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UNITED STATES ARMY

X-RAY MANUAL

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UNITED STATES ARMY X-RAY MANUAL

UNITED STATES ARMY

X-RAY MANUAL

AUTHORIZED BY THE SURGEON-GENERAL OF THE ARMY

Second Edition, Rewritten and Edited by

LT. COL. H. C. PILLSBURY, M.D., U.S.A.

[228 ILLUSTRATIONS]

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PREFACE TO THE SECOND EDITION

The first edition of this manual appeared during the World War as the cooperative work of various men and was intended to cover the problems of war service. Since that time conditions have changed. Added to the care of the casual sick of a peace time Army is the diagnosis and treatment of many veterans of the World War. Today the radiologists of the Army have the same problems as their colleagues in civil life.

This edition has been prepared to meet the changed conditions; it has been expanded to include descriptions of the improvement in apparatus and in the methods of interpretation that have developed since the first edition went to press.

The section on physics has been rearranged to permit more convenient reference, and descriptions of new types of apparatus and appliances have been added. The description of gas tubes and induction coil apparatus have been placed together; gas tubes are an episode in *x*-ray production that is interesting to all; induction coil apparatus may at some future time return to favor in modified form.

Technique, formerly distributed through the book, has been consolidated in one section. This section describes how films may be exposed and developed. Exposure tables are furnished, that may serve as a basis upon which the operator may build an exposure technique adapted to his own apparatus, and which will best meet his individual problems. As an exception, the technique for exposing sinus and mastoid films is described in the section devoted to their interpretation; the technician making films of these parts must understand the principles of their interpretation or failure will surely result.

In the section on the localization of foreign bodies the description of a number of the methods of localization has been omitted, as the omitted methods were seldom used during the World War.

The sections on interpretation have been amplified and brought up to date. New illustrations have been borrowed from many sources. Wherever possible this policy was followed in preference to the introduction of original text figures, as an *x*-ray film that exactly shows the point described may fail to be informative when reproduced. The greater part of the new illustrations have been taken from "The Annals of Roentgenology."

The Manual is a condensed description that covers apparatus, technique and interpretation. All reference to therapy has been omitted, as an adequate description is beyond the scope of the book. For the analysis of the unusual case the radiologist should refer to the more detailed descriptions available in the larger works.

H. C. PILLSBURY,
Lt. Col. M.C.

WASHINGTON, D. C.,
April, 1931.

PREFACE TO THE FIRST EDITION

THIS manual has been prepared under the direction of the Surgeon General of the Army to serve as a guide to roentgenologists who are doing the x-ray work in our military hospitals, and as a textbook for instruction in military roentgenology. It will supersede the small U. S. Army X-Ray Manual which was hurriedly prepared at the beginning of the war to facilitate the instruction of the many inexperienced men who, of necessity, had to be trained to do x-ray work.

The manual is not intended to be a complete treatise on roentgenology, but in the portion devoted to x-ray diagnosis the aim has been to state as concisely and clearly as possible the facts that have been established by experience, and to avoid all controversial points.

There is, of course, no clear line of demarcation between military roentgenology and roentgenology of civil practice. It is the same art, but practiced under different circumstances and, sometimes, with an entirely different type of apparatus. The principal aim in the preparation of this manual and in the courses of instruction carried on by the Medical Department has been to familiarize the already experienced roentgenologist with the apparatus with which he is to work, and to give him additional instruction along any lines in which he may be deficient. The need for a large number of roentgenologists, however, has rendered it necessary to train for this work physicians who have had little or no previous experience and, for this reason, it has been necessary to cover in the manual practically all phases of roentgenology.

The parts of the manual devoted to the localization of foreign bodies and to a description of new apparatus deserve special attention. The localization of foreign bodies occupies most of the roentgenologist's time in the forward hospitals, and he must thoroughly master the methods described. The new apparatus described in Chapter III has been developed either just preceding or subsequent to the entry of our country into the war. It differs in many respects from the apparatus in use in civil hospitals. Some of this new apparatus, such as the portable and the bedside unit, have certain limitations. These must be recognized and must not be exceeded. It should not be concluded, however, that because there are certain limitations the apparatus is of little value. For instance, the maximum current to be obtained from the bedside apparatus is five milliamperes, but this low milliamperage is rendered very effective by the constant and properly selected voltage and the quality of the plates resulting from the fine focus of the special type of Coolidge tube employed. For bedside work in many of our large hospitals this apparatus has been found invaluable.

The great importance of the x-ray in military surgery and medicine has been established so that the roentgenologist has a position of much responsibility. He must remember, however, that his work is valuable only in so far as he assists the physician or surgeon in arriving at correct conclusions, and that this can be accomplished only by mutual coöperation. The roentgenologist does his part by presenting to the surgeon accurate findings carefully recorded in a usable form. After he gains the confidence of the surgeon in the accuracy of his work and the soundness of his judgment, the exercise of a little tact will always make it possible for him to secure full coöperation and thus give to the x-ray examination its maximum value.

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UNITED STATES ARMY X-RAY MANUAL

CHAPTER I

X-RAY PHYSICS

Introduction. The following brief notes on the physical aspects of the apparatus likely to be used in military radiology have been written with the hope that their study might enable the radiologist to prepare for service in less time and be better able to utilize the apparatus with which he is compelled to work. With the belief that brief reasons as to why things are done are good guides in operation, rather more explanation of fundamental principles has been given than is usually included.

X-Rays. The roentgen or *x*-rays are produced by an electric current in a glass-walled vacuum tube. Such a current is due to the projection of minute electric particles (electrons) from one metal terminal, the cathode, to another metal terminal, the anode or target. The *x*-rays originate at the point of impact of the electrons on the target and travel out from their origin in all directions except where dense material obstructs or prevents their passage. When passing through bodies made up of various parts differing in density, some of the rays that enter the denser portions are permanently cut out and a new distribution of intensity in the beam results.

The presence of *x*-rays must be determined by some of the effects they produce when acting on material bodies. These actions are:

1. Effect on the emulsion of a photographic plate.
2. Excitation of light in certain crystals (fluorescence).

3. Rendering gases conducting to electricity (ionization).

4. Stimulating or destructive action on living cells (biological action).

The first, second, and fourth of these are of fundamental value in the medical and surgical uses of the rays. The third has been very useful in the study of the radiation.

These rays do not excite vision on reaching the retina of the eye, but are capable of originating light in certain crystals. A uniform beam, falling on a piece of cardboard covered with such crystals, would cause uniform illumination. If regions of unequal material density have been traversed by the beam before reaching the screen (fluoroscope), such dense portions will show as areas of lesser brightness or, as we say, will cast shadows. In the same way, a photographic plate or film sufficiently acted upon by such rays will, on development, give areas of unequal blackening, marking out the *projections* of volumes in the body whose densities differ from those surrounding them. On the fluoroscopic screen, dense bodies show as *dark* areas; in a photographic negative, they show as *light* areas.

It has been shown by various investigations that *x*-rays are identical in their nature with light and electric waves, except that their wave lengths are very much less than even the shortest light waves. On account of this extremely short wave length, the effect of matter upon their propagation is quite different from that in the case of longer waves. Such short waves are only produced by a change in the velocity of electrons taking place in intervals of time too short to be easily conceived. The gamma rays of radium, etc., are simply rays due to the sudden *starting* out of electrons by atomic breakdown. They may be shorter or longer than the *x*-rays we use in fluoroscopy or in radiography.

The term ray is used to designate two distinct types of phenomena. One refers to a projection of small particles by atomic disintegration, as beta and alpha rays. The other refers to the transfer of physical effects by the agency of wave motion. In this class we have light, gamma and *x*-rays.

It may be also noted here that gamma rays are of the same physical nature as *x*-rays, but some gamma rays are of shorter wave length than the *x*-rays we are able to produce at the present time.

The following general properties of this radiation should be understood in order to facilitate its intelligent application.

Paths. These rays travel in straight lines into, through, and out of material bodies, except where the atoms themselves cause scattering. They *cannot be directed* by mirrors or lenses for purposes of optical focus or concentration, as is done with light. The slight amount of regular reflection by the uniformly spaced atoms in crystals is too small to be of any importance to the radiologist.

Velocity. The rays travel out from the target at the same velocity as light or electric waves.

Energy. The actual energy involved in an *x*-ray beam is small compared with that expended in getting it started; only a few parts in a thousand of the energy supplied is converted into *x*-rays.

Scattering. *X*-rays are scattered in passing through matter exactly as light is scattered in turbid water, fog, paraffin, etc. Only a part of a beam is thus scattered, the remainder passing straight through or being absorbed. Scattering confuses shadows on screen or plate in a very troublesome way.

Passage through Matter. When rays pass through material, the substance is called transparent to the radia-

tion. If little or no radiation gets through, we say the material is opaque to this radiation. The terms transparent and opaque refer to the action of the material with reference to a specific type of radiation. If one arranges a variety of substances of like thickness in the order of *increasing density*, their *opacity* to *x*-rays will be nearly in the same order. But this will vary somewhat according to the quality of the *x*-ray beam considered. That portion of the incident radiation neither transmitted nor scattered is changed into heat or, as we say, absorbed in the material. We then say that absorbing power increases with the density of the absorber. This absorbing power is best expressed as the fraction of the rays absorbed by a definite thickness of material. Thus, if 1 cm. of water should reduce a particular radiation so that the emerging beam is half as effective as the entering one, we might say this radiation has a *half value* layer of 1 cm. of water. Two centimeters of water would transmit only 25 per cent of the incident beam or that reaching the surface proximal to the tube.

The quality of short wave length and high penetration can be secured only by means of high voltage operation. (See penetration, p. 29.)

Electrons. The modern concept of atoms involves the idea of their general electrical constitution. From any atom there may be abstracted one or more small negative charges, all precisely alike, whose properties are in no wise dependent on the atom from which they come, and all are quite capable of existence by themselves without the presence of the remainder of the atom. These little bodies have been variously named as corpuscles, cathode rays, beta rays, electric ions, etc. The common designation of electron is derived from the latter. An electron is able to respond to electric force and to acquire velocity under such

force action. When in motion, they show all the characteristics of an electric current.

The main physical features of electrons are:

1. Their fixed and definite negative charge.
2. Their extremely small mass and volume.
3. The extreme speed they may acquire.

Production of X-Rays. Roentgen or *x*-rays originate in any region where the velocity of electrons is suddenly changed. In the radioactive breakdown of atoms, this change is a sudden *acquisition* of velocity, and the gamma rays are produced. In *x*-ray tubes, the high-speed electron is stopped in its flight by the interposition of a target metal of high atomic weight placed in its path, and *x*-rays result from a *loss* of velocity.

The problem of *x*-ray production for our purpose, then, resolves itself into four parts.

1. The separation of electrons from atoms.
2. Giving them high speed.
3. Concentrating them on a small area.
4. Stopping them with sufficient suddenness.

The first of these is accomplished in one of two ways. In the tubes containing a *small amount* of gas, electrons are secured in part by high electric field, but to a much greater extent by the disruption of atoms due to the moving electrons and by the *x*-rays themselves. In the hot cathode tube (Coolidge), electrons are set free from the atoms in a tungsten wire by the action of heat. In the former, the number of available electrons is rather hard to control, while in the hot cathode tube this offers no difficulty.

In order to secure high speed (one-half to one-third the velocity of light) a high voltage must be available, and the electrons must all be urged toward the same small area in order to get sharp shadows. The concentration on the target is secured by proper design of the electrodes

and their proper position in the tube. In all cases the path to be followed must be quite free of gas in order to avoid obstruction.

The choice of metal as a barrier is of great importance, and only a few elements satisfy the conditions. Every fast-moving electron has some mechanical energy and this goes mainly into heat by impact; there results a great rise in temperature at the point of electron concentration. As radiographs and fluoroscopic images are purely shadow effects, a source of radiation starting from a point is very desirable. This high concentration of heat will melt any target material at high power operation. Only metals of high melting points can be utilized, such as platinum, tungsten, osmium, and iridium. Of these the first two are in common use, the tungsten to a great extent during recent years. High atomic weight is also desirable, and fortunately this goes with high melting points in the foregoing metals.

General Instructions and Precautions. 1. *Excessive* exposure to *x*-rays results in serious injury to the skin. Such injury does not manifest itself at once but may develop some weeks later. To a degree, the action is cumulative, so that a single dose, in itself too small for injury, may, when frequently repeated, be harmful. Read carefully the notes as to protection, page 104. While it is unwise to be over timid, it is much easier to prevent an injury than to cure it.

2. *X*-ray apparatus is expensive, and not only is it costly in money to repair damage, but even more important is loss of service from breakdown. Do not try to see how much current you can pass through a tube or how long a spark the transformer will give. Do not imagine that a tungsten target cannot be melted; it can, and very quickly.

3. Acquire the habit of observing whether high tension wires are sufficiently far from patient, assistants, etc., *before* you close the operating switch.

4. Make all tests of tubes, etc., on low power, when possible, and do not make unnecessary speed your ambition. When through work, throw all controls to low power.

5. Never test out a tube when the patient is in position.

6. Always see that current is passing through the filament of a Coolidge tube before closing the main transformer switch.

7. Do not imagine you can make plates of thick parts on very low spark gaps. It cannot be done, but you may get some very unfortunate experience trying it.

8. Remember that any current that passes across the spark gap or leaks from one line to the other along walls, etc., does not help to produce *x*-rays, although it may increase your milliammeter reading.

9. Try to develop a definite order and sequence in the various details of any examination. It will save time and prevent errors.

10. The only safe time to label a plate or film for identification is at the time of exposure.

11. Don't imagine that so and so's good plates are due to the particular machine he is using; and don't chase off after every new exposure "technique" you hear about. The fact that some individuals advocate one after another is ample evidence of their uselessness.

Electrical Terms. Certain terms are used so frequently in all discussion of electrical matters that they are introduced at this point for convenience in reference.

Charges. When any physical or chemical action breaks down the connection between an electron and the remainder of the atom, the electron constitutes the elementary particle of negative electricity. All negative charges are

simply countless numbers of electrons kept away from the positive portions of the atoms from which they were separated.

Generators. Generators do not create electricity. They take electrons and positive atomic remainders apart against their natural tendency to keep and come together. Thus, if G, Figure 1, represents a generator, A and B metallic plates connected to its terminals, A is covered with electrons and B with enough positive to neutralize the negative on A. If we call e the negative charge of one electron, and Q the total charge on A, N the number of electrons, then Q equals Ne, where N is an incredibly large number in most cases.

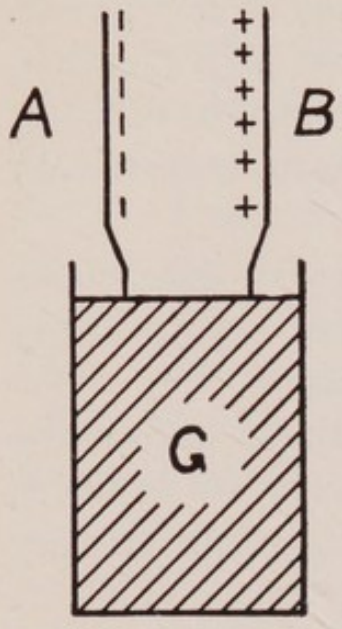


FIG. 1. Generator on open circuit.

Voltage. Electric charges separated as shown in Figure 1 show: (1) a mechanical pull on the bodies A and B, (2) a decided tendency to pass between A and B.

A voltmeter does *not* measure electricity but something like a pressure or strain trying to pass a charge between two regions.

The Volt. The volt is the unit in which the tendency of charge to move from one place to another is measured. The electrical tension between the terminals of a special cell (Weston or Cadmium cell) is taken by legal definition as 1.0184 volts.

Current. When proper external connections are made to the terminals of a generator there results a transfer of charge. If we could count the number of electrons passing on to A per second, say n, we would call ne the current passing through G. An electric current may then be regarded as a measure of the number of electrons passing

per second. It must be observed that after *A* and *B* are charged as highly as is possible for the particular generator, there will be no further current, but the voltage is present. *We may have voltage existing and no current, but never a current without some voltage.*

The Ampere. The ampere is the unit of electric current. It is legally defined as the rate of transfer of electric charge which deposits silver from a special solution at the rate of .001118 grams per second. The unit electric charge is the coulomb. Five amperes, for example, will transfer 40 coulombs in eight seconds.

Resistance. It requires but little voltage to move a big supply of electrons through some materials, while with others a very great voltage will cause but little electron movement. The former are named conductors; the latter, insulators. Note carefully that the difference is one of degree, and that perfect insulators do not exist so far as high applied voltage is concerned. Thus, dry, clean glass may be considered an insulator for moderate voltages, but may conduct to a considerable extent at high voltage. The objection offered to the passage of an electric current by any material included in a circuit is called its resistance.

The Ohm. The unit of electrical resistance. Legally defined as the resistance of a uniform column of mercury 106.3 cm. long and 1 sq. mm. section at 0° Centigrade.

Power. The ability of the electric current to do work is termed its power.

The Watt. The watt is the unit of electrical power. It is the power of a current of 1 ampere in a region where it loses 1 volt. The product, amperes × volts lost = power in watts; 746 watts are equivalent to one mechanical horsepower, and 1 kilowatt is therefore equal to about 1⅓ horsepower.

Derived Units. The foregoing units are not of convenient size in all cases, and some modifications are in common use. The terminal voltage on the tube is high, and it is often expressed in kilovolts (1 kilovolt equals 1000 volts). The current ordinarily used through *x*-ray tubes is small and is expressed in milliamperes (1 milliampere equals $\frac{1}{1000}$ ampere). The power used to operate electrical devices is generally expressed in kilowatts, when the number of watts is large (1 kilowatt equals 1000 watts). One kilowatt maintained for one hour is named a kilowatt-hour.

As applied in particular cases, a 4 kw., 110 volt generator, is a machine that delivers 4000 watts at full load and is designed to operate at 110 volts. The full load current would be $\frac{4000}{110} = 36.3$ amperes. If a machine gives 50 *milliamperes* at 70 *kilovolts*, the power delivered is $\frac{50}{1000} \times 70 \times 1000 = 3500$ watts, or $3\frac{1}{2}$ kw.

Measuring Instruments. The electrical measuring instruments that may concern the radiologist are the ammeter and the voltmeter for *low tension circuits*, the milliammeter, and the kilovoltmeter for *high tension circuits*. Most kilovoltmeters are of little real value as they vary with the secondary current. The milliammeter is a most valuable aid to the work. It is often designed for two ranges. From 0 to 30 ma. on one scale and 0 to 300 ma. on the other is the best for most work.

Do not try to draw 150 ma. when the meter is set for a maximum of 30 ma. If the pointer gets bent, due allowance must be made in reading.

Electric Circuit. An electric circuit consists of some sort of a generator and a more or less complex conducting path between its terminals. Electricity *outside* a generator always passes from high to low voltage, and the current

may properly be said to *lose voltage* en route from one generator terminal to the other.

Consider a very simple circuit (Fig. 2) consisting of a

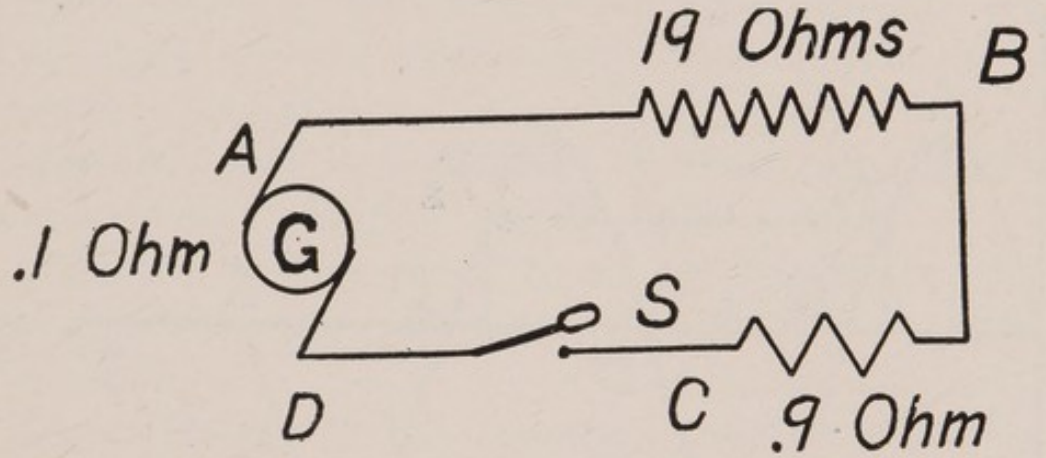


FIG. 2. Simple electric circuit.

generator, G; generator resistance one-tenth ohm, two other resistances as shown. The fundamental law of such a circuit is that if when the switch, S, is open we have, say 220 volts, then for any total resistance, R, we will have a current, on closing S, such that

Current $\times$ total resistance = 220, or in this case.
No. of amperes $\times$ (.1 + .9 + 19) = 220
Current, $I = {}^{220}\!/_{20} = 11$ amperes.

The voltage is used up as follows:

In the generator	$11 \times .1 =$	1.1 volts
Between A and B	$11 \times 19 =$	209.0
Between B and C	$11 \times .9 =$	9.9
Total		220.0 volts

This relation is true for all circuits, viz., volts lost due to resistance of R ohms when a current of I amperes is flowing $= IR$. (Ohm's law.)

Direct Current (d.c.). When the electron flow is in only one direction, the current is named direct. Dry cells,

storage batteries, static machines, and d.-c. dynamos deliver direct current. A current may be intermittent or pulsating, and still be called a direct current.

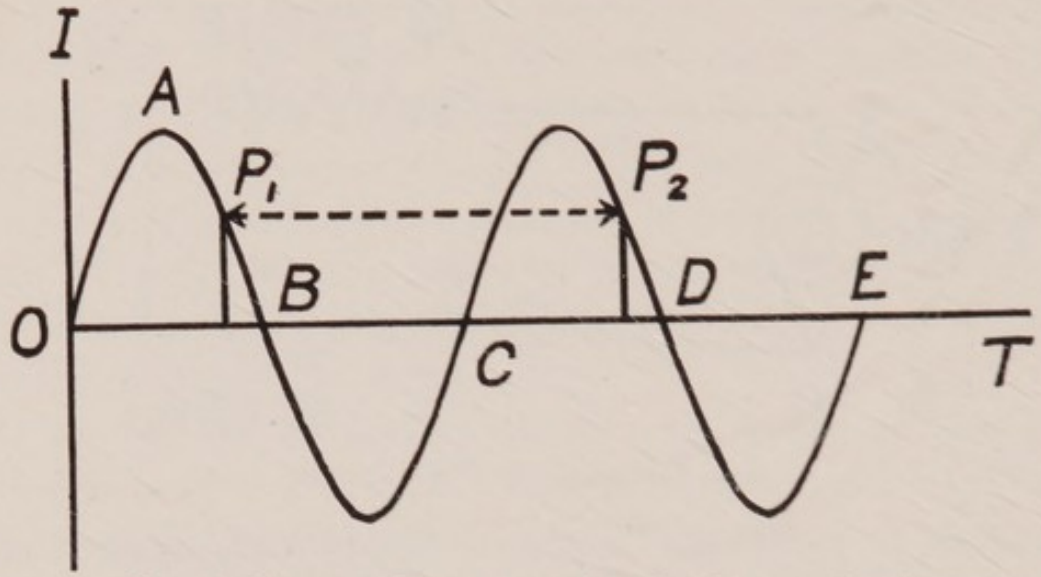


FIG. 3. Current-time curve of a simple a.c. circuit.

Alternating Current (a.c.). When the electrons flow in one direction for a short time and then the flow decreases and a reverse flow occurs, we say the current is alternating. A.-c. dynamos are the only sources of true alternating current.

Such a current in its simplest form may be pictured by a suitable time-current diagram. In Figure 3 time is shown as increasing from left to right.

Let

$$OC = \frac{1}{60} \text{ second}$$

Then

$$OC = BD = CE = P_1P_2 = \frac{1}{60} \text{ second}$$

This current takes all its variable values once in 1/60 of a second, and repeats the operation 60 times in one second. It is designated as 60 cycle a.c. If drawn from

a 220 volt service, its complete designation is 220 volt, 60 cycle, alternating current of a certain number of amperes.

During the times *OB*, *CD*, *EF*, etc., current flows in the opposite sense to that during the times *BC*, *DE*, etc. Note that there are two *alternations* to each cycle, or 120 per second in this case.

Effective and Peak Voltage. Voltage may be expressed either as the "effective" or the "peak" value.

Effective voltage (root mean square) is the computed value of the entire alternation: of the entire curve *OAB*, Figure 3.

Peak voltage is the maximum at the summit of the alternation: at *A* on the curve *OAB*, and represents the voltage existing at only a moment of time.

To convert effective to peak values, multiply by 1.41 (for a pure sine wave).

To convert peak to effective values, multiply by .707.

Peak voltage may be measured with reasonable accuracy by the length of a spark between spheres 10 cm. in diameter. It may be measured approximately by the length of a spark between blunt points. After passing through the mechanical rectifying switch of an *x*-ray machine the wave form is changed so that the peak value as determined by a sphere gap cannot be converted into the effective value.

CORRECTION FOR ALTITUDE

Altitude	Spark gap (blunt points)	Kilovolts (peak)
Sea level	6 inches	100.0
1000 feet elevation	6	96.3
2500	6	91.3
5000	6	84.1
7500	6	78.7

Radiologists express voltage in terms of the peak value; on the other hand, electrical engineers express alternating current in terms of the effective value.

X-ray Current-Voltage Requirements. At present *x*-ray tubes are used with currents varying between 3 and 300 ma., and at voltage running between 25 and 300 kv., i.e. 25,000 to 300,000 volts. This high voltage requirement cannot be met by simple d.-c. generators.

High Voltage. The requisite voltage is secured by the use of:

1. The so-called static machine (direct but impractical).
2. The periodic *interruption* of a direct current through one coil, causing high voltage in a neighboring coil (induction coil).
3. Using a low voltage alternating current in one coil and getting a high voltage alternating in an adjacent coil (transformer).

The second device is still used to some extent, but has largely been displaced by the transformer in recent years.

The use of an induction coil or a transformer to increase voltage involves two distinct circuits, one connected through some control device to the supply line or generator, and known as the primary circuit; the other, insulated from the primary and connected to the tube terminals, known as the secondary circuit.

The primary always:

Is of relatively low voltage.
Is a moderately large wire.
Carries a current of some *amperes*.
Is reasonably safe to touch.
Requires good metallic contacts at all connections.

The secondary always:

Is high voltage.
Is quite a small wire.

Carries a current of some *milliamperes*.

Is unpleasant and often dangerous to touch.

Will pass current across loose connections or even through some insulating material.

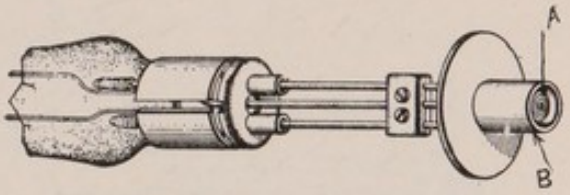


Fig. 4. Coolidge cathode construction.

The induction coil and a few transformers have both coils wound on hollow concentric cylinders, the primary within the secondary, and the space inside the primary coil is filled with thin iron sheets or wires. These are named open magnetic circuit devices.

Most transformers now in use have the iron in the form of a closed rectangle, and the two coils wound so as to slip on the sides of this rectangle. These are known as *closed magnetic circuit* transformers.

Coolidge Tube. It was discovered by Richardson and others that electrons are emitted by hot metals. The simplest application of this principle to *x*-ray development was worked out by W. D. Coolidge. In the tube devised by him the cathode is a spiral filament of tungsten wire (*A*, Fig. 4) heated to a high temperature by a current from an *insulated* storage battery, or by a special transformer. The form of electrostatic field needed for focusing the electron stream is fixed by a small molybdenum cylinder, *B*, within which the cathode is placed. The target is usually a solid piece of wrought tungsten mounted on a molybdenum rod, around which collars are placed to distribute the heat conducted from the target.

Figure 5 shows the Coolidge tube.

1. Cathode terminal.
2. Electron focusing cone.
3. Solid tungsten target.

4. Molybdenum supporting rod.
5. Anode terminal.

In order to operate properly, it was found that the

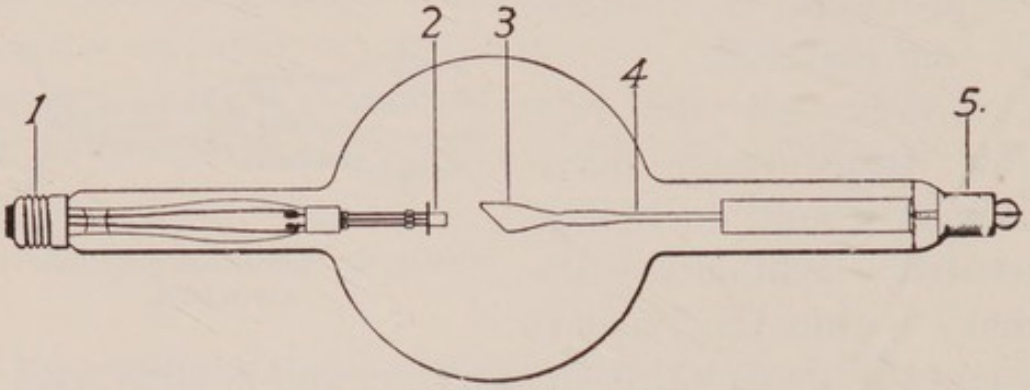


FIG. 5. Coolidge tube.

highest possible vacuum must be attained. Not only was the greatest care required in pumping, but the metal parts had to be freed from occluded gas by heating in a vacuum nearly to their melting point. In this tube there is no source of electrons except from the hot filament, and as this supply *depends only on the temperature of the filament,* the operator has perfect control of the number of available electrons by simply changing the auxiliary current. A small transformer is now generally used to supply low voltage for the filament current. Connections are as shown in Figure 6. The winding connected to the filament must be well insulated from case and primary winding.

The *current* through the tube cannot be increased after the supply of electrons is entirely utilized, no matter how much the *voltage* is raised. This maximum current for each particular filament temperature is named the *saturation* current.

