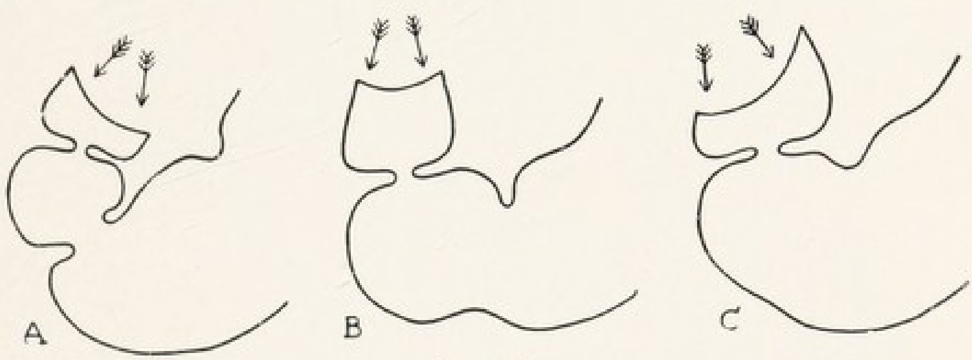


Fig. 240.

The normal gall-bladder rests on the transverse colon and on the pyloric part of the ventricle of the stomach; more posteriorly it touches the duodenum (Rauber). On this is based the indirect proof of an enlarged gall-bladder, in that it presses upon and produces a *deformity of the duodenal cap* when filled with a contrast-meal. Thickening of the walls of the gall-bladder, increase of the bile, or stones make a characteristic impression on the stomach or duodenum; on the first, albeit rarely, on the greater curvature near the pylorus; on the second, in its first or second part (Figs. 240 and 241; see in the latter figure a gall-stone the size of a walnut). The shadow defect is in these cases limited by a concave curve; we have before us a flattened helmet.[1] It is advisable here, as in duodenal ulcer, to use cushion-compression. A normal gall-bladder ought to be too soft to make any impression. Nevertheless, it is an accepted fact found at operations that a normal gall-bladder temporarily dilated may without a doubt produce such impressions.[2]

Spots in the region of the anterior costal margin and of the shadow of the eleventh and twelfth long rib can be produced by *gall-stones*; they are fairly certain to be due to gall-stones when they are ring-shaped. Even

[1] Our experience being comparatively small we refer to the monograph of George and Leonard, see footnote, p. 390.

[2] Case, quoted by Haenisch.

with the very best technique for gall-stones a negative Röntgen finding does not exclude the presence of very many and large stones. After isolated statements upon positive Röntgen findings of gall-stones at the beginning of the century great and successful endeavours have been made, especially from the American side, to advance Röntgen diagnosis in this particular during the last decade.[1] Seeing these shadows of stones are anything but distinct, everything turns upon a first-class technique. The plate or the film must be of faultless finish, and equally too the intensifying screen or screens, if one believes their use to be indispensable. Double intensifying screens are better, surface to surface. All drugs should be stopped two days before the examination, in order that there be no mistake made from shadows emanating therefrom. A small focal point of the tube and a good iris-diaphragm are essential. The position of the patient, prone and horizontal. Plate 18×24 cm. Central ray vertical to the plate. Costal margin cutting the middle of the plate. In scoliosis the gall-bladder may be overshadowed. Degree of hardness of tube: the softest possible rays that can penetrate through the patient. Time of exposure, 1–2 seconds or longer with the breath held. It depends less on the number of seconds than on the breath being absolutely held. The patient should practise that in advance. A single exposure is seldom sufficient, usually two to three

[1] J. T. Case: 17. Internat. Med. Congress, 1913, London. *Ibid.*: Röntgenoscopy of the liver and biliary passages with special reference to gallstones. J. of the Am. Med. Assoc., Vol. LXI, September, 1913. *Ibid.*: Negative and positive Röntgen diagnosis of gallstones. Amer. J. of Röntg., Vol. III., May, 1916 Cole: The detection of pure cholesterine gall-stones by the Röntgen-rays. Amer. Journ. of Röntgen, February, 1915. —George and Leonard: The Röntgen - Diagnosis of a pathological Gall - bladder. Am. Journ. of Röntgen., July, 1917.—W. George and Ralph D. Leonard: The pathological Gall-Bladder. 1922. (B. Hoeber, New York.)—Further Rieder: Zur Röntgendiagnostik der Gallensteine. Fortschritte, Bd. 28, 1922.—J. Schütze: Fortschritte in der röntgenologischen Darstellbarkeit der Gallensteine. Fortschritte, Bd. 28, 1921.—R. A. Ahrens: The gall-bladder. Journ. of Radiologie, Vol. III, October, 1922.—Sessa, P.: Contributo allo studio röntgenologico della calcolosi biliare. La Rad. Med., 1920, Vol. VII, Fasc. 9/10. —Palmieri: Röntgenogrammi di calcoli biliari. IV Riunione dei Radiologi Emiliani, Piacenza, 1920.—Rubaschow: Zur Röntgendiagnostik der Gallensteine. Fortschritte, Bd. 21. —P. Duval et Béclère: Etude röntgenographique des voies biliaires normales et lithiasiques. Arch. des Mad. de l'App. digest. et de la Nutr., Tome 12, No. 6, 1922.—F. Romany: Beiträge zur Röntgendiagnostik der Cholelithiasis. Fortschritte, Bd. 35, 6.—Friedmann. Strauss and Ahrens: A clinical röntgenological study of the gall-bladder. Radiology, August, 1925.—B. H. Nichols: Differential diagnosis of gall-stones and kidney stones. *Ibid.*— L. J. Carter: Pathology in the right upper abdomen. Radiology, September, 1924.— C. S. Oakman: Röntgenographic diagnosis of gall-bladder disease. Radiology, 1926.— C. Thurstan Holland: A case of gall-stones, with radiograph. Arch. Röntg. Ray, 1906, 10, p. 242. Liverpool Med. Chir., July, 1914, p. 308.—*Ibid.* On gall-stones. Arch. Röntg. Ray, 1913, 17, p. 374.—Robert Knox, London: The examination of the liver, gall-bladder and bile-ducts. Arch. of Rad. and Elec., 1919, July, August, September, October.—E. A. Graham and W. H. Cole: Visualisation of the gall-bladder by the sodium salt of tetrabromphenolphthalein, May 31, 1924. J. Am. Med. Assoc., 1924, lxxii, p. 1777.—J. Thompson-Walker and R. Knox: Observations on the lateral position and other methods of examination of the renal and gall-bladder areas. Amer. J. of Röntg., September, 1923.—D. P. D. Wilkie and C. F. W. Illingworth: Cholecystography. Brit. Med. J., December, 1925. Also Brit. Med. J., April 2, 1927, I, pp. 613–614.—Berkeley Moynihan: The relationship of radiology and surgery. Brit. Med. J., July 11, 1925, pp. 47–51.—A. Bruce Maclean: Cholecystography. Brit. J. of Rad., January, 1927. The X-Ray visualisation of the gall-bladder by means of sodium tetraiodophenolphthalein. Glasgow Med. J., No. 3, September, 1926.

of them are needed, sometimes even more. (Watch not to burn the patient.) Every film should be developed and carefully studied before doing another. The picture should show the eleventh and twelfth ribs, the lower dorsal and upper lumbar region. The transverse processes of the lumbar vertebræ should stand out clear, also the lower border of the liver and a part of the right kidney, which—in consequence of the distance from the plate—appears much enlarged. It is an advantage if the patient when in the prone position turns his thorax hard to the left, with a view to widening the distance between the last ribs and the crest of the ileum.

As already mentioned, the majority of the *gall-stones* visible in a negative contain calcium in their peripheral layer, and therefore cast a ring-shaped

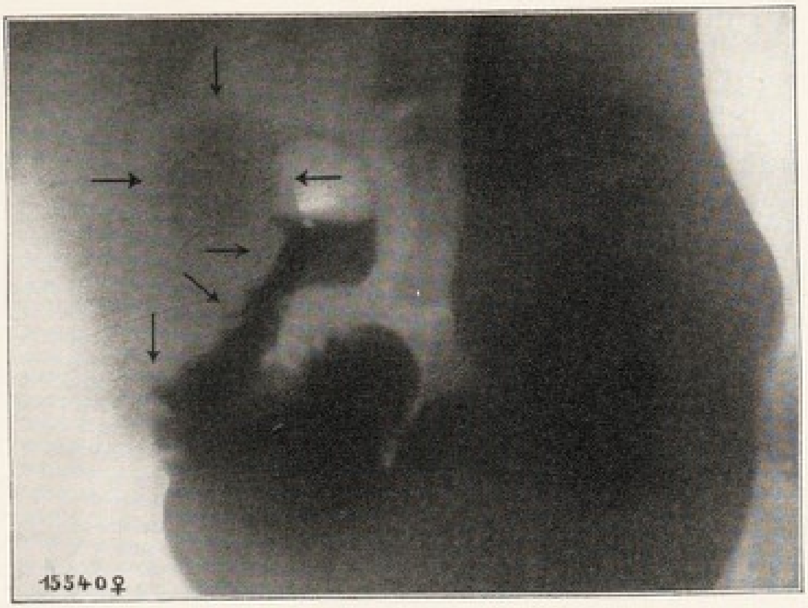


Fig. 241.

shadow. A calcium percentage of less than 10 per cent. should be sufficient to render them visible. Only one segment of the stone may be visible. Concentric stones are also recognisable. Their Röntgen shadow resembles the year-rings of a sawn tree-trunk. Moreover, homogeneous stones are sometimes found, very similar in appearance to kidney stones. The proof of calcium in the stones is especially important, because it shows not only the existence of the stones, and their number and position, but because the presence of calcium indicates that inflammatory processes were at work in the production of the stones. Also shadows are found corresponding to collections of sand or a mass of stones of the very smallest size. Most remarkable of all are the "negative stone-shadows," which consist only of pure cholesterin. The latter is thinner in density than the bile in which they float, and the surrounding tissues. They give a shadow about half as dense as a layer of water of the same thickness. They absorb roughly the equivalent of a layer of fat of equal thickness, which sometimes indeed is visible on the Röntgen film in the interior of the other soft tissues. They, therefore, appear clear in the negative of the soft tissues; it takes the best negatives to recognise them, and, besides, they are very rare. Pure bilirubin-calcium stones have practically the same absorptive qualities as water. They therefore completely escape detection by direct Röntgen examination.

For *the differential diagnosis* of gall-stones from similar pictures one can say that the shadows of gall-stones are more regular than those of kidney-stones. Single stones are mostly circular; when a number of large facetted stones are present polygonal or triangular shadows are found, in mosaic-like formation. Also solid shadow-spots (from cholesterin-bilirubin-calcium stones) appear; they can look very like ossification within the ribs. Therefore one should look carefully to see whether any other ossifications of the ribs are present. In total ossification of the ribs there is no chance of mistake. In cases difficult to diagnose a profile picture should be taken: Kidney-stones then appear just in front of or in the vertebral shadow. Further calcified lymph-glands and calcifications in the suprarenals give very irregular shadows, mesenteric glands are in addition freely movable. "Negative stones" can be confused with small collections of gas in the hepatic flexure. Collections of gas vary in size from minute to minute. The same applies to fæcal masses in the great intestine. Foreign bodies that have been swallowed (buttons, etc.) can give rise to mistakes in diagnosis, also papillomata of the skin and moles.

When gall-stones are certainly present in a case, upon Röntgen or ordinary clinical diagnosis, it is to be carefully observed whether ossifications of the lower costal cartilages are present. While calcifications of the first costal cartilage are the general rule after the twentieth to the twenty-fifth year (see under "Ribs"), calcifications of the lowest ribs are much rarer. In looking through the pictures of gall-stones recorded in the Röntgen literature I was struck with a great number of pictures in which a marked and even a maximal degree of calcification of the lowest costal cartilages was present. There appears to me, therefore, to be a relation or parallel between *calcification of the ribs and visible gall-stones*, which indeed is a fact not altogether surprising.

One author [1] says that in 50 per cent. of his cases in which at operation a gall-bladder was found packed with facetted gall-stones, the stones had been already positively diagnosed by the Röntgen rays. Further, in about 60 per cent. of the cases of cholesterin-pigment calcium stones, which occur singly or two or three at a time in the gall-bladder, the Röntgen examination proved positive.

Stones in the cystic duct or *in the common bile duct* should be more easily recognised than stones surrounded by bile; indeed, it used to be advised to aspirate the contents of the gall-bladder before taking a Röntgen plate. Shortly before writing these lines the author photographed a case with all the clinical symptoms of gall-stones. The negative showed faintly but very beautifully a conglomeration of a round stone larger than a hazelnut, above it one of half that size, below it seven to ten facetted smaller stones, all these shadows together forming roughly the form of the gall-bladder, in this

[1] Romany, *l.c.*

case 6 cm. in length and 2–2·5 cm. in breadth, running in the direction from supero-medial to infero-lateral. A control negative exhibited the same finding, but further 4–5 cm. downwards and medial to the shadow of the gall-stones, and in very similar direction to their course, five lentil-shaped to small cherry-sized shadows, placed at distances of 3–4 mm. and arranged in a row (see Fig. 242). On examining the first negative a second time one found these same five shadows also present, but at a distance of 7 cm. from the gall-bladder. The changing position of the gall-bladder is naturally the consequence of projection. Hitherto the patient had refused all operative interference. The author has not any doubt but that these five small shadows are of stones in the common bile duct (or cystic duct); although, indeed, the ureter runs in very much the same direction, and at this point calcified mesenteric glands are wont to occur; the appearance of mesenteric glands is, however, quite different. The shadow of the kidney can also be seen on the plate. The gall-stones shadows sketched appear on the plate more homogeneous. Their external margins are sharp and clear, but the facet-lines of the lower five stones in the biliary duct are not quite so clear on the plate as in the sketch; doubtless there are other stones behind these, so that the gall-bladder contains not nine, as in the sketch, but probably half a dozen more.

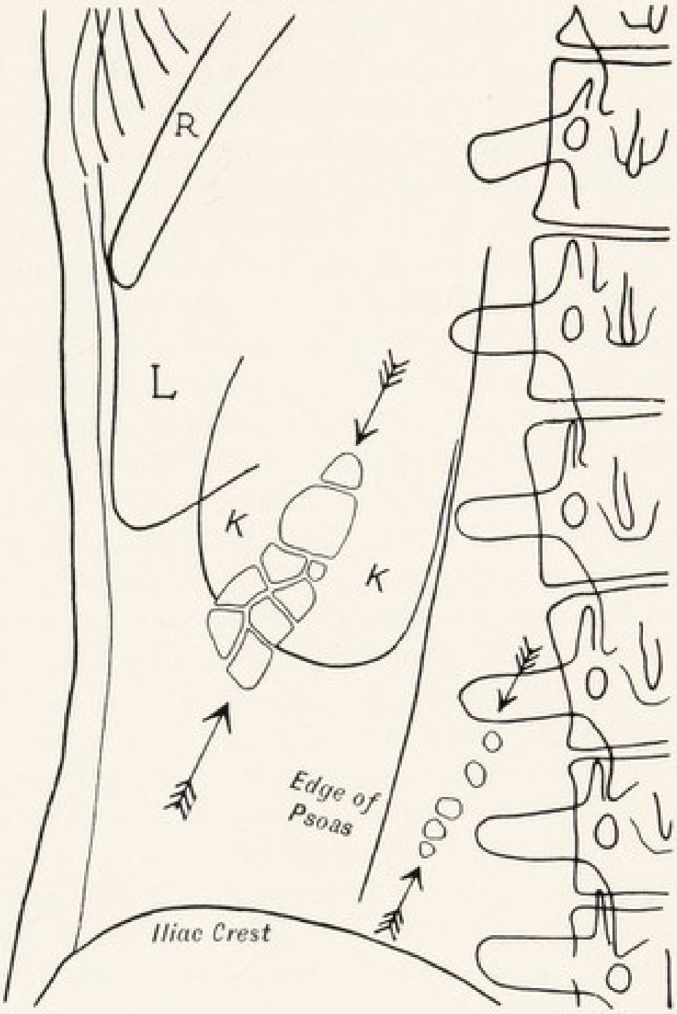


FIG. 242.

Naunyn claims to have observed that gall-stones may again lose their calcium-content by absorption of the lime. Their visibility (in the Röntgen plate) might naturally then disappear.

SPLEEN [1]

Röntgen examination of the spleen has not hitherto attained much importance. Percussion and palpation being methods easy to carry out,

[1] Le Page: La röntgénoscopie et la röntgénographie de la rate. Thèse de Paris, 1912, Orléans.—Rautenberg: Röntgenphotographie der Leber, der Milz und des Zwerchfells.

there is not any great practical need for it. In occasional cases the spleen comes completely into view, when there is much collection of gas in stomach and intestine; it is seen more frequently in children, for they have comparatively more gas in the intestinal tract. This circumstance is all the more fortunate, as it is especially in children that it requires great care to percuss the size of the spleen. In the plates taken of adults, secured in the standing position, the upper pole of the spleen is seen not infrequently in the clear area of the gastric sac, often indeed the whole spleen, if at the time of the examination there be much gas in the splenic flexure of the colon. The right lateral position, especially when the gastric sac is large, affords sometimes better pictures than are obtained in the standing position. Naturally such conditions give us the indication to increase the gas-contents of the stomach by the admixture of effervescing powder and by the insufflation of oxygen per rectum into the colon. These methods have secured very good results (see also under "Liver") and consistently excellent pictures of the spleen. One obtains an easy survey of the position, size, and form. In addition to plates screening should always be done, in profile, obliquely and dorsal. Orthodiagrams can also be taken. The photograph itself must be made with the breath held and secured as quickly as possible. One should not neglect to observe the position of the diaphragm, particularly when stomach and intestine have not been treated with the introduction of gas.

It should be remembered that the average length of the spleen is 12–14 cm., its breadth 8–9 cm., and its thickness 3–4 cm.

Double contours of the shadow-view of the spleen do not require to be abnormal; they are produced very simply, by the sagittal beam being projected through both the anterior and the posterior medial contour.[1]

If a view of the spleen cannot be obtained in this way, *a contrast-meal* to fill the stomach usually succeeds in rendering the spleen shadow visible. In displacement or enlargement of the spleen the Röntgen examination is completed at the time the splenic flexure is filled with the contrast-meal.

When the spleen is not enlarged and is normally situated it cannot be differentiated from the diaphragm. Its lateral border becomes visible only a little below the diaphragm. The lower pole of the spleen is nearer the mid-line than the outer costo-phrenic angle. From the lower pole the median shadow-contour bends up obliquely. The Röntgen form of the normal spleen is usually semilunar, but ellipsoidal forms or tongue-like forms elongated in the long axis are not uncommon, more rarely rounded or rectangular forms. Displacements of the spleen are said to occur most

Deutsche med. Wochenschr., 1914, No. 24.—F. M. Groedel: Die Röntgen-Darstellung der Milz. Deutscher Röntgen-Kongress, Berlin, 1920.—Calm: Echinococcus der Milz. Verh. d. Deutschen Röntgen-Ges., 1921, Bd. 12, p. 136.—Lubbers en Noordenbos: Echinococcus van de milt. Nederl. Tijdschr. voor geneesk., 1922, I, p. 460.—H. Lossen: Die Röntgen-Untersuchung der Milz. Atlas Groedel, 4th ed., 1924.—Schittenhelm und Wels: Die Milz; in Schittenhelm's Lehrbuch.—H. Rieder: Die Röntgenuntersuchung der Milz; in Rieder-Rosenthal's text-book, Bd. 1, 1924.—A. Hensselmann: Die Röntgendiagnostik der Milz. W. kl. W., 1918, No. 33.

[1] Rieder, *l.c.*

frequently in association with umbilical hernia. Diaphragmatic herniæ can bring the spleen to rest in the pleural cavity. Ptosis of the spleen without enlargement, according to radiological experience, happens more frequently than clinicians admit. When the spleen appears in the normal position with the body horizontal, splenoptosis cannot by any means be excluded, and it is therefore advisable to carry out the screening or photographs in the standing position. If the stomach be markedly displaced to the right, without any other reason therefore existing, always look whether an enlargement of the spleen can be seen in the plate. For we know that an enlarged spleen cannot be mapped out clinically in every case.[1]

The spleen can always be rendered visible by introducing *gas into the colon*, just as by pneumoperitoneum (see above under "Liver"). The spleen then gives a shadow like an egg set upon its end, or like a breakfast roll—usually oblique, with the end set somewhat laterally. Its upper pole is in contact with the lateral half of the diaphragm to a greater or less extent, and its shadow is not distinguishable from that of the diaphragm, its broad convex surface rests against the lateral abdominal wall, with which the splenic shadow merges as far as its lower pole. The lower pole and the median border are almost free in their whole length. A longer or shorter part of the median border projects into the gastric sac (or the splenic flexure). In *ptosed and in wandering spleen* the upper border appears separated from the linear shadow of the diaphragm. Transverse and vertical spleens are usually characteristic of certain constitutional conditions. In this way enlargements of the spleen can sometimes be determined, when they are not revealed by clinical examination, when accompanied by diseases like obesity, ascites, defensio musculorum, abdominal tumour, meteorism, etc.[2]

A spleen covered by coils of intestine filled with gas can sometimes not be seen, is "spirited away."

The author drew attention long ago to the fact not yet mentioned in the Röntgen literature but given in text-books of pathology, the presence of phleboliths in the spleen. These ought sometimes to give shadows similar to the phleboliths of the ligamentum latum. One observer has now reported in the region of the spleen spots varying in size from that of a lentil to that of a bean, sharply defined, partly isolated, partly confluent, of the density of a calcified focus, in varying numbers, and described them as phleboliths.[3]

PANCREAS[4]

The pancreas has not been clearly shown yet in Röntgen view, except with the aid of a pneumoperitoneum (Hessel). If a short paragraph is

[1] The last statements verbatim after Groedel, *l.c.*

[2] After A. Hensselmann: Über den röntgendiagnostischen Wert des Dickdarm-Aufblähens bei der Milz-, Leber- und Gallenblasen-Untersuchung. Fortschritte, Bd. 29, 1922 (with list of the literature).

[3] E. Koppenstein: Phlebolithen in der Milz. Fortschritte, Bd. 36, 1, 1927.—W. Mitchell: Splenic calculi. Arch. of Rad. and Elec., July, 1919.

[4] Armani: Tumore pancreatico simulante un tumore gastrico. La Rad. Med., 11/12,

devoted to the subject here, it is because *pancreatic-stones*, albeit rarities, do cast shadows at a point where the examiner least expects to see any, and can give rise to difficulties and mistakes. At this date only a very few observations of this kind have been recorded,[1] and in not a single case was the diagnosis of pancreatic concretions made on the strength of the Röntgen findings. According to the statistics of the pathologists there occurs one case of pancreatic-stone to every 2,000 people; usually only men are affected, from the age of thirty upwards. It is now recommended that a Röntgen plate of the pancreas should be taken in every case of diabetes, especially when associated with colic of an indeterminate nature. It is very rare for the stones to be solitary; they usually appear a number at a time, from a lentil to a hazelnut in size. They are rarely quite circular, usually having a pointed or warty appearance, occasionally of a mulberry-like form. Under especially favourable conditions and in larger concretions there is a prospect with the help of the Röntgen rays of making a correct diagnosis.

If one looks through his Röntgen films of past and recent years for an occasionally visible pancreas, one should recollect that its length is normally 14–18 cm., its breadth 3–5 cm., and its thickness 2–3 cm.; it runs almost horizontally transversely in front of the vertebral column at the level of the first and second lumbar vertebræ.

One case has been reported,[2] where deposits of lime were held to be kidney stones in a carcinoma of the head of the pancreas. *Calcifications* may also be present in the pancreas without carcinoma.

An enlarged pancreas sometimes appears *indirectly* in contrast-pictures of stomach and intestine. Various cases have been described. The author desires to refer to his own autoptically controlled cases, which are given in sketches in the parts " Stomach " and " Transverse colon " of this book. An observer of wide experience has recently said: [3] " Tumours of the pancreas are wont to press the pars pylorica from behind forwards. The stomach above the tumour then appears normal, the most striking feature being the greatly increased palpation motility of the contents. A slight pressure of the finger is enough to cause the shadow masses to disappear, the reason of this being that the stomach is stretched over the retroventricular tumour. Under certain circumstances, however, a tumour of the pancreas can produce a complete defect in the filling of such an extent that the extraventricularity of the pathological process can be inferred from the size of the occluded area."

1920.—Ruggi: Ematoma traumatica in cisti del pancreas. Il Policlinico, Sez. prat., 1911, No. 35.—F. Haenisch: Die Röntgenuntersuchung bei Pankreaserkrankungen. In Rieder-Rosenthal's text-book, Bd. 2, 1925.—Assmann: Klinische Röntgendiagnostik, 1924.

[1] M. Simmonds: Über Lithiasis pancreatica. Fortschritte, Bd. 30, 1923.

[2] L. G. Cole: Med. News, 1905.

[3] G. Schwarz: Die Röntgenuntersuchung der Verdauungsorgane; in Schittenhelm's text-book of Röntgen diagnosis, 1924, p. 846.

URINARY ORGANS

Kidneys [1]

For the indirect reproduction of the renal pelvis and ureters the method of "Pyelography" is available. A ureteral catheter is passed and 2–8 cubic centimetres of a suitable contrast-fluid is introduced: Potassium iodide 5–10 per cent., Lithium iodide 25 per cent., Thorium nitrate 15 per cent., Sodium iodide 13·5 per cent., Iodide of Silver, or Sodium bromide in 25 per cent. solution, and others. Collargol, which was first employed, has now been given up on account of the danger of argyria. The procedure is useful in congenital anomalies, dystopias, renal stones, hydronephrosis and pyonephrosis, tuberculosis and tumours. Contra-indications are: Advanced age, arteriosclerosis, high fever, recent hæmorrhage, acute pyocystitis, insufficiency of the kidneys with uræmia. Pyelography has become

[1] Haenisch: Die Röntgenuntersuchung des uropoëtischen Systems, in Groedel's Atlas, 3rd ed.—Burchard: Die röntgenologische Nierendiagnostik. Fortschritte, Bd. 22, 1913.—Dietlen: Die Röntgenuntersuchung des uropoëtischen Systems, in Rieder-Rosenthal, Leipzig, 1924.—Immelmann: Das Röntgenverfahren bei Erkrankungen der Harnorgane. Berlin, 1913 (Meusser).—Nogier: La röntgénographie de précision appliquée à l'examen des voies urinaires. Paris, 1911 (Baillière fils).—Ratera and Pulido: Radiologia en Urologia. Revista espan. Radiol., 1912, No. 10ff. and II. Congreso Espanol de Urologia, Madrid, May, 1912.—Werner Altschul (Prague): Die Röntgendiagnostik der Nierenerkrankungen. Zentralbl. f. d. Grenzgeb. d. Medizin u. Chirurgie. Bd. 18, No. 5, 1914.—Fenwick: The value of Röntgenography in the diagnosis and treatment of urinary stone. London, 1908.—Albers-Schönberg: Das uropoëtische System. Die Röntgentechnik, 5th ed. Hamburg, 1919.—Nemenow: Zur Kasuistik der angeborenen Missbildungen des Harnapparates. Fortschritte, Bd. 18, 1911/12.—Alexander: Vergleichsbilder der Nieren und Nierengegenden. Fortschritte, Bd. 21, 1915.—F. Eisler: Röntgenolog. Fortschritte im Bereiche der Physiologie, Pathologie und Diagnostik der Harnorgane, etc. Fortschritte, Bd. 29, 1922 (with list of the literature).—O. Goetze: Röntgenologie der Nieren, Ureteren und Blase im Leitfaden der Röntgenologie von Gerhartz, 1922.—A. Aievoli: Applicazione della röntgenografia alla diagnostica delle malattie urinarie. Riforma medica, Anno 34, Fasc. 6, 1918.—F. Saraceni: Appunti di röntgenologia delle vie urinarie. Atti II Congr. d. Soc. Ital. di Rad. Med., Genoa, October, 1919.—H. Schlecht: Röntgendiagnostik des uropoëtischen Systems; in Schittenhelm's text-book, 1924.—Assmann: Die Röntgen-Diagn. d. inn. Erkrank. Leipzig, 3rd ed., 1924.—Baensch and Böminghaus: Ztschr. f. urol. Chir., Bd. 7, Heft 1–3. —Eugen Joseph: Die Harnorgane im Röntgenbild, 1926 (Leipzig, Thieme).—J. C. Sargent: The Röntgen-ray in urology. Radiology, 1926, p. 480.—G. Söderlund: Nierentuberculose. Acta rad., 1926, Vol. VII, p. 504.—J. Thomson-Walker, London: Brit. J. of Rad. Röntgen-Soc., Sect. 1922, 88, p. 91.—Révész-Vidor: Chronische Perinephritis. Fortschritte, Bd. 34. 1/2, 1926.—C. Thurstan Holland: Some difficulties in the X-Ray diagnosis of renal calculus. Arch. Röntg. Ray, 1907, 12, p. 61.—Short exposures in kidney work with a mercury break. Arch. Röntg. Ray, 1909, 13, p. 196.—Exposure in the X-Ray examination of the kidney region. Arch. Röntg. Ray, 1911, 16, p. 132.—On the statistics of the X-Ray examination for stone. 17th International Congress of Med., 1913, Radiology Section XXII, p. 87.—A note on the renal calculi with an account of an interesting case. Arch. of Rad. and Elec., 1916, 21, p. 83.—Thelwall Thomas: The Liverpool Bio-chemical J., 1908, Vol. III, p. 346, 1910; Vol. V, p. 161.—W. F. Braasch, Rochester, Minn.: Pyelography (Pyelo-Ureterography), W. B. Saunders Co., Philadelphia, 1915.—H. Cabot, Ann Arbor: Errors in diagnosis of renal and ureteral calculus. Surg. Gyn. and Obstet., Vol. XXI, p. 403, 1915.—Cabot and Donn: The diagnosis of stone in the pelvic portion of the ureter. Boston Med. and Surg. J., Vol. VII, p. 21, 1910.—A. E. Barclay, Manchester: A large pure uric acid renal calculus. Brit. J. Radiol. (B.A.R.P. Section), March, 1924, XXIX, 73–76.—W. W. Galbraith and J. R. Riddell, Glasgow: The radiological examination of the urinary tract. The Urinary and Cutaneous Review, Vol. XXX, No. 1, 1927.—J. S. Eisenstaedt: Primary congenital megalo-ureters. Arch. Surg., July, 1926, XLII, 64–74.

almost a small science of its own. As this book is primarily intended for practitioners, the description of pyelography findings will not be attempted.[1]

General

Kidneys of Children

In *children* the kidneys in the Röntgen rays are much more inconspicuous than in the adult. That is a striking fact. In adults and even in corpulent people the kidneys can be rendered visible in whole or in part in nine out of ten cases. We may take it as certain that in adults it is the more strongly developed fatty capsule of the kidneys that enables the latter to be differentiated.

In *the newly-born* even the least experienced should not mistake the shadow of the iliac fossa for a kidney shadow.[2]

Congenitally displaced kidneys are placed further down and more mesial than normal. If a congenital heterotopy is suspected the Röntgen photograph should be taken not in the usual kidney area, but deeper and nearer the mid-line of the body.

The upper pole of the kidney is not often recognised, nor generally the upper third of the lateral and medial kidney contour. We are fairly certain, even in highly situated kidneys, to render the upper parts of the kidneys accessible, by getting the patient to draw a deep breath and hold it while the plate is being taken.

In very *small infracostal angles* (in children and women) the edge of the tube-diaphragm should not be brought below the infracostal margin, but should be set directly on the margin ; otherwise it is the rule to direct the diaphragm obliquely from below and mesial to above and lateral.

Form, Position, Size, and Motility of the Kidneys

The Potter-Bucky diaphragm is of little aid in the direct examination of the kidneys and ureters. It is better to take small compression-exposures on a duplitised film without intensifying screens and with the breathing firmly held.

In estimating the form of the kidneys we should never forget that *collections of gas in the intestine* can simulate alterations of form in the shadow of the kidney. In intestinal adhesions, especially after operations on the vermiform appendix, it is often impossible to exclude intestinal gases from the shadow of the kidney, for they cannot without danger be compressed to one side.

On the *pelvic aspect* of the kidney the normal contour of the kidney forms a concave arch (see Fig. 243). Frequently, however, the inner border of the kidney forms an almost straight line. In the latter case the kidney rests with the lateral border turned more backwards. This is nothing abnormal ; it is often present in people whose kidneys are quite healthy.

Occasionally the spleen is projected into view on the left side (*e.g.* in a

[1] Voelcker and Lichtenburg : Pyleographie. Münich. Med. Wochenschrift, 1906, 3, p. 105.

[2] The author might never have imagined the possibility of such a misinterpretation, if the mistake had not actually occurred in the literature.

thin abdomen with an enlarged spleen). When the spleen cannot be palpated and a decision arrived at, a Röntgen plate can be taken on deep inspiration; for then the spleen does not descend so far as the kidneys. The shadow of the spleen is not so clear as the shadows of the kidneys, because the organ is further away from the plate.

The breadth of the normal kidneys in Röntgen picture is about $6\frac{1}{2}$ cm.; the difference of 1 cm. from the figure given in the anatomical text-books (5·5 cm.) being due to projection and the distance of the kidneys from the plate. The length is not easy to determine, for we cannot see the upper pole in the normal position. An attempt has therefore been made to measure from the pelvis to the lower pole and so to establish half the length of the kidney; that should amount to 6·15, and the whole length 13·3 cm.[1] When the kidney shadow is specially narrow, we should not immediately diagnose a diminution in its size, for the kidneys may be abnormally turned on their long axes and the focus of the tube may have been set somewhat more medial than usual.

FIG. 243.

Normal view of kidney region. a=Border of psoas; b=margin of quadratus lumborum muscle; c=frequent process at iliac crest.

Narrowing of the kidney shadow in consequence of the kidneys being turned with their hilus backwards has been observed in scoliosis.

An *enlarged kidney shadow* need not necessarily be due to an enlarged kidney. The kidneys can be displaced more towards the abdomen, and owing to the then greater distance from the plate can cast a larger shadow. Palpation can decide that.

In a really enlarged kidney in cases where the other kidney has been previously removed, we should always consider the possibility of the condition being a simple compensatory enlargement.

[1] Sträter, quoted by Schlecht in Schittenhelm's text-book.

Diminished kidneys (atrophy, shrivelled kidney) are often easier of diagnosis, in that their contours exhibit notchings.

For *orientation* of the position of the kidneys one should direct attention not to the ribs but to the vertebral column, especially to the transverse processes of the lumbar vertebræ. That is advisable, because the twelfth rib varies tremendously in its length and relations (between 4 and 15 cm. in length), and one can more easily make a mistake from a projection of the ribs.

Yet orientation from the spine is not always easy, especially when no plate of the whole area has been taken—which is not always demanded:

FIG. 244.[1]
Excursion of dropped kidney during respiration.

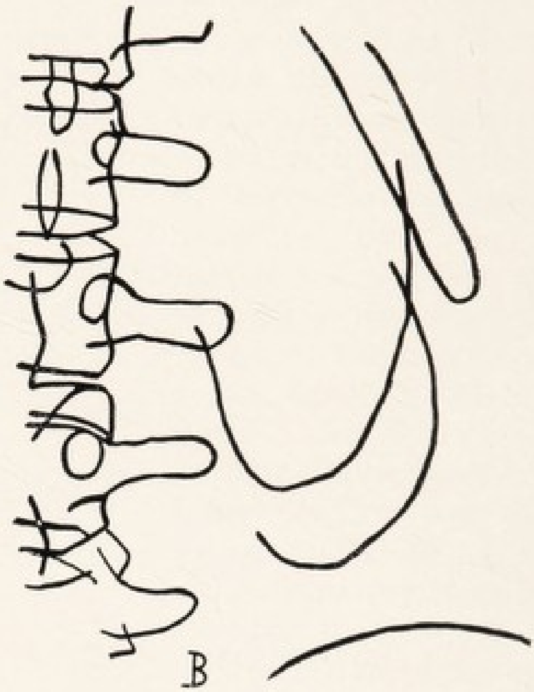


FIG. 245.[2]
Excursion of the normal kidney during respiration.

thus, it is not at all uncommon for thirteen pairs of ribs to be present. The thirteenth ribs, including the so-called *lumbar ribs*, are quite short ones, about 4–5 cm. long; nevertheless, there are many individuals whose twelfth ribs are just as short, and one must then examine the vertebræ themselves to decide whether it is the twelfth dorsal or the first lumbar we are dealing with; we can only be certain of these conditions if a survey-view of the area has been taken or the diaphragmatic aperture permits of observation down to the sacro-iliac synchondrosis (see also section on "Spine").

In every case in estimating a Röntgen view of the kidneys one has to note that *the position of the kidneys* on the plate is affected to a greater or less degree by the compression-diaphragm. A normally embedded kidney cannot escape from the pressure to any extent (see also below).

[1] According to Fenwick, *l.c.*
[2] According to Hasselwander, *l.c.*

The shadow of the *right kidney* usually reaches 1 cm. lower than the left, and is a little nearer the spine.

One should be careful not to call *a Riedel's lobe* of the liver a ptosed kidney. Riedel's lobes have usually got a long kidney-like form.

When the most inferior point of the kidney shadow descends below the lower edge of the third lumbar vertebra, we are dealing with a pathological condition (*displacement* or enlargement of the kidneys).

It is possible in a palpable *mobile kidney* to find the kidney shadow on the plate in its normal place. That happens indeed not infrequently. The reason: first the horizontal position of the patient, second the upward directed pressure of the cushion-compression. To guard against such mistakes: control photographs without heavy pressure and with heavy pressure, but in a different direction. Anomalies in position can be determined in this way. It should be noticed that even a normal kidney alters its position a little through extra strong compression (see above). This fact is often clearly seen at the psoas muscle (see under "Ureters"). Many authors recommend [1] three plates being taken in simple mobile kidney, one standing and two horizontal, either in the oblique one with the pelvis elevated and one with the pelvis depressed, or in the horizontal one upon inspiration and one upon expiration.

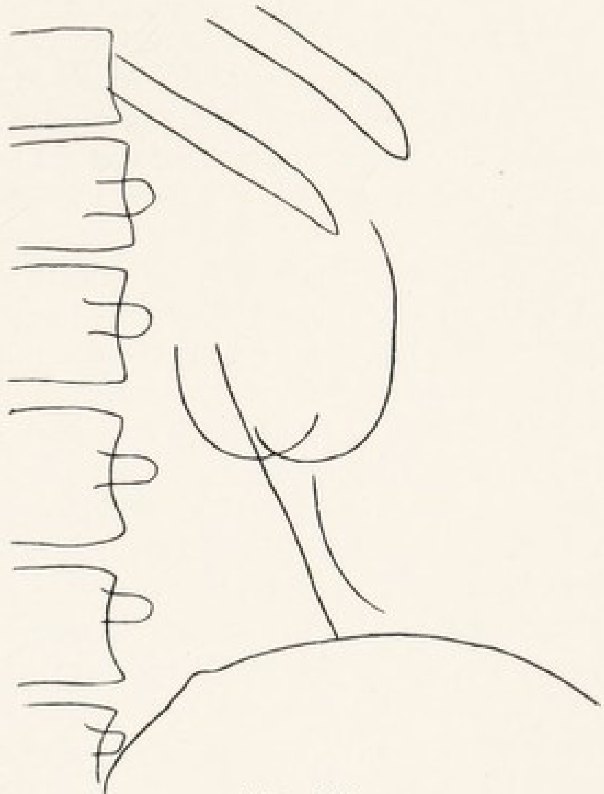


Fig. 246.

Concerning *the respiratory movements* of the normal kidneys, these can be very considerable. To be aware of that is important when a mobile kidney is suspected (see also later). One anatomist [2] (who is also a radiologist) found in the case of a man of graceful, light, and æsthetic build—who appeared otherwise normal—that the right kidney in excessive inspiration descended till its lower pole was below the level of the iliac crest, the lower pole of the left kidney reaching the level of the iliac crest. Upon expiration both kidneys glided up to below the twelfth rib, with the inferior pole at the level of the third lumbar vertebra (see Figs. 244 and 245).

For the relation of the diaphragm in *downward displacements of the*

[1] Lange, Fenwick, Sträter, quoted by Altschul, *l.c.*

[2] A. Hasselwander: Die Bedeutung des Röntgenbildes für die Anatomie. Ergebn. der Anatomie u. Entwicklungsgesch., Bd. 23, 1921.—Hryntschak: W. M. Wschr., 1921. —F. Gastreich: Zur Frage der Nierenbeweglichkeit. Arch. f. kl. Chir., 134, 2/3.

kidneys and general enteroptosis—the angle formed by the posterior crura of the diaphragm, which in direct lateral irradiation forms about 20° with the vertebral column, tends to be enlarged in these conditions—see under " Diaphragm."

It should be impossible to confuse the shadow of the spleen with that of the kidney. It has, however, happened. In the case where decision is difficult, a possible contingency, the introduction of air into the colon, should clear up the diagnosis. See also section on " Spleen."

Various

Every crossing of the psoas line by the kidney is to be considered pathological.[1] It most frequently occurs in mobile kidney.

If the lower contour of the kidney forms a ‿‿ shaped arch (Fig. 246), this is typical of hydronephrosis or pyonephrosis.[2] In these cases psoas muscle and transverse processes of the vertebræ appear usually vague and indistinct.

A kidney displaced well forwards from the photographic plate may display an enlarged shadow ; but apart from that and a tumour of the kidney the latter may appear enlarged, sometimes very greatly enlarged, with more or less irregular and sac-like form, without the kidney itself being enlarged, especially in peri- and para-nephritic abscesses.[1] The observer had already noticed that an infiltrated fibrous capsule and adipose capsule (demonstrated at operation) could appear of unusually large dimensions in the röntgenogram, without any increase in size of the kidney itself. (Therefore in one's reports it is better to say, not the kidney, but rather the kidney shadow is large.) This important alteration of the Röntgen appearances in peri- and para-nephritic abscesses might be caused simply by serous or purulent infiltration of the fatty capsule. The infiltrated layer of fatty capsule becomes denser, its specific weight greater, the difference of density between the kidney and the fatty capsule is lost, and thus the Röntgen rays are absorbed in equal amounts by the kidney and the fatty capsule. Hence to the shadow of the kidney there is added as an extra the shadow of the infiltrated fatty capsule and the resultant is a strikingly large shadow. As the contour of the fatty capsule runs altogether parallel with the contour, the combined view of the kidney plus the fatty capsule simulates the form of the kidney. What is seen is not the abscess itself, but only the infiltration of the fatty capsule. The kidney itself in these cases may even be contracted. Further, angle-contoured renal views and mantle-like enveloping appearances around the kidney may indicate peri- and para-nephritic abscess formations.

A uniform enlargement of the kidney shadow, similar to the normal,

[1] Schürmayer, Haenisch, quoted by Altschul, *l.c.* [2] Haenisch, *l.c.*

[2] V. Révész: Die direkte Röntgendiagnostik der peri- und paranephritischen Eiterungen u. die Röntgenuntersuchung der chronischen Perinephritis. Fortschritte, Bd. 34, 1/2, 1926

occurs not only in hyperplasia, but also in tumours of the kidney. The diagnosis of tumour is naturally easier, if the enlarged kidney shadow exhibits swellings and prominences.

Displacement of the kidney shadow in the linear or transverse direction is typical of tumour.

Displacement downwards and outwards occurs regularly in kidneys that have been shifted by a nephrotomy.

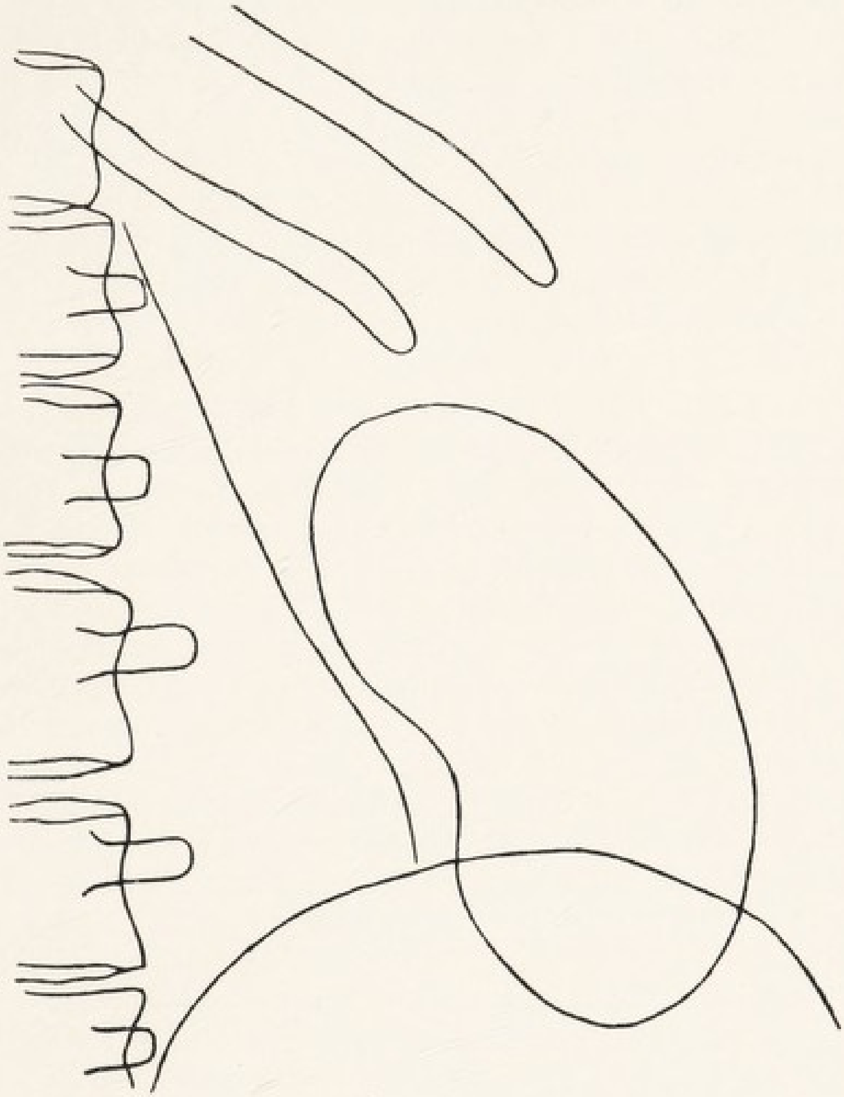


Fig. 247.

The horse-shoe kidney is a typical radiological symptom-complex. It should be here mentioned, for the appearances are so easily missed that the inexperienced may overlook them altogether: (1) Vertical position of both kidneys (the inner margin running parallel with the spine). (2) Median position of both kidneys (the distance between the border of the kidney and the spine is abnormally small). (3) Double-sided ptosis of the kidneys, often equally well marked. (4) Immobility of the kidneys in the medio-lateral direction (mobility in the axial direction can be retained). (5) Apparent displacement of the lower poles of the kidney relatively to the spine, in an opposite direction in ventro-dorsal irradiation and in the same direction in dorso-ventral irradiation (in the normal kidney the reverse of this apparent displacement being found). (6) A possible view of the shadow of the connecting bridge of kidney tissue. In one case it is easier to radiograph the upper contour of the connecting bridge, in another case it is easier to radiograph the lower. For the diagnosis of horse-shoe kidney the ordinary Röntgen examination is sufficient, *pyelography* is not required.[1]

If a large shadow like that of a tumour be visible lateral from the right shadow of the kidney—and in good plates that frequently is seen—we have always to think of the liver. The contour of the liver (*e.g.* in women with ptosis) runs obliquely upwards across the kidneys, so that in the parts over-shadowed the kidneys appear thickened along a broader or narrower band. In other cases the kidney contour and the liver contour run a certain distance parallel to each other, so that the kidney appears to be placed within a niche of the liver. In photographs on deepest inspiration the two shadows can sometimes be clearly distinguished.

Stones and Stone-like Shadows

Concretion shadows of the kidneys are always lighter on the plate and always darker in the positive print than the surrounding kidney tissue. Large round or oval and very transparent markings (*i.e.* dark on the negative) are due to *gases* in the coils of intestine over the kidneys. They are an exceptional trouble in diagnosis and render the estimation of a kidney stone almost impossible. They can generally be pressed to the side by good compression with a lufa-sponge under the diaphragm. If it proves impossible to displace the collections of gas from the intestines over the kidneys, the presence of adhesions should be thought of.

In searching for concretions *a negative finding* is no proof of the absence of concretions. On the other hand, very small but very dense stones (*e.g.* oxalate stones) always come out well in technically complete and correctly diaphragmed negatives; while large uratic stones may remain completely undifferentiated.

That pure uric acid stones are not rendered visible by the Röntgen rays is because pure uric acid—taking the density of water as that of the body=1·00—has a density of 0·97. After exact calculations [2] the following *table of density* has been worked out, which moreover corresponds completely to the order of the various substances found empirically in Röntgen plates. Invisible: Uric acid=0·97; xanthin=1·00. Visible: Cystin =1·18; calcium phosphate=1·25; calcium carbonate=1·33; ammoniated magnesium oxalate and phosphate=1·20; calcium oxalate=1·36.

[1] The whole paragraph almost verbally after Voorhoeve: Der röntgenol. Symptomen-Complex der Hufeisenniere. Fortschritte, Bd. 30, 1923.—See further: H. Boenninghaus: Ztschr. f. urolog. Chir., 1926, Bd. 19, p. 15.—E. Puzzi: Arch. di rad., 1925.—A. Possati: Rad. med., 1926; and Arch. di rad., 1926, 2 and 3.—Eisendraht, Phifer and Culver: Ztschr. f. urol. Chir, 1926, Bd. 20.—Colston and Scott: Journ. of Urol., 1926, 16, 5.—W. Boss: Ztschr. f. urol. Chir., Bd. 19, 1926.

[2] Telemann: quoted by Schlecht in Schittenhelm's text-book.

Oxalate stones are characterised by their rounded and pointed form, phosphatic stones by their coral form. If the shadows of the stones have the same density as the vertebral bodies, that is typical of calcium oxalate stones.[1]

A pathological but quite innocent condition is the cause of many *mistaken diagnoses of kidney stones :* quite a number of people possess one or two mesenterial glands earlier affected with tubercle and afterwards calcified. These cause a dense shadow on the Röntgen plate, which appears most frequently at the level of the kidneys and is projected right into the shadow of the kidneys. If one could take profile photographs of the kidneys, perhaps with the help of pneumoperitoneum, one would see at once that these shadows lay in front of the kidneys. Stereoscopic photographs could elucidate the condition, but are too complicated, and can even be the cause of mistakes in compression exposures, for the glands are pressed back firmly on the surface of the kidneys, perhaps even making an impression upon them. A definite decision between a calcified gland or a kidney stone, is sometimes quite impossible. Yet there are some points of difference, a knowledge of which is useful : while kidney stones give mostly a homogeneous shadow, the shadow coming from a gland has usually an appearance as if it consisted of a number of fairly large particles (it sometimes exhibits a mulberry marking) ; provided always the negative is technically flawless. Its contour is mostly rough and uneven. Then in glands the round form of the shadow is the usual, while in stones the shadows encountered are generally oblong.[2] As the shadows of the glands are usually visible also in the screen, the examination of their mobility may be utilised for the differential diagnosis : If the shadows in question be displaced about 4–5 cm., that indicates calcified glands and not renal- or gall-stones.[3]

The majority of renal stones are situate near the twelfth rib, frequently just below it, about the level of the second lumbar vertebra or even below it. Occasionally they appear near the upper pole of the kidney, in one of the upper calyces. Stone shadows near the spine or covered by it render the presence of a horse-shoe kidney probable. In one case,[4] however, that exhibited these characteristics, and in addition certain definite clinical signs, a mistaken diagnosis of horse-shoe kidney was arrived at. The operation, however, revealed a pyonephrotic abscess.

A spontaneous retrogression of kidney stones has been described. In the course of four years the shadows of the stones became considerably reduced in size. As shown at subsequent operation the condition was one of calcium-phosphate stones with a rich admixture of organic constituents.[5]

[1] Heilporn : Ann. de la soc. Belge d'urol., 1912.

[2] A good Röntgen picture is found in W. Schmidt : Ein Beitrag zur Diagnose der isolierten Mesenterialdrüsen-Tuberculose. Fortschritte, Bd. 27, 1920.

[3] Zeitlin : Zur Röntgendiagnostik verkalkter Mesenterialdrüsen. Moskauer Röntgenologen- und Radiologen-Gesellschaft. Fortschritte, Bd. 32, p. 469, 1924.

[4] Kraft : Zur Diagnose der Hufeisenniere. Fortschritte, Bd. 29, 1922.

[5] Scheele : Ärztl. Verein. Frankfurt. a. M., 4, 2, 1924. Reference article : Münch, M. W., 1924, p. 383.

In the Röntgen literature a large nævus pigmentosus of the skin of the back has been reported as a source of error for renal stones, and a cutis pendula the size of a cherry.[1]

For an isolated shadow at the end of the twelfth rib and in its continuity, see under "Ribs."

If the contour of the kidneys suddenly loses its clearness at certain points, the appearance may be produced by *para- and peri-nephritic collections of pus.*

Many small modifications in the kidney shadow are occasioned by *tubercular processes.* It is repeatedly mentioned in the literature that tuberculous kidneys show larger or smaller spots not sharply delimited. Naturally we cannot expect to arrive at such a discovery at the commencement of a tuberculosis, where an enlargement of the kidney is all we get. We should also note that pus cavities in their early stages hardly alter the picture of the kidneys at all, unless the pus contains small particles of lime, the presence of even small quantities of lime being sufficient to produce a shadow. An unusual mottling of the kidney shadow with dark and light areas is as a rule due to large caseated spots and cavities. Extensive calcifications give naturally the strongest shadow. They appear most usually in the cortex of the kidney.[2] In Fig. 248 the shadow of the kidney might appear almost like normal in a photograph rich in contrast; it is, however, much too dense for that, and in the original radiogram it is finely spotted, "as if powdered with bismuth." The case is one of tuberculosis of the renal cortex, especially of the inferior half. The extensive calcifications are situated mainly in the peripheral regions of the kidney, as could be seen from the anatomical preparation of the kidney removed by operation from the other side, where the pathological changes were very great indeed.

Fig. 248.

But the case in Fig. 248 is really a considerably advanced one, and does not occur every day. The first Röntgen shadows of chronic tuberculous calcifications of the kidneys have quite a remarkable and yet typical appearance, "like putty"; that is, as a rule, not very dense and, so to

[1] J. Gottlieb: Über Fehlerquellen der Röntgendiagnostik von Nierensteinen. Fortschritte, Bd. 35, 6, 1927.—Most: Ztrlbl. f. Chir., 1926, 38.

[2] A. Köhler: Internat. Congress of Medicine, London, 1913.

speak, smeared over ; the appearance very much like a small quantity of putty, which is pressed flat with the finger on a glass plate and smeared at the edges. One never finds a shadow quite like this in diseases anywhere else in the human body.

Another substance that may be quite physiological especially in elderly people, and is otherwise innocuous, misleads the unskilled diagnostician, namely, *calcification of the costal cartilage* where it joins the bony ribs. In exposures taken with the compression-diaphragm, in which the cylinder is pressed up under the costal margin, this possibility is naturally excluded. These ossifications of costal cartilage have as a characteristic the fact that they are directed from above and externally to below and internally, which is scarcely ever the case in renal stones (which are nearly always directed from above inwards to below outwards).

The transverse processes of the lumbar vertebræ are often so narrow and translucent that their whole shadow cannot be observed, only their end being prominent. That may then be mistaken for a concretion.

It is recommended in the text-books to take kidney photographs with *as soft a tube* as possible. That advice, however, especially in cases of possible stone, should not be taken too literally, for only an uncontrasted shadow of the kidneys will result. It is absolutely necessary for the rays to pass through the kidneys and darken the plate sufficiently ; for otherwise no differentiation of concretions in the shadow of the renal parenchyma is possible.

Just recognisable *light and indistinct spots*, usually on both sides, in the vicinity of the renal calyces and pelves, which upon repeated investigations are not constantly present, are seen in people suffering with gravel.

Gall-stones (see under " Liver ") are known to be seen only rarely on the Röntgen plate, being particularly obvious when their structure is rich in lime salts, which does not occur once in several dozen cases. It is quite possible when the clinical signs point to a stone being present on the right side, and a gall-stone with lime in it is present, its shadow falls directly into that of the kidney and leads to an incorrect diagnosis. The same can occur with *pancreatic stones*, but even less commonly. A decision can be arrived at by taking oblique and profile photographs in different directions, whereby the pancreatic and gall-stones can be projected from out the shadow of the kidney.

Regarding other conditions that may simulate concretions, see under " Ureters," and also under " Soft tissues of the pelvis."

Translucent bands crossing transversely through the kidney shadow, but continuous to the outside of it, varying in width from half to one centimetre, are due to *skin folds*.

It is stated in the pathological text-books though not in the Röntgen literature : *Calcification of necrotic epithelium* in the kidneys can be observed constantly in the kidneys after certain poisons (especially with quicksilver). The possibility of seeing such a change in thin individuals should not be excluded.

Ureters [1]

(The direct examination with colloid substances is not included.)

General

The ureter cannot be seen [2] unless it be filled with an opaque substance (collargol); or when its course can be exhibited by the introduction of a catheter. Many beginners mistake the edge of the psoas muscle, which is almost always visible in good Röntgen plates, for the ureter.

Another shadow-line, more rarely found, a few centimetres lateral to the psoas and running almost parallel with it but not reaching quite so high, is due to the quadratus lumborum muscle.

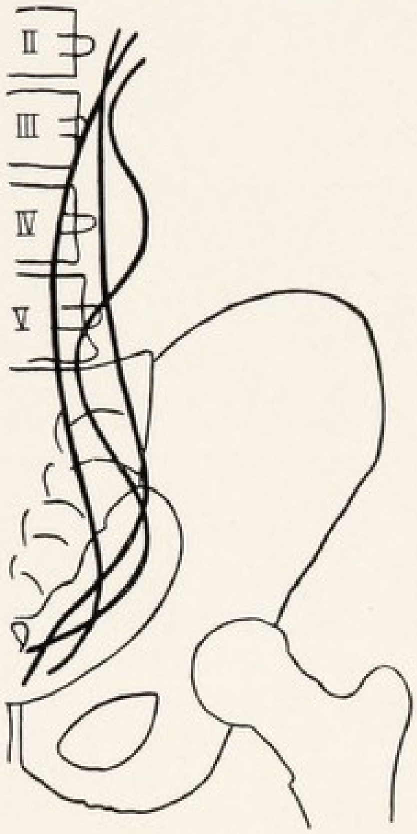


Fig. 249.