Voltage Limits. Coolidge tubes are made in a number of designs, each intended for a particular function. While the current limit is ordinarily engraved on the tube, the voltage limit is not. To avoid tube breakage the limit of

voltage should not be exceeded. The self-rectifying tube (one form shown on p. 18, Fig. 7) may be used on any voltage up to 85 kv. (peak) corresponding to a 5 inch

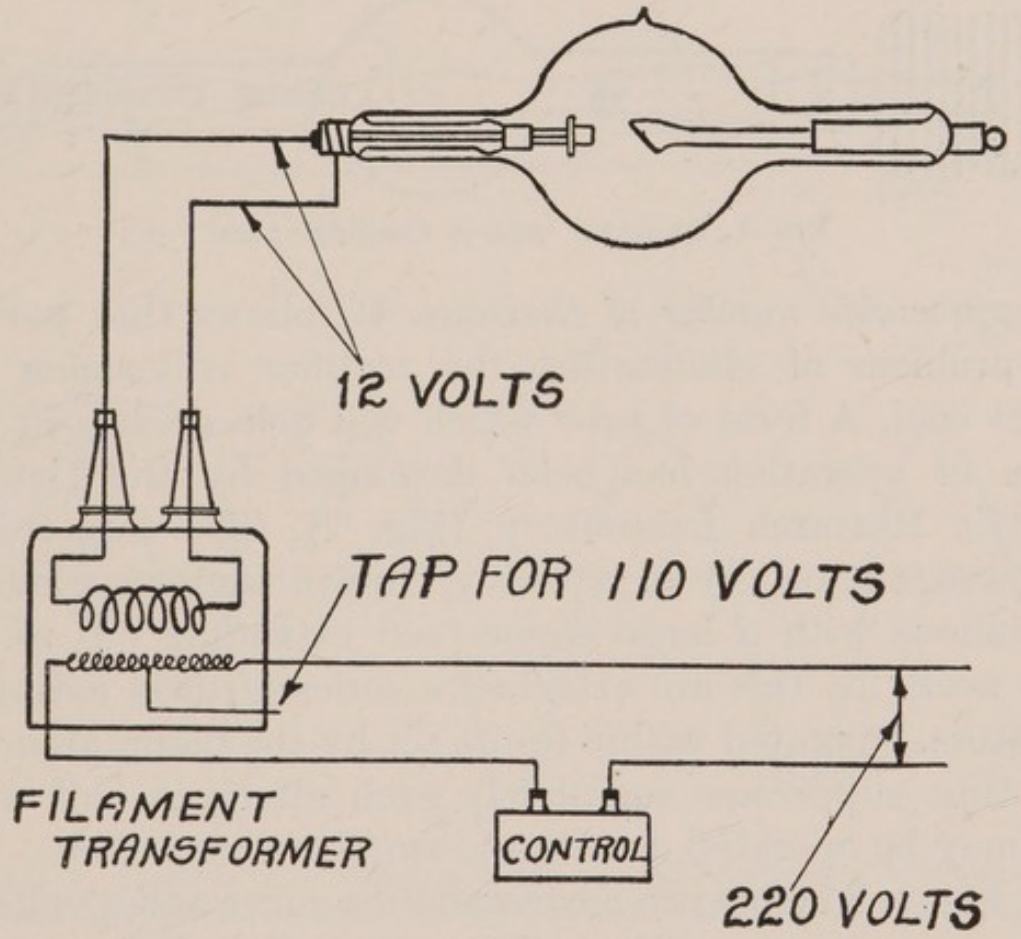


FIG. 6. Wiring diagram for step-down transformer to supply current for filament of Coolidge tube.

spark gap between blunt points. The type of tube referred to as the "Universal" or "7 inch tube" has a voltage limit of 140 kv. (peak) corresponding to a 10 inch spark gap. The therapy tubes may be used up to 200 kv. or more, depending on the manufacturer's warranty.

There is no fluorescence of the glass walls except a slight illumination in the anode neck. Sometimes a minute chip in the glass or a slight evolution of tungsten vapor will give a momentary flash of green, but on further operation at moderate power this disappears.

Radiator Coolidge Tube. The ordinary form of Coolidge tube will operate satisfactorily without a rectifier *if the focal spot is at a temperature below that at which it gives off*

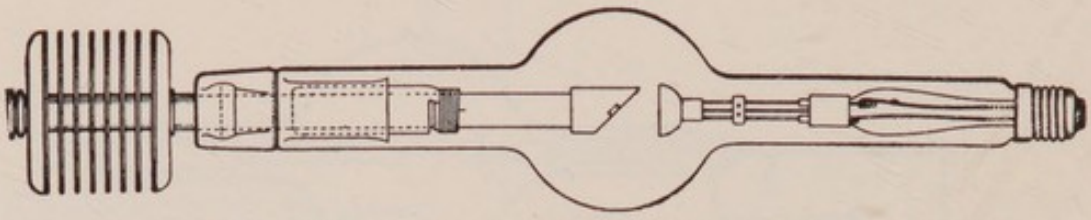


FIG. 7. Radiator type of Coolidge tube.

an appreciable number of electrons. It follows that part of the problem of eliminating the rectifier is keeping the target cool. A form of tube which will help greatly in this mode of operation has been developed by the General Electric Research Laboratory (Fig. 7). The target is a tungsten button set in a heavy copper backing which is continuous with a large copper rod extending out of the tube neck. To this are attached a series of discs acting as radiators. Operated within limits set by the manufacturers, this tube suppresses completely each alternate half wave and may be operated direct on a *suitable transformer.*

In Figure 8 are shown a current-time curve and a voltage-time curve for the self-rectifying tube. In the latter *OA* is the working peak voltage which determines the tube radiation, and *BC* is the peak voltage of the suppressed wave which would give the spark gap reading.

A transformer should be used which will not vary its voltage too much from no current to that needed to operate it properly, since the voltage of the suppressed wave is quite decidedly higher than that of the one used, thereby causing spark-over and giving an incorrect idea of the actual working voltage.

The value of this arrangement for field work can hardly be overestimated, as there is no heavy and complicated rectifier. Operated from a small gas engine-driven gen-

erator, it is ideal for fluoroscopic work and satisfactory at low power. (See U. S. Army Field Unit, p. 169.)

When operating an *x*-ray machine on the self-rectifying

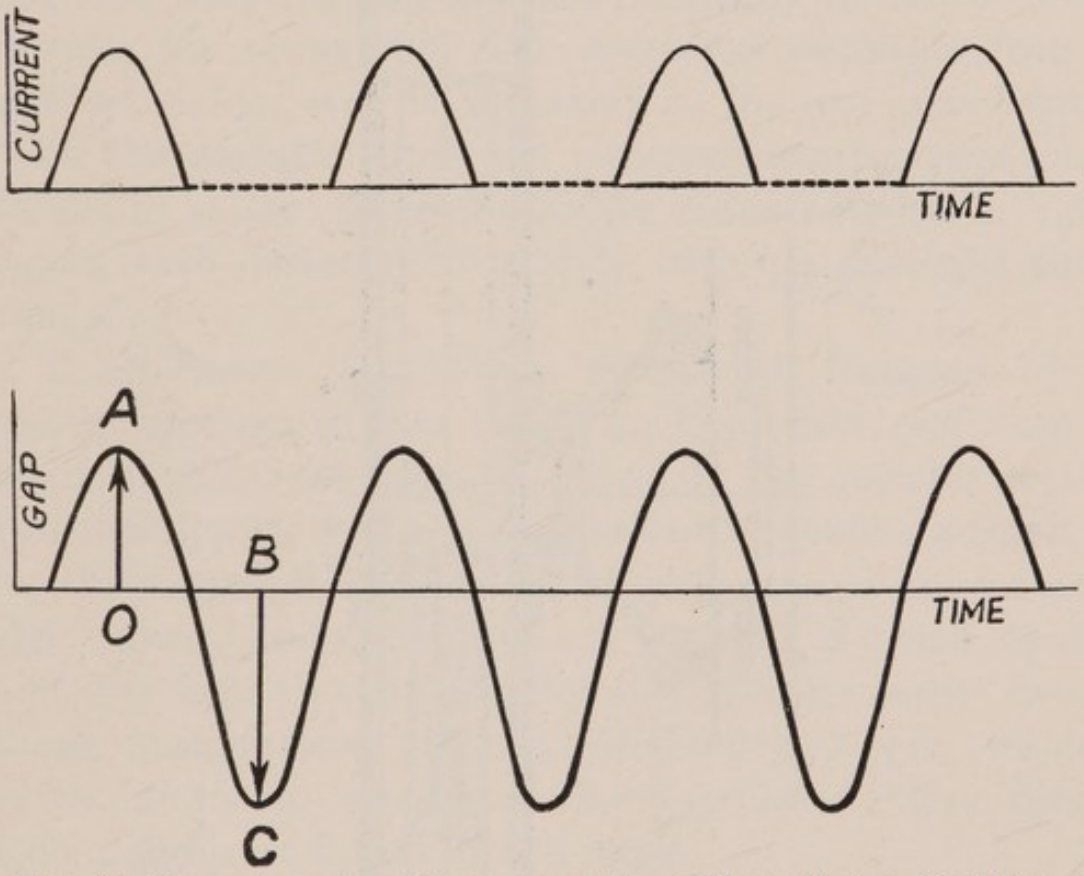


FIG. 8. Current and voltage curve for self-rectifying Coolidge tube. The voltage difference indicated by the excess of *BC* over *OA* will depend on design of transformer and control.

principle every other alternation is suppressed, and yet for the same reading of the milliammeter the same amount of radiation is produced as when the current is rectified and both alternations are used. This apparent discrepancy is due to the operation of a milliammeter, which registers *average* current.

Autoprotective tubes (metalix, Fig. 9) are hot cathode tubes. The cathode and target are enclosed in a metal cylinder except for a small glass window for the *x*-ray beam.

Tubes that are not autoprotective emit radiation from points other than the focal spot; this radiation must be

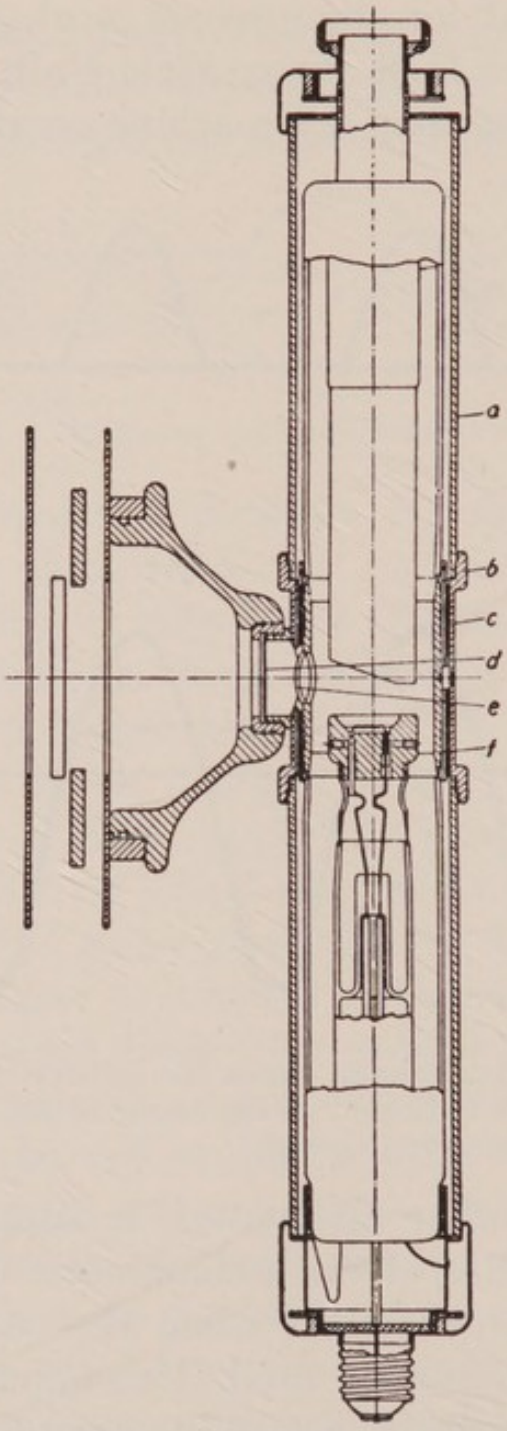


FIG. 9. Metalix tube. *a*, Special bakelite cover; *b*, brass cover; *c*, lead cover; *d*, filter; *e*, window; *f*. metallic cylinder. (From Weatherwax: Physics of Radiology.)

stopped from striking the patient and the operator by enclosing the tube in a cumbersome lead glass bowl or similar protective device. As the autoprotective tube emits only the useful beam, it is not necessary to add to it extra devices for protection. The scattered radiation from the patient, table, etc., is the same as for any *x*-ray tube.

In the metalix tubes the electrons are focussed on the target in a line. These tubes are manufactured in various types, each designed to operate within a specified current range.

Tube Focus. The *x*-rays cannot be focussed by any known method, so that the terms focal point, etc., are misleading. *Electrons* can be directed by suitable cathode construction so that the greater portion strike a small area on the target. The diameter of this area is known as the the "focus," and it is customary to speak of broad, medium, and fine foci. One can hardly state precise limits between these designations, but anything below 3 mm. would be extra fine focus; 3 to 4 mm. fine focus; 4 to 7 mm. medium focus; and over 7 mm. broad focus.

The size of focus is found by the use of a pin-hole camera, and should be given by the maker. Its size is important in two ways: First, in relation to the sharpness of image on plate or screen; second, as fixing the power that may be used without damage to the target. When an electron stream is maintained at high velocity against the target, there is a rapid rise in temperature which may result in vaporization or fusion of the metal. The rate of removal of heat by conduction is increased by broadening the focal spot, and the amount of metal suffering extreme rise in temperature is increased, so that for two reasons there is less danger of target damage.

The effect on sharpness of image is shown by using an exaggerated diagram as in Figure 10. F_1, F_2 are the bound-

aries of the focal spot and 1-2 is the object. With the plate in plane A, had the only source been a point, F_1, a sharp shadow PQ would result; had F_2 been the only source,

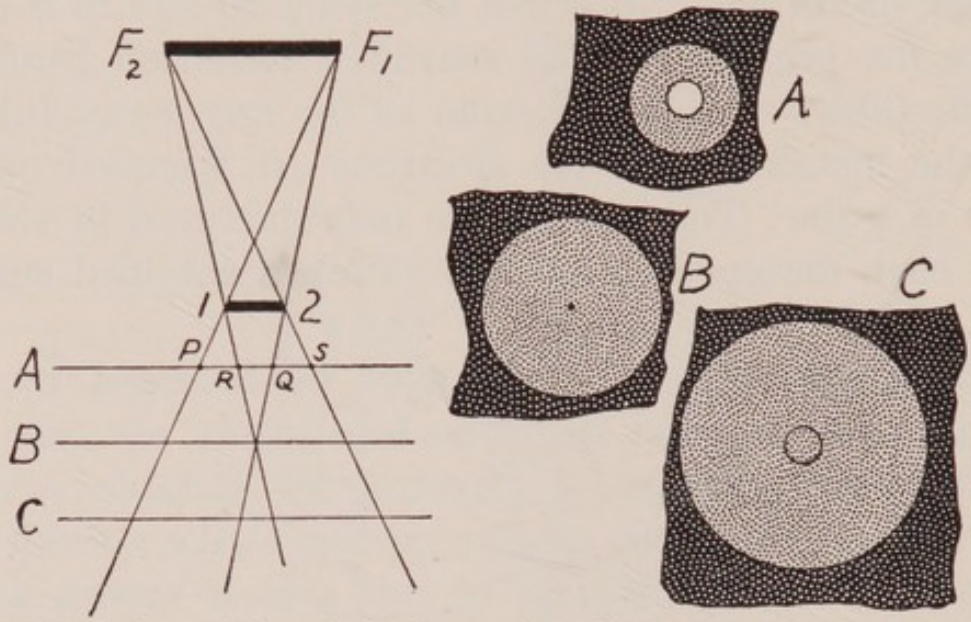


FIG. 10. Variation of size of shadows of small objects when a wide focus is used close to the plate.

then RS would result. The only portion entirely shaded is RQ, and if the object is round, we have a central white spot with a variable shading out to a diameter PS. If the focal spot were very wide and the object very small a plane B could be found beyond which there would be no white image.

The ring PR and QS is narrower the closer the object to the plate, the smaller the focal spot and the greater the target-plate distance. The apparent size of the shadow will vary somewhat with exposure, as regions partly shaded may be underexposed when the exposure is brief and the true shadow may not appear at all.

Fine focus tubes are not needed in gastrointestinal work, and should be used in other work with care.

Double focus tubes are made with two filaments, so constructed that one will give a fine focal spot, and the other a larger focal spot. By turning a switch on the cathode

arm of the tube, the same tube can be used for fine detail with low current capacity, or for less fine detail with larger current capacity. The maximum current for each

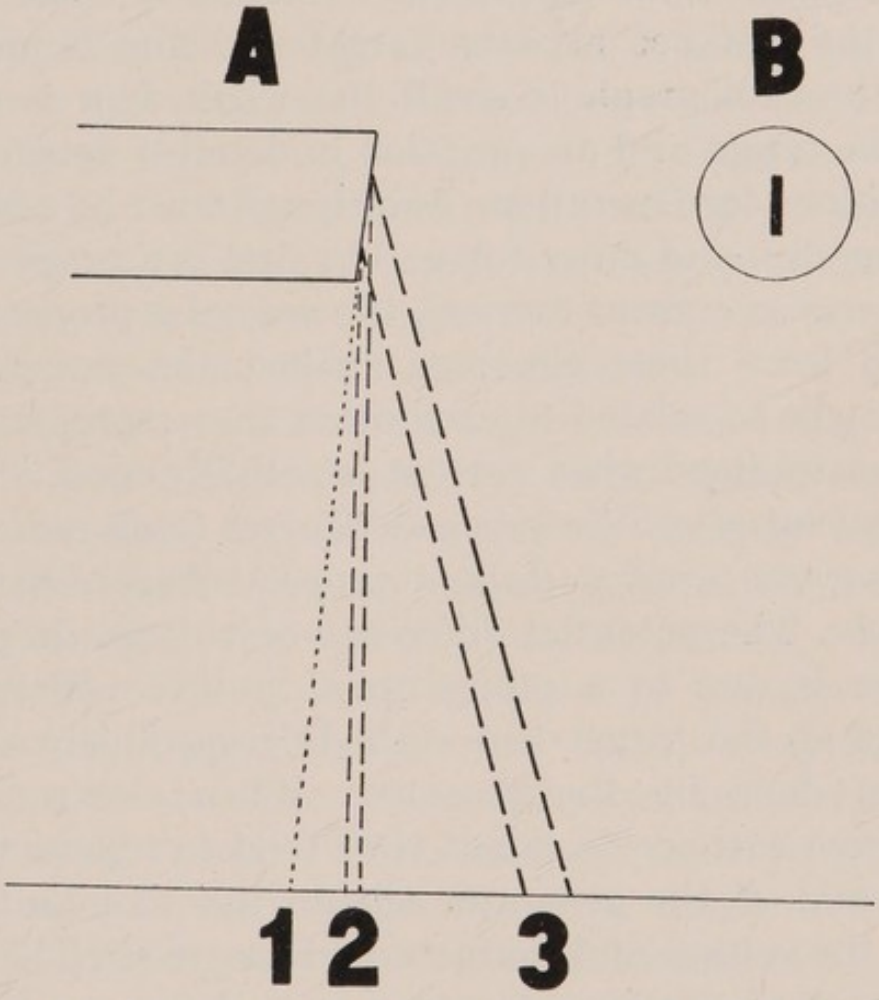


FIG. 11. Line focus. *A*, Side view of target; *B*, front view.

focal spot is marked on the switch.

Line Focus. As already noted, the rate of removal of heat by conduction is increased by enlarging the area of the focal spot. In some tubes this is effected by focussing the electrons in a line. The target face is nearly perpendicular to the window through which the radiation emerges. Directly under the window the line is foreshortened to a square. In the exaggerated diagram (Fig. 11) it may be noted that the projection of the focal spot is smallest at 1, a square at 2, and a line at 3.

When a large radiograph is made the detail may not be uniform, as it is fine at one end of the film, toward (1), and poor at the opposite end, toward (3). This effect is more noticeable when the target-film distance is short, and is less as the distance between target and film is increased. When the radiograph is small the whole film is directly under the target and no variation in detail is detected.

Conditions for Operation. Two things must be considered in the operation of *x*-ray tubes. The first is a proper supply of electrons as current carriers, the second a proper electric drive to force these electrons against the target. These two must be so related to each other that a proper voltage can be maintained when current is actually used.

No amount of milliamperage will serve to do radiographic or fluoroscopic work without a proper voltage consumption at the tube. The potential difference or voltage drop across the tube is due to a piling up of positive charges and electrons at the target and cathode respectively and this must be done by the *generator*. When electrons move across from cathode to target they tend to relieve the congestion and, if the generator should fail to maintain the supply, the voltage and charge would disappear. The greater the number of electrons passing across in a given time, the more the terminal voltage will be reduced for a given ability of the generator to pump a new supply. The current is the charge of one electron multiplied by the number passing per second. Hence the greater the milliamperage, the greater the power demanded from the generator to maintain voltage and the more the drop in voltage from that shown on open circuit or on small current.

When the current increases, irrespective of the type of tube used or the design of the machine, the operating voltage will be reduced unless the rheostat or autotransformer control is moved to apply more power to the pri-

mary. *The spark gap on open circuit is no guide to the ability of the transformer or induction coil to keep up voltage when current is drawn.*

Inasmuch as reduced voltage very much more than offsets the effect of change of current in *x*-ray production as regards quantity, and likewise decreases the ability to pass through material, the proper maintenance of voltage is the most indispensable requisite in any *x*-ray installation. *By increasing exposure time nearly all work may be properly done at low current, but no increase of exposure time will compensate for too low voltage.*

The transformer must be designed for the voltage supply on which it is used, and it is very essential that the proper terminal voltage on the transformer primary should be maintained at all times and at all loads. After a machine is once installed the operator has no control over these matters. The size of wire required to transmit current from the usual power transformer to the *x*-ray room will depend on the distance between the two transformers and on the voltage used. To transmit the same power at 110 volts as at 220 will require twice the current. Whenever a given current is passed over a resistance there is a voltage drop or loss. This loss is greater, the greater the current and the greater the resistance. When the line resistance and the current are known the voltage loss is found by taking their product. A loss of 2 or 3 per cent of the line voltage may be permissible. (See line wiring, p. 63.)

Coolidge Tube Characteristics. The electron supply in the Coolidge type of hot cathode tube is due entirely to the hot tungsten filament, as all the gas it is possible to remove has been taken out in pumping. The current carried by the tube is limited by the rate of electron supply and is thus determined solely by the filament current. This maximum *tube* current at a given *filament* current is

only attained at a sufficiently high voltage and this voltage *increases* as the filament temperature is raised. When all the electrons are being driven across as fast as they are

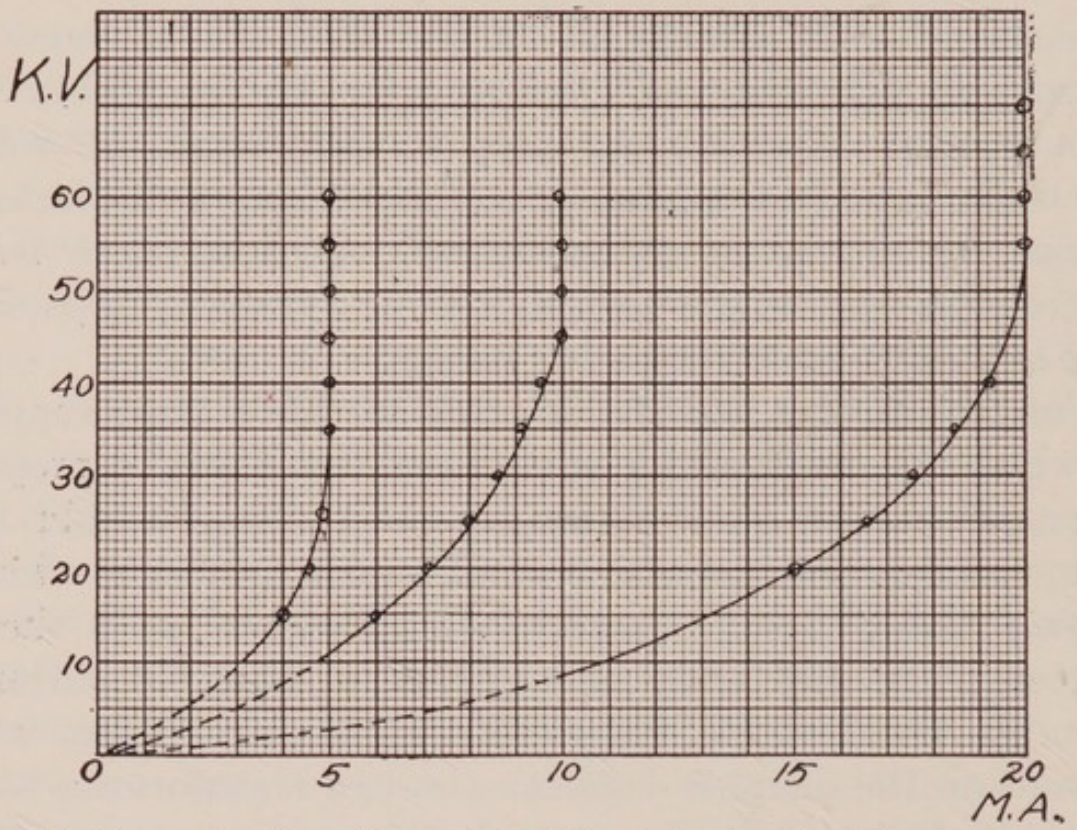


FIG. 12. Current-voltage lines of Coolidge tube for fixed filament temperatures. Vertical portions are above "saturation" points.

produced, the corresponding current is named the *saturation* current. After such a current is reached the voltage may be greatly increased without a rise in tube current. Figure 12 shows this characteristic of the tube. On account of the *great* increase of tube current resulting from a *slight* rise in filament current it is impractical to depend on a filament ammeter as a guide to tube current, especially when using rheostat control.

Outflow of Radiation. As radiation proceeds from the origin on the target it spreads out and flows through the surfaces of larger and larger spheres. The amount received in a given time by any *fixed* area then decreases as the

distance of the receiving surface is greater. This decrease always follows the *inverse square* law. Thus if 100 arbitrary units reach a given area at 10 inches from the target, the *same area* 20 inches from the target will only get ¼ as much in the same time, i.e., 25 units. At 30 inches the *same area* receives but ⅑ as much or 11⅑ units. Or to get the *same* radiation to this area at the increased distances the time must increase as the *square* of the *distance*, i.e., if at 15 inches 2 seconds are required, at 20 inches $2 \times (^{20}/_{15})^2 = 2 \times {}^{16}/_{9}$, at 25 inches $2 \times {}^{25}/_{9}$, at 30 inches $2 \times (^{30}/_{15})^2 = 2 \times 4 = 8$ seconds, etc.

Amount of Radiation. The measurement of *x*-ray radiation has proved a rather difficult matter and need not be fully discussed here. For our purpose the photographic measure is sufficiently accurate and determines the usefulness of the rays in practice. Whatever the conditions of operation, we might take a time of exposure so as to get the same blackening on two spots on a photographic plate, and then say that the two *had the same exposure*, when exposure does not mean time of tube action alone.

Such a method measures only the effect of rays used in changing the emulsion, *not* the total beam, the greater portion of which passes through the film.

Quality. Fully as important as the amount of radiation is the quality or distribution of radiation among various wave lengths. Quality determines the ability of the rays to pass through flesh and bone. It depends on the voltage used to drive the current across the space between cathode and anode, and may be expressed in terms of voltage or gap.

Dependence of Quantity on Electrical Conditions. It is very important to realize that the amount of radiation as measured by the photographic effect is simply related to the electrical conditions under which a tube is operated.

If we let

I = Current in milliamperes
V = Effective voltage in kv.

Then radiation leaves the target at a rate depending on the product of current and the *square* of the voltage. The amount reaching a given area placed at right angles to the flow and at a distance d from the target and in a time t is measured by $\frac{IV^2t}{d^2}$.

Thus if I_1, = 40 ma., V_1 = 30 kv., d = 20 inches, t = 1 second, in one case, and

I_2 = 10 ma., V_2 = 60 kv., d = 20 inches, t = 1 second in another, then $Q_1 = 40 \times 30 \times 30 \times \frac{1}{400} = 90$ arbitrary units where Q_1 = amount of radiation in the first case and $Q_2 = 10 \times 60 \times 60 \times \frac{1}{400} = 90$ units in the second case. That is, 40 ma. at 30 kv. and 10 ma. at 60 kv. will produce the same quantity of x-rays as measured by photographic effect.

These equations are simple and useful for calculating exposure time. They are only approximately correct, as the quantity does not vary exactly with the square of the voltage.

However, the radiation produced at 60 kv. is better able to penetrate any piece of matter, and a higher percentage passes through, so that a plate exposed partly to one and partly to the other through a block of material will show much more darkening for the second case, even though the quantities of radiation generated at the tube are equal. It would darken the plate equally if no body were interposed.

No matter what amount of current is passed through a tube it is useless for radiographic or fluoroscopic work, unless a voltage able to break down from 2 *to* 6 *inches of air between*

blunt points is used. For thick parts the higher voltage (gap) must be used.

The relation of sparking distance (between blunt points)



FIG. 13. Approximate relation between effective kilovolts and spark gap for moderately blunt points.

to kilovolts is shown in Figure 13. The kilovoltage is approximately ten times the gap in inches plus ten.

Penetration. The most characteristic feature of *x*-rays is their ability to pass through material quite opaque to other types of radiation. In all cases there is some absorption, but the rate of absorption or the amount left after passing through any layer of material varies according to the composition of the *x*-ray beam. The most penetrating rays are produced only at higher voltages. This penetration could be accurately defined in the case of a beam of one wave length, but it is quite difficult in the case of an actual complex beam.

It is essential for the operator to realize that increasing the tube voltage will (a) add shorter and more penetrating rays; (b) increase the quantity of the less penetrating rays which were produced at the lower voltage.

X-ray Transformer. There is no practical means of directly generating an electric current at the voltage needed in the production of useful *x*-rays, hence it is necessary to use a transformer, stepping up low voltage current to the high voltage required. The transformer consists of two coils of wire around a common iron core. For complete insulation of the coils from each other the system is immersed in oil or in wax. If in the latter, it is shipped complete; when oil insulated, the oil is usually shipped separately. In this case, it should be siphoned into the transformer; the inlet side should be raised an inch or so to get complete expulsion of the air. It is well to operate at a low power, allowing sparks to pass across an inch gap for some time to dislodge small air bubbles before putting it into service.

Use no oil not furnished for the purpose by a reliable manufacturer; *the oil must contain no moisture.*

Examine the oil level every two months to be sure it fills the tank. An exposed coil is sure to break down by puncture of the insulation. The top of the case should be kept free from oil and dirt. For protection against surges or sudden high tension pulses which are likely to damage the transformer, a resistance should be placed in shunt with the low tension terminals. If this is not provided by the maker, ordinary lamps may be used. (Fig. 14.)

The middle of the secondary is usually connected to the case (grounded); this insures a distribution of potential equally above and below the "earth" potential. Thus, if the terminal voltage is 40,000 volts, then the tendency to pass a spark to any grounded conductor is 20,000 volts.

This arrangement avoids in some measure the tendency to discharge to patient, stand, and tube that would result if the full terminal voltage were effective to earth.

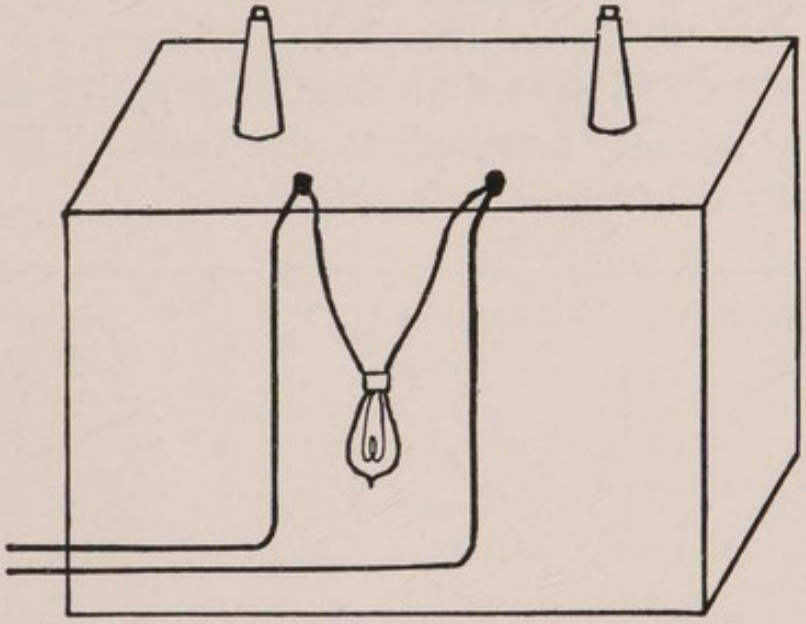


FIG. 14. Protection from surge by use of a lamp.

Care must be taken to keep all contacts on the low voltage side tight. See that low tension wires are kept as far away from the high tension terminals as possible. If trouble actually occurs, due to short circuit or break inside the transformer, there is no use in trying to repair it, as a rule, unless the trouble is close to the terminals. If there is trouble arising from sparking across between the high tension terminals of the transformer, attaching small spheres will relieve the tension and usually cure the trouble, or insulating barrier plates may be used.

Control of the Transformer. Corresponding to each of the various high tension voltages maintained at the tube terminals, there must be applied a definite voltage across the primary of the transformer. The transformer changes voltage approximately in the ratio of number of turns in the primary to number of turns in the secondary, and changes current in the inverse ratio. Thus a particular

x-ray transformer might be wound with 500 turns in the secondary for each turn of primary, and it would be said to have a step-up ratio of 500. The secondary voltage would be 500 times the voltage in the primary and the secondary current $\frac{1}{500}$ of that in the primary.

A table of the voltages that must be supplied and maintained at the primary terminals to give various high tension voltages can easily be made in this case.

Primary Applied Voltage	Resultant H. T. Voltage	Spark Gap (approximate)
80 v.	40 kv.	3 in.
90	45	3 ½
100	50	4
110	55	4 ½
120	60	5
130	65	5 ½
140	70	6
150	75	6 ½
160	80	7
220	110	10

Such primary voltages can be secured from a line supply of 220 volts (a) by the use of a rheostat, (b) by the use of an autotransformer.

Rheostat. The rheostat is an adjustable resistance used to consume a part of the line voltage and leave the proper voltage to be applied at the transformer. Suppose, for instance, it is desired to have 40 ma., at a 5-inch gap delivered to the tube. The *primary* must be supplied with 120 volts and a current of 40 ma. $\times$ 500 = 20 amperes. In this case the rheostat must consume 100 volts from the 220 volt line with a 20 ampere current (Fig. 15). By Ohm's law ($V = IR$) the voltage consumed in the flow of current

through a resistance is equal to the product of the current in amperes and the resistance in ohms. Therefore, $100v = 20 \times R$ from which $R = 5$ ohms, hence we would need 5

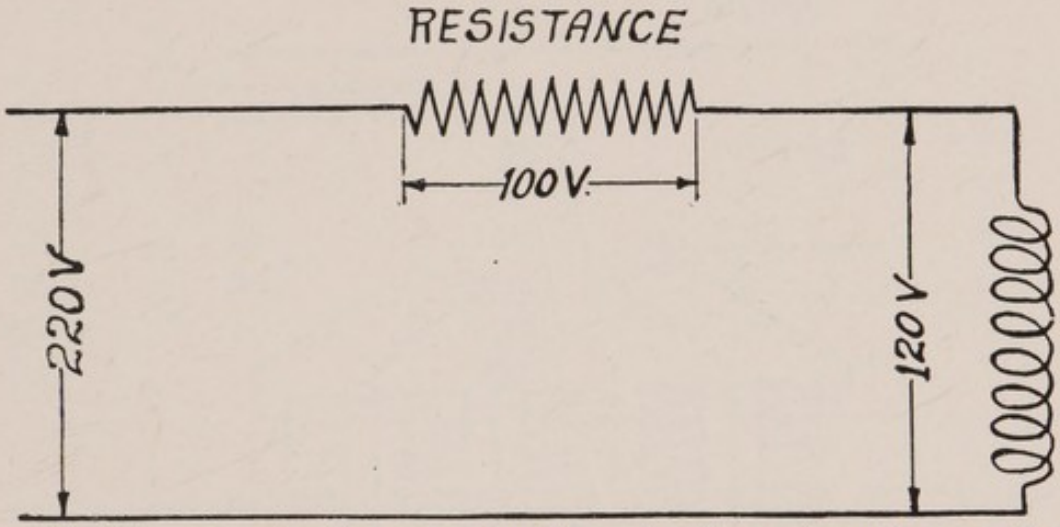


FIG. 15. Diagram showing consumption of voltage by primary of x-ray transformer and series resistance for a particular case.

ohms of the rheostat to get the setting desired.

The rheostat consists of coils of resistance wire connected end to end, one end of the series being permanently connected to one wire of the power line. Resistance wire is made of some special material of considerably higher resistance for the same diameter and length than copper. An adjustable contact is used to join one transformer terminal to any desired point of the rheostat so as to include the required amount of resistance in the circuit. Figure 16 shows the essential parts of a rheostat.

The usual numbering makes the power increase as the control lever is moved over to higher numbers. A good rheostat should be of substantial construction, well ventilated, and of such current capacity as not to get overheated under any operating conditions. It should be so graded as to give 30 to 70 ma. on a 4-inch to 7-inch gap for radiographic work.

The use of a rheostat to control tube voltage has the disadvantage that slight variations in tube current result

in serious changes in voltage. To see how different tube currents cause such enormously different voltages on the same control setting, let us first construct a table to give

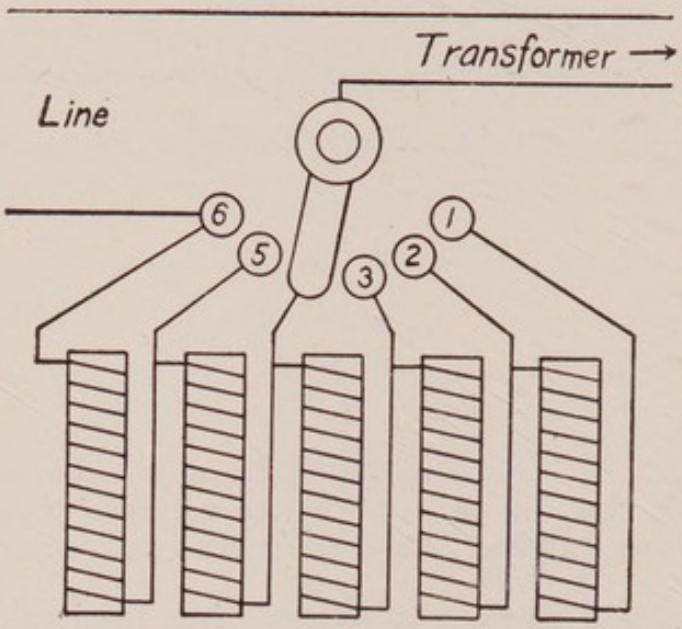


FIG. 16. Rheostat construction and connections.

the primary currents corresponding to different tube currents. Each primary current is 500 times the corresponding secondary.

Secondary Current	Primary Current
0 ma.	0 amps.
10	5
20	10
40	20
60	30
80	40
100	50

Assuming the setting of 5 ohms resistance, let us see how the voltage applied at the transformer varies under different loads. The voltage consumed in the rheostat is $V = IR$, where I is primary current and R is constant at 5 ohms.

Secondary Current	Primary Current	Voltage consumed in Rheostat	Voltage left over to apply at Primary	Resulting Secondary Voltage
0 ma.	0 amp.	0 v.	220 v.	110 kv.
10	5	25	195	97
20	10	50	170	85
40	20	100	120	60
60	30	150	70	35
80	40	200	20	10
100	50	250		

These figures are represented graphically in Figure 17. This results in the theoretical chart line corresponding to operation on the particular rheostat control button selected. For simplicity, no account has been taken in these figures of line wire resistance, resistance in the windings of the transformer, "magnetic leakage," and other factors which enter to a greater or less degree.

The voltage "regulation" under various loads of a rheostat controlled transformer is poor. On any one control setting the voltage will fall off very rapidly with an increase in current, and rise rapidly with a decrease. In Figure 17 at 60 kv. and 40 ma. an increase of 8 ma., due to softening of a gas tube during exposure or to fluctuation in the filament temperature of a Coolidge tube, will lower the voltage 10 kv., or about an inch of spark gap. The loss in voltage and penetration will have considerably more influence on a plate than the increase in current. Also, if there were a break in the Coolidge filament line, or polarity were wrong, so that no current flowed in the secondary circuit, the primary voltage would rise to that of the line with considerable likelihood of sparking to the patient or causing damage to apparatus.

Autotransformer. To secure better voltage maintenance under varying loads an autotransformer is often used. It consists of a continuous coil of wire wound around

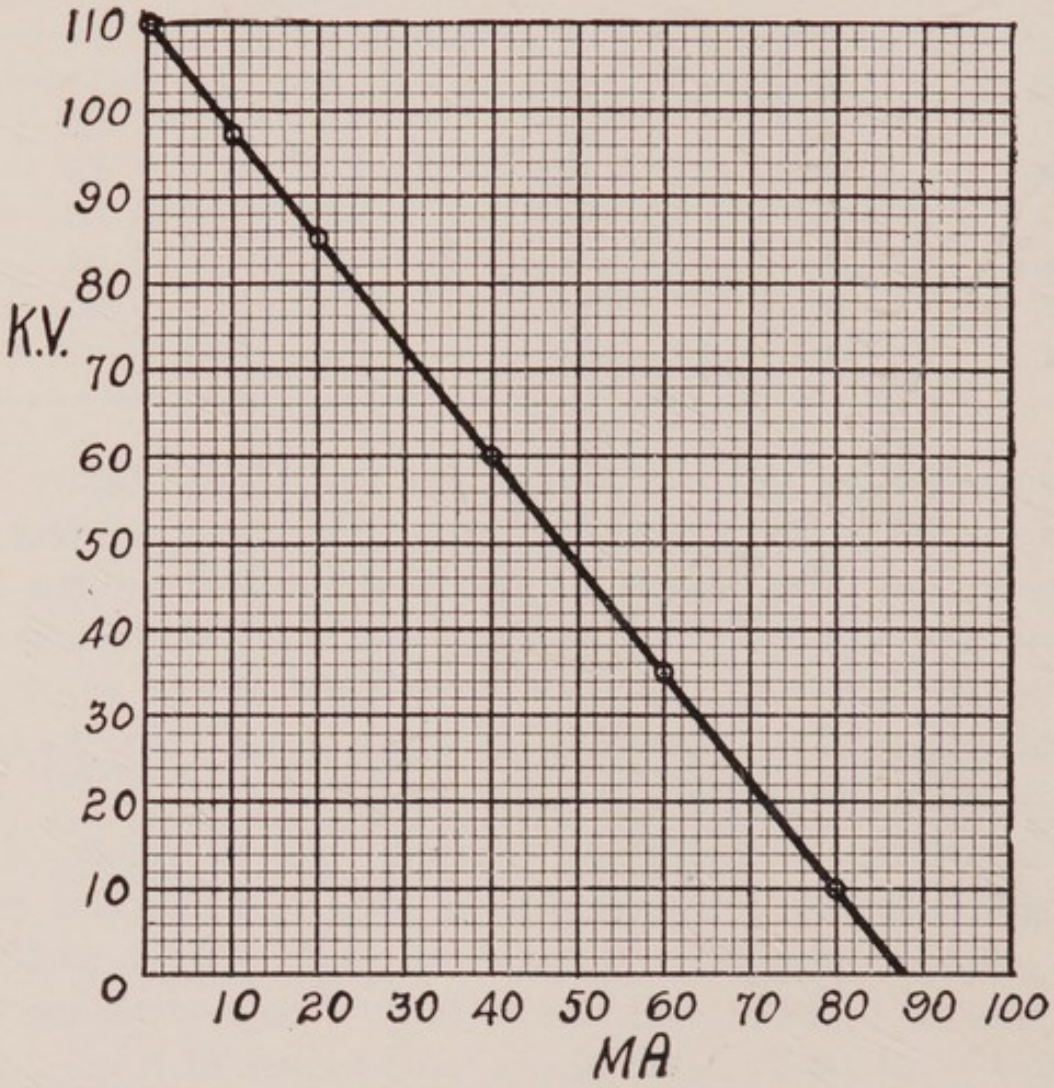


FIG. 17. Theoretical chart line plotted from data given in table on page 35. This line shows, for the particular machine and setting, the voltage at which various currents will be delivered.

an iron core with taps taken out to control buttons at proper intervals, as shown in Figure 18. If alternating current be applied to the complete winding of such a coil there will be a voltage induced in any part of the winding, bearing the same relation to the applied voltage that the number of turns of this part of the winding bears to the number of turns in the whole coil. It is essentially the same as

any other transformer, except that primary and secondary are part of the same continuous wire rather than separate windings, and its action depends on self-induction in a sin-

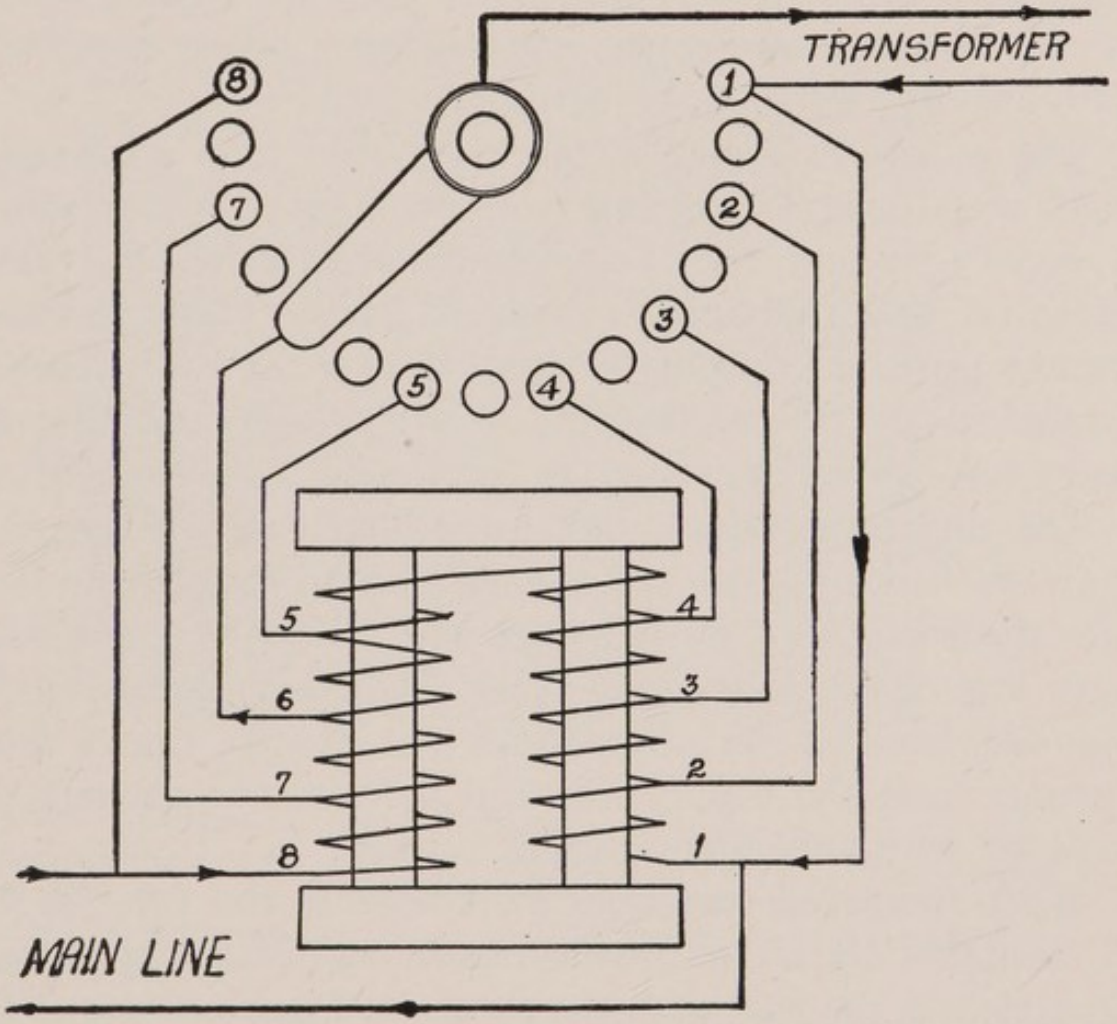


FIG. 18. Wiring diagram of autotransformer. Notice dead buttons between the active ones which are numbered.

gle coil rather than on mutual induction between two coils. The ratio between the number of turns in the primary and secondary circuits is changed by setting the control lever on the various buttons. The autotransformer is used as a control device to reduce the line voltage to that which is applied to the *x*-ray transformer primary, hence it is a step-down transformer and has fewer turns in the secondary circuit than in the primary. As the control handle is moved to higher readings, more turns are cut into the

secondary circuit and higher voltage is applied to the primary of the *x*-ray transformer. Blank or "dead" buttons are placed between adjacent live buttons, which differ from each other by a few volts, to prevent a short circuit of this low voltage by the control lever being in contact with two live buttons at one time.

The autotransformer is more suitable than a variable ratio step-down transformer, which might be used, since it saves wire and iron, being much smaller for equivalent capacity, and therefore cheaper to build. The autotransformer principle cannot be applied to *x*-ray and filament transformers because their ratio is too large and the primary and secondary must be insulated from each other.

The autotransformer, like an ordinary transformer, is very efficient and does not change electric energy into heat like the rheostat. The windings are of large copper wire, with low ohmic resistance. When increased current is demanded from an autotransformer, it simply draws more current from the supply line and delivers the current demanded with very little drop in voltage.

When increased current is demanded in the tube, it will be supplied by an autotransformer with far less voltage drop than is the case with the rheostat. Figure 19 shows the behavior of the two devices on a particular machine. Starting at 10 ma. and 60 kv., and raising the tube current on a fixed rheostat setting, gives the series of currents and voltages shown by the line AC; while on a fixed autotransformer setting we have the line AB. Since the quantity of radiation (measured photographically) increases as the current and the square of the voltage, we may compute the *relative* amount of radiation regardless of penetration. Curve DE shows the rheostat delivery down as low as useful rays are produced; DF shows the delivery on the autotransformer up to 60 ma.

This form of control is of special value when the filament current of a Coolidge tube is not entirely steady. Thus, if the tube current in the case cited changed from

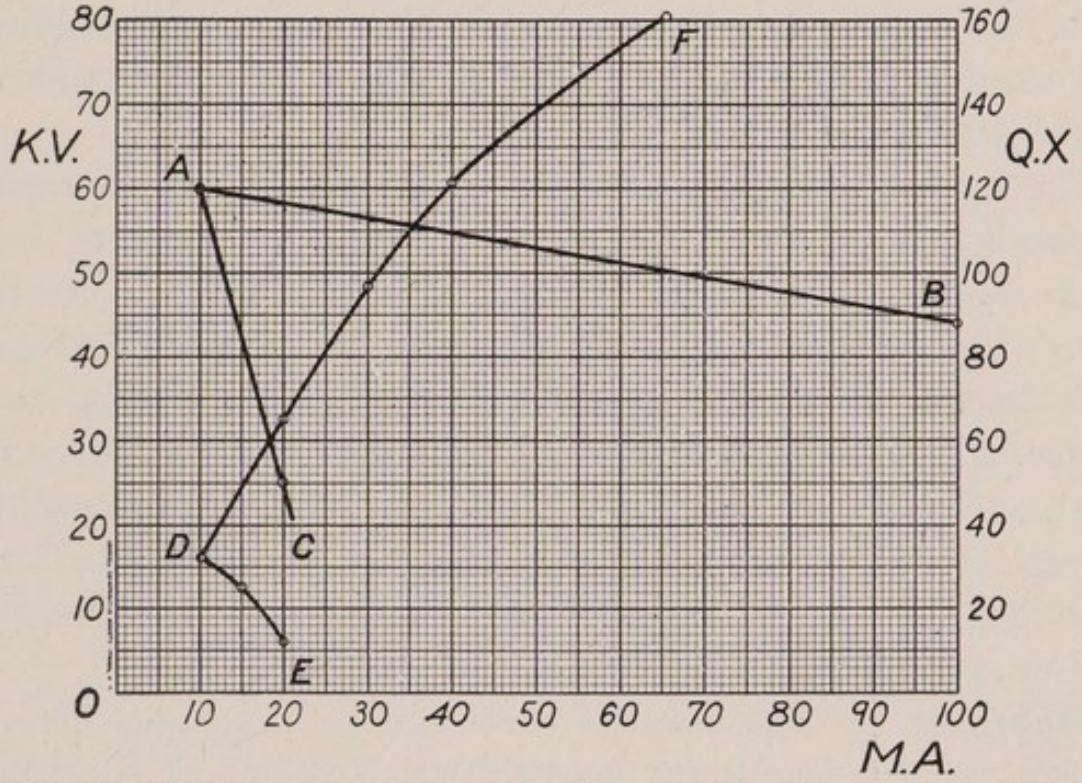


FIG. 19. Relation of x-ray production on two types of control. On rheostat control we have AC as the voltage-current line. Voltage ordinates at the left. DE, corresponding x-radiation quantity, ordinates at the right. AB, autotransformer chart line. DF, corresponding quantity line. Quantity in arbitrary units.

10 to 15 ma., with a rheostat control, the radiation would be reduced in quantity from 32 to 25 arbitrary units and also would be much less penetrating; while with the autotransformer the same change would result in an *increase* in quantity from 32 to 50 units very slightly less penetrating than at 10 ma.

"Inductance" Taps. Instead of controlling completely by variation in the applied voltage, in some instances the winding ratio of the x-ray transformer is variable by a dial switch which cuts in more or less turns of the transformer primary. The lowest ratio of step-up corresponds

to the complete primary and, since the secondary winding is fixed, to cut out turns of the primary will increase the step-up ratio and give higher secondary voltage. As usually applied, the machine has essentially a rheostat control, with rheostat rather than autotransformer characteristics, and usually more taps are made in the winding than serve a useful purpose.

The same principle is conveniently applied in transformers built to operate on either 220 or 110 volt mains, half as many primary turns being used for 110 volts as for 220. The bedside unit uses this principle for 110 volt a.c. and the lower voltage a.c. obtained from the rotary converter. In some instances the primary is wound in two sections which are connected in series for 220 volts and in parallel for 110 volts, in the latter case giving carrying capacity for the heavy primary currents as well as the higher step-up ratio.

Stabilizer. A stabilizer is a device to maintain steady current in the circuit for heating the filament of the tube. Steady current in the filament circuit is necessary, as a variation of one volt in the filament circuit may make a difference of 20 per cent in the current passing through the tube.

The stabilizer has an electromagnet connected in the high tension circuit. Opposite this is an armature, held away from the magnet by a spring. When the high tension current increases beyond the value desired the attraction of the electromagnet for the armature overcomes the tension of the spring; a contact is broken and a resistance is cut into the filament circuit. The filament becomes less hot and the high tension current is reduced.

The pull of the electromagnet on the armature varies with its distance from the armature; when the distance between magnet and armature is greater, more current is

required to attract the armature. By changing the distance between the electromagnet and the armature the current that passes through the tube may be varied at will. This distance is changed by an insulated control, which is provided with a scale calibrated in milliamperes.

Most stabilizers are made with an extra magnet and armature, to protect against the surge that may be expected at the instant the operating switch is closed.

Usually the stabilizer is connected into the high tension side of the filament circuit. The stabilizer may be devised to control the primary of the filament transformer.

Calibration Charts. A proper procedure in handling machine and tube is indispensable. Such a method should be adopted as will:

1. Save time and tubes.
2. Render reproduction of results possible.
3. Require a minimum amount of instrument reading when operating.
4. Indicate the working range of the machine.

X-ray machines are calibrated according to the type of their controls. While machines of different manufacture vary, there are two main classes: (1) Where the autotransformer is provided with 20 or more steps, permitting voltage regulation in increments of not more than 5 volts. (2) Where the autotransformer has less steps, and rheostat control must be added.

1. *Pre-reading Voltmeter.* Voltage may be controlled with the autotransformer only. A voltmeter is placed across the primary circuit between the autotransformer and the high tension transformer, for example, at the position *KV* in Figure 42, p. 71. As the voltmeter indicates the potential available before the operating switch is closed, it is called a pre-reading voltmeter.

To make the chart, proceed as follows.

A standard sphere gap is placed across the secondary circuit near the tube. The operator manipulates the controls, an assistant operates the sphere gap. The rheostat is placed on the highest button and left there. The machine is set for 10 ma. The autotransformer is placed at its lowest step. The voltmeter is read and noted. The operating switch is closed, and the balls of the sphere gap are slowly approximated until a spark just passes; the operating switch is immediately opened and the kilovolts read from the scale on the sphere gap.

The process is repeated for each step of the autotransformer, within the practical range that would be used for radiography. The results are tabulated. The chart for one machine read as follows:

Autotransformer	10 ma.	
	Voltmeter	Kilovolts
1	60	37
2	65	41
3	70	44
4	75	49
5	79	53
6	85	58
7	90	60
8	95	64
9	100	68
10	105	71
11	110	74
12	115	77
13	117	80
14	121	83
15	125	87
16	129	92

The entire procedure is repeated for other values of secondary current, such as 20 ma. and 100 ma.

When the charts are completed the sphere gap is removed.

Comparing the charts for 10, 20, and 100 ma. it will be noted that the voltage at the tube for a given setting of the autotransformer is decidedly higher for low current than for larger currents. As a rule different machines, installed under various conditions of electric service, do not give the same chart. It is for this reason that dependence must be placed on the charts, rather than on a scale furnished by the maker of the apparatus.

When a radiograph is to be made, select from the exposure table the kilovolts and current required. Refer to the chart for the proper reading of the voltmeter. Adjust the autotransformer until the reading is attained, before the operating switch is closed. Do not use the rheostat. Adjust the stabilizer, and check the current by closing the operating switch. The patient may then be placed in position for the *x*-ray exposure.

It is convenient to enter the values of the pre-reading voltmeter in the exposure table (p. 147).

2. *Transformer Chart.* The working spark gap, with moderate sized blunt points for a gap, varies from about 3 to 6 inches, and currents vary from 5 to 100 ma. in fluoroscopic and radiographic work. Any possible combinations on the machine, giving settings outside these limits, are practically useless.

On any transformer outfit find first a 5 ma. 6 inch gap setting, then a 40 or 50 ma. 6 inch gap or an 80 ma. 4 inch gap setting. Study no settings outside these limits. In Figure 20 take rheostat setting *G* as an example. *Read the current through the tube when a* 6 *inch gap just fails to break* (25 ma.). Record your setting and the current. Leaving the *x*-ray transformer *control unchanged* find the tube

current at which a 5 inch gap just fails to break. Do the same for a 4 and for a 3 inch gap. When these readings are plotted to scale, as in Figure 20, they should fall nearly

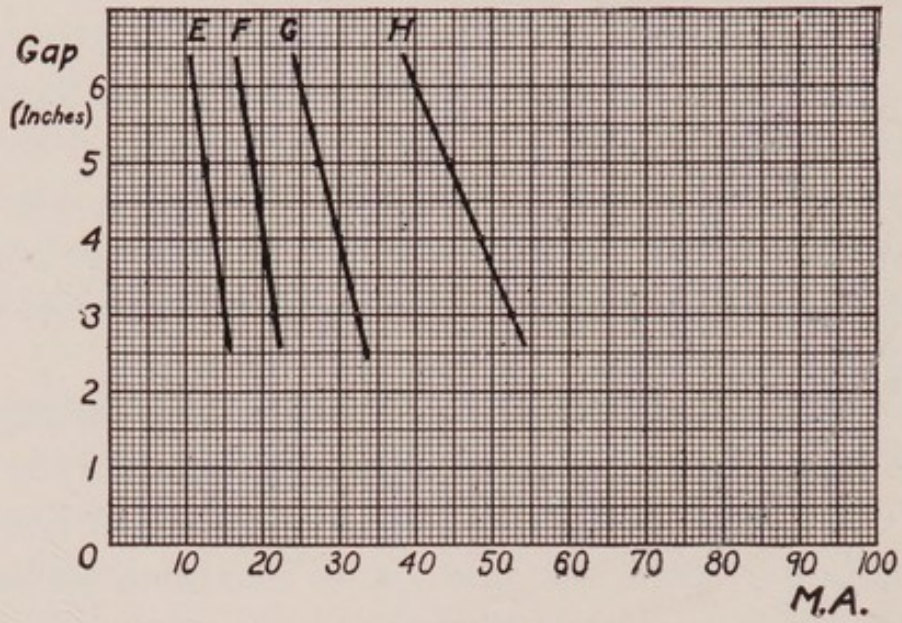


FIG. 20. Partial "chart" of a particular machine with rheostat control. Note that gap change, as tube current increases, is very rapid. On *G*, for example, we have a 6 inch gap at 25 ma. and only a 5 inch gap at 27.5 ma. or a change of an inch for each 2½ ma. Compare with Figure 21.

on a straight line. If they do not do so, repeat the observations.