The ureter runs more medial than is generally thought. It runs from above downwards only a few millimetres from the lateral edge of the vertebral bodies; sometimes it runs for a short distance in the vertebral shadow itself. In Fig. 249 there is a sketch, constructed from three plates with catheters introduced, which indicate roughly the course of the normal ureter, in order that the beginner may know at what points of a plate to look in searching for stone shadows in the ureter. It should, however, be observed that the ureter (like the kidney and the lateral edge of the psoas) can be somewhat altered in its position by compression of the cylinder-diaphragm. Departures from the normal course are really quite frequent. In the male the ureter is usually more median, in the female its course is more lateral.

The left ureter is generally nearer the middle line than the right.[3]

The length of the ureters is in the adult 26–30 cm. in the average, the right ureter a little shorter than the left.

The distance apart of the two ureters at the point where they approach each other most nearly is about 8 cm.

[1] Literature, see under "Kidneys."

[2] Nevertheless, Aubourg and Lomon have seen thickened ureters in the röntgenogram; mentioned by Altschul, *l.c.*

[3] Regarding the examination by means of collargol solutions of the renal pelvis, of the ureter and of the bladder, references should be made to the works of Völcker, Lichtenberg and Dietlen, etc. Münchener Mediz. Wochenschr., 1905, p. 1576; further 1906, p. 105, and in Bruns Beitr. z. klin. Chir., 1907, Bd. 52; Münchener Med. Wochenschr., 1911, No. 25.—Regarding Pyelon and Jodkali solutions, see Mosenthal, Röntgen-Kongress, 1920.

Stones and Stone-like Bodies

In the Röntgen examination for *ureteral stones* one must know the whole list of the possible sources of error, in order to avoid making gross mistakes. In addition to the bodies described above in the kidneys the following come under review: Calcified myoma, teeth in dermoids,[1] extrauterine pregnancy, prostatic stone; calcification of the iliac artery and the uterine vessels; deposits at the ischial spine; deposits in the sacro-iliac ligaments; formation of bone in laparotomy scars; coproliths; fruit-stones; cold abscesses, whose contents have been absorbed or undergone caseous change; scybalæ; calcified debris in a carcinomatous kidney; calcified ovary; salol, ingested prior to the examination; lime-stone in the wall of the cæcum; caseated cysts of the broad ligament; broken-off transverse process; calcified tubercle of the rectum; granulations of the bladder; calcified parasites; deposits of sulphur (in the kidney).[2] Yet these are all rarities. Most frequent of all (nearly in every third adult negative) one encounters harmless phleboliths. It is readily understandable how phleboliths and ureteral stones can appear near each other. (For the details consult p. 203, etc.) Further, the following rare discoveries have led to mistake: Enteroliths of the vermiform appendix; exostoses of the iliac bone; compact-islands in the iliac fossa; sesamoid bone in the tendons of the obturator muscles; calcified appendix epiploicæ; previous ingestion of drugs casting a shadow, like bismuth, iron pills or salol (see above); limy deposits in tuberculous processes of the kidney; concretions in old-standing peritoneal adhesions;[3] calcification of the vasa deferentia (see in each case also the statements under "Soft tissues of the pelvis"). An exposure taken with the ureteral catheter introduced will decide for or against stone of the ureter; a very rare accident it would be for the suspected body and the ureteral catheter to be exactly behind each other, and the former considered to be in the ureter (a profile picture not being always easy to secure).

One should never omit to examine with attention the *sacrum* and the *iliac bone* to see if *a stone shadow* comes within their outlines, for such a shadow is never conspicuous.

The *predilection points for ureter stones* are the lowest narrow portion just before the ureter enters the bladder, where stones can stay for years; secondly, the commencing part at the neck of the renal pelvis, where stones are frequently found especially after attacks of colic, and perhaps also the region where the vertebral column meets the sacrum.[4]

[1] E. Sonntag: Vortäuschung eines Uretersteins im Röntgenbild durch Zahnkeim im Ovarialdermoid. Fortschritte, Bd. 27, 1920.

[2] Given completely with reports of the various authors by Altschul, *l.c.* Also refer Ethel C. Dunham and A. M. Smythe: Tuberculosis of abdominal lymph nodes; diagnosis by means of Röntgen rays. Am. J. Dis. Child. June, 1926, xxxi. 815–831.

[3] Lejeune: Présentation de trois cas de calculs du peritoine cause possible d'erreur d'interprétation des images röntgénologiques de la région abdominale. Journ. de Rad., 1911, p. 242; see also, 1910, p. 119.

[4] Dietlen, *l.c.*

At *the upper border of the iliac crest*, near the sacro-iliac synchondrosis, a shadow about the size of a pea and like a button in form projects out into the soft tissues (Fig. 243, *c*). That is quite normal to the skeleton, and is always present on the other side. If one is not aware of it, and has taken only a negative of one side, one is apt to think of the possibility of it being a stone in the ureter.

Bladder [1]

General

The bladder is not usually seen. Sometimes a well-filled bladder appears on the negative. To photograph it unshadowed by the horizontal rami of the pubic bone and the coccyx, the central ray from the tube with the patient in the horizontal position should run obliquely from above proximally to below distally. The area in the soft-tissue-lumen of the pelvis occupied by the bladder is seen in Fig. 250, where it is filled with collargol.

The bladder of the newly born is of pear-shaped form when empty, and oval when filled.[2]

In large (inguinal) *herniæ* the bladder is often drawn to the side of the rupture.

Stones and Stone-like Shadows

A *negative finding for stones* contra-indicates the presence of stones still less than it does in the case of the kidneys and ureters. For the uratic stones are the most transparent, and they are just the ones that appear most frequently in the bladder and seem not to be easily photographed even with the best diaphragm exposures. Moreover, it is not permissible to estimate the number of the stones present from the number appearing on the plate. Before one declares the Röntgen finding to be negative in a suspected case of bladder stone, one should carefully observe whether a concretion shadow is not concealed in the shadow of the sacrum or the rami of the pubis ; for a considerable part of the bladder is placed either in front of or behind these bones. The one and only possibility of projecting uratic stones upon a Röntgen plate is by the introduction of air or oxygen into the empty bladder. This procedure, however, is not without danger, and is not easier to perform than the effective methods of cystoscopy, sounding and bimanual palpation.

Regarding pictures *simulating bladder stones*, see under " Soft tissue lumen of the pelvis," also under " Kidneys and Ureters." The most frequent cause of error to the beginner and uninitiated are the phleboliths

[1] For literature refer to " Kidneys " ; further the works of Voelcker and Lichtenberg.—Zuckerkandl : Münch. M. Wschr., 1914, No. 35.—Maingot : Journ. d'urol., 1912.—A. Schönfeld and F. Kraft : Harnblase im Röntgenbilde. Leipzig and Munich, 1925.—L. A. Rowden, Leeds : The value of " screen " examination in the X-ray diagnosis of urinary calculi. Brit. Med. J., 1910.—C. Thurstan Holland, Liverpool : The Röntgen diagnosis of calculus of the bladder. Arch. Röntg. Ray, 1912, 16, p. 458.—J. M. Garratt : Diverticula of the urinary bladder. Surg. Gyn. and Obstet., vol. xiii., pp. 292–294, 1911.

[2] E. Vogt : Fortschritte, Bd. 29, 1922.

present in every third adult person (see Fig. 148, p. 203). For prostatic stones, see Fig. 150.

It is often difficult to say whether *a concretion* belongs to the bladder or to the ureter. Therefore be careful in giving a verdict.

A negative Röntgen finding in the region of the bladder in a case suspected of a foreign body means no more than that no metallic bodies are present.

Scirrhus thickening of a greatly shrivelled bladder may simulate a stone shadow.[1]

It is mentioned in the pathological text-books but not in the Röntgen literature: Calcifications of superficial necrotic layers of the vesical mucous

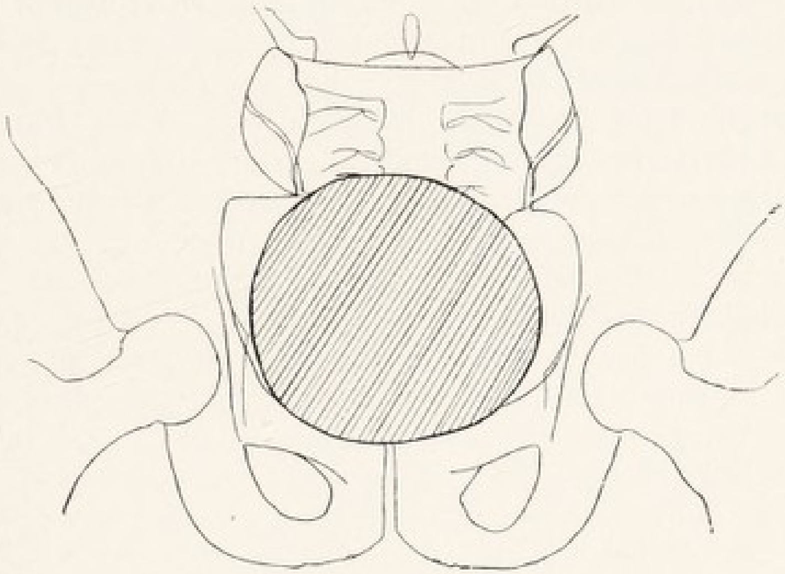


FIG. 250.

membrane can occur after poisoning (*e.g.* by quicksilver); see also under "Kidney."

Calcified myoma of the uterus can deceive those who have never seen these in Röntgen view, resembling the form of the bladder both in size, symmetry, and median position. For the differential diagnosis: Calcified myoma always casts a marbled spotted shadow and manifests more or less distinct archings and bays in its contour, bladder stones nearly always show a homogeneous shadow, which is sharply oval or sharply circular.

PROSTATE[2]

Some authorities declare they have seen the prostate in Röntgen view, especially when enlarged; others, however, are very doubtful about the possibility of this. The determination of the form and size of the organ is made easier and better by means of palpation. Nevertheless, the aid of the Röntgen rays should not be neglected for establishing confirmation of

[1] Gottschalk's case: Deutsche Med. Wochenschr., 1910, p. 2367.

[2] Fr. Kraft: Zur Röntgenologie der Prostata. Fortschritte, Bd. 28, 1922.

diagnosis of stone, and they may be especially useful in giving us valuable indications for a definite therapeutic treatment.

Pathological *enlargements of the prostate* can be disclosed from the close relationships of the organ to the bladder. Thus, albeit only in the more advanced cases, we can see the extension of the tumour to the wall of the bladder, how the normal smooth contour of the lower border of the bladder (filled with contrast-fluid) is lost, like the pictures we know in gastric radiography. In hypertrophy of the prostate the base of the bladder loses its normal shape, its lower border is a finger's breadth above the symphysis, and shows a sharply marked-off defect in the floor of the bladder ; there is thus a broad fundus and a narrower apex, so that the bladder appears pear-shaped in form, or even heart-like in form when the middle lobe is excessively prominent. Diseases of the prostate, which can be recognised directly in Röntgen view are (1) Stones. (2) Deposits of calcium in prostates altered by inflammation (see Fig. 150). Prostatic stones have hitherto never been found in persons under forty-seven years.[1] The size of these concretions varies between that of a hemp-seed and that of a pea, sometimes being even as large as a hazelnut ; they are mostly developed in both lobes and are multiple ; in one case 130 stones were found.[2] Radiologically they present themselves usually quite clearly to both sides of the mid-line about 2 or 3 cm. over the symphysis, and the facets on them can often be observed. Secondary stone formations in the region of the prostate usually occur singly, and are situate as a rule in the mid-sagittal plane ; they arise either from the renal side of the urinary system (kidney, ureter, bladder), and are discovered only later in the prostatic part of the urethra, where they go on growing by apposition ; or they may be urethral stones. All prostatic stones are wont to cast a very dense shadow. In the differential diagnosis these should be considered : gravel in the bladder—that is movable, and its separate particles are closely in contact ; vesical stones—the same applies ; deposits of lime in the prostate (see below) ; deposits of lime in the seminal vesicles and in the ampulla of the vas deferens ; calcifications of the vasa deferentia are very rare, and appear almost always in advancing years—usually present on both sides ; phleboliths (refer to the index) ; foreign bodies in the rectum ; calcifications in carcinoma recti, very rare ; calcification of the cartilage of the symphysis, especially when it affects only a part of the cartilage (Author). Calcifications in the tissue of the prostate have irregular contours, often as if etched ; they are irregularly spotted, of varying density, and in addition are very rare. As regards technique, the best method of photographing the prostatic region is to move the tube as far as possible towards the head, directing the central beam as obliquely as possible on the plate—dorsal decubitus of patient.[3]

[1] According to Forssell, quoted by Kraft.
[2] Golding-Bird, quoted by Kraft.
[3] Almost verbally abbreviated after Kraft, *l.c.*

STOMACH AND INTESTINE

General [1]

Form, position, peristalsis, and *motility* of the gastro-intestinal tract are röntgenologically examined nowadays almost exclusively by the introduction of contrast-meals. (The ones most used are bismuth carbonate, subcarbonate ; barium sulphate ; [2] and the so-called cito-barium.) For stomach and small intestine the meal is introduced by the mouth, for the great intestine and rectum the introduction may be by the mouth or also per rectum. The introduction of gases into the stomach and bowel is now practically never done (nevertheless see section " Liver and Spleen ").

When in the following pages we speak of *a contrast-meal,* we generally mean 350 grm. of one of the usual cereals with 30 to 50 grm. carbonate of bismuth or 150 to 250 grm. cito-barium. With the " normal-röntgen-meal " of Groedel the stomach is given 400 grm. with an average dilatation amount of 300 c.c. (150 grm. barium sulphate, 15 grm. good cocoa, 20 grm. mondamin, and 10 grm. sugar to 400 grm. of water).

For securing the richest view of the finest details in gastro-intestinal examinations buttermilk with bismuth has been recommended, more especially from the American side.

For representing the finest details and throwing into relief the mucous membrane of the stomach and duodenum, Rieder's meal and the usual meals are not fluid enough. Berg employs a solution for drinking of the purest barium sulphate (Merck) in water in the proportion of 3 to 4, and gives one-third of a litre of that, only a few small mouthfuls being taken to begin with.

The making of relief-negatives of the unfolded stomach has also been proposed : [3] 20–30 grm. of barium sulphate are mixed with some bolus alba and a thick solution of it drunk, it is then distributed in the stomach by massage. A thin stomach tube or duodenal sound is then passed and 400–500 c.c. of air introduced, the stomach distended, and a Röntgen photograph taken at once in the dorsal position with a tube below the table. The danger of an ulcer perforation is not any more than at an ordinary meal. Gastric ulcers are recognised in the mucous membrane by the stellate appearance of the folds of the mucosa. Tumours projecting into the interior of the stomach are recognised by their smooth surface without any folds. Ulcers in the region of the cardia and the pars descendens of the lesser curvature cannot be shown up by this method. But it might enable one to obtain stereoscopic views of the stomach.

The consistency of the contrast-meal exerts no influence on the time the

[1] For references to the literature, see the various sections.

[2] In order to avoid the use of poisonous barium preparations, one should ask for " Chemically pure barium sulphate for Röntgen purposes."

[3] Hilpert : Das Pneumorelief. Fortschritte, Bd. 36, Supplement (Kongressheft, 1927).

stomach takes to start emptying, so far as the difference in consistency between the thin-fluid meal and the thick-fluid meal is concerned.[1]

An estimate of the size of the different parts of stomach and bowel, to decide whether they are normal or pathological, is not possible, for with the tonus maintained the size is usually related to the degree of filling.

Screening is an indispensable step in the röntgenological examination of stomach and intestine. It is carried out with various ways of diaphragming, best of all with the honeycomb diaphragm. In screening one should always make it a rule to examine at short intervals. "Consideration and explanation of the diagnosis should not be made during the running of the tube. That would impose too great a strain on it. After one has concluded one point of the examination, one should switch on again and proceed to the next, . . . and so on. This method gets work done in the right way. The tube gets time to cool down, which avoids any chance of over-softening, and at the same time the patient is protected from over-irradiation."[2] For the securing of the finest details and also of the grosser changes in stout patients, a negative should always be taken in addition and is superior to screening.

The form and position of the several parts of the intestinal canal, especially of the stomach, are dependent to a considerable degree on the conditions of space in the abdominal cavity, the relation of the height to the breadth of the abdomen, the state of the diaphragm, the position of the liver, the fixation and filling of adjacent parts of the gut, the external form of the body, and also in a lesser degree on the pressure with which the body has rested against the screen on the plate during the Röntgen examination. The body should not be pressed too firmly against the plate, yet it should be completely in contact with it, before the best negatives can be secured.

The tremendous *variety of pictures* within physiological limits is certainly conditioned by the adaptation of the position and form of the abdominal organs to the erect posture of man not being yet completed.

The level of parts of the stomach and bowel can be estimated by marking the *umbilicus* with a small piece of lead. It should not be forgotten, however, that the distances of the umbilicus from the symphysis pubis and from the xiphoid process of the sternum are not always in the same proportion in different individuals. At the same time there is naturally a certain regularity in the position of the umbilicus, and it would be a mistake not to be guided at all by it. The suggestion was advanced some time ago from the American side that the highest points of the iliac crests should be taken as a guide, which generally are about the level of the umbilicus (examine them on all the figures of this book). In ventral photographs or examinations we have naturally to recollect that if such a mode of determining is to be exact, the focus of the tube should be arranged exactly at the level of the crests. It has recently been pointed out, however, that

[1] Löw-Beer, Mahler and Stary: Zur quantitativen Bestimmung der Magenfunction. Fortschritte, Bd. 36, 4, 1927.

[2] Holzknecht, quoted by G. Schwarz in Schittenhelm's text-book.

even the estimation by means of the iliac crests has to be made with care, because in different individuals the distance between the diaphragm and the upper border of the iliac crest varies. It varies between 14 and 23 cm., corresponding to the physical development of the person ; and seeing in general the physiological development of the stomach bears a definite relationship to the development of its owner, the larger the phrenico-iliac space the larger the stomach.[1]

The *folds of the gastro-intestinal mucous membrane*, according to more recent researches,[2] is not a passive process consequent upon the contraction of the muscular wall, but an independent active movement of the muscularis mucosæ ; this brings about the sifting and sorting of the stomach-contents, which cannot be done in the digestive tube by the muscularis propria, because its action is comparatively too coarse and clumsy. In any particular stage of contraction of the stomach wall, therefore, the form of the stomach lumen is determined not only by the contraction of the muscular coat of the stomach but also by the mucosa-relief modelled by the muscularis mucosæ. In the Röntgen picture both the longitudinal folds and the transverse folds can be seen. See below under " Rippling or indenting of the greater curvature."

The following organs are clearly visible to Röntgen examination in these *times* : [3]

	Meal of bismuth carbonate.	Meal of barium sulphate.
The duodenum	after 15 minutes	10 minutes
The stomach empties normally . .	,, 2– 4 hours	1– 2 hours
In delayed motility	,, 4– 6 ,,	2– 4 ,,
In motor insufficiency, first degree .	,, 6– 8 ,,	4– 6 ,,
In motor insufficiency, second degree .	,, 8–10 ,,	6– 7 ,,
In obstruction insufficiency, third degree	,, 10–24 ,,	7–24 ,,
The small intestine well filled . .	up to 5 ,,	3 ,,
The cæcum becomes visible . . .	after 2– 3 ,,	1– 1½ ,,
The right flexure	,, 4– 6 ,,	2– ,,
The left flexure	,, 4–12 ,,	4–12 ,,
The ampulla at latest	,, 24 ,,	24 ,,

The times given for barium sulphate are applicable also to cito-barium.

Spastic conditions are apparent in every section of the gastro-intestinal canal. They are frequently accompaniments of other diseases of the stomach and intestine (ulcer). They can also arise reflexly (spastic conditions in renal colic). Although these spastic conditions in the gastro-intestinal canal are not diseases and though the fact of their existence affords no diagnosis, proper regard must be paid them. It is becoming more and more manifest that in diseases of the intestine a part of the gastro-

[1] Campo and Campo de Cos, *l.c.*, p. 416 of this book.

[2] G. Forssell.—See further Rendich : Amer. Journ. of Röntg.

[3] According to Groedel, *l.c.*

intestinal canal a considerable way above the affected area may evince spastic symptoms.

The motility of the lower parts of the intestine is increased, upon the introduction of a fresh meal into the stomach and small bowel.

In puzzling signs of gastric and intestinal motility one should never omit to ask the patient whether he has taken aperients or pills daily. If *aperients* have been given prior to a gastro-intestinal examination they probably induce a more rapid advancement of the meal and a quicker peristalsis. It is therefore advisable to allow the patient a light breakfast between stool and the time of the contrast-meal.

Stomach [1]

General

The *normal form, size, and position of the stomach* has been much debated in the Röntgen literature. It is difficult for the inexperienced to form a correct estimate of these points, because there is really no such thing as a

[1] Groedel: Grundriss und Atlas der Röntgendiagnostik in der inneren Medizin, München, 1924 (Lehmann).—Levy-Dorn and Ziegler: Zur Kritik der krankh. Veränderungen d. röntgenologischen Magenbildes auf Grund autoptischer Befunde. Sammlung-klin. Vorträge. Leipzig, 1914 (Barth).—Holzknecht: Der jetzige Stand der Röntgenuntersuchung des Magens und Darmes. 17. Internat. Congress of Medicine, London, 1913.—Leonard: The röntgenography of the stomach and intestines. 17. Intern. Congress of Medicine, London, 1913.—Nemenow: Untersuchung mit Röntgenstrahlen. Extra volume of the Russian edition of Schmierer-Vierordt's Encyclopedia of clinical medicine, 1914, pp. 210ff.—Kaestle: Die Röntgenuntersuchung des Magens; Rieder and Rosenthal's text-book of Röntgen diagnosis. Leipzig, 1913 (Barth).—Béclere et Mériel: L'exploration röntgénologique dans les affections chirurgicales de l'estomac et de l'intestin. Arch. d'Electr. med., Bd, 20, 1912.—Arnsperger: Die Röntgenuntersuchung des Magen-Darm-Kanals und ihre Ergebnisse für Physiologie und Pathologie. Leipzig, 1912 (Vogel).—Faulhaber: Die Röntgendiagnostik der Magenkrankheiten. Collection of papers from diseases of digestion and metabolism, Bd. 4, Heft 1. Halle (Marhold).—Ratera, Julian and Santiago: Exploracion röntgenologica del estomago. Madrid, 1918.—Campo, Gonzalez, and Campo, Gonzalez, de Cos: Los rayos Röntgen en el diagnostico de las enfermedades del estomago. Madrid, 1919.—Forssell: Über die Beziehung der Röntgenbilder des menschlichen Magens zu seinem anatomischen Bau. Hamburg, 1913 (Sillem).—Rieder, Magnus and de Quervain: Drei Referate über Röntgenologie des Magen-Darm-Kanals. 29. Congress of Internal Medicine, Wiesbaden, 1912 (Bergmann).—Brewer and Cole: The röntgenologic diagnosis of surgical lesions of the stomach and duodenum. Annals of surgery, January, 1915.—Eug. Rosenthal: Über die Symptomatologie und Therapie der Magen- und Duodenalgeschwüre. Berlin, 1920 (Karger).—G. Jefferson: The contraction forms of the human stomach illustrated by plasticine models. Arch. of Rad. and Elec., 1917, 22, p. 161.—C. Thurstan Holland: The hour-glass stomach. Arch. Röntg. Ray, 1911, 15, p. 416. Brit. Med. J., January 1, 1921.—A. E. Barclay: The etiology of gastric ulcer. Arch. Röntg. Ray, 1913, 18, p. 234. The normal stomach. Arch. of Rad. and Elec., September, 1922. Also the Alimentary Tract. A radiographic study.—J. R. Riddell, Glasgow: The X-Ray examination of the alimentary tract. Glasg. Med. J., March, 1924.—Lebon and Colombier: Der normale Magen. Journ. de Rad. et d'Electrol., July, 1922.—G. Forssell: Röntgenologie des Magens und Darms; in Leitfaden der Röntgenologie by H. Gerhartz, 1922. Berlin and Vienna.—G. Schwarz: Die Röntgen-Untersuchung der Verdauungsorgane; in Schittenhelm's text-book of Röntgen-Diagnostik. 1924 (Berlin, Springer).—Alvarez: The Mechanics of the Digestive Tract. 1922 (Hoeber, New York).—Kerley and Le Wald: Digestive Disturbances in Infants and Children. 1923 (Hoeber, New York).—Carman: The Röntgen-Diagnosis-of Diseases of the Alimentary canal. 2nd ed., 1921

normal stomach form or a normal stomach position.[1] The two most frequent typical forms are: the fish-hook form (or syphon form) and the steerhorn form, the first being at least thirty to fifty times more frequent than the latter; the steerhorn form can be regarded as the rarer variety and is usually found only in corpulent people. "There is no such thing as a steerhorn form, its Röntgen shadow is just a sign of a definite position of the stomach."[2] In the fish-hook form the pars pylorica stands higher than the lower level of the greater curvature, in the steerhorn form the pylorus forms the most dependent point of the stomach, although it can be a little above it. The shadow-form and position of the stomach is in the same person quite different, according as the stomach is examined in the *standing* or the *horizontal* position. (In ptotic stomachs the fish-hook form is retained even in the horizontal position.) The majority of stomachs move in the horizontal position more upwards and to the right, others again, and especially the narrow stomachs of women, move still more to the left. The position of the pylorus remains practically unaltered.

Nomenclature

For an understanding of the terms in the following sections it may be observed that different descriptions are used for the same or similar parts, according as the author follows one or another authority. Forssell divides the stomach into fornix, body, sinus, and egestive canal; Holzknecht into fundus, pars media, body, and pars pylorica; Groedel into cranial pole (fundus with gastric air-space), pars descendens, gastric sac, pars ascendens (with sphincter antri and antrum). The presence of an antral sphincter, the subject of long debate, seems now to have been decided in the affirmative.

Stomach of the Newly-Born and of Children

Regarding the stomach of the *newly-born child* it is established[3] that it is of fish-hook form and is composed of a pars cardiaca, body, and pars pylorica. When empty it is shaped like a tube. The axis of the body and the axis of the stomach meet at a sharp angle. The average time of emptying is $1\frac{1}{2}$ to 3 hours for mother's milk, for cow's milk somewhat longer. The pylorus does not shut the stomach off tight, and the duodenum is very quickly traversed by the meal. Other investigators find no principal

(Saunders Co., Philadelphia).—Balli: Magen d. Neugeborenen u. des Kindes.—Juan Cunha: Röntgenologic considerations of gastro-duodenal anatomy and physiology. Radiology, December, 1925.—Assmann: Die klinische Röntgendiagnostik der inneren Krankheiten. Leipzig, 1924.—Solomon and Trau-Nhu-Lan: Situation et dimensions de l'estomac chez le sujet normal, ptose et dilatation gastrique. Arch. d'Electr. méd., June, 1927.

[1] Simmonds: Über Form und Lage des Magens. Jena, 1907 (G. Fischer).—Froriep: Naturf. Vers. Stuttgart, 1906.—Tandler, Vienna: W. M. Wschr., 1922, p. 333.

[2] F. W. Müller: Kl. Wchschr, 1923/24, p. 1107.

[3] E. Vogt: Zur Röntgendiagnostik des Magen-Darm-Kanals des Neugeborenen. Fortschritte, Bd. 28, 1921, and Bd. 30, 1. Kongressheft, 1922.

difference between the fœtal or infantile stomach and the adult's ; a fish-hook form being present even in the fœtus.[1] According to recent researches by means of solutions of rapidly fixing stearin (in the bodies of newly-born children), it was established that the pylorus does not always form the deepest point of the stomach ; in the majority of cases the pylorus is nearly at the same level as the cardia (whereas the text-books maintain that the pylorus in the empty stomach of the newly-born represents the most dependent point of the organ). The fundus (fornix) is of modest dimensions, it never forms a blind ending as in the adult. The form of the stomach itself is very variable. Its average capacity is 20–30 c.c. The ontogenesis of the gastric canal, which it is possible to regard as the phylogenetic rudiment of the gastric canal of ruminants, has been established in this examination.[2]

In children the form and position of the stomach is found to be as follows.[3] In the standing position the normal infant's stomach when filled with liquid nourishment is usually situated horizontally, the pyloric portion being a little higher ; more rarely a retort form with the left side fixed ; occasionally a steerhorn form with the pylorus as the most dependent point was found. The pure fish-hook form is very rare in children. The amount of gas in the stomach is usually remarkable, and apparently all the more the broader or more prominent the abdomen of the child. The majority of children's stomachs are empty in 1 to $1\frac{1}{2}$ hours. The pylorus and the first part of the duodenum are very clearly seen ; a wave on the lesser curvature is practically never seen.

It is stated from the radio-anatomical side : [4] the form and position of the stomach in a child is influenced by the position of the body, the breathing, and the neighbouring organs. In the majority of cases the stomach when filled with fluid contents is situated horizontally, even on examining it in the vertical position, and extends pretty far to the right. The fish-hook form is not pronounced, the pylorus is not much elevated. Change of form always accompanies change of position.

If inside an hour the stomach of a newly-born child has not allowed any of the contrast-meal to pass through the pylorus—which normally happens at once—there is as a rule *a congenital hypertrophic stenosis* of the pylorus present, even though no corresponding tumour can be palpated. If the greater part of the meal has left the stomach within three hours (a point established by repeated Röntgen examination : guard against Röntgen injury !), it will not be found necessary to operate, for we are

[1] H. Lossen : Form und Lage des foetalen Magens. Fortschritte, Bd. 30, 1. Kongressheft, 1922.—Kerley and Le Wald, note 1, p. 416.

[2] E. Vogt : Vergleichende Untersuchungen über den Magen des Neugeborenen an der Hand von Röntgenaufnahmen und Ausgüssen mit Stearin. Fortschritte, Bd. 35, 3, 1926.

[3] Alwens and Husler : Röntgenuntersuchungen des kindlichen Magens. Fortschritte, Bd. 19.—Pisek and Le Wald : The further study of the anatomy and physiology of the infant stomach based on serial röntgenograms. Americ. Journal of Diseases of Children, October, 1913, Bd. 6.

[4] A. Hasselwander : Die Bedeutung des Röntgenbildes für die Anatomie. 1921. (Publishers, S. F. Bergmann, Munich.)

then dealing with a pure spasm that can be remedied by atropin, lavage of the stomach, and careful diet. But if the pylorus is still shut after 24 to 48 hours, operation should at once be performed.

Pylorospasm alone frequently occurs in intestinal disease further down the tract, and also in children of spasmophilic tendency, and in the cyclical vomiting of older children. The typical Röntgen finding is usually this: the pars pylorica takes some little time to fill, the contrast-meal is retained in the stomach for 55 to 60 minutes, then the spasm passes off, the pylorus functionates fairly regularly, so that at the end of the normal emptying period only a little of the meal is left behind. Exceptional cases may occur with a more prolonged spastic closure of the pylorus and a larger retention.

Chronic gastric *dilatation* without spastic or organic pyloric stenosis is ascribable to atony of the musculature of the stomach. Active peristalsis is then in abeyance. The stomach is seen to fill completely with the contrast-meal which travels immediately into the duodenum (thus differing from pylorospasm). The passage of the meal follows slowly, and in consequence the time of emptying of the stomach is lengthened. The cardiac end of the stomach is thereby enlarged by a large air-sac (magenblase) which presses up the left half of the diaphragm as in commencing eventration. The ballooning of the abdomen sometimes gives rise to a mistaken diagnosis of enlarged colon; the Röntgen examination, however, disproves that. Naturally some cases show intestinal anomalies in addition to the gastric condition.

Congenital *extra-high fixation* of the commencement of the duodenum is said to be the cause of a more marked angularity of the pars descendens and the pars ascendens, a delay in the emptying time and a consequent dilatation and ptosis of the stomach. An identical result can be brought about by a congenitally elongated mesentery.

Syphilitic changes in the stomach are said to be very frequent in children. One finds: (1) A dumb-bell shaped shadow of the stomach, in consequence of infiltration of the mid-third (not to be confused with hour-glass stomach!). The diminished capacity of the stomach is compensated for by an œsophageal dilatation. (2) A diminution without dumb-bell form, with rapid emptying in consequence of pyloric insufficiency, and in spite of this a six-hour retention, because the infiltrated stomach walls do not functionate normally. (3) An ulcer-like alteration of the pyloric region, which acts as a stenosis and produces a delay in emptying and a dilatation of the stomach similar to that seen in new growths.[1]

The Röntgen view of the adult often resembles that of a carcinoma. The diagnosis should be made from the absence of cachexia, a positive Wassermann, improvement of the anatomical and functional findings after antiluetic treatment, increase of weight, cessation of the vomiting, and

[1] This last section after Kerley and Le Wald, *l.c.*—The same: Radiology, February, 1926.—B. Cohn: Med. Klinik., 1926, No. 7.—E. Gäbert: D. Ges. f. Inn. Med., 38 Congress, 1926.—P. B. Mulligan: Radiology, July, 1926.—F. Hirschberg: Über syphil. Schrumpfmagen. Med. Klinik, 1926, No. 17.

disappearance of pain. (In carcinomatous tumours the time for a life-saving operation has long passed.) [1]

Sex and Stomach Form

There is no more a characteristic form for *the male* and *the female stomach* than there is a normal form of the stomach. The most one can say is that the majority of male stomachs are (in standing) broader and shorter than the female. On the other hand, it is stated from the anatomico-röntgenological side [2] that the form, position, and length of the stomach manifests a characteristic difference in the man and the woman. (In the different types of people this influence is of importance and affords indications for the diagnosis of ptoses.) The abdominal cavity in the woman is larger and narrower than in man of the same height, and this explains the difference of the position of the stomach in the two sexes.[3]

Size, Position, and Form in General [4]

Position and form are dependent upon the spatial conditions of the abdominal cavity, the relation of the height and breadth of the abdomen, the level of the diaphragm, the position and degree of filling of the intestine, and the external shape of the body.

As long as there are not subjective complaints and the function is not affected, certain apparently highly divergent forms of the stomach need not be regarded as pathological.

The *mobility* of the normal stomach upon palpation is quite considerable, in a number of different positions. But every time it returns quickly to its original positions.

A *displacement of the pylorus* upwards and to the right is normal towards the end of emptying of the stomach.

As in the heart (which see), though perhaps in lesser degree, the stomach picture reflects *the constitution* of the particular individual.

Considerable departures in form and position of a stomach in standing and in the horizontal are indicative of atonic stomach.

Displacement of the stomach upwards, approximation of its walls to each other, diminution of its lumen in an irregular way, occur in carcinoma of the colon and ileus of the great bowel. The diagnosis is arrived at from the

[1] B. Cohn: Med. Klinik., 1926, No. 7.—E. Gäbert: D. Ges. f. Inn. Med., 38. Kongr., 1926.—P. B. Mulligan: Radiology, July, 1926.—F. Hirschberg: Über syphil. Schrumpfmagen. Med. Klinik, 1926, No. 17.—L. T. Le Wald: Radiology, February, 1926.

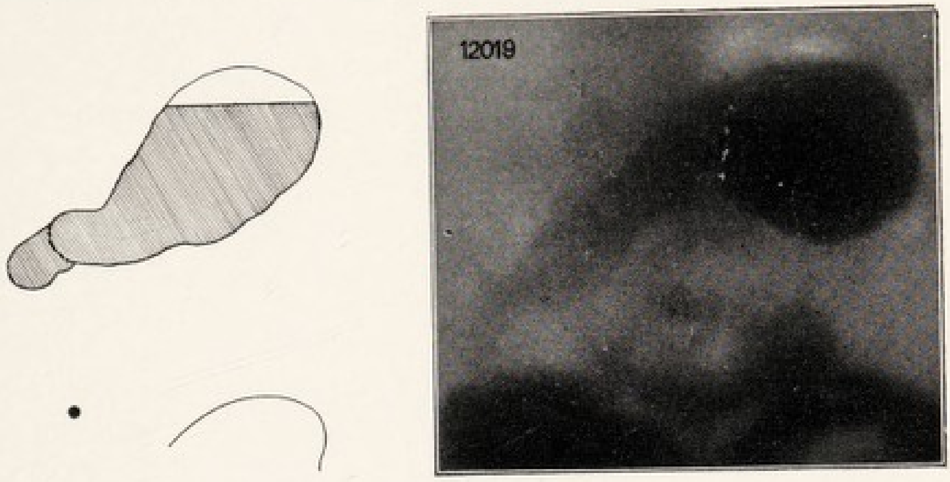
[2] A. Hasselwander, *l.c.*

[3] Groedel, *l.c.*

[4] The author is perfectly well aware that the headings of the sub-divisions of this section on stomach and intestines are not immune to strong criticism and do not appear to be altogether consequent in their choice. They might have been left out altogether, but then the same survey would not have been obtained. It is to be remembered that in this book we are not dealing with a systematic text-book, but with an innumeration of a number of warnings against mistakes, and this obviously cannot be brought into a system.

examination of the great bowel. The colon can encroach upon the space occupied by the stomach, produce defects in filling or hour-glass form of the stomach, and lead to the diagnosis of tumour, etc.

Exceptional *smallness* and *elevation* of the silhouette of the stomach with irregular contours indicates *scirrhus*. In these cases the upper portion of the stomach is usually round and circular, and the entire stomach retort-shaped. It is said that this condition of " microgastry " may also be due to shrinking processes that are not carcinomatous (*e.g.* lues). A functional microgastry can also be caused by too tight lacing and by too quick eating.[1]



A Fig. 251. B

Elevation and transverse fixation of a stomach of normal size along with ballooning out of the cardiac third and tube-like narrowing of the distal third is the typical appearance of the *hypertonic stomach*. Such is found in all illnesses resulting in hypertonic stomach, not only in ulcers of the small intestine but also often in appendicitis, also after dysentery, and more rarely after enteric. See the next paragraph.

A dragging of the pyloric region to the right or below and to the right in a highly situated stomach points, in perigastric and pericholecystitic processes near the pylorus and in certain types of duodenal ulcer, to *adhesions of the tissues around the pylorus with the liver and gall-bladder* (see Fig. 251, A, autoptic finding, B, not operated, a year after cholecystitis and peritonitis). Nevertheless, if the findings in this area be negative we should not necessarily assume the absence of adhesions. There has been recently much discussion about the röntgenological signs of adhesions of the stomach and of the intestine. In an elevated and transverse stomach we have reason to think of adhesions from the pars pylorica and the gall-bladder, only when a pendulous abdomen is at the same time present ; it is, however, difficult to arrive at a certain diagnosis.[2] (The patient, in whom the finding

[1] Groedel, *l.c.*

[2] Holzknecht : Report on Discussion, 10th German Röntgen-Congress, 1914, p. 70. See further W. Teschendorf : Zur Erkennung intraabdomineller Verwachsungen. D. M. W., 1923, No. 21.

of Fig. 251, A, was seen, was a very tall individual, the one in B was short and thickset.)

As regards *the most dependent point of the stomach,* one may regard as the normal limits : in standing, two finger-breadths above to two finger-breadths below the umbilicus, in lying four finger-breadths above the umbilicus to the umbilicus. In women all these figures should be displaced two finger-breadths downwards. In the horizontal position the sound contrast-filled stomach bears a resemblance to the figure found in atlases of normal anatomy. The most dependent point of the great curvature can be 2–3 cm. deeper, as already stated, without ptosis being present, especially when the case is one of emphysema.

Linear measurements have been carried out on 100 normal stomachs, or rather on their shadows.[1] The distance taken was from the highest

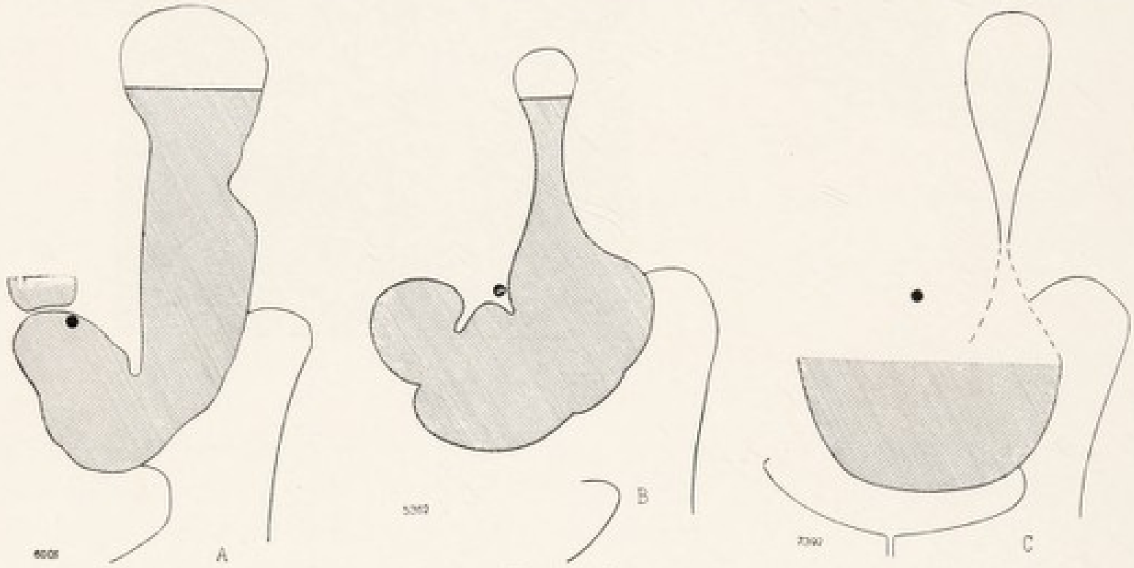


Fig. 252.

point of the gastric air-sac to the most inferior point of the greater curvature. Twenty-one cm. was the average measurement in fish-hook type of stomach (Rieder). The longest stomach measured 28 cm., in a corpulent man, the shortest 18 cm., in an adult of small size. See also p. 414.

Distance of pylorus from the symphysis : Average figure for men 10·5 cm. (minimum 6, maximum 15·5) and for women 7·5 cm. (minimum 3, maximum 13·5 cm.). These limits are so wide that these measurements are really not of much value.[2]

The *typical picture of gastroptosis* is as follows : a long, thin stomach, with its axis usually vertical but occasionally inclined to the left, which extends far down, frequently as far as the floor of the pelvis, then turns sharply upwards, and is also sometimes associated with an elongated duodenal cap.[3] Some observers, however, maintain that a low level of the pylorus does not justify the use of the term " ptosis," which requires also

[1] Campo and Campo de Cos, *l.c.*

[2] Groedel, *l.c.*

[3] Strauss : Die Gastro-Koloptose in röntgenologischer Beziehung. Deutsche med. Wochenschrift, June 10, 1915.

a dropping of the pylorus in consequence of loosening of the suspensory ligaments (Fig. 252, A). The pylorus is usually displaced to the right and is more movable upon palpation than normal. One worker recommends [1] instead of the term " Gastroptosis " the employment of the term " Enteroptotic elongation of the stomach " either with or without ptosis of the pylorus (see also Fig. 255, F).

One should only speak of *a pure gastroptosis* when the two fixed points, the pylorus and the cardia, and the hook-like gastric tube between them, are abnormally removed from their normal point of fixation, the diaphragm and the liver. On the other hand, a dropping of the stomach which depends upon a dropping of both halves of the diaphragm, is not a ptosis. The purely ptotic stomach can exhibit a very strong tonus with powerful peristalsis and have a normal period of emptying. Usually, however, the ptotic stomach shows a greater or less degree of atony, " enteroptotic elongation of the stomach with atony." If the atony is more considerable dilatation does not take long to follow (Fig. 252, C). But considerable dilatations may occur without atony (Fig. 252, B).

There is still much uncertainty as to the cause of gastroptosis. Constitutional weakness of the connective tissue, marked thinning with consequent ptosis of the so-called intestinal cushion and depression of the most dependent parts of the stomach are not the only factors. Apart from extragastric factors there are perhaps also intragastric factors, such as atony ; nevertheless, a hypertonic stomach can be markedly ptosed and, on the other hand, a plump hypertonic stomach can be situate high in the epigastrium. The position of the stomach when filled is said to exhibit wide variations in one and the same person, and not on different days only, but also in the course of a single irradiation.[2] By nausea, for example, a ptosis of the distal end of the stomach can be produced,[3] and also by exhaustion, fainting, and migraine ; there may also occur a gastroptosis due to irritation of the sympathetic, a gastrogenic factor in many ptoses of the stomach, that may be quite independent of the surroundings of the stomach and external pressure conditions.

A gastroptosis of a greater or less degree is (strange to relate, and not easily explainable) present in about nine-tenths of all cases of ulcus ventriculi (also in ulcus duodeni), even marked gastroptosis in seven-tenths of the cases.[4] This frequent combination of gastroptosis and ulcer has been frequently observed, although not in the percentages above mentioned ; it may therefore be accepted as an undoubted fact. An explanation that is quite feasible [5] is that gastroptosis by interferences with the circulation or other conditions in the pars media sets up a locus minoris resistentiæ, which is favourable to the production of ulcer (see also the three cases in Fig. 261).

[1] G. Schwarz, *l.c.*

[2] W. Ruhmann : Zur Entstehung der Gastroptose (Neuromusculäre Gesichtspunkte). Fortschritte, Bd. 35, 1927.

[3] Barclay and Walinski, quoted by Ruhmann : see footnote [2].

[4] Krempelhuber, *l.c.*

[5] Rösler, quoted by Krempelhuber.

The position of the stomach is above all dependent on the fullness of the transverse colon, and vice versa. When the latter is well filled, the stomach is thereby raised. Although not always practicable, the great bowel should doubtless always be emptied before the stomach is examined with the rays.

Normally two-thirds of the stomach are to the left side of the mid-line of the body, one-third being to the right.

Whether the form and doubtless also the position of the stomach is influenced by *collections of gas in a great bowel* more or less empty is easy to determine, for the intestinal gases always show up clearly in the picture, see Fig. 254. It might be assumed that a filled transverse colon would draw down the stomach. That is a mistake. The stomach becomes displaced upwards by a filled normal colon.

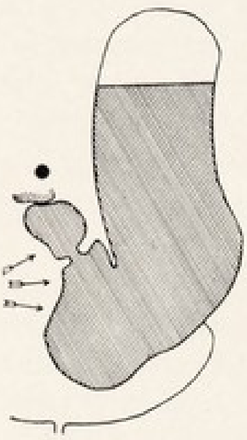


FIG. 253.

Displacement of the cardiac portion to the right may be produced by tumours of the spleen. Dislocations of the middle and pyloric portions upwards and to the right can be produced by tumours of the left kidney. If the *whole stomach is displaced to the left,* tumours of the pancreas or the liver should be considered, while dragging of the stomach upwards and to the right is usually due to pericholecystitic adhesions: see also the illustrations later in the section on " Duodenal adhesions." Fig. 253 gives the view of a stomach, whose pyloric portion was displaced and pressed in by an extraventricular tumour. In large tumours of the uterus or its annexa, and also in the later months of pregnancy, one finds the stomach pressed upwards more or less. Also it is somewhat raised in a well-filled transverse colon. In displacements of the stomach one should never omit to take a profile picture.

In scirrhus the stomach is abnormally small and displaced completely under the costal arches.

Complete *elevation* of a large normal stomach is frequently met in diseases of the bile ducts and the common bile duct.

A *displacement of the stomach to the right* is said to occur in certain forms of duodenal ulcer. Also after *dysentery,* and less often after enteric fever, displacements of the stomach are encountered.[1]

The normal shadow of the *horizontal part of the duodenum* is a semilunar short shadow in projection-picture ; if it runs vertically downwards, a *pyloroptosis* is present. In such a case the angle of the stomach is usually displaced downwards. The descending limb of the stomach is simply longer, the ascending shorter ; a distinct diminution of the stomach picture does not occur. The body of the sac also descends. The fundus remains undisturbed.

A peculiar anomaly in the position of the stomach has been described.[2] The gastric-sac (magenblase) and the cardiac part of the stomach lay quite

[1] Groedel, *l.c.*

[2] A. Eisenstein : Fall von eigenartiger angeborener Lageanomalie des Magens. Fortschritte, Bd. 36, 1, 1927.—Meisels : Acta Rad., 1925, IV, 4.

normally below the left cupola of the diaphragm, while the pylorus and duodenum were diverted towards the left. The greater curvature lay right, the small curvature left. Spleen and liver were in normal position, as also were the thoracic organs. This was a case of congenital torsion, or, although this is improbable, of a situs inversus partialis pylori et duodeni.

The author adduces in Fig. 254 two cases of displacement and rotation of the stomach, caused by large collections of gas in the left flexure of the colon. In both cases the stomach itself might be of normal form. The distal third is wholly overshadowed by the middle third. In modern technique it should be easy in such cases to take supplementary profile negatives.

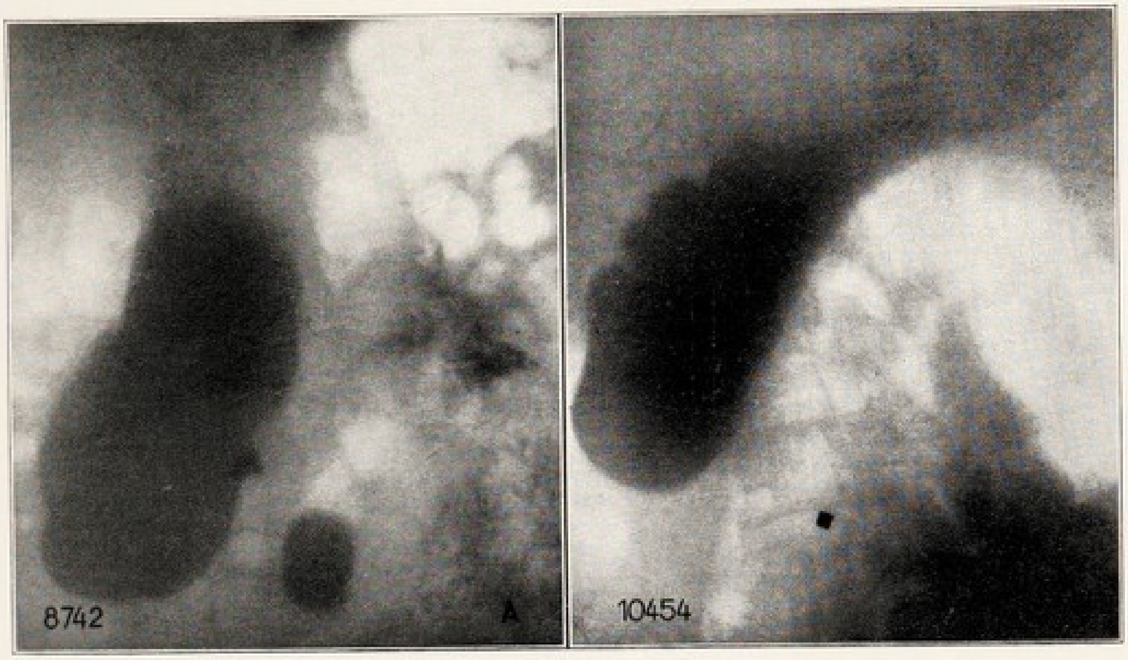


Fig. 254.

Form alone, as a Whole

Of the *three kinds of normal stomach form,* the transverse, the oblique, and the vertical, the second and third occur most frequently, the first more rarely. The first is met with principally or almost always in stout, broad people. The average degree of the third type, in which the pylorus is found at the level of the third to the fifth lumbar vertebræ, amount to at least two-thirds of all forms of the stomach.

The *form of the stomach* is dependent, in the living as well as in the dead subject, upon the state of contraction, in which the stomach finds itself at the moment of examination. It is supplied with a number of arrangements, which enable it to adapt itself to any conditions and requirements. Consequently, we find its form and the manner of its subdivision constantly changing. It assumes from moment to moment a position suited to the work it is doing. " The only thing constant about the form and position of the stomach is its change." [1] And yet the stomach has a constant anatomical

[1] Froriep and Simmonds, quoted by Groedel.

construction, definitely dependent on a constant and typical architecture of the stomach wall, which is found in all Röntgen pictures showing normal variations of form. The muscle bundles contract in certain definite directions, each typical of one part of the stomach. Thus corresponding to every state of contraction of the different parts of the stomach there is a certain form of each part.[1] Lastly, the form is said to be conditioned by the peristaltic action. The anatomical stomach offers a number of form-possibilities. The form, however, is due to the activity of the nervous system. Seeing the form is conditioned in the first place by the tonus it is natural that the most striking differences in the form of the stomach should be produced by anomalies in tonus.[2]

Fig. 255 shows a number of normal, fairly normal, and slightly pathological stomachs. A. Stomach of normal size, tone, and peristalsis. But form and position are influenced by extraventricular factors (enlargement of the neighbouring organs, such as the liver), hence the displacement of the stomach in this figure. B. The somewhat unusual pathological form of stomach with balloon-like enlargement of the fundus and narrowing of the middle third of the stomach is due to adhesions to the posterior wall of the stomach. At operation (by Heile) an ulcer was found on the lesser curvature towards the posterior and adhesions of the posterior wall of the stomach to the pancreas. C. In this stomach, which is otherwise normal, one sees in the lower half of the descending part of the greater curvature an indrawing not peristaltic and somewhat semicircular. This was due to a tumour of the head of the pancreas (operation by Heile). Regarding findings of the stomach in pancreatic tumours, see also under Fig. 257. D. Normal transversely placed stomach of a stout individual. Normal peristalsis and tone. (In these stomachs the cap of the duodenum is usually placed behind the end of the stomach and therefore covered by the sagittal rays traversing the stomach.) E. Normal stomach. Intermediate between steerhorn and hook-form stomach. F. Narrow hook-like stomach with pyloroptosis, causing no symptoms whatever. Good normal tone, as shown by the uniformly broad upper end of the stomach. The peristalsis, too, as seen here, may be described as normal for this kind of stomach, although it runs quite evenly in the cephalic third. G. Short extra broad stomach of a small, very broad, stout man with moderate pains at times for about ten years, indicative of spasm at the pylorus. The stomach is perhaps a little broader than one would expect from the build of the patient. H. Stomach with enlargement limited to the cephalic half, peristalsis slight, distal half narrow, and normal in tone and showing hyperperistalsis. (A pleuro-diaphragmatic adhesion under the apex of the heart.) Fifteen years previously the patient had been operated on for peritonitis. See also illustration with the same number (12948) below among the illustrations of the small intestine. (The figure is almost identical with the sketch by Klee, in insulation of the particular nerves of the stomach in experimental work: warming of

[1] G. Forssell, in Gerhartz's "Leitfaden der Röntgenologie."

[2] Groedel, *l.c.*

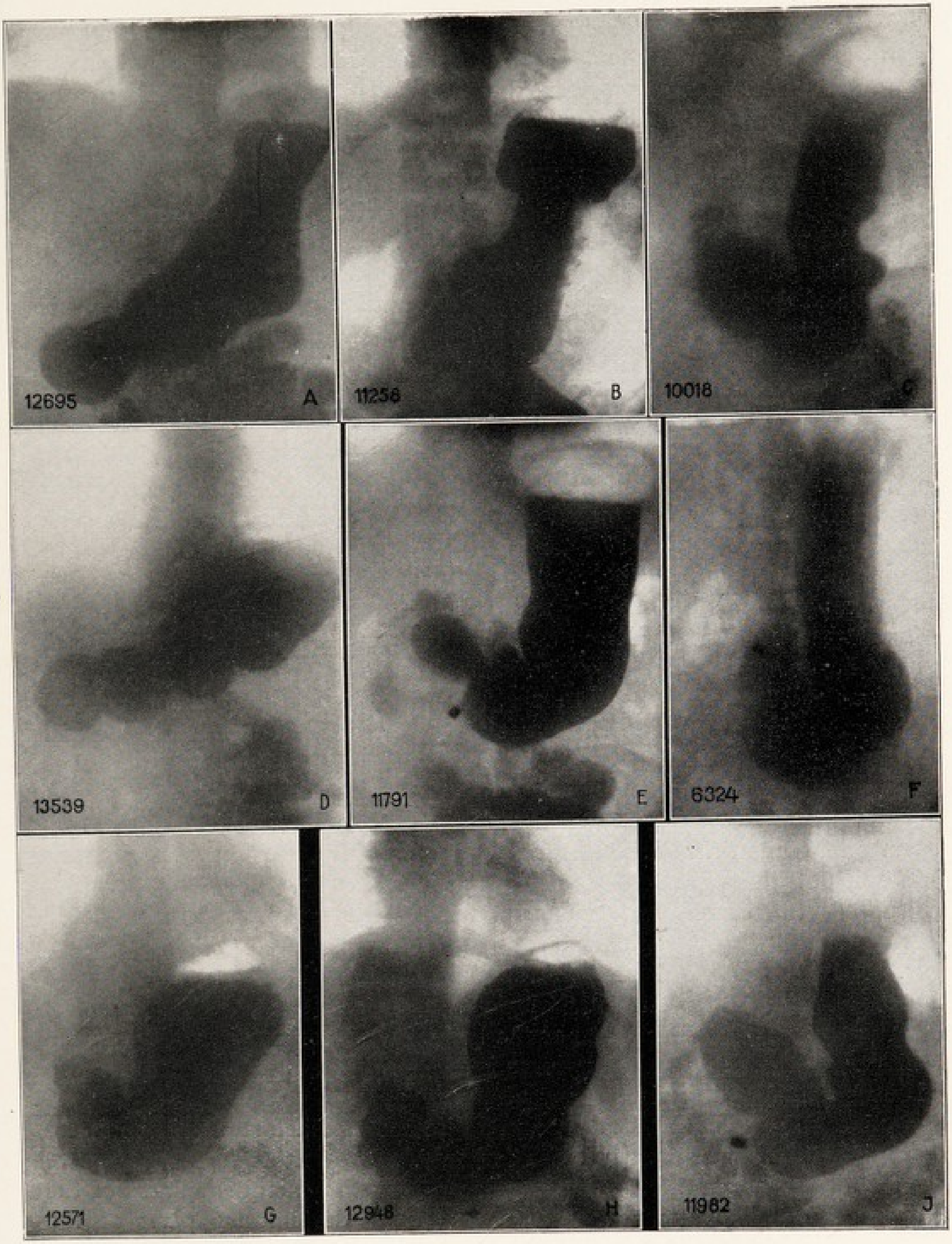

12695 A
11258 B
10018 C
13539 D
11791 E
6324 F
12571 G
12948 H
11962 J

FIG. 255.

the vagus with retention of sympathetic nerve tone [see Schinz, Baensch and Friedl, Fig. 1347].) I. Stomach with good peristalsis and good tone, but with a moderate degree of enlargement of its pyloric fourth, which is a comparatively frequent finding. Upon a barium meal there was a layer of secretion measuring 3 cm. The patient had a malignant tumour of the bowel.