So long as the power supply is kept at the voltage prevailing when this chart was determined the coördinates of a line give all the currents and voltages at any time available on the indicated rheostat setting. *H* gives the currents at which gaps between 6 and 3 inches are broken on button *H*. Figure 21 shows five such lines for a particular machine on autotransformer control.

How to Use the Chart. Using chart, Figure 20, one needs for a particular case 20 ma. at a 4 inch gap. The vertical line through 20 cuts the line marked *F* at the 4 inch gap. Hence we must use buttom *F*. Have the spark gap open to 7 or 8 inches as a safety valve and forget it entirely. Move the rheostat lever to *F*, look at your milliammeter, use

one hand on the transformer primary switch and the other on the Coolidge control. Close the transformer switch and bring the filament control to a setting, giving 20 ma.

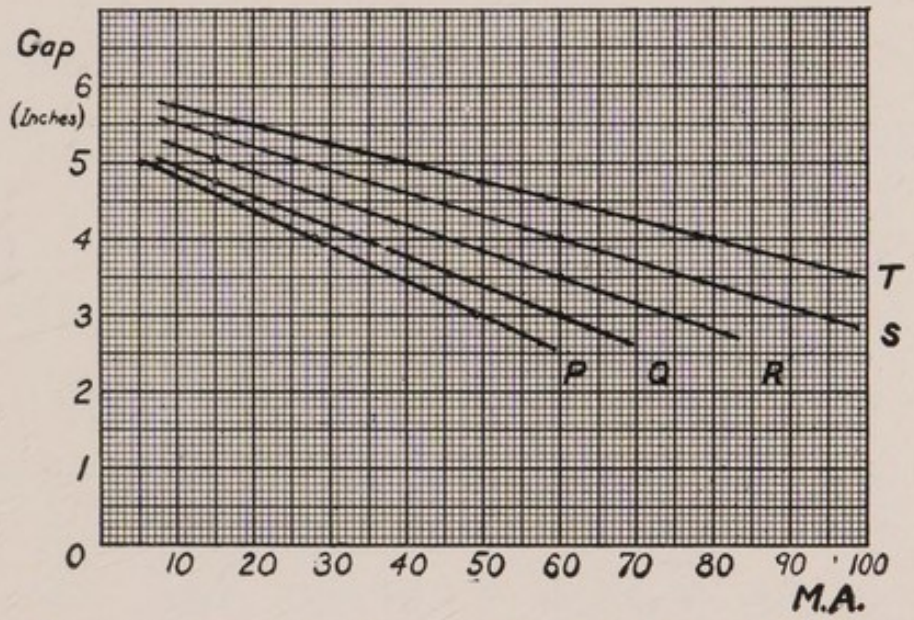


FIG. 21. Partial "chart" of the same transformer using autotransformer control. Note that line marked *P* shows all *useful* currents that can be had on this setting: changing from 5 ma. to 50 ma. lowers gap from 5 to 3 inches.

tube current; there is no need of testing the spark gap.

Do not try to read the milliammeter on the throw. Learn to start and set your machine within ten seconds. On 20 ma. desired, a current of 19 or 21 ma. is close enough for this work.

Using chart, Figure 21, for 45 ma. at a 4 inch gap, go at once to *R* and proceed as before. A little time spent in making this chart and in using it will reduce time lost and failures. Note that the faster the spark gap falls with increase of tube current the more accurately must the filament current be adjusted and maintained.

Synchronous Motors. A synchronous motor is one that makes either the same number of revolutions per minute as the generator feeding it or a fixed fraction thereof. Thus, if fed by a 60 cycle alternating current, there are 7200

alternations per minute. One alternation is produced whenever a conductor passes one pole piece of the generator. Thus, a 60 cycle current from an eight-pole machine requires

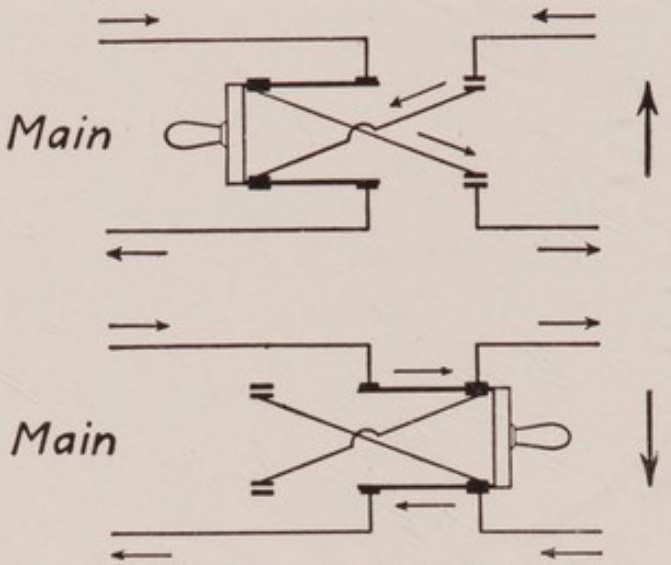


FIG. 22. Wiring of "polarity" switch.

900 r.p.m. (revolutions per minute), since $7200 = 8 \times 900$. For a four-pole machine we must have 1800 r.p.m., etc. A four-pole motor must then make 1800 r.p.m. for synchronism if on such a circuit, and it must not make 1801 or 1799. Since the rectifier for a 60 cycle current must make a quarter-turn each $\frac{1}{120}$ of a second, the motor must turn at 1800 r.p.m. It must be observed that such a motor is designed for a given frequency and cannot be expected to work on one greatly different from that intended.

Starting. Many motors require connection to a special starting device in order to bring them up nearly to the required speed before making the running connection. Do not delay too long, and do not throw over the switch too quickly. A little practice will enable you to tell by the sound of the machine when the speed is about right.

Polarity Indicator. Some machines have a field winding which ensures the same terminal polarity each time the machine is started. In most machines there is as much

chance of a given terminal starting + as − . Polarity indicators are often used to show which way the rectifier comes into step. Either a primary reversing switch. (Fig.

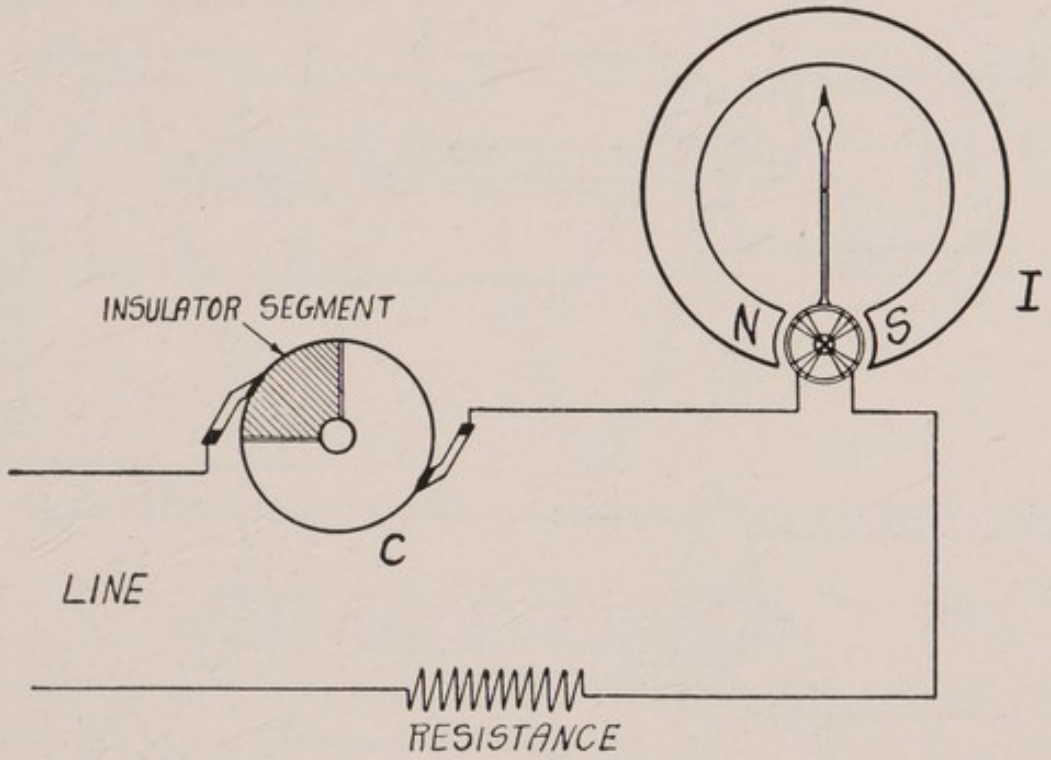


Fig. 23. Principle of polarity indicator. Note resistance in series.

22) is used or the motor switch is opened for an instant and again closed, thus allowing the motor to drop back with the chance of changing polarity of the high tension lines. These indicators are devices to indicate direction of current flow, used in connection with a small low-tension rectifier driven by the motor. In Figure 23 a source of alternating current is obtained from the primary lines; *C* is the low tension rectifier, or commutator, fastened on the same shaft as the high tension rectifier, and *I* is the indicator.

The direction of the rectified current through the indicator circuit will be one way or the other, depending on how the two rectifiers happen to come into step. The indicator itself consists of a movable coil with pointer attached, working against a hair-spring in a permanent magnetic

field, and it is very similar in construction to a direct current voltmeter or ammeter. If the rectified current flows one way through the coil, the needle will be deflected to

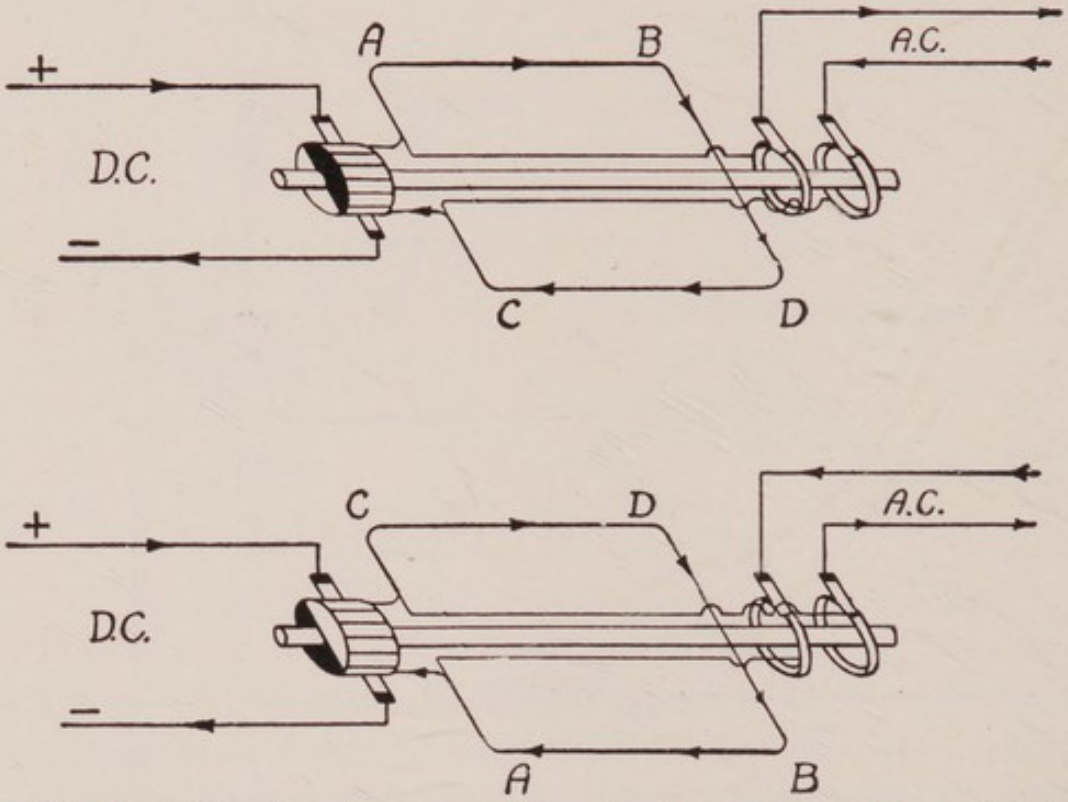


FIG. 24. Principle of rotary converter showing two positions of active coil 180° apart, armature current being always alternating.

one side; if the current flows in the reverse direction, the needle will swing to the opposite side.

The indicator is usually of low resistance with an auxiliary resistance unit included in the circuit to prevent burnout of the indicator coil. Never connect the indicator without this resistance in circuit, and in testing to find the proper connections always use a lamp in series with the indicator to prevent burnout, if connection is accidentally made to too high voltage.

Rotary Converter. If the line supply is direct current it must be changed into alternating by means of a rotary converter, since the *x*-ray transformer will operate only when its primary is supplied with alternating current.

The operation of the converter is based on the fact that the current flowing through the armature of a direct current motor is alternating. To simplify explanation, consider the

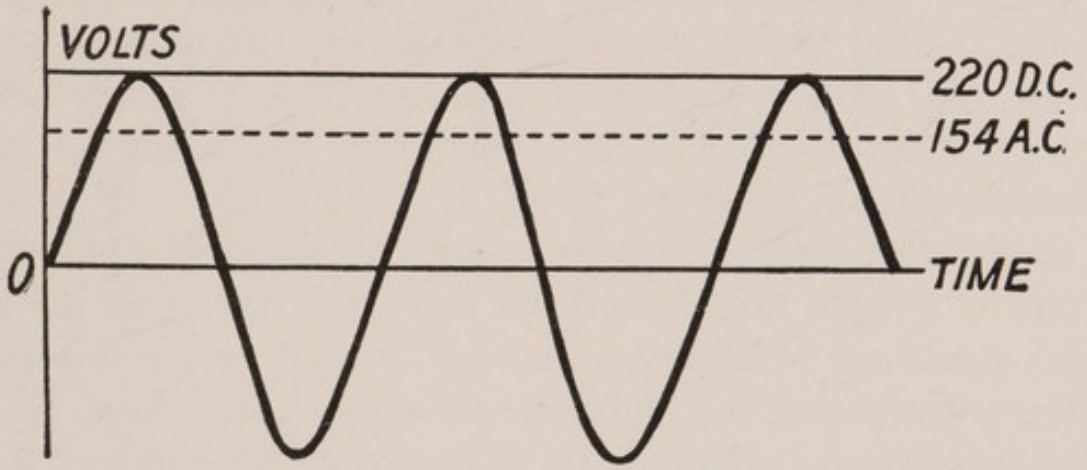


FIG. 25. Relation between d.c. voltage supplied and a.c. voltage delivered.

case of a machine having two field poles and a single armature coil. At the left (Fig. 24) are the brushes to which the direct current line is connected, and at the right those from which the alternating current is drawn. The flow of current through the armature coil in the direction of the pointers causes rotation of the coil as indicated, owing to the reaction with the magnetic field between the stationary pole pieces. When the coil has rotated just beyond the vertical plane the connection of the rotating commutator segments with the d.-c. feed brushes is reversed, the current through the armature coil is reversed, and rotation is thereby made to continue. Each half revolution of the armature causes a reversal of current through the armature winding and a change in polarity of the two segments. If, now, these segments are continuously connected to the same collector brushes by means of slip rings, the current drawn from these brushes will be alternating current.

The direct current voltage supplied to the rotary converter corresponds to the peak voltage of the alternating current wave, and the effective voltage of the alternating

current is only about 70 per cent of this (Fig. 25). Thus a converter operating on 220 volts d.c. will deliver only 154 volts a.c. and if 220 volts a.c. are required, it is necessary to step up by means of a special transformer or autotransformer. Under heavy load the voltage will fall considerably below the 70 per cent, and serious difficulties will arise from trying to use a rotary converter too small for the demands placed upon it.

In direct current *x*-ray machines the rotary converter drives the rectifying device. In this case, the machine always starts up with the same high tension polarity, and a polarity indicator or polarity switch is unnecessary. If polarity is wrong permanently, interchange the primary lead wires at the transformer or reverse the tube in the stand.

In using a rotary converter, one should remember that all the power used passes into the rotary through the d.-c. brushes, and all used by the *x*-ray transformer passes out from the slip rings. In the a.-c. machine the transformer power does not pass through the motor, so that greater care of brushes, etc., is needed in the d.-c. machine.

A considerable proportion of failures of rotaries is due to the breakdown of insulation at the connection of the armature wires to the slip rings. "The Care of Motors" on page 76 applies also to rotary converters. Protection should be made against high tension surges by connecting an incandescent lamp across the a.-c. end, as is done to protect a transformer (Fig. 14).

Rectifier. Two forms of rotating circuit changers are in common use, the cross-arm type and disc type. Both are run by a synchronous motor, and they must be correctly placed relative to the motor armature if efficient delivery is to be secured. Figure 26 shows the current path for the four-arm type, Figure 27 for the two-arm, and Figure 28 for the disc type.

In Figure 26 when the right hand terminal of the transformer is −, the flow of negative charge or of electrons is from *A*-*B*-tube-*C*-*D*. If the spindle turns 90° while the

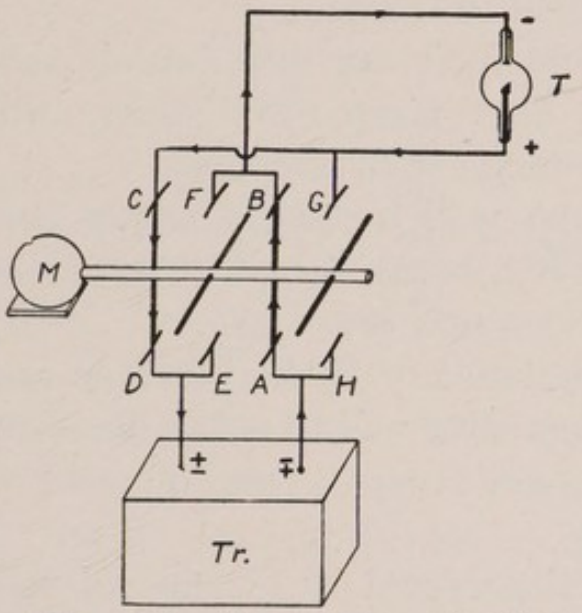


FIG. 26. Secondary circuit: Cross-bar type rectifier, four arms.

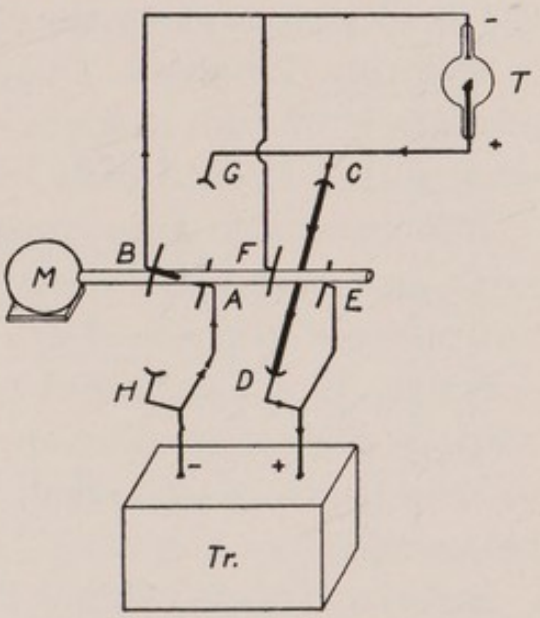


FIG. 27. Secondary circuit: cross-arm type, two arms.

polarity of the transformer is reversed, electrons flow from *E*-*F*-tube-*G*-*H*. In both cases the current takes the same direction *through* the tube.

The disc type is shown in Figure 28. *PQ* and *RS* are two conducting sectors fastened to an insulating disc turned by the motor.

Flow is *A*-*B*-tube-*C*-*D* in one case and a quarter turn connects *D* to *B* and *C* to *A*. Meanwhile the transformer has reversed so that electrons pass from *D*-*B*-tube-*C*-*A*.

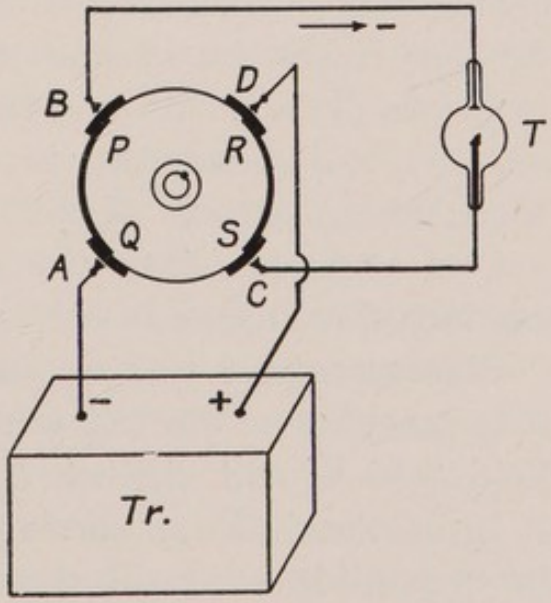


FIG. 28. Secondary circuit for disc type of rectifier.

In Figure 26 the cross-arm machine, *E* and *A*, *C* and *F*, *B* and *G* must be well insulated by barriers, or else the shaft

must be unduly long. In the disc machine the diameter must be large enough to insure insulation between the shaft and the rim and also to avoid establishing an arc between the fixed sectors along the edge of the disc.

Sparking Troubles. Dust and moisture may impair the insulation of the barriers or disc. Keep them clean and wipe with a cloth *slightly* moistened with kerosene.

The cross-arm type must be well insulated where the arms pass through the shaft. If a break occurs there, it is not possible to patch it up. Get a new cross-arm.

Noise. If a disc is out of balance or if the bearings are worn by lack of lubrication a machine will be noisy. Be sure to keep bearings well oiled. Do not accept a machine poorly balanced.

Inverse. Inverse shows by fluorescent rings back of the target in a gas tube and by sparks across the gap on a low power setting on the Coolidge tube. It is caused by the rectifier being out of position. It is assumed that the maker will *mark* the shaft of the cross-arm type or the disc in the other class with reference to the motor shaft so that one can see if slip has taken place and adjust to the proper position. If this has not been done, readjust so that the current is a maximum on a low power setting and with the filament current of the tube kept constant.

One accustomed to the appearance of the arcs at the rectifier terminals can set fairly accurately by observation.

Electromagnet and Solenoid. Surrounding a wire while it is carrying an electric current there is always a magnetic field which will deflect a compass needle placed near it into a position as shown in Figure 29. If now the wire be wound into a coil the magnetic action formerly distributed along the length of the wire is concentrated in the center of the coil, and if a piece of iron be inserted as a core the intensity of the field will be still further increased

since the iron is much more permeable to magnetism than air. The coil is a magnet only while current is actually flowing and its magnetic strength is greater the more

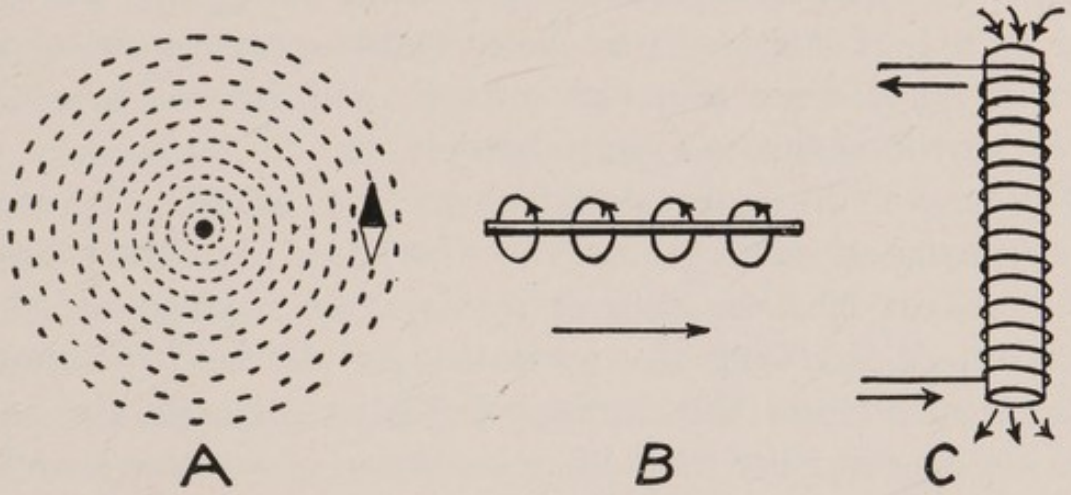


FIG. 29. Relation between an electric current and its resulting magnetic field. *A* Coss section of conductor with compass needle in field. *B* Straight portion of a conductor showing current and field. *C* Magnet coil with iron core. Greater strength than the same coil without iron core.

turns of wire and the greater the current, and depends also on the dimensions and the quality of the iron core and the design of the magnet as a whole. If the core is fixed and the magnetic action attracts an iron armature, as in some remote control switches, it is called simply an electromagnet, whereas if the winding is hollow and by its magnetism sucks an iron plunger into the coil, as in the throttle control of the portable unit engine and certain remote control switches, it is called a solenoid. An electromagnetic winding should never be connected on a voltage for which it was not designed, and a winding made for a.c. or d.c. must never be connected to the other type of current supply, as is explained in the next section.

Choke Coil. If an alternating current be applied to an electromagnet there will be a choking due to the slow magnetizing of the core and the rapid alternation of the current. Less current will flow than if a correspond-

ing voltage of direct current be applied, and the difference will depend on the properties of the magnet and the frequency of alternation. Never expect a magnet designed for d.c. to operate satisfactorily on a.c., for it will not let pass sufficient current; and *never* connect an a.-c. winding to d.-c. lines, since so much current will flow as to most likely burn out the coil immediately.

The choke coil is occasionally used instead of a rheostat as a means of control for the Coolidge filament transformer. Variation is secured by moving a piece of iron in or out of the field, the more iron in the field the more choking effect and the dimmer the filament, and the less iron the brighter the filament. Gradation of control is complete and there are no sliding contacts to cause trouble.

The inductance type control is more durable. Two coils are mounted so that one is fixed and the other may be turned. The first coil is connected to the main leads, the second to the step-down transformer. There is no direct electrical connection between the two coils. The transference of energy is by induction. When the coils are parallel, voltage is maximal; when at right angles, minimal. By rotating the coil any voltage may be secured between the highest and lowest fixed values.

Protection against Surge. The insulation of the apparatus in the primary circuit is sufficient for 220 volts, but not for high tension. If a sudden impulse or surge of electricity is set up in the primary circuit, due to a ground or short circuit of the secondary, or a spark back to the primary, the voltage in the circuit may amount to many times what it normally is.

Most of the apparatus in the primary circuit is inductively wound (electromagnetic coils with an iron core) and offers so much objection to the passage of a *sudden surge* that the path of least resistance may be through

the insulation of the coils rather than through the complete winding. When the insulation is punctured by the momentary pulse of high temsion and a spark established, the low voltage is able to maintain this spark and build up a heavy arc, resulting in a burnout.

Protection against surges in the primary can be secured by connecting in shunt with the main transformer and motor a protective resistance, as shown in Figure 14. This resistance is so high that it normally lets pass an insignificant amount of current, but in case of a surge the current will go through the resistance rather than break down the insulation, and the apparatus is protected.

The protective resistance may be in the form of a carbon rod, an open winding of fine resistance wire, a resistance wire baked into an enameled porcelain shell, or simplest of all, an ordinary incandescent lamp. If the more elaborate devices become broken and cannot be replaced, a lamp should be substituted rather than leave the equipment unprotected. If the lamps at hand are not of sufficient voltage, they can be connected in series; two 110 volt bulbs in series are equivalent to a 220 volt bulb.

Remote Control Switch. Machines are frequently equipped with remote control switches or contactors which serve to make and break the heavy primary currents and to permit the use of a small, convenient operating switch. The operating push button or other device makes and breaks a small current in an auxiliary circuit, which is sufficient only to operate the magnetic switch. When the auxiliary circuit is closed, current passes through the magnet of the remote control switch and attracts an iron armature, thereby making contact and closing the main primary circuit. When the auxiliary circuit is opened the magnet ceases to attract the armature and a spring or gravity opens the contact in the main primary.

The timing elements of most timers are delicate devices and not able to make and break the heavy main primary current. They should be connected always in the auxiliary circuit of a remote control switch, where the current is light and will not cause damage, and they should never be inserted directly in the main primary circuit.

Bedside machines use the self-rectifying tube, and omit the motor and rectifying switch. The power limit varies with the design of the manufacturer; in most machines the upper limit is 30 ma. at 85 kv. peak. The machine and its tube stand are mounted on wheels. The tube stand is counterbalanced and has a long horizontal extension to allow work over a bed. The tube is enclosed in a lead glass shield.

Except for the absence of a rectifying switch these machines are miniature replicas of the larger types described in the preceding pages. Like them, there is a high tension transformer and a filament transformer, an autotransformer for the control of primary voltage, a filament control, a primary voltmeter, a milliammeter, an overload circuit breaker, an operating switch, and a mechanical timer. As there is no rectifying switch there is never any question of wrong polarity.

It is necessary to know whether alternating or direct current is supplied; if the supply is direct current, a rotary converter must be added. Should direct current be applied to the transformers, burnout is sure to result.

Operating Notes. The capacity of the electric fuses in the service lines should be known. Apparatus operating with self-rectifying tubes draws approximately 1 ampere of primary current for each milliampere of secondary current. When the milliamperes through the tube are kept within the limit of the fuses in the ward, no fuses will blow out, saving loss of time and inconvenience. When the

source of power is direct current and a rotary converter is used, reduce the allowable milliamperes to one-half.

Before rolling the machine up to the bed, connect with

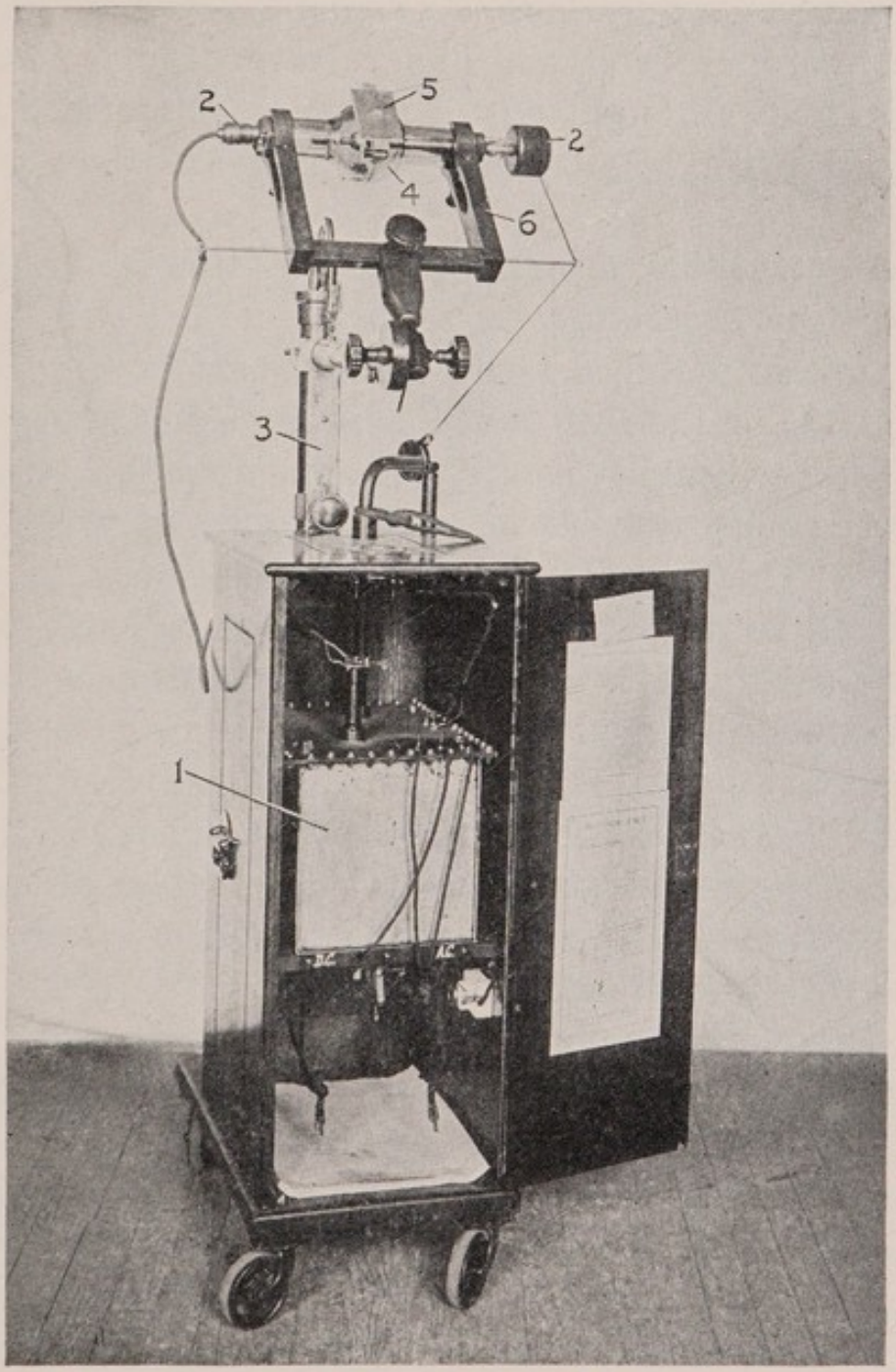


FIG. 30. United States Army bedside unit, complete for alternating current operation; double throw switch to be drawn to the right, loose connections below for rotary converter in using direct current.

the source of current. Close the operating switch and note the reading on the instrument board. Make sure the fila-

ment lights. Adjust the autotransformer and the filament control until the meters give the proper reading.

In some wards the resistance of the service wires leading tot he ward is unduly high. As explained on page 64, there will be a drop in voltage. The voltage drop is increased as the current through the tube increases, and it is better to operate with less current and increase the exposure time.

When everything is ready, place the tube in the desired position. Check carefully to see that neither wire leading to the tube is within 6 inches of any part of the patient, an assistant, or the iron bed. These machines are so small and operate so quietly, that technicians are liable to neglect the precautions they take with larger and more noisy apparatus. They may even forget that insulation on a wire is intended to withstand 110 volts, and will not protect against 60,000 volts. An electric shock from a bedside machine is rarely dangerous, but it is exceedingly unpleasant.

The U. S. Army bedside unit, developed during the World War, was the first machine of this type. The design was extremely simple, and is an excellent example of what can be done with uncomplicated apparatus.

The complete machine as it was used in the World War is shown in Figure 30 and the wiring diagram in Figure 31. Both the high tension and the filament transformers are in the same case; one primary winding serves both secondaries. There are three taps to the primary winding. Taps 1 and 3 subtend the entire length of the primary and are used when 110 volt alternating current is available. Taps 1 and 2 subtend a lesser number of turns in the primary and thus increase the step-up ratio; these taps are used when the current passes through a rotary converter and the applied voltage is about 80. When the

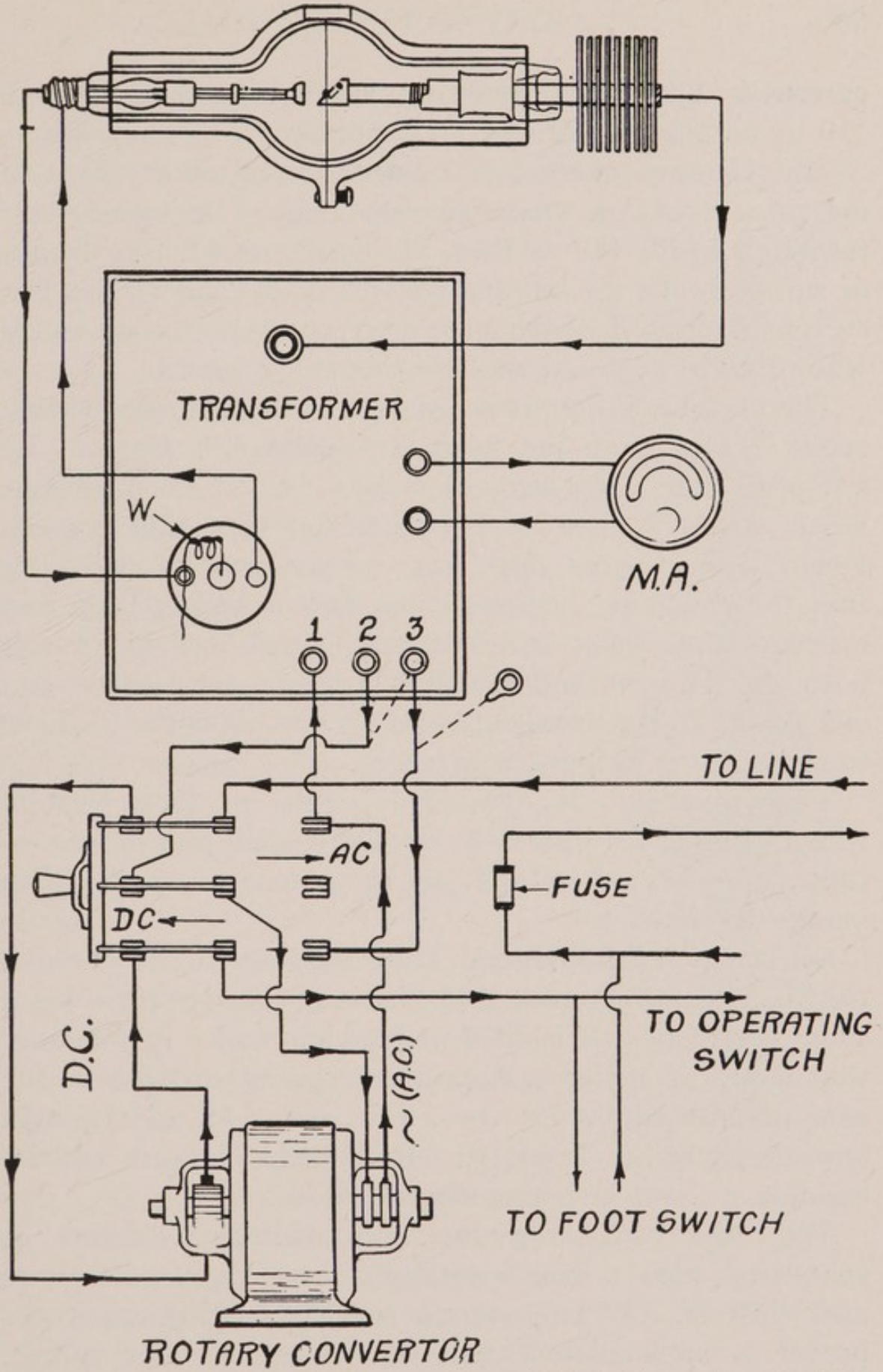


FIG. 31. Wiring diagram for connections, United States Army bedside unit for 110–220 volt d.c. or 110 volt a.c.

current is 220 volts alternating, the voltage is reduced to 110 by adding an extra autotransformer.

The filament current is adjusted by a short piece of nichrome resistance wire at the top of one of the transformer terminals inside the cabinet, at *W*, Figure 31. The length of wire between the binding posts is made longer when less current is desired, shorter for more current. The nichrome wire must be adjusted while no current is passing.

The machine is operated exactly as are the more modern types, except that the secondary voltage is fixed at 85 kv. peak. The tube current is best left at a convenient value, adjusted once for the particular tube that is used. Fewer milliamperes than the proper reading indicates that the resistance in the service lines is unduly high and exposure time must be increased. As one switch controls both the filament and the high tension transformer, add one second to the usual exposure time to allow the filament to come to the proper temperature.

The machine is provided with a foot switch, which should be operated by hand and guarded carefully; a footswitch left on the floor may be stepped on inadvertently.

Oil Immersed Apparatus. The high tension transformer, the filament transformer, and the *x*-ray tube are placed in a single case. The case is filled with oil and sealed in a manner that makes it oil tight. A radiotransparent window in the case permits egress for the *x*-ray beam. As all the high tension parts are insulated by the oil, the case can be handled without incurring electric shock.

The case containing the high voltage elements is connected with a stand equipped with the usual meters and controls. The only wiring required on the apparatus proper is an insulated cable that brings the low voltage current from the control stand, much the same as a cable

is used to conduct current to other electrically operated equipment.

The case is heavy and bulky. It should be used only with the system of counterbalances and supports that were designed for it.

As the insulation of the high tension system depends on the oil within the case, the oil must not be allowed to leak out. Should an oil leak occur, the case must be repaired.

Oil immersed units must be operated within the limits of power prescribed by the manufacturer. For most radiographic work the power limit is ample. Occasionally it may be necessary to decrease the usual distance between the tube and the film, and secure more radiation by the inverse square law (p. 120). The case containing the tube can be brought as close to the patient as is desired.

Although it is possible to treat skin lesions by bringing the case nearly in contact with the skin, the use of oil immersed units for therapy is not recommended.

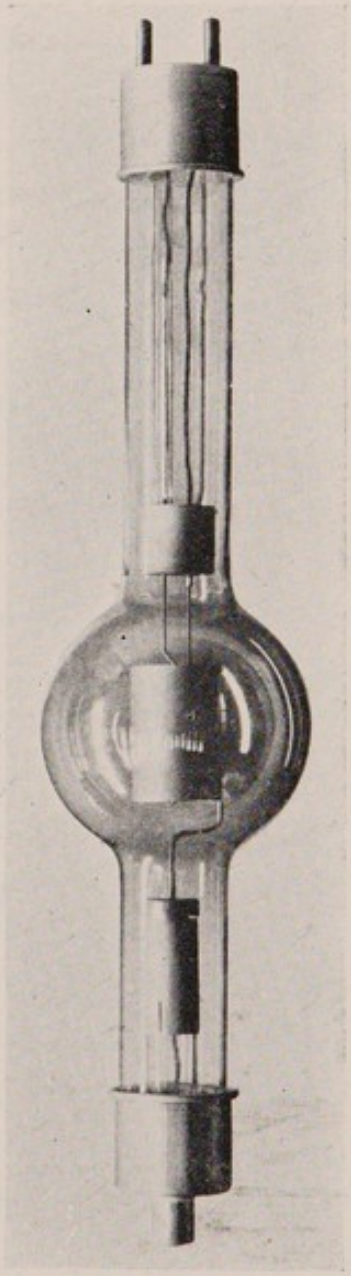


FIG. 32. Valve tube; within the power limits for which the tube is designed, current can pass in only one direction.

Valve Tube Rectification. Valve tubes (Fig. 32) are a modification of the Coolidge *x*-ray tube. They permit current to pass in one direction only. Their resistance is low as compared with an *x*-ray tube. When properly used no *x*-rays are emitted from them. Each valve tube has its own filament transformer.

The valve tubes may be arranged in the high tension circuit in many ways, depending on the type of apparatus and the judgment of the manufacturer. They may be used

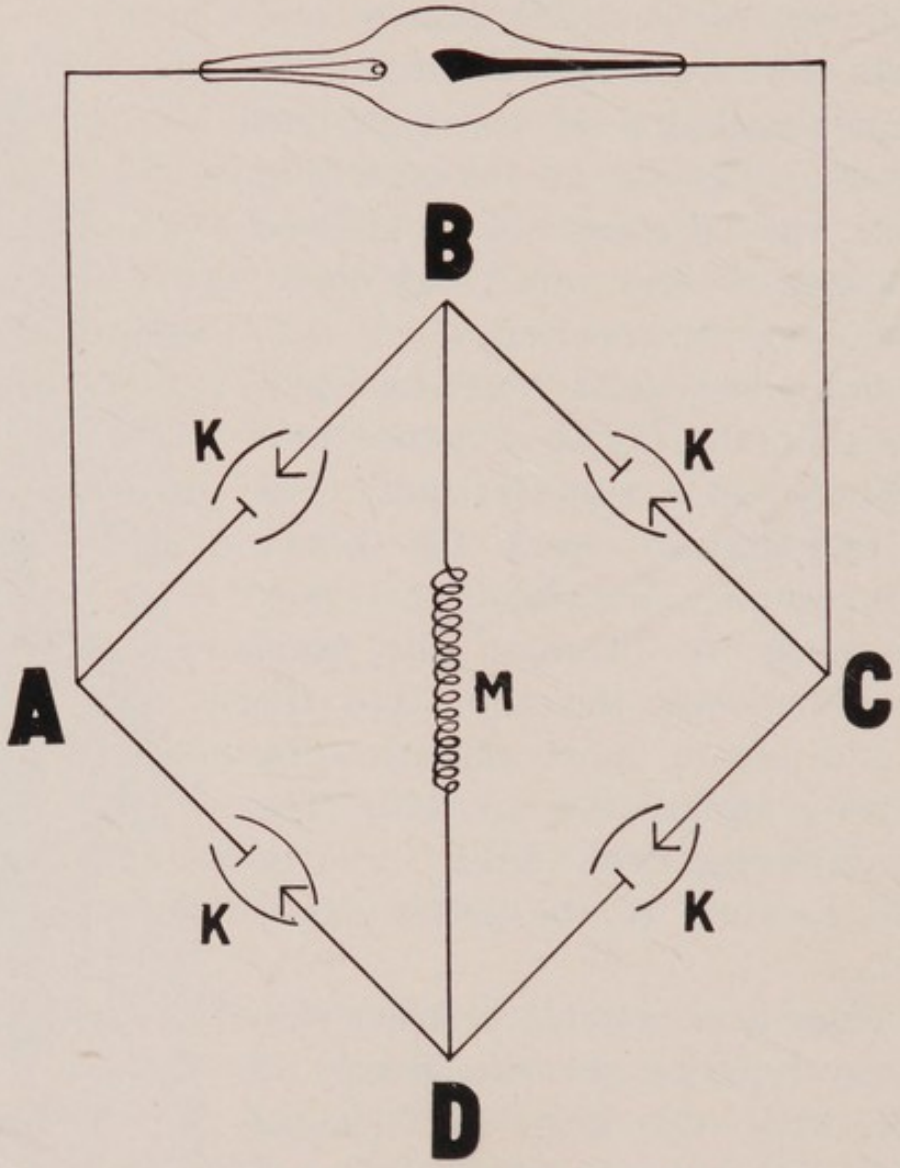


FIG. 33. Valve tube rectification. *K,K,K,K*, Valve tubes. *M*, Secondary of the high tension transformer.

in combinations of one, two, or four. One method of rectification with four tubes is shown in Figure 33. When the alternation is from the transformer to *B*, it cannot go to *C* as the valve tube does not permit; it must go from *B* to *A*, then through the *x*-ray tube to *C*. At *C* there are two possible paths: to *B* or to *D*. The impulse cannot go back to *B*, as *B* is at the same potential level as *C*; it must go to *D*,

thence to the transformer, completing the circuit. When the opposite alternation comes along, the path is from *D* to *A* to tube to *C* to *B* and back to the transformer.

It may be noted that when four valve tubes are used, no impulse is suppressed.

Valve-tube *x*-ray machines are efficient. An *x*-ray tube operated by them does not vary its radiation output with changes in atmospheric conditions. As compared with machines equipped with a good mechanical rectifying switch, there is little increase in the radiation emitted from the tube, unless the valve tube machine is equipped with condensers.

Valve tube machines are well adapted for use with condensers. When these are added to the high tension circuit, the potential applied to the tube is nearly constant, and the radiation output is increased. The constant potential principle is especially desirable in machines designed for therapy; it is not as important in machines to be used for radiography.

The principal advantage of valve tube machines designed for radiography is their silence of operation. There is no doubt that a quiet laboratory is more uniformly efficient than a noisy one. There is an element of risk, in that technicians accustomed to noisy machines have come in contact with the tube while it was taking current, with unfortunate results.

Valve tube machines are equipped with the same controls as are the machines described in the preceding pages; they are operated in the same way. Although each valve tube has its own filament transformer, the adjustment of their filament circuits is not changed by the operator.

Line Wiring. The line for *x*-ray installations should receive more careful attention than has usually been given to such important work.

The primary or low tension wiring should contain enough copper to insure that there will be no considerable voltage drop on the line even when the heaviest work is done. If a line from a supply transformer or a generator has a resistance of say 0.3 ohms, and one draws 50 amperes, a loss of $0.3 \times 50 = 15$ volts would result. If the original voltage was 100, the total available at the *x*-ray transformer would be 85 volts. On 220 volt operation this is not so serious, but more reliable operation will be attained if the wire is such that at the *highest* primary current the line drop does not exceed 3 per cent.

When a.c. lines are used, the transformer from which power is drawn should be of ample capacity, and on d.c. the generator should have a capacity exceeding any estimated demand. Connecting a 10 kw. *x*-ray transformer to a 5 kw. line transformer is poor business. Fuses or circuit breakers should be conveniently placed, and all care should be exercised to avoid short circuiting or grounding the lines.

The following table shows the loss in voltage of a primary line for 50 and 100 amperes low tension current, on the

No.	Ohms per ft.	Volts lost 200 ft. 50 Amp.	Volts lost 200 ft. 100 Amp.
00	.0000778	.778	1.5
0	.000098	.98	1.96
1	.000124	1.24	2.4
2	.000156	1.56	3.1
3	.000197	1.97	3.9
4	.000248	2.48	4.9
5	.000313	3.13	6.2
6	.000394	3.94	7.8
7	.000497	4.97	9.9
8	.000627	6.27	12.5
9	.000791	7.91	15.8
10	.000997	9.97	19.9

assumption of a run of 100 feet between an *x*-ray transformer and the power transformer, giving 200 feet of line. The terminal voltage to be taken by primary and control is the difference between the line voltage and the loss. Thus, a machine drawing 100 amperes for a short exposure on a 220 volt circuit, using No. 10 wire, will have 220–19.9, or about 200 volts available. On 110 volt operation, 110 − 19.9 = 90 volts, making a very decided percentage drop. For this reason, machines using a large primary current are unsuited for 110 volt operation if rapid work is required.

To compute the size of wire needed, one must know: (a) the maximum primary current in the *x*-ray transformer; (b) the distance from the supply transformer (or generator) to the *x*-ray transformer.

The *loss* in voltage due to line resistance is given by the product of *current in amperes by resistance in ohms of line wire per foot, by length of supply wires in feet.* Thus, on a 220 volt line, *if* a drop of 6 volts is permissible, the line being 220 feet long and the maximum current 60 amperes, then

$60 \times 200 \times$ Resistance per foot $= 6$ volts

$$\text{Resistance per foot} = \frac{6}{60 \times 200} = .0005 \text{ ohms.}$$

The smallest permissible wire then is "No. 7." Better use a wire considerably larger to insure the best operation.

High Tension Wiring. In the use of high power machines, much greater care should be taken in high tension construction than is generally the case. Three points should be carefully considered. These are: First, safety of the patient and operator; second, prevention of loss by leakage; third, avoidance of puncture of tubes.

While one might get a very unpleasant jolt from an induction coil, yet danger to life is slight as compared

with transformers of like voltage. In general, a *maintained* voltage of 500 through vital portions of the body is dangerous if a current of 100 ma. or more can be delivered. A static machine, an induction coil, or a condenser may give a high initial voltage with a *brief* rush of current upon contact or grounding; this is disagreeable but usually harmless. In a power transformer which *maintains* voltage, the current continues, with possible fatal results. In most, if not all, installations the *middle* of the secondary coil of the transformer is connected to the iron case or to the "earth"; the earth is such a large reservoir that its electrical condition may be regarded as constant. The "ground" need not, and in fact should not, be completed by an actual metallic connection of transformer case to a water pipe. Thus, when working at 60 kv. between the tube terminals, the voltage between the + line and the earth is +30 kv., and between the − line to earth −30 kv.

This divides the insulation strain on the transformer and reduces danger of sparking to the stand. If one terminal of the transformer were grounded, the full voltage would tend to pass current from the other line to anything connected to the earth. Thus, there would be a 10 inch spark length to stand, floor, water, and gas pipes, etc. When treating at a 10-inch gap the strain is then double that in the other connection, but the line to the grounded side of the transformer is safe to touch. When using metal stands, tables, and protecting screens with the metal screens *between the tube* and the patient, they should be well grounded. The patient is then free from induced "static" and from any discharge that may occur between the parts of the outfit. *When the patient is between the tube and the grounded metal, there is always more danger to the patient,* and corresponding care must be used.

Aside from the difficulty of preventing spark discharges and arcs, it is of great importance to prevent leakage between all parts having a high potential difference. This

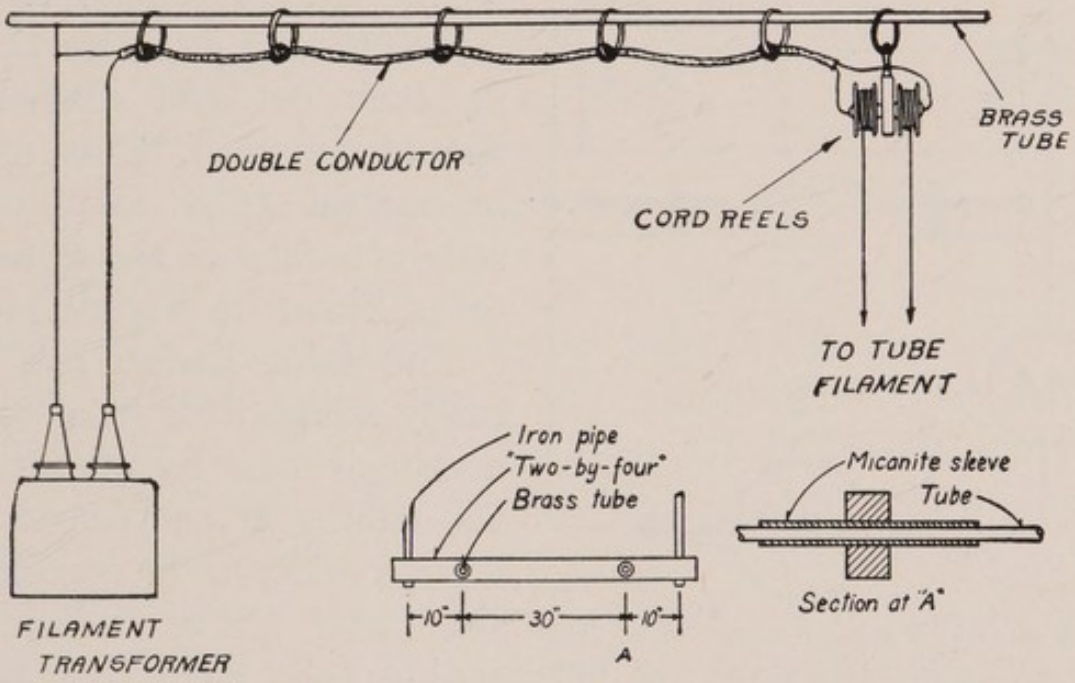


FIG. 34. Arrangement for constant resistance between filament transformer and Coolidge filament. Wire may be used instead of brass tube in the same way.

leakage is due to high electric stress, rendering the air conducting and giving rise to "corona." Also, many good insulators when clean and dry become conducting when dusty and moist. High tension wires mounted on ordinary wood or on glass may be expected to leak badly.

Surface leakage is less on hard rubber and micanite than on glass. Wiping insulating surfaces with a cloth *slightly* moistened with kerosene will often greatly reduce leakage over the surface.

Corona loss is decreased by reducing the electric stress between the conductor and the surrounding air. This is accomplished by avoiding points, sharp edges, and close proximity of conductors of high potential difference. High potential overhead lines should be from 24 to 30 or more inches apart. All sharp points and corners should be avoided

and small wires, especially if cloth insulated, should *not* be used. Gutta percha covered wire *without* braided covering is useful where a flexible conductor is needed. For rigid wiring and overhead lines, metal tubing not less than ½ inch external diameter should be used. This may be mounted by insulating rods attached to the ceiling, or as shown in Figure 34.

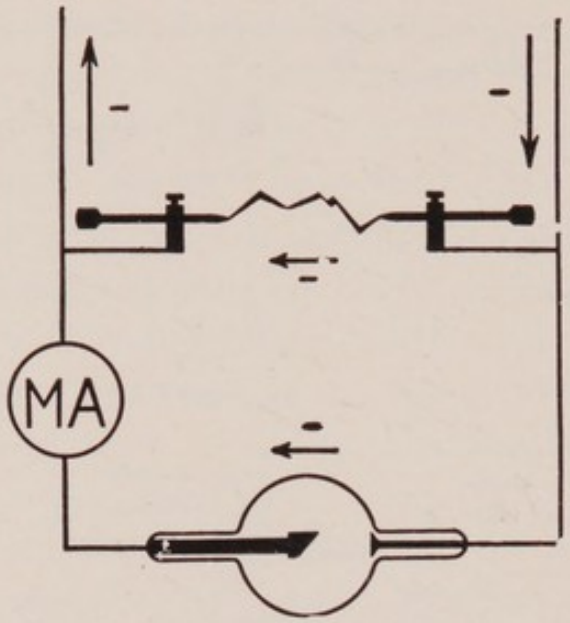


FIG. 35. Path of negative charge from line through spark gap, tube and milliammeter.

The same design can be easily adapted to inter-connecting rooms by mounting the tubing in the center of a large micanite or porcelain tube and filling the space with a good insulating wax. The insulating tube should be extended 6 to 8 inches from the wall. The rings for tube connection may carry reels if desired.

While line leakage of moderate amount may be tolerated in fluoroscopic or radiographic work, it may be of great importance in treatment. A milliammeter measures not only the tube current but all leakage *beyond* the instrument itself. Corona between wires, spark gap corona and surface leakage together may give an error of 200 or 300 per cent. We may avoid this (1) by proper design, (2) by *always* connecting the milliammeter beyond the spark gap as shown in Figure 35. (3) Where any doubt arises check by testing with a second milliammeter connected directly to the tube.

Tracing Circuits. The modern transformer *x*-ray machine is rarely characterized by simplicity of wiring or accessibility of connections. In case of trouble, or where one must

connect or set up the machine without expert aid, it is well to learn to trace the circuits and to test out for breaks, etc.

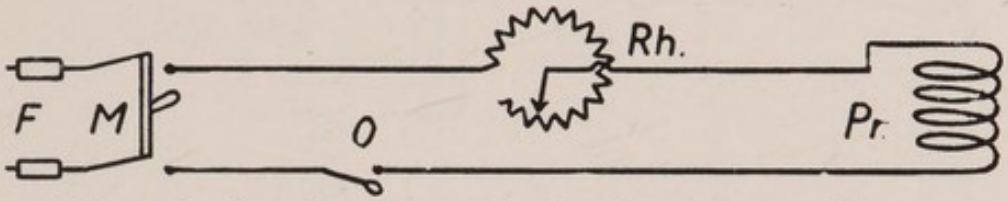


FIG. 36. Simple primary circuit, rheostat control.

While to one unaccustomed to do this, it seems very difficult, a few suggestions may help. There are only two main current paths from one supply line through the apparatus to the other line—the motor circuit and the transformer circuit. In tracing either circuit, follow a complete metallic path from one supply line through the motor or transformer back to the other supply line. Where paths divide, they must come together again further on, and one must avoid simply chasing around some loop. The main

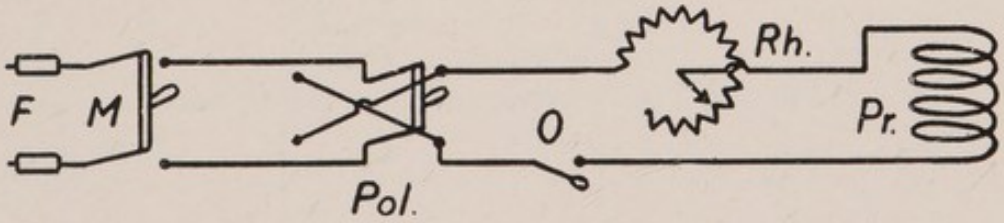


FIG. 37. Addition of reversing switch (polarity changer).

circuit in outline on all resistance controlled machines is shown in Figure 36.

Where no attempt to bring the motor contact into correct phase is made, a reversing switch is provided (Fig. 37) which changes polarity of transformer without disturbing the motor circuit. There may be a special switch to be operated by a small current through a magnet (Fig. 38). A timer connection may be added, as in Figure 39. Several taps (inductances) may be brought out from the primary winding (Fig. 40). There may be a polarity indicator to

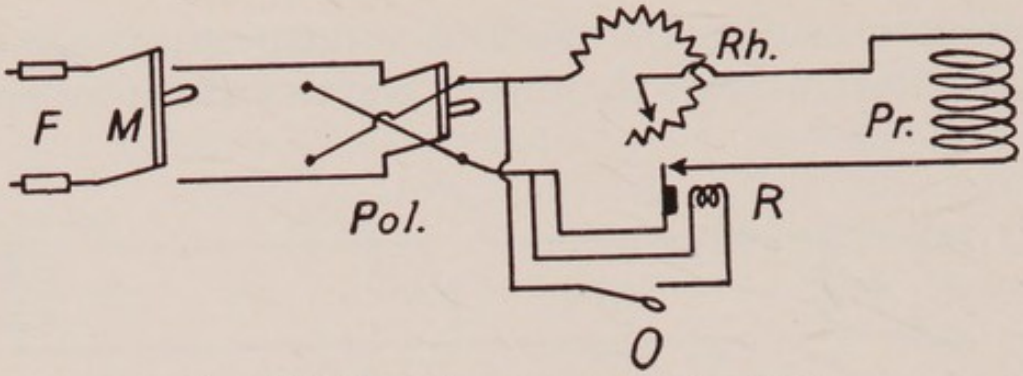


FIG. 38. Magnetic control switch added.