In profile view the normal stomach is tongue-shaped, becoming smaller from above downwards. If it is markedly dilated below, that is not regular but a sign of atonic dilatation ; it is not a sign of mechanical dilatation ; see next paragraph.

When the stomach shadow viewed *in profile* shows nothing more than a marked degree of narrowing, especially of the descending part, together with an elongation of the same, a picture that appears frequently in women and very thin men, we have the picture of " mechanical dilatation " before us.[1] It appears usually in weakly and myasthenic individuals. Mechanical dilatation is due to an overloading of the muscular supporting apparatus of the stomach-wall and is the result of a diminished intra-abdominal pressure. But such a stomach is even in the highest degrees of elongation and narrowing completely filled with the normal quantity of contrast-meal, and its tone is normal. " Atonic dilatation " is when the muscle of the stomach has lost its tone ; the dependent parts of the stomach are then abnormally broadened out. (In dilatation, the clinical ectasia, the lumen is enlarged both in the empty and the filled state.) The picture described may be an accidental discovery. Therefore in severe complaints of the patient and the presence of such a narrow elongated stomach one should always avoid declaring all his complaints as explained by that alone and remaining content with that. In such cases complaints are doubtless correlated with the clinical picture of gastroptosis.

Extreme dilatation with extreme delay of the emptying time is probably dependent upon a fibrotic stenosis of the pylorus. In malignant stenosis in spite of abnormal retention being present extreme dilatation does not usually result therefrom (yet one should consider that a previously dilated stomach may become carcinomatous).

In abnormally tall men the stomach can manifest a striking length without being in the least pathological. It runs then vertically or almost vertically in the erect posture of the body. In pyloroptosis, which gives a similar shadow picture, the pylorus is further down, and the duodenal cap is usually directed vertically upwards.[2]

The form of both a healthy and a diseased stomach stands in no direct relationship to the quantity of its contents.

Abnormal dilatation of the cardiac part with general smallness of the remainder of the stomach and narrowing of the inferior parts of the stomach is indicative of *gastrospasm*. The shadow picture resembles that of a glass-filter or a short thick steerhorn. There is an entire

[1] Groedel, *l.c.*

[2] M. Bönninger : Die Form des Magens. 29. Kongr. f. innere Med., 1912.

absence of peristalsis in the parts involved. The contour of the shadow is coarsely or finely notched. Apart from a total gastrospasm, partial or regional gastrospasm also occurs. In the latter one finds a sharp demarcation from the parts not affected, similar to the circular carcinoma of the pars pylorica (*cf.* Fig. 266). It has therefore been said: In the morphological picture of a carcinoma and the clinical picture of an ulcer or hyperacidity we are justified in suspecting a gastrospasm. Differential diagnosis: in carcinoma the picture does not change from day to day, in gastrospasm it naturally changes. (Gastrospasm has been observed in morphia and hydrochloric acid poisoning, in tabes, tetany, hysteria, cholelithiasis, nicotine intoxication, amyloidosis, gastric phlegmon, uræmia, and lead poisoning.)[1] Thus in Fig. 256, A, the view gives the impression of a malignant tumour (no longer operable) encircling the pars pylorica (egestive canal). But the negative taken 2 hours after (see B), where instead of a defect the walls were well expanded, proved that it was spasm we were dealing with. Moreover, the clinical history was not that of tumour. The patient now, three years afterwards, has scarcely any symptoms.

Fig. 256.

In hypertony of the whole stomach *a steerhorn form* also occurs; if only the pars pylorica and the body are affected, and not the region of the fundus, *a filling-horn form* is the result; an *angle-form*, if only the pars pylorica is hypertonic. In these the stomach is displaced some way from the liver.

In hypertony an abnormal narrowing of the lower half of the stomach occurs, in the *atonic stomach* there is an abnormal narrowing of the upper half of the stomach.

If a part of the stomach outline corresponds to a neighbouring organ, *extensive adhesions* should always be thought of.

[1] Groedel, *l.c.*

A completely negative Röntgen finding in sagittal and profile pictures of the stomach does not disprove the presence of a fresh ulcer.

In fairly large *tumours of the pancreas* the shadow picture of the stomach (and intestine: see later in "Transverse colon") is usually more or less altered. The author found the above condition of stomach: Fig. 257, the second view 10 minutes after the first. Confirmed by operation. The pyloric half of the stomach which was otherwise normal was broadened by pressure upwards and downwards. Others found broadening of the angle of the stomach in pancreatic tumours, with displacement downwards and to the left. In five cases of pancreatic cyst one röntgenologist observed marked displacement of the stomach to the left in every case.[1] One should

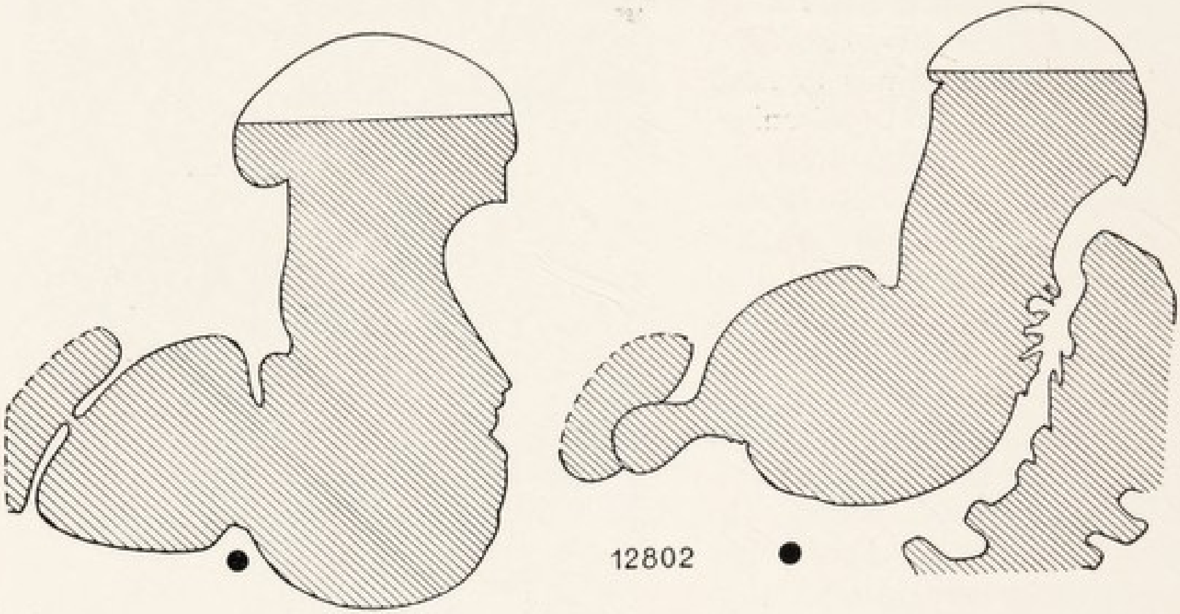


Fig. 257.

also note Fig. 255, C. A typical picture of the stomach, pathognomonic of pancreatic tumour, does not appear to exist, which is really not surprising. But it is the business of the röntgenologist to take the possibility of a pancreatic tumour into consideration in any peculiar picture of the gastric shadow. For changes in the transverse colon in tumour of the pancreas, see the later illustration in the corresponding section.

Details of Form

1. *Cardiac Third*

With the patient in the standing position there is close under the left cupola of the left diaphragm behind the apex of the heart both in the empty stomach and the full one a pear-shaped or semilunar intense transparency in the highest part of the stomach, directly under the left half of the diaphragm. That is *the air-sac of the fundus* (*the "magenblase"*), which is

[1] Albu, quoted by Groedel. See further O. Gross: Kl. Wschr., 1923/24, p. 1346.—Arens: Journ. of Rad., August, 1923.—Herrnheiser: Med. Klin., 1922, No. 8.

not pathological but normal. In the horizontal position and with the stomach filled the gastric air-sac, when visible, appears more over the middle of the stomach, yet owing to its flatness in comparison with the opacity of the contrast-meal, it does not usually appear in this position very prominently to a Röntgen examination.

The gastric air-sac is already present early in life ; a child that has once breathed has swallowed air into its stomach (apart from a congenital closure of the œsophagus). That is very important from the forensic point of view. In the bodies of children that have lain for a long time decomposition gases in the stomach must also be considered. Unequivocal results are obtained in children who have not breathed either within or without the uterus. If the children are stillborn a few hours after intra-uterine death, there is always found in a Röntgen plate an entire absence of the internal organs ; neither intestine, stomach, lungs, heart, nor liver are visible. The Röntgen examination does not help us in all those cases in which several hours have elapsed since death.[1]

The gastric air-sac is at its largest after the taking of a meal, it then gradually diminishes in size, may disappear completely shortly before the stomach empties, reforms when the stomach is empty, and attains to greater dimensions with the increasing feeling of hunger.

The gastric air-sac is oval and pointed downwards when the stomach is empty ; in a full stomach it is low and widened out ; but it can appear oval when its lateral part is covered or occluded by the shadows of the spleen or liver. A specially long-drawn-out, narrow air-sac in an empty or partly filled stomach indicates a gastroptosis or an atonic dilatation.

A large air-sac is no longer physiological, as soon as the diaphragm is pressed upwards by it (see under " Diaphragm "). Large gastric air-sacs of this kind are even in the horizontal position of the patient easily visible in spite of contrast filling, and are usually seen about the middle of the stomach picture. In aerophagy a large air-sac occurs without elevation of the diaphragm. An air-sac of considerable and fairly uniform size (so-called idiopathic chronic air-sac) is most frequently seen in people who suffer from prevalent general nervous diseases ; we have then probably to do with atony of the diaphragm, others say [2] a special neurosis of the stomach with relaxation of its wall. Thus there is described a *rudimentary eventration* as a strong blowing up of the stomach, which is said to be the forerunner of the whole symptom-complex of eventration and which may at the same time be caused by a circulus vitiosus picture of an eventration. One assumes that in these cases the air swallowed normally with the intake of food collects in the fundus instead of being brought up. A diaphragm that is muscularly weak is pressed upwards by the pressure of the air. If the stomach is highly

[1] Quite a good summary, with the literature up to date, is found in E. Vogt : Die röntgenologische Lebensprobe. Zeitschr. f. Geburtshilfe und Gynäkologie, Bd. 80 ; further E. Vogt : Fortschritte, Bd. 30, 1. Kongressheft, 1922.

[2] Hoffmann : Magenbeobachtung mit Röntgenstrahlem und die chronische idiopath. Magenblase. Med. Ges. zu Leipzig, 14, 2, 1905, and Münchener Medic. Wochenschrift, 1905, No. 17.

placed it causes a kinking of the cardia and a consequent closure of the valve is possible.[1]

Sometimes one sees in the usually homogeneous transparency of the air-sac one or two straight or slightly oblique linear longitudinal shadows, the meaning of which is not at once clear to any one seeing such a picture for the first time. It is due to the coils of the splenic flexure filled with gas. This rises up when filled with gas and the stomach is empty. We are dealing here with quite a normal condition.[2] Nevertheless, it is often really difficult to say exactly which parts of the transparent areas belong to the gastric air-sac and which to the flexure of the colon. The point is not usually of practical moment.

A large transverse semi-oval shadow of medium density above the whole cardiac end of the female stomach arises from the overhanging *mamma*. The inexpert observer sometimes cannot believe that the breast can cast such a distinct shadow.

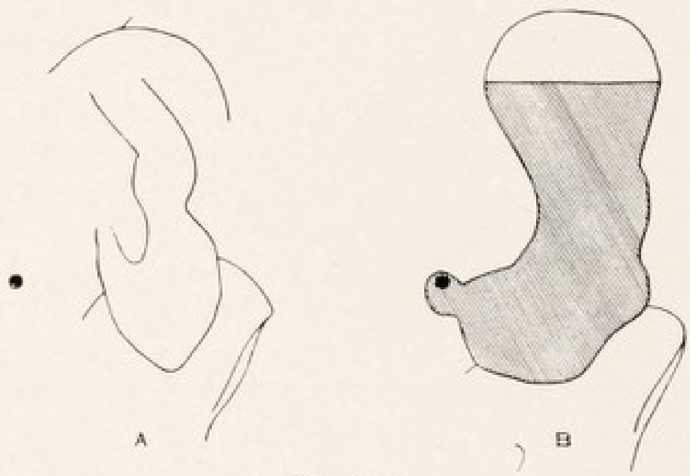


Fig. 258.

It is extremely rare to see a case in which the whole stomach is filled with air. Some of these discoveries are accidental ones. The first case of the kind was published by the author.[3] Since then I have seen another case. Another author [4] described the appearance as a cardiospasm. Fig. 258, A, shows the author's case, viewed in advance of a meal, picture B shows the same stomach after a bismuth meal. (These pictures are suitable also for contradicting the view that the tube-like form of many stomachs is conditioned by the astringent action of the bismuth.) The clinical symptoms in the author's case were not such as to render cardiospasm likely. Moreover, the configuration of this stomach was quite different from that described by the other author.

A stomach examined in the standing position, even though the filling of the contrast-meal does not show the slightest suspicious symptom, may be the seat of a large tumour, namely, in the fundus of the stomach, where only air is. In favourable cases one can make a certain diagnosis of the tumour from the displacement of the air. Happily, tumours in this part of the stomach are very rare. Such tumours are recognised more readily when

[1] Wels, quoted by Groedel.

[2] A condition which is already described in Braune's anatomical atlas, in the explanation of his table 14, Fig. 3.

[3] Köhler: Verh. des Deutsch. Kongr. f. innere Medizin. Wiesbaden, 1912. Discussion, p. 191.

[4] Dietlen: Beitrag zur Pathologie des Kardiospasmus. Zeitschrift für Röntgenkunde, 1912, p. 306.

the stomach is filled with the contrast-meal in the horizontal position and then photographed (indeed, diseases of the fundus are best diagnosable in the horizontal), or by observation of the first contrast-meal mouthfuls as they enter into the stomach, or by both these ways. By insufflation carcinomata of the fundus are rendered more visible. *Tumour of the cardia* is also diagnosable by masses of contrast-meal remaining behind, directly visible in the gastric air-sac.

Malignant tumours of that part of the stomach lying immediately below the air-cap of the stomach sometimes produce quite distinctive pictures, at an

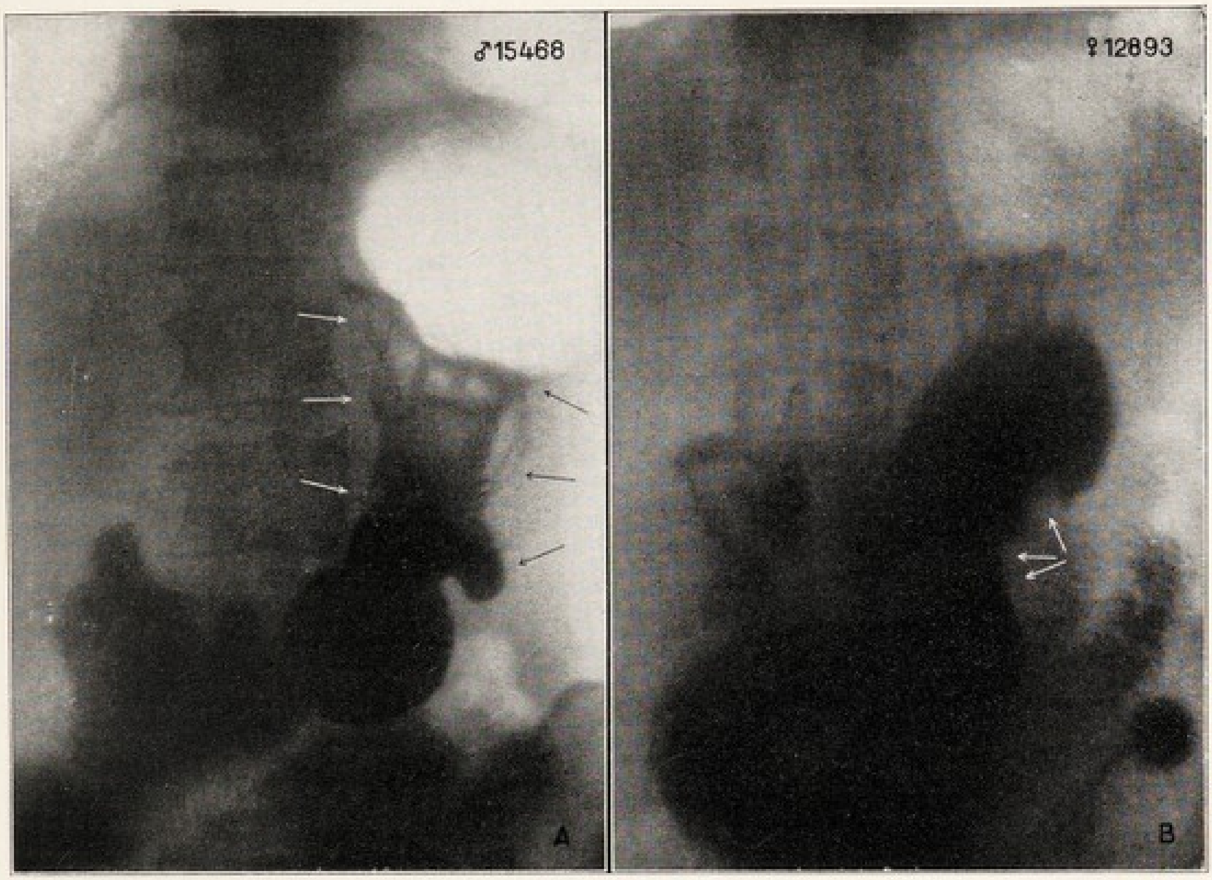


Fig. 259.

early stage when there could not yet be any definite defect in the shadow of the contrast-meal; this is illustrated in Fig. 259, A (histologically, carcinoma). The " architecture " of the shadow is in this case due partly to the folds of mucous membrane being drawn out and irregular. It is of interest to observe how peristalsis sets in immediately at the greater curvature, at the lower end of the tumour, with a powerful wave of release. In the case of B, Fig. 259, the malignant tumour is situate somewhat further down, more in the middle third of the stomach. It does not show up for certain as a tumour, for the triplicate defect seen is placed exactly where the deepest peristaltic rippling is generally found, and examination by the screen affords no certain decision. The clinical symptoms in this instance were against carcinoma, so the operation was unfortunately delayed till too late.

Marked *enlargement of the cardiac third* of the stomach with the remainder of it within the normal limits of form and position indicates *a hypertony;* Fig. 255, H. The explanation of this is that the musculature of the fundus of the normal stomach is less developed than its remaining musculature. Peristalsis is usually thereby increased. Hypertony is said to occur frequently in diseases of the bile-passages, and in pathological changes of the duodenum, appendix, and pancreas.

In the *superior* part of many stomachs from which the meal has emptied one often sees long, vertical, narrow, opaque, parallel coursing lines. They are due to the contrast-meal remaining sticking in the folds of the mucous membrane. This appearance has no pathological significance.

A very slow funnel or wedge-shaped propulsion of the first spoonful of meal in an empty stomach towards the pylorus is not pathological, but merely the consequence of the resistance of the contracted walls of a stomach of good and normal tone.[1] In an atonic stomach the mouthfuls fall more or less down into the interior as if through an open tube. In general it may be said that the pictures of the filling process of the stomach show marked variations within the limits of the normal, and frequently one observes a rapid and irregular propulsion of the contents.[2]

Diverticula of the stomach are decidedly rare. They are either congenital or acquired, and are found only by the aid of the Röntgen rays. There is no characteristic clinical symptom-complex, and they are usually found accidentally in examination of the stomach with symptoms that are not due to diverticulum.[3]

Many mistakes of diagnosis appear in the literature, owing to shadows diagnosed as diverticula of the stomach turning out to be diverticula of the small intestine situated behind the stomach. Organic diverticula of the stomach are characterised by their rounded form, by the changes in amount of filling and distension, by their delicate and mobile contour and the want of all röntgenological signs of an infiltration process in their neighbourhood. Almost all diverticula are situated in the tract of the cardia, exhibit a contrast-meal persisting after 4 hours, and show a gas-bubble at their summit in the standing position.[4]

The author found recently in a case of carcinoma of the lesser curvature (see the three arrows, Fig. 260, B) high up on the lesser curvature at × a remarkable step in the shadow. I do not recollect ever having seen this projection as clearly before, and have found nothing similar in looking through my film collection. I attached no further importance to the finding, and regarded it as a longitudinal projection of the anterior or posterior wall of the stomach at one of the terminals of the tumour. A few weeks later a photograph taken of another patient showed the same finding, Fig. 260, A. Here we had to deal, however, with a prepyloric ulcer, as the

[1] Kaestle, *l.c.*

[2] A. Hasselwander, *l.c.*

[3] Irving Gray: Diverticulum of the stomach. Am. J. of Röntg., August, 1925.

[4] Åke Åkerlund: Diverticula of the stomach. Acta Rad., Vol. II, 6, No. 10, 1923 (with complete list of the literature).

operation showed. (In the negative the ulcer was quite hidden—as usually happens in prepyloric ulceration.) I then found a similar though not so marked condition (Fig. 260, C) in a female patient with diseased intestine, but whose stomach appeared normal. All three photographs which are figured here were secured in the standing position. The place where the step is to be seen corresponds to the level of the entrance of the subdiaphragmatic part of the œsophagus into the stomach. The point of entrance, according to the anatomists' findings, is situated further forwards, and therefore it ought not to fall exactly in the tangential rays, but is overshadowed and concealed by the contrast-filled cardiac end of the stomach. Who looks through his series of films for this step shadow will scarcely find it once in a hundred pictures, and even then only slightly indicated. I have gone through a number of Röntgen atlases of the stomach and international works, including those of Carman, Forssell, George and Gerber, George and

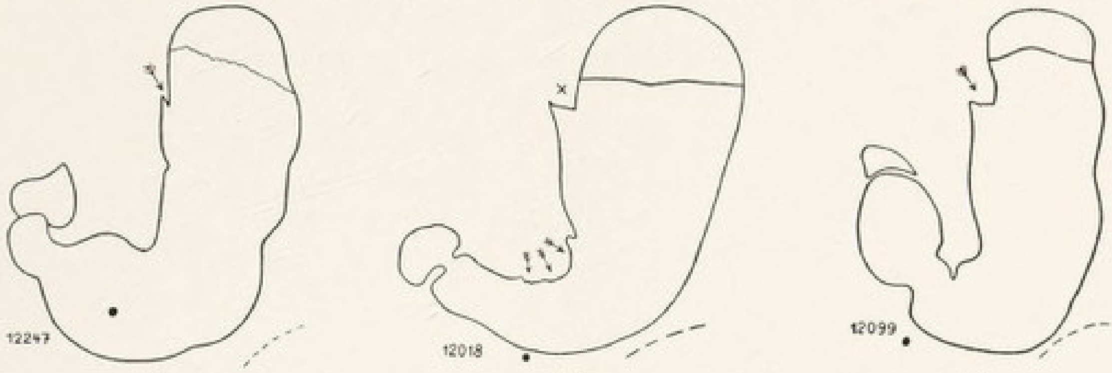


Fig. 260.

Leonard, Groedel, Kerley and Le Wald, Rieder, Schlesinger, Schwarz ; but the step-shadow occurs out of many hundreds of pictures only four times well marked and four times indicated. It is, therefore, extremely rare. And in the few cases in which it is well marked, the photographs were taken in the prone position. (In the stomachs of children not a single picture like it has been seen.) Does the sign possess no importance ? That is hardly to be assumed. The fact is there and there must be a reason for it. The fact that it is seen most often in the prone position gives probably the desired explanation. In the prone position and a full stomach the latter undergoes a slight rotation, so that the part of the small curvature into which the œsophagus enters moves into the middle frontal plane of the stomach, and thus is brought into the tangential rays in the photographic exposure. And when the phenomenon appears in pathological cases in photographs in the standing position, it is probably due to some mechanical action ; in the pulling or pressure in tumours, the scars of ulcer, adhesions, etc., the stomach gets slightly rotated. When, therefore, no other symptom of tumour, ulcer, or adhesion is present, the step shadow might, perhaps, yield us an important indication of the presence of such lesions. (As an opposite instance to step shadow, see Fig. 257, left.) Schinz describes a retrograde filling of the œsophagus with an open cardia.

Middle Third

A small shadow projecting from out the stomach shadow is fairly certainly ascribable to *a callous ulcer*. It is situated usually on the lesser

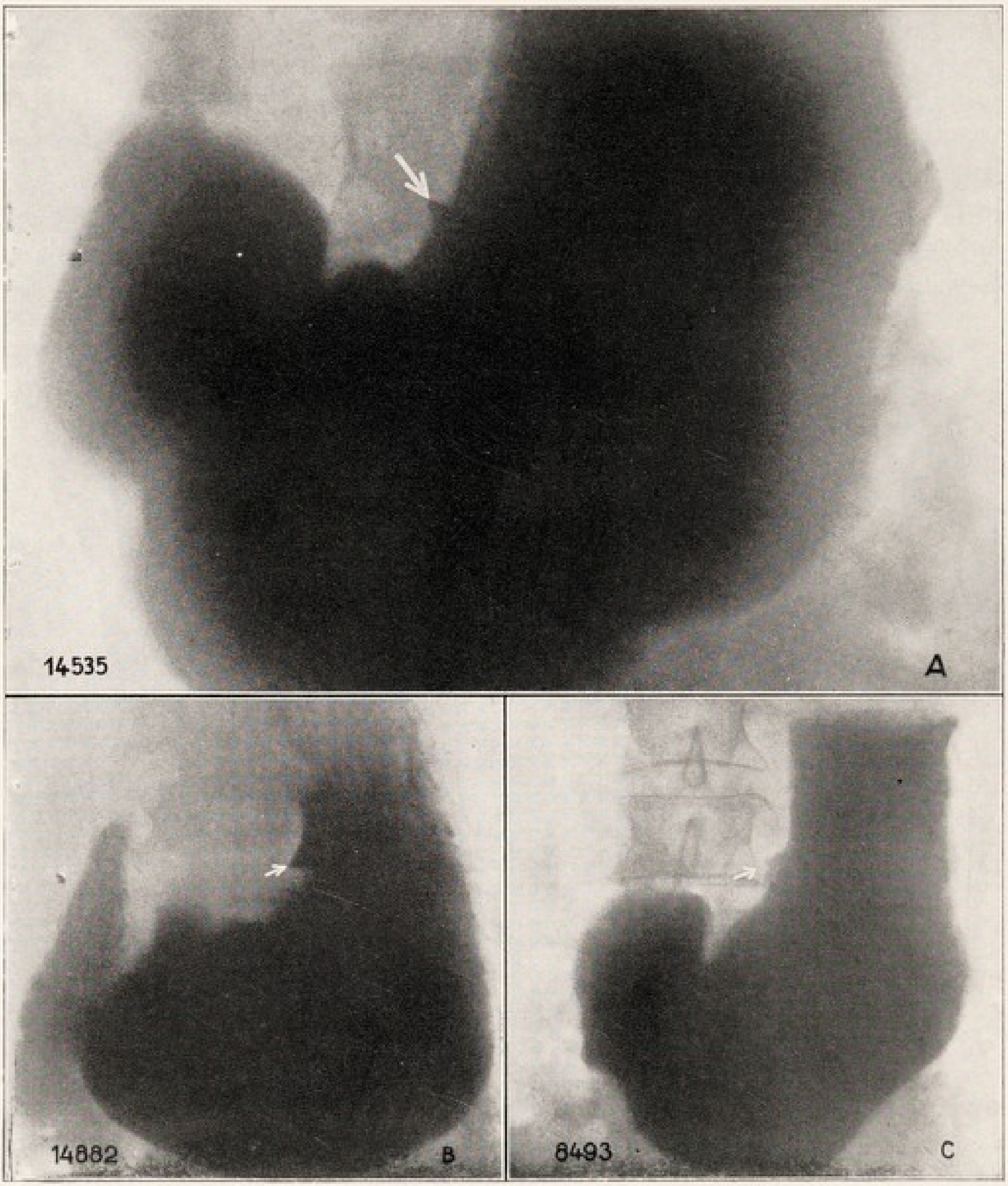


FIG. 261.

curvature, more rarely on the greater curvature. (Regarding its presence on the anterior or posterior wall of the stomach, see the next paragraph.)

In observing the first mouthfuls of contrast-meal while on their way to the pylorus a shadow the size of a hazel-nut may be seen to remain hanging about the middle of the stomach ; this appearance makes one suspicious of *callous or penetrating ulcer on the posterior wall* (or anterior wall) of the stomach. Upon further filling of the stomach it is naturally covered by the total shadow. It would be altogether hidden from view, if one did not examine the stomach during the first mouthfuls of meal or contrast-fluid. (When the shadow in question shows the fluid barium and a small bubble of gas above it, the diagnosis becomes certain.)

Fig. 261, A, a case with a six-hour remainder, shows clearly a callous ulcer of very small dimensions, disappearing on turning one or two degrees; B, of the same illustration, a large thorn-like ulcer; C, a small callous ulcer;

FIG. 262.

pains for ten weeks; report two years later that he was feeling quite all right. Refer also below to the section "Peristalsis" illustrating a case of ulcer niche.

It happens more rarely that a defect in the contrast shadow is visible instead of a niche. Such a case of ulcer is shown in Fig. 262 (operation by Heile). Where the clinical findings are doubtful and a defect like this is present, one has to reckon with the possibility of a carcinoma. In all these four cases just described one should not overlook the other classical signs of gastric ulcer: Hypotonia, Gastroptosis, Dilatation, and Moderate peristalsis.

W. J. Mayo found among 639 cases of gastric ulcer 85 cases, in which the ulcer was situated on the posterior wall of the stomach far from the curvatures, and of these 75 per cent. were in the middle third of the stomach and 16 per cent. in the cranial third. Those ulcers and tumours placed on the posterior wall and high up on the stomach can be rendered visible by deep palpation, by observing the rugæ by means of careful screening.

Normally the rugæ run in parallel lines, but in tumours and ulcers they are obliterated at the diseased spot.[1]

The shadow of a niche on the descending part of the lesser curvature cannot easily be missed or misinterpreted. Occasionally cases do occur, where in spite of a typical shadow of a niche with a gas-bubble no ulcer or the like was found in the stomach ; a calcified part of a pancreatic tumour was then taken to be the cause of the niche shadow, the bubble of gas being considered due to a coil of small bowel having come into the path of the rays. Another opinion was held of these cases, however (a further similar case having been noted), that they were probably due to diverticula at the duodeno-jejunal flexure, where diverticula are not uncommon (see " Duodenum ").[2]

Penetrating ulcer on the greater curvature—an extremely rare occurrence—is usually met with roughly at the same level as on the lesser curvature. It can be overlooked very easily, especially at the beginning, on account of the contour at the descending edge of the greater curvature being already so rich in details through peristalsis, rippling, and intersection on the side of the jejunum. It appears more plainly, when the part of the stomach at whose level it is, is already empty of contrast-meal, or when one allows only a small portion of the contrast-meal or fluid to enter upon an empty stomach.[3]

Small bosses on the lesser curvature are usually due to *adhesions* from a healed ulcer, or sometimes even to a fresh ulcer.

Fairly large contrast-meal shadows situate far outside the stomach shadow with three-fold stratification, a gas-bubble, and delayed emptying, is indicative of *a penetrating ulcer.* Yet continuity of the shadows of the contrast-meal with that of the stomach and absence of a gas-bubble does not necessarily permit us to assume the presence of a non-penetrating ulcer.

A defect in motility on the lesser curvature about 1 cm. long (not easy to see on the screen, but distinctly visible after cinematographic exposures), indicates a commencing ulcer at the " ulcer-bar." The bar is not an immediate expression of the ulcer itself—that is, it is not the expression of the anatomical substratum, but it is the sign of a segmental limited functional alteration of the transverse musculature of the stomach, evoked by the irritation of the ulcer. Above the bar it is usual to find a relative hyperperistalsis, which simplifies the diagnosis. In contradistinction to the niche the bar is not pathognomonic of ulcer, it can be produced by a carcinoma, provided

[1] R. D. Carman : Technical aids in the röntgenologic demonstration of lesions high in the stomach and on the posterior wall. Radiology, January, 1925.—Eisler and Lenk : D. M. W., 1921.—Forssell : Am. J. of Röntg., October, 1923.—A. E. Barclay : Acta Rad., 1926.—H. Maclean, I. Jones, and G. Fildes : The cure of gastric and duodenal ulcers. Lancet, January 7, 1928.

[2] Altschul : Nischenschatten ohne Vorhandensein eines Ulcus. Fortschritte, Bd. 29, 1922.—M. Zehbe : Nischenschatten ohne Vorhandensein eines Ulcus. Fortschritte, Bd. 29, 1922.

[3] Ch. G. Sutherland : Niches of the greater curvature. Reports of 2 cases. Radiology, September, 1925.—E. S. Blaine : Simple penetrating ulcer of the greater curvature of the stomach. Am. J. of Röntg., July, 1925.

the latter is quite small and is bounded on the inner side by a smooth (not broken) surface. A sickle-like indentation of the lesser curvature, " lesser curvature sickle " (shortening of the lesser curvature by contraction, the consequence of carcinomatous infiltration), is also a sign of a carcinoma, one that is probably not resectable on account of its size.[1]

That a carcinoma in its earliest stages must be accompanied by a visible rigidity of the wall of the stomach is in a way natural. It is to-day almost unbelievable that almost a decade has elapsed since Rieder's observation before this fact was utilised in Röntgen practice. The author does not know who first called attention to the method in the Röntgen literature, but might refer to the case he described in 1911 in a brochure, " The Röntgen Method in Surgery " (Berlin, Publishers, Meusser) : " A stomach wall in which a commencing tumour has altered the conditions of elasticity at the place where it is situated must be changed, for the tumour stiffens the gastric wall and is bound to bring about a retardation in the peristaltic movement ; it should be visible on the screen, provided that it does not lie exactly in the middle of the posterior wall. I do not suggest that this would be seen often in practice, for it is just in this stage of the tumour that the patient has scarcely any symptoms and has not yet consulted his doctor. But according to the present state of röntgenological science, the condition that we have described is what we have to expect. The bismuth shadow in these cases shows no defect in filling."

The angle formed on the lesser curvature by the ascending and descending part of the stomach measures somewhat less than a right angle in the majority of cases, but it varies normally within wide limits between an elevated stomach with pylorus drawn to the right and a dropped stomach with pylorus displaced to the left. It is therefore risky to deduce pathological conditions from the size of this angle. Occasionally, however, one should be in a position to infer the presence of a process (usually a tumour) from a flattening of that angle.[2] Here the flattening of the angle may be considered as it were the equivalent of a defect in filling. Conversely, one finds a deepening of the angle in the involution of the lesser curvature in ulcus ventriculi.

Indentations at the greater curvature, which are larger than the ordinary peristaltic waves, can be of a physiological or pathological nature. On the lateral contour of the body, at the juncture of the upper and middle thirds, there is frequently perceived a fairly large impression of the wall of about 5–15 cm. That is physiological, if laterally to it there occur considerable collections of gas. The latter gather in the splenic flexure or in the uppermost part of the descending colon. Also extraventricular tumours can press in upon the stomach at this point. The inexpert observer, who is not usually thinking of externally placed causes, is easily led to diagnose such

[1] Arthur Fränkel : Die Eigenbewegungen des Magens im Röntgenbilde. 16. Congress d. D. Röntgen-Ges. Nauheim, 1925.

[2] Levy-Dorn and Ziegler : Zur Kritik der krankhaften Veränderungen des röntgenologischen Magenbildes auf Grund autoptischer Befunde. Collection of clinical addresses. Leipzig, 1914 (Ambr. Barth).

cases as organic hour-glass stomachs, while he has to deal only with a pseudo-hour-glass stomach. At the spot described, however, or somewhat below it, there appear also the indrawings of the true hour-glass stomach. The first of these is the spastic (Fig. 263, A), which is a sign that at the point of the lesser curvature opposite to the indrawing (the curvature itself not being contracted) a fresh ulcer is present: it need not be visible itself. This spastic narrowing resembles most a deep wave, it is sometimes called a "standing wave" because it does not move forwards. It is typical of the spastic hour-glass stomach that the pyloric end fills relatively fast and the fundus empties rapidly, with changes in the width of the stenosed part. Atropin stops the spasm. Whether spastic hour-glass stomach arises from a purely nervous basis is not yet decided. It appears most frequently following upon a fresh ulcer, *i.e.* one that has not yet contracted. "The narrowing points like a finger to the seat of the ulcer" (Kaestle). A spastic hour-glass stomach can disappear on the healing of the ulcer.

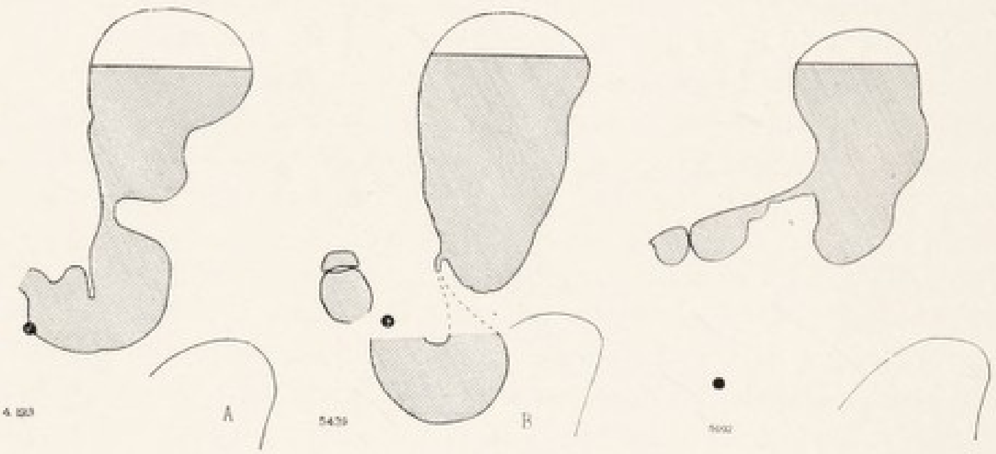


Fig. 263.

Less regularly rounded or formed is the indrawing in *fibrosed hour-glass stomach* (Fig. 263, B); it is typical of the latter for a small spur to be present on the lesser curvature. The narrowing generally tails off to a point which is always situate on the lesser curvature.

The hour-glass stomach following *a malignant tumour* is quite irregular in its contours, especially towards the great curvature. In contradistinction to fibrotic hour-glass stomach due to ulcer, the narrowing in the hour-glass stomach of tumour extends to a larger section of the stomach, not to a "point." Moreover, in tumour in consequence of the excessive breaking down of the neoplasm the stenoses are never so narrow, as in the scar of ulcer. One type of hour-glass stomach is illustrated in Fig. 263, C (see also Fig. 266, E). In all three cases (A, B, C) the findings were confirmed by operation.[1]

The "bridge" of the hour-glass stomach is usually situate even in

[1] In case A the doctor in charge and the surgeon-specialist believed a tumour to be present, until the operation showed an anatomical abnormal stomach; but a commencing ulcer might still have been present.—P. Eisen: Segmentation in the Diagnosis of Stomach Lesions. Amer. Journ. of Röntgenology, July, 1916.

carcinoma of the body at the lesser curvature, in spastic hour-glass stomach it is always there.

The functional hour-glass stomach occurs more frequently than the organic.

Well-marked forms of hour-glass seen in Röntgen view are not always found in operation or in section when the stomach is devoid of tone.

A narrowing of the Röntgen shadow the breadth of one's hand often corresponds only to a slight scar indentation of the stomach wall or the light pressure of a perigastric band no thicker than a thread.[1]

In an insufflated stomach *a spastic hour-glass stomach* is clearly seen when an ulcer is present ; the spastic contraction can be elicited in many such cases, in which the action of the contrast-meal is too slight to produce visible results.[2]

Tenderness of the small curvature, corresponding to the hour-glass contracture of the greater curvature is always indicative of organic disease of the stomach.

If the hour-glass form occurs only at intervals and completely disappears on the stomach being filled, reappearing on emptying of the viscus, it is probable that *perigastric pathological conditions* are present.

The two segments can be placed behind each other (in the path of the rays). They will then naturally cause figures difficult of interpretation in ventral picture, but profile photography usually clears up the diagnosis.

In hour-glass stomach due to scarring the upper part of the stomach usually shows no peristalsis, as in Fig. 263, B, in contrast to A.

The principal characteristic of the spastic hour-glass stomach is its inconstancy. Sometimes the contracture can be induced to disappear by a deep breath or a strong indrawing of the abdomen.

Many operators have reported that a spastic hour-glass stomach arises simultaneously *in duodenal ulcer* [3] and in diseases of the *gall-bladder and bile passages ;* [4] hence that it can be regarded almost as a symptom of duodenal ulcer.[5] Further cases do occur in which with a spastic hour-glass stomach there was undoubtedly a duodenal ulcer, but at the same time a gastric ulcer also present opposite the contraction.[6] Such indications of hour-glass stomach, "hypertonic hour-glass forms," may be observed also in appendicitis, tabes, lead and nicotin poisonings, usually associated with a general elevation and diagonal extension or right displacement of the stomach. In the course of a single examination the condition may again disappear.[7]

[1] Groedel, *l.c.*

[2] Koll: Über die Röntgendiagnose von Geschwür und Neubildung am luftgeblähten Magen. Fortschritte, Bd. 24, 1916.

[3] Baron and Bársony: Über die Röntgendiagnostik des Ulcus duodeni und anderer duodenaler Affectionen. Wiener klin. Wochenschrift, 1912, No. 42.

[4] Groedel, *l.c.*

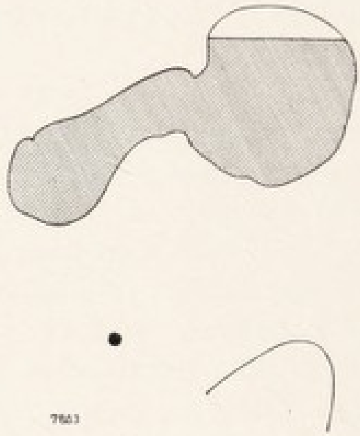
[5] See also pp. 415–16 and L. G. Cole: Am. Journ. of Sciences, July, 1914.

[6] See also the explanation of Holitscher: Röntgenbefund bei Ulcus ventriculi et duodeni desselben Falles mit Sanduhrmagen. 10. Deutscher Röntgenkongress, 1914.

[7] Groedel, *l.c.*

Röntgenologists, who carry out many examinations of the stomach and photographs in the horizontal position, very often encounter hour-glass-like shadows and regard them as purely physiological. Probably the pancreas plays a definite rôle in producing such forms.

A typical hour-glass stomach can arise by a contracting process (ulcer of the smaller curvature with retraction, perigastritis with adhesions, or adhesive bands) traversing the posterior wall of the cardiac end in the direction of the roof of the stomach so that a cup is formed above and behind with a gastric tube hanging from it. Upon a meal being taken the cup fills first, which looks very similar to a diverticulum of the œsophagus ; upon further filling the contrast-meal passes forwards into the dependent gastric tube, so that the picture of a cascade is produced : *cascade stomach* (see also Fig. 264, A).



A Fig. 264. B

The recognition of this condition while sometimes impossible in antero-posterior examination, is easy upon profile examination.[1] During breathing one sees as a rule how the upper part of the stomach is more movable than the lower part (Author). There are also said to be *cascade stomachs which are of purely spastic nature.*[2] The spasm can be either intermittent or persistent. They are believed to be a reflex from a primary intra-abdominal disease, arising most frequently from a duodenal ulcer or as one of the signs of a neurosis. When due to spasm or ærocholy they are inconstant in form and usually respond to belladonna or atropin.

A peculiar form of hour-glass stomach is produced, when a stomach normal in other respects rides upon an adhesion band, as was the case in Fig. 264, B. The typical feature of this particular case (always ?) is that the corresponding point of the lesser curvature is also elevated and arched up. (The Röntgen picture was explained at operation.) It seems,

[1] Zehbe : Über Kaskaden-Magen. Fortschritte, Bd. 24, 1917.—J. Schütze : Über Kaskadenmagen. Deutsche M. Wschr., 1920, No. 24.

[2] Emmo Schlesinger : Über den spastischen Kaskadenmagen. Fortschritte, Bd. 27, 1920.—R. Feissly and A. Fried : Zur Ätiologie des Kaskadenmagens. Fortschritte, Bd. 29, 1922.

however, that in a number of cases [1] this form appears to arise from the pressure of a meteoritic intestine ; either because the colon is abnormally large or long or elevated by anatomical causes, or because stenosis of the bone has led to dilatation and subsequent meteorism and brought about an elevation of the bowel. And certainly not only the great intestine but also the small intestine produces such conditions. It is desirable to call this form the "riding stomach." [2]

The typical picture of *the corset-stomach* is illustrated in Fig. 265, A. It is quite understandable that the external contour of the body, the so-called waist-line of the body, runs fairly parallel to the narrowing of the stomach. Quite a similar form of stomach can be produced without the pressure of lacing, if the coils of the splenic flexure of the colon are ballooned with gas and encroach upon the stomach, as shown in Fig. 265, B.

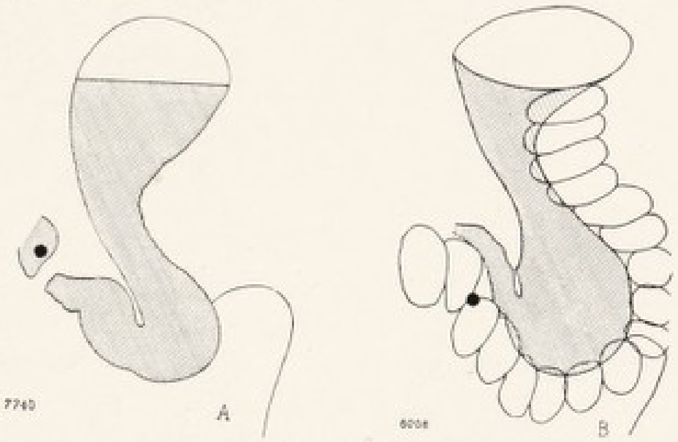


FIG. 265.

Ptosis of the sac of the stomach is only a consequence of a space-anomaly of the abdomen or of a position-anomaly of the stomach, it is therefore a secondary manifestation devoid of importance ; but an extension of the gastric sac, the consequence of increased pressure from within causing an alteration in form of the stomach wall (dilatation symptom), is pathological.[3]

Numerous small indentations and ridges, not deeper and higher than 1 cm., along the greater curvature, more rarely along the lesser, are typical of chronic gastritis. At the same time the stomach is somewhat irregular and laboured in its peristalsis. One meets these irregular peristaltic waves most frequently at the lower two-thirds of the greater curvature, also in the pyloric region and at the base of the duodenal cap. This irregularity in contour is said to occur only in exposures made in the prone position and be absent completely in views obtained in the erect position (?).[4] In representing the röntgenologic mucous membrane with the method of small contrast-meals one has a surer way of proving a chronic gastritis ; while one can recognise in the normal stomach between its folds a quite uniformly homogeneous shadow-picture, the thin fluid meal appears in the view of the mucous membrane in gastritis hypertrophicans to be full of holes. These are of unequal size and form, are usually round and oval

[1] V. Révész : Der reitende Magen. Fortschritte, Bd. 29, 1922.
[2] G. Schwarz, the author, Révész.
[3] Groedel, *l.c.*
[4] A. Bassler : Additional Röntgen-ray signs of chronic gastritis. Am. J. of Röntg April, 1926.

translucencies, and are the expressions of elevations of the mucous membrane, which one usually finds upon screening in gastritis hypertrophicans.[1]

Pyloric Third

Deep waves of the greater curvature resembling indentations but of quite irregular form and gross interruptions of continuity are usually due to *tumour defects* (Fig. 266). When these defects have reached a certain size,

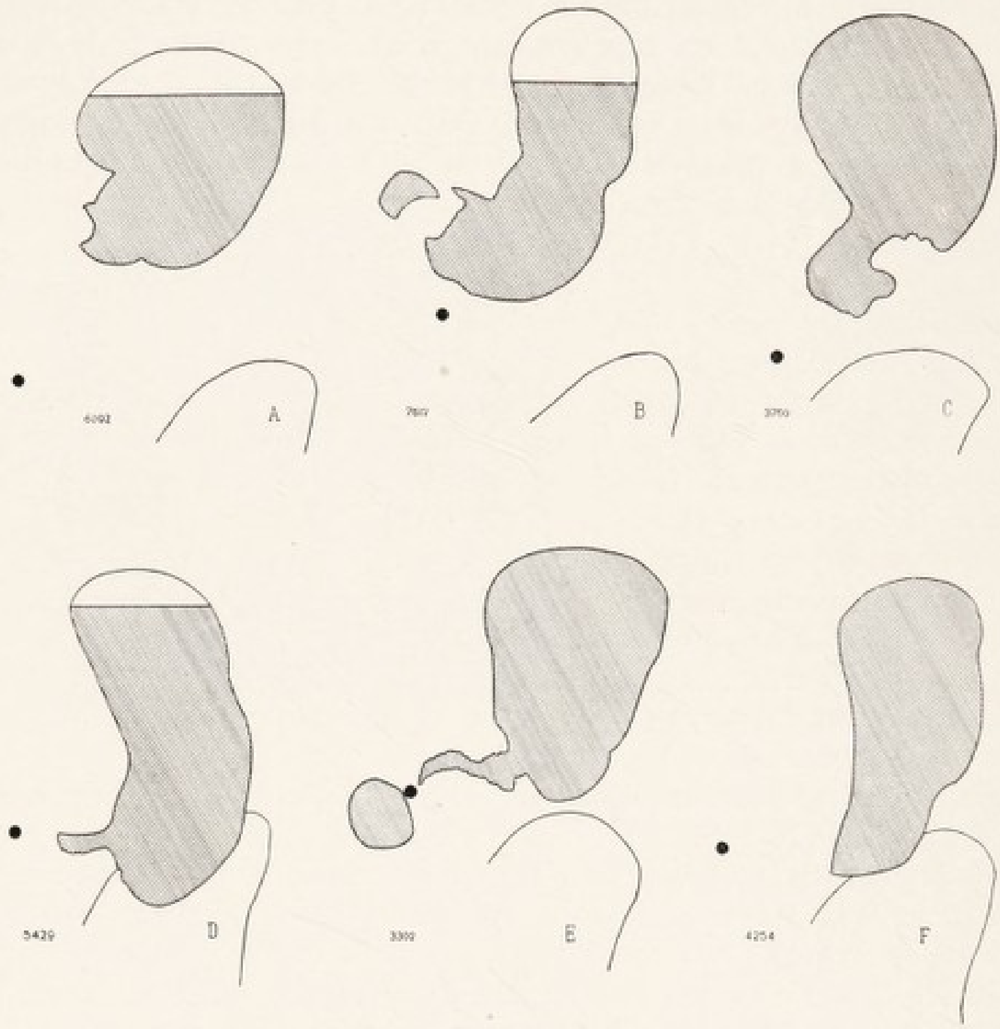


Fig. 266.

as here shown, the diagnosis is not as a rule difficult, especially if the tumour is already palpable. Further, these grosser changes hardly come into the scope of this work, which might include only the very earliest stages of such defects of the stomach shadow. But unfortunately it is just in such cases that there are too few pictures, however desirable they are. Therefore, these pictures which show an advanced stage of alteration may enable us to understand how the first beginnings in these tumours are manifested. (Fig. 266. A. Tumour of the pylorus region ; laparotomy ; inoperable. B. Tumour of the pylorus region ; exitus after three months. C. Tumour

[1] K. Gutzeit : D. Arch. f. klin. Med., Bd. 153, 5/6, 1926 ; and 38. Kongr. d. D. Ges. f. innere Med., Wiesbaden, 1926, and Med. Klinik., 1927, No. 14.—H. H. Berg : Acta Rad., Vol. VI, 29–34.

of the pylorus region: laparotomy; inoperable. D. Tumour of the pylorus region the size of a plum; exitus after five weeks. E. Tumour of the pars media of the stomach. Hour-glass form of the stomach. Exitus ten weeks later. F. Tumour of the pylorus region. Exitus after four months.) Naturally tumours in their earliest stages show a minimum of direct symptoms, which are scarcely to be recognised on the screen; therefore one adheres almost exclusively to direct symptoms; if the history, the clinical symptoms, and the indirect Röntgen evidence (delayed period of emptying, remains of the meal after six hours, etc.), all agree, then any one with sufficient experience can diagnose a tumour with a measure of certainty.[1] Doubtless if the tumour delayed the period of emptying, it was already inoperable. There is no doubt that with betterment in technique—a beginning is already made—even the smallest tumours can be recognised in a number of cases, not perhaps on screening (even with honeycomb diaphragm), but by the taking of plates. With first-rate technique the smallest filling-defects at or immediately in front of the pylorus can be recognised.[2] These defects have usually a ring-shaped structure, which differentiates them from the ordinary chronic ulcer. The reason for the origin of such ring-shaped defects is not quite clear. It is quite possible that the spread of cancer cells in the deeper layers of the stomach wall influences its contractility so that the defect is apparently enlarged and produces the ring-shaped appearance. The defect must be seen on several plates, and if possible twenty-four hours afterwards, and also in profile. Also other authors maintain that small changes in the Röntgen shadow must show the same image upon many plates, unless one is to be deceived by an accidental finding.[3]

In the customary stomach form and rounded, "stamped-out," island-like filling defects, benign tumours, polyposis, were found at operation. On account of the anæmia, loss of weight and anacidity, a tentative diagnosis was made of carcinoma.[4] In another case numerous transparent areas were found, most clearly marked in the pyloric region, which in its entirety bore a resemblance to a honeycomb.[5]

In spite of all the specially directed anatomical and röntgenological examinations it was disputed for a long time whether one can speak of *an antrum* of the stomach, and whether such an antrum was separated by a special sphincter from the remainder of the stomach. We see, indeed, on the screen that the contraction ring gradually moves towards the pylorus until

[1] For a good summary see Crane: Röntgenology of gastric cancer. Internat. Abstract of Surgery, June, 1915.—J. T. Case: The value of the Röntgen-Ray Examination in the Diagnosis of gastric cancer. Internat. Clinics, Vol. I, Series 25, 1915.—J. T. Case: The Röntgen-Investigation of Carcinoma of the alimentary Tract. Interstate Medical Journal, July, 1915.

[2] A. W. George and I. Gerber: The early diagnosis of gastric carcinoma. Canadian Med. Assoc. Journ., March, 1915.

[3] Campo and Campo de Cos, *l.c.*

[4] D. Galdau and A. Pop: Über gutartige Magentumoren. Fortschritte, Bd. 35, 1926.

[5] R. Sielmann and R. Schindler: Beitrag zur Röntgendiagnose u. Klinik der Polyposis ventriculi diffusa. Fortschritte, Bd. 33, 1925.

it merges into it, while a new contraction is in progress from the middle of the stomach. Therefore one cannot well describe the sphincter antri as a strictly localised phenomenon, and therefore one of the authorities proposed the term "canalis egestorius." If in spite of this we sometimes employ the term "antrum" in the following pages, we do it more for practical reasons on account of brevity and because the more recent anatomical investigations would seem to indicate the presence of a sphincter antri.

Benign tumours of the stomach are very rare: want of filling similar to defects in the stomach wall have been described in such cases.[1] In the midst of the contrast-meal shadow of the antrum a filling defect was seen, with smooth edges and as if stamped out, "a hole as large as a florin," therefore not irregular and notched as in carcinoma.

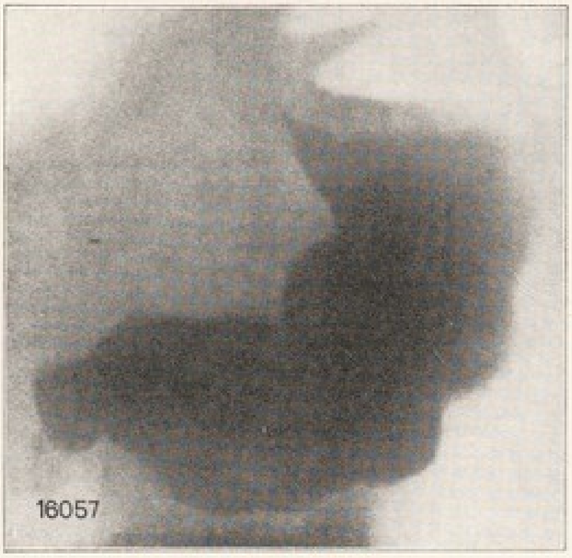


Fig. 267.

When the stomach shadow at the pyloric third suddenly stops with an indefinite and almost vertical border, then that is a fairly sure sign of a *tumour of the pyloric region*. On the other hand, when the shadow stops in front of the pylorus with an equally indefinite and horizontal border, the appearance is usually of a harmless nature: most frequently the contrast-meal has fallen or the stomach was not quite empty before the contrast-meal, or there is hypersecretion present. For making certain of the diagnosis, the upper part of the antrum should be filled in by the hand or distinctor, or a photograph be taken either in the prone or right lateral position.

A long, *horizontal, but sharp, straight contour* to the left of the pylorus, without peristalsis, is often found in carcinoma. The straight, horizontal line is doubtless due not only to rigidity of the stomach wall through the tumour, but also to adhesions dragging on neighbouring tissues. We have described several of such cases and illustrate an instance of it in Fig. 267. Operation (by Heile): A tumour the size of the hand at the lesser curvature to near the pylorus, crateriform, firmly adherent to the vertebral column, extending to the vessels and the pancreas, hard, with all the signs of carcinoma. Radical removal impossible. Gastroenterostomy.

In the child the antrum appears as a supple-like or balloon-like structure; in the adult it is generally balloon-like. (For the child's stomach, see pp. 417 *et seq.*)

In some examinations of the antrum and of the region of the pylorus,

[1] Lossen: Zur Röntgendiagnostik gutartiger Magengeschwülste. Fortschritte, Bd. 30, I. Kongressheft, 1922.

especially when there are very fine changes present in the contour, the best results are obtained by viewing the patient *in the prone position ;* especially so in these instances where, as in very marked cases of pyloric stenosis with dilatation, the antrum in the standing position does not fill upwards or the contrast-powder in the meal sediments too quickly, or where an intermediary layer is rapidly formed.