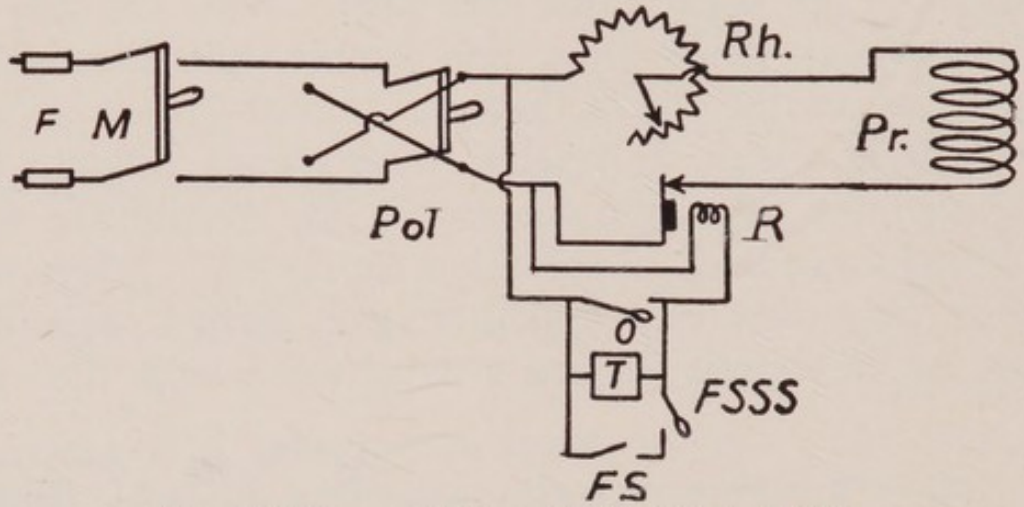


FIG. 39. Time switch and foot switch added.

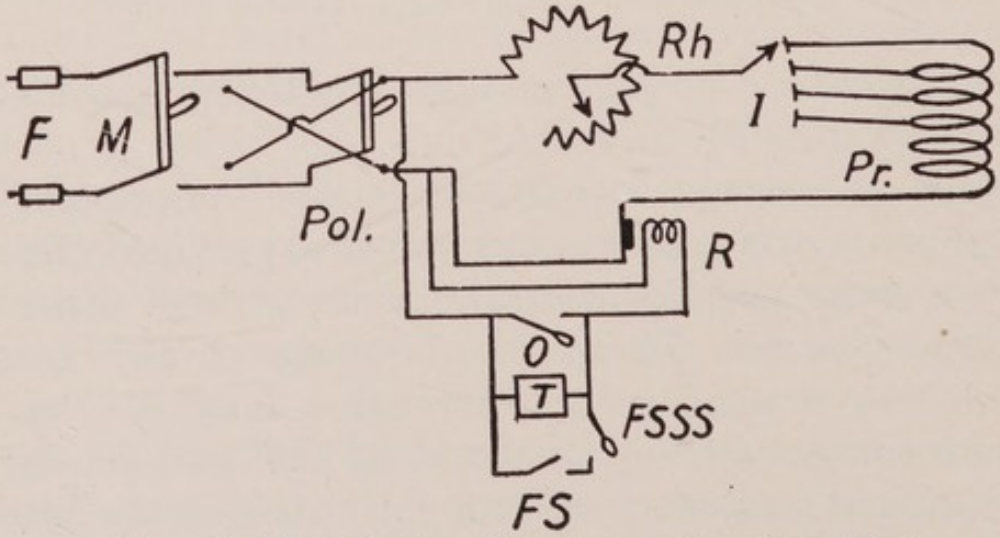


FIG. 40. Multiple taps ("inductance taps") added.

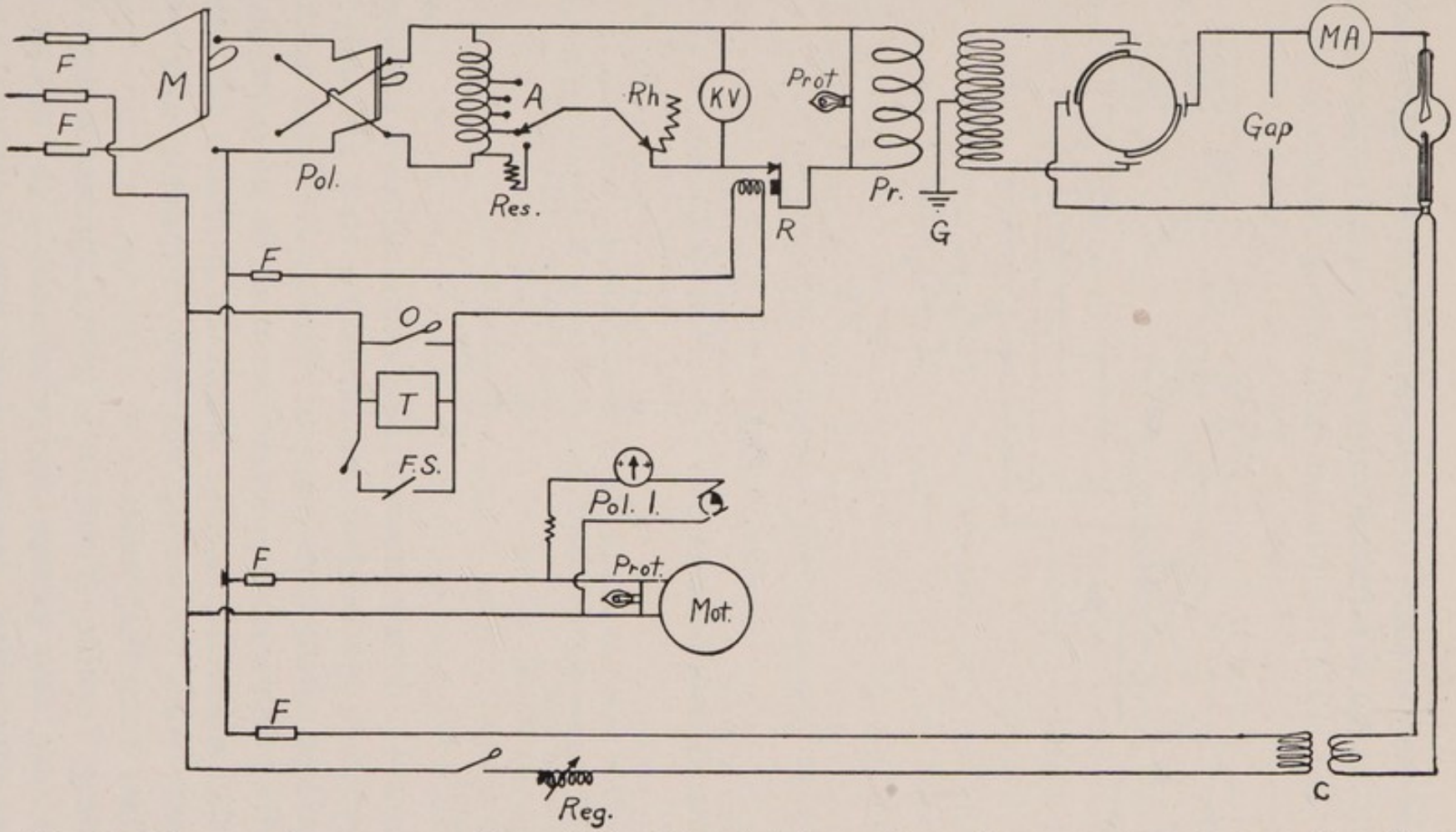


FIG. 41. Diagram of an *x*-ray machine, which, although it does not exactly represent any one machine, illustrates the fundamental connections of all of them. The principal low tension circuits are main primary, remote control, motor, and filament primary. Key to lettering is on page 72.

show the way to place the reversing switch for a given tube connection. An autotransformer may be used as the control device (Fig. 42). The fundamental wiring scheme is shown

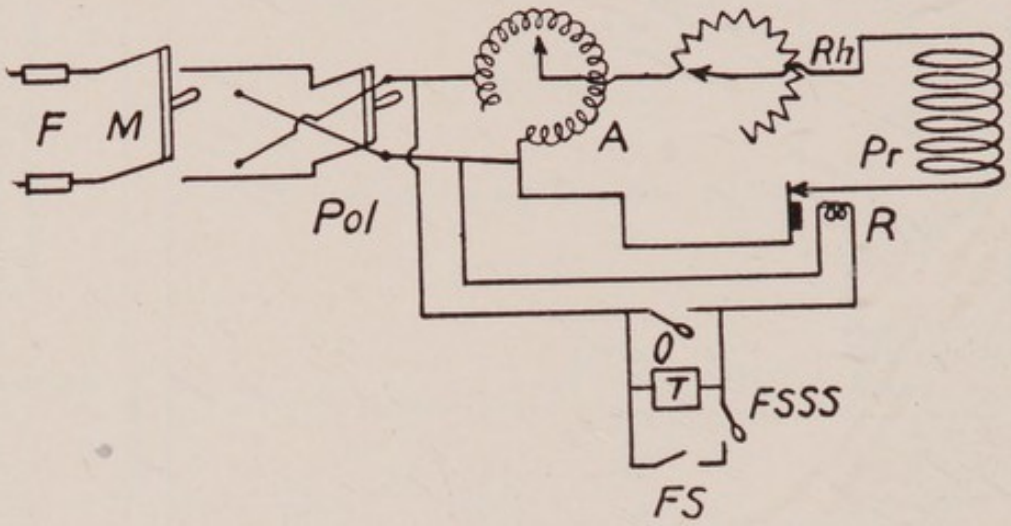


FIG. 42. Autotransformer instead of multiple primary taps.

Key to Figs. 36–42

A. Autotransformer.
C. Coolidge filament transformer.
F. Fuses.
F.S. Foot Switch.
F.S.S.S. Foot switch safety switch.
G. Ground to case of transformer.
I. Inductance taps.
K.V. Kilovolt meter.
M. Main switch.
Mot. Motor.
O. Operating switch.
Pol. Polarity changer.
Pol.I. Polarity indicator.
Pr. Primary of transformer.
Prot. Protective resistance.
R. Remote control contactor.
Reg. Filament regulator.
Res. Resistance.
Rh. Rheostat.
T. Timer.

in Figure 41. There are a considerable number of differences between the various machines but they all conform more or less to the same general scheme. Different models put out by the same manufacturer may be no more alike than the different makes. Whatever machine be used, familiarity with the wiring will help to quickly overcome difficulties when they arise.

Locating Trouble. Troubles in *x*-ray apparatus may be divided into two groups: (a) mechanical; (b) electrical.

Under mechanical, we may have worn bearings, worn or broken brushes, slip of rectifier on shaft; warping of

wood, thus throwing shaft out of alignment. Care in oiling and keeping apparatus clean and dry will prevent most of these.

Under electrical troubles we have: (a) Improper connections; (b) break in conducting line; (c) loose connections; (d) failure of insulation.

To avoid (a) all wires removed from their connections should be labeled as well as the binding posts, etc., from which they were disconnected. Serious damage may be done if one attempts to operate with improper connections.

To find breaks, close switches and use test lamps, as directed in the following pages. When the lamp lights on connecting two points between which the resistance should be low, there must be a poor connection or a break.

Loose contacts are likely to cause irregular or intermittent action. Failure of insulation may cause current to pass between two wires without going through the proper path.

If the fuse in any part of the circuit blows when only moderate power is used, open all switches and look for a short circuit; and if none is found insert a new fuse and test out on low power before attempting to continue work. Beware of the high tension line and terminals when hunting trouble on the primary or motor circuit.

Primary Circuit. When a machine which has been operating fails to work, there must be trouble in either the supply or some part of the circuit insulation or wiring. The low tension side may be most easily tested by using an ordinary incandescent lamp of suitable voltage. Start back of the fuses on the main line, having motor and transformer switches *open*. (Fig. 43.)

Touch lamp terminal wires (bared ends) to bare wire at 1 and 2. If the line is "alive," a 220 volt lamp will light up to half brightness. Do the same for 2 and 3. Con-

nect 1 to 5, and if lamp fails to light, fuse *B* is burned out. Or, if switches are closed and the lamp lights when connected to the opposite ends of a fuse, as 2 to 5, the

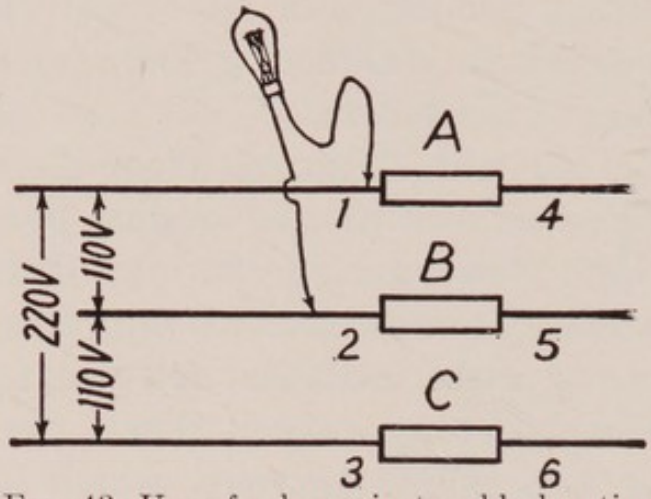


FIG. 43. Use of a lamp in trouble hunting.

fuse must be burned out. Try 2 to 4 and 2 to 6; if all these connections give equal brightness to the filament, the trouble must be farther along.

Close motor starting switch, and if motor does not start connect lamp across motor fuses one at a time. If a fuse is intact, it has so low a resistance that current will not pass through the lamp; if broken, the full line voltage appears at the break, and the lamp will light.

Finally, connect across the motor terminals, and if the lamp lights fully the trouble is *inside* the motor.

Follow the same general procedure in testing the transformer circuit, but *use great care to keep away from the high tension terminals;* also, be sure to set rheostat at lowest power.

If the lamp lights across the low tension terminals and no spark can be driven across a short gap between the secondary terminals, the trouble is inside the transformer and the chance of its repair by an operator is slight. If a break is near the terminals, it may sometimes be located and repaired; otherwise it must be sent to a manufacturer.

Secondary Circuit. Outside of a break in the secondary coil or an arc to the case, the most common trouble in the secondary line is a complete or partial short circuit. This may occur in various ways:

1. In a cross arm machine, the insulation may break down between the cross conductor and the rectifier shaft.
2. In a disc machine, the disc may be dirty or carbonized, "shorting" around the periphery or to the motor shaft.
3. A high tension line may be in contact with the tube stand, a wall containing metal lath, the floor, etc.

The latter may, of course, be remedied at once by the operator.

In case of rectifier trouble, a Coolidge tube may be run directly on the transformer, *provided low spark gap and current is used so that the target does not get hot.* For fluoroscopic work there is no trouble in doing this, but for radiography time must be allowed between exposures for the target to cool.

Care of Tubes. In a new Coolidge tube the glass bulb is colorless, the target smooth and brightly polished. Some tubes show a flickering greenish yellow light in the tube arms. A tube that has been kept in storage more than three years should be "seasoned" by energizing at 60 kv. peak, 5 ma., for thirty minutes. With use the clear glass bulb acquires a purplish violet color; the face of the target becomes pitted; and the bulb opposite the target is blackened. The change in color is caused by the *x*-rays. Pitting is due to the impact of the electron stream, which heats the tungsten and throws minute particles from it. Blackening is due to the tungsten particles on the glass. These effects progress more rapidly when the tube is used at high voltage and heavy current. Although changed in appearance the usefulness of the tube is not impaired.

All tubes are fragile and may easily be damaged by fracture. A warm tube should not be placed on a cold support.

Puncture is caused by sparking to the bulb. The high tension wires should be kept 5 or 6 inches from the bulb; at high altitudes the sparking distance for the same voltage is increased, and the clearance must be greater. Dust collects on the bulb; the dust attracts moisture and causes the surface of the bulb to become conductive. Under these circumstances a spark may jump along the surface and cause puncture. To prevent this, tubes should be polished and kept free from dust, moisture, and finger marks.

When a tube is in operation, the heat developed at the target is measured by the current $\times$ voltage. If this heat is produced at such a rate that it cannot be dissipated by conduction and radiation, the metal at the focal spot may be vaporized or melted and the tube ruined. Occluded gas may be liberated, which lowers the vacuum.

A type of tube should be selected that is best suited to the work at hand. Thus if the technique calls for heavy current at high voltage, such as 100 ma. at 90 kv. peak, the best type is the medium or broad focus soild tungsten target tube, or the 100 ma. radiator tube. On the other hand, a radiograph of bone requires the best possible detail but speed is not a requisite; for these cases the technique permits the selection of the fine focus 10 ma. radiator tube. The 30 ma. radiator tube is an intermediate type.

Care of Motors. 1. All motors need oil at periods depending on the amount of use. Failure to oil may cause the bearings to wear enough to allow the armature to rub on the field supports and ruin the motor. Follow the maker's instructions, if any are given. Do not use too light an oil. An oil like 3 in 1 is good for sewing machines, but must not be used on power motors. Use real machine oil.

2. Most, if not all, motors used on *x*-ray machines have either slip rings or commutators, or both. Bearing on these are carbon or other conducting brushes. As the tension is low, these must have a good, even contact. Springs are provided to secure this, and if these break or get out of adjustment there will be either intermittent contact or none. The motor then either fails to start or it sparks at these bad contact points and corrodes the metal rings or commutator bars. If only slightly injured, they may be smoothed down by 00 sandpaper (not emery cloth), lubricated slightly with paraffin or *light* oil and rubbed off with a clean cloth. New brushes should be inserted *before* any serious trouble occurs. Be sure and put them in right, noting carefully how the old ones were placed.

3. Many motors have two sets of connections, one for *starting*, the other for *running*. Usually a double throw switch is used and marked for the purpose. Don't close on the running side and wait for something to happen. Don't throw over too quickly. Don't leave the switch on the starting position.

4. Keep the motor clean and in as dry a place as circumstances permit.

5. If the motor fails to start, *open* the starting switch and test the fuse on the motor circuit; also be sure the line is "alive." If power is on and the fuse is intact, go carefully over the wiring to the motor, examine brushes, look at all external wires, and if no break is found it is fairly probable that some internal trouble has developed requiring technical motor knowledge for repair.

6. Be very sure not to connect a motor on a line for which it was not designed, as an a.-c. motor on a d.-c. line; or a 200 volt motor on a 110 volt line, or the reverse; or an a.-c. motor designed for 60 cycles on a 40 cycle line, etc.

7. If an a.-c. motor fails to run at the right speed, do not try to operate tubes with it.

8. It is well to have the field and the armature of an *x*-ray motor protected from small sparks due to transient surges. Ordinary incandescent lamps in shunt serve very well for this purpose. Most machines have such protection, using either lamps, or special high resistances, or condensers.

Care of Transformers. The attention of every technician should be called to the danger to the *x*-ray transformer arising from carelessness in operation. There are certain things which should never be done even though they might be done many times without damage.

1. Never operate at high applied voltage when the tube is taking no current, or on an open circuit, especially with rheostat control on high buttons. In this case the effective gap measuring the strain upon the insulation may be very much in excess of what is needed in practice.

2. High tension wires should not come in contact with or close to steam or gas pipes, electric service wires, metal ceilings or walls, metal tube stand, or the *x*-ray cabinet. Keep them away from things, where they belong. When a discharge occurs from one high tension line to the earth the danger to the insulation of the transformer may be greater than in the case of a discharge between the two lines.

3. In all cases when starting up the machine test out for proper operation on low power and especially be careful not to attempt operation of any kind of tube with rectified current of wrong polarity. If, on moderate filament current and a low power setting, no current is drawn through a Coolidge tube, reverse the polarity and again test. After a machine is once up to synchronism it will very rarely change polarity while running, but it may do so in case of a momentary interruption of service or unsatisfactory line conditions. It is wise, whenever lights operating on the same power circuit as the *x*-ray apparatus become dim or

are temporarily extinguished, to throw the machine to low power and again test for polarity.

4. Look to the oil level about every two months and record the date on a tag attached to the transformer. If the level is low, add more oil until all the coils are properly covered. Be sure to use *transformer oil* that has not been open and exposed to dirt and moisture. Wipe oil and dirt off the top of the transformer case.

5. Be sure that the transformer is adequately protected against surges by a suitable type of protective resistance.

Care of Batteries. The only type of battery likely to be met in *x*-ray practice is the storage battery. This is sometimes used for portable coil work, and occasionally to light the Coolidge filament. Each separate cell of a storage battery adds about two volts to the line. For any given voltage, then, half as many cells must be used as volts are needed. This voltage is independent of the size of the cells. A storage cell does not store electricity; it uses electricity to cause a chemical change in its plates, and when it is discharged this chemical change is reversed and electric current flows from the cell. The amount of chemical change on proper charge is in proportion to the charging current and the time of flow, and is estimated in ampere-hours.

Thus, a 10 ampere-hour battery will deliver 10 amperes for one hour, 1 ampere for ten hours, ½ ampere for twenty hours, etc. Too rapid charge or discharge should be avoided because of damaging the battery.

The storage battery consists of two sets of plates, each containing a salt of lead held in some sort of small lead pockets, the whole being immersed in a solution of sulphuric acid. In a single cell, all the positive plates are joined together, likewise all the negative, and these sets must not be in contact. The negative of one cell must be joined to the positive of an adjacent one, leaving one +

and one − for external connection. The ampere-hour capacity depends on the area of + and − plates per cell.

The following are the main points to be kept in mind when using storage batteries:

1. They must be charged on *direct* current.

2. The charging rate given by the maker should not be exceeded.

3. The discharge rate allowable should not be exceeded.

4. Loss of electrolyte by evaporation must be replaced by adding distilled water, rain water, or as pure water as can be had.

5. Loss of electrolyte by accidental spilling must be replaced by adding an *acid solution* of the proper density.

6. In making up an acid solution, never pour water into the acid, but pour acid slowly into the water.

7. Never let the solution get so low as to leave a portion of the plates bare.

8. Do not overcharge, nor discharge after the voltage falls below 1.8 volts per cell.

9. Do not let the battery freeze.

10. Do not let the battery stand idle for long periods. If it must be laid up, charge it fully and draw off the solution. For short periods, put a high resistance across its terminals and let it slowly discharge, and charge it up again at intervals.

11. If overheated by too high current passing in or out, the active material is likely to crumble and fall to the bottom of the cell and cause a short circuit, whereby the battery discharges internally.

12. The discharge voltage falls quite rapidly after a battery is first charged, then more slowly until nearly discharged, then rapidly. When used on a Coolidge filament, which requires about 4 amperes, it is well to pass 12 or 15 amperes through a suitable resistance for three

or four minutes to bring the voltage down to the steady state the first time it is used after charging.

13. A small voltmeter is very useful in charging a bat-

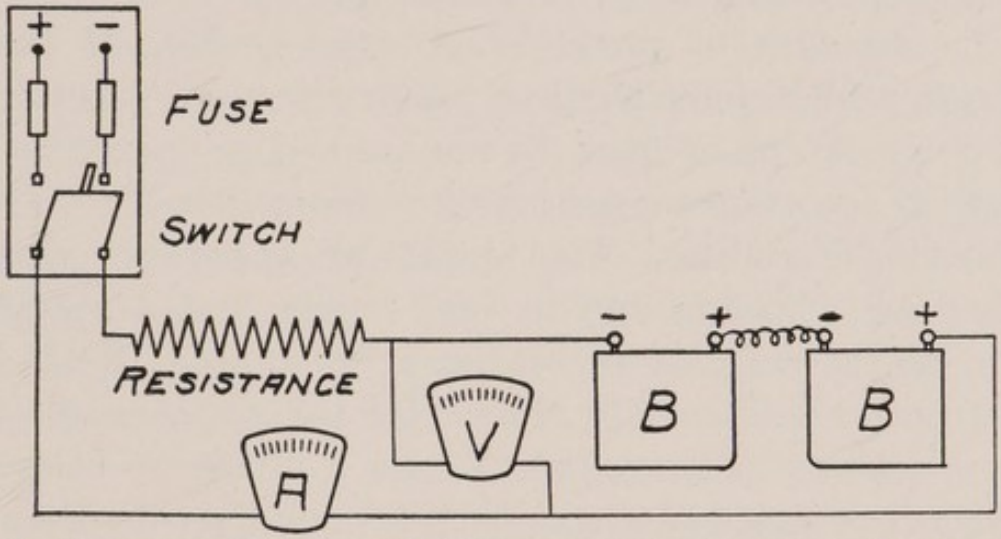


FIG. 44. Storage battery charging: *BB*, two cells in series; *V*, voltmeter; *A*, ammeter.

tery, and a suitable resistance to bring the line voltage down to that required in charging should always be at hand. Either a voltmeter or a test for acid density may be used to indicate full charge.

14. Do not fail to disconnect the charging line before using on a Coolidge tube.

15. Storage cell terminals are almost sure to corrode; scrape clean when connecting.

The charging connections are shown in Figure 44. If the battery has any charge, it will deflect the voltmeter in the same direction when discharging as when charging. Connect the voltmeter in the right way before starting to charge, and it will tell you whether you have connected to the charging line correctly. The ammeter may be omitted if one knows that the charging current is neither too large nor too small.

Emergency Provisions. In military *x*-ray work it is of the utmost importance that apparatus be kept going at all

times to meet the demands that are placed upon it. The radiologist must keep in mind the human lives dependent on him, and he must make every effort to repair, improvise, or do without whatever piece of apparatus may fail in the rush of work. There may be loss of time in securing replacement parts or repair assistance, and during this delay the plant must be maintained in operation. The following are some suggestions for emergencies.

Polarity Indicator. This piece of apparatus may be classed as a luxury, and in case repair cannot readily be made no interruption of service is warranted. With a gas tube, polarity is readily shown by the appearance of the tube. Correct polarity results in a uniform color and inverse in a series of rings. With a Coolidge tube the milliammeter serves as a guide, for no current will flow through the tube in the inverse direction. If the meter registers, the polarity is right. Always test on low power to avoid puncturing the tube. Spark gap may be used as an index if the meter also has failed, since on the same control setting the gap will be greater when the tube is not taking current than when it is.

In case of burnout of the resistance, sometimes included in the polarity indicator circuit, an incandescent lamp may often be substituted. Never attempt to connect up without the resistance.

Milliammeter. In working without a milliammeter the appearance of a Coolidge tube gives no idea as to the amount of radiation produced. If the machine is on a steady power line the transformer chart may be used as an accurate means of obtaining a setting of the machine. Suppose a 5 inch gap and 40 ma. are desired, refer to the chart and find which control button must be used. Then, instead of using the chart in the customary way, set the gap for 5 inches and vary the filament temperature until

the spark is barely able to break the gap. The milliamperage will now be right—40 ma.

In working under uncertain conditions, *be sure that the spark gap is as high as it should be.* A difference in tube current will affect only the quantity of radiation; a difference in voltage not only changes the quantity but the penetration as well.

Timer. If the timer fails, exposures may be made according to the second hand of a watch or by counting seconds. "One thousand one, one thousand two, one thousand three," etc., is a convenient method, and a little practice will enable one to keep close pace with a stop watch.

Remote Control. In case of failure of the remote control magnet coil or another device in its circuit the customary operating switch will be of no service. It is possible, in some instances, to wire around the remote control switch, or block it closed, and operate from an auxiliary switch in the main circuit, such as a pole-changing switch. Of course, care must be taken to *always close the switch the right way,* otherwise there is great danger of tube breakage and sparking to the patient on inverse polarity. Or, in some cases it would be more convenient to operate by holding the remote control switch closed with a stick during the exposure.

Protective Resistance. If the shunt resistance or condensers protecting against surges become broken or unserviceable, do not leave the circuits unprotected, since a more vital element may be damaged. An incandescent lamp of proper size and voltage (usually 220 v., 16 candle power, carbon filament) connected in shunt as shown in Figure 14 is very good protection.

Motor or Rectifier. In case of breakage of the rectifier or burnout of the synchronous motor, work may still be done by working on *low power* and letting the Coolidge

tube do its own rectifying. (If the rotary converter fails on a direct current installation and alternating current is not available, nothing can ordinarily be done.) Set the rectifier in position so there will be a minimum of sparking distance to the collector brushes, or wire across these gaps. Leave the motor switch open, or in case it must be closed to get current through the main primary and filament primary circuits, disconnect the lead wires to the motor and tape the ends to prevent short circuit. Then, *starting on low power*, set the tube for a 5-inch working gap and 5 ma. All Coolidge tubes will operate self-rectifying so long as the target does not become hot enough to emit an appreciable number of electrons. Do not work at more than 5 ma. and *do not let the target heat to redness*, or the tube will no longer rectify, and will very soon be ruined.

Spark gap is not a reliable guide to working voltage in a self-rectifying tube, since the inverse voltage is higher than the working voltage. (See page 19.) The excess over working voltage depends on the resistances in circuit and the type of control. To secure a setting of 5-inch working gap and 5 ma., refer to the chart of the machine and set to 5 ma. on the proper control button. Check by seeing that the spark gap is approximately that at which the chart line crosses the vertical axis of the chart. Be sure that the working voltage is what it should be to give rays of adequate penetration. Do all radiographic work either by giving increased time or by using intensifying screens and exposing as with the bedside unit.

Autotransformer or Rheostat. On many machines having combined control, a failure of one of these elements would merely necessitate leaving it out of circuit and controlling by the other. Broken wires or burned-out coils in a rheostat are easily wired across, but a failure in an autotransformer is a much more difficult proposition. In case

it is necessary to improvise a complete new control, this may be done by building a water rheostat.

Fill a large wooden pail with water and drop into it a

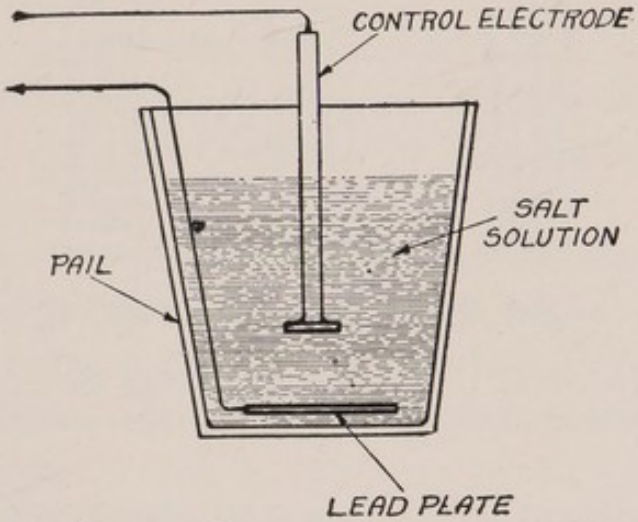


FIG. 45. Emergency rheostat for control of primary of x-ray transformer.

lead or iron plate of about 60 square inches area with wire attached, for an electrode, as in Figure 45. As the other electrode suspend a smaller piece of metal, secured so that its immersion may be definitely controlled. Immerse it slightly to correspond to the lowest power setting desired. Test it out, and add ordinary salt slowly, making sure that it is all dissolved, and testing at intervals until the desired low-power setting is reached. Pure water is a very poor conductor of electricity, and the addition of salt lowers the resistance of the solution to the desired amount. Higher powers will be secured by immersing the upper electrode deeper into the solution and lower powers by withdrawing it.

It may be noted that in case of failure of both rheostat and autotransformer on 220 volt machines, as a general rule we may secure reasonable operation by applying 110 volt service directly to the 220 volt connections on the transformer. Then select, when using the Coolidge tube, that current which will give a 5-inch gap and modify exposures if the current is greater or less than that usually employed.

Fuses. In case the supply of plug or cartridge fuses runs out *never wire across the cut-out block with copper wire.* Have an ample supply of 10 ampere fuse wire on hand and include

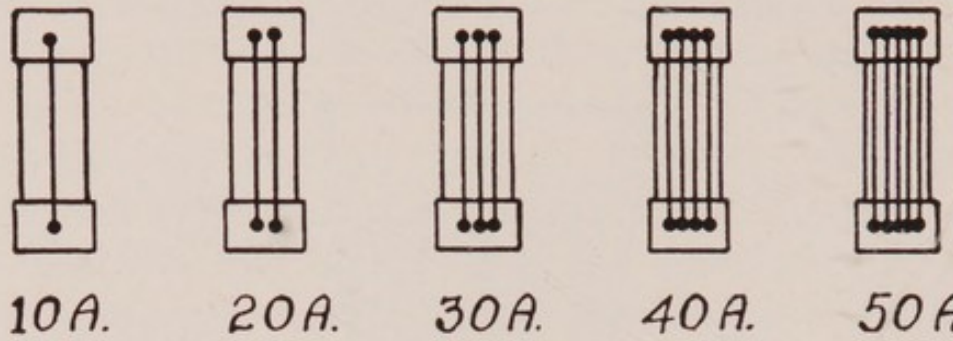


FIG. 46. Method of using 10 ampere fuse wire to secure capacity desired. It may be soldered to the brass ends of the burned out fuses.

the proper amount of this in the circuit. To fuse for 30 amperes use 3 strands in parallel, for 50 amperes use 5 strands, and so on (Fig. 46). For less than 10 amperes the wire may be whittled down to smaller cross section. The length of the fuse wire does not alter the current at which it will blow, nor does the voltage of the line on which it is used.

The foregoing suggestions cover most of the cases that are likely to occur. The resourcefulness of the radiologist is relied upon to cover the others and to keep his plant in operation so long as he has electric power, a transformer, and a tube. With these three essentials and a little ingenuity he should be expected to generate *x*-rays and do creditable work in an emergency rather than shut down and wait for assistance.

Ordering Supplies and Repairs. Much delay and inconvenience will be avoided if care is taken to state explicitly just what is wanted and the exact quantity. The work of the supply depot must be done by people who cannot be familiar with every minute detail of *x*-ray equipment and mind readers are scarce.

When ordering a machine specify:

1. Type of current, a.c. or d.c.
2. The frequency of cycles, if a.c.
3. The voltage.
4. The power available in kw.
5. Gauge and length of wire needed to connect up.
6. If d.c., always specify a rotary converter and the d.-c. voltage.
7. Be sure to state that the motor, transformer and Coolidge filament transformer when used on 154 volts or 70 volts a.c. from a rotary must operate properly.

Thus—220-volt-a.c.-60 cycle-10 kw.—specifies a definite type of machine.

In ordering repair parts state the name of the apparatus, the maker, if known, and either give a drawing or such an exact description or name as to identify the piece required. Sometimes one may return a broken or defective part as a complete identification.

In case of supplies be sure to give the amount and any other information that will make your needs clearly understood. Thus an order for "an *x*-ray screen" is meaningless; one for a "10 × 10 inch fluoroscopic *x*-ray screen, mounted with lead glass," is definite.

Never fail to give complete address to which goods are to be forwarded.

No small part of what we protest against as "red tape" is made necessary by failure of individuals to convey a *clear* idea of what they desire.

When possible confine your requests to those articles specified in the supply tables.

Induction Coils. It sometimes becomes necessary to work for a time, at least, with an induction coil. While not often used in this country one must be prepared to use it if need be abroad.

Coil Characteristics. A good induction coil should be able to give a heavy discharge at a voltage high enough to break a 10 or 12 inch gap.

Under no circumstances must a coil be operated at high power long enough to heat the insulation, as the insulating power is much reduced at high temperatures. Each coil has its own characteristics which determine its best working conditions. These characteristics depend on the primary and secondary resistances, on the amount and quality of iron in the core, on the number of turns in the coil, and on the mode of winding.

The most undesirable feature in coil operation for *x*-ray work is the unavoidable inverse which must be minimized in the use of the ordinary tube. The amount of inverse depends on the coil, the interrupter and the tube. A coil having a considerable number of primary turns and but little "magnetic leakage" gives less trouble with inverse than other types.

The direction of secondary current while the primary is increasing is opposite to that during a *decrease* of primary current. Generally it is possible to reduce primary current at a greater rate than that at which it can be built up. Hence the "break" voltage is usually higher than that at "make." The current of higher voltage is useful in the tube, but the inverse is not only ineffective for ray production but is a source of positive injury to the ordinary tube. If the make current could be caused to rise slowly enough, the resulting secondary voltage would not force current through the tube. In practice this is not possible, although the voltage giving "inverse" may be very much smaller than that giving "direct."

Valve Tubes. In order to reduce "inverse" as far as possible, various unsymmetrical tubes (Fig. 47) have been devised; these offer much greater resistance to discharge in

one direction than the other. Such valve tubes are often supplemented by a series of small spark gaps which are readily broken down by the "direct," but not by the lower

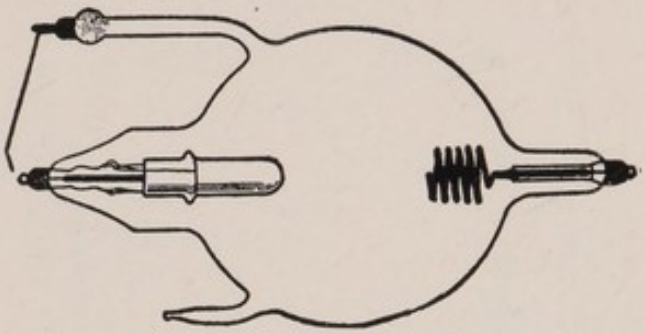


FIG. 47. Valve tube.

voltage "inverse." These devices all reduce the energy available for *x*-ray production. Figure 48 shows a tube designed to indicate the presence of inverse. If there is no inverse, only one of the metal terminals at the gap will glow. If both glow to the same extent, inverse current is present.

Figure 49 shows the wiring diagram for a coil with mercury interrupter, condenser, oscilloscope, valve tube, and

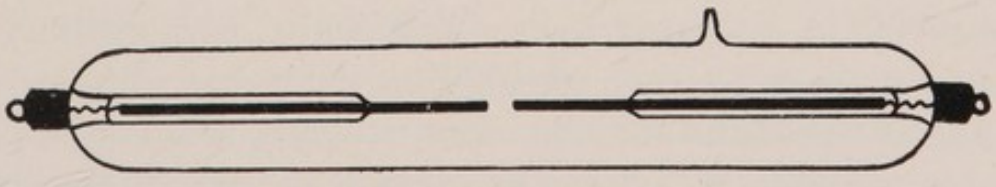


FIG. 48. Vacuum tube oscilloscope.

series spark gap. Note that the milliammeter is next to the tube.

When the spark gap is placed between the meter and the tube, leakage across the gap may make the reading much above the current actually passed through the tube.

Interrupters. The secondary voltage of an induction coil is the result of *change* of current in the primary. It is evident that we cannot have the primary current grow indefinitely, so we must allow it to decrease and increase

alternately. The value of the secondary voltage for a given coil depends entirely on the *rate* at which the primary *current* is changed. Thus, if a current of 80 amperes should

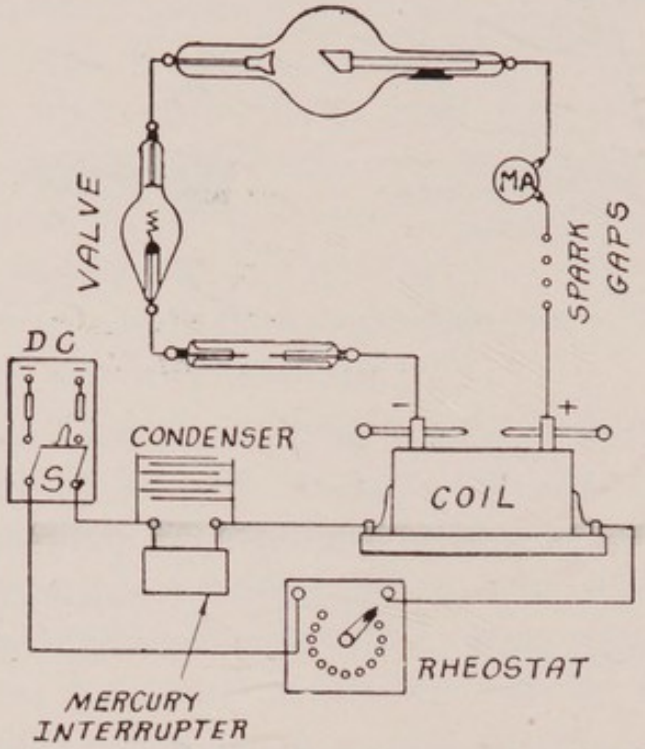


FIG. 49. Complete connection for the operation of tube with induction coil and mercury interrupter.

be reduced to 0 amperes in .02 seconds, the current has changed at a mean rate of 4000 amperes per second. If it requires .04 seconds for the same change, the rate is 2000 amperes per second. The mean secondary voltage is twice as great in the former case as in the latter.

As induction coils are intended to operate on an interrupted direct current, some device must be used to open and close the circuit. The early interrupters were of the vibrating hammer type, but these have largely been superseded by others much better adapted to *x*-ray work. They are still used on small outfits where large power is not drawn.

The Wehnelt Interrupter. The Wehnelt interrupter consists of a lead and a platinum electrode immersed in a solution of sulphuric acid. The amount of platinum exposed

to the solution is usually variable at will. When connected as shown in Figure 50, the application of sufficient voltage will result in the formation of a non-conducting layer

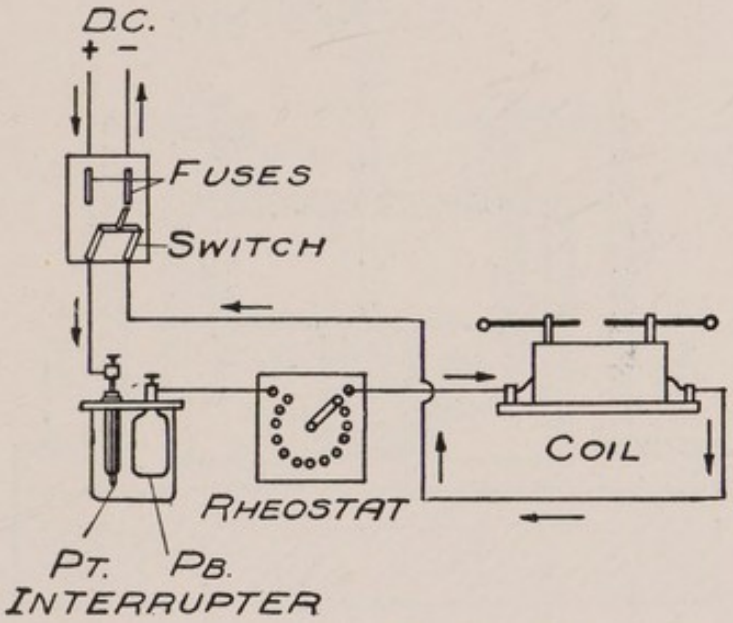


FIG. 50. Wiring for induction coil with electrolytic interrupter.

between the solution and the platinum, thus interrupting current flow. The layer is very quickly dissipated, reestablishing current only to be again formed, etc. When only a small amount of platinum surface is exposed, the number of interruptions per second is high and the current is small. Greater immersion lowers the number of interruptions and draws more current.

Operating Notes. 1. The solution should contain 30 to 35 per cent pure sulphuric acid. In mixing, be sure to add *small* amounts of *acid to water*, allowing the mixture to cool after each amount is added. *Never pour water into the acid.*

2. *Do not use a condenser*, as is done with the mechanical interrupter.

3. If your point or points are adjustable, use little or no resistance in series with coil and interrupter on a 110 volt circuit.

4. Your coil may not have the correct self-induction for use with a Wehnelt, at least over a wide range of frequencies of interruption. If *inverse* is prominent, try a greater amount

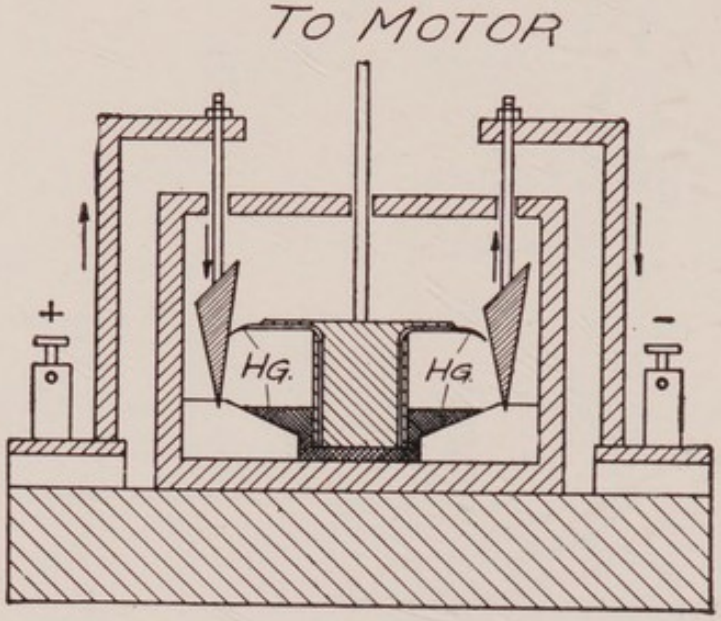


FIG. 51. Centrifugal jet mercury interrupter.

of platinum exposed, thereby lowering the frequency of interruption.

5. Do not run too hot, and if possible enclose interrupter in a sound-proof box, or place outside.

6. Be sure that connections are made to the proper terminals.

7. Do not try to operate on alternating current without a rectifier. This has been done in a few instances, but is not advised.

The Mercury Interrupter. Various forms of interrupters using mercury have been invented, and have some advantages for use with heavy coils. They allow variation in two essential particulars, viz., number of interruptions per second and relative duration of make and break. Two forms are in common use. In the jet type (Fig. 51) a centrifugal pump throws small streams of mercury against V-shaped iron terminals. The motor speed determines the

number of interruptions, and raising or lowering the iron decreases or increases time of flow relative to that of no current.

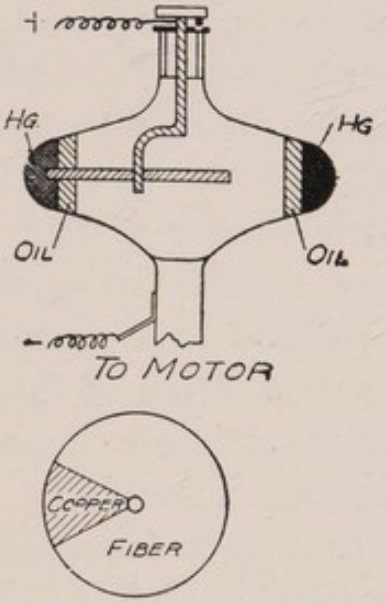


FIG. 52. Rotax interrupter.

In the Rotax interrupter (Fig. 52) the mercury is thrown into a ring revolving with the case. An insulating disc with a small conducting sector is mounted so that it may be moved to and from the circumference. When in contact with the mercury, the disc rotates at a speed depending on the mercury speed and the amount of immersion of the disc. The latter is insulated from the case and is connected to an external binding post. The relative time of current "on" and "off" varies with the immersion of the disc in the mercury. A small amount of paraffin oil is used, forming a ring inside the mercury to prevent oxidation. A better plan, when the apparatus will permit, is to use illuminating gas in the case, which reduces contamination of the mercury and enables long periods of operation without refilling. If gas is used, a small burner should be connected to the cavity and kept burning, and the current should never be turned on until this light continues to burn, as severe explosions may result by spark ignition of

an air-gas mixture. Recent forms have a safety valve to protect against explosion.

A suitable capacity must always be connected to the terminals of interrupters of this type. The amount of this capacity will vary with different inductances of the primary and to some extent with the frequency of the interruption.

Operating Notes. Carefully read and preserve any directions furnished by the maker of the interrupter used. If none are at hand, and trouble arises, some one or more of the following may be found to account for it.

1. *No current in any position of the disc.* Look for poor contacts, either from bad brush on revolving case, loose binding posts, or broken wires. The mercury should be examined to be sure that there is enough and that the oxide does not prevent contact.

2. *Very heavy primary current and little or no secondary current or voltage.* Examine the capacity to see if it is punctured; if so, renew at once. If the condenser is all right, see if the disc is free to turn and is not immersed too far by reason of an overcharge of mercury.

3. Be sure to keep the required amount of oil in the case, as, if there is too little it becomes carbonized by the arc and gives trouble.

4. The mercury must be kept clean. When it is dirty, oxidized, or emulsified with oil, either clean by filtering and washing or put in new mercury.

A coil in which a current is changing always develops an active opposition to the alternation of current. On an attempt to increase the current, the coil acts as an opposing generator, and when current falls the generator action reverses. This action is due to *self-induction.* The opposing voltage, when we change current at the rate of 1 ampere per second, is an important factor in behavior of the coil, and is named the *coefficient of self-induction.*

On account of self-induction, no really instantaneous change of current can take place, and the response to variable voltage will depend on this feature of the coil

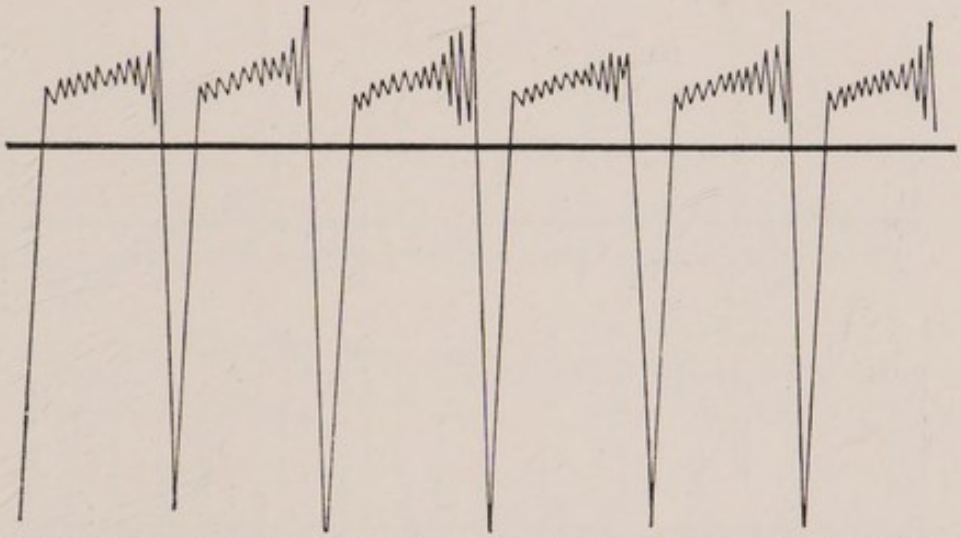


FIG. 53. Oscillogram, induction coil current with a gas mercury interrupter.

and on the rate at which we attempt to make current changes. Each coil is an individual in this respect, and one should find by trial the conditions under which it operates best for each purpose, and then adhere to these conditions. A little time spent in this way will save much time and annoyance later.

Tubes for Use with Coils. The current wave from a coil is quite different from that from a transformer. The current consists of a series of short rushes with considerable time between each impulse. Figure 53 shows the variations of current with time on an induction coil with a good mercury interrupter. Figure 54 shows two curves with a Wehnelt break. Note the large amount of inverse in the latter. In order that the tube current may not lower the voltage below the required point, it is essential to have gas tubes at relatively high vacuum, or hard. Thus we must have *small* tube currents.

Readings. Milliampere and spark gap readings are far less reliable guides for radiography when coils are used than

on transformers. The gap shows peak voltage which may be high but transient. As the ordinary milliammeter indicates the *difference* between direct and inverse, one may

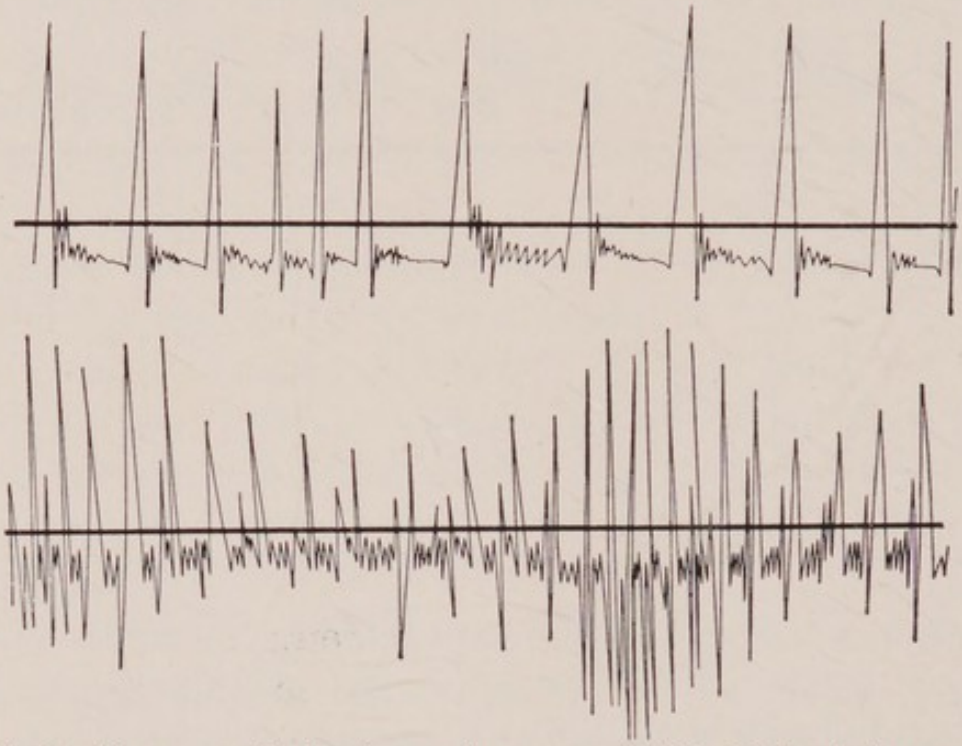


FIG. 54. Oscillograms, induction coil currents with Wehnelt interrupter.

get 0 reading and yet have the tube operating.

Portable Coils. Portable coil outfits are so varied as to make brief description impossible. Those heretofore in use were largely of the "Tesla" type.

The electric lighting current is stepped up to about 2000 volts by a small step-up transformer, if the supply is from an alternating current line.

If the current is direct, the circuit is made and broken by some form of vibrating interrupter, giving much the same effect in the transformer as though an alternating current was used.

The 2000 volt current from the secondary of the step-up transformer charges a condenser. The condenser is discharged through a few turns of wire wound around the outside of a secondary, consisting of a large number of

turns of fine wire. The discharge of the condenser is at an enormous frequency, and high voltages of high frequency are generated by the Tesla coil.

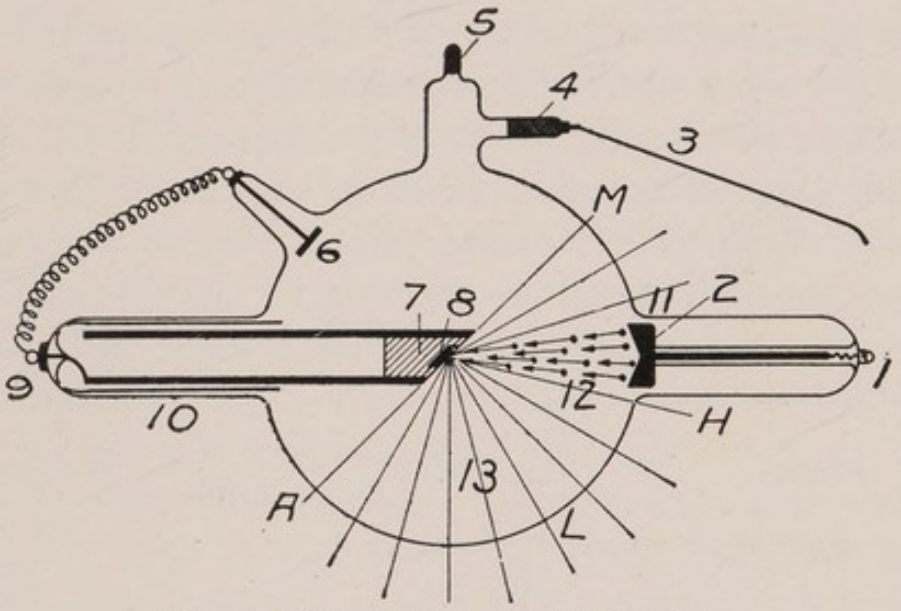


Fig. 55. Regular gas containing tube.

1. Negative or cathode terminal.
2. Cathode of aluminum.
3. Adjustable connections for softening.
4. Softening material.
5. Sealing off tip.
6. Auxiliary anode.
7. Copper block.
8. Tungsten button.
9. Positive or anode terminal.
10. Anode neck.
11. Cathode neck.
12. Cathode particles.
13. Path of *x*-rays.

A L M, Anterior hemisphere showing fluorescence.

As the current delivered by the Tesla coil is alternating, a different form of tube must be used from that for other types of *x*-ray generator, if best results are desired. This special tube has a valve arrangement built into it which tends to suppress one wave of the current.

The Gas Tube. While a great variety of special forms of gas containing tubes have been introduced from time

to time, the general form shown in Figure 55 alone has survived for ordinary use.

The target material has a great influence on the behavior of the tube and the quality of the rays. The atomic weight must be high, as the fraction of cathode ray energy transformed into *x*-ray increases with increase of atomic weight. The melting point must be high or the metal will melt at the focus. It should conduct heat well, and must not vaporize readily below its melting point. The following table gives the approximate data relating to possible metals for this purpose. Taking platinum as a standard radiator:

Metal	At. Wt.	Amount of *X*-Radiation	Melting Pt.
Platinum	195.2	1.	1760. C.
Iridium	193.	.98	2300
Osmium	190.9	.97	2700
Tungsten	184.	.91	above 3000
Tantalum	181.	.90	2900

The essential features of *all* tungsten target gas containing tubes are shown in Figure 55. Various minor modifications may be seen in tubes from different makers, but each part shown must be present in some form.

The cathodes may differ in shape, but only aluminum gives good results and long tube life. The mounting of cathode and target must be firm, and the position in the neck carefully chosen. The adjustable arm (3) is often absent, and a third wire is run to a variable spark gap connecting with the negative terminal of the machine. The auxiliary anode (6) has a great variety of forms; in many water-cooled tubes, and sometimes in others (6) and (10) are interchanged. Numerous special devices for conducting heat away from the target are in use and are

more or less effective. For treatment or for long fluoroscopic examination with this type of tube, water cooling is essential, and a good stream of air directed against the glass adjacent to the cathode is also of considerable assistance. A satisfactory tube must have a stable position of anode and cathode; all attempts to use an adjustable cathode have been unsatisfactory. The metal parts must be pre-heated and the tube itself heated during exhaustion. A well made and properly exhausted tube shows a good hemisphere on the anterior portion, and the remainder of the tube should show but little fluorescent light; a working tube should not be "flashy" or "cranky." When one attempts to operate a moderately hard tube at too low potential, this unstable state may result and either the voltage must be raised or the tube softened. The vacuum must be within fairly well-defined limits, averaging not far from .001 mm. pressure of mercury, and must be in some manner under control, if the life of the tube is of consequence.

The tendency of all gas containing tubes on low current is to "harden," i.e., to require more voltage for the same current, or, if the voltage is not changed, the current decreases. On operation above a certain power peculiar to each tube, the tube softens on account of heating; when this proceeds so far that the tube shows and maintains a purple glow marking out the cathode stream, it is useless until repumped.

Many devices have been used to soften tubes. The more common are the following:

1. A side tube containing mica, asbestos, etc., and through which a small discharge current may be sent, thereby liberating gas. (No. 4, Fig. 55.)

2. A special target is placed in a side tube to be bombarded by rays from a small auxiliary cathode.

3. A fine palladium tube projects through the walls of the tube; when this is heated by a small flame it allows hydrogen to pass into the bulb. This has been modified by Snook, where the tube is heated by a spark discharged from the operating transformer.

4. Heating the entire bulb. (Useless except in an emergency.)

5. A mercury-controlled porous valve allows air to pass slowly into the bulb when the inlet is not covered by the mercury (Heinz-Bauer).

2, 3, and 4 are rarely used in this country, although 3 (osmosis regulators) are sometimes seen outside the more useful Snook form. The great difficulty in the operation of the ordinary gas containing tube lies in the irregular supply of electrons and the impossibility of control of their development. When operated above very moderate power, the trend is always larger quantities of electrons and a consequent drop in penetration, unless the current is greatly increased, when a still greater supply is developed, so that there is no automatic self-protection of the tube.