Owing to increased contraction of the antrum *pseudo-tumours of the pylorus* may occur in cases of gastric neurosis. Normal motility is then present, while the stomach picture is normal or even hypertonic.[1]

The normal closed pylorus is shown in the Röntgen picture as a narrow translucent cleft, if the first part of the duodenum is well filled. The cleft is formed like the section of a concavo-convex lens with two different radii, in which the stomach one is the larger (see Fig. 268, and pp. 448 and 450). For spasm of the pyloric sphincter, see the end of the section. The pylorus does not open regularly before each approaching wave.

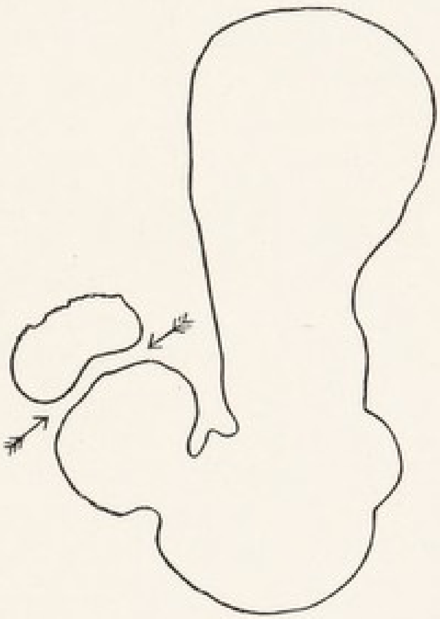


Fig. 268.

In the first stage of digestion the contraction of the *pyloric sphincter* is so strong that its lumen seldom exceeds 3 mm. in cross-section. In the further course of digestion the sphincter dilates to about 6–7 mm.[2] The lumen is usually ring-shaped or oval, the longer axis being from before backwards ; according to the anatomists (Luschka) it is sometimes semicircular, according to others (Jonnesco) in about 4 per cent. of the cases ; it can also be oval with the ends narrowing to a point. In the semicircular valve shape it is naturally eccentrically placed. According to other anatomists (Merkel), however, an eccentric position of the pyloric lumen can only arise by differences in the state of contraction of the pyloric musculature.[3]

The pylorus is situated normally above the umbilicus, sometimes in the mid-line of the body, sometimes more to the right of it at the level of the first to the third lumbar vertebra. Its motility usually amounts to 8–10 cm. The same pylorus can be at the level of the twelfth dorsal vertebra at the end of expiration in the horizontal position, and be at the level of the third lumbar vertebra at the end of inspiration in the standing position.

The pylorus is found above and to the left in contracted carcinomatous stomachs and in contraction of the lesser curvature ; it is found above and to the right of the normal in hepatofixation (Fig. 251), in carcinoma of the

[1] Groedel, *l.c.*

[2] L. G. Cole: Physiology of the pylorus, pilleus ventriculi and duodenum as observed röntgenographically. Journal of American Med. Assoc., September, 1913.

[3] According to Åkerlund : see later in " Duodenum."

pylorus (Fig. 266, B), but such a condition is not pathological in men of strong broad stature; it is also present in perigastric and pericholecystitic processes and in duodenal ulcer. It is displaced downwards and to the left in constricted stomach (Fig. 265, A), in atonic dilatation, and in long thin women with relaxed abdominal muscles.

Upon indrawing the abdomen the pylorus moves as a rule 1–2 cm. to the right. But in all cases in which this movement in the horizontal direction and with indrawn abdomen is unusually great, about 3–4 cm. or over, we ought to consider adhesions as being fairly certain.[1] In marked motility of the liver a certain diagnosis upon fixation of the exit of the stomach by adhesions is not possible. Falling of the bulb by more than 1 (up to 11) cm. indicates a freely movable pylorus. A smaller degree of motility than 1 cm. may be regarded as a proof of adhesions at the exit of the stomach. Naturally, however, a reliable diagnosis on the adhesions at the exit of the stomach is only possible when the whole stomach is not retained in its position by adhesions or other processes (fixed colon, tumours, etc.).[2]

Displacements of the pylorus and the first part of the duodenum to the right and upwards in consequence of adhesions occur likewise in ulcer of the duodenum.

If the lumen of the pars pylorica is strongly reduced for some time during the examination in comparison with the dimensions of the rest of the stomach, also somewhat distorted, its contour deeply indented, shrunken, and wrinkled, while at intervals the pylorus appears quite to regain its normal appearance (movements of relaxation), then we have a picture of *spasm of the pars pylorica*. A spasm of the pars pylorica, of the pyloric sphincter, and of the first part of the duodenum (duodenal cap), are often indirect symptoms of lesions of more distant parts of the bowel (especially of ileostasis, dilatation of the ileum, and chronic appendicitis). How these intestinal lesions are related to the stomach is not quite clear.[3]

In a very nervous woman, with clinical signs of duodenal ulcer, the first photograph (Fig. 269, A) showed first an extreme degree of indentation of the duodenal cap, which was otherwise normal in form, and second a still grosser indentation or folding of the terminal part of the stomach, similar to a pomegranate. In the next negative, about three minutes later, this contraction of the mucous membrane had completely disappeared, and the contours of the bulb were quite smooth like the end of the stomach, Fig. 269, B. The appearance is not very frequent, and in this degree is certainly not normal. It is doubtless a compensatory excess of activity of the mucous membrane, for in case C of the same illustration there occurred much delay at the commencement of motility and there was a strong suspicion of ulcer near the pylorus; and even in D, where the appearance is the most pronounced, we see at the duodenal cap the typical picture of an ulcer with adhesions.

[1] Levy-Dorn and Zieger, *l.c.*

[2] F. Gassmann: Zur Feststellung von Verwachsungen am Magenausgang. Fortschritte, Bd. 30, 1. Kongressheft, 1922.

[3] L. G. Cole: Relation of lesions of the small intestine to disorders of the stomach and cap as observed röntgenologically. Americ. Journ. of the Medical Sciences, July, 1914.

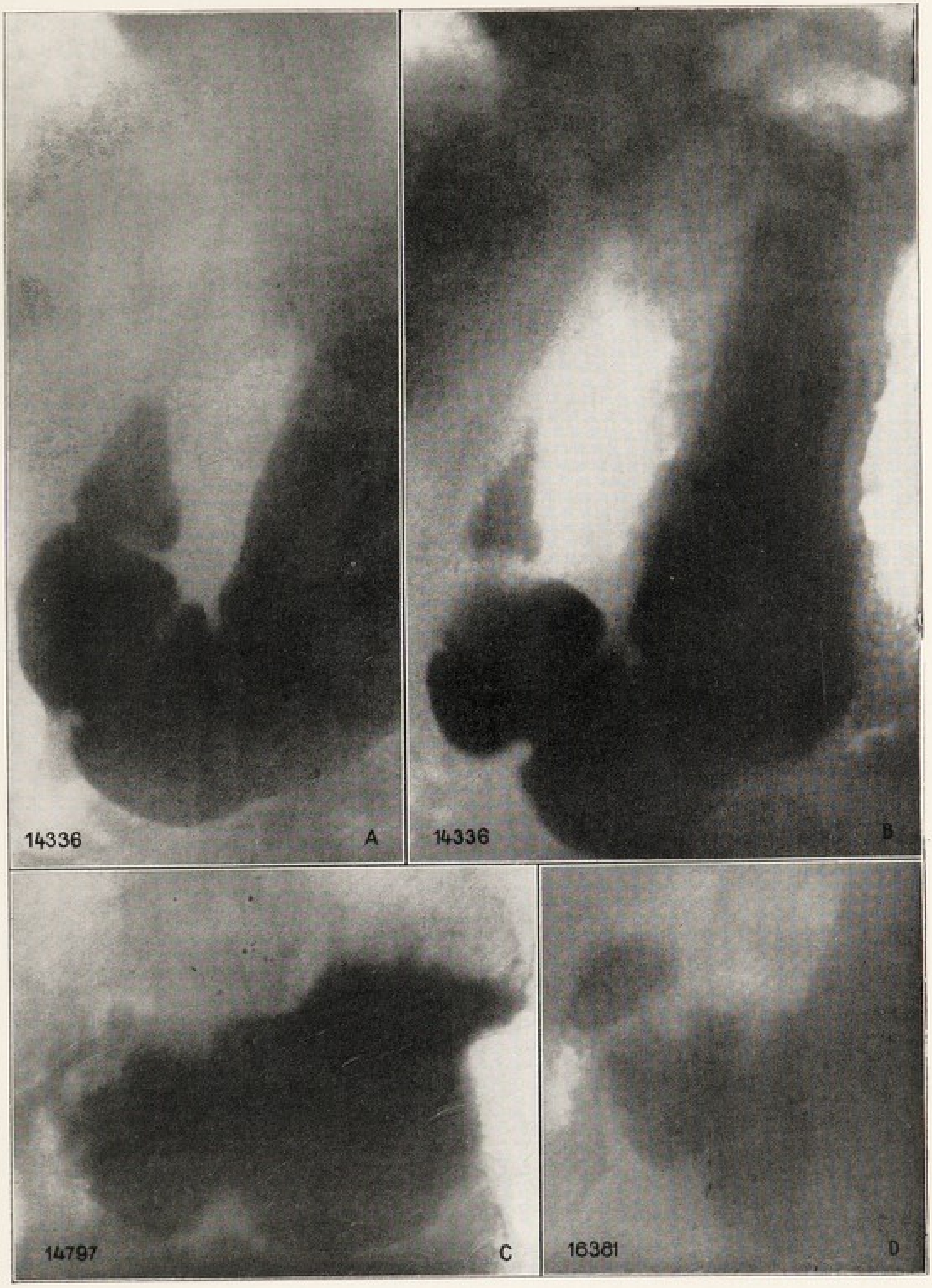


FIG. 269.

If no pyloric lumen can be seen for a considerable time, while there was previously a free passage from the pars pylorica into the first part of the duodenum, that indicates *a pylorospasm*. Frequently the pars pylorica of the stomach appears dilated and hyperperistalsis is present (see the previous remarks). The pylorospasm can be reduced by papaverin.[1]

Pyloric insufficiency can be diagnosed when the stomach shadow passes over evenly into the duodenal shadow.

Pyloric insufficiency is present *inter alia* in duodenal ulcer, *pylorospasm* in ulcer of the stomach, even when the latter is not at the pylorus itself. In a florid ulcer of the stomach the pylorospasm and the delay in motility occasioned thereby (six hours remainder) is generally the principal symptom.

Spasm of the pylorus (the stomach being completely full after $\frac{1}{2}$ to $\frac{3}{4}$ hour) is usually due to a nervous cause (duodenal ulcer, ulcus ventriculi, hyperacidity).

One cannot discover from the Röntgen view of the pyloric region whether it is pyloric stenosis or pylorospasm that is present: which it is must be decided from the function.

A spiral involution of the pyloric region, a shortening of the lesser curvature, can be caused by spasm of the longitudinal muscle fibres in consequence of ulcus ventriculi. Often this involution only makes its appearance during the emptying of the stomach.

A spiral involution of the lesser curvature indicates also a contraction of the lesser curvature,[2] which finds expression in an approximation of the pars pylorica to the body of the stomach and in the pylorus being directed upwards and to the left. This symptom will not be applicable when the shrunken small curvature has adhesions also to the liver.

The defect or contrast-free zone between the lumen of the stomach and the filled duodenum is described as the "*carcinoma distance*."

Tonus

The hypotonic and atonic stomach is doubtless pathological, whereas the hypertonic stomach may be taken as on the border between the normal and the diseased.[3]

Hypertony of the stomach is said to contra-indicate callous ulcer or penetrating ulcer of the body of the stomach. In an ulcer of the pars pylorica hypertony is said not to occur.[4]

An increased tonus is found frequently in *subacidity*, a decreased tonus in *hyperacidity*. Usually the tone of the stomach is dependent upon the general condition of the individual.[5]

[1] Holzknecht and Sgalitzer. Münchener Mediz. Wochenschr., 1913, No. 36.

[2] v. Schmieden: Differentialdiagnose zwischen Magengeschwür und Magenkrebs. Berlin, 1911 (Hirschwald).

[3] E. Schlesinger, quoted after Lebon and Colombier.

[4] H. Lorenz: Zur exacten Diagnose des Ulcus duodeni. Fortschritte, Bd. 28, 1921.

[5] Vogeler, *l.c.* in "Peristalsis."

Although atony is not common without ptosis, one should not confuse these ideas. *Atony of the stomach* means simply a diminished peristaltic function. The atonic stomach has often the appearance of a ptotic one, without its being so in the sense of a pyloroptosis. A long extended air-sac is typical of atony, as is also the taille-shaped constriction junction between fundus and body (both somewhat like C, Fig. 252).

A moderate atony is not always of pathological significance in the clinical sense. In this respect it is like hyperchlorhydria, which one can regard as still normal in people who have never felt the slightest trouble in digestion. It is only when the hypotony is accompanied by other subjective and röntgenological symptoms that it should be described as pathological.[1]

If the contrast-meal forms *a large semi-oval shadow* in the stomach (Fig. 252, C), we are faced with a considerable dilatation with atony. The pylorus and antrum conditions can be viewed in such a case—to determine whether a stenotic tumour is present in that area—if one examines the patient in the right lateral position, unless one prefers to pass a tube into the stomach and fill up the stomach completely.

In the profile view, which is always possible, unless the patient is too stout, the normal stomach terminates below in a tongue-like shape; the same occurs in a simple mechanical dilatation; in atonic dilatation and obstructive dilatation, on the other hand, it ends below in the form of a sac.

Marked enlargement of the cardiac third in a stomach otherwise normal in form and position indicates hypertony. The appearance is explained [2] by the fact that the musculature of the area of the fundus of the normal stomach is less developed than the rest of its musculature. The peristalsis is usually increased at the same time. Hypertony is a frequent feature of diseases of the bile-passages, and changes in the duodenum, appendix, or pancreas.

On the other hand, abnormal enlargement of the cardiac part with a general reduction of the rest of the stomach with narrowing of the lower parts of the viscus indicates *gastrospasm*. The shadow picture then resembles a funnel or a short, thick steerhorn. There is no sign of peristalsis present. The contour of the shadow is coarsely or finely notched. Apart from a total gastrospasm there also occurs a partial or regional gastrospasm. In the latter one finds a sharp demarcation from the parts that are not affected, similar to what is found in a circular carcinoma of the pars pylorica, roughly like A, Fig. 266. It has therefore been said: In the morphological picture of a carcinoma and the clinical picture of an ulcer or in symptoms of hyperacidity the probability of a gastrospasm is very great. The differential diagnosis: In carcinoma the picture remains the same from day to day, in gastrospasm it naturally changes. (Gastrospasm was observed in morphia poisoning, hydrochloric acid poisoning, in tabes, tetany, chole-

[1] Campo and Campo de Cos, *l.c.*
[2] Groedel, *l.c.*

lithiasis, nicotin-intoxication, amyloidosis, phlegmon of the stomach, uræmia, and lead-poisoning).[1]

Intermittent spasm appears in ulcer always at the same spot ; when it appears at different places the cause is neurotic.

In duodenal ulcer and in pyloric ulcer *spasms at a distance* are produced in the cardiac and middle thirds of the stomach.

The types of stomach-spasm that can be diagnosed röntgenologically are : total gastrospasm, partial gastrospasm, spastic hour-glass stomach, spastic involution of the lesser curvature, spastic stretching of the stomach with pyloric insufficiency, and spastic cascade stomach.[2]

Gastrospasm of the body of a filled stomach occurs most commonly in neurotic people. In gastrospasm the peristaltic movements are absent.

Increased tonus (in ulcus duodeni, etc.) may be said to retard and render difficult the unfolding of the stomach. The first mouthfuls stay longer in the fundus. But even in mechanical dilatation a slower unfolding of the stomach occurs.

Peristalsis

The *normal movement of a wave* from the cardiac to the pyloric pole of the stomach occupies usually 18–30 seconds ; in accelerated peristalsis, 10–15 seconds. The exact figures of the normal course in one phase of motion were : 22 seconds, 18–22 seconds, 20–28 seconds, 22·5 seconds, 20–30 seconds.

The peristaltic wave travels normally 2·5 cm. a second at the greater curvature

The peristaltic waves attain normally their *maximum depth* 3–4 finger-breadths before the sphincter pylori.

If the contour of the lesser curvature exhibits a longish pointed process (Fig. 270, B), that is a perfectly normal appearance, a phase of the normal peristalsis for the formation of the pars pylorica. There are added some rather exceptional yet really quite normal phases (Fig. 270, A, C, D).[3]

The *depth* and *periodicity* of the waves varies within moderate limits according to the quantity and kind of the meal and the humour of the patient during the examination.

The peristaltic waves in the ventral sagittal picture are regarded as normal when they are about half a centimetre broad, are uniformly deep on the lesser and greater curvatures in the region of the pars pylorica, and move unhindered in their progress towards the pylorus.

[1] Grunmach : Zur Diagn. und Therapie des Gastrospasmus. 10. Röntgen-Kongress, 1914 (and Discussion).—Freud : Gastrospasmus bei Urämie. Fortschritte, Bd. 22, p. 386.—Holzknecht and Luger : Zur Pathologie und Diagnostik des Gastrospasmus. Mitteil.-Grenzgebiete der Medizin und Chirurgie, Bd. 26, 1913.

[2] After Emmo Schlesinger, Fortschritte, Bd. 27, 1920, p. 264.

[3] After Rosenthal, Rieder and Kaestle : Über Röntgenkinematographie. Bioröntgenographie innerer Organe des Menschen. 2. Mitt. Zeitschr. f. Röntgenkunde, Bd. 12, Heft 1.—W. B. Cannon, Boston : The movements of the stomach. Amer. J. of Physiol., vol. I., No. 3, p. 359, 1898.—W. B. Cannon and Murphy : The movements of the stomach and intestines in some surgical conditions. Annals of Surgery, April, 1906.—Walter C. Alvarez : New light on gastric peristalsis. Am. J. of Rontg., 1923, X, 31–35.

If only a single wave runs along the curvatures or along only the lesser curvature, and if this starts just before the pyloric antrum, that has to be reckoned within the limits of the normal (monocyclical type).

If *the peristaltic contractions* exhibit over a definite area broad, flattened forms, that indicates *hypertrophy of the mucosa and submucosa.*

The diagram of the photograph given in Fig. 270A affords a good instance of *peristalsis in stenosis.* Operation showed a purely fibrous stenotic tumour at the pylorus, microscopically not a carcinoma.

A *moderate acceleration of peristalsis* with four or more wave-indentations at one time is not only peculiar to pure neuroses, but also occurs in achylia gastrica, as a duodenal gastric motility, in irritable states of the pylorus, etc. In a still more marked degree of irritability the peristaltic

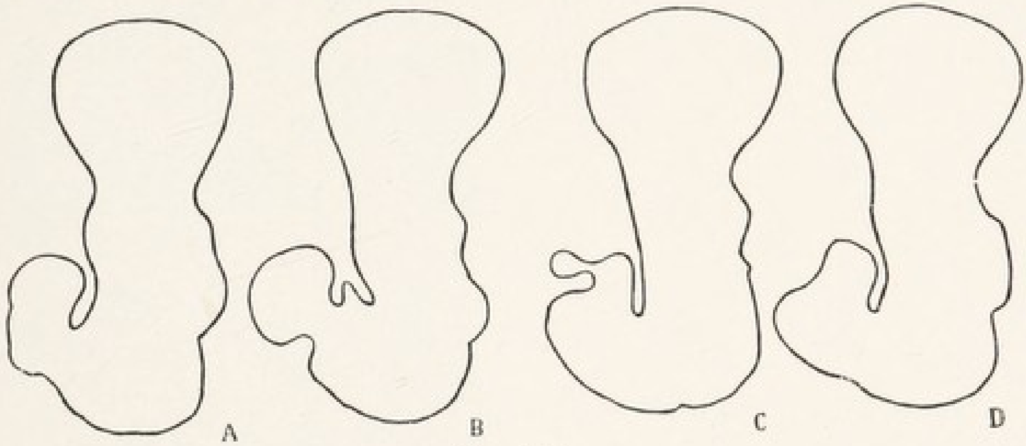


FIG. 270.

waves cut across the pylorus, and one speaks of peristalsis frequens, celer, dissecans. This condition is found in duodenal ulcer (in its hyperkinetic form) and in ulcus ventriculi. These forms of peristalsis, to which there is a certain common symmetry, are contrastable with the pathological forms of peristalsis : the peristalsis asymmetrica obliqua. It is pathognomonic of certain anatomical changes of the stomach, which are readily recognisable from the condition of the distal end of the stomach. It usually represents the first stage of the so-called dilatation of the stomach, seen in the pronounced increase in the volume of the so-called concentric terminal contraction, which sets in at the bend of the stomach and exceeds the normal by a considerable amount in breadth as well as in length.[1]

Different from the peristalsis of stenoses, whose type is illustrated in Fig. 270A, p. 454, is as mentioned the accelerated peristalsis of neurotics. Fig. 270B, p. 454, illustrates such a stomach. The patient had an action of the bowel immediately after each meal, and was in consequence exceedingly thin.

On the cause, nature, and purposes of *the small arhythmic superficial waves*, which appear sometimes in addition to the rhythmic peristaltic waves (see Fig. 271A at the left border of the stomach), one has no certain know-

[1] After W. Bauermeister : Die verschiedenen Formen der Magenperistaltik und -spasmen im Röntgenbild. Fortschritte, Bd. 33, 1925.

ledge. They are seen almost exclusively on the greater curvature situate usually on the major peristaltic waves, apparently because they are here larger than on the lesser curvature. They have not been observed in the antrum. Among the explanations given of these waves are cardiac pulsations, movements of the mucous membrane, chemical stimuli, etc. The condition sometimes simulates the indefinite edges appearing especially in poor negatives, and it should not be taken as a symptom of commencing carcinoma (screening prevents one making that mistake); also the impressions made by the haustra of the filled transverse colon produce similar although much coarser depressions. There has recently been described [1] an indentation similar to these small waves on the left lateral margin of the gastric shadow,

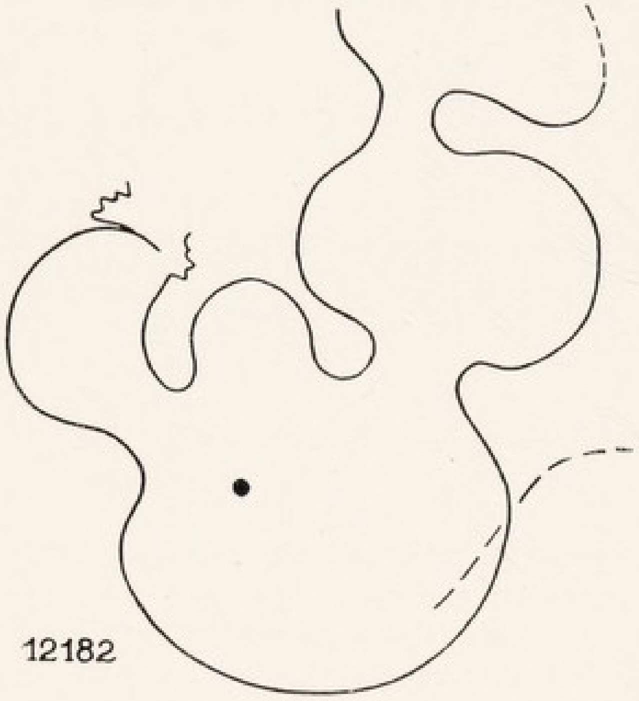


Fig. 270a.

Fig. 270b.

"an appearance ranging in degree, cutting more or less deeply, not quite regular in its sequence, and consisting of numerous small indentations." That is not regarded as minor peristalsis, for it does not progress like waves, but remains constant, or disappears, to reappear suddenly. These might be small spastic or hypertonic indrawings, by which the folds of mucous membrane running in the long axis of the stomach tend partly to occupy a transverse position. (They should not be confused with perigastric adhesions, for the latter are longer pointed and do not change their appearance.) The indentation is regarded as a condition of irritation set up by changes in the stomach itself or in its immediate neighbourhood, usually in the majority of cases by a fresh ulcer in the stomach or its neighbourhood. Such indentations are rarely visible on the lesser curvature. The site of the ulcer can be diagnosed, when on pressing the finger upon a specially painful area the

[1] Schütze: Was bedeutet im Röntgenbild die Zähnelung der grossen Curvatur des Magens? Fortschritte, Bd. 25, 1918.

indentations are definitely increased, in a way "as if a goose-skin contraction had passed over the stomach." Another observer has already given a similar explanation for the condition.[1] We do not say that when an ulcer is present it must have its seat opposite the indentations on the lesser curvature, nevertheless we illustrate such a case in this book, in which this occurred in ideal fashion, Fig. 271B. The callous ulcer here looks exactly as if it represented the centre of the indented folds. The large spastic indrawing of the greater curvature, usually opposite the niche, is here absent.

A third observer objects to that explanation,[2] stating that the indentation is not a symptom of ulcer, and that waves of peristaltic character or standing small waves (multiple little spastic contractions) are the real explanation. He maintains the indentation is neither absolutely pathological, nor even a pathological symptom, because it occurred also in gastro-enterostomy patients, in pericolitic and periduodenal processes,

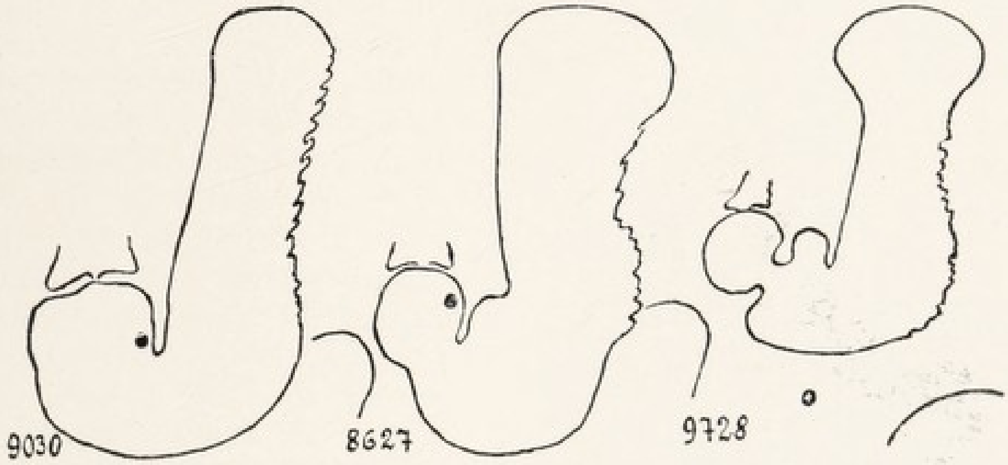


FIG. 271A.

in gastritis, and even in the normal stomach. Probably the phenomenon is due to the small arhythmic waves described in 1912 which might be functionally and mechanically compared with the small movements of the bowel, and have presumably to do with increasing the contact surface between the stomach and the chyme. Whether under certain circumstances the small movements could be stopped by multiple spastic contractions of certain muscle-fibres and then—though only in this sense—exhibit an appearance of disease, would have first to be proved. One should note, however, that the indentation can be seen on the screen only by paying particular attention and using a suitable diaphragm. (In Fig. 271A, No. 8627, the patient was operated on with a negative finding. The patient was then free from trouble for two years, which, however, recurred.) A more recent and thorough investigation [3] arrives at

[1] G. Schwarz: Wiener med. Wochenschrift, 1916, No. 47. (Quoted by Schütze.)

[2] F. M. Groedel: Die Zähnelung der grossen Curvatur des Magens im Röntgenbild, eine functionelle Erscheinung. Fortschritte, Bd. 25, 1918.

[3] F. Stocada: Über die Bedeutung der Zähnelung der grossen Curvatur des Magens. Fortschritte, Bd. 27, 1921.—J. Schütze: Die Zähnelung der grossen Magencurvatur im Röntgenbilde und ihre Kritik. Berl. klin. Wochschr., 1920, No. 39.

the conclusion that the indentations occur in the stomach and duodenum in at least a quarter of the cases, in carcinoma of the stomach only in one case out of nine, and in other disturbances of gastric function in a fifth of the cases. In spite of the relative frequency of the phenomenon of gastric ulcer it cannot be said to be a sign of gastric ulcer in the narrower sense. Contrasted with non-ulcerative, *e.g.* nervous, disturbances of the stomach, the sign is hardly utilisable, for there is no marked difference in the frequency. The conclusion, however, might indeed be drawn that in a doubtful case an evident folding of the gastric wall indicates ulcer rather than carcinoma. At any rate the rippling appears to be a sign of increased tone, which can certainly occur as a functional disturbance without ulcer being present. If one might venture upon an explanation, one might say that in the folding of the gastric wall seen in Röntgen view, whether we are dealing with longitudinal shadows or with omental or transverse folds, in addition to certain individual points not yet exactly known, the function and also the tone of the muscularis mucosæ appear to play a part. The author saw a case in which there was not only a high degree of rippling on the greater curvature, but also a *distinct deep rippling on the lesser curvature* (see Fig. 272). The cause of this rippling could not be explained in this case, for no operative inquiry has yet (in four years) been done. The condition is probably a reflex from cholecystitis. One authority believes that the rippling or indentation is due to the folds of mucous membrane and is quite a normal appearance.[1] Refer first to the remarks on the formation of the mucous membrane picture in "Stomach and Intestine. General." In strongly marked contraction of the body in pathological conditions—for instance, in ulceration of the lesser curvature—this folding of the mucous membrane is beautifully seen. The deep furrows of the mucous membrane of the body of the stomach might often stand out in the prone position against the layer of air and might deceive the inexpert into thinking it a carcinomatous infiltration. Not infrequently in an ulcer the folds of

Fig. 271b.

[1] G. Forssell, *l.c.*

mucous membrane are directed towards it. The nature of the indentations may be a duplication of the mucous membrane, with fine line or tuft processes projecting into it from the outer submucous layer (submucous lymph space, and fine small vessels).[1]

In Fig. 273, we are dealing not with the usual picture of indentation at the greater curvature, but with a case with a marked degree of hypertrophy of the mucosa and increased activity of the same. By " activity " is meant the autoplasty of the mucous membrane according to Forssell's description. That is proved also by the continuous change of view of the gastric folds. The author took five to six exposures at about two-minute intervals and obtained different views of the lining folds every time. Our illustration (273) shows more evidence of longitudinal folds in the upper half of the indented area, and more transverse folds below. The peristalsis in the greater curvature was naturally sluggish. The patient had had dysentery and was suspected of having enteric fever while serving twelve years before the Röntgen examination. That may be mentioned, for the gastric symptoms may have begun shortly afterwards.

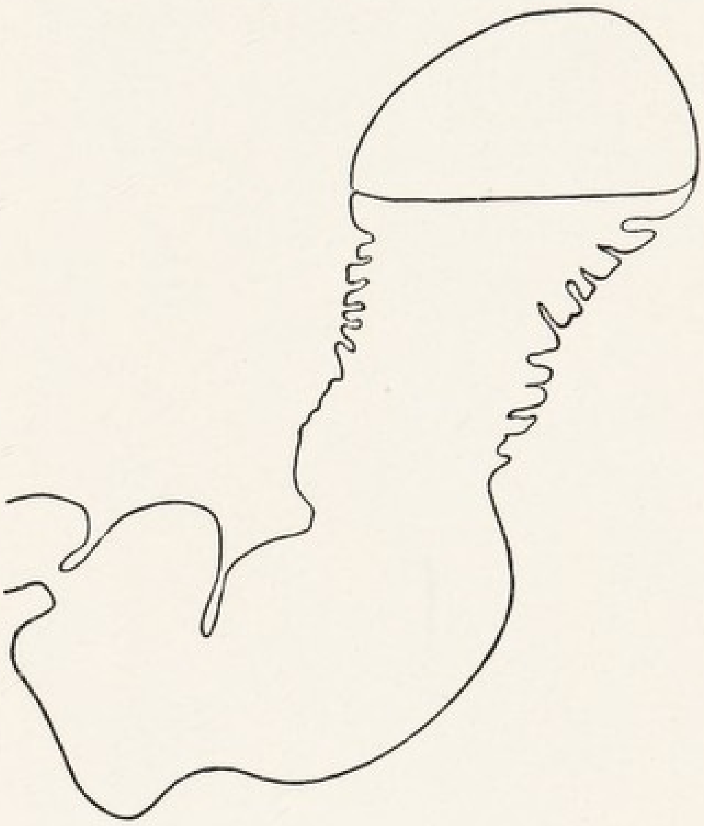


Fig. 272.

Increased peristalsis, yet with much delayed period of emptying, indicated a functional or organic obstruction at the pylorus (see below under " Motility ").

Cases have been observed in which movements of the antrum were present when the body was without peristalsis (one of the reasons for attributing an independent function to the antrum). It is believed that this is not a pathological condition.

Towards the end of gastric digestion the antrum is frequently inactive and immobile, only at the place of the sphincter antri there can be observed an indrawing of the greater curvature.[2] All that is quite physiological.

[1] W. Bauermeister: Die Schleimhaut des Magens im Röntgenbild. Fortschritte, Bd. 36, 2, 1926.

[2] Groedel.

If the peristalsis is always absent at one point, and if the rugæ or folds are wanting, this is not an unimportant symptom, but often a most important early sign of *a commencing tumour* at the affected spot, especially if the lumen of the stomach at this spot remains unaltered in form and size during the course of the peristalsis. Appearances like finger-marks are due to offshoots of the tumour into the normal tissue.[1]

A *much increased peristalsis* is frequently met with in neurasthenics, also in marked hypersecretion, but above all in dilatation in consequence of obstructive pyloric stenosis. In the last instance peristaltic rest ensues after a certain time owing to exhaustion, whereas in the pylorospasm a continuously violent peristalsis is kept up. (Fig. 270A (p. 454), hyperperistalsis in pyloric stenosis following scar of ulcer above in the lesser curvature in the neighbourhood of the pylorus. Confirmed at operation.)

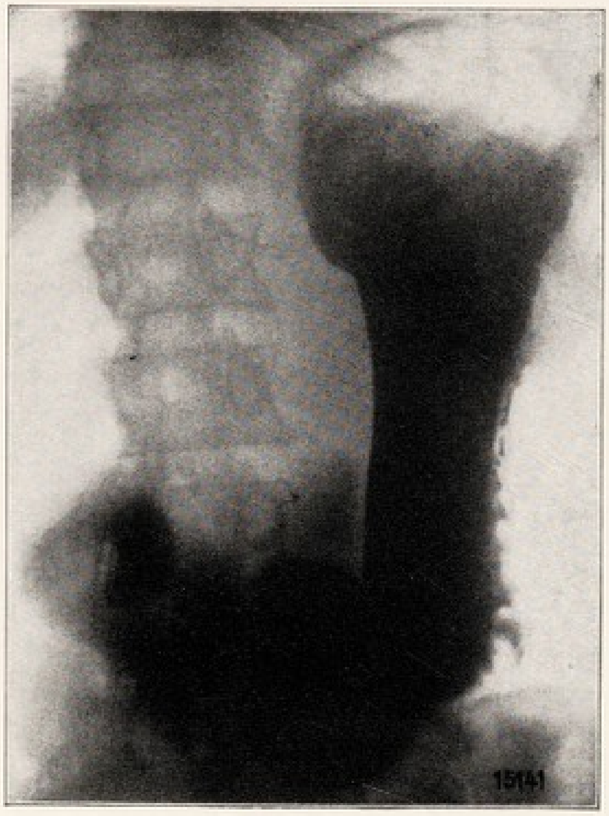


Fig. 273.

A *constant stomach-wave* should always be regarded as pathological. Its most frequent cause is a continual irritation of a limited area of the wall of the viscus (commencing carcinoma, ulcer). See also under "Hour-glass stomach."

Peristalsis does not start the instant the first mouthfuls enter the stomach, but only when the meal reaches the pylorus, as a number of observers have verified.

In *complete gastrospasm* (tetanic contraction) there is an entire absence of stomach movement, there is a cessation of peristalsis. For the causes of total gastrospasm, see p. 451.

Absence or considerable delay in the stomach movements are said to follow psychical influences.

Increased peristalsis has been observed to occur under the influence of morphia.

Generally speaking, deep peristalsis is associated with subacidity, flat peristalsis with hyperacidity. Nevertheless, there is no regular relation between acidity and peristalsis.[2]

[1] L. G. Cole: Serial röntgenography of the stomach and duodenum. Arch. of the Röntgen-Ray, October, 1912.

[2] Vogeler: Motilität und Acidität des Magens in ihren Beziehungen zueinander, geprüft im Röntgenbilde und an der Sahlischen Suppe. Inaug.-Dissert., 1921.

In hour-glass stomach a different degree of peristalsis can obtain in each part.

Whether antiperistaltic waves occur in the stomach also under physiological conditions has been denied.[1]

Antiperistalsis is an important early symptom in carcinoma of the pylorus. Quite irregular peristalsis is a sign in advanced cases, as is also deficiency in movements of the antrum. The author found the most decided antiperistalsis he ever saw in a case of complete fibro-ulcerative occlusion of the pylorus (principal symptoms: vomiting and debility). Others have also observed antiperistalsis in the pyloric stenosis of infants, in ulcus ventriculi, in gastric crises. In hysteria, neurasthenia, and tabes it has also been noted, but others again do not agree to that.

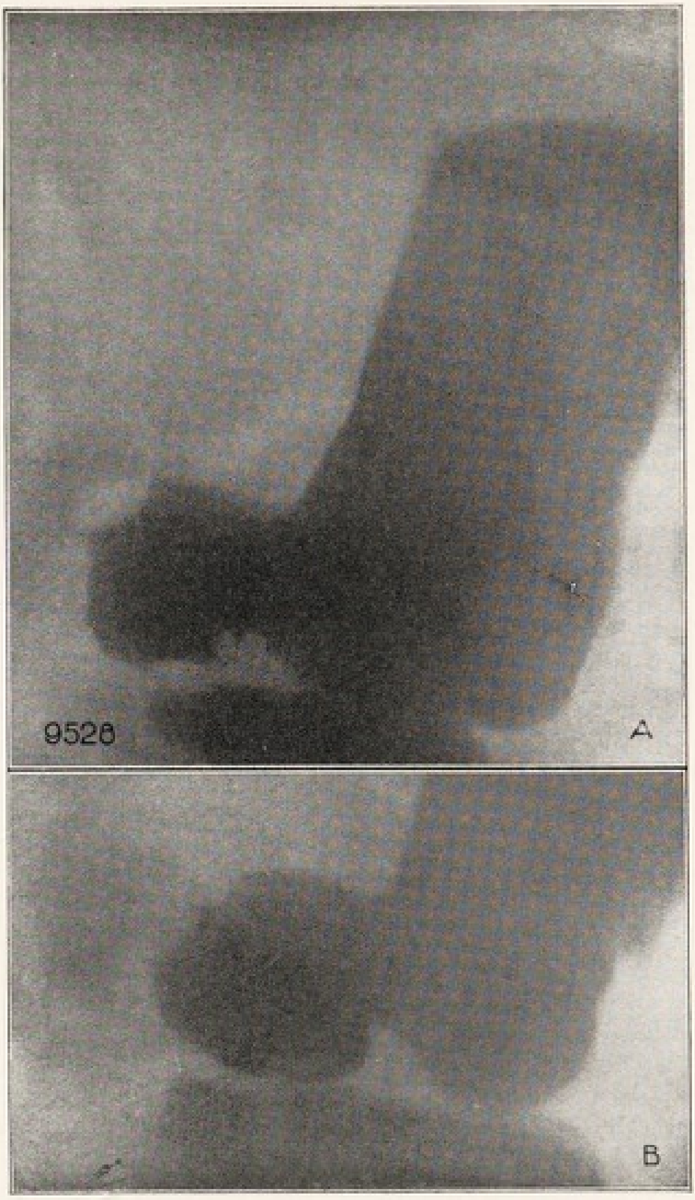


Fig. 274.

A peristalsis, as seen in Fig. 274, is in all circumstances beyond the limits of the normal. We have apparently to deal here with an antiperistalsis: the pointed end of the stomach indicates that. It was impossible to make the diagnosis by screening alone. Operation ten months later (Prof. Heile). Immediately to the left of the pylorus a ring-shaped, completely encircling tumour, apparently carcinoma, freely movable, and not adherent to the neighbouring viscera. Still operable, but owing to the weak state of the patient, only a gastro-enterostomy was done. It is important to note what the author has described for the peristalsis in this case; the waves at the greater curvature travel only about as far as the pars pylorica. As soon as three to four waves have arrived there one after another, but without going any further, a very large wave goes as far as the

[1] Haudek, quoted by Rieder; see next footnote.

pylorus, and the stomach empties some of its contents into the duodenum. Shortly before this emptying action the greater curvature heaves out strongly, *i.e.* it bends out far downwards, standing almost at right angles to the pars pylorica. Extremely striking is also a deep narrow indentation that occurs about every 40 seconds on the left and upper aspect of the greater curvature, similar to a spastic contraction opposite an ulcer of the lesser curvature, and disappears completely soon thereafter.

Naturally antiperistalsis is only apparent in a good light and with exact observation and search by a well-accommodated eye. When the antiperistaltic wave has travelled to about the middle of the greater curvature, it usually stops, and it is only rarely that it reaches as far as the cardia.[1] One röntgenologist [2] claims to have observed antiperistalsis in 3 per cent. of all gastric irradiations. Antiperistalsis is much less regular than peristalsis, and is best marked when the stomach is only partly full. The first deep waves are accompanied by shallower, smaller wave-motions. Peristalsis is either seen alone, or antiperistalsis alternating with peristalsis. Antiperistalsis does not necessarily occasion any delay in the emptying of the stomach. Antiperistalsis is present principally in the neighbourhood of the pylorus, but only rarely begins at the pylorus itself ; it begins usually some little way from it, generally at the greater curvature, even when the disease is situated at the lesser curvature.[3] There is no functional antiperistalsis, but organic changes of the stomach or of the duodenal mucous membrane (ulcer or carcinoma) are always present, and most often at the pylorus.[4] Antiperistalsis appears to occur most frequently, when a dilated stomach is combined with a pyloric stenosis. Moreover, antiperistalsis appears to occur in circular, callous ulcer, especially in niche formation on the lesser curvature, further in hour-glass stomach, scars of ulceration, adhesions, etc., also in adhesions of the pylorus with the gall-bladder. In pylorospasm in children antiperistaltic wave-movements have been found lasting as long as 13 hours.[5] One can say that antiperistalsis generally points to the necessity of operative interference ; whenever it is observed the diagnosis of carcinoma and ulcer should be at once considered. The causative factors of antiperistalsis are still completely unknown. Antiperistalsis is found exclusively at the greater curvature. The sequence of the movement is repeated in typical antiperistalsis in periods of different length. They have not yet been seen on the lesser curvature.

Antiperistalsis should not be confused with " retrograde displacement of the contents." The latter is not really a wave-movement, but a passive contraction movement—usually accompanied with considerable displacement of the contents—which is especially for the adjusting of abnormal pressure conditions. It is observed very frequently in stenoses. Thus in

[1] Groedel : Die Magenbewegungen, 1912. Illustration 337 ; quoted by Rieder.

[2] Holitsch.

[3] After Haas, quoted by Rieder.

[4] Haudek, quoted by Rieder.—N. S. Finzi, London : Hour-glass contraction of the stomach with intense reverse peristalsis. Arch. Röntg.-Ray, 1912, 16, p. 414.

[5] Jamin, quoted by Rieder.

duodenal stenosis a retrograde acceleration of the contents of the duodenum occurs into the stomach. For retrograde displacement of the contents in the jejunum and ileum, see the same.

Probably the most important displacement of the contents in the alimentary canal of man is that which occurs normally in every human stomach in the prepyloric region during digestion. As is well known when the pylorus opens usually only a small quantity of chyme passes into the duodenal bulb ; but when the pylorus is shut a gradual reduction takes place in the canalis egestorius (the pyloric part of the stomach), in which its contents are pressed backwards in the course of peristole, so that they travel back into the body of the stomach. But this retrograde action, which doubtless does occur and can be clearly seen in experiments on animals, has not yet been seen in the normal human stomach either in the screen or on the photographic plate. Special examinations for the purpose yielded no certain result. But it may be confidently expected that it will be recognisable in pathological cases, where it is more definitely marked, " Pseudoperistalsis." [1] No wave-motion occurs in these cases, but a to-and-fro fluctuation, *i.e.* alternating ortho- and retrograde (forwards and backwards) movement of the contents, usually very rapid and occurring irregularly ; whereas antiperistalsis is to be thought of as a definitely orderly active process, which in man—at least up to now—has been observed only in the stomach. The evidences of movement which have often been described as antiperistaltic waves in other hollow abdominal viscera (duodenum, small intestine, and great intestine) are certainly not so, but are alternating ortho- and retrograde displacements of the contents of the stomach.[2] Further, the author has never seen retrograde displacement in the stomach, doubtless without making any special search for it, yet he has observed it repeatedly in the colon.

Motility.

Many observers are united in the experience that the course of digestion is not influenced by a bismuth meal either in delay (constipating action of bismuth) or in acceleration (stimulus caused by gravity). Perhaps these factors counteract each other.

The *normal period of emptying* of a bismuth-meal is taken as 2–4 hours, the average 3 hours, and 1–2 hours for a meal of barium.

It is advisable to estimate *the motility* of the stomach not by the time in which the last small remnant disappears from the stomach, but according to the time in which the greater part of the contrast-meal is expelled.

Emptying of the stomach occurs *in duodenal ulcer* more quickly than normally. The cause of this is probably insufficiency of the pylorus. At the same time a small remnant of the meal may remain longer than six

[1] After Sick, quoted by Rieder.

[2] H. Rieder : Antiperistaltik u. rückläufige Inhaltsverschiebung. Fortschritte, Bd. 35.

hours. Rapid emptying is also met with in achylia, and in pancreatic diseases of the biliary tract.

Sluggish motility of the stomach is characteristic of pylorospasm and organic pyloric stenosis: papaverin affords a differential diagnosis.[1] The latter stops the slowing in motility due to pylorospasm, and increases that due to organic pyloric stenosis (for fluids, see below).

If it is desired to estimate the emptying time of the stomach correctly, never forget to instruct the patient to refrain from fresh nourishment or fluids during the entire Röntgen examination.

Remnants of contrast-meal in a fish-hook stomach (with a normally functioning pylorus) long after the main mass of the meal has been emptied are a frequent concomitant in hypersecretion.[2] An extreme amount of secretion soon thins the contrast-meal, the contrast-meal sediments rapidly, and it is principally the secretion itself that is emptied through the pylorus.

Small remains in the stomach 4½ to 5½ hours after a contrast-meal, which, however, are emptied after six hours, are usually due to simple atony.

Considerable remains after six hours are always pathological. Cause: ulcerative or carcinomatous stenosis of the pylorus, or pylorospasm, which nearly always indicates the presence of an ulcus ventriculi, although not situate necessarily at the pylorus itself. Meals are delayed both in stenosis and in spasm of the pylorus, fluids are delayed only by spasm.

A large remainder of meal after six hours and deficient peristalsis in an otherwise normal stomach is frequent in women a few hours before menstruation and on the first day thereof.[3]

Normally with each contraction of the antrum only a very small portion of the meal is passed through the pylorus into the duodenum, although it often looks on the screen as if the contents of the whole filled antrum had been conveyed into the duodenum all at once. If that were so the stomach would be empty in 5 to 10 minutes. While a new wave is forming the antrum, the pylorus closes and stops the regurgitation of any food.

Without either benign or malignant lesions being present in the stomach and duodenal cap a large retention of meal can still be present in the stomach six hours after its ingestion. Cause: functional disturbances in the second and fourth part of the duodenum (deficiency in bile and pancreatic-secretion, whereby the acid and hyperacid contents of the stomach are not sufficiently neutralised ?).

There is certainly an influence exerted by conditions of the small intestine and the great intestine (rectum also ?) upon the emptying time of the stomach, and the action appears to be the greater, the nearer the trouble in the intestine is to the stomach.

Sex is also said to have an effect upon the emptying time: in women it tends to be rather longer than in men.

[1] Holzknecht and Sgalitzer: Papaverin zur röntgen. Differentialdiagnose zwischen Pylorospasmus und Pylorusstenose. Münchener Med. Wochenschrift, 1913, p. 1989.

[2] Haudek: Hypersecretion und Magenmotilität. 10. Röntgenkongress, 1914.

[3] Lüdin: Röntgenol. Untersuchungen über das Verhalten des Magens während der Menstruation. Fortschritte, Bd. 23, 1915/16.

A deeper and more rapid peristalsis is not essential to a comparatively rapid though still normal emptying time, and vice versa, however inclined one might be to accept this hypothesis. We are here dealing with questions which have not yet been solved. Some men of experience draw parallels between tonus and depth of peristalsis on the one hand and the rapidity of emptying on the other hand ; other weighty authorities contradict this. Accelerated emptying time has been observed in complete aperistalsis, and the natural inference would be that emptying in a stomach of normal tone is dependent less upon peristalsis than upon hydrostatic factors.

A retrogressive movement from intestine to stomach has been observed in one or two cases. The stomach empties normally to begin with, but refills backwards again to a considerable extent. This refilling took place more than once in a few cases. In these cases there is always a highly situated stenosis of the small bowel present.[1]

Secretion

Between *motility* and *secretion* there is no connection.

When the patient has taken a sufficient quantity of contrast-meal and the photograph is technically satisfactory, we can always recognise whether *a layer of secretion* is present on the contrast-meal or not ; it can usually be well seen on screening. It is more difficult to determine the level of the secretion layer in complete atony, because there is not enough breadth of fluid to show up.

The *level of the secretion layer* can be estimated best 15–20 minutes after the intake of the meal ; provided, however, that the contrast-meal was of quite uniform consistence and did not sediment.

While in *ulcus ventriculi* peristalsis and tone are usually unaltered, the secretion is as a rule increased.

If the first mouthfuls slide without resistance from the cardiac to the pyloric end of the stomach, then *hypersecretion* is present. When the stomach is well filled with the contrast-meal then the so-called intermediate zone makes its appearance above the meal. Also in *atonic ectasia* (gastrectasia) the food flows without difficulty into the stomach, and naturally too in anatomical dilatations.

Various

Ascarides have been observed once or twice in the Röntgen view of stomach and intestine.[2] In the antrum or egestive canal a spiral loop was seen as thick as a goose-quill, which could at once be distinguished as the ascaris. The enormously deep and spastic peristalsis was the striking feature in the stomach. The ascaris during about a 10 minutes' examination was twisted by the deep spasms from the antrum towards the cranial

[1] Groedel, *l.c.*

[2] O. Fritz : Askariden des Magendarm-Tractes im Röntgenbild. Fortschritte, Bd. 29, 1922 ; further Italien. Kongress für Radiologie, Palermo, 1923.

pole of the stomach. See also later illustration and text in the section "Jejunum and ileum. General."

A shadow picture that is physiological in form and position has been described up to date at least four times in the literature. Within the contrast shadow one sees a large round oval or stomach-shaped transparency with great motility and of soft tissue density.[1] We have here to deal with *a hair-ball*. In screening during the taking of the contrast-meal, one can see how on entering the stomach the barium appears to divide at once into two parts, which flow together again below. Upon one occasion it was observed how the top of the hair-ball projected upwards into the air-sac.

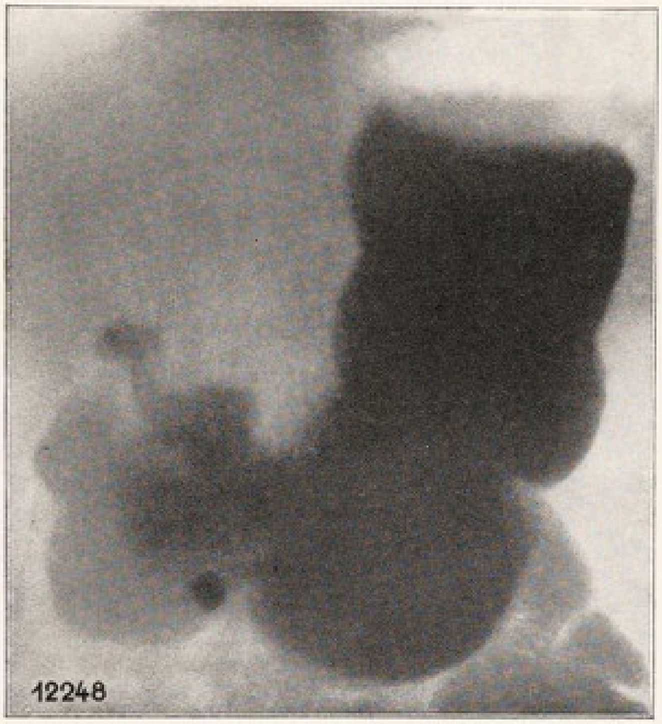


Fig. 275.

We should here mention a striking condition at the pyloric end of the stomach, which may be described as outside the limits of the normal, see Fig. 275. The last 3–4 cm. of the stomach to the left of the pylorus are narrowed by 7–10 mm.; they project somewhat like a wick from the rest of the stomach; on this portion there rests a rounded duodenal cap, so that the whole appearance resembles that of a mushroom or water-lily. It bears only a distant resemblance to the picture of carcinoma. The patient complains of pains 2–3 hours after a meal. Hyperacidity was present. Operation (by Prof. Heile) was carried out $1\frac{1}{2}$ years later: "Extensive adhesions in the upper abdomen between liver, stomach, and diaphragm. Lower abdomen fairly free, no cholelithiasis, no gastric or duodenal ulcer." Since then, well for $4\frac{1}{2}$ years. Gastro-entero-anastomosis was not performed. The author would not have adduced this case, had he not a radiograph of another similar case, in which the narrowing extended even further. An Alexander-Adam's operation and an appendicectomy had been performed several years before. Heart-burn and bulimia are the present symptoms. On attempting lavage of the stomach excruciating pains extending to the left shoulder. Operation on the stomach has hitherto been refused.

For tumours of the cardia, see under "Œsophagus."

[1] Clairmont and Haudek: Die Bedeutung der Magenröntgenologie für die Chirurgie. Jena, 1911 (Fischer).—Thurstan Holland: Röntgenography in a case of hair-ball in the stomach. Archives of the Röntgen-Ray, 1913, No. 156, and 1914, No. 164.—Lehmann: Trichobezoar im Röntgenbilde. 10. Deutscher Röntgenkongress, 1914.

In syphilis of the stomach the Röntgen picture is extremely various, as also in tuberculosis.[1] Tuberculous glands in the vicinity of the pylorus may lead to mechanical compression.

In umbilical herniæ parts of the stomach can enter the hernial sac.

In conclusion, a short summary of the *symptoms of ulcus ventriculi* may be enumerated for the sake of clearness. The appearance of a niche (with or without an air-bubble) on the smaller curvature or a little behind it. Tenderness on pressure in the region of the stomach shadow accompanied by indrawing of the abdomen and variations in the length of the stomach. Intermittent contraction at the greater curvature. Permanent indrawing thereat, B-form. Energetic peristalsis. Stoppage of the peristaltic waves at one point. Six-hour remainder. Dilatation. Gastrospasm. Gastroptosis.

The indirect symptoms of ulcer near the pylorus (parapyloric ulcer, juxtapyloric ulcer, ulcus ad pylorem) usually resemble those of duodenal ulcer: Hypertony, hyperperistalsis, elevation of the stomach, displacement to the right of the pylorus, hypersecretion, usually also hypermotility, and later, obstruction.

In case the reader does not find what he wants under "Stomach," he should not omit to refer to the headings of "Small Intestine. General" and "Duodenum."

Small Intestine[2]

General

Contrasted with the great bowel (see below) the small intestine, with the exception of the most dependent coils of the ileum, never normally contains the meal in the form of a longish continuous strand. The duodenum behind the cap is rapidly traversed and the jejunum shows the meal distributed in flake-like shadows (see also below).

Of the three portions of the small intestine it is the ileum, particularly its lowest coils, that normally hold up the meal the longest time.

[1] Charles Hermann: Syphilis of the Stomach. B.J. of Rad. Aug. 1927.—David Smith: Syphilis of the Stomach. Glasgow Med. J. Sept., 1927.—A. B. Moore and J. R. Aurelius: Röntgenologie manifestations in gastric syphilis. Am. J. of Röntg. May, 1928. With discussion.

[2] For literature refer especially to those works under the heading of "Stomach" dealing with the entire gastro-intestinal canal; further, Groedel: Dünndarmerkrankungen im Röntgenbild. 10. Deutscher Röntgenkongress, 1914.—Schwarz: Neue Röntgenbeobachtungen zur Darmbewegung des Menschen. 85. Vers. Deutscher Naturf. und Arzte. Vienna, 1913.—Stierlin: Zur Röntgendiagnostik der Dünndarmstenose und des Dünndarmileus. Med. Klin., 1913, No. 25.—David, Halle: Dünndarmstudien. 10. Röntgenkongress, 1914.—Faulhaber: Die Röntgendiagnostik der Darmkrankheiten. 2nd ed., Halle, 1919 (Marhold).—Cole: Relation of lesions, etc. American Journal of the Medical Sciences, July, 1914.—E. Schlesinger: Die Röntgendiagnostik der Magen- und Darmkrankheiten. 2nd ed., 1922. Berlin and Vienna (Urban & Schwarzenberg).—E. Stierlin: Klinische Röntgendiagnostik des Verdauungskanals. 1916. Wiesbaden (J. F. Bergmann).—Balli: Sul limite fra il normale ed il patologico nella röntgenologia del tubo digerente. Modena, 1922 (Orlandini).—Perussia: Röntgenologia dell' intestino. Rivista Ospedaliera, 1913. No. 3.—G. Schwarz: Die Röntgenuntersuchung der Verdauungsorgane; in Schittenhelm's textbook, 1924.—H. Rieder: Die Röntgenuntersuchung des Dünndarms; in 2nd volume of Rieder-Rosenthal. 1925.—For special exposures of small intestines, refer Sinclair Tousey: Medical electricity, Röntgen-rays, and radium (published by Saunders Co., Philadelphia).

Provided the stomach has emptied itself normally, one finds *contrast-meal in the duodenum* usually a few minutes after its ingestion, in about 10 minutes it reaches the jejunum, in 20–30 minutes the ileum, after 2–4 hours the cæcum, after 3–7 hours it reaches the hepatic flexure, in 5–10 hours the splenic flexure, in 12 hours it has reached the sigmoid, and not later than 24 hours post cœnam it is in the rectum (see also above in "Stomach and Intestine. General").

As already mentioned, one finds in the small intestine, with the exception of the last coils of ileum, that the meal is normally hardly ever a continuous strand, but is in the form of pieces or short, separate, cylindrical, more or less curved shadows, or sometimes in feathery, tassel-like or fine firework-like coils (as shown in Fig. 292). Consequently, it is as good as impossible to determine the course of the small intestine either of the normal or of the greater part of a pathological one (apart from the duodenum and the last coil of ileum) as can be done in the case of the great intestine. When the meal has occupied the whole jejunum and ileum, one often sees under normal conditions a shadow on the film like a cauliflower (see also Fig. 276).

Fig. 276.

Markedly enlarged, band-like shadows with a ribbed structure or with ampullary spaces filled with fluid and gas and in the background isolated contrast shadows, visible from one to several days, are found in stenosis of the jejunum or ileum.[1]

In cases difficult to diagnose with displacement of the intestines one should think of the possibility of a congenital *transposition of the viscera.*

Gas-bubbles are not seen as a rule in the normal small bowel, at any rate not in the jejunum and ileum, though occasionally in the duodenum. Gas-bubbles in the duodenum should not be confused with gas-bubbles in the hepatic flexure. The gas-bubbles in the duodenum are always smaller; they usually show a cupola-like border above and are above the pylorus in the majority of cases.[2]

The air expelled from the stomach—most of it is eructated through the

[1] Schwarz, *l.c.*

[2] Bucky and Fuld: Gasgehalt der Flexura dextra bei Adhaesion. Fortschritte, Bd. 30, 1. Kongressheft, 1922.

œsophagus—is rapidly passed through the small intestine in consequence of peristalsis. A stationary gas-bubble in the small intestine is indicative of a narrowing of the lumen of the bowel ; usually the gas-bubble appears above a horizontal layer of fluid. Such pictures indicate an ulcerative process of the wall of the intestine, which may lead to a fibrous stricture, or peritonitic processes of the peritoneal coat, which may occasion a strangulation of the lumen of the gut ; duodenal ulcer is the principal cause.[1]

Carcinoma of the small intestine is exceedingly rare. Upon one occasion a carcinoma of the duodenum was diagnosed correctly with the Röntgen rays ; see under "Duodenum."

Duodenum [2]

General

A duodenum the course of which one can see in apparently its normal form (Fig. 277, A, B, C) is in the great majority of instances very pathological (in the rest of the cases its surroundings are pathological) ; for always when it is normal and also in a number of diseased conditions (ulcer, etc., see later) the entire duodenum with the exception of the commence-

[1] Alfred Weil: Über die röntgendiagn. Bedeutung normaler und abnormer Gasansammlung im Abdomen. Fortschritte, Bd. 24, 1916.

[2] For literature see the works mentioned under the heading "Stomach" dealing with the entire gastro-intestinal canal ; further the above note under "Duodenum" ; further Holzknecht : Das normale röntgenologische Verhalten des Duodenum. Zentralbl. f. Phys., Bd. 23, p. 974.—The same : Duodenalstenose durch Füllung und Peristaltik röntgenologisch erkennbar. D. Zeitschr. f. Chir., Bd. 105, 1910.—Skinner : Röntgenuntersuchung des Duodenum. Amer. Röntgen-Ray Soc., 1911.—Desternes : Röntgénographie du duodenum. Soc. de Rad. méd., July, 1910.—A. W. George and I. Gerber : The Röntgen-Diagnosis of duodenal ulcer. Surgery, Gynecology and Obstetrics, September, 1914.—George and Leonard : The Röntgen-Diagnosis of surgical Lesions of the Gastro-Intestinal-Tract. Boston, The Colonial Medical Press, 1915.—Cole : Relation of lesions of the small intestine to disorders of the stomach and cap as observed röntgenologically. Amer. Journal of the Med. Sciences, July, 1914.—Haudek : Röntgenbefunde bei Ulcus duodeni. 42. Vers. d. Deutsch. Ges. f. Chir., Berlin, 1913 ; further the works on Ulcus duodeni by Altschul, Baron and Bársony, v. Bergmann, Cole, David, Dünkeloh, Eisler, Kreuzfuchs, Glässner, Jonas, Moynihan, C. Müller, Novak, Schwarz, Stierlin, Strauss, Westphal and Katsch (for titles of year of issue refer to Groedel's Atlas, 4th ed.) ; further the works of Chaoul-Stierlin, see Münch. Med. Wochenschr., 1917, No. 84, p. 1552.—A. Akerlund : Röntgen-Studien über den Bulbus duodeni, mit besonderer Berücksichtigung der Diagnostik des Ulcus duodeni. Stockholm, 1921 (J. Marcus Publishers) (with complete list of the literature).—H. J. Panner : L'examen röntgenologique de l'ulcère du duodenum. Acta Radiologica, Vol. I, 1921.—Walter, St. Petersburg : Beiträge zur chir. Anatomie des Zwölffingerdarms. Arch. f. klin. Chir., Bd. 120, p. 472.—H. R. Schinz : Das Ulcusleiden im Röntgenbild und seine Kontrolle durch den Operationsbefund. Hamburg, 1921 (Gräfe & Sillem).—H. R. Schinz : Das Ulcusleiden im Röntgenbild und seine Kontrolle durch den operationsbefund. Hamburg, 1921 (Gräfe and Sillem).—W. Teschendorf : Der gesunde und kranke Zwölffingerdarm im Röntgenbilde (with list of 225 articles). Erg. d. Inn. Med. u. Kinderhlk., Bd. 29, 1926.—A. Åkerlund : Die Röntgendiagnostik des Ulcus duodeni, etc. Mitt. aus d. Grenzgebieten der Med. u. Chir., Bd. 36, 5, 1923. —O. David : Der Zickzackkurs in d. Röntgen-Diagnostik des Duodenum. Klin. Wchnschr., 1926, No. 26.—R. W. Morse and L. G. Cole : The anatomy of the normal small intestine as observed röntgenographically. Radiology, February, 1927.—H. H. Berg : Die directen Röntgensymptome des Ulcus duodeni und ihre klinische Bedeutung. Ergebn. d. medic. Strahlenforschung, Bd. II, 1926 (Thieme, Leipzig).—M. Haudek : Die Röntgenuntersuchung des Duodenum, in Rieder-Rosenthal's Manual, Bd. II, 1925.

ment of the duodenal cap is traversed in a few seconds, at longer or shorter intervals, and therefore a complete filling of this part of the intestine or of its proximal part is always a pathological feature. This is due either to a spastic or an organic stenosis of the duodenum or of the commencing ileum, or to compression by a neighbouring tumour. A marked degree of peristalsis (stenosis-peristalsis) is naturally present in these cases; its recognition is not always easy. If a stenosis has been there for some time, then the duodenum is also dilated. Or we may have to deal with a stoppage of the peristalsis of the duodenum, particularly when the filling of the whole duodenum takes place towards the end of the emptying of the stomach (see later under "Dilated cap"). Fig. 277, A: Diagnosis: Ulcer or stenosis of the duodenum; operation declined. Hæmorrhage six weeks

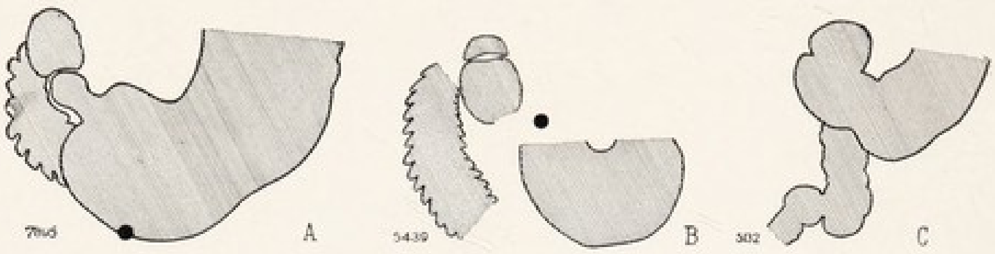


Fig. 277.

later. A subsequent examination of the plate indicated the probability of an ulcer (with niche) having been present about the middle of the lesser curvature. B: Spasm correlated with fibrous hour-glass stomach (the same case as 263, B). C: Atonic duodenum after a tropical enteritis followed by continued use of bismuth.

If one wishes for any purpose to bring the *duodenum rapidly to view,* a mixture of barium or bismuth should be administered upon an empty stomach. A part of the fluid then leaves the stomach immediately and traverses the duodenum. This examination can be rendered more complete by lifting the contrast solution with the hand from the dependent pole of the stomach to the level of the pylorus.[1] A mixture of bismuth and buttermilk is said to be specially useful for exhibiting the duodenum. It stays longer in the intestinal tract than other contrast mixtures, but one has to employ two to three times the normal amount of bismuth.

The first part of the duodenum is easily movable, for it hangs from the hepato-duodenal ligament (which forms the right portion of the lesser omentum and in its right portion encloses the portal vein, artery, and the bile duct). The ligament is attached to the duodenum along a line which is the direct continuation of the lesser curvature. *The second or descending part* of the duodenum, on the other hand, is attached to the posterior abdominal wall. One might, therefore, consider that it could never be displaced; some authoritative anatomists (Braune) maintain that its

[1] After Holzknecht.

mobility is very slight or entirely absent; according to others (Glenard), the retroperitoneal coil of duodenum shows a fair amount of mobility, depending on the fact that the peritoneum along the line of attachment from the posterior abdominal wall to the duodenum is fastened very loosely to the abdominal wall. The latter view has found confirmation from the röntgenological side.[1] Passively also, according to röntgenological experience, the duodenum is said to be surprisingly movable in its entirety.[2] Hence *a ptosis of the duodenum* is possible, although very rare. It is present only in myasthenia and in cases of general enteroptosis.

The further the pars descendens is to the right and the further to the left the pylorus and bulb, the more circular or horse-shoe form does the

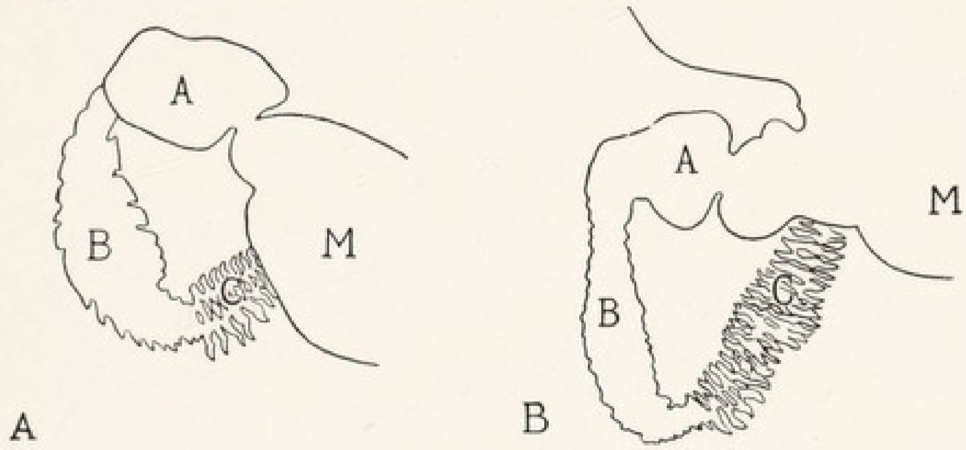


Fig. 278.[3]

Normal duodenum of a thin woman (verified by operation). A=First part of the duodenum. B=Second part of the duodenum. C=Transverse part of the duodenum.

Profile view of a normal duodenum in a heavily built man.

duodenum assume. The upper and lower parts come closer together through approximation of the pylorus to the pars descendens or by the former covering over the latter. If the stomach is high up the pars superior also runs more horizontal, etc. In rare cases the duodenum may even make an arch to the left.[4] An elongation of the first part of the duodenum (in long atonic stomachs) can be accompanied with a turning of the whole duodenum towards the front. In extreme cases the turning may proceed still further, so that an inverted duodenum is produced.[5]

With the exception of the first part, the duodenum is supplied with plicæ and *valvula conniventes* (Fig. 278).

In diseases of the duodenum (and the gall-bladder) *hypermotility* extends as far as the great bowel, and six hours after the intake of the meal the contrast-meal has succeeded in reaching the splenic flexure.

Increased valvulæ conniventes are signs of muscular hypertrophy.[6]

[1] Åkerlund, *l.c.*
[2] Holzknecht: Fortschritte, Bd. 21, p. 471.
[3] Drawn from röntgenograms by George and Gerber, *l.c.*, p. 467.
[4] O. David: Mitt. a. d. Grenzgeb. d. Med. u. Chir., Bd. 31, 1919.
[5] Siegmund, quoted in Teschendorf, *l.c.*
[6] G. Schwarz, *l.c.*

Watery contents of the stomach enter the duodenum at once in large quantities, meals containing carbohydrate enter in small quantities, fill the postpyloric ampullary smooth commencing part (bulbus duodeni =duodenal cap), and are thence pushed on rhythmically, at intervals of a minute or so, fairly quickly into the jejunum.

A *reduced ability to transmit* the meal through the duodenum is held by some to be symptomatic of duodenal ulcer.[1]

The author has very often seen in possible cases of ulcer a rapid *retrogression* of the meal through the whole duodenum.

A full duodenum with visible contractions, which are ineffectual in moving the meal onwards, with retention of the meal also in the stomach, is the typical picture of a marked *duodenal stenosis* (see also above).

Naturally the *organic* stenoses give more typical pictures than the *spastic*.

First Part

The *first or ascending part* of the duodenum should not be confused with the pyloric part of the stomach, a mistake often made by the inexperienced. Cases really do occur, however, in which it is at first sight difficult even for the expert to arrive at a correct decision ; a further screening or additional photographs usually clear it up.

The first part is described by röntgenologists as the " vestibule," or " ampulla," or " bulb," or " cap," and quite often indeed the onion-like enlargement of the first part of the duodenum includes the whole or nearly the whole pars superior. According to the anatomists, it is placed at the level of the first lumbar vertebra, is 3–6 cm. long, and when the stomach is well filled can be as far as 7 cm. to the right of the mid-line of the body. As contrasted with the rest of the duodenum the duodenal cap shows no valvulæ conniventes. It is only in the contracted state that sometimes irregular folds of the mucous membrane are observed running longitudinal. The cap has a certain independence, compared with the other parts of the duodenum.

As the duodenal cap generally fills incompletely and irregularly with contrast-meal, some artifice is required to render it visible. *The best way to view the cap* is to carry out " effleurage " of the stomach before the photograph and during screening, with the patient in the standing position ; or during the taking of the meal to place him first on the right side or prone, or first in the one position and then in the other, or to place him on his back slightly turned towards the right. A further help is to get the patient to draw his abdomen in, and others, on the other hand, say to relax all the voluntary musculature and take deep breaths. For the examination of the whole duodenum, if we have no special instrument available to hand, we place a right-sided inguinal truss round the abdomen, turning the truss so that the spring grips the back and the left side of the patient, while

[1] Munk, *l.c.*

the pad presses the duodenum firmly against the vertebral column. This has the advantage over other compression methods, that the patient, once the truss has been correctly fastened, can be turned any way, without loss of pressure or displacement of its point of application.[1]

On account of many circumstances (position, form, size and emptying time of the healthy or diseased stomach, constitution position and attitude of the patient during the examination, a more or less complete filling of the bulb, the different time of examination whether immediately after the contrast-meal or later, etc.), the *Röntgen picture of the normal bulb* offers a great variety of forms, more numerous even than the shadows of stomachs and hearts. The diagnosis of the duodenal cap would be rendered easier could we always succeed in photographing the bulb when completely filled (see above regarding technique).

The most frequent form of a well-filled *normal cap* is a more or less distinct triangle (see B, A, Fig. 279). The transition of the base into the two

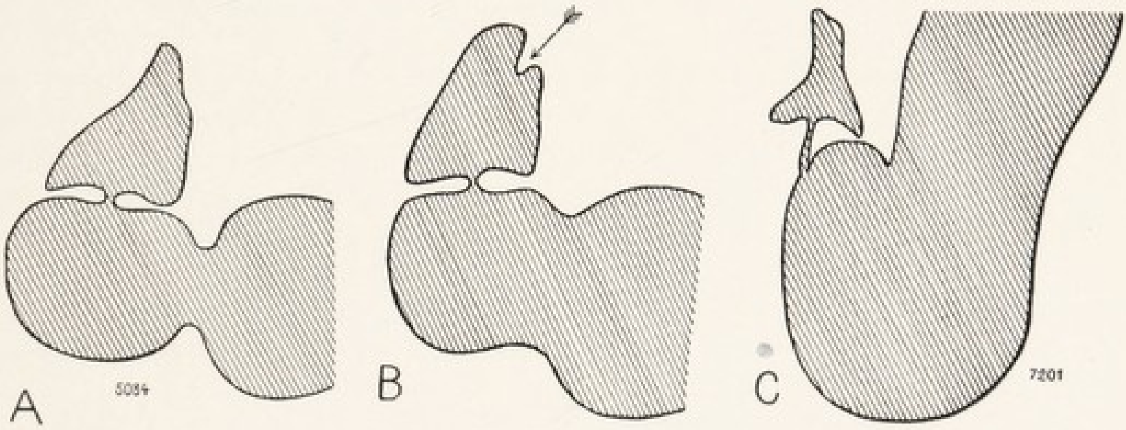


FIG. 279.

lateral contours is often rounded, rarely an angular recess, and still more rarely slightly dilated like a pocket, the " medial and lateral recess of Cole." One can compare the shadows of the cap with an onion, a pear, a beehive, a bishop's mitre, a three-cornered hat, a boomerang, a reversed ace of hearts, or still better an ace of spades, in which the pylorus lumen represents the stem. The triangular form appears above all in J-formed stomachs with the main part of the stomach in the vertical position. In elevated diagonally set stomachs and a short first part the duodenal cap is as a rule round, because it is here viewed in marked foreshortening. Also rhomboid and circular, elliptical and circular forms occur. Shell-like or semicircular forms, very like a small œsophageal diverticulum, appear on incomplete filling, above all, in the latter half of emptying the stomach. The normal cap shadow is usually symmetrical, yet asymmetries are not at all uncommon and are without pathological significance, and these asymmetries have definite types, so that they can be at once recognised as normal asymmetries. Thus the lesser curvature side of the cap is often less developed than the

[1] Åkerlund, *l.c.*

greater curvature. In such a case if the pyloric lumen is in the middle or only a little displaced towards the side of the lesser curvature, we may regard the bulb as normal. The lesser curvature contour is sometimes compressed by the gall-bladder, and even the greater curvature side also (see Figs. 240, 241). Sometimes a sharp notching is seen distinctly above to the right or left (see Fig. 279, B), but that is not pathological, although indeed its origin is not quite clear; it is said to be due to pressure from the descending part of the duodenum, the common bile duct, or the vena portæ.[1] One author [2] on comparing two Röntgen plates with anatomical preparations hardened in situ, found that the notching was caused by the common bile duct. Inconstant irregularities of the same cap shadow in different exposures would not appear to be a matter of pathological importance. A series of caps, all to be reckoned normal, is seen in Fig. 282A. The pyloric end of the stomach is sketched in too, with a view to seeing whether a transverse, dropped, or pyloroptotic stomach is present, or whether the stomach is in an average position; for the position and form of the stomach can affect the shape of the cap. The height of the bulb is sometimes smaller, sometimes larger than the diameter of the base; and the length of the convex surface or summit is not so long as the length of the diameter of the base. When one remembers that the cap in Röntgen projection can be represented in different individuals according to constitution, filling, etc., in almost all positions in space, one gets some idea of the tremendous variety of shadow pictures of the normal cap; while the pathologically altered cap produces a still more infinite profusion of shadow forms.

Also *the size of the bulb* will be found normally to vary greatly. The breadth of the pyloric end of the stomach should serve as a clue, for normally their diameter is the same. The author doubts the value of such comparisons for making a definite diagnosis, for with dilated cap the pyloric end of the stomach may momentarily be dilated too, and because the peristaltic configuration of the pylorus at the time of the exposure does not permit the breadth of the pylorus to be seen.

One author calls attention to the fact that the duodenal cap two hours or so after taking the contrast-meal appears somewhat larger than immediately after the meal; this is ascribable to the alteration in the conditions of tone with the progress of digestion. An *enlarged bulb* may be a simple anatomical variation. Thus it has been described in ptotic stomach, and high fixation of the duodeno-jejunal flexure accompanied by mobile duodenum, but it can also be an indirect sign of cholelithiasis with cholecystitis.[4] One observer [3] has shown that associated with enlargements of the neck of the gall-bladder and enlargement of the cystic duct with its furrow impression on the bulb there is frequently seen a difficulty of passage of food through the bulb and dilatation of the part of the bulb next the pylorus.

[1] Cole, *l.c.* [2] Åkerlund, *l.c.*

[3] Schinz, *l.c.* (Das Ulcusleiden im Röntgenbilde. Archiv der Fortschritte, Bd. 34).

[4] Berg: D. M. W. 1925/16. Erg. d. med. Strahlenforschung, Bd. 2. "Die directen Röntgensymptome des Ulcus duodeni u. ihre klin. Bedeutung."

The diseased gall-bladder may also bring about a persistent cap and enlarged bulb.

A very *large dilated cap*, in excess of the normal, is shown in Fig. 280, A. It is resting upon the pyloric end of the stomach. Operation (Prof. Heile): "Crateriform ulcer in the middle of the lesser curvature, adherent to the liver." The case is ten years ago. The ulcer was not diagnosed by the Röntgen rays. There have been no complaints since. A quite unusual appearance, certainly a departure from the normal, is shown in B of the same illustration. There appears to be only one other instance recorded in the literature (by Lorenz, in "Fortschritte," vol. 30, plate 13), with the description: "Duodenal cap in expression. Röntgendiagnosis: Alteration in the wall of the cap. Atony. Ptosis. Small residue. Surgical

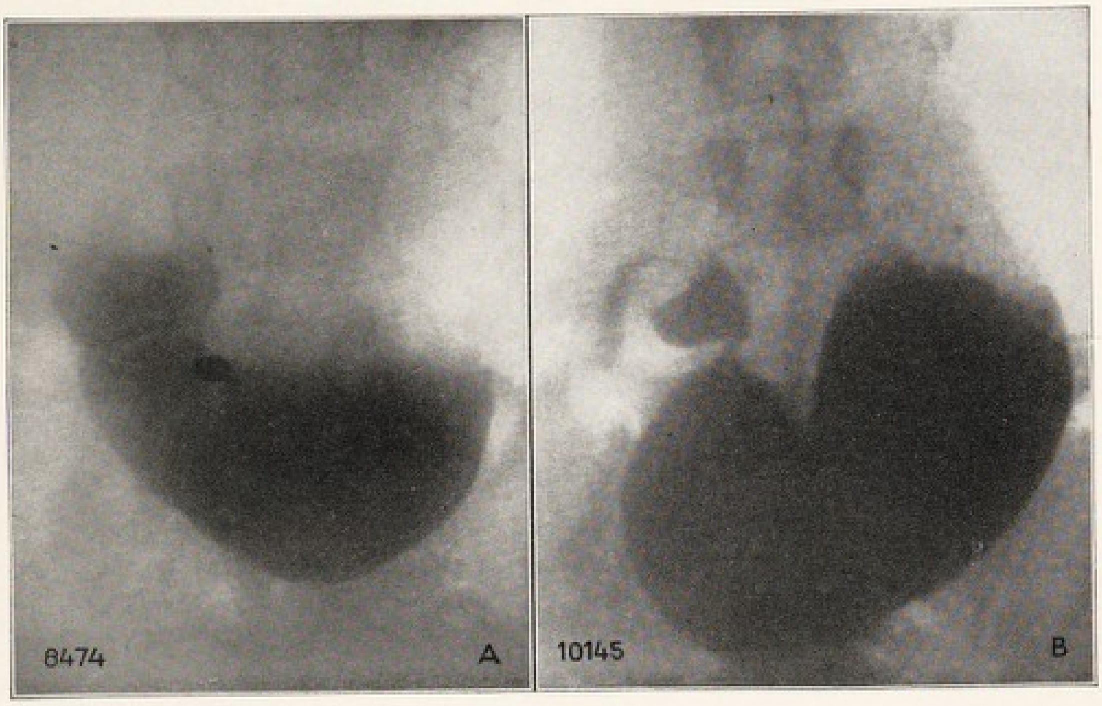


Fig. 280.

findings: a spot in the pars pylorica resembling ulcer." An operation was also carried out in the author's case, a year after the Röntgen examination. There was found (by Prof. Hackenbruch): Pyloric stenosis (scar!). No ulcer. Now, six years after operation, almost free of symptoms. One should note the conical and tapering terminal portion of the stomach.

Congenital enlargement is known to affect the duodenum; but this has not yet been observed for jejunum and ileum.

The position of the cap is the subject of great variations. In a stomach filled with contrast-meal and in the erect position of the body the normal cap (*i.e.* the first part of the duodenum) is situate opposite the intervertebral disc between the third and fourth lumbar vertebræ, *i.e.* about the level of the umbilicus.[1] Röntgen work has also taught us that the superior flexure

[1] Strauss, H.: Diagnostik u. interne Therapie des Duodenalgeschwürs. Ztschr. f. ärztl. Fortbildung, 1913, No. 4.

of the duodenum with the patient in the standing position is placed about 2 cm. below the level that anatomical writers describe for it. (In the horizontal position the cap and the pylorus with it move up the distance of one vertebra or of one and a half, extremely rarely two or more vertebræ upwards.) The first part usually elongates in the same amount as the pylorus drops [1] (see also Fig. 288). The axis of the cap runs usually slightly obliquely upwards and to the right. If the pylorus for any reason is displaced to the right, then the cap runs obliquely up and to the left. An asymmetrical position of the cap in relation to the pyloric end of the stomach

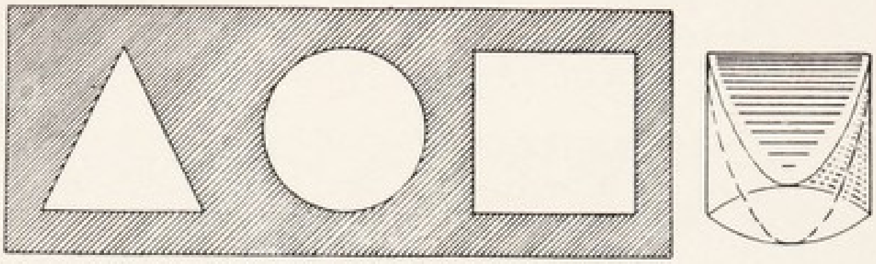


FIG. 281.

That the apparently peculiar shadow outlines of the duodenal cap may be due to quite normal anatomical forms, can be best indicated to the sceptic by asking and answering the following question: "What shape must a solid body have, for it to be passed exactly through openings of a board at once triangular, quadrilateral, and circular?"—Answer: "It should have a form like Fig. 281, B." In case the illustration is not plastic enough or incorrect in plastic, one can secure such a body by taking a massive cylinder and cutting it in the form of a roof with equal sides and diameter, so that the two halves of the roof reach as far as the base of the cylinder.

Quite similar conditions appear in the duodenal cap, which, according to its state of tonus, has the form of a more or less stiff or soft cap for the head, as worn by the soldiers of many nationalities. Sometimes the height of the cap is less than, sometimes more than, the diameter of the base, the floor; and the length of the top or peak of the cap is not usually the length of the diameter of the base. When one considers that the cap in Röntgen projection in different people can be represented in space in almost all positions according to constitution, filling, etc., one will readily appreciate the enormous variety of shadow views of the normal cap. And still more the pathologically changed cap will produce an infinite number of shadow forms.

is usually due to differences in the size of the liver or the gall-bladder or to abnormal adhesions.

There is little that can be said about *peristalsis* in the duodenum. It appears that the contraction through which a full cap empties is to be regarded as a progressive muscular wave of considerable width (rather than a contraction cylinder).

A small gas-bubble is sometimes found in the upper part of the duodenum, at the summit of the first part, and at the point of flexure to the pars descendens. Some experts have urged this as a sign of ulcer, others explain it as perfectly normal; a gas-bubble at the flexure should never be confused with a gas-bubble in the niche of an ulcer or a penetrating ulcer.

Regarding the filling of the bulb: it usually fills at once during the taking

[1] Holzknecht: Die Duodenalstenose durch Füllung und Peristaltik röntgenologisch erkennbar. D. Ztschr. f. Chir., Bd. 105, Heft 1 and 2.

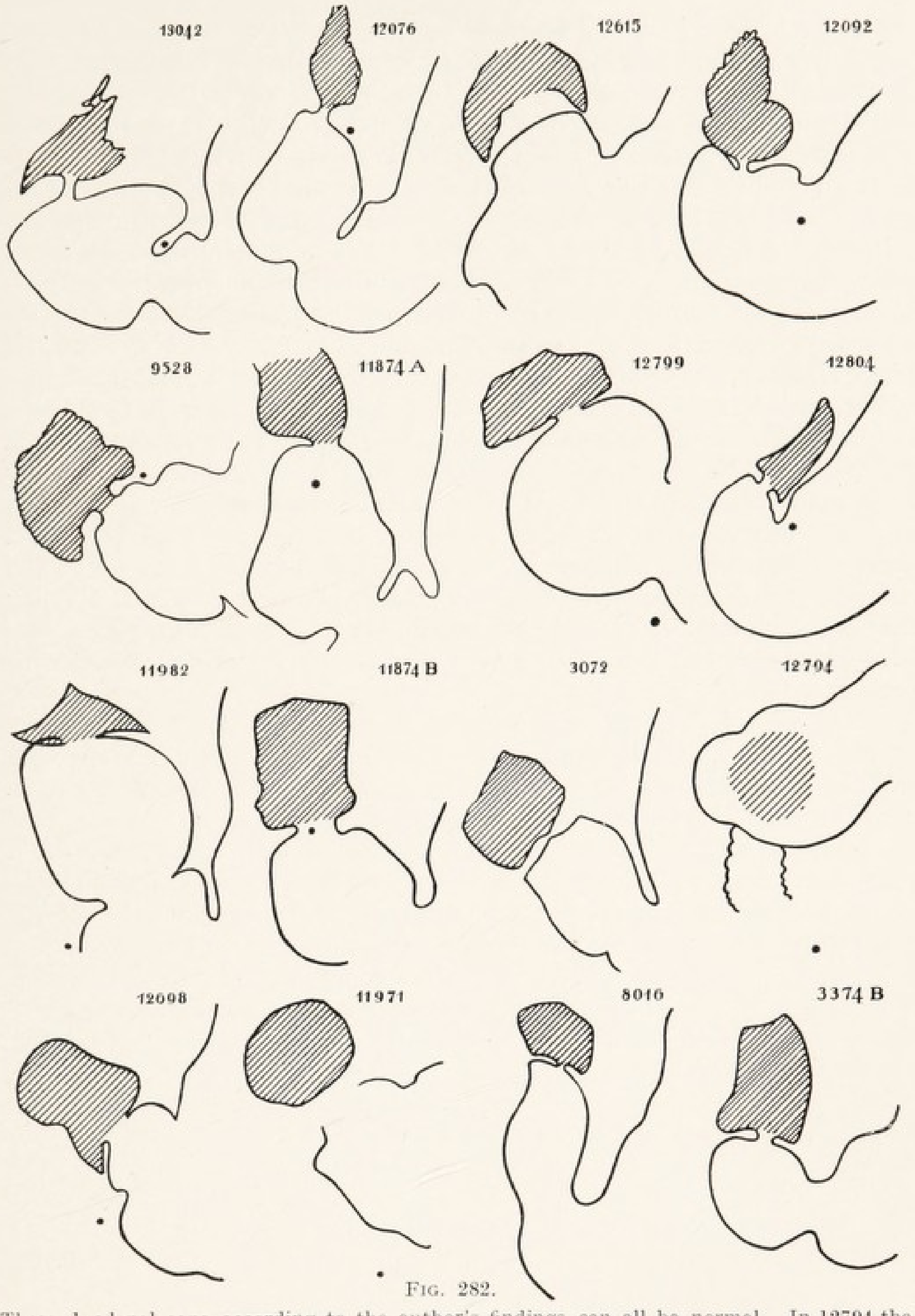


FIG. 282.

These duodenal caps, according to the author's findings, can all be normal. In 12794 the reader has to think of the cap as right behind the pyloric end of the stomach; it does not appear in the picture, but is traced in. In some cases (12076, 12804, and others) the form of the cap is the immediate result of the pyloroptosis, elongation or diagonal position of the stomach; without knowing the form and position of the latter, we could deduce it from the form of the bulb. Diagrams 11874 A and B were from the same case taken at a short interval. From the "rippled" appearance of 9528 spasm appears to be present.

of the meal; occasionally it takes 10–15 minutes before the barium passes the pylorus. It is possible, though not certain, that a 15-minutes' delay is within the normal limits.

Concerning the emptying time of the duodenum reports are very various. One author states 25–60 seconds.[1] Another thinks [2] that the duodenum—after intake of a small amount of thin contrast fluid and propulsion of the greater part of it into the duodenum—should be emptied normally in a few minutes. A third [3] found a multiple of this time as normal, especially in long J-formed types of stomach. In examination after an ordinary contrast-meal one finds the cap more or less well filled. Under the action of the muscularis contractions the cap empties itself at longer or shorter intervals; often, however, not completely, but on each contraction a smaller amount of barium is left behind within the base of the cap. The cap in these cases has the character of a reservoir or a receptacle, which gets ever refilled from the pylorus. In other cases the cap empties itself completely at every fresh contraction, and in certain cases these contractions come so quickly, at least when the stomach begins to empty, that the cap is filled up for a short moment with contrast-meal. During later stages of emptying of the stomach the contractions of the cap may occur at longer intervals, enabling the observer better to examine the conditions at the cap. Where exactly the normal ends and the pathological begins cannot yet be determined with certainty.

A duodenal ulcer only gives slight alterations in the Röntgen view, although they are usually quite characteristic; it can easily, therefore, be missed or misinterpreted, so that every detail of the direct symptoms must be gone into exactly and thoroughly. Above all, the direct proof of the anatomical lesions by the plate method should be secured with a single film or a series of exposures. For the indirect method of röntgenoscopy of arriving at a diagnosis on the result of the screening and the orderly interpretation of symptoms can replace röntgenography only in a very few cases, and can be the occasion of considerable mistakes, for in this method the changes in the duodenal shadow—which are often slight—are overlooked, and certain manifestations from the stomach side accompanying the duodenal ulcer come prominently into view.[4] Only the chronic, so-called peptic ulcer comes into consideration in Röntgen examination, and this in the vast majority of cases has its seat in the first part of the duodenum (about 90 per cent.), *i.e.* in the duodenal cap, and in the part of the gut immediately abutting upon the pylorus. Surgical statisticians differ as to whether the anterior or the posterior wall is the seat of election. At all events the ulcer—just as in the stomach—selects the lesser curvature,

[1] Desternes: Röntgenographie du duodénum. Bull. et mém. de la Soc. de Rad. méd. de Paris, July, 1910.

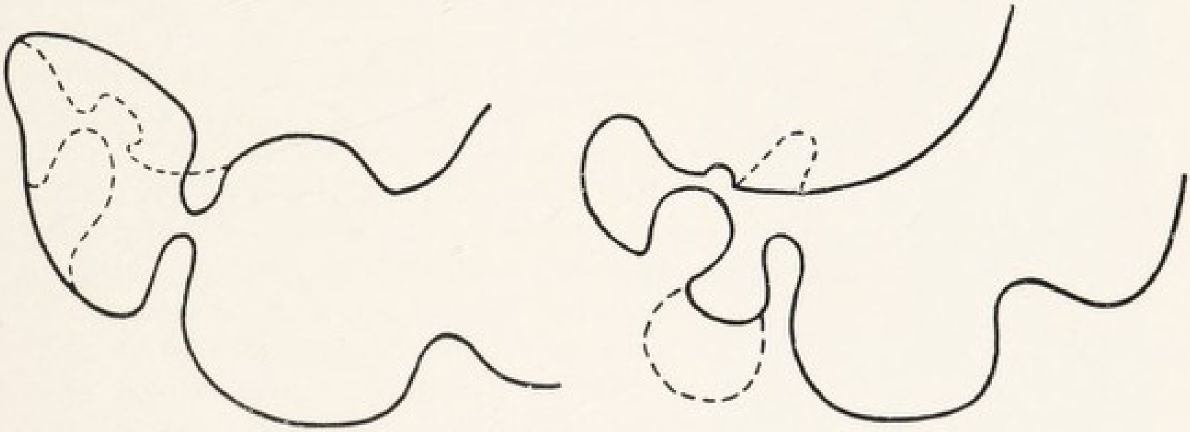
[2] Holzknecht, *l.c.*

[3] Åkerlund, *l.c.*

[4] Verbally after Faulhaber-Katz: Die Röntgen-Diagnostik der Darmkrankheiten, 2nd ed., Halle, 1919, pp. 48/49 (printing rights reserved).

certainly nearer the lesser curvature than the greater curvature.[1] Further, chronic duodenal-ulcers appear to be solitary in about 95 per cent. of the cases.[2] A completely negative operation finding does not settle the problem whether an ulcer is present or not. An ulcer can heal up within a month ; that is to be remembered in scientific inquiries upon cases when any considerable time has elapsed between the Röntgen examination and the autopsy. Complications of duodenal ulcer are stenosis and diverticulum formation ; the first occurs in at most 10 per cent., diverticula are still rarer. Moreover, periduodenal formation of adhesions are very rare in the first part of the duodenum, certainly much rarer than is usually believed. For Dilatation and Diverticulum, see later.

It appears that—with extremely rare exceptions—every open duodenal ulcer involving the deeper layers of the duodenal wall produces a demonstrable form, or contour-change of the duodenal cap, given careful irradiation and exposures. The literature gives certain changes in the form of



A Fig. 283.[3] B

the duodenal cap as pathognomonic of duodenal ulcer : Conical, Trefoil-shaped, Hook-form bent backwards, Pine-tree form, Coral-like, Rod-like or Sword-form, more rarely a Vermicircular pyloric process, Hook-like pyloric process or spur. All these forms are, however, explainable upon one or several of the following principal grounds :

(1) The niche-like projection of the cap shadow produced by the crater of the ulcer (Fig. 283, A, the dotted projection of the lesser curvature).

(2) The indrawing of the so-called defect in the duodenal cap caused by spasm, new tissue formation, scar contraction or adhesions (A, the dotted indrawing on the greater curvature). This defect may also be produced by swelling of the folds of mucous membrane or abnormal spastic contractions of the same, without any spasm of the tunica muscularis.[4]

(3) The retraction or shortening of the cap contour caused by scar

[1] Åkerlund, *l.c.*, this and the following statements are almost verbally taken albeit in a condensed form from, Åkerlund's monography on the Duodenal Cap.

[2] But see six pages further on, under " By direct compression of the cap."

[3] After Åkerlund, *l.c.*

[4] G. Forssell : Acta Rad., Vol. III, 12/13, 1924, pp. 217 *et seq.*

contraction or spasm, which often produces an asymmetry and an eccentric position of the lumen of the pylorus (Fig. 283, A, the dotted flattening of the lesser curvature in front of and behind the niche).

(4) The more or less defined, saccular or diverticulated projection of the cap shadow usually situate within the annular recess of the cap produced by the formation of a duodenal ulcer (Fig. 283, B, the dotted projections).

These four form types combine in various ways, but sometimes appear individually and distinct. Changes in the form of the cap, which a few years ago were ascribed usually as due to spasms, appear frequently, according to the more recent researches, and in the majority of the cases are due to swellings of the mucous membrane.

FIG. 284.[1]

The formation of a niche is as frequent in the duodenum as in the stomach. From the practical standpoint it is the most important Röntgen symptom, being found in about 60 per cent. of definite cases of duodenal ulcer. The usual pathological basis of a niche is an ulcerated crater in the callous and thickened duodenal wall. Probably with improvements in technique niches will be demonstrated in even larger numbers even in non-callous ulcerations—such as simple indurated or non-indurated intramural ulcer and the scars of ulcers covered over with mucous membrane. Gas-bubbles may occur in niches of the duodenal cap.

The niche is usually situated, as mentioned above, on the lesser curvature, and is nearly always accompanied by a deep indentation on the greater curvature (see Fig. 283, A and B). If this bulbar deformity be lacking, the correctness of the diagnosis of a niche should be questioned. On the other hand, the deformity may catch the eye first, and be the means of leading to the diagnosis of an ulcer-crater.

At the same time the contour of the cap in the vicinity of the niche is usually altered; the contour of the lesser curvature which is normally more or less convex is shortened, retracted, and indrawn towards the axis of the cap. It now runs more or less straight or becomes even slightly concave. The retraction often produces obliteration of the annular recess at this part of the bowel, completely or partly masking the outline of this half of the cap, and displacing the lumen of the pylorus into an eccentric and more or less patent position (see Fig. 283, A, and Fig. 286A).

One should remember this complex of three symptoms and refer to Fig. 283, A. They represent the points of chief practical importance.

[1] After Stierlin.

In about 10 per cent. of definite cases of duodenal ulcer *the niche*—which is then very small—is placed on the pyloric border of the cap (Fig. 284←). When these niches are present there is not usually any other deformity of the cap. The niches may make their appearance at any part of the recess.

Niche formation on the greater curvature occurs in scarcely one per cent. of cases (of definite ulcer niches of the duodenum). Opposite it there occurs a round indrawing of the lesser curvature.

Further, there are some 10 per cent. of niches situated high up on the cap, on the anterior or posterior wall of the cap. One should not fail to recollect the physiological defect illustrated in Fig. 279, B.

All the niches mentioned are favourable in so far as they are projected by rays passing tangential to the cap, and are seen in profile. Naturally some niches are so placed that they are covered by the whole shadow of the cap, the so-called "*Enface-niches*" (about 4–5 per cent. of the cases). They yield complicated shadow pictures, in which an indrawing on the right and left side of the bulb is the most constant symptom (probably also on both sides. Author).

Fig. 285.

The *type of cap defect* given above in (2) is usually of spastic nature, as is also proved by its beautiful wavy and changing contour. (A wider experience of the effect of anti-spasmodics is desirable.) An organ cap defect is naturally lacking in rounded form, it is angular, irregular, relatively shallow, and does not change its form (except at long intervals).

In the case of Fig. 285, which has not yet been operated on and whose clinical symptoms point to a definite ulcer, the defect is not quite circular and sharp; at the same time its form does not appear to alter. It is, therefore, certainly not of a spastic nature, at least not in the main. Moreover (in the examination made), a niche was not found.

At the pyloric contour of the cap there sometimes appear very small though usually sharply defined indrawings, usually two or more. Their origin is probably spastic, probably local contraction of the muscularis mucosæ at the site of the ulcer itself, probably small fissural ulcers, which are placed between the radiating folds of mucous membrane formed by the contraction of the pyloric sphincter (*cf.* anal fissure).

The retraction mentioned above under point (3) can be caused either by a spastic state of contraction or by organic changes or by both. Usually the retraction arises through a combination of spastic and organic changes. The retraction is wont to produce, as already mentioned, *a wide patency of the pylorus.*

Of the diverticula formations of prestenotic origin mentioned under the four headings the largest are at the greater curvature of the stomach ; they are placed inside the basal part of the bulb and immediately oral to a deep indrawing of the greater curvature (Fig. 283, B). Smaller diverticula on the lesser curvature can sometimes be confused with an ulcerative crater, all the more that their position closely agrees with the predilection site of

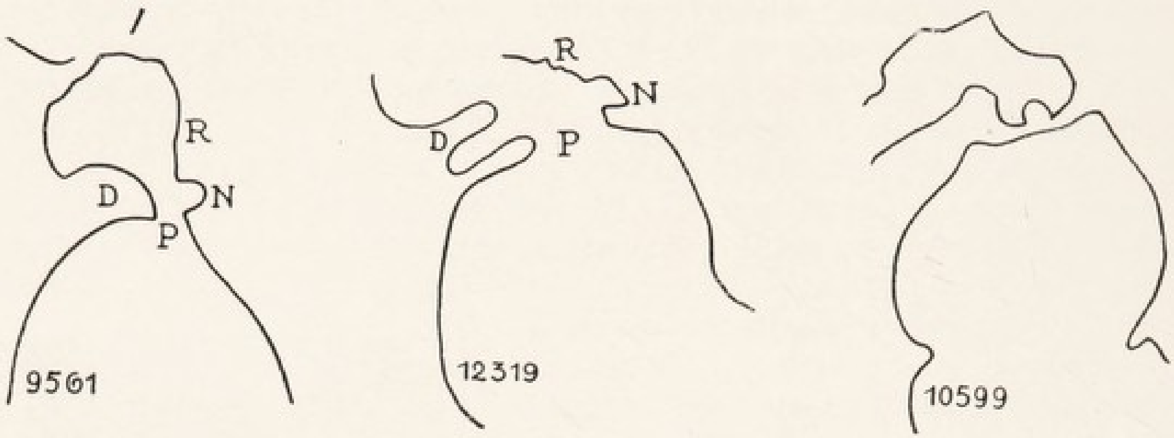


FIG. 286A.

bulbar niches ; nevertheless, they possess the power of contractility and are placed not like niches at the level of the bulbar indrawing of the greater curvature side, but clearly to the oral side thereof on the lesser curvature. Such a diverticulum seems to be an indication (according to autopsy

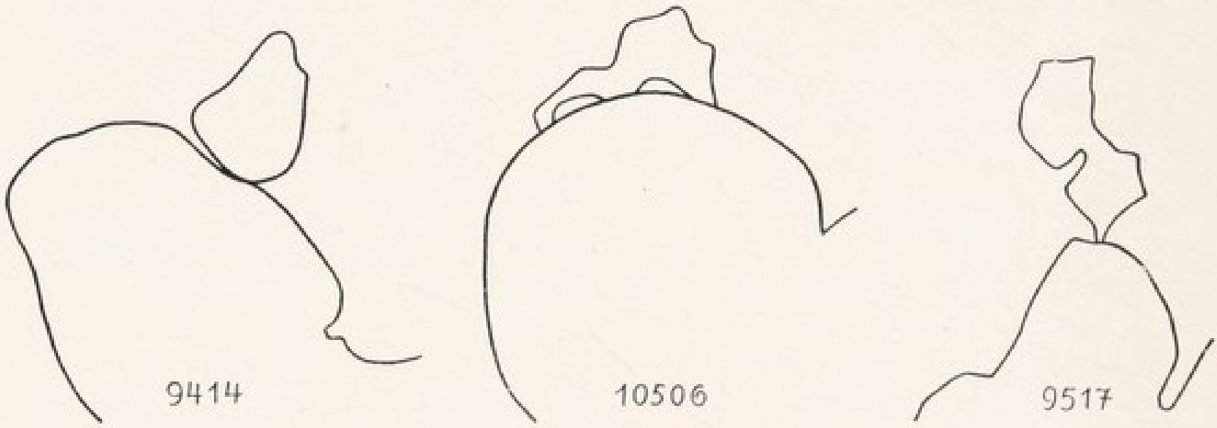


FIG. 286B.

findings) that there is an organic narrowing below it. These diverticula are therefore to be classed as pulsation diverticula. Traction diverticula are rarer, arising through long-continued pull or through contraction of adhesions accompanying the duodenal ulcer.

Figs. 286A and B show some cases of duodenal ulcer confirmed at operation,.

An extreme diminution of the bulb by processes of contraction, a " phthisis bulbi," can also arise in duodenal ulcer (see Fig. 286B ; three cases of the author confirmed at operation) ; they should not, however, be confused with an incomplete filling of the cap.

Dextroposition and dextrofixation of the pylorus and the cap is not infrequently met with in duodenal ulcer ; one should note, however, that the former is a physiological event in stout fat people with elevated diaphragms. Dextroposition can be brought about through abnormal gas-ballooning of the colon, which now and then is present in duodenal ulcer in considerable degree ; also through enlargement of the stomach, also through periduodenal adhesions ; and also simply through the extreme hypertonus sometimes seen in duodenal ulceration.[1]

Persisting cap (continuous filling of the cap during and even hours after complete emptying of the stomach) and also " persisting cap-spots " (more definite, usually round contrast spots within the area of the cap, that remain after repeated contractions of the cap and after emptying of the stomach) were held as pathognomonic of duodenal ulcer in the earliest years of röntgenology ; they do not now carry so much diagnostic weight ; the former may occur in various forms of pyloric insufficiency without any ulcer being present,[2] the latter do not appear any more to be reliable signs of ulcer ; occasionally, however, one can easily understand it does happen that a persistent spot in the cap is caused by retention of barium in the crater of an ulcer, in other cases by retention in other parts of the cap and in diverticula.

Normal remainders in the cap can be expressed more or less easily, but barium in a niche cannot be pressed out by the hand without danger.

Tenderness to pressure on the cap seems to possess a diagnostic value for duodenal ulcer, when it is a feature well-marked and definitely circumscribed, and clearly follows the cap on indrawing of the abdomen, manual displacement and change in position.

An occasional anomaly occurs in the first part of the duodenum, *the formation of a loop*. It hangs like a garland between the summit of the cap and the superior flexure of the duodenum, its convex surface directed downwards and dilated into the form of a purse (Fig. 286D).

A very *extreme diverticular dilatation of such an abnormal loop* was present in Fig. 286C. Complaints : 1–1½ hours after food colicky pains over the umbilicus, not followed by any action of the bowels. The clinical signs suggested neurosis or ulcer. The patient later, without letting the surgeon know of the Röntgen examination, submitted to operation. It was four years later before the author came to hear of it. The surgeon upon inquiry said that he had not found anything akin to ulcer and had closed the abdomen up again. He does not appear to have seen anything unusual in the duodenum. Three further negatives of the patient showed the same condition.

In pericholecystitic adhesions deformities of the cap sometimes appear, and the majority of authors find it impossible to distinguish them from

[1] Baron and Bársony, further Paul Eisen, quoted by Åkerlund.

[2] v. Bergmann : Die Röntgendiagnostik des Ulcus duodeni. Röntgentaschenbuch, 1913, 5. Bd.

ulcerative changes, seeing that duodenal hypermotility of the stomach may be present in both conditions. At the same time one should recollect that affections of the gall-bladder and duodenal ulcer may sometimes occur simultaneously.

New growths in the cap (papillomata, etc.) bring about deformities that simulate ulcer; they are, however, extremely rare and set up a different train of clinical symptoms.

An appearance of the bulb "as if wrung out or cut up," resembling ulcerative deformity, is often due to "distance spasm"; it can arise in a number of irritative conditions extrinsic to the duodenal wall, like chronic appendicitis, ileostasis, kidney conditions, gall-stone affections.[1] In them,

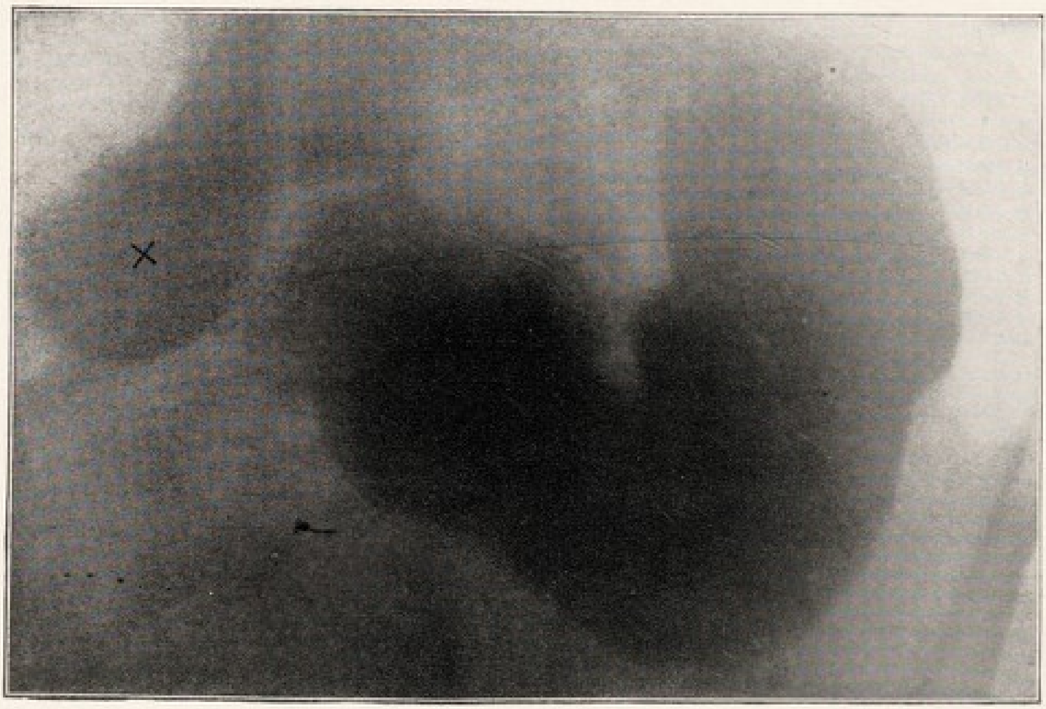


FIG. 286C.

however, the shadow details alter during examination, and they should disappear on giving belladonna.

Increased function of the stomach, consisting in hyperperistalsis, hypertonus, hypermotility, "duodenal stomach-motility," and hypersecretion of the stomach are held to be *indirect symptoms of duodenal ulcer*. In such circumstances if there is no direct Röntgen symptom in the duodenum one should be exceedingly chary of diagnosing a duodenal ulcer. Only direct and local symptoms caused by a change in the duodenal wall can be of decisive value in the diagnosis of duodenal ulcer, above all the proof of the existence of the ulcer-crater itself, the defect of substance in the wall of the niche. And also the defect on the greater curvature side of the cap, even when it forms the only deformity of the cap, is indicative of duodenal ulcer

[1] Cole, quoted by Åkerlund, pp. 235–236.

in the majority of cases, becoming almost a certainty, when a retraction occurs simultaneously on the lesser curvature side. Diverticula of the cap without an associated ulcer appears to be extremely rare.[1]

The diagnosis of niche in duodenal ulcer has made great progress in recent years through direct compression of the cap by means of cushions of wool, cork, or aluminium (between the cassette-holders and the patients). It is thus not uncommon to exhibit small superficial niche formations in the cap, which without compression show an almost completely normal appearance. And upon compression of a deformed cap niches may be brought into view that were not before visible, with not infrequently distinct folds converging towards them from different sides. Thus niches are found on the anterior or posterior wall of the cap (" relief-niches " distinctly oftener than the so-called " classical " contour-forming lesser curvature niches). It is thus becoming relatively more frequent to diagnose multiple ulcers. Almost in every case in which autoptic control was secured it has been shown that a niche formation diagnosed by the Röntgen rays had an ulcer crater for its anatomical basis.[3]

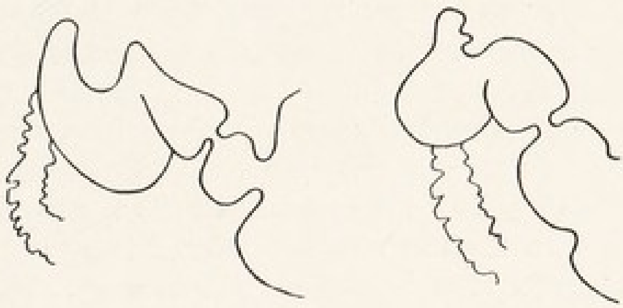


FIG. 286D.[2]

Several authors [4] consider a peg- or rod-like or occasionally worm-like *process of the pylorus* (a pyloric hook) to be pathognomonic of duodenal ulcer. Spasm of the cap with at the same time pyloric insufficiency is regarded as the cause of the occurrence of such a Röntgen shadow.

Occasionally a peristaltic ring-wave can simulate a cap defect or hourglass duodenum.[5] Unfortunately, papaverin does not usually assist us to make the differential diagnosis.

Paradoxical retention in the stomach is of some importance in the diagnosis of duodenal ulcer. The emptying is rapid to begin with, initial hypermotility, yet a small portion of meal remains behind for hours in the stomach. How this condition is brought about is not yet clear.

Whether *mirror formations* in the cap are normal or not has not been decided yet.[6] An air-sac is in any case a normal occurrence at the summit of the duodenum.

A dilated cap, whose shadow appears more circular than the normal form, is regarded as a result of diminished duodenal peristalsis ; as digestion

[1] All these observations condensed from Åkerlund's monography.

[2] After Åkerlund.

[3] Åkerlund : Nordischer Radiologen-Kongress in Copenhagen, 1927 ; due to appear in Acta Rad.

[4] Bier ; Stierlin ; Chaoul, quoted by Schlesinger.

[5] Hans A. Hofmann : Zur Röntgenologie des Duodenum. Münch. med. W , 1921, No. 5.

[6] For further details, see in Teschendorf, *l.c.*

proceeds there takes place a lessening or complete cessation of the propulsive peristalsis of the duodenum. It sometimes happens that this lessening or stoppage sets in while the stomach still contains barium and is going on emptying.[1] The meal then remains an abnormally long time in the cap and the cap dilates more than normal. Sometimes the motor strength still present in the stomach is sufficient to drive the meal on into the descending part and the horizontal part. (The picture that then arises cannot be confused with duodenal stenosis, because hyperperistalsis is present in the latter.) It is a remarkable fact that this lessening of duodenal peristalsis during the later stages of gastric evacuation is somehow (directly or indirectly) related to ileostasis and ileodilatation, just as if the over-filled ileum wished to prevent the food from leaving the stomach too quickly. The commonest cause of ileostasis again is stasis in the colon.

Also in ulcus ventriculi a very large cap is often found.[2] Moreover, a dilatation may be simulated by mistakes in projection. Also anomalies of the cap might occur. In one case the dilatation disappeared on the injection of papaverin, the condition being therefore due to spasm in stomach and duodenum.[3]

In slight degrees of duodenal stenosis one observes a more or less *extensive dilatation of the cap*. These slight duodenal stenoses are not directly visible. The enlargement of the cap is established in such a case by filling it with the aid of the duodenal tube and from the secondary manifestation deducing the fact of the primary stenosis distal to it.[4]

Dilatation of the duodenal cap may also occur in consequence of pyloric insufficiency.

More rarely one meets with a *bubble of air at the top of the duodenum* or duodenal cap. Some observers consider this a pathological appearance, while others of equal authority regard it as perfectly physiological.

In a case suspected of *chronic ulcer* (about 95 per cent. of duodenal ulcers are situated near the pylorus) screen examination should be carried out and then several röntgenograms taken. If even only one of these shows a quite normal picture of the cap, this almost excludes the possibility of a callous ulcer being present, even if several pictures show abnormalities in the same case. The normal cap has sharp slightly curved contours without indentations (see Fig. 279, A). Every defect or every departure from the normal contour can be regarded as pathological, when the particular finding remains a constant one.[5] The most important indirect symptoms are: increased peristalsis, six-hour remainder, and several hours after emptying of the stomach contrast-meal still present in the duodenum. Occasional

[1] L. G. Cole, *l.c.* Relation of lesions of the small intestine, etc. Amer. Journ. of the Medical Sciences, July, 1914.

[2] Rosenthal, *l.c.*

[3] Faulhaber and Katz, *l.c.*

[4] O. David: Dilationen des Duodenum im Röntgenbild bei directer Füllung. Fortschritte, 1914/15, Bd. 22.

[5] George and Gerber: The Röntgendiagnosis of Duodenal Ulcer. Surgery, Gynecology and Obstetrics, September, 1914.

symptoms: hypermotility and hypertonus of the stomach and tender spots in the duodenal region.

If the cap appears as if hollowed or wrung out, but at the same time contrast-meal remains behind in single large folds, we have to deal with *a spasm of the cap.* Reduction in the lumen of the cap usually occurs at the same time, especially if the spastic condition has been present a long time (as in chronic appendicitis). The Röntgen picture produced resembles in other respects that of a postpyloric ulcer; the cap appears as if scarred and contracted. This spasm (see also above, p. 450, in spasm of the pars pylorica which may be combined with spasm of the cap) is often a sign of concomitant acute or chronic appendicitis or of other distal lesions of the intestine, colon carcinoma, and the like.[1]

We may perhaps here sum up all *the signs of ulcer* of the duodenum given in the literature, enumerating both the indirect and the direct symptoms. *Indirect symptoms* (clinically: hyperchlorhydria, hypersecretion, and pylorospasm): Increased and deepened peristalsis of the stomach. Increased tone of the stomach. Immediate passage of quantities of contrast-meal through the open or frequently opening pylorus into the bowel, on the other hand (after two hours), retarded emptying of the stomach, six-hour remainder (both of them uncommon in the author's experience), displacement to the right, and ptosis of the stomach. Following the stage of hyperperistalsis ensues a stage of complete exhaustion of the stomach wall with marked hypersecretion. The indirect signs, however, may be quite undependable, and may be produced just as well by a cholecystitis or some other condition referable to the gastro-intestinal nerves. Further, the eccentric position of the pylorus in comparison with the cap and the propulsion of the pylorus as such are included in the indirect symptoms of ulcer, both of them being products of periduodenal adhesions. In " Propulsion " (Schlesinger), " Forceps-movement " (Groedel), it appears as if the pyloric end of the stomach became fliped over the duodenal cap. Hurried filling of the cap is also another indirect symptom (diseased intestine being more rapidly traversed by food-stuffs than the normal).

Direct symptoms: Compare the above description and further—albeit the last word has not yet been said on this important subject—let us now enumerate the symptoms that have been regarded in the last decade with more or less right as direct signs of ulcer. These are: Persistent spot in the duodenum. Irregular emptying of the duodenal cap. Spigot-like passage of a stenosis of the duodenum with atonic dilatation of the stomach. Deformities of the cap. Hour-glass cap. Persistent cap. Persistent spot in the bulb. Parabulbar spots of contrast-meal. All of these are expressions of the interruptions of tone and peristalsis in the commencement of the duodenum due to ulcer. The deformity of the cap

[1] Cole, *l.c.*, and Brewer and Cole: The Röntgenologic Diagnosis of surgical lesions of the stomach and duodenum. Annals of Surgery, January, 1915; further Cole: Negative Diagnosis of surgical Lesions of the stomach and cap. Am. Journ. of Röntgenology, November, 1914.

may have the form of a crater, of a piece of coral, of an incisura or of a filling defect; spastic conditions of the cap would speak for a fresh ulcer, and are therefore expressed in a marked change of its form: on the other hand, scar changes are evidenced by constant defects in filling. Pyloric process, probably through spasm of the bulb of the duodenum alone or with parapyloric stenosis due to scar; insufficiency of the pylorus evidenced by manipulative compression.[1]

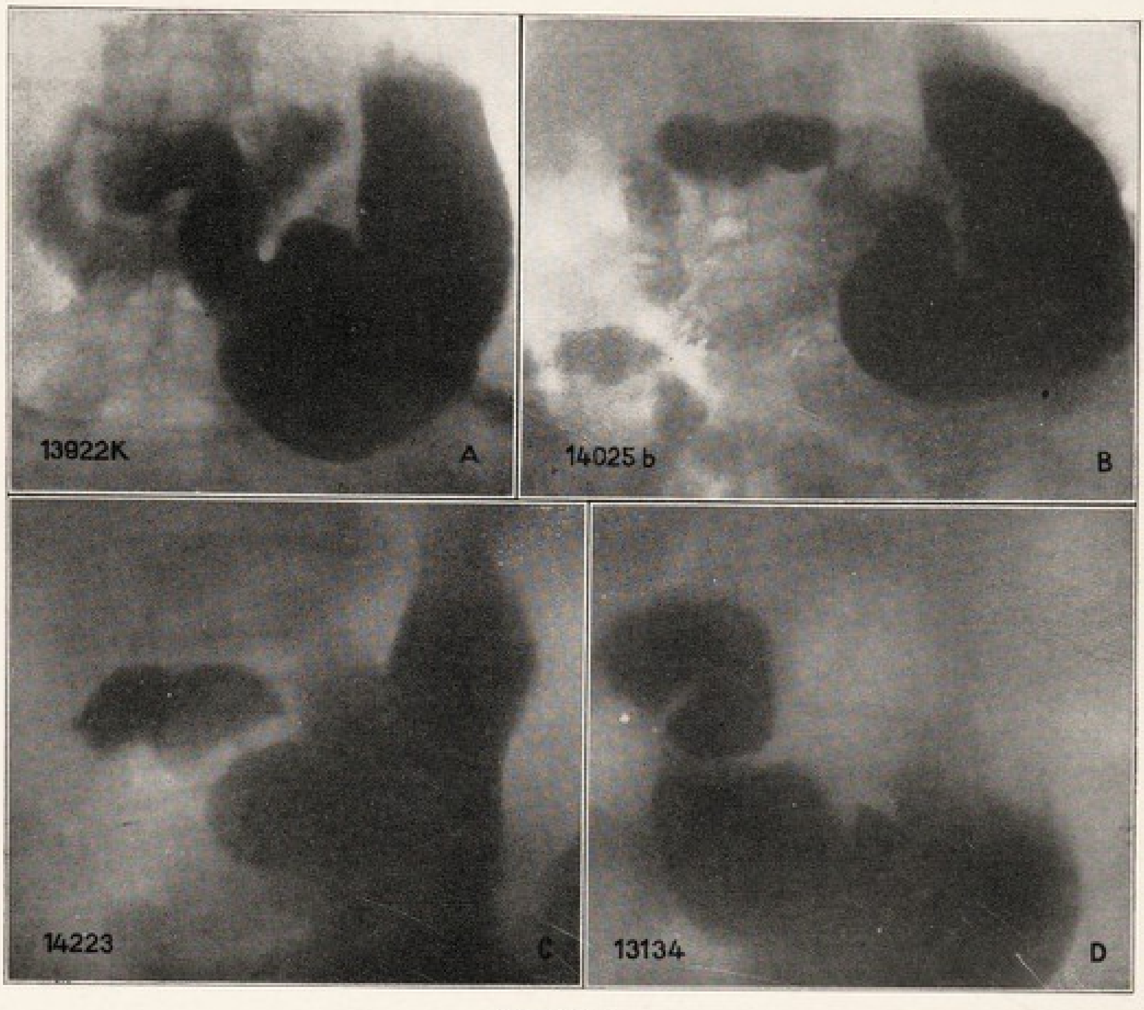


Fig. 287.

The normal flask, onion or egg-shaped portion, the cap, often includes the whole or nearly the whole of the first part of the duodenum as far as the superior flexure of the duodenum. But there is sometimes a short piece of it attached to the cap, before the duodenum can be described as the pars descendens. Thus it was shown in Figs. 286c and 286d, that as an anomaly a more or less marked extension is sometimes like a loop to the cap. What is normal, what is a harmless anomaly, what is certainly pathological, is at the moment still very difficult to decide. Those cases that have very few symptoms are unlikely to be cleared up by operative interference. Let us refer to a few cases and appreciate them as best we may. Fig. 287, A:

[1] Summarised from Chaoul, Stierlin, Barclay, Bier, Campo.

The cap extends in the horizontal position, or a congenital loop-formation is related to a small bulb. This finding can be considered as normal, or rather as a harmless anomaly, for we are dealing here with a purely accidental finding, found in a technical negative. The patient, forty-three years old, of asthenic type, has never had stomach or duodenal symptoms in his life. In B of the same illustration a well-defined although relatively small cap is present. To that is connected a portion running horizontal $3\frac{1}{2}$ cm. long and the thickness of the finger, apparently hypotonic, and then comes the pars descendens turning downwards at right angles. In this case also a congenital anomaly may have been present, for the patient, now fifty-two years old, is believed to have suffered from gastric cramps as a child. For all these cases it should be remarked that the patients required to submit to an operation on the uterus (? adhesions). The short filled horizontal portion, in direct relation to the large normal cap, seen in C of this illustration, is probably to be described as normal or at least practically normal, although the patient of fifty-five years has definite symptoms which a stomach specialist ascribes to ulcer. On the other hand, D must be regarded as certainly pathological, and as a dilatation of the first part of the duodenum, with a stenosis behind it (?). Also the passage from the pars descendens into the pars ascendens is enlarged. At an operation later an old crateriform ulcer was found on the lesser curvature.

Fig. 288.

The first part of the duodenum is more freely movable than the pars descendens, which is fixed to the back of the abdomen: it follows that a ptosed stomach must affect the view of the commencement of the duodenum. In any marked degree of gastroptosis, therefore, there is visible a marked *kinking of the first part* against the pars descendens. The cap receives, therefore, a narrower form drawn out upwards and to the right; see Fig. 288 (laparotomy without pathological finding in stomach and duodenum). In a plate taken in the prone position similar views are obtained.

Pars descendens and Pars transversa

At the junction of the middle and lower thirds of the pars descendens there often occurs a slight physiological arrest of the contents. Is this functional or organic? At this spot the mesocolon passes over the pars descendens. That is thought to be the cause.[1]

The pars ascendens and the duodeno-jejunal flexure are completely covered by the stomach. At the point where the pars descendens passes into the pars ascendens the root of the mesentery crosses the duodenum.

[1] Teschendorf, *l.c.*

In adhesions to the intestines retardations in quite a normal duodenum may occur through dragging of the mesentery.

An irregular radiating *filling-defect* on the medial side of the descending part of the duodenum, about 5 cm. behind the pylorus, was diagnosed as carcinoma of the duodenum and confirmed at operation.[1] Carcinomata of the duodenum are extremely rare.

A round, sharply defined spot of contrast-meal belonging to the pars descendens and showing relatively great mobility, not tender to pressure, and remaining in place days after emptying of the stomach and duodenum, was recognised as *a diverticulum* and confirmed by operation. Clinical history : " stomach troubles " after meals for fifteen to twenty years ; sour mouthfuls ; apart from eating, troubled in the night towards morning.[2]

A backflow of the meal from the pars transversa into the pars descendens up to the duodenal cap is very common. One finds this in almost half of all cases suspected of ulcer. It is still at the moment not quite clear whether it is normal or pathological.[3] An easy source of mistakes is the following : The pars ascendens can be covered over by the pars descendens. If now a small collection of barium passes through the pars ascendens, that may give the impression as if the meal were travelling back into the pars descendens. That is cleared up by turning the patient into another position.

Congenital stenosis of the duodenum are situated usually at the exit into the jejunum.

Organic stenoses naturally afford more typical pictures than *spastic*.

In slight degrees of duodenal stenosis one observes a more or less extensive dilatation of the cap. These slighter forms of duodenal stenosis can hardly be seen directly, the enlargement of the cap in such cases being diagnosed by the aid of the duodenal tube ; the primary stenosis further on can in this way be logically inferred.[4]

A cap (bulb) greatly enlarged in its distal portion, and also a stenosis at the junction of the middle and lower third of the pars descendens duodeni with a huge dilatation is shown in Fig. 289. That considerable adhesions are present is deducible from the great collections of gas in the neighbouring parts of the intestine. At the same time the pars descendens at the lowest border of the dilatation turns upwards and somewhat to the left, coming finally to run above the cap. The pyloric part of the stomach is also broadened out. Symptoms : A great deal of eructation for the past year. (The

[1] J. T. Case : The Röntgen-Investigation of Carcinoma of the Alimentary Tract. Interst. Med. Journal, July, 1915.

[2] Forssell and Key, Stockholm : Ein Divertikel an der Pars descendens duodeni, mittels Röntgenuntersuchung diagnosticiert und operativ entfernt. Fortschritte, Bd. 24, 1916.—For duodenal diverticula see also : J. T. Case : Röntgen-Observations on the Duodenum with special Reference to Lesions beyond the first Portion. Amer. Journ. of Röntg., June, 1916

[3] See also O. Bilfinger : Die Durchleuchtung des Duodenum. Fortschritte, Bd. 31, 1924.

[4] O. David : Dilatationen des Duodenum im Röntgenbild bei directer Füllung. Fortschritte, Bd. 22, 1914/15.

patient still lives, eight years after the particular Röntgen examination, without an operation having been required.)

A pars descendens duodeni bent to the right cannot be considered normal. It indicates the formation of *adhesions*. A number of autoptic findings have been made. It is best described as a "lateral bend" and can always be regarded as a sign of *pericholecystitis*.[1] At any rate, one can usually in lateral bending of the duodenum diagnose with a measure of reserve the formation of adhesions. Apart from the bend there is

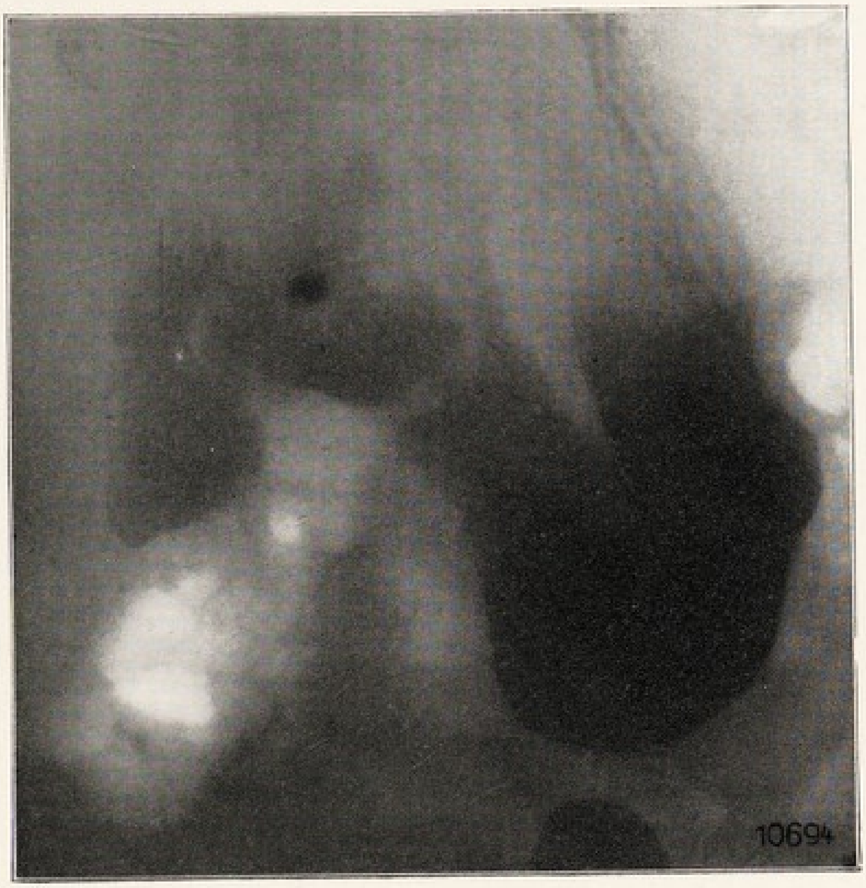


Fig. 289.

usually a reduction of the distance between the pylorus and the hepatic flexure. Naturally it is impossible to determine whether the adherent strand is non-inflammatory, inflammatory, or the remains of a previous inflammation.

Two cases with adhesions of the superior flexure or rather of the upper part of the pars descendens to the liver or gall-bladder are met with in Fig. 290, A and B. The two röntgenograms are almost identical in appearance; one might almost think we are dealing with a not uncommon anomaly. But the many other exposures, at any rate of case A, leave no shadow of doubt

[1] First communicated by Ehrmann and K. E. Neumann, confirmed by Siegfried Weinstein: Zur Röntgen-Untersuchung der Pars descendens duodeni. Fortschritte, Bd. 31, 1924.

that adhesions are really present. In B, in addition, the pars pylorica (canalis egestorius) is extended in a horizontal direction, while in A in another negative a large rounded dilatation is present opposite the adhesion.

A widely atonic duodenum may mislead one into failure to diagnose a dilatation from a stenosis. A certain decision is not always secured.

Seeing the duodenum is directly fixed to the posterior abdominal wall, *a ptosis of the duodenum* is extremely rare. It occurs only in myasthenia and also in general enteroptosis.

In diseases of the duodenum (and of the gall-bladder) the hypermotility may extend as far as the great bowel, and six hours after the intake of the barium meal have proceeded as far as the splenic flexure.

A remarkable finding reported from a number of sources is apt to be

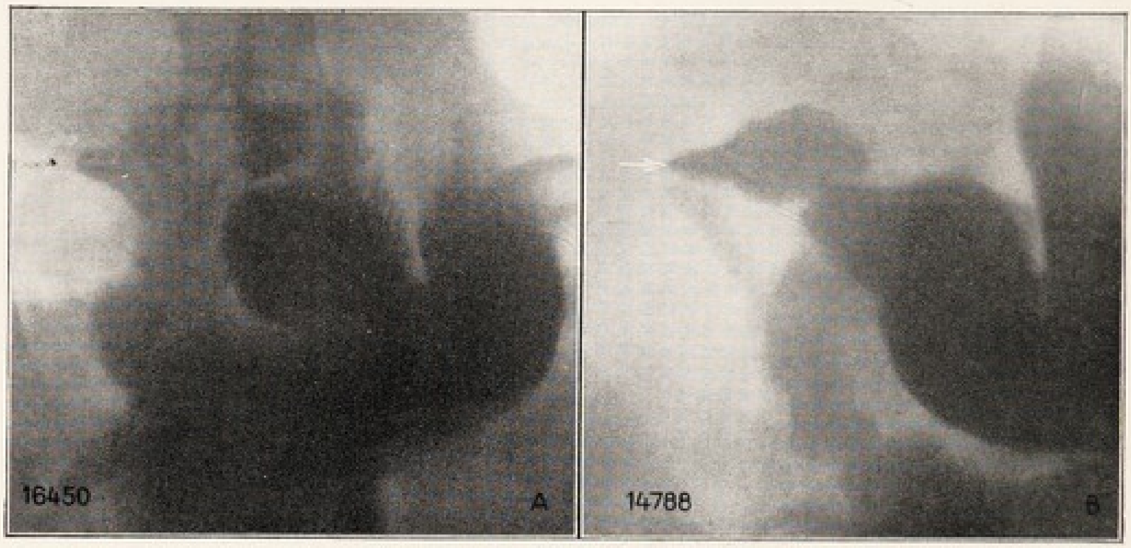


FIG. 290.

mistaken for a diverticulum above the pyloric end of the stomach, the discovery being remarkable in that at the operations nothing unusual could be made out at the affected part of the stomach. It appeared afterwards, however, that *a diverticulum of the duodeno-jejunal flexure* had been present. This is certainly the most usual site for diverticulum, and an enlargement here, filled with contrast-meal, resembles a projection of the lesser curvature.[1]

Small duodenal diverticula are very easily overlooked. Some of these are of congenital origin (" genuine "), others have developed secondarily to

[1] Åkerlund: Magendivertikel simulierende Duodenaldivertikel an der Flexura duodenojejunalis. Fortschritte, Bd. 26, p. 327.—M. Zehbe: Über Duodeno-Jejunal-Divertikel (a case of functional diverticulum of the duodenum). Fortschritte, Bd. 28, 1921 (with complete list of the literature); see also J. Sanlader: Ein Divertikel an der Flexura duodenojejunalis, etc. *Ibid.*—H. Schaefer: Congenitale Anomalie des Duodenum mit Divertikelbildung. Fortschritte, Bd. 29, 1922.—W. Baensch: Röntgendiagnostik des Duodenaldivertikels und spezieller Berücksichtigung seiner Aetiologie. Fortschritte, Bd. 30, 1923 (with complete list of the literature).—W. Teschendorf: Der gesunde und kranke Zwölffingerdarm im Röntgenbilde. Erg. d. inn. Med. u. Kindhlkde., 29. Bd., 1926 (with 225 articles from the literature).

other diseases of the wall of the duodenum (pseudo-diverticula). Diverticula are very rare in the pars horizontalis, they occur more frequently in the descending part (sometimes there being even two at once), being usually found on the inside of the duodenal ring. Many diverticula are no larger than a millet-seed—though they have been met with as large as a hen's egg—and they are therefore very easily overlooked and misinterpreted, and it is right to describe them in these pages. The largest diverticula are said to occur at the duodeno-jejunal flexure. Before the fortieth year of life genuine diverticula are hardly ever observed. Their origin is therefore not exactly congenital, but at a congenitally weakened and less resistant place.

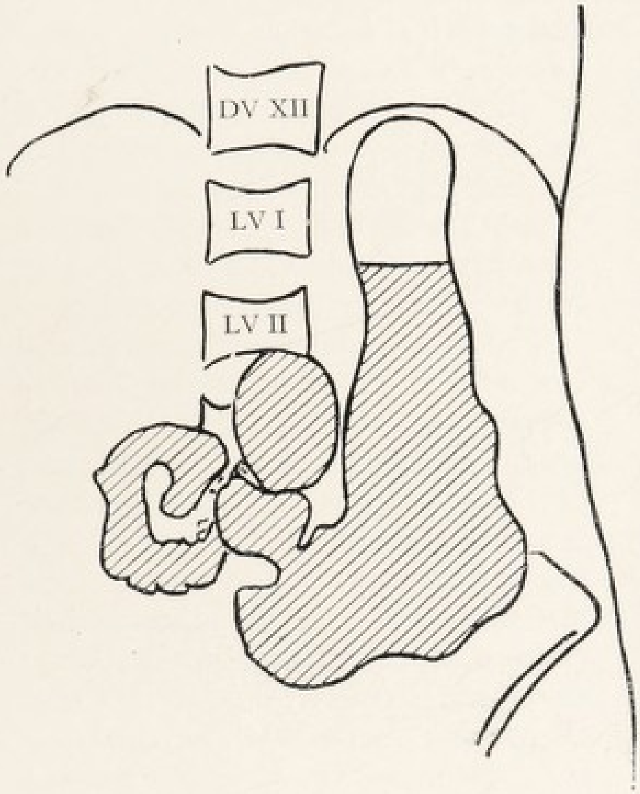


Fig. 291a.[1]

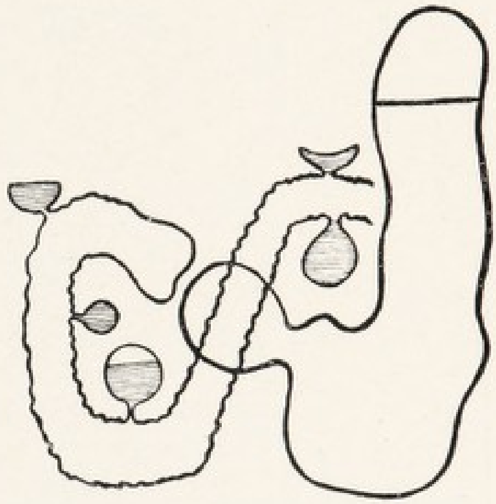


Fig. 291b.[2]

The clinical picture is usually " indefinite complaints " and is of little help The pains are almost always localised in the epigastrium and only occasionally radiate to the back. A definitely limited tenderness on pressure appears to be absent in the majority of cases, and occurs especially in *diverticulitis* or *peridiverticulitis*. Chemistry of diverticula : achlorhydria or normal or hypacid values of hydrochloric acid. A diverticulum may also show a temporary filling and not simply a retention alone. The Röntgen symptoms are therefore : Round or crescentic sharp shadow, without valvulæ conniventes, in immediate proximity to the duodenum, often with the well-known three-layer filling appearance. Shadow connected by a shorter or longer stalk with the lumen of the duodenum. Persistence of the shadow for many days after stomach and duodenum have emptied. Absence of

[1] After Zehbe, *l.c.*

[2] After Polgar, *l.c.*

motility disturbances of stomach and duodenum. A diverticulum of the duodeno-jejunal flexure may simulate a penetrating ulcer of the stomach (see also the preceding paragraph and illustration), or a diverticulum of the stomach. The genuine diverticulum is in the majority of cases only an accidental finding. We may regard as predisposing factors those diseases that bring about an increase in intra-intestinal pressure (intestinal catarrh, appendicitis, ventricular or duodenal ulcer, etc.),[1] see also Fig. 291B, which gives a systematic collection of the most frequent types of genuine diverticulum of the duodenum.

If by accident the contents of a previous meal lodge in a diverticulum, it can happen that the diverticulum does not fill with contrast-meal, and therefore remains hidden on röntgenological examination.[2]

FIG. 291C.

Gall-stones and pancreatic stones have been upon occasion mistaken for duodenal diverticulum.

A Röntgen shadow of the pars descendens duodeni, as seen in Fig. 291C, is never under any circumstances a normal occurrence, and still less so is the *spur branching from the upper part of the descendens to the liver.* This condition is one of the rarest and yet most interesting; it may therefore be referred to here, although no operation was performed and the ultimate fate of the patient (who came from another country) could not be ascertained in spite of all possible inquiries. The man was forty years of age and had suffered with pains in the gastric region for six years, also at night when he woke up. The Röntgen examination was made fifteen years back: the stomach transverse, with its most dependent point 2 cm. below the umbilicus; hyperperistalsis. Pyloric sphincter in evidence. First part of the duodenum packed full of meal and about the size of two hens' eggs; at the same time lively peristalsis at this point without recognisable propulsion onwards. Only at larger intervals of several minutes a small quantity of bismuth meal thinner than a pencil passes downwards and to the right, corresponding with the course of the distal two-thirds of the duodenum. Four hours after food: In the stomach still about one-third of the contrast-meal. In the duodenum the same play of peristalsis. Potter-Bucky radio-

[1] After F. Polgar: Röntgenbild u. klinische Bedeutung der genuinen Duodenaldivertikel. Fortschritte, Bd. 35, 1927.

[2] Schinz. Fortschritte, Ergänzungsband 34. (Das Ulcusleiden im Röntgenbilde.)

graph of the duodenum (see Fig. 291c). The meaning of the process visible in the picture to the right is not quite clear. Röntgen diagnosis: Changes in the duodenum, bringing about a stenosis. Repeat Röntgen examination eight days later. The same appearance on screening, but this time it was found that there was about a tablespoonful of contrast-meal in the stomach twelve hours after food. One must think now on the possibility that the peculiar spur is produced by a partial filling of the common bile duct with contrast-meal, which might be quite possible owing to the narrowing of the pars descendens and the amount of hyperperistalsis. Åkerlund describes a case with a diverticulum of the pars descendens at the papilla of Vater. In this case there is also a short spur bearing a distant resemblance to ours, but split at the end, the enlarged openings of the common bile duct and pancreatic duct. But this spur emerges from the medial contour of the pars descendens and appears on the inner side. On the other hand, two extremely similar cases to our case have just appeared showing internal biliary fistulæ. In both cases a similar spur passes to the right, only in both of them the entire shadow complex is somewhat higher than in our case. The letter-press beneath the two views reads: " The extra-hepatic biliary passages are filled with barium meal." A biliary fistula is therefore the most probable explanation in our case also. In operated cases air has been found in the gall-bladder. Also in our case a large air-transparency is visible to the right of the spur and surrounding it in front. It appears to me to be extremely unlikely that in our case there is any congenital anomaly of the duodenum.

Normally the portions of meal do not stay in the pars descendens and the pars transversa of the duodenum, but traverse both of these sectors comparatively rapidly. But there does occur *obstruction in the duodenum*, recognisable in that the middle and last third, without special anatomical change or with a moderate uniform enlargement, can be seen filled up to the time of the stomach emptying, and often even a short time thereafter. Cause: The superior mesenteric artery may press from in front on the terminal third of the duodenum and so produce a chronic obstruction; or duodenal ulcers or ptosis of the terminal third in consequence of abnormal fixation, floating kidneys, and ileo-cæcal prolapse.

For a stenosis in the lower third of the duodenum the following conditions have to be considered: Carcinomatous glandular metastases near the root of the mesentery, adhesions of the high jejunal coils with the anterior abdominal wall in consequence of peritonitis, fixation of the duodeno-jejunal flexure, paraduodenal hernia, diaphragmatic hernia, pericæcal adhesions, when the inflamed appendix is adherent to the root of the mesentery; infiltrating carcinoma of the pancreas; gastric ulcer in which the inflammatory process lifts up and kinks the duodeno-jejunal flexure and is associated with

[1] J. E. Kantor and A. E. Jaffin: Visualisation of the bile ducts with special reference to internal biliary fistulæ. Radiology, January, 1928. (With list of the literature.)—See also Duval, Gobellier and H. Béclère: Etude röntgenol. des voies biliaires normales et lithisiaques. Arch. malad. appar. dig. et nutr., XII, 1922.

a mesenteric artery obstruction of the duodenum. In non-malignant cases a combination of pressure of the superior mesenteric artery, and the root of the mesentery plus the pull of the coils of small intestine on the root of the mesentery, is the frequent cause of obstruction at the duodeno-jejunal flexure. There also occurs *an intermittent* duodenal *stenosis*, principally in gastroptosis, when the mesentery is elongated.[1]

Jejunum and Ileum

General

A successful *screening* of these parts of the intestine is uncommonly difficult. The jejunum is especially difficult, on account of the great confusion of coils, whose shadows cover over each other and in consequence of the rapid propulsion of the meal are constantly changing in appearance and configuration; one or more *photographic* exposures are always necessary for the elucidation of any clinical condition. It is perhaps advisable for the special examination of jejunum and ileum not to give a full contrast-meal, but only two or three spoons of it, and to watch the advance of this small quantity right through the small intestine. After giving a full contrast-meal the appearances of the normal jejunum and ileum in Röntgen picture are as follows: If the stomach has emptied its contents faster than usual, as in the presence of a gastro-enteroanastomosis, in pyloric insufficiency, hyperacidity, etc., the jejunum and ileum appear on the plate like a sea of mist seen from the top of a hill; only large thick veils, without sharp outline, flowing principally in horizontal lines. The more slowly the stomach empties, the firmer the contours of the various coils and the more distinct their appearance. That depends on the fluid-consistency of the meal. Normally the end of the ileum is more distinct than the beginning and the jejunum. Apart from the last coils of ileum a long continuous strand is never seen, but only a beaded-chain or cylindrical picture of about 5–10 cm. in length. The gradual reduction of the diameter of the small intestine from above downwards does not appear in Röntgen picture. The connection between jejunum and ileum cannot be determined either, for even the anatomists do not recognise any definite limit either on the outside or the inside of the bowel (see next section). The appearance of the various coils is, however, fairly characteristic, according as they are proximal or distal. Thus in the vicinity of the duodenum, and especially in the left iliac fossa, one meets with shadow figures like Fig. 292, A, without a whole coil being seen. The peculiarly feathery appearance has been aptly likened to a veterinary rowel. One may also speak of catherine-wheel figures, when a coil is seen in the form of Fig. 292, A; if the section is more extended, one could speak of heads of corn. The characteristic appearance of these coils is due to the valvulæ conniventes.

[1] See the works upon chronic duodenal obstruction by Case, Bell, J. P. Keith, D. Y. Keith, E. L. Kellog, W. A. Kellog, Wolfer, Holmes and Ivy in Radiology, July, 1927; also Assmann's text-book, and H. Cramer: Fortschritte, 1927, Bd. 35.

The feathering is accordingly best marked where these valvulæ are best developed and numerous, *i.e.* in the pars inferior duodeni (see Fig. 278, in the pars superior they are altogether absent), and in the upper third of the jejunum. From there they decrease, and in the terminal portion of the ileum are almost entirely absent, according to the anatomists. Other peculiar shadow complexes, as Fig. 292, B, are met with principally in the left half of the abdomen; they correspond to parts of the jejunum like A, but after the main mass of the contrast powder has passed the particular piece of gut, leaving more or less barium behind in the folds, remains situate only in the peripheral ends of the folds produce snowflake dots like C. The valvulæ

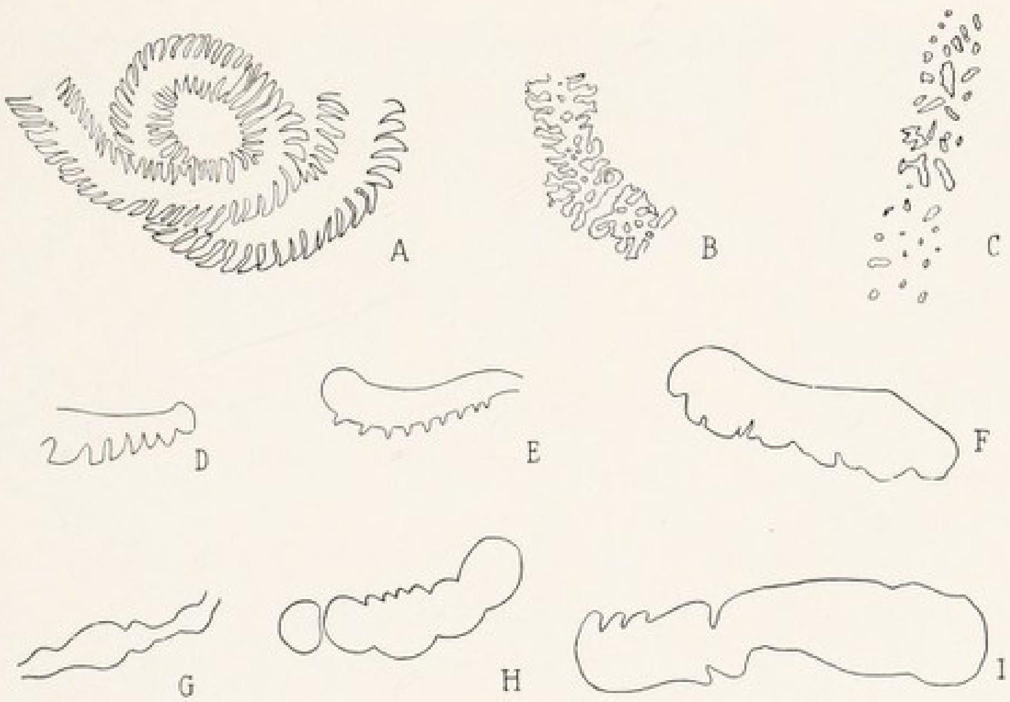


Fig. 292.

are, as is well known, found only in a part of the diameter of the gut, otherwise they run round a part of the circumference of the gut, or encircle it in the form of a spiral turn. In the first case pictures are obtained like Fig. 292, A, and Fig. 278, C, duodenum; in the latter cases appearances like Fig. 292, D, E, F. More distal one meets shadows like G, H, I, beaded-chain pictures, all of them quite normal manifestations; and towards the end of the ileum long almost continuous cylindrical strands and loops so that one obtains pictures like Fig. 293, A–I, anything from three to eight hours after the intake of a meal. In this case we no longer see the jejunum, but the last third or two-thirds of the ileum. When only a small portion of the contrast-meal remains in the ileum, the last coil and its opening into the cæcum is very plainly visible (I, Fig. 293).

The Röntgen picture of *the normal jejunum* is described also as cauliflower shape. One can say that it is exactly the "irregularity" in the convolution shadow that points to a normal intestine, while sharper and more definite shadow pictures, extending for wide stretches, give rise to the supposition that a pathological process is present.[1]

As appears from the foregoing, it is not an easy matter *to distinguish jejunum from ileum.* Having recourse to pure anatomy: in the embryo and the newly-born child two groups of coils are present and can be differentiated from each other; they are sometimes disinguishable to the röntgenologist in older children and even in the adult; the coils of small intestine are not irregular in their disposition, but are arranged in quite a definite sequence and correspond to the attachment of the mesentery which runs from above

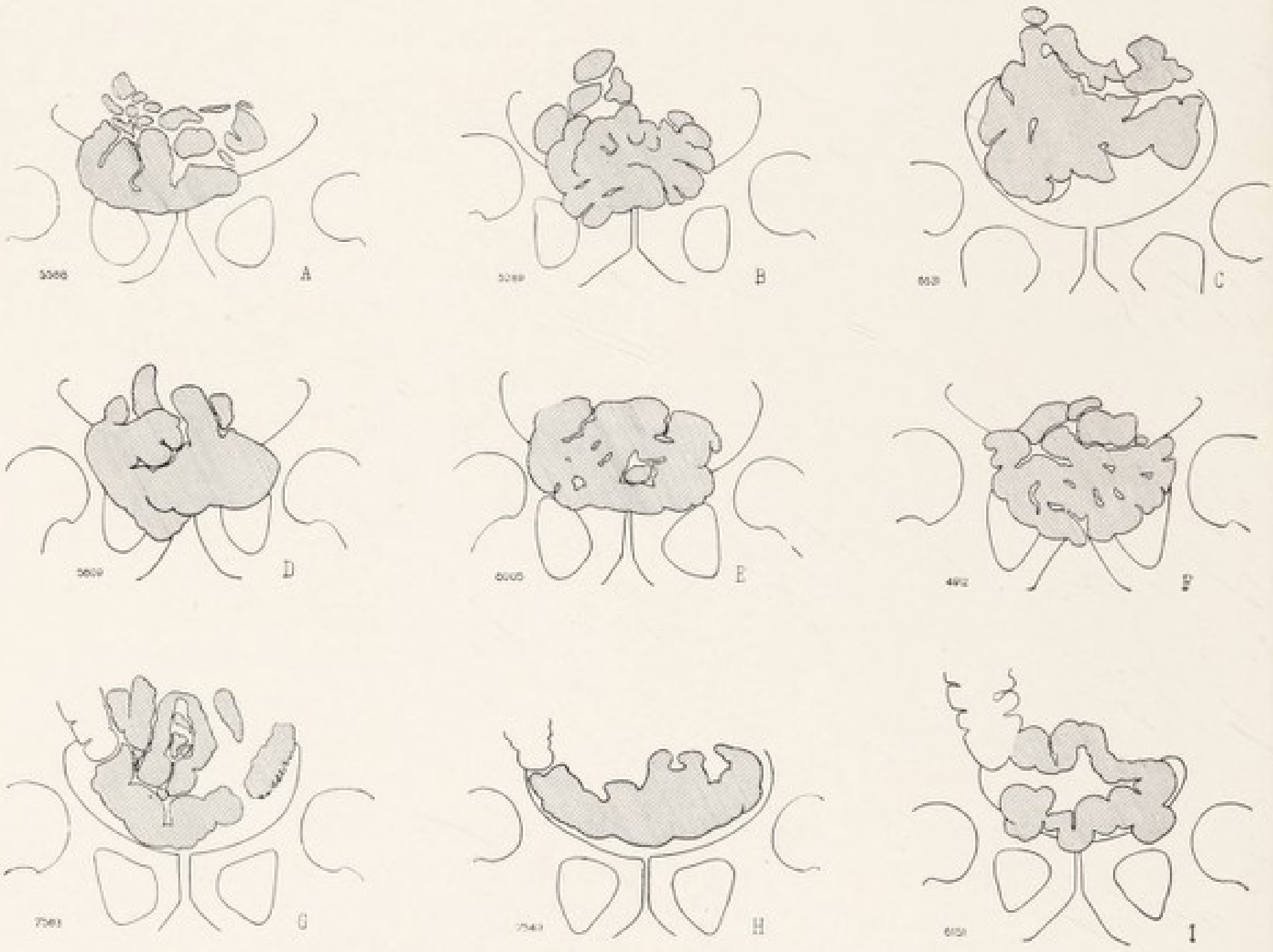


FIG. 293.

and the left downwards and to the right. The coils of jejunum are normally situated above and to the left and arranged usually horizontal in layers one above another, while the coils of ileum are found more to the right inferior aspect of the abdominal cavity and are in the main directed vertically; many coils of ileum are placed in the adult even in the pelvis. The ileum is usually better filled than the jejunum. The feathering of the shadow of the jejunal coils by the valvulæ conniventes was described in a previous paragraph. These folds are already present at the superior flexure of the duodenum and reach to the lower end of the small intestine, but towards the ileum they

[1] Faulhaber-Katz, *l.c.*

become fewer and smaller. They do not therefore mark a definite limit between jejunum and ileum. The röntgenological subdivision of the two portions of the small intestine is more readily secured from the different localisation and the different forms of the full coils, but even the Röntgen picture shows no recognisable limit. The jejunum has only—as mentioned—more valvulæ conniventes, the ileum a more clustering and band-like form, with typical segmentation of its coils. The further down they are, and in ptosis they reach right into the pelvis, the more difficult it is to follow the various coils and separate the one from the other : see Fig. 297. The contents of the ileum coils being denser, their shadow is better marked than the coils of

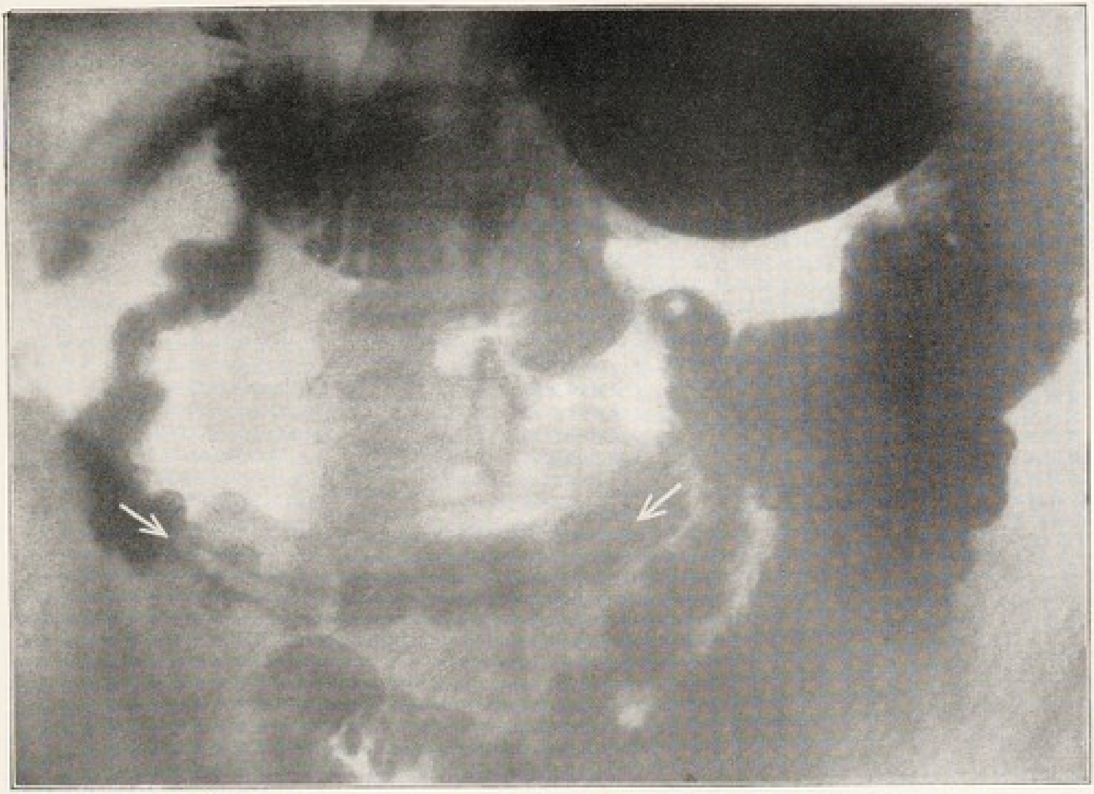


FIG. 294.

jejunum. In consequence of the longer mesentery the position of the coils of the ileum are not so fixed and regular as those of the jejunum. In tumours of the pelvis, in pregnancy and a filled bladder, the coils of ileum are ranged around the tumour. But also in the prone position of healthy young individuals and in children a shadow defect of this kind may be visible. In herniæ jejunal coils can sometimes be distinguished from ileum coils, often indeed more easily distinguishable because better seen.[1]

The röntgenological proof of *ascarids* has been already mentioned at the end of the section on the stomach. Fig. 294 shows very plainly an ascaris as a shadow-defect in the contrast-meal of one of the uppermost coils of jejunum,

[1] After Rieder : Die anatomische und röntgenologische Unterscheidung von Jejunum und Ileum. Fortschritte, Bd. 31, Kongressheft, 1923.—G. A. Pirie, Dundee : The diagnosis of the contents of a hernia sac by X-ray examination. Edinb. Med. J., N.S. 8, 1912.

see →←. The Röntgen examination was undertaken on account of a short attack similar to ileus. The worm was passed three hours later. In the left flexure of the intestinal coil, about 3 cm. above the arrow, one sees a small round polyp-like defect in the shadow. That is the worm in the direction of the rays, photographed orthodiagraphically. In the literature it has been mentioned that ascarids may swallow the contrast-meal into their alimentary canal. So when all the contrast-meal has been cleared out of the intestines of the patient, the intestine of the ascaris may still occlude some of it, and the contrast-filled intestine—for the ascaris itself is not visible—appear like a straight or coiled wire ; this may occasion great difficulty to any one ignorant of this possibility.

The last coil of ileum seems to play a special motor part. Peristalsis similar to that of the stomach has been observed here.[1] The last coil is naturally the one best seen, when all the other coils are free from contrast-meal. The passage of the contents into the cæcum appears not to proceed uninterruptedly, but occurs at intervals, the opening and closing of a muscular ring preceding it—" the ileocæcal sphincter of Hertz." Its function is similar to that of the pylorus. The inflow of contrast-meal into the cæcum proceeds normally from the third till the seventh hour, according to the rapidity of emptying of the stomach.

Considerable delay in the passage of the small intestine is a very important sign of stenosis of the intestine. An organic narrowing is certainly present, when nine to twelve hours after food no contrast-meal has yet reached the cæcum. As generally in intestinal stenosis, fluidity mirrors are characteristic of stenoses of the small intestine. There are nearly always several in the small intestine (usually they can be diagnosed on screening without contrast-meal !), while in the great intestine sometimes only a single fluidity-mirror is present.

Abnormal width, large gaseous contents, and considerable segmentation of an enlarged coil of small intestine may simulate a loop of great intestine.[2]

Normally one sees the lowest coils of ileum at the level of the symphysis. *In enteroptosis*, on the other hand, they are found deep in the pelvis. These coils cannot then be palpated from the outside. In extreme enteroptosis the ileum can exhibit fairly large shadow masses even twelve hours after the ingestion of the contrast-meal ; normally it should be empty in eight hours at the longest.

Concerning *ptoses of the small intestine* it is pretty certain that in general enteroptosis the small intestine drops too ; in a few places in the Röntgen literature brief references are made to this, without systematic examinations appearing to have been carried out. In the pictures of Fig. 293 of the small bowel some coils appear to be further down than others. Yet too much weight should not be set thereon, first because the diagrams were not orthodiagrams, second because in some of these cases, *e.g.* in C, gastroptosis and pyloroptosis were present, while in B the small bowel appears to be deeper,

[1] G. Schwarz, in Schittenhelm's text-book, 1924.—Busi-Rad. med., 1921.
[2] Reider, *l.c.*

but without any gastroptosis or enteroptosis. In A, where the small intestine is certainly placed deeper, gastroptosis with pyloroptosis is present. Accordingly one could regard all the pictures in Fig. 293 as normal, or still within normal limits, or at least as positions of the intestine that would give rise to no clinical symptoms; for in none of these cases did the clinical signs point to the small intestine.

Elevations of the convoluted small intestine occur in tumours of the pelvis.

The coils of the jejunum are normally not made out very exactly, because the meal is hurried onwards by the chyme. Consequently it is hardly ever possible to diagnose an anomaly in position with any certainty.

Views of the jejunum, seen in Fig. 295, A and B, do not belong to the realm of the normal, but are in all cases pathological, although not trouble-

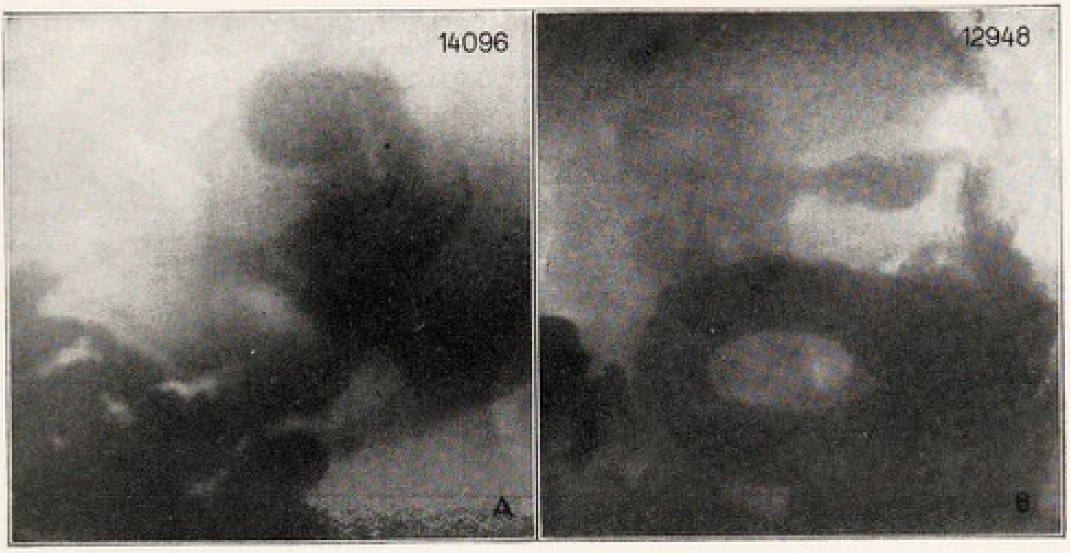


FIG. 295.

some in these two. The patient in A, a very corpulent lady, had suffered from dysentery nine years previously. Her symptoms are now referred to the stomach, so that one must describe the saccular enlargement of one of the jejunal coils on the left as an accidental finding, due to an old adhesion behind that part of the gut. The patient in B was operated on for peritonitis sixteen years before our Röntgen examination; appears at the moment to be perfectly healthy, but for five years past has had a few slight pains after food in the region of the stomach. The negative was taken five hours after food. A large jejunal coil, representing a horizontally placed open oval, is filled completely, being hypotonic or atonic.

Fig. 296 shows enlarged coils of ileum. Although in A the last and most deeply situate coils of ileum might still be normal, the long, well-filled coil on the left, which comes from above, is pathological. Also the short thin loop between it and the transverse colon is certainly pathological. Exact diagnosis is naturally impossible without operation; especially difficult to unravel is the shadow in the middle of the picture almost the size of a child's head. The man was forty-one years and had complained of definite symptoms for twenty years. Alternating diarrhœa and constipation; no sickness, no eructation. The patient reports six years after the taking of the above Röntgen view: "Condition fairly good, not been ill again since." B of the same illustration was taken seven hours after food. We see an unusually dependent coil of ileum and a very highly placed cæcum (also the duodenum reaches up higher than usual). In consequence the last coil of ileum is only the thickness of a pencil. The patient has always had a very sluggish action of the bowels, and the uterus is retroverted. She was operated on soon after the Röntgen examination, and though the patient is none too clear about it there appears to have been a right-sided hydronephrosis. Two years have elapsed since then, and constipation is still present.

Abnormal dropping of the terminal portion of the ileum and retention of the contrast-meal here twelve to fourteen hours after the meal in consequence of a kinking arising at that coil is usually described as *Lane's kink.*

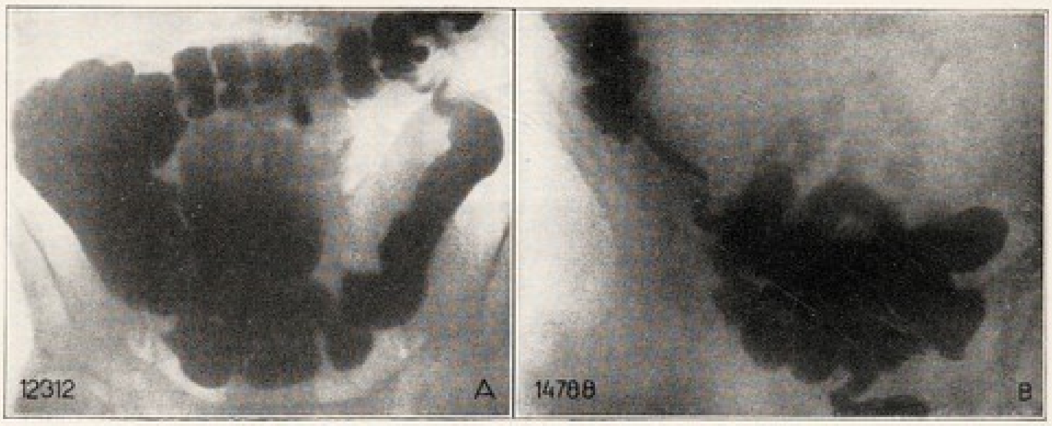


Fig. 296.

An *ileo-cæcal intussusception* may be present and yet the contrast-meal slip smoothly through the ileo-cæcal orifice.[1]

In the chronic form one finds an abnormal position and dilatation of the coils of small intestine, stagnation of their contents and presentation of the small intestine with its contrast contents in the gas-containing cæcum. But sometimes all that appears is hypomotility of the small intestine or even a negative finding.[2] Invagination is said to be often brought about by inflammatory processes of the appendix.

In general when a barium enema is given an invagination is recognised by two narrow parallel contrast lines or walls, produced by the contrast enema pressing in between the two opposing walls of the gut, between the invaginated and the external walls. Between the two dark walls formed by the barium there is seen a relatively transparent intermediate space, which corresponds to the invaginated piece of the intestine.[3]

[1] F. M. Groedel: Die Invaginatio ileocoecalis im Röntgenbild. Fortschritte, Bd. 22, 1914/15.

[2] Rieder, *l.c.*

[3] Lehmann: Ein Fall von Invag. ileo-coec. im Röntgenbilde. Fortschritte, Bd. 21.

Concerning the passage of *the duodenum into the jejunum*, the so-called duodeno-jejunal coil is situate usually to the left near the umbilicus; not infrequently, however, it is in the left hypochondrium, not far distant from the splenic flexure of the colon; sometimes too in the vicinity of the linea alba, sometimes even as far as McBurney's point. (The duodeno-jejunal coil and the passage of the ileum into the cæcum are fixed points.) [1]

Various Details

Parts of the intestine may appear filled in the form of isolated cylindrical convoluted coils and are regarded as typical of *stenosis*; it need not be of an extreme degree.[2] In more chronic stenosis with marked stasis single coils show a definite ribbing, produced by the enlarged valvulæ conniventes, and due probably to œdema of the mucous membrane. In chronic stenosis of an extreme type the dilatation of the intestinal coils can reach a considerable degree.

In the jejunum and ileum *mixing* and *kneading movements* are normally observed.[3] A heaped-up mass of contents changes in a few seconds to a broad band, then rolls up into a ball, then a pause, then the process is repeated three times in eighteen seconds (=Mixing movement). A band-like mass is divided into several rounded segments so that a beaded-chain appearance is the result (=Kneading movement). The meal is propelled in the small intestine, by a little heaped mass that was undergoing kneading movements being drawn out into a band, being set into motion, running round a bend of the intestine, forming a ball about 12 cm. long, and coming to a halt.

Adhesions of the jejunum or ileum are only diagnosable when they have led to a stenosis of the lumen, resulting in a stoppage in the bowel contents.

The terminal coils of ileum do not show any peristalsis normally, but in stenosis peristalsis is said to occur.

Spasms of the small intestine (which are often very difficult to recognise) have been observed in meningitis, tabes, and lead poisoning.[4]

A retardation of the contrast-meal in the terminal coil of ileum with some enlargement of it with occasionally presence of gas-bubbles is found in *ileo-cæcal tuberculosis*, if the ileo-cæcal valve is not functioning (see also under "Great Intestine").

Formation of a fluid with gas above it in the intestinal coils down the tract, and there multiple, is indicative especially of *tuberculous ulceration* of the bowel.[5]

Peristaltic displacement of a thick round fullness between two contraction-rings on a considerable stretch of intestine is given as a *sign of stenosis*.

[1] David: Dünndarmstudien. 10. Röntgenkongress, 1914.
[2] G. Schwarz, in Schittenhelm's text-book, 1924.
[3] After cinematographic investigation by Kästle and Brügel.
[4] G. Singer: D. m. W., 1912, No. 23.
[5] Alfred Weil, *l.c.*, p. 365.

In such a case the stenosis itself may be quite a distance behind this part.[1]

If after the contrast-meal has passed completely out of the small intestine some of the meal remains behind at a definite spot, this indicates an ulcerated site (tumour). If we wish to be certain whether the spot does not belong to the great intestine, we can clear up the diagnosis by running in a barium enema.[2]

From the observations of one authority [3] retrograde displacement of the contents of the great intestine can take place into the small intestine or rather into the lower end of the ileum, as a physiological process and in temporary insufficiency of the valve of Bauhini.

FIG. 297.

Abnormally marked filling of the terminal coils of ileum situate in the right half of the pelvis and delayed propulsion of barium into the cæcum occurs in atony and ptosis of the small bowel (usually in habitus asthenicus).

An excessively long stoppage of the contrast-meal in the ileum may occur in marked enteroptosis, and it has been observed in diabetes with insufficiency of the ileo-cæcal valve.[4] Normally the small intestine is empty in seven hours. In constipation of the ascending colon (see later) as well as in many diseases of the cæcum, the terminal coils of ileum remain filled twelve to twenty-four hours after food, owing to the retrograde transport of the meal into the ileum.

When pain occurs on filling the cæcum with a contrast-meal insufficiency of the valve of Bauhini would tend to support the clinical diagnosis of "chronic perityphlitis." [5]

Entrance of the contrast mass of *a high enema into the ileum* (provided

[1] Novak: Zur röntgenologischen Diagnose der Dünndarmverengerung. Wiener klin. Wochenschrift, 1912, No. 52.

[2] David, *l.c*

[3] Rieder: Fortschritte, Röntgenstrahlen, Bd. 35, p. 911.

[4] Case, *l.c.*

[5] Lohfeldt: Zwei Fälle von Insufficienz der Valvula Bauhini bei Perityphlitis chronica. Fortschritte, Bd. 22, 1914/15.

the barium has not been forced to enter under pressure) denotes an insufficiency of the valve of Bauhini (Fig. 297). Röntgen examination has shown that its insufficiency is really much more frequent than was formerly thought. The ætiology is not yet clear; but is supposed to depend upon anatomical anomalies of form (in young children no conclusion has yet been arrived at), over-distension of the ascending colon, catarrhal affections of the cæcum, and chronic perityphlitic processes. All observers are agreed in calling this insufficiency a symptom and not an independent disease. It occurs in every sixth case of constipation, but we do not yet know whether the constipation is the cause or the consequence of the insufficiency. The filling of the small intestine with a high enema does not take place, however, if the patient has first taken a hearty meal. The reflex in the ingestion of food seems, therefore, sufficient to bring about a contraction of the sphincter. According to modern researches on a large number of cases,[1] an incompetent ileo-cæcal valve is always pathological; in acute dilatation of the colon a temporary insufficiency is not unknown. Not diarrhœa, as was generally thought, but ileo-stasis, is the usual concomitant of insufficiency of the valve. According to others, an insufficient valve cannot be described as pathological without some other cause.[2]

An *overfilling of the jejunum* occurs usually only in duodenal motility (ulcus duodeni), occasionally in achylia gastrica and pyloric insufficiency.

Semicircular displacement of the coils of small intestine upwards is usually due to an overfull bladder, but myoma of the uterus and ovarian cysts produce similar pictures.

A *vertical course* of the first part of the jejunum with steeply descending arrangement of the coils is found frequently in general ptosis.

A striking increase in the gas contents in the coils of small intestine without fluidity-mirror has been often described in the literature in nervous flatulence of the small intestines.

Fig. 298 shows quite an unusual röntgenogram of the small intestine. In wild disorder, without any resemblance to normally situated coils, and at considerable distances from one another, "just like a packet of fireworks exploding," are seen caterpillar-like shadows 15–20 cm. long in all possible positions and angles. Complaints of considerable discomfort on the part of the patient, who sought one authority after the other; without result. About a year from the taking of this negative the patient discovered that he was suffering from tæniæ. After removing them by a three days' course of treatment "he has never had a repetition of intestinal disturbance. Up to the time of his demise two years later in the war he had never had a day's illness." One may take it that the tæniæ had acted in some way as an irritant for the intestinal condition illustrated, in the sense of a *hypermotility*.

[1] J. T. Case: A critical study of intestinal stasis, with new observations respecting the causes of ileal stasis. Arch. of the Röntgen Ray, Vol. XIX., No. 168, p. 45, July, 1914. *Ibidem*: Further Röntgen-ray studies on the ileo-cecal valve and the appendix. Amer. Journ. of Röntgenology, August, 1914.—See also Dietlen: Die Insufficienz der Valvula ileocoecalis im Röntgenbilde. Fortschritte, Bd. 21, 1913/14.

[2] Rieder.

Hypomotility of the small intestine (*i.e.* retardation of the passage through the intestine) is often only secondary, *i.e.* the consequence of hypomotility of the stomach, whereas the motility of the small intestine is almost independent of that of the great intestine.[1]

Oval spaces in the region of the jejunum or ileum, that show a fluidity-mirror in the standing position, with gas above and opaque material below, arise from *jejuno-ileal diverticula.* Duodenal ulceration is a frequent complication of jejuno-ileal diverticulitis. Many cases indicate diverticula in other parts of the digestive canal and also in the bladder.[2] In the differential diagnosis one has to consider: Peritoneal tuberculosis with multiple obstruction in the small intestine, diverticula of the stomach or duodenum, especially at the juncture between duodenum and jejunum, and a Meckel's diverticulum.

FIG. 298.

Ileal stasis was found in three-fifths of 161 patients. It appears to be associated not so frequently with constipation as with cæcal stasis. It appears to vary conversely with the extent to which the cæcum is displaced downwards (the length of the cæco-colon). Ileal stasis also appears associated with a diminution of the capacity of the colon in consequence of increased irritability, and clinically with an associated colitis. Ileal stasis is therefore best explained as a functional protective reaction to defend a weak segment of the intestinal tract. It may be temporary or recurrent or even persistent in its occurrence. The result of these investigations would appear to support the block-control-system theory of the gastro-intestinal motor function.[3]

[1] Quoted in Rieder, *l.c.*

[2] J. T. Case: Jejuno-ileal Diverticula. Acta Rad., Vol. 6, No. 29–34.

[3] J. L. Kantor: The clinical significance of ileal stasis; its association with colitis. Am. J of Röntg., July, 1926.

Great Intestine

General

The Great Intestine in the Infant and the Child

The Röntgen rays have established that the great intestine of *the newly-born child* is the subject of lively movements in its proximal part, at any rate more active than in the adult. The cæcum is very high. The transverse colon forms an arch convex towards the umbilicus. The summit of the splenic flexure is far above the level of the hepatic flexure. The descending straight part of the colon is short, while the sigmoid is correspondingly larger ; it arches with a large coil in a great curve as far as the iliac fossa.[1] According to anatomical findings, the child is born with a long sigmoid flexure, but during the first years of life the remainder of the colon grows at the expense of the sigmoid, so that at the end of five years the relative length of the sigmoid is normal. According to röntgenological researches such cases may occur, but they are certainly not the rule. A child born with a long sigmoid keeps it throughout life.[2] It appears that the formation of coils at one or other part of the great bowel is congenital. They give rise to little trouble at the sigmoid, but at other parts of the colon they are often the cause of an extreme degree of constipation (in young people).[3]

In megacolon through the great collections of gas the liver is sometimes completely trans-illuminated, so that it might be thought there is a considerable displacement of the liver. If there be the slightest doubt one takes a dorsal exposure, which is the best way of exhibiting the liver in its usual position.[4]

The Great Intestine in the Adult

It will be remembered from *normal anatomy* that the great intestine of the adult is 6–8 cm. thick and 130–160 cm. in length. The cæcum plus ascending colon measures 25 cm. and the sigmoid colon 45 cm. The cæcum and the transverse colon are easily movable, the hepatic flexure hanging at the lower end of the right kidney, the splenic flexure being well fixed (through the tight phrenico-colic ligament that connects the colon to the anterior abdominal wall or rather to the insertion of the diaphragm).

In examinations of the great intestine, especially in *obstruction*, the examination is best arranged by the patient receiving a suitable opening medicine the day before, followed on the same evening by an enema of

[1] E. Vogt : Über den weiteren Ausbau der Röntgen-Diagnostik für die Anatomie und Physiologie des Neugeborenen. Fortschritte, Bd. 30, 1. Kongressheft, 1922.

[2] Kerley and Le Wald : Digestive Disturbances in Infants and Children. New York, 1923 (Holber).

[3] See further also : Dr. Buchheim : Die Bedeutung der Röntgenologie des Magen-Darm-Kanals im Säuglingsalter für seine Physiologie und Pathologie. Arch. f. Kinderheilk., Bd. 72, Heft 1, 1922.

[4] Kerley and Le Wald, *l.c.*

one litre of lukewarm water. Diet, occupation, and bodily movements should not be in any way altered.[1]

The *characteristics* of Röntgen pictures of the normal great intestine,[2] when a contrast-meal has been taken by the mouth, are as follows: cæcum and ascending colon are continuously filled, also the right half or two-thirds of the transverse colon, sometimes also the splenic flexure. At earliest from the middle of the transverse colon the meal begins to break up into large separate fragments, which are met with singly or multiple in the left half of the transverse colon, in the splenic flexure, in the descending colon and sigmoid colon. The more or less early subdivision of the continuous fæcal contents into single lumps is dependent upon the quicker or slower action and kneading of the intestinal movements.

Complete filling of the colon from the cæcum to the rectum (as in Fig. 308, A and B) is a sign of hypermotility. The spreading out of the barium is probably the consequence of energetic intestinal movements.

As regards *the movement of the contents of the great intestine* in general with a normal function, the following points may be noted[3]: the cæcum begins to fill four hours after the meal, and as the filling proceeds it sinks somewhat. Up to the commencement of the transverse colon (which it reaches in from five to six hours) the head of the contrast-meal moves evenly along. Then powerful movements of the haustra take place in the transverse colon, under whose influence the masses are not only divided into packets but also at the head of the alimentary column are moved first backwards and then onwards again. About the twelfth hour the shadow of the column reaches the sigmoid, and about this time it is elongated to its greatest extent. In the lower part of the descending colon and in the sigmoid there ensue greater or less forward and then backward displacements. After twenty-four hours the principal mass is collected in the sigmoid and ampulla in the form of a sausage or ball. At the same time in the descending colon and in the transverse colon there collect little masses separated by intervals free from shadow. Also in the cæcum and ascending colon there are still a few flaky fragments of meal left behind. Until forty-eight hours after ingestion of the contrast-meal there are still fragments of meal visible in the colon. It is probable periods of greater activity alternate with periods of lesser activity in the great intestine.

[1] Schlesinger, *l.c.*, pp. 326–327.

[2] G. Schwarz: Klinische Röntgendiagnostik des Dickdarms und ihre physiologischen Grundlagen. Berlin, 1914 (Springer); see further the literature mentioned under "Stomach"; further Aubourg: La röntgénographie de l'instestin. Arch. d'Electr. méd., 1911.—Haenisch: Über die Leistungen des Röntgenverfahrens bei den Untersuchungen des normalen und pathologischen Dickdarmes. Münch. med. Wochenschr., 1911, p. 2768, and Röntgentaschenbuch, Bd. 4, 1912.—Faulhaber-Katz: Die Röntgen-Diagnostik der Darmkrankheiten. Halle, 1919 (Marhold).—R. D. Carman: The Röntgen-Diagnosis of Diseases of the Alimentary Canal. 1921. (Saunders, Philadelphia and London).—W. Knothe: Röntgenstudien am Schleimhautrelief des normalen und kranken Dickdarms. Fortschritte, Röntgenstrahlen, Bd. 36 (Congress Report), 1927.—A. E. Barclay: Note on the movements of the large intestine. Arch. Röntg. Ray, 1912, 16, p. 422.

[3] After Rieder: Die physiologische Dickdarmbewegung beim Menschen. Fortschritte, Bd. 18. The times are for bismuth meals.

Antiperistalsis of the great intestine seems always to be pathological, but not so a *retrograde* movement alternating with an orthograde. Great displacements of the contents are thereby produced, which take the form of great movements of the colon first orthograde and then retrograde, these being most clearly seen in the normal transverse colon.[1]

If the *position* and *form* of the great intestine change, quite apart from the influence of the position of the body, in a short time in one and the same individual, that has *per se* no particular pathological significance. It is usually simply due to the momentary degree of filling of the intestine and also of the stomach.

As already mentioned above, the contrast-meal in ordinary intestinal activity reaches the cæcum two to four hours after food. The last remainder of the meal is extruded from the small intestine into the cæcum after eight to nine hours.

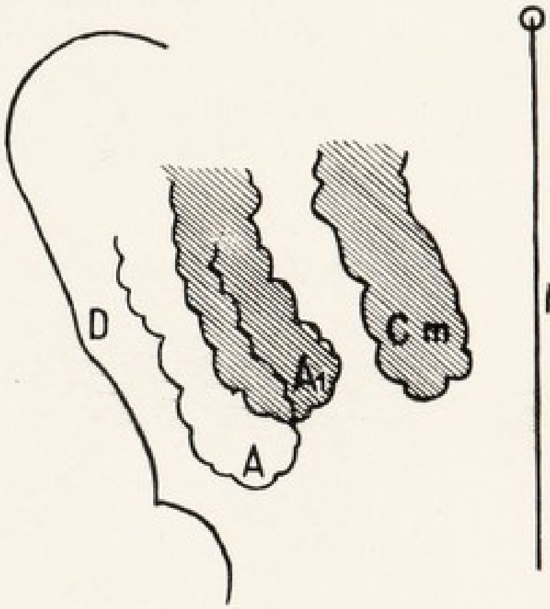


Fig. 299.—Orthodiagram in proof of "Mobile Cæcum."[2]

M=Mid line. D=Iliac bone. A=Ascending colon in erect posture. A_1=Normal ascending colon in left lateral position. Cm="Mobile Cæcum" in left lateral position.

Cæcum and Ascending Colon

The *cæcum* and *ascending colon* have normally a few deep constrictions corresponding to the plicæ semilunares, about half as deep and double as wide as the haustra of the transverse colon. The cæcum is 7 cm. long; it is marked off from the ascending colon by the habenula cæci (tænia mesocolica). In Röntgen picture, however, this delimitation is only rarely seen, and only when this tænia is specially well developed.

Normally about a half of the shadow of the ascending colon is placed in the shadow of the iliac bones.

Retrograde transport movements (active to-and-fro movement of the contents) in the proximal colon are physiological appearances.

If the cæcum in the *left lateral position* moves about a hand-breadth inwards as compared with its situation in the *standing position*, see Fig. 299, one may then speak of *a mobile cæcum*. The latter gives the clinical symptoms of a chronic appendicitis.[3] We do not now attach such pathological importance to the mobile cæcum as formerly. Many findings go to show that the cæcum is frequently involved in diseases of the gastro-intestinal tract.[4]

[1] Rieder: Fortschritte, Röntgenstrahlen, Bd. 35, 1926.

[2] After Schwarz, *l.c.*

[3] Wilms.

[4] Herzog: Über das "Coecum mobile" und ähnliche Erkrankungen. Fortschritte, Röntgenstrahlen, Bd. 321, 1923.

The principal symptom in mobile cæcum is the delay in emptying of the cæcum, and in the second place the defective mixing of the contents. The anomalies in position are of less importance. To be noted is the enlargement of the upper part of the cæcum. The chief clinical feature is constipation, associated with complaints of abdominal pains, which often appear after prolonged abstinence from stool and are sometimes combined with active movements of the intestine.

Normally *the lower end of the cæcum* shadow is in the standing position situated one to two finger-breadths above the centre of the hip-joint. Its mesentery being longer than that of the ascending colon it can be moved about fairly easily on palpation.

A deeply situated cæcum is said to be a common anomaly, to be met with in 18 per cent. of all patients suffering with the colon, especially in the

Fig. 300.

asthenic type, and therefore found most frequently in women. These patients may have a remarkable tendency for certain reflex or toxic symptoms, the so-called autointoxication. The majority of them are troubled with vomiting (59 per cent.), and many suffer with headache (48 per cent.). The exact sequence of events is not yet clear. One should therefore always look to the colon as a factor in the act of vomiting. The deeply placed cæcum can be often certainly diagnosed only by means of Röntgen examination.[1]

In Fig. 300, A, not merely is the cæcum lying abnormally far down, but it also extends 4–5 cm. to the left across the mid-sagittal plane of the body ; there is thus *distopia of the colon* (taken six hours after food). In addition there is a mobile cæcum ; for twenty-five hours after food it had moved 20 cm. upwards and to the right, as seen in Fig. 304B, A ; the same case ! Fig. 300, B, also shows a cæcum, that extends still further across the middle to the left. It does not appear to reach far down, but this negative was

[1] J. L. Kantor : The low cecum. Am. J. of Röntg., September, 1925.

taken in the horizontal position, so that its high position is easily explainable. The appendix is seen filled with barium, but no thicker than a match.

At the proximal end of the colon *small movements* normally take place in very slow time. The manner of these movements is still under dispute, they being described as small successively repeated changes of contour, as concentric contractions and dilatations, or as small pendulum movements.

Displacement and fixation of the cæcum and ascending colon towards the middle line can take place in right-sided iliopsoas abscess, gravitation abscess.[1]

Intraperitoneal abscesses issuing from the cæcum itself, of appendicular or tubercular nature, and annexa tumours of the ovarium, do not displace the cæcum in this way, because the attachment of the mesentery prevents it.

If some three to six hours after ingestion of a contrast-meal by the mouth *a shadow-cavity* appears in place of the cæcum (and ascending colon), while the lowest coil of ileum is still full of barium, and on the far side of the cæcum (and ascending colon), the transverse colon appears again as a normal and well-filled shadow outline, and if the clinical symptoms be those of blood or pus in the stool, resistance at the affected spot, fever, or even only somewhat colicky pains in a patient suffering from tubercle, we are in a position to suspect an *ileo-cæcal tuberculosis.* The part of the colon affected with tubercle remains evenly obliterated in the picture, and at no time of the examination is it visible as a full shadow. One has the impression that the contrast shadow, as soon as it reaches the cæcum, hurries through it too quickly, that it has not time to fill it : circumscribed hypermotility. This is indeed present when the tubercle is limited as an ulcerative process to the wall of the mucous membrane, even when it has transformed the affected part of the bowel by fibrous induration into a tube with rigid walls.[2] The ileocæcal region is well known to be a predilection spot for the development of a solitary tuberculosis of the bowel. The symptom, however, is typical not only for tubercle, but in general for any chronic inflammatory fibro-ulcerative process in the ileo-cæcal region (carcinoma, lues, and even actinomycosis have also got to be considered).[3] Moreover, in ileo-cæcal tuberculosis the ascending colon is remarkably short, so that the hepatic flexure seldom projects above the crest of the ileum. Yet in many cases of non-constricting tuberculous or carcinomatous infiltration of the cæcum the *Stierlin's symptom* (as the whole appearance is called) is absent. The Röntgen diagnosis is still possible in these cases by noticing the abnormal smallness of the ascending cæcum and the want of sharpness and ridging of its contours, as well as the rapidity of its emptying.[4] The examination by means of a barium

[1] Stierlin.

[2] Stierlin : Röntgenographie in der Diagnose der Ileocoecaltuberculose. Münch. med. Wochenschr., 1911, No. 23; further summary by Stierlin : Klinische Röntgen-diagnostik des Verdauungskanals, p. 474. Wiesbaden, 1916.

[3] Révész : Positives und negatives Stierlin-Symptom bei Ileocoecal-Tuberculose. Fortschritte, Bd. 26, 1918.

[4] Faulhaber : Zur Diagnose der nicht stricturierenden tuberculösen und karzinomatösen Infiltration des Coecum-Ascendens. Fortschritte, Bd. 24, 1916.

enema can be dispensed with in ileo-cæcal tuberculosis. It may be noted nevertheless that a barium enema can show the characteristic emptiness of the diseased portion of the bowel even in these cases. To do this one can fill the colon with a barium enema and take a photograph and another one after partial emptying of the enema. The second then shows in favourable cases the gross defect in the shadow of the cæcum and ascending colon.[1]

In Fig. 301, left, we have a case of a tumour-forming tuberculosis (confirmed by the microscope). The last coil of ileum climbs steeply up out of the pelvis. Instead of a broad cæcal shadow only a short portion the

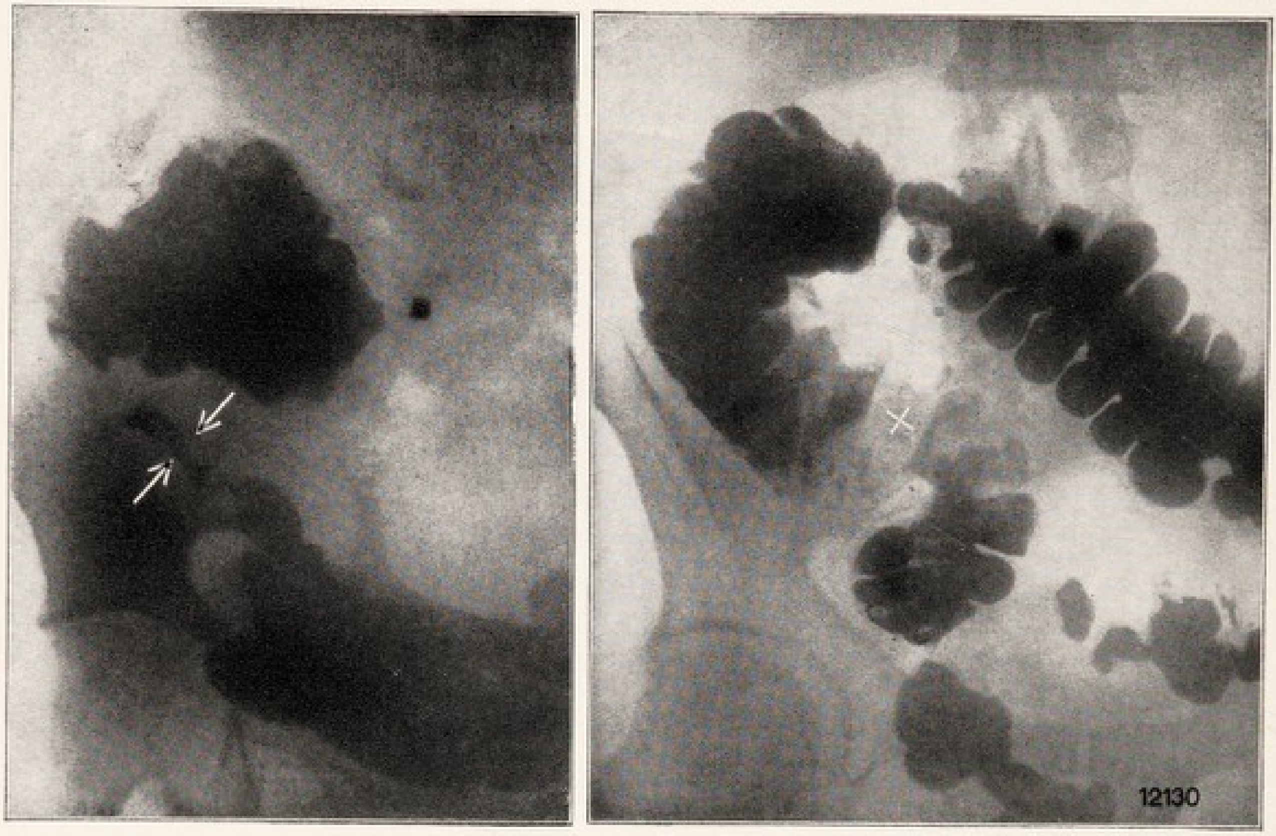


Fig. 301.

thickness of a pencil shows up any barium (see arrows) ; above that there comes next the normally filled or possibly dilated hepatic flexure. The patient, whose repeat examination is given in Fig. 301, right, was not operated upon, but it is quite certain that the defect at × was produced by cæcal tuberculosis. The patient lives still, five years after the exposure, and is typically phthisical. There is no palpable tumour, only a diffuse hardness in the right iliac region.

Cases occur in which at the time of the Röntgen examination (oral) only the cæcum, ascending colon, and only a quarter to a third of the transverse colon is filled, yet this part of the transverse hangs so far downwards that it somewhat covers over cæcum and ascendens. This broadly resembles the picture of a *strongly dilated cæcum and ascending colon.* The

[1] Stierlin, *l.c.*

diagnosis is cleared up by palpation with wooden spoon or hand or by in-drawing the abdomen. This parallel course of the right part of the transverse colon occurs, however, also in real dilatation of the cæcum, with at the same time a normal level of the adherent hepatic flexure, this being said to be the typical picture of cæcal retention.[1]

Broad filling of the cæcum, ascending colon, and rectum (Fig. 302, B), while in between only a few fragments are visible on their way through transverse colon and descending colon is indicative of a frequent form of constipation (atonic constipation of the ascending type). A=the normal appearance.[2]

If the barium meal remains two to three days in the cæcum, we may suspect a chronic torsion of a mobile cæcum.[3]

The picture of a filled but not dilated cæcum and ascendens, all the other

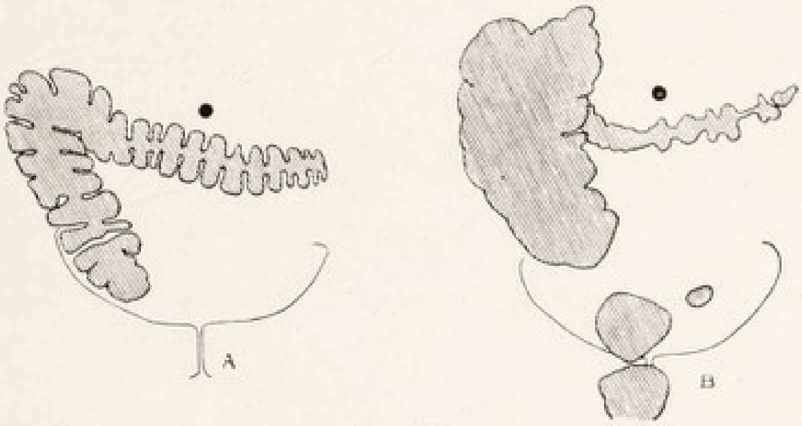


Fig. 302.

parts of the great bowel being empty, corresponds to the normal, if the patient has had a previous action of the bowel.

Conspicuous *defects in the contrast filling* of the atonic (or atonic and dilated) cæcum usually do not mean any more than that in consequence of stasis in the cæcum parts of the following contrast-free meal has found its way into the contrast-meal. The diagnosis is clarified by the defects changing their position in different examinations; a similar appearance is seen in defects due to spasms. Localised and constant defects, present also in later control contrast-meals, signify adhesions.[4]

In estimating *a simple chronic constipation* one should bear in mind regarding diagnosis of the seat of the trouble: a slow advance of the meal in the proximal colon can also originate from overloading of the sigmoid. If the distal end of the meal proceeds downwards in normal or only slightly

[1] After Jackson: Surg. Gyn. Obs., Vol. 9, p. 280; quoted by Skinner: The interpretation of pericolic membranes. Amer. Journ. Röntgenology, October, 1914.

[2] After Stierlin. Münchener med. Wochenschr., 1911, No. 36.

[3] See Klose: Die habituelle Torsion des mobilen Coecum. Ein typisches Krankheitsbild. Münch. med. Wschr., 1910; further Klose: Klinische und anatomische Fragestellungen über das Coecum mobile. Beitr. z. klin. Chir., 1909.

[4] Skinner, *l.c.*

slower time, and nevertheless a deep shadow remains for long in the proximal colon, there is no doubt about the seat of the trouble being in the latter.[1]

In several cases, in two of which the appendix had been removed, the author found a small quantity of contrast-meal in the blind end of the cæcum, about one or two teaspoonfuls, remaining many hours after emptying of the colon ; see Fig. 303. The patients (women and girls) complained of a considerable amount of pain. The author regarded the Röntgen finding as a sign of adhesions at the cæcum, and finds the same opinion held by another author.[2] One may briefly describe the condition as *a cæcum-stasis.* Even by strong aperients the remainder of barium is not much affected. The sign has perhaps an importance for the röntgenological *diagnosis of appendicitis* in so far that it indicates adhesions of the cæcal wall and appears to exclude purely functional disturbances in the ileo-cæcal region. In another case (after appendicectomy) the author found the like remnant of a quantity of contrast-meal for several days in the hepatic flexure. (For more on "Appendicitis" see the next section.)

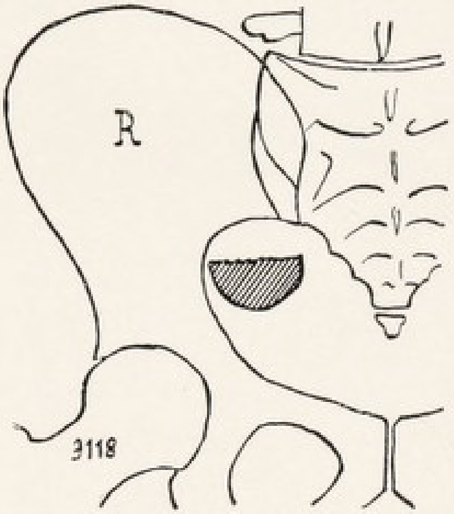


FIG. 303.

According to anatomical statements,[3] *the ascending colon* can show an oblique S-shaped kinking, the afferent and efferent intestinal coils being almost parallel. A further variety on account of a very short mesocæcum is placed higher up at the level of the normal lumbar curvature. The last coil of ileum then occupies the iliac fossa in place of the cæcum. The ascending colon may then form a medially directed coil (" Dystopia coeci superior congenita ").

The *hepatic flexure* is sometimes absent altogether, the ascendens passing over direct into the transverse colon. One has considered adhesions as the cause of these cases (see Fig. 314). This explanation has much to favour it, especially as the appearance occurs only rarely. Perhaps only a congenital shortness of the colon may be the cause of the appearance.

With corresponding clinical symptoms and a fairly large central shadow defect in the cæcum (after inflow) one should think of *an intussusception* of the end of the ileum into the cæcum.

A cæcum and ascending colon situate on the left side in a normally placed stomach is a congenital condition in which the cæcum has not rotated.[4]

The rather unusual röntgenogram, Fig. 304A, is from a man, who two years before recovered from an enteric. There is the typical view of an altered mucous membrane. In the hepatic flexure is a collection of gas

[1] Stierlin: Über chronische Functionsstörungen des Dickdarms. Erg. d. inn. Med. u. Kindhlk., Bd. 10, 1913.

[2] E. Schlesinger, *l.c.*—See also Basler and Lutz: Am. J. of Röntg., August, 1922.

[3] Brosch, quoted after G. Schwarz.

[4] Corresponding pictures and diagrams, see Kerley and Le Wald, *l.c.*

sufficient to mask the finer shadows, but one can still see the roughened and coated mucous membrane at the margins of the haustra, whereas in the region of the cæcum the mucous membrane offers a more spotted and chequered appearance. The transverse colon appears to be quite normal.

Vermiform Appendix [1]

Anatomy and Physiology: The appendix is 9 cm. long on the average, though lengths of from 2·5 to 24 cm. have been observed. It runs generally from the most dependent part of the cæcum, sometimes a little further up near the ileo-cæcal valve. It is normally comma- or S-shaped. It can hang down free into the pelvis, or run up in front of or behind the cæcum. The latter or "retrocæcal" position with secondary fixation to the parietal peritoneum is of special importance. Concerning its function one can see that the contrast-meal is pressed into the proximal part of the appendix, at the same time peristaltic movements taking place at the wall of the cæcum, in the vicinity of the appendical orifice. The proximal part of the appendix contracts to and fro, and the contents are thus pushed on into

Fig. 304a.

[1] Schwarz, Groedel, *l.c.*, Cohn: Der Wurmfortsatz im Röntgenbilde. Deutsche med. Wochenschr., 1913, No. 13, and 10. Deutscher Röntgenkongress, p. 87.—Desternes and Baudon: Quelques röntgénographies de l'appendice iléocoecal. Arch. d'Electr. méd., Bd. 20, 1912.—Case: Further Röntgen-ray studies on the ileo-cecal valve and the appendix. Amer Journ. of Röntgenology, August, 1914.—Gourcerol: La röntgénographie de l'appendice. Paris, 1912 (Steinheil).—Case: Röntgen-ray-studies on the ileo-cecal region and the appendix. American Quarterly of Röntgenology, November, 1912; *ibidem*, August, 1914.—Quimby: Differential diagnosis of the appendix by aid of the Röntgen-ray. New York Medical Journal, October, 1913.—Bles: Röntgenonderzoek bij chron. Appendicitis. Nederl. Tijdschrift voor Geneeskunde, 1915.—P. Eisen: Röntgenoscopic evidence in Appendicitis. New York Medicin. Journal, August, 1915.—Imboden: Röntgen-Diagnosis of Lesions of Vermiform Appendix. Am. Journ. of Röntgen., January, 1915.—Moreau, Arch. d'Electr. méd, 1922.—F. W. White: The clinical importance of chronic changes in the appendix. Am. J. of Röntg., January, 1925.—Boston Med. and Surg. Journ., 1923, 188, 587.—A. F.

the appendix, or occasionally backwards into the cæcum.[1] The normal appendix becomes free of barium again, usually in from one to two days; in particularly long appendices the retention of the barium might continue for five days. In series exposures at intervals of a minute packeting of the contents is visible through slowly changing segmentation and snake-like movements.

Up to 1911 it was thought that the appendix was not visible in Röntgen view, that it did not fill with contrast-meal, but from that time scattered references occurred in the literature, that in this or that case distinct appendix shadows had been seen. Possibly some errors were then made (worm-shaped remainders of contrast-meal in the neighbouring parts of the ileum); some observations, however, were certainly quite correct. The number of correct observations then increased, and one or two authors went so far as to assert that they could bring the appendix into view in every normal individual. Gradually the conditions cleared up, and filling of the appendix by a contrast-meal was regarded as pathological or at least exceptional. That even in pathological cases the appendix can only rarely be seen is explained by one author by the fact that it is hidden by the shadow of the cæcum when the patient is in the upright position, but that on examining the patient in the horizontal position it projects medial to the shadow of the cæcum, when it is filled. In high barium enemata it does not appear, only when the contrast-meal is given by the mouth.[2] (One case, see Fig. 308, A.)

Observers who have made a special study of the Röntgen examination of the appendix, are agreed that when the process can be seen filled with barium it remains like that for several days, on one occasion for four weeks. Others hold another view[3]: "Our opinion is that an appendix that fills with bismuth and barium and soon empties does not call for any special attention, but an appendix that remains filled several days after the colon has emptied is certainly pathological." According to these authors, cases have been seen, at least in children, in which the appendix fills with contrast-meal and becomes emptied of meal with the emptying of the cæcum. It is asserted that a normal appendix is free from contents, but this is contradicted, and as röntgenology shows probably rightly so.[4]

Hertz: Common fallacies in the X-ray diagnosis of disorders of the alimentary canal. Arch. Röntg. Ray, 1912, 17, p. 216.—H. K. Pancoast: Arch. Surg., January, 1923.—G. Vilvandré: Appendicitis: its radiodiagnosis. Arch. of Rad. and Elec., 1916, 21, p. 49.—L. E. Ellis: Intestinal radiography in chronic appendicitis. South African Med. Rec., 1921, June.—R. T. Petitt: The Röntgen-rays in the diagnosis of chronic appendicitis. Arch. of Rad. and Elec., 1917, 21, p. 345.—E. I. Spriggs: The examination of the appendix by X-rays. Arch. of Rad. and Elec., March, 1919.—J. T. Case: New York Med. J., 1914, 161.—R. D. Carman, J. Y. Brown and W. Engelbach: Anatomic, pathologic, and clinical studies of lesions involving the appendix, and right ureter. J. Am. Med. Assoc., 1910, liv, p. 1491.—A. Simon: Appendical stones simulating gall-stones and kidney stones. Radiology, May, 1925, ix, 428–430.

[1] Ström. Acta Radiologica, 7, 1921.

[2] Other authors are of a contrary opinion, *e.g.* Faulhaber.

[3] Kerley and Le Wald, *l.c.*

[4] Aschoff: Die Wurmfortsatzentzündung. Jena, 1908 (Fischer).

Further investigations have been carried out on the experience of several hundred cases,[1] in which attention was paid to the presence or absence of the appendix, to narrowings and kinkings, adhesions, emptying-time, relation of the visible shadow of the appendix to a tender spot, retrocæcal, procæcal, and other positions, and it would appear that valuable conclusions can be drawn from a broad appendix shadow that remains for many days after the bowel is already emptied completely of bismuth. To find the appendix the patient must be examined in the horizontal position, screen on the abdomen, tube under the table, and the examiner should be expert at using the gloved hand or the examining ladle. The filling of the appendix takes place in about six hours after ingestion of the contrast-meal. If an ileum has just emptied of contrast-meal, one should be careful not to diagnose a thin shadow strip in the iliac region as an appendix ; for we are possibly then dealing only with a narrow remnant of meal in the coil of ileum. The same author saw the appendix in 273 out of 763 intestinal examinations of patients in which the appendix was not operated on—that is, in about a third of the cases. This is a high percentage, but it should be noted that only patients with gastro-intestinal symptoms were examined ; and it should be added that in the majority of cases constipation was present. The same author considers every visible appendix as pathological, but warns against handing over every case to the surgeon, especially those in which the appendix shadow disappears with the emptying of the colon ; for when the appendix can empty itself there is little to fear ; in other cases, on the other hand, when there is a retention of several days' duration in the appendix there is danger that the contents are extra rich in pathological bacteria. In patients who have taken regularly small therapeutic doses of bismuth the appendix was always seen in Röntgen picture (it was only in five cases that this point was specially examined). In all cases in which the appendix was filled with bismuth at the first examination, it did the same at subsequent examinations, and conversely. When the appendix is not seen it can be due to chronic obliteration of its lumen, by kinking near its cæcal end, or by infiltration and swelling in acute appendicitis ; or it can be filled, but escape recognition by such a dilatation or adhesion of the cæcum that the retrocæcal appendix shadow is hidden, and that is said to occur frequently, especially by examining in the standing position. For enteroliths of the vermiform process, see p. 204. Certain abnormal positions of the fixed sigmoid are said to be caused by appendicitis adhesions.

An invisible vermiform process is not necessarily a shut one. It can contain some of the meal taken previous to the contrast-meal, and so make entrance to the contrast-meal impossible.

It appears from this that an appendix visible in the Röntgen rays is pathological, and a number of observations are recorded in which with such findings regular chronic-appendicitis changes have been observed at the operation. At the moment, however, it is impossible for a variety of reasons to diagnose immediately as an appendicitis every appendix that has remained

[1] Case, *l.c.*

visible for several days. It is perhaps, however, legitimate to regard such patients as predisposed to appendicitis. The Röntgen symptoms of appendicitis are said to be [1]: ileo-cæcal stagnation, a sharply kinked and also a straight stretched and adherent vermiform appendix, or an incomplete filling of the latter, coincidence of maximal tenderness with the shadow of the cæcum or with the position of the appendix determined by screening, shadows of enteroliths, and finally insufficiency of Bauhini's valve.

In systematic screenings made six, eight, ten, and twenty-four hours after the ingestion of the contrast masses, the appendix could be made out in 70–80 per cent. of all patients examined, especially in examination in the dorsal position, making use of the wooden ladle or other palpation manœuvre for displacing the cæcum.[2] Another observer saw the appendix only in 23 per cent. of the cases without clinical symptoms of chronic appendicitis, in 62 per cent. of cases with clinical symptoms pointing to appendicitis.[3] Both a normal and a pathological appendix can be filled with contrast-meal; and an appendix that does not fill cannot *a priori* be regarded either as diseased or as normal. Angular and kinked appendix shadows undoubtedly disclose by their characteristic form "an elbow-like kinking of the appendix." If the appendix is not displaced on movement of the cæcum, but is stretched out more or less, that is indicative of adhesive post-appendicitis conditions. Fixation of the tip of the appendix is reported a frequent occurrence by the surgeons. The emptying of the remains of barium from the appendix appears, as said, to be a difficult business. If they persist for weeks, they experience in time a more or less extensive change of form, become rounded, so that one can speak finally of barium concretions. Also barium-free coproliths in the vermiform appendix can sometimes be seen in Röntgen view, if they are encrusted with lime. Do not confuse them with stones in the ureter, which ought to be placed more medial. In a doubtful case pass a ureteral sound or catheter and take a second photograph. Uncalcified fæcal concretions in an appendix filled with barium show up as transparent defects encircled by a shadow mass.[4] According to another author,[5] the appendix fills with contrast-meal in 50 per cent. of the cases, and fills better if given through the mouth than per rectum. This author agrees with others claiming that the appendix must be exactly examined by raising the cæcum or displacing it to the side. One cannot decide the state of the appendix from its degree of filling. In favour of a chronic appendicitis are: Fixation of the appendix. Its hypertonus (rose-garland filling). Persistent remains of meal after emptying of the colon. Point of maximal tenderness

[1] George and Gerber, Quimby, quoted from Groedel, Atlas, 3rd ed., 1920.—Case: X-Ray studies of the ileocoecal region and the appendix. American Quarterly of Röntgenology, November, 1912.—Singer and Holzknecht: Röntgenologische Anhaltspunkte zur Diagnose der chronischen Appendicitis. Münchener medicin. Wochenschrift, 1913, No. 48.—Schlesinger, *l.c.*

[2] Ström, *l.c.*

[3] Alwens, quoted by Schwarz.

[4] After G. Schwarz, in Schittenhelm's text-book. Last sentence from Ström, *l.c.* See also A. Mülleder, Ztrlbl. f. Chir., No. 10.

[5] S. Henszelmann: Über die Röntgenuntersuchung der Appendicitis. Röntgenologie, Heft 1, 1922.

agreeing with its position. Localisation of the periappendicular infiltrate. Downward opening of the left coil of ileum (inflammatory shortening of the mesocæcum and mesoappendix). On account of the importance of the subject the author considers it right to include the particular findings of recognised researchers, even though they contain many direct contradictions.

Fig. 304B, A, shows a vermiform appendix probably not yet described, namely, an ampullary enlargement at its insertion into the cæcum. The appendix was not normal in other respects, for another later negative showed that the tip of the appendix was not above at the transverse colon, but formed a sharp angle and was adherent there, the appendix being filled with contrast-meal for a further 5 cm. Further, the cæcum was mobile, being sometimes

FIG. 304B.

well down in the abdomen; see Fig. 300, left view = the same case nineteen hours earlier. At operation: cobweb adhesions to gall-bladder and up to the stomach. In case 304B, B, the appendix is pathological and turned upwards at right angles; it is somewhat kinked in the middle, dilated, and cylindrical at its end, and not well filled with contrast-meal. At operation: an appendix turned up and firmly adherent.

The author used, five to ten years ago, to see the vermiform appendix only occasionally, but now much oftener, the reason of this being that he does not expect to find it with a filled cæcum. When the cæcum is full it usually hides the appendix, and then it can only sometimes be seen by turning the patient into the first oblique screening position; it may then stand out lateral from the cæcum. It is best to wait until the cæcum and ascending colon is empty or almost empty, and then to examine carefully whether the shadow of the appendix is visible. The shadow is then generally visible for a whole day or more. The best time for the examination is when the patient has taken the meal early, about eight o'clock, and is examined that evening about seven o'clock or the next morning.

If one gives an ordinary meal $1\frac{1}{2}$ hours after a cito-barium meal and finds contrast masses still present in the lowest coils of ileum six hours after the cito-barium meal, it is then likely that *a chronic appendicitis* is present, provided there is no stenosis of the bowel or disease of the peritoneum.[1]

There is one case on record [2] where the curved part of a broken *surgical*

Fig. 305.

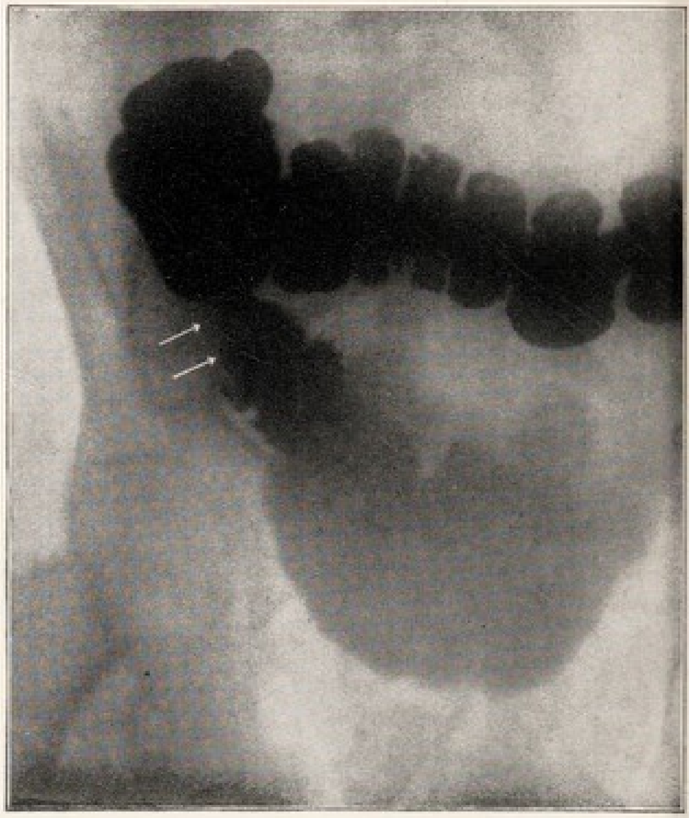


Fig. 306.

forceps, which had been left in the abdominal cavity through an oversight at operation, simulated a portion of filled appendix at a later contrast-meal examination, as it was projected exactly at the inner and lower border of the cæcum.

Occasionally, although relatively seldom, one meets at the level of the iliac crest, or above it in the Röntgen view of cæcum and ascendens, a constricted or almost constricted part; this is called the "*cæcum-colon sphincter*." In the vertebrata, especially in the herbivorous creatures, a proximal part of the colon is normally in a state of contraction. Anatomical, physiological, and röntgenological facts indicate the existence of a similar spot in the human colon. This cæcum-colon sphincter prevents an active

[1] Ehrlich: Röntgen-Diagnose der sog. Appendicitis chronica. D. med. Wchschr., No. 14, 1923.

[2] Case, *l.c.*

backflow of the intestinal contents, until the cæcal digestion and absorption is completed. The contraction and relaxation of this part of the intestine is doubtless regulated by chemical processes, resembling those to do with the opening and closing of the pylorus. In the formation of cæcal distension and stasis spastic conditions might arise, that might finally produce an inflammation. The cause of the spastic condition cannot always be removed by appendicectomy, for cases occur in which the symptoms return after removal of the appendix. Pathological changes of the intestinal tract most commonly occur in the vicinity of anatomical or physiological " narrowings," where a change of the epithelium takes place, as in the œsophagus, cardia, and pylorus. One may add the cæcum-colon sphincter to this list.[1]

Fig. 307.

It is a well-known fact that a fluidity-mirror in the bowel is generally an early sign of malignant tumour or rather of stenosis in consequence of a tumour (or more rarely of a tuberculosis). As was mentioned above in " Jejunum and Ileum. General," a fluidity-mirror is often the only sign in a stenosis of the large intestine. In the author's case, Fig. 305, five to six fluidity-mirrors with gas-bubbles were present in a carcinoma of the hepatic flexure of the colon confirmed by histological section. The tumour was the size of a small fist and nodular.

A case of a constricting tumour of the ascending colon is shown in Fig. 306. Operation was refused. Exitus $2\frac{1}{2}$ years later. The view of the tumour in Fig. 307 is also interesting: negative taken in the horizontal position: the tumour in the transverse part of the hepatic flexure. The column of barium in a normal bowel never breaks off at this point. A tumour the size of one's fist, and inoperable.

[1] J. Seth Hirsch: The Cecocolic Sphincteric Tract. Journ. of Rad., October, 1922.

Transverse and Descending Colon

Functional

As already mentioned above, one finds in normal conditions of the bowel *the contrast-meal* after three to six hours at the hepatic flexure, and in four to twelve hours at the splenic flexure.

When the contrast-meal is already *at the hepatic flexure* divided up into pieces, which usually does not happen until the middle of the transverse colon is reached, there is delay in the progress of the meal (dyskinetic constipation).

The colon carries out normally *small continuous movements*, which can be seen only after lengthy observation of some of the haustra, best in the transverse colon. The haustra alter their form a little, become broader at one point, longer at another, two haustra appear to merge into one here and there, sometimes a haustrum appears to send out an extra long irregular process. Secondly, the colon carries out *larger movements* for the propulsion of its contents greater distances. They occur only every two hours or so, run very quickly, so that one sees them on the screen only if one is fortunate. During these movements the haustral segmentation is stopped. Also the next section, into which the contrast-meal is advanced, remains at first smooth and cylindrical, but soon begins too to segment. It is not yet absolutely certain whether, under pure physiological conditions (apart from the process of defæcation in the lowest part of the colon), these larger movements occur in the majority of people. Thirdly, there are snake-like movements, pendulum movements of the colon.[1]

To-and-fro movements with fluid contents do not belong to the region of the physiological; they occur in diarrhœic processes.

In the case of the smaller movements it is normal for concentric contraction and enlargement of the haustra to follow each other alternately. The haustra are sometimes broad-based on the colon and sometimes divided up; they can also be contracted into a single one or several adjacent ones. The haustral narrowing can at some points be so deep that it becomes a complete constriction.

More rapid propulsion of the meal in the colon occurs a short time after the stomach has taken up a fresh meal.[2]

A not uncommon picture is for the contrast-meal to remain two days and longer in the transverse colon in maximally contracted haustra, either continuous or divided here and there by deep haustral narrowings. When at the end of the fæcal column there are no signs of stenosis or the like present, that is the typical picture of *spastic constipation*.

If the intestinal contents that have advanced up to the hepatic flexure travel back through the ascending colon into the ascending colon and cæcum, we have to deal with antiperistaltic manifestations. That *antiperistalsis and retrograde defæcation* may under normal conditions occur in the proximal

[1] Rieder, *l.c.*

[2] Hertz, quoted by Stierlin.

section of the colon, is now generally admitted. (Among animals antiperistalsis is observed almost regularly in the proximal colon, and to the most marked degree in the herbivora.) The antiperistaltic waves appear at four to five minute intervals, then five waves occur every minute. The antiperistalsis is reduced or stopped in hypermotility and nervous diarrhœas ; it is increased in constipation, and especially in spastic constipation ; above all, also in stenosis of the bowel. In the great intestine, however, the waves of antiperistalsis cannot be followed so clearly on the screen as in the stomach. Antiperistalsis at the descending colon and sigmoid has hitherto been observed only from the surgical side after operative interference on the bowel. But in the transverse colon near the hepatic flexure, definite antiperistaltic waves were seen thirty-seven times out of 1500 cases.[1] The waves ran towards the cæcum and disappeared about the ileo-cæcal opening. (The same observer thinks he has also observed antiperistalsis in the descending colon, and especially in cases of chronic or acute obstruction.) A " tonic constriction ring " has long been observed in animals,[2] and the same may occur also in the human transverse colon, to the right of the middle line. It is from there that the antiperistaltic waves proceed towards the cæcum. In cases of severe obstruction of the bowel (in spastic constipation or other benign or malignant obstruction), an " exaggerated antiperistalsis " is seen.

If four to six hours after the ingestion of bismuth parts of it have already reached *the splenic flexure* of the colon, hypermotility of the stomach is present.

Circumscribed hypermotility of the colon indicates simple ulcerative processes without gross contraction or intumescence of its wall.

Anatomical

Concerning the form, position, and length of *the normal colon* the greatest differences are met with. One can well say that no part of the human body shows in the healthy state such a variety of pictures as does the colon (and the stomach). It would therefore be difficult to give a survey of normal pictures, which might also be too exhaustive ; quite apart from the fact that the limits from the normal to the pathological cannot here be viewed. " Nearly every pathological displacement and fixation of the colon has its accompaniment in physiology. Therefore every diagnosis of a pathological anomaly of position is uncertain," though to-day such a statement is perhaps hardly correct. The cause for this many-sidedness of the colon is not at all clear.[3] The position is certainly related to the transition of man in course of phylogenesis from the horizontal to the erect position, and to the varying

[1] J. T. Case : Röntgen-ray observations on colonic peristalsis and antiperistalsis with special reference to the function of the ileocolic valve. 17th International Medical Congress in London, 1913.

[2] By Cannon and others.

[3] Holzknecht, *l.c.*

width of the abdomen. Concerning the very varying length of the colon, it may be remarked that the colon of the newly born is said to show no

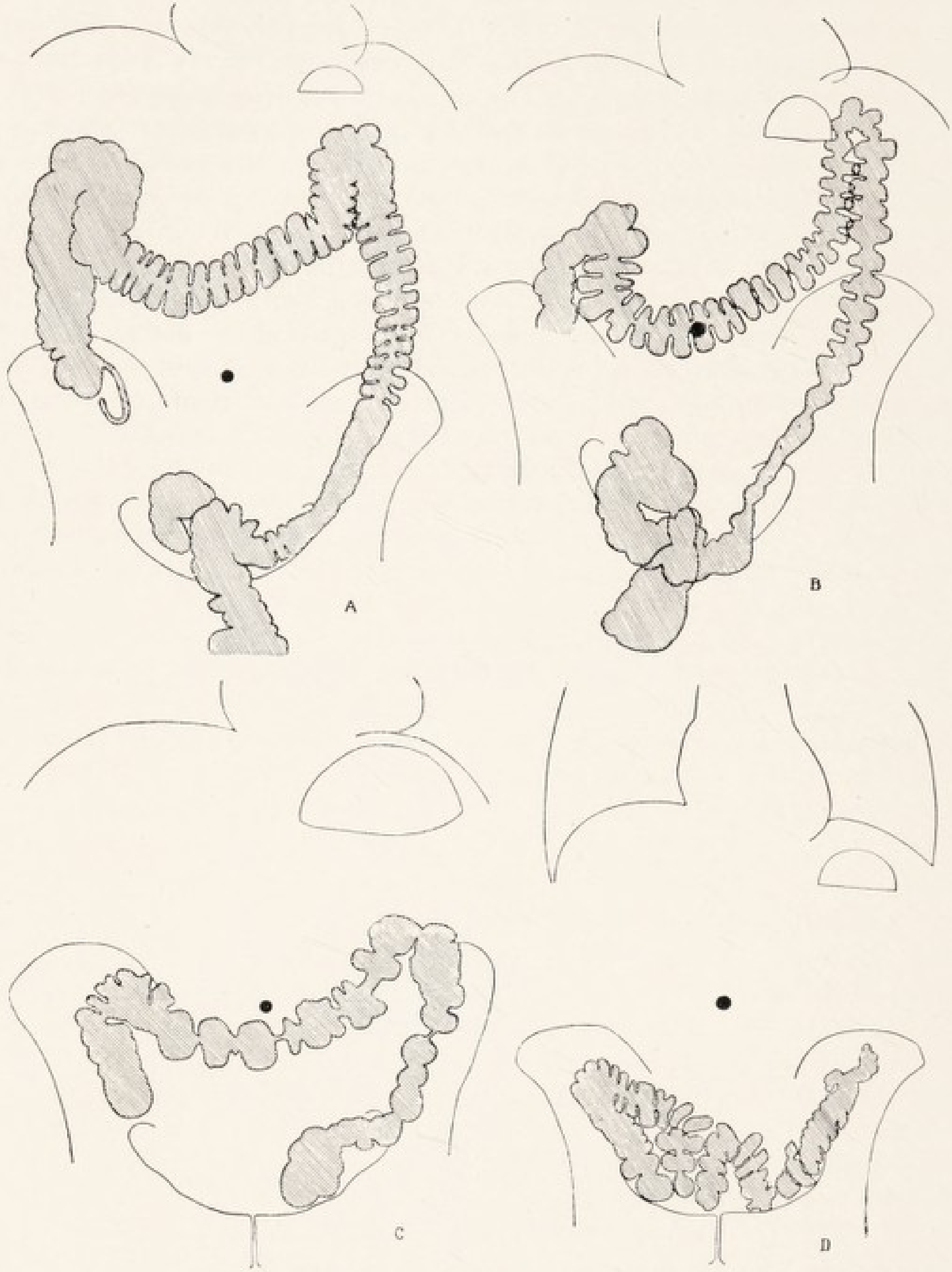


Fig. 308.

differences in length [1] (see, however, above "Great intestine of the infant and child"), the differences in the length of the adult's colon is acquired, constipation playing a principal rôle in its production. Conspicuous length

[1] Cruveilhier: Traité d'anatomie humaine.

of the colon was found in specially directed Röntgen examinations [1] in a fifth of the cases of intestinal diseases. The transverse colon and the sigmoid colon were the parts found most often lengthened. A long colon was found more frequently, the older the patients. Actually the most cases were found in constipation, and it is really remarkable that the transverse colon and sigmoid are almost never found dilated. Upon all these points, for which there is certainly something to be said, further researches are to be welcomed. The author in Fig. 308 gives four types, in which A and B can be termed normal; in C there is considerable ptosis especially of the left flexure; and D shows a maximal coloptosis; and yet apart from slight constipation no symptoms pointing to the colon were present, D in fact being a purely accidental discovery. A shows a finding that one should always expect from the illustrations of the normal-anatomy atlases, and yet one hardly ever finds it in this way, *i.e.* with such an elevated hepatic flexure; the author encountered among many hundred photographs and screenings not another röntgenogram with such an elevated right flexure. In general, it is the depression of the hepatic flexure that is most striking in the majority of pictures of the colon. No pathological importance is to be attached to this manifestation, so long as it is combined with no other striking feature. Ptosis of the splenic flexure is remarkably rare. If the latter is at a considerably deeper level than usual, that is more akin to a pathological condition. In its left third the transverse colon follows under physiological conditions the greater curvature of the stomach.[2]

One researcher describes four types of transverse colon: (1) horseshoe form curved upwards, (2) horizontal, (3) U- and V-shaped, (4) transverse. The form depends upon the form of the abdomen, which is determined by the relation between the tenth rib and anterior superior spine to the distance from the angle of the ribs to the symphysis ("Index spinarum").[3]

The author of this book has for years been interested in the condition of a very short transverse colon in people who are putting on size and weight. Taking the number of the haustra first. These number ten to thirty, and on the average about twenty. The number of the haustra seems to bear no relation to the external constitution. Now if an individual has a very short transverse colon with loose suspensory ligaments right and left, and when she begins to put on weight in the middle years of life, there can come a time when an adjustment by stretching till it becomes quite straight becomes of some importance to the state of health. Fig. 309 illustrates two such cases: a short transverse colon with ten to twelve haustra, completely or almost completely stretched in patients that have broadened out and are suffering from a variety of indeterminate symptoms. Such Röntgen findings as

[1] Lardennois and Aubourg: Allongements segmentaires du gros intestin, les dolichocolies; leur importance dans la pathologie du gros intestin. Journ. de Radiologie et d'Electrologie, Band I, February, 1914.

[2] Diagrams of different types of colon, see also in R. Balli: Sul limite fra il normale ed il patologico nella röntgenologia del tubo digerente. Modena, 1922.

[3] Kuprijanoff, St. Petersburg: Über die Lage des Colon transversum. Arch. f. klin. Chir., 125, 3.

these are wont to be regarded as quite normal, because the entire or almost the entire course of the transverse colon can be inspected and not sufficiently appreciated. The author once saw a transverse colon with scarce ten haustra, but in which the intervening furrows were all drawn out 2·5–3 cm. in length, and the intestine itself had only a small width of half a centimetre; a very rare condition.

The transverse colon alters its position, curvatures, and coiling several times during digestion, which is permitted by its long mesentery. These changes occur most strongly before defæcation.

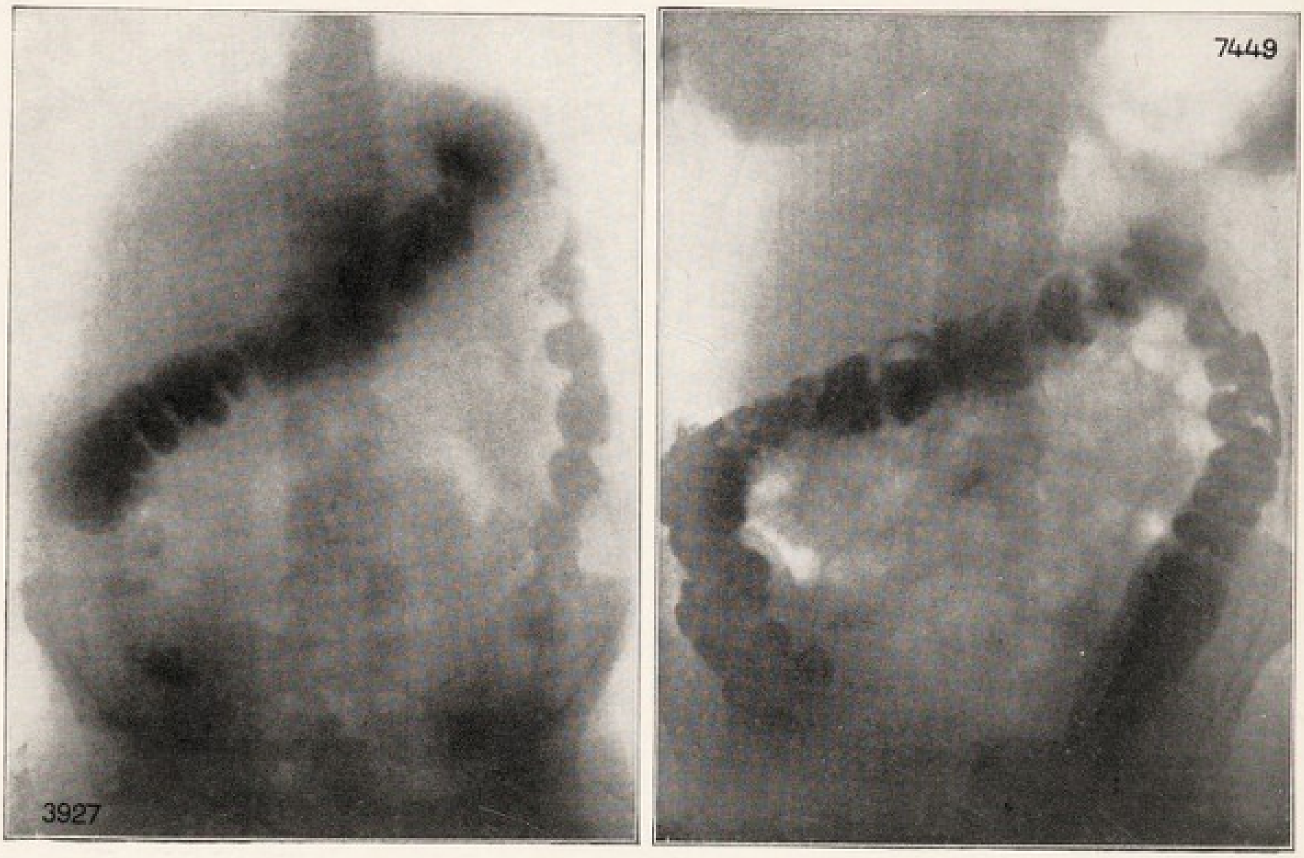


FIG. 309.

The transverse colon follows normally the course of the greater curvature of the stomach; if the stomach is filled it is deeper than if the same stomach is empty; its course, therefore, corresponds to the displacement of the stomach pathologically up or down to right or left. Only in marked dilatation of the stomach and exceptionally short mesentery is the transverse colon unable to follow the greater curvature, but remains at a higher level above it; in exceptionally long mesentery the transverse colon can sink down alone, and with stretching at the same time of the gastro-colic omentum leave the stomach in its place.[1]

The position of the colon probably alters not only with the filling of the stomach, but also with the filling of the intestine.

[1] After Schwarz.

One reason for *the downward displacement of the flexures* of the colon is enlargement of the liver and the spleen. The flexures then show scarcely any alteration from their normal form, they are only situate somewhat higher or lower. Occasionally, however, the flexures take on quite unusual forms, at least the hepatic flexure. The beginner then often imagines the most unusual causes, and in about nine-tenths of the cases the real cause is only a yielding of the bowel before the descent of the liver. One often sees the liver quite clearly in good photographs, and one should not forget in the views of the flexure to bear it in mind. The cause may, however, be an enlarged or dropped kidney.

Owing to the various reports in the literature of what were here normal, and what pathological, *systematic measurements* were carried out on the position of the colon,[1] which revealed that both in men and in women with a normal alimentary canal the transverse colon often occupies a position that would previously have been considered a sure sign of ptosis. The presence of a ptosis could be suspected from the position of the transverse colon, when the organ oversteps the normal by several centimetres; *i.e.* a colon a distance even of 15 cm. below the umbilicus cannot be regarded as definitely pathological. The diagnosis becomes very difficult in the given case. Still more difficult when the position on the next day is either a higher or a lower one.

But as little attention was paid in this inquiry to the position of the flexures and a variety of statements had been made on the situation of the umbilicus, which itself is not a fixed point, further researches were made into the physiological position of the colon.[2] The results of these were: *the variations in position of the right flexure* in normal cases after a meal by the mouth were between 6 cm. above and 3 cm. below the iliac crest, most frequently between 4 cm. above and 3 cm. below. Men and women showed no difference. After a contrast enema the flexure occupied usually a higher position; most frequently 4–7 cm. above the crest; often considerably higher, 9–11 cm., maximum 15 cm. In women the figures were somewhat less. The rule is in men and women: by the mouth, 3–5 cm. higher than by barium enema. *Left flexure:* by the mouth, considerable elevation above the iliac crest, especially in men; maximum 16 cm.; but fairly often, especially in women, only 2–3 cm. above the crest, occasionally even below the latter. Greater physiological variation extremes on the left than on the right. In asthenic cases a lower position of the flexure was found somewhat more frequently. After barium enema the level of the flexure is as a rule from 10–16 cm. above the crest (maximum 21 cm.); only a few (women) less than 8 cm. above the crest (minimum 5 cm.); asthenic cases likewise. On account of the different length and form owing to ptosis the *most dependent point of the transverse colon* is not such a fixed point. Therefore (normally) a great range of variations

[1] Hess Thaysen: Grenzgeb. d. inn. Med. u. Chir., Bd. 34, p. 175, 1922.

[2] H. Rotky and Herrnheiser: Untersuchungen zur physiologischen Dickdarmlage und zur Frage der Koloptose. Fortschritte, Bd. 31, 1924.

is possible. Distance of the most dependent point of the transverse colon 0–15 cm. from the upper edge of the symphysis. In men a greater distance (10 cm. and more) than in women. Asthenical people showed in about the half of the cases about the same relative position (1 cm. above or below) of the transverse colon and the edge of the symphysis. In barium enema hardly any alteration in the extent of variation. Sexual and constitutional differences play only a minor rôle as a cause of variations in position. A certain sexual difference might be the generally higher levels in men. Asthenics, and a certain percentage of normal women, show a relative preponderance of the lower positions. Generally speaking, intestinal positions which can be called at once " ptosis," are not at all so rare even in quite healthy bowels and normally built people.

In views taken with the patient in the standing position portions of the colon and sigmoid may overlap, which in the horizontal position of the patient may become distinguishable; the horizontal position with downward inclination of the upper half of the body affords often the best results. If they do not then separate and cannot be moved apart by other manipulations, we have to suspect *adhesions between the colon and the sigmoid*. The author found in one case of adhesion of the middle of the transverse colon with the sigmoid that the angle of the V-shaped transverse colon became smaller in forced expiration. Also the separation of the limbs of the hepatic and splenic flexures can often be successfully brought about in this way.

An elevation of the hepatic flexure, as in Fig. 308, A, is sometimes to be regarded as an adhesion with the liver. This diagnosis should not be made unless some other sign of adhesion is present. In the above figure adhesion could in all probability be definitely excluded.

The *haustra* of the colon can show the most varied forms without its being necessary to diagnose them pathologically.

The examination of the colon by *high enemata* has also great disadvantages. At any rate, the transverse colon becomes often much altered thereby in its position.

A close approximation of the hepatic and splenic flexures may be due to a constricting band.

Many gastroptoses and coloptoses should not be called definitely pathological, seeing the transition from the normal to the pathological is quite a gradual one.

Coloptoses [1] may affect either the transverse colon or only the ascending colon (very rare) or the two flexures and the transverse colon. Slight degrees of ptosis of the ascending colon are frequent (see also above).

A *festoon-like hanging* of the middle two-fourths of the transverse colon belongs to the region of the normal, and has nothing to do with coloptosis.

[1] Refer to the explanations by Strauss: Die Gastro-Coloptose in röntgenol. Beziehung. Deutsche med. Woch., June 10, 1915.

Large *coil-formation of the colon* entails naturally a considerable lengthening of the same, which can only be explained as of congenital origin. The coil formation is best seen when the patient is allowed to draw in the abdomen or after forced expiration closes the glottis and lifts the thorax.[1]

In a contrast enema the *haustra* of the colon are at first almost obliterated. (That informs the röntgenologist at once, whether a picture given him for diagnosis has been obtained by a contrast-meal or a contrast enema.) A definite haustral segmentation returns only gradually after barium enema. Contrast enemata are to be observed especially during segmentation.[2]

Oblique positioning of the haustra either towards the mouth or downwards is a frequent occurrence and *per se* does not mean anything pathological. The form of the single haustral shadows is also normally extremely different.

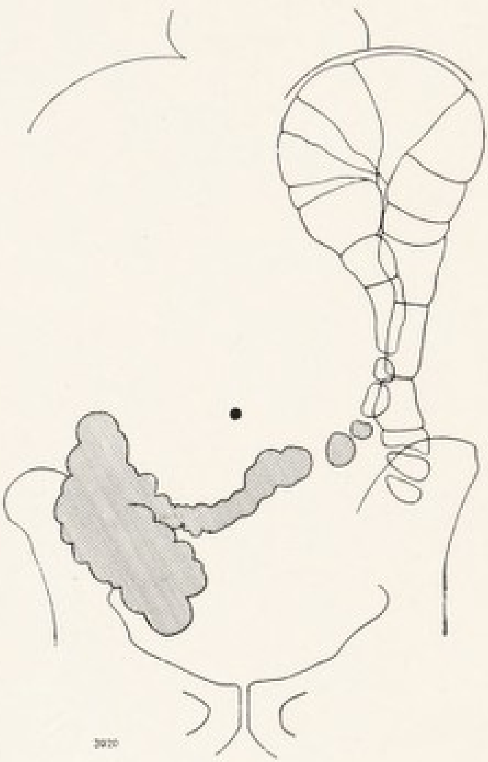


Fig. 310.

Gases in the Intestine

Large collections of gas (which naturally is visible in simple plates without contrast-meal) are met with in the hepatic flexure, in the splenic flexure (see above under "Stomach"), in the sigmoid flexure, and in the rectal ampulla under normal conditions. Strikingly large gas collections in both flexures of the colon, pushing up the latter in the form of clubs, occur in colitis. Considerable collections of gas at the splenic flexure and a large collection in the descending colon seems to be a regular occurrence in simple *chronic constipation*. A constant gas-distended coil of colon should not at once lead us to diagnose a stenosis. Kinking, coil-formation, or also muscular inertia of the great bowel suffice to bring about a marked hold-up of its gaseous contents.[3] For advanced pathological cases, see Figs. 310 and 312.

Small collections of gas in single contrast-filled haustra are devoid of pathological significance.

A differential diagnosis has to be made from air-bubbles in the duodenum, but these are not frequent. The gas-bubbles in the duodenum

[1] After Chilaïditi.

[2] Haenisch.—S. Gilbert Scott: Radiological examination in organic diseases of the colon: the opaque enema method. Brit. M. J., January 24, 1925, 151–154.

[3] Alfred Weil, *l.c.*

are always smaller, they show usually a rounder upper margin, and are in the majority of cases at a higher level than the pylorus.

Long gas-bubbles in the hepatic flexure and in the transverse colon, with their long axis running obliquely from medially and above laterally and downwards, are said to be typical of adhesions.[1]

If the splenic flexure is filled with gas and touches the diaphragm, that indicates an empty stomach ; for with the stomach empty and contracted there is room left in the left cupola of the diaphragm, into which the splenic flexure filled with gas ascends.

Very large collections of gas remaining in the left flexure of the colon, as in Fig. 310, cannot be regarded as physiological A patient showing such a condition of affairs usually complains of stabbing pains in the left hypochondriac region and a tendency to flatulence ; " pneumatic valve stenosis " is the name given to the condition. The patient, to whom the diagram Fig. 310 belongs, suffered from intermittent stoppage of the bowel, lasting usually four to eight days, and at first his condition was thought to be mobile cæcum.

FIG. 311.

Now and then there occur normally in the middle of the ascending colon, still more frequently in the descending colon, two to three haustra, which in addition to the barium contain accumulations of gas. While the latter fill out the haustra in regular fashion, a point somewhat easily overlooked by the beginner, the contrast masses take on the most peculiar forms, and may induce one to diagnose a stenotic tumour where none exists.

Fig. 311 shows great collections of gas above and on both sides of the stomach which is displaced inwards and elongated. In this way also the left half of the liver shadow is delimited by a slightly curved vertical line running 3–4 cm. from the shadow of the vertebral column, and illuminated by the gas-containing coils of bowel. The patient was a woman in whom evidences of intermittent intestinal stenosis had been present for years.

[1] Bucky and Fuld : Gasgehalt der Flexura dextra bei Adhaesionen. Fortschritte, Bd. 30, Kongressheft, 1922, 1. Heft.

On operation there was found an opening in the great omentum—probably congenital—in which a piece of transverse colon had been caught after the manner of a hernia.

Various

In estimating Röntgen findings in *a barium enema,* which can be recognised immediately from the want of haustra, we should never forget that one has to deal with quite unnatural conditions of filling and loading. It is certain, too, that the tone of the intestine is altered in many cases, and spastic conditions and even organic constrictions can be simulated, and elevation and shortening of the transverse colon produced. One has also to note in estimating, whether the examination is done on standing or in the dorsal decubitus or in the prone position. The intestines are different in all these positions in the same patient.

For exact study of the great intestine three warm-water enemata should be given before the contrast enema. The barium enema should be watched as it runs in, and the patient had best introduce the tube himself.[1]

It is often of use after the patient has been allowed to evacuate part of the enema to screen again and take a photograph. The distribution of the remaining enema allows one to draw inferences on the movement of the contents during the act of defæcation: a hypermotile section will then be found more or less empty. Remains of the enema will be found above a stricture, while the contents of the bowel below it are evacuated per rectum. It is also important to recognise fine contrast remnants in inequalities of the mucosa.[2]

The latest recommendation is to combine the contrast enema with the introduction of air.[3] During the passage of the enema the mucosa is coated with a fine lining of contrast substance and then becomes unfolded by the enema. Begin first with observing the regular inflow of the enema and only then proceed to introduce air per anum.

Dense shadow spots at the end of a massive shadow column are produced by the ensuing descending meal beginning to mix with the previous contrast one.

If one sees in Röntgen view *dilatation of the colon* with continuous *fluidity* of its contents, we are at liberty to diagnose a stenosis (in consequence of tumours or in consequence of tuberculosis). The bowel is dilated also in congenital ileus, but without the characteristic gas and fluid contents of a stenotic dilatation. With the patient in the standing position the fluid consistency of the contents is clearly visible, being met tangentially by the rays. In the horizontal position of patients that is not possible, for the fluid is horizontal, and its limits from the gas is not projected as a line but as a surface (the contrast-meal being given by the mouth).[4] The author

[1] W. O. Upson: Technique for röntgenological study of the colon. Am. J. of Röntg., November, 1926.

[2] Stierlin, quoted by A. W. Fischer, *l.c.*

[3] A. W. Fischer, *l.c.*

[4] Schwarz: Klin. Röntgendiagnostik des Dickdarms. Berlin, 1914 (Springer).

shows a typical illustration of this in Fig. 312, a carcinoma being found in the sigmoid flexure at operation. (The oblong body to the right of the umbilicus made a difficulty in diagnosis ; it looked like a metal ring. It is, however, clear that a piece of the gas-filled colon has been projected in the direction of the rays.) If the contents of the great intestine are rendered fluid by catarrh or from use of aperients, they are evacuated at once. Hollow spaces filled with fluid appear only in a congestion of the contents of the great bowel—that is, in stenosis. One can occasionally even without a contrast-meal recognise the state of affairs by means of the screen.[1]

In examining for *a malignant tumour of the colon* one nearly always gets better results with a contrast-enema than with a contrast-meal. The Röntgen symptoms of cancer of the colon are (1) defect in filling, and (2) closure.[2] The filling defect is brought about by a tumour projecting into the lumen, an infiltration or a stiffening of the intestinal wall. By spastic contractions of the intestinal wall the defect can appear to be even larger than it is. Incomplete closure is not easy to distinguish from physiological retardation of the passage. Stenosis may occur also without any Röntgen signs. An enlargement of the proximal parts in a well-running enema is indicative of a stenosis. To determine from spasm only : the latter can be relieved by drugs. Tuberculosis, actinomycosis, appendicitis, and typhlitic abscesses may produce similar Röntgen signs to those of carcinoma. Similarly an ulcerative colitis, if circumscribed, can scarcely be distinguished from carcinoma.

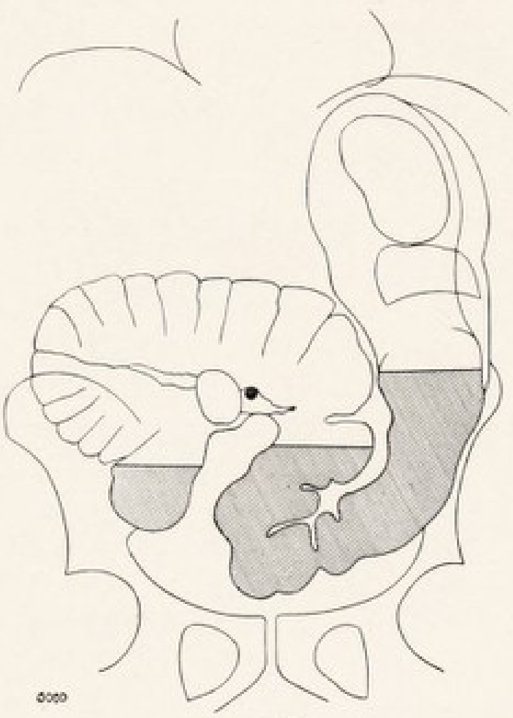


Fig. 312.

Simple interruption of filling of a contrast-meal without alteration of the proximal (or distal) intestine at this point is devoid of any pathological significance (nevertheless refer to " Ileo-cæcal tuberculosis ").

If the intestine in a larger or smaller portion is not segmented, but smoothly *cylindrical* (*i.e.* formed like a band in the shadow picture), that indicates a fixation of the intestine (see Fig. 313).

Small pericolic adhesions may sometimes be the cause of a somewhat unusual position of the transverse colon. But when a piece of bowel runs a certain distance quite straight and then makes a sharp bend, that indicates a strong adhesion, see *e.g.* Fig. 313 (confirmed at autopsy) and Fig. 314 (con-

[1] Schwarz ; see especially Kloiber, " Ileus," Röntgenkongress, 1920. Berlin.

[2] Russell D. Carman : Röntgenologic signs of cancer of colon. Journ. of Radiol., May, 1923.

firmed at autopsy). That does not mean to say that every rectangular kinking in the transverse colon must be due to an adhesion. It may also be remembered that adhesions might remain quite concealed, especially when a direct pull is not exerted in the position in which the patient was examined. But a sharp kink of a part of the intestine, present on repeated examination, is always indicative of adhesions ; also a repeated absence of haustration in parts of the bowel in which haustra usually occur.

If any röntgenogram of the colon could lead to the diagnosis of " firm adhesions," Fig. 315, A, might, for the transverse colon, which on the right hangs far down, makes suddenly a sharp bend straight upwards as far as the umbilicus, although at this point thin and not well filled. It then bends round again, at right angles and to the left. But B, another view of the same case, taken fifteen hours afterwards, is surprisingly different, showing quite another and quite unexpected appearance, with the transverse colon displaced far upwards, in

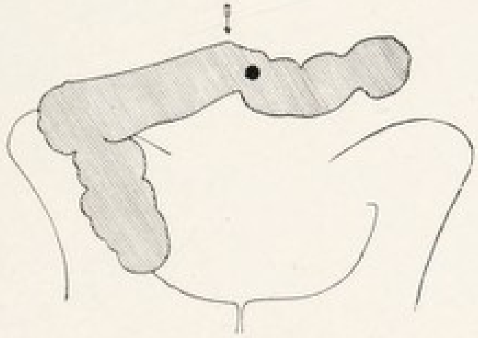


Fig. 313.

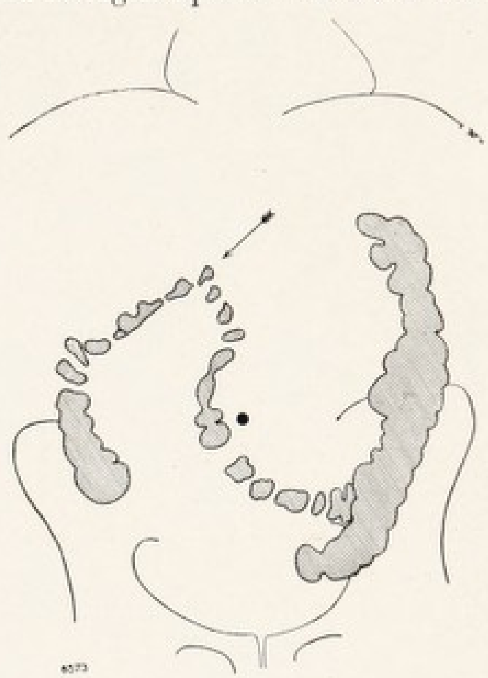


Fig. 314.

quite a normal position. The form and position in Fig. A must naturally have a cause, but adhesions may be excluded.

If the shadow of the colon is without sign of haustra, band-like and narrow, and the contrast-meal does not show any homogeneous black shadow, but is altogether mixed through with small flakes and gross splashes and fine streaks (Fig. 316, left middle, " plaited band form "), that speaks for *colitis ulcerosa ;* particularly the non-tuberculous form, which usually occurs in the distal sections of the colon (severe diarrhœas without colic, stools with mucus, pus, and blood). In these cases the flexures (after a barium meal by the mouth) contain much gas, interstratified and dotted with the shadows of many contrast flakes (Fig. 316, left above, " marbled air-cylinder," where the whole descending colon is like that).[1]

Continuous, very fine shadow-bands over large distances are said to occur in simple chronic catarrhal colitis. But above all dense shadow-strips are visible many hours or several days at the same places ; these are several centimetres long, in thickness from a thread of wool to a pencil, and

[1] Kienböck.

mostly curved and arched; they are as a rule arranged in groups (cannot always be removed by aperients and enemata), and are characteristic of catarrhal colitis. The appearance arises through the barium being retained in the folds of the hypertrophied and strongly wrinkled mucous membrane.[1]

Moreover the gas-containing splenic flexure, as represented in Fig. 317, is not—on account of its dotted and mottled appearance—normal, but is indicative of a catarrhal change in the mucous membrane. A change like this localised to one narrow area is found only very rarely; the author at least saw it only two to three times. Such cases when examined as a control

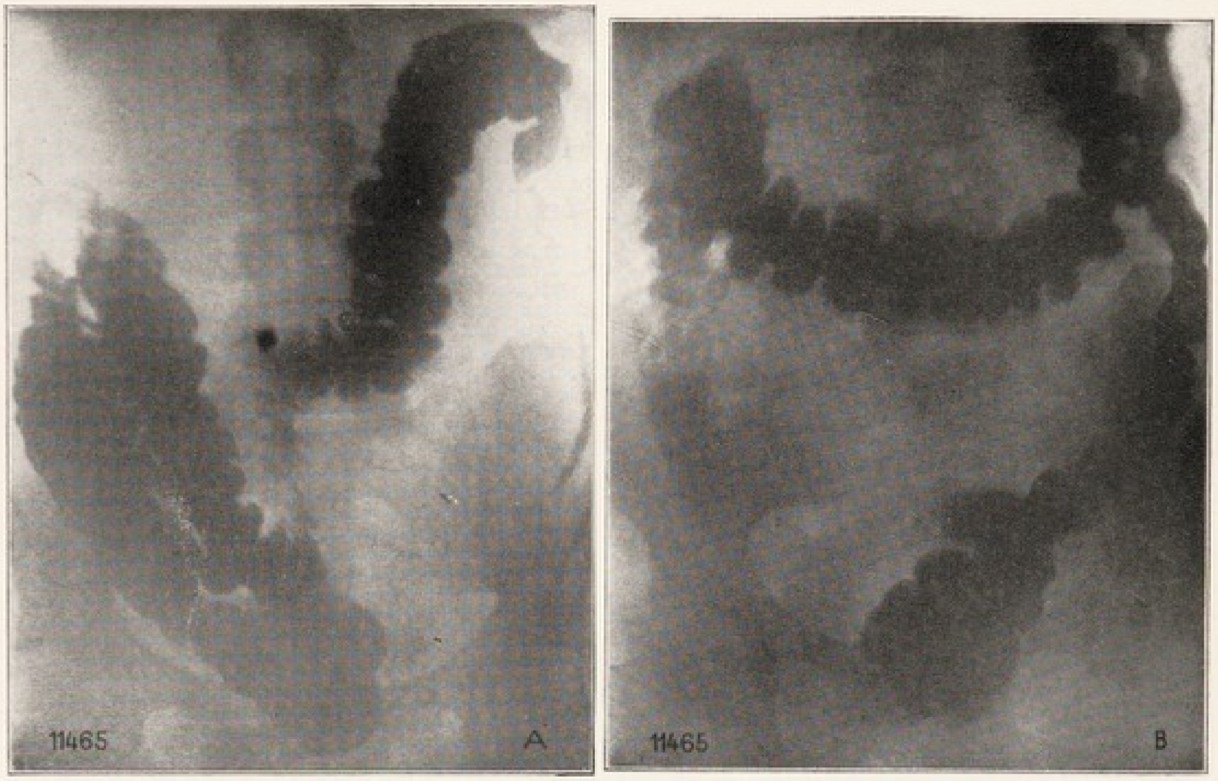


Fig. 315.

by a barium enema do not show anything remarkable at the particular points. (From a private communication by Forssell.)

Displacements of the transverse colon upwards occur especially in pericolitic adhesions. The hepatic flexure can be quite drawn up, as in Fig. 314.

A shadow of the transverse colon, as shown in Fig. 318, representing a complete arched band, was found once by the author in a case of *pancreatic tumour* (autoptic finding). The diagnosis was made tentatively before the operation. Also in tumours of the kidneys and mesentery displacements of the great intestine have been described.

In the clinical picture of a chronic, benign, and mechanically produced stenosis of the great intestine there was found at operation an inner adhesive obliteration of the terminal part of the transverse colon and of the first part

[1] E. Schlesinger, *l.c.*

of the descending colon.[1] The course of these two pieces of bowel is sometimes represented nearly parallel (which, moreover, often happens normally). The hepatic flexure in these cases is usually not particularly pronounced. People of middle and old age are the ones generally affected. A pain is constantly felt under the left infracostal margin. Virchow drew our attention to the frequent occurrence of inflammatory adhesions, especially in the region of the two flexures of the colon. When the "double-barrelled shadow" of the two limbs of the coil of intestine can be separated by Röntgen palpation on the screen, no adhesions are present. If palpation is not possible owing to the flexure being situate high up under the costal arch,

Fig. 316.

Fig. 317.

then we should first make (see also above) one exposure in the dorsal decubitus, then another one in the lateral position. If adhesions are present, the picture of the flexure is the same in both photographs; if adhesions are not present, the double-barrelled shadow separates apart.

A *marked coil-formation* in an otherwise straight descending colon appears to be of congenital origin, or acquired by overfilling.

Normally typical formation of fæcal balls are found usually first in the descending colon, at the highest in the left third of the colon, but in pathological cases, as is well known, they may occupy the part proximal to the hepatic flexure.

[1] Payr: Über eine eigentümliche Form chronischer Dickdarmstenose an der Flexura coli sinistra. Zentralblatt f. Chir., 1905, No. 30; see also the same: Therap. Monatshefte, 1909, Heft 1 and 2.

If the descending colon, through which normally the meal passes in lumps, be filled up with meal in one complete stretch, one should inquire before diagnosing an obstruction of the end of the descending colon whether the patient took any opium before the examination. On the other hand, again, hypermotility may reach as far as the descending colon.

An extensive constriction of the descending colon may be produced by a *contraction of the longitudinal musculature*, and belongs to the picture of spastic constipation.

A very rapid advance of the intestinal contents in the proximal parts of the colon, and considerable delay in the distal parts in the same patient, is not uncommon, and belongs to the picture of constipation. Often, too, the barium shadow moves at a uniform rate from the ascending colon to the

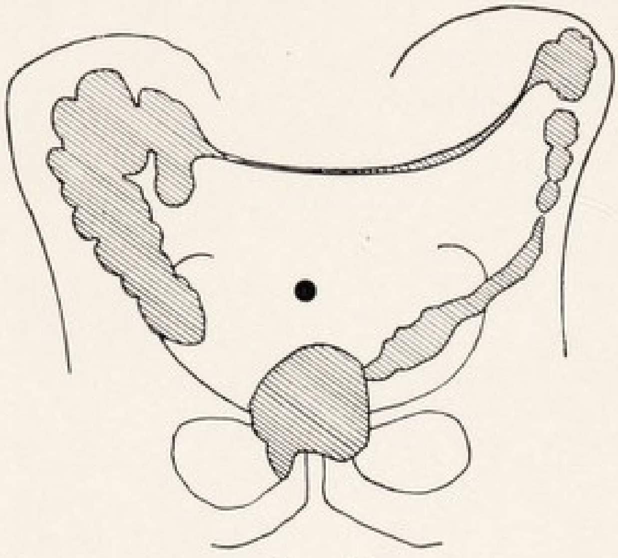


FIG. 318.

FIG. 319.

sigmoid flexure, the proximal end of the shadow progressing about as quickly as the distal; and there remains during the whole examination in spite of subsequent evacuation an extended shadow of the sigmoid flexure, that can be seen for some time; in that case it is the sigmoid flexure that is primarily responsible for the constipation.

Bulb-like fillings of a piece of descending colon, as seen in Fig. 319 ↑, are occasionally found. When one meets them for the first time, one thinks at once of a dilatation before a stenosis. Yet it appears that no particular stress should be placed on these if no other severe clinical symptoms are present. It is not impossible that in this condition we are dealing with a stretching of the bowel at the moment when large fæcal masses are moved forwards, or shortly afterwards.

A tap-like narrowing of the descending colon at its transition to the sigmoid is physiological. This narrowing is particularly evident in barium enemata. Its position is about the middle of the left iliac fossa.

Diverticula

Sharply circumscribed shadows from a lentil- to a finger-nail-size, placed on the haustra of the colon, especially the descending colon and sigmoid, still visible several days after the emptying of the contrast-meal, often multiple and arranged in groups, rarely single, are probably *diverticula*.[1] Congenital diverticula are rare ; the acquired are to be regarded as pathological. The latter are mostly incomplete ; they are herniæ of the mucous membrane through the muscularis, mostly at places where blood-vessels perforate the wall. They occur in all parts of the colon, varying in number from 1 to 300 or 400 ; they are circular or ovoid, generally situate upon the wall itself, occasionally obliquely placed thereto. Their openings into the intestine may be stenosed or the width of the diverticulum itself. These diverticula usually contain fæcal masses, occasionally coproliths. In long chronic processes they can give rise to pericolitis, peridiverticulitis with adhesions from sigmoid and small bowel, bladder and uterine adnexæ. They affect males two or three times oftener than females. In general, however, diverticula are not very common ; in sections there occurred on the average one case in 450, and in ten out of thirteen cases the diverticula were multiple. The relation of diverticulitis to neoplasms of the colon is said to be one to three. The patients almost without exceptions are inclined to be stout, and are of a good colour of the skin. Chronic constipation is usually a feature. Proctoscopy gives a negative result, and there is no blood in the stool. The clinical symptoms resemble those of a left-sided appendicitis, and sometimes bear a distant resemblance to a carcinoma. Contrast-meal can be seen sticking in the diverticula ten days after the introduction by the mouth or by a barium enema. If the whole contrast-meal (or the whole enema) is still present, one may often observe in addition to the diverticula spasm, constriction and filling-defects of the affected part of the bowel ; this train of symptoms appears to be pathognomonic of diverticulitis. The pocket-like shadow-spots in carcinoma of the bowel have not the fine rounding and symmetry of diverticula. If the diverticula are occupied by firm fæcal masses, it can easily happen that the contrast-meal is unable to enter, and so the diverticula are not visible. They are best seen on the second to the

[1] R. D. Carman : Report of a case of diverticulitis of the sigmoid with the röntgenologic findings. Amer. Journ. of Röntgenol., February, 1915.—J. T. Case : The Röntgen demonstration of multiple diverticula of the colon.—*Ibid :* The X-Ray investigation ot the colon. Arch. of the Röntgen Ray, London, Vol. XIX., p. 375, April, 1915.—A. W. George and R. D. Leonard : The Röntgen diagnosis of surgical lesions of the gastro-intestinal tract. Boston, 1915.—*Ibid. :* The value of the Röntgen ray in the study of diverticulitis of the colon. Am. J. of Röntg., Vol. VII., No. 9, p. 421, September, 1920, and No. 10, p. 505, October, 1920.—Carman : The Röntgen - Diagnosis of diseases of the alimentary canal. Philadelphia and London, 1921. (Saunders Co.) (with list of the literature).—J. T. Case : Der röntgenologische Nachweis des multiplen Dickdarmdivertikels. Fortschritte, Bd. 30, 1923 (with list of the literature).—F. W. Mackoy : Family diverticulosis of the colon. Radiology, December, 1926.—Ch. D. Enfield : Diverticulitis of the colon, with especial attention to the diagnosis. Radiology, November, 1926 (with large list of the literature).—E. L. Spriggs, Proc. Roy. Soc. Med. 1926–7, xx. 665. Subsection 57.—Refer also, An X-ray atlas of the normal and abnormal structures of the body by Archibald McKendrick and Charles R. Whittaker, 1927 (E. and S. Livingstone), pp. 198–201 : Radiograms by Dr. Hope Fowler, Edinburgh.—Robert Knox : Radiography (A. and C. Black) emphasises the necessity for differential diagnosis between carcinoma and diverticulitis.

third day after ingestion of the contrast-meal (once they were seen to remain as long as the sixteenth day), and they are more difficult to see after barium enema; the latter must be retained at least half an hour to an hour. In the differential diagnosis we have to consider phleboliths, calcified glands (see next paragraphs), kidney and ureter stones, and occasionally contrast-meal remaining in contracted haustra.

If we go through our pictures of the colon, we find a number of *haustra*, in which we might think of diverticula, when none are present. It is to be noted in this connection that diverticula shadows are usually associated with filling defects, while in haustra filling defects are not found. Shadows

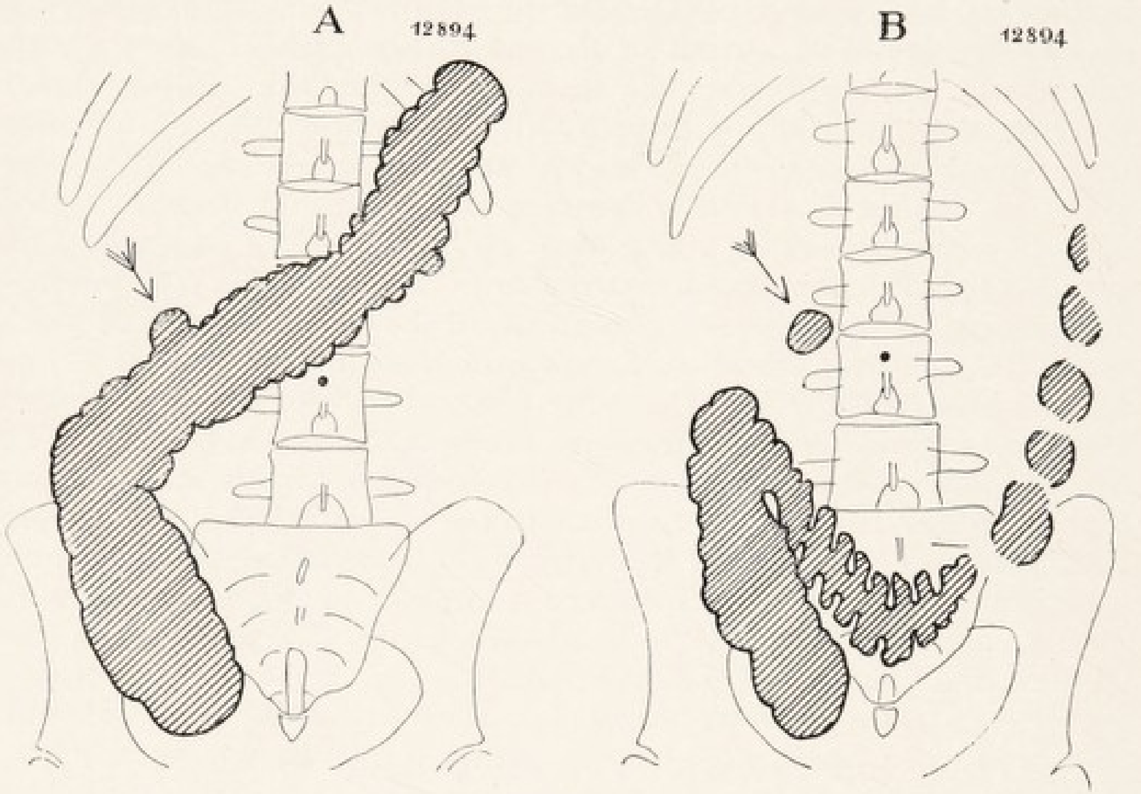


Fig. 320.

of the haustra are apt to disappear or rarely to alter their position. Diverticula shadows retain their position, often even after the bowel has been completely or partly emptied. An examination after emptying of the whole colon corroborates the diagnosis. It should be recollected in a bowel filled with contrast-meal that diverticula placed in front or behind are overshadowed and can be discovered only by profile irradiation—at least in thin individuals.

One occasionally meets with pictures of the descending colon, which are probably quite normal, but in which one, two, or three haustra contain one-half gas, one-half contrast-meal. In such cases the contrast-meal often assumes the most peculiar forms and may easily resemble one or more diverticulum shadows.[1]

Fig. 320, A and B, illustrate how a diverticulum can be simulated by a

[1] Such a case, see, *e.g.*, in R. Balli: Sul limite fra il normale ed il patologico nella röntgenologia del tubo digerente. Modena, 1922.

calcified mesenteric gland, whose shadow has been accidentally cast on the shadow of a haustra. Naturally it is sufficient, when the questionable shadow has been discovered first on the screen and not on the plate, to turn the patient a little or to set the tube a little higher or lower, or to alter the position of the colon, in order to separate the shadow of the gland from that of the colon.

Sigmoid Colon [1]

The *beginning* of the sigmoid cannot be clearly distinguished from the descending colon, even in the purely anatomical sense; therefore one takes it in the middle of the left iliac fossa (see Fig. 321, roughly Rauber-Kopsch. The demarcation between sigmoid and descending colon is placed at ×, the commencement of the rectum between * and ↓).

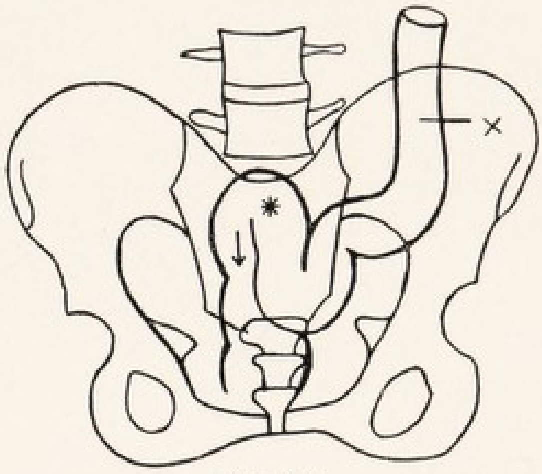


Fig. 321.

In the examination of the sigmoid *the high barium enema* is often indispensable.

As already mentioned above, a contrast-meal taken by the mouth occupies the sigmoid in normal conditions for about twelve hours.

An *abnormally large sigmoid* is regarded as a congenital anomaly. A markedly long sigmoid might be on the border-line of pathological (macrosigma); it is considerably enlarged at the same time; the other parts of the colon also take part in the condition: megacolon (Hirschsprung's disease=severe cases of megacolon in children).

The sigmoid may at times be encountered in every part of the abdominal cavity. Its position and length is very various, and several examples of this are shown in Fig. 322. One should also note the sigmoid in the other illustrations of the great intestine in this book. The sigmoid can also enter the rectum from above or even further from the right side, instead of from the left, without its being described as pathological; or it may form a high, narrow, persistent coil (C and D one and the same case).

After careful anatomical inquiries in 101 subjects,[2] four groups of *variations* can be distinguished: (1) the sigmoid is situate in the pelvis and has coils or windings (vertical or horizontal); this is the most complete and physiological form; (2) the coils of the sigmoid are outside the pelvis and to the left of the vertebral column; (3) the sigmoid is displaced to the right side of the abdomen; (4) the sigmoid represents an almost straight

[1] See the literature on the gastro-intestinal canal given on pp. 505, *et seq.*; further, Jaugeas and Friedel: L'examen du rectum et de l'anse sigmoïde par les rayons de Röntgen. Journ. de Radiologie et d'Electrologie, Bd. 1, May, 1914.

[2] Ssoson-Jaroschewitsch, St. Petersburg: Die Analyse der Variationen des S. romanum. Arch. f. klin. Chir., 125, 1/2, p. 283.—F. Walcher, St. Petersburg: Die Grundtypen der Form und der Lage der Bauchorgane des menschlichen Körpers. *Ibid.*, p. 490.

tube (rarest and most incomplete form). The form and position is determined by the root of the mesentery, the form and size of the mesentery and length of the bowel; the embryonal pre-formation, the age, the shape of the pelvis, the physiological state of the intestine and of the neighbouring organs determine the topography.

Constricted lumen and excessive segmentation of the contents are indicative of *spasm.*

A very long sigmoid with cessation of segmentation, *i.e.* almost parallel edges of the contrast-meal shadow points to *atony.*

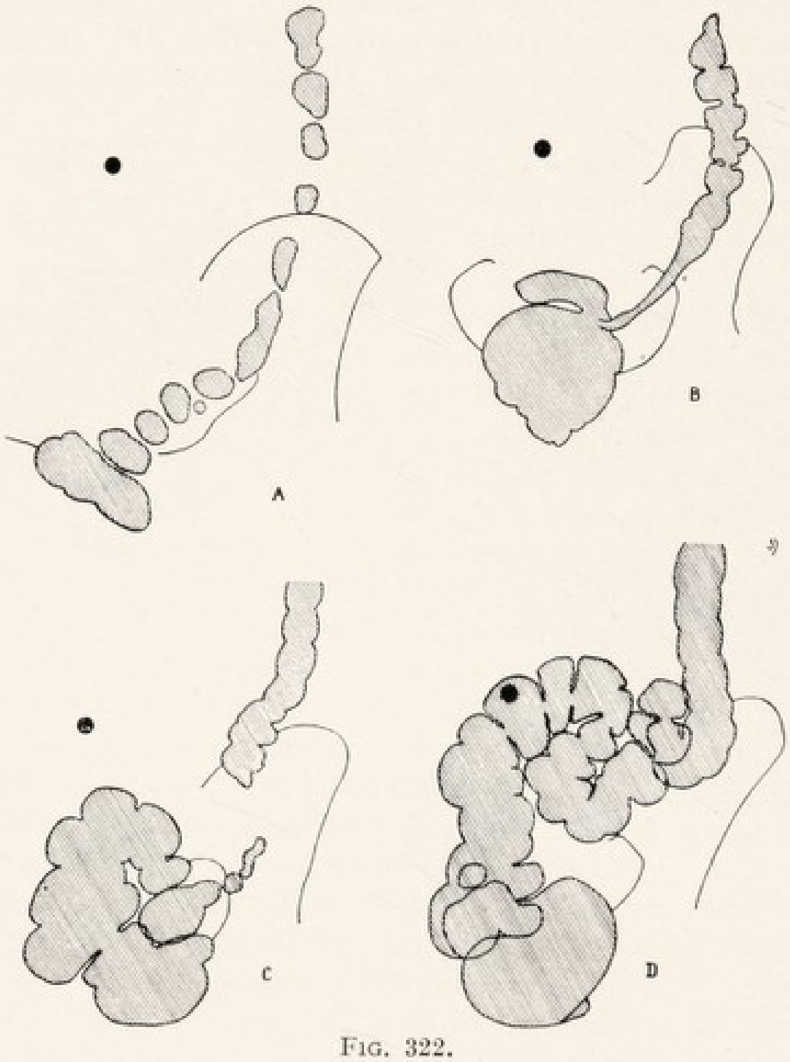


Fig. 322.

Persistent irregular jagged defects make us suspicious *of malignant tumour.*

When uncertain whether a large round translucent zone in the picture of the iliac fossæ or of the sacrum and coccyx is a bony tumour, or is due to a gas-bubble in the sigmoid colon or rectum, we can make sure by repeating the examination the next day or later. A gas-bubble, even if it remains in a definite part of the bowel for a long time, does not give exactly the same picture exactly to a millimetre in a series of photographs as does a bony tumour. With the careful use of a lufa-sponge compression the gas-bubble may not disappear altogether, but it may be displaced or considerably altered in its form. (This section refers to findings without contrast-meals.)

In a case suspected of carcinoma of the rectum or sigmoid attention should be especially directed to the terminal part of the sigmoid colon, which is a favourite site for *malignant tumours*.

When a barium enema stops suddenly at one point in the sigmoid or the rectum and does not go any further, but is restricted to a definite cul-de-sac, offering an insuperable obstacle to the introduction of the enema, there is usually a *carcinoma* present. The growth does not necessarily occasion any considerable stenosis, but it may be in its very earliest stages, and an ordinary contrast-meal given by the mouth can pass through the constricting point quite easily. This symptom has been called " valve-closure." [1]

For determining *the position of the sigmoid colon* the introduction of the contrast-meal by the mouth is nearly always the method employed, for enemata produce many displacements (see also p. 529).

In the part of the sigmoid next to the rectum, which anatomists were wont to reckon as belonging to the rectum, the lumen is normally strikingly narrow. (The region of the rectal end of the sigmoid represents the angle that has to be flattened out during a sigmoidoscopy.)

Large tumours of the uterus and of the adnexa may alter the shadow-picture of the sigmoid very considerably. One should remember this possibility, when otherwise plain pictures of the sigmoid cannot be explained.[2]

Rectum [3]

Rectum and sigmoid are not sharply delimited, and let us therefore relate what the anatomists understand by rectum proper ; it starts at the level of the third sacral vertebra and ends at the anus. One limit can be recognised in favourable cases, namely, that the haustra cease in the rectum, which, though none too plain, are still recognisable in the sigmoid. In the upper part of the rectum are found transverse folds, usually two, seldom more, maximum five. The lowest is placed about 6–7 cm. above the anus. One sees these folds, occasionally more than five in Röntgen view, with the bulgings of the bowel between them (Fig. 323, A, B, C, etc.). The rectum, according to anatomical estimate, is 13–15 cm. long, of which the greater portion is formed by the ampulla (9–11 cm.), 2–3 cm. are in the upper cylindrical part and as much again in the perineal portion, which is called the " anus " (see also Fig. 321).

Normally the rectum is held empty by a tonic contraction at the place where rectum and sigmoid meet, the " recto-sigmoid valve," and becomes

[1] G. Schwarz, *l.c.*

[2] J. Odelscalchi : La Rad. med., January, 1922.

[3] See the above-mentioned literature on the entire intestinal canal ; further, Jaugeas et Friedel : L'examen du rectum et de l'anse sigmoïde par les rayons de Röntgen. Journ. de Radiologie et d'Electrologie, Bd. 1, May, 1914.

filled only during defæcation. After a normal defæcation in the morning the rectum stays empty. The normal recto-sigmoid valve is about 5–8 cm.

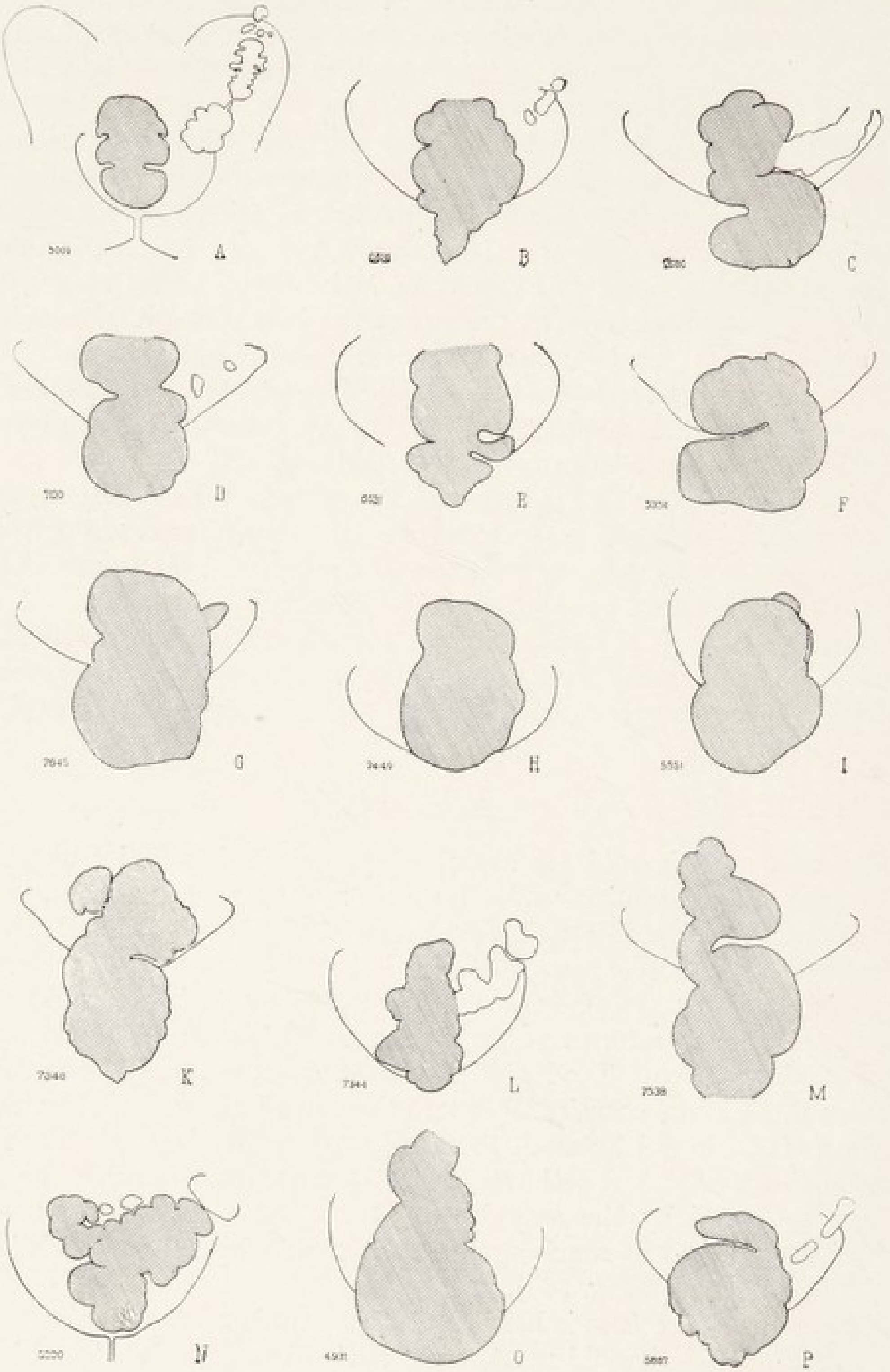


Fig. 323.

long. Variations occur in its tone. According to statistics of a leading surgeon, 63 per cent. of the neoplasms of the rectum and sigmoid are in the region of this valve. The visualising of the recto-sigmoid apparatus is very difficult, also the application of a contrast-meal does not help us much.[1]

The Röntgen anatomical picture of the rectum and of the last part of the sigmoid is under normal conditions just as different in different individuals as that of the stomach or the transverse colon. The description of the anatomical text-books, a cylindrical tube with flat constrictions, one never finds. In the majority of cases two principal folds appear (see Fig. 323, B, C, E, K, M, N, O). The form of the rectum in adults, taking it all in all, corresponds to a spindle, pear, ellipse, or a thick plump S. The latter form (C, K, M) arises when the two principal folds are projected in their greatest depth by the tangential rays. The more elliptical, pear, and sac-form variety is probably brought about when these folds run more ventral and dorsal or are completely obliterated in maximal filling (B, G, H, I, O). The beginner is easily inclined to regard this latter form as an extreme dilatation, especially when the patient has complained of constipation for years. This view, however, is not correct, for it may be mentioned here that in the case of O, the patient had been constipated for years, that in the similar cases, B and G, chronic constipation had never been a feature, but rather chronic diarrhœa and a normal easy action of the bowels, and that, on the other hand, in the well-indented forms L, M, N, many years' constipation was complained of. With the exception of C the diagrams relate to contrast masses given by the mouth. In contrast enemata the pictures of the rectum resemble each other more, but such pictures are again incomplete in other respects. Whether it is a matter of any consequence to pay attention to the height of the rectum has not in the meantime been decided. Although in the diagrams the lowest point of the rectum is very variable in position, we are not in a position to draw any conclusions therefrom, for the diagrams are not orthographic, and the focus of the tube was not always in the identical position.

The last part of the rectum, the so-called " pars perinealis," is usually found free from contrast-meal.

During ten years the author has seen only one instance in which the thickness of the rectum was scarcely more than that of a pencil, in S-shaped coils, and dotted with contrast-meal. We now know that in such a case we are dealing with a chronic maximal catarrhal alteration of the mucous membrane.

If none of the contrast-meal has reached the rectum in twenty-four hours, the condition may be regarded as pathological. Usually a simple form of constipation is the sole explanation.

Continuance for days in the ampulla of the contrast-meal taken by the mouth, without action of the bowel, occurs in rectal constipation (dyschezia). It arises in a diminished state of irritability of the rectum. The colon in these cases is normally active and the contrast-meal reaches the rectum in the normal time. Fig. 323, O, can be reckoned in this category.[2]

[1] Soper: Über die Function der recto-sigmoidalen Klappe. Am. J. of Röntg., July, 1922.

[2] See also Harry J. Isaacs: Dyschezia. Am. J. of Röntg., November, 1925.

A normal rectal picture does not exclude the presence of *a smallish tumour* in the anterior or posterior wall of the bowel, or even with an otherwise large lumen in the lateral wall; this being easily explainable owing to projection.

Breaking up of the fæcal column in or near the beginning of the sigmoid colon, with the rectum quite empty, is found in the first hours after a normal emptying of the bowel.

Fig. 324, A, B, C, show the possibilities of misinterpretation. Clinically, suspicion of an organic constriction at the transition of the sigmoid into the rectum. B (meal taken by the mouth) seems to render the suspicion a certainty. A (several days later, meal taken again by the mouth) makes

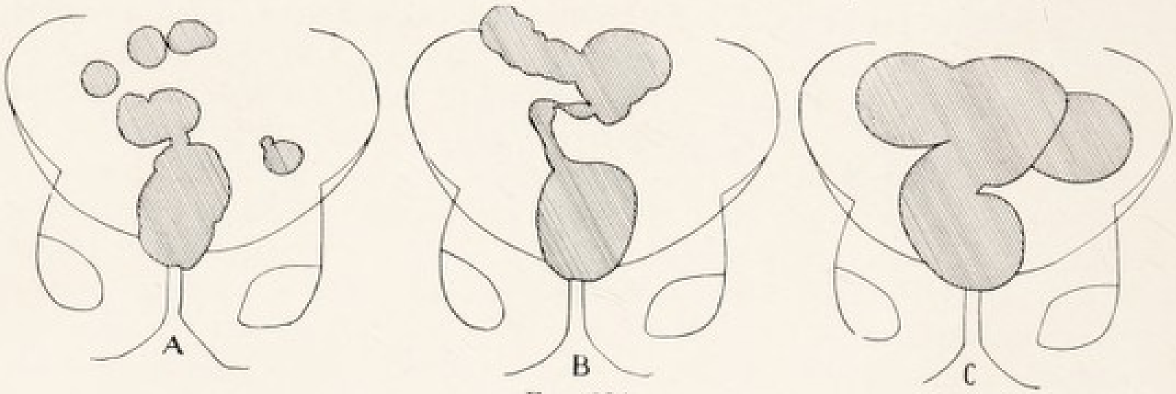


FIG. 324.

that diagnosis appear very doubtful. C (barium enema) excludes an organic constriction absolutely.

If after contrast-meal by the mouth or in contrast enema one obtains strange configurations of the rectal shadow, one should not immediately diagnose a diseased change. The student usually thinks the rectal diameter diseased, because its diameter is seen to be thrice the thickness of the colon. It cannot, however, be denied that in many men with a sedentary habit of body a moderate dilatation seems to be present, which can be distinguished from the normal only with difficulty.

As in the stomach, so we have also to consider in the rectal shadow that defects can arise from *tumours in the immediate vicinity*. We are not yet in a position to arrange these shadow defects into definite types, nevertheless there are in the literature two very instructive röntgenograms in extensive carcinoma of the uterus and prostate.[1]

Marked reduction in the height and breadth of the rectal picture speaks for *spasm*, there being also a very definite segmentation.

Filter-form of the end of the rectum is said to indicate *atony*.

A rectum that appears quite reduced and puckered in its lumen and its contour is suggestive of a diffuse infiltrating *carcinoma*; a more or less reduced lumen is found in *syphilis* and *tuberculosis*.[2]

Regarding " valve-closure " (one of the signs of carcinoma) in a high barium enema, see under " Sigmoid colon."

[1] J. T. Case: The Röntgen-Investigation of Carcinoma of the Alimentary Tract. Interstate Medical Journal, July, 1915.

[2] Jaugeas et Friedel, *l.c.*

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