Gas Tube Characteristics. The earlier type of tube depended for its supply of electrons on the breakdown of the atoms of its gaseous atmosphere, whereby the electrons and the positive remainder of the atom were separated and driven in opposite directions. This breakdown or ionization may be due to several causes:

1. The high electric stress between cathode and target.
2. The shooting of electrons through the atmosphere.
3. The passage of *x*-rays through the atmosphere.

The number of electrons set free will depend on the tube vacuum. If too few can be had, the tube is of too high vacuum and is called "hard." It backs up a very high spark gap, and may become "cranky." If too much gas is present the tube carries so much current that it is quite

impossible to keep up voltage. The amount of free gas in the tube will increase as the parts of the tube rise in temperature, since gas tends to stick to a cold surface. Therein often lies the explanation of failure in radiography when the exposure is prolonged.

The rate of softening of a gas tube operated at a given initial current and voltage varies with its original exhaustion and its use afterward. On low power with small current and high voltage there is a marked tendency to *reduce* the amount of free gas and thus raise the vacuum. When this tendency is just balanced by the evolution or release of gas by heat the tube runs at a nearly uniform current and voltage. On slightly higher power it will soften and the rate of softening will generally be greater with a new tube than in case of a well-seasoned one.

Danger in Testing. It is unwise to test a gas tube at the power used in gastrointestinal or other heavy work, as it is likely to over-soften before a milliammeter can be read or spark gap really ascertained. The usual recourse is to note current and gap at low power, and assume that when this is properly adjusted on, say, button *X*, it will give a proper result on a higher button *Y*. Careful study of these tubes shows that this is only approximately the case, for not only will tubes vary one from another, but the same tube will behave differently on different days. No better method has been suggested, however, so the operator should endeavor to season a tube, if possible, before attempting fast work.

Use great care in softening gas tubes. Never soften a gas-containing tube with rheostat set for heavy radiography; use low power. If a tube is too soft, the rays emitted will not pass through the flesh. Better take more time and soften stepwise, testing after each *short* passage of current through the softener.

To soften the Snook hydrogen tube, pass through the reducer about 15 ma. five or ten seconds at a time. Repeat if necessary. Do not use more current; *use more time.*

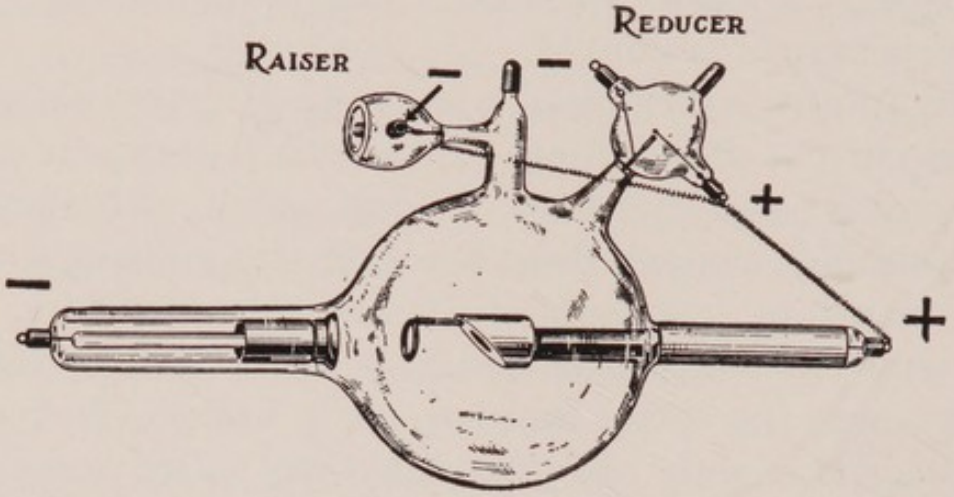


FIG. 56. Diagram showing softening and raising connections on Snook hydrogen tube.

Always maintain polarity, as shown in Figure 56. To harden the tube, pass through the raiser about 25 ma. (never more than 30 ma.) twenty seconds at a time. If the tube is excessively soft, disconnect the spiral temporarily from the + terminal of the raiser. Connect the anode wire to the + terminal of the raiser and the cathode to the − terminal of the raiser. Run three minutes with 22 to 25 ma. Repeat if necessary. Replace the spiral. Regulate the tube before making the exposure. It should test out at 2-inch gap and about 5 ma. The tube tends to harden a trifle during the first exposure when the tube is cold. To compensate, introduce a little more gas. Operate at 40 ma. for a medium focus tube. It will give much more service than at 45 to 50 ma. A sharp focus should be limited to 20 ma. and the time of exposure doubled. Use a broad focus tube for extremely fast exposures in making stomach and intestinal plates.

When a tube is in operation, the heat developed at the target is measured by the current × voltage. If this heat

is produced at such a rate that it cannot be dissipated by conduction and radiation, the metal at the focal spot may be vaporized or melted and the tube ruined very quickly.

It is rarely necessary to do so-called flash or instantaneous work, and it can only be done at high tube cost. Properly used, a tube is capable of a large amount of work.

Do not use intermittent excitation during an exposure. In heavy work, if 60 ma. for four seconds overheats the tube at the gap needed, many operators close the switch for four separate seconds with three *intervals* of a second or more. The patient must remain at rest for seven seconds. The same exposure may be secured with 40 ma. continuously delivered for six seconds. In the latter case the danger of pitting or cracking the target is less and the part need be held immobile for less time. This intermittent method has been suggested to overcome the tendency for voltage drop on heating gas tubes while in operation, but the allowable interval is too short to do much good.

CHAPTER II

DANGERS AND PROTECTION

Dangers from the *X*-Rays. The danger to the skin of operator and patient requires careful consideration in order to avoid serious injury. It is customary to speak of a dose that will cause a slight temporary redness of the skin as an erythema dose. This dose undoubtedly varies considerably according to the age of the patient and to the judgment of the observer as to the extent of redness which may be called "slight."

The skin dose will depend on the following factors:

1. Target-skin distance.
2. Spark gap (voltage).
3. Current through the tube.
4. Time or duration of exposure.
5. Nature and thickness of filter used.

While complete agreement as to what will give an erythema dose can hardly be expected, all will agree that the dose will increase with the duration of exposure, with the current and with the voltage; and will decrease as distance between target and skin is increased and as thicker filters are used.

It is convenient in this connection to combine the tube current in milliamperes and the time in minutes, and speak of milliampere minutes, but it *must be clearly understood that the number of milliampere minutes allowable varies with the voltage.*

Working at a target-skin distance of 20 inches and 85 kv. peak, 45 milliampere minutes may be safely allowed if no filter is used. For general safety, a filter of 1 mm. of aluminum is advised, and then an increase of about 40

per cent may be allowed—or about 60 ma. minutes may be taken as a safe total to be received by the skin at this gap and target-skin distance. Thus, at 5 ma.—85 kv. peak—20 inches—1 mm. Al, a total of twelve minutes may be used on one skin area for fluoroscopic examination, *if no radiograph is to be taken.*

If 20 ma. minutes at 85 kv. peak were used in fluoroscopy there remains only 40 ma. minutes for radiographic work. If 40 ma. is used and 10 seconds is required for a negative, only 6 plates could be safely made. On this account it is wise to make fluoroscopic examinations as brief as is consistent with good work and to use intensifying screens in serial radiography.

If a fracture has been reduced under fluoroscopic control it is better to make radiographs with intensifying screens. Fluoroscopy, whether in the radiological department or out of it, is usually more protracted than the estimated time.

A very important point to remember is that when using less voltage, although the amount of radiation reaching the skin is less for the same current, the exposure required in radiographic work is very much longer. To get the same plate density at low voltage, the skin risk is greater. Many cases of dermatitis are due to prolonged or repeated exposure with too low voltage for the work in hand.

Be sure that unfiltered rays along the axis of the tube, which do not have to pass through the lead glass bowl, do not reach the patient.

When an erythema dose is reached or approached, an interval of three weeks should elapse before again exposing.

Protection of the Operator from the *X*-Rays. The element of increase in the work time makes care in the protection of the operator of extreme importance. Two things are clear in this matter: First, that effects are cumulative; second, that evidence of injury may develop late.

Under no circumstances should an operator use any part of his body for fluoroscopic demonstration, nor should he hold any plate or dental film in position during exposure.

It should be understood that the final responsibility for protection, both of the patient and the operator, rests on the radiologist himself, and after his apparatus is installed he should not neglect to test for gross leaks and insufficient protection.

The fluoroscopic screen in a well-darkened room will help to find where danger may lurk but gives no idea of the amount of radiation involved in the indicated directions.

Electrical Dangers. In the use of high-power *x*-ray apparatus, care must be taken to avoid discharge from high tension lines to earth through the body of either patient or operator. Fatal results may follow, and in any event the nervous shock to the patient may be serious. Danger arises from sparks followed by an arc discharge from the high voltage line to the body, thence to earth.

To get such a discharge, we must have:

1. Grounding of patient or contact with badly insulated grounding material.

2. So short an air distance from some part of the high tension system as will allow a break over spark.

A single spark, while disconcerting, is not dangerous to life, but it serves to pave the way for a heavy *discharge from the line* if the supply is maintained. On static machines and most induction coils, body connection so reduces the line voltage as to preclude any fatal amount of current; but with the modern high power transformer it is a different matter.

The danger of an initial spark-over to the body is solely a matter of line to skin distance and voltage from line to earth. When a tube is taking current, the voltage from either line to earth is less than it would be on the same control

setting if no current were passing. Hence, failure of the tube to take current at any time tends to cause discharge to the patient. The following are the common ways in which this may happen:

1. Failure to complete high tension connection.
2. Failure to light Coolidge filament before turning on high tension.
3. Break or disconnection of Coolidge filament circuit while running.
4. Attempting to pass current through Coolidge tube in wrong direction.

Another cause for spark-over is the high tension surge often caused on closing the primary switch of the transformer.

Keep all high tension lines at least twice as far from any portion of the patient as the working spark gap. Thus, if using an equivalent gap of 6 inches, allow no wire closer than 12 inches. A grounded metal or conducting screen *between* the high tension lines and the patient is complete protection for the patient; thus, a horizontal fluoroscope with a grounded frame is safe with the tube below; but when the patient is between the high tension line and a grounded metal or conducting table, danger is greatly increased.

Type of Control. Much has been said of the relative danger with various controls. Simply stated it amounts to this: the rise in voltage when the tube fails to take current is very much greater on a resistance control (see Figs. 20 and 21), so that the chance of an initial spark is greater; but after such a spark, the chance of a following arc is reduced by reason of resistance in the primary circuit.

With autotransformer control, or operation without resistance, i.e., with rheostat all out, the rise in voltage on open circuit is less; but if an arc *is* started, it is very danger-

ous. A quick-acting, over-load primary break is very desirable.

Recommendations Adopted by the Second International Congress of Radiology, July, 1928

1. The dangers of overexposure to *x*-rays or radium can be avoided by the provision of adequate protection and suitable working conditions. It is the duty of those in charge of *x*-ray and radium departments to insure such conditions for their personnel. The known effects to be guarded against are: (a) injuries to the superficial tissues; (b) derangements of internal organs and changes in the blood.

1. *Working Hours, Etc.*

2. The following working hours, etc., are recommended for whole time *x*-ray and radium workers:

(a) Not more than seven working hours a day.

(b) Not more than five working days a week. The off-days to be spent as much as possible out of doors.

(c) Not less than one month's holiday a year.

(d) Whole time workers in hospital *x*-ray and radium departments should not be called upon for other hospital service.

2. *General X-ray Recommendations*

3. *X*-ray departments should not be situated below ground floor level.

4. All rooms, including dark rooms, should be provided with windows affording good natural lighting and ready facilities for admitting sunshine and fresh air whenever possible.

5. All rooms should be provided with adequate exhaust ventilation capable of renewing the air of the room not less than ten times an hour. Air inlets and outlets should be arranged to afford crosswise ventilation of the room.

6. All rooms should preferably be decorated in light colors.

7. *X*-ray rooms should be large enough to permit a convenient layout of the equipment. A minimum floor area of 250 square feet (25 square meters) is recommended for *x*-ray rooms and 100 square feet (10 square meters) for dark rooms. Ceilings should be not less than 11 feet (3.5 meters) high.

8. A working temperature of about 18°C. (65°F.) is desirable in *x*-ray rooms.

9. Wherever practicable the *x*-ray generating apparatus should be placed in a separate room from the *x*-ray tube.

3. *X-ray Protective Recommendations*

10. An *x*-ray operator should on no account expose himself unnecessarily to a direct beam of *x*-rays.

11. An operator should place himself as remote as practicable from the *x*-ray tube. It should not be possible for a well rested eye of normal acuity to detect in the dark appreciable fluorescence of a screen placed in the permanent position of the operator.

12. The *x*-ray tube should be surrounded as completely as possible with protective material of adequate lead equivalent.

13. The following lead equivalents are recommended as adequate:

X-rays generated by peak voltages not exceeding	Minimum equivalent thickness of lead (mm.)
75 kv.	1.0
100	1.5
125	2.0
150	2.5
175	3.0
200	4.0
225	5.0

14. In the case of diagnostic work, the operator should be afforded protection from scattered rays by a screen of a minimum lead equivalent of 2 mm.

15. In the case of *x*-ray treatment the operator is best stationed completely outside the *x*-ray room behind a protective wall of a minimum lead equivalent of 2 mm. This figure should be correspondingly increased if the protective value of the *x*-ray tube inclosure falls short of the values given in paragraph 13. In such event the remaining walls, floor and ceiling may also be required to provide supplementary protection for adjacent occupants to an extent depending on the circumstances.

16. Screening examinations should be conducted as rapidly as possible with minimum intensities and apertures.

17. The lead glass of fluorescent screens should have the protective values recommended in paragraph 13.

18. In the case of screening stands the fluorescent screen should, if necessary, be provided with a protective "surround," so that adequate protection against direct radiation is afforded for all positions of the screen and diaphragm.

19. Screening stands and couches should provide adequate arrangements for protecting the operator against scattered radiation from the patient.

20. Inspection windows in screens and walls should have protective lead values equivalent to that of the surrounding screen or wall.

21. Efficient safeguards should be adopted to avoid the omission of a metal filter in all *x*-ray work.

22. Protective gloves, which should be suitably lined with fabric or other material, should have a protective value not less than 0.5 mm. lead throughout both back and front (including fingers and wrist). Protective aprons should have a minimum lead value of 0.5 mm.

4. *Electrical Precautions in X-ray Rooms*

23. The floor covering of the *x*-ray room should be insulating material, such as wood, rubber, or linoleum.

24. Permanent overhead conductors should be not less than 9 feet (3 meters) from the floor. They should consist of stout metal tubing or other coronaless type of conductor. The associated conducting leads should be of coronaless wire kept taut by suitable rheophores.

25. Wherever possible earthed guards should be provided to shield the more adjacent parts of the high tension system. Unless there are reasons to the contrary, metal parts of the apparatus should be efficiently grounded.

26. The use of quick-acting double pole circuit breakers is recommended. Overpowered fuses should not be used. If more than one apparatus is operated from a common generator, suitable overhead multiway switches should be provided.

27. Some suitable form of kilovoltmeter should be provided to afford a measure of the voltage operating the *x*-ray tube.

5. *Radium Protective Recommendations*

(A) Radium Salts

28. Protection for radium workers is required from the effects of:

(a) Beta rays upon the hands;

(b) Gamma rays upon the internal organs, vascular and reproductive systems.

29. In order to protect the hands from beta rays, reliance should be placed, in the first instance, on distance. The radium should be manipulated with long-handled forceps, preferably made of wood, and should be carried from place

to place in long-handled boxes, lined on all sides with about 1 cm of lead. All manipulations should be carried out as rapidly as possible.

30. Radium, when not in use, should be stored in a safe as distant as possible from the personnel. It is recommended that radium tubes or applicators be inserted into separate lead blocks in the safe, giving a thickness of protecting wall amounting to 5 cm. of lead per 100 mg. of radium element.

31. A separate room should be provided for the "make-up" of screened tubes and applicators, and this room should be occupied only during such work.

32. In order to protect the body from the penetrating gamma rays during handling of the radium, a screen of not less than I inch thickness of lead should be used, and proximity to the radium should occur only during actual work, and for as short a time as possible.

33. The measurement room should be a separate room, and it should contain the radium only during its actual measurement.

34. Nurses and attendants should not remain in the same room as patients undergoing radium treatment.

35. All unskilled work or work which can be learned in a short period of time should preferably be carried out by temporary workers, who should be engaged on such work for periods not exceeding six months. This applies especially to nurses and those engaged in "making up" applicators.

36. Discretion should be exercised in transmitting radium salts by post. In the case of small quantities it is recommended that the container should be lined throughout with lead not less then 3 mm. thick. It is more satisfactory to transport large quantities by hand in a suitably designed carrying case.

(B) Emanation

37. In the manipulation of emanation, protection against the beta and gamma rays has likewise to be provided.

38. The handling of emanation should be carried out, as far as possible, during its relatively inactive state.

39. The escape of emanation should be very carefully guarded against, and the room in which it is prepared should be provided with an exhaust fan.

40. Where emanation is likely to come in direct contact with the fingers, thin rubber gloves should be worn to avoid contamination of the hands with active deposit. Otherwise, the protective measure recommended for radium salts should be carried out.

41. A separate pumping room should be provided with a connecting tube from the special room in which the radium is stored in solution. The radium in solution should be heavily screened to protect persons working in adjacent rooms. This is preferably done by placing the radium in solution in a lead lined box, the thickness of lead recommended being according to the following table:

Quantity of radium element, in grams	Thickness of lead	
	inches	cm.
0.5	6.0	15.0
1.0	6.6	16.5
1.5	6.8	17.0
2.0	7.2	18.0

Resuscitation from Electric Shock or Asphyxiation. The prone pressure method of artificial respiration, devised by Prof. Schaefer, of Edinburgh, has been advocated as the most effective method by the United States Bureau of

Mines' Committee. This method can be used with oxygen inhalator. It should always be used immediately to resuscitate asphyxiated persons and kept up continuously until

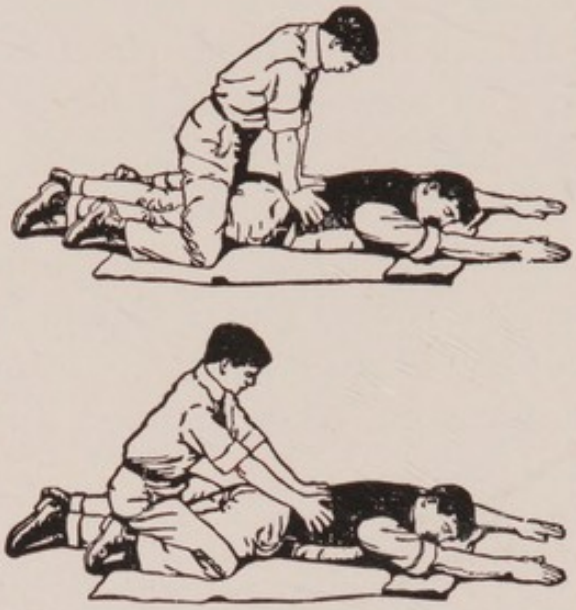


FIG. 57. Resuscitation from electric shock.
Above: Expiration, pressure on. Below: Inspiration, pressure off.

approved mechanical resuscitating devices are brought to the scene and adjusted on the patient. Heart stimulant should be given as frequently as necessary.

This system can be used in cases of electric shock, after the victim has been removed from the live conductor, in cases of gas poisoning or asphyxiation from any cause. *Artificial respiration should be begun promptly, as life persists only a few minutes after breathing stops.*

Quickly feel with your finger in the victim's mouth and throat and remove any foreign body (tobacco, false teeth, etc.), then begin artificial respiration at once. Do not stop to loosen patient's clothing; every moment is precious.

Lay the subject on his belly, with arms extended as straight forward as possible, and with face to one side, so that the nose and mouth are free for breathing. Draw forward the subject's tongue.

Do not permit bystanders to crowd around and shut off the air.

Kneel, straddling the subject's thighs and facing his head; rest the palms of your hands on the loins with thumbs nearly touching and with fingers spread over the lower ribs. (Fig. 57.)

With arms held straight, swing forward slowly, so that the weight of your body is gradually brought to bear upon the subject. This operation, which should take two or three seconds, must not be violent, lest internal organs be injured. The air is thus forced out of the lungs.

Now immediately swing backward so as to remove the pressure, but leave your hands in place. The air thus enters the lungs.

After two seconds swing forward again, repeating this operation twelve to fifteen times to a minute, a complete respiration every four or five seconds. While this is being done, an assistant should loosen any tight clothing about subject's neck, chest or waist.

Continue artificial respiration (if necessary) two hours or longer, without interruption, until natural breathing is restored. Even when natural breathing begins, carefully watch that it continues. If it stops, begin artificial respiration again.

Keep subject warm by applying a proper covering or artificial heat, hot water bags, etc.

Do not give stimulants or liquids by mouth until subject is fully conscious.

Failure to revive the shocked person after artificial respiration is usually due to ventricular fibrillation.

CHAPTER III

LABORATORY EXPERIMENTS

Laboratory Instruction in Preparation for Radiology. The following experiments are part of a series used in the laboratory course during the World War.

The objects of such experiments are:

1. To give practice in quickly adjusting machine and tubes to any desired current and voltage.

2. To impress on the mind of the student the relation of the fundamental factors: voltage, current, distance and time, to the nature of image desired.

3. To assure the operator that results are reproducible if conditions are right.

4. To show some of the pitfalls usually encountered and to avoid having to acquire experience on the living patient.

While at first such experiments may seem very time-consuming, experience has shown that the skill and confidence acquired will much more than repay it in a comparatively short time.

Experience in the training of a considerable number of students has clearly shown that the handling of *x*-ray apparatus *cannot be learned by seeing some one else do it.* Only when the students have repeatedly carried on the actual manipulations themselves, time after time, can they be depended upon under working pressure. Much time is lost in not knowing just what exposures should be given and the test plates described are excellent checks on accuracy and rapidity. The student should be well drilled in quickly setting the tube and control for definite readings. In the study of plates as well as in the technical work the student should do *absolutely individual and independent work.*

Instruction Unit. A small instruction unit has been devised to clearly set forth the basic principles of the large x-ray machines and to avoid unnecessarily tying up expensive

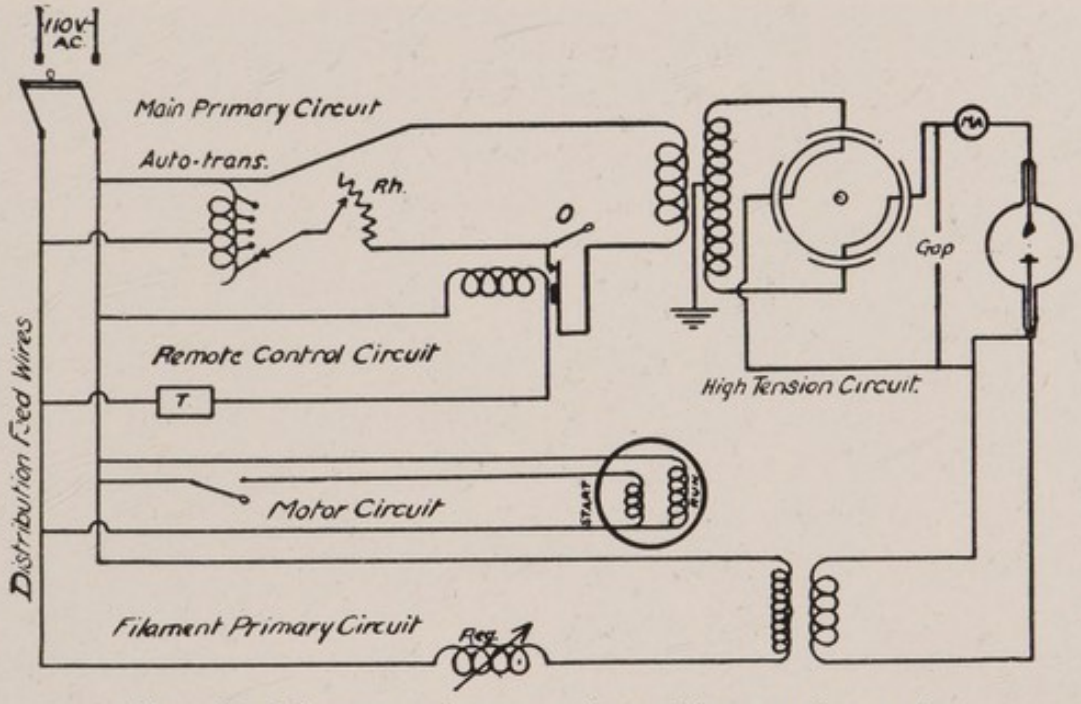


FIG. 58. Diagram of connections of instruction unit.

equipment for elementary instruction purposes. This machine is composed of only the customary elements and these are arranged on an ordinary pine table so that all parts and all wires are completely in view and readily accessible. For instruction purposes high power is unnecessary, and a small transformer is ample for the purpose. With the transformer used, loads up to 5-inch gap, 30 ma., may be safely drawn for test plate and other experimental work. The autotransformer, rheostat, filament transformer, timer, etc., are standard parts as used on the large machines, so that the student may become familiar with their function and operation.

It is intended to have the machine as simple as it is possible to make it, and to this end the various circuits are distinguished from each other by the color of wire used. Thus, the main primary circuit is black, the motor circuit

is blue, the Coolidge filament primary is red, and the remote control circuit is green. Even to a beginning student the circuits stand out separate and distinct, and the machine

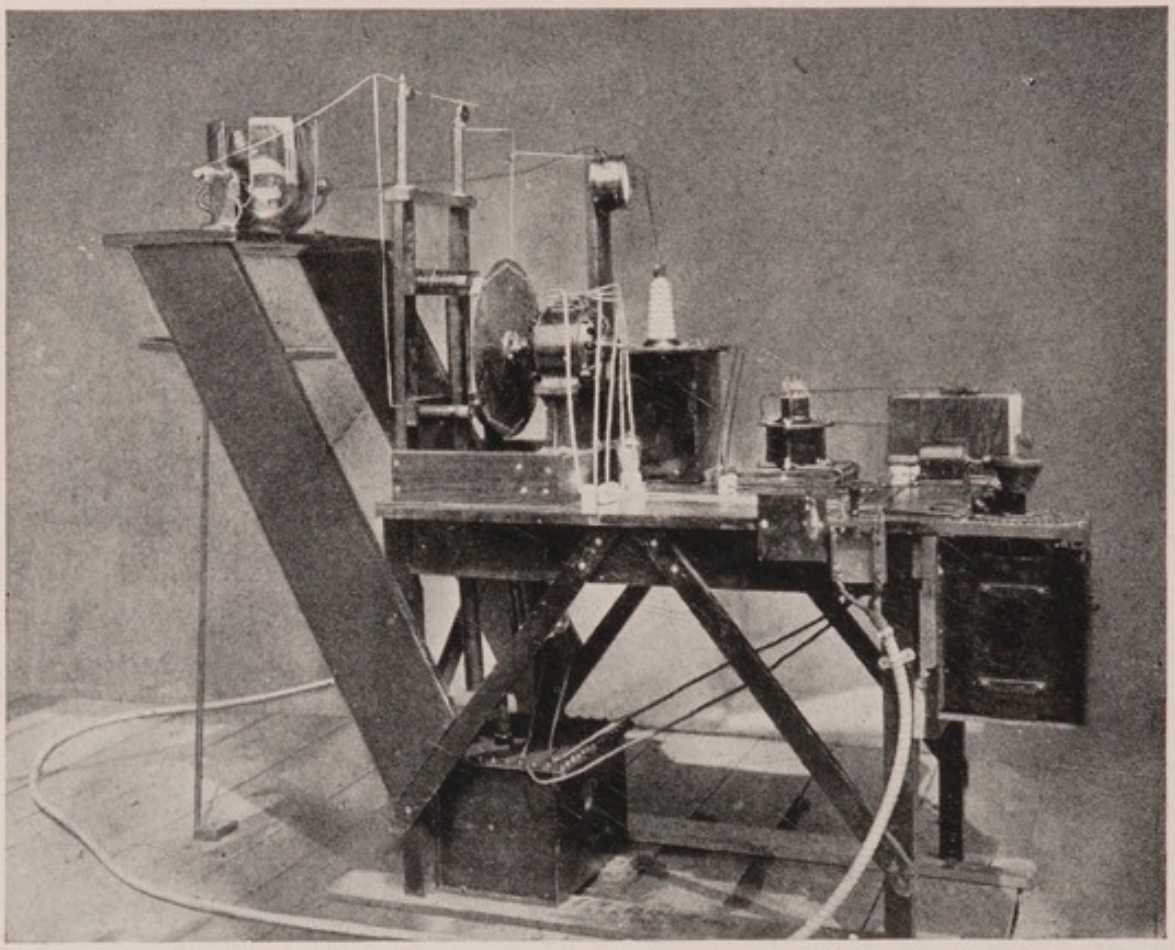


FIG. 59. Machine used for instruction purposes. All parts and wiring are openly displayed.

appears organized and rational rather than a hopeless maze of wiring. Figure 58 shows the diagram of connections and Figure 59 shows the machine itself. Superfluous parts have been eliminated and the features shown are so fundamental that each student should be able to wire up the complete machine as part of his laboratory work.

Aside from giving a knowledge of the electrical elements of *x*-ray machines, the unit is used to give considerable practice in setting for any desired tube voltage and milliamperage, in operating when failure of some non-essential

element occurs, and in studying the physical properties of the *x*-rays.

Test Plates. The quantitative measurement of *x*-ray radiation has proved a difficult matter, but for our purpose the photographic effect is sufficiently accurate and determines the usefulness of the rays in practice.

We cannot readily compare the radiation received on two spots of unequal density. Under any conditions of operation, however, if two portions of a photographic plate subjected to radiation and given the same development have equivalent blackening we may say that the two parts *received the same quantity of photographically effective radiation* per unit area, or that they *had the same exposure*, in which case exposure does not mean time alone.

If a spot exposed 1 second and a spot exposed 2 seconds are of equal darkness, then we can say that the first spot was subjected to radiation twice as intense as the second, for it took only half as long to give equal effect. The spots should not be heavily overexposed or overdeveloped, for it is in the medium gray tones that distinctions in density are most accurately and easily made.

A 5×7 plate is cased in the usual envelope or in a light-tight plate holder. The student's name, laboratory number and the number of the experiment should be written on the emulsion side of the plate with soft lead pencil when loading. A 5×7 lead plate with ten 1-inch holes is used to protect the body of the plate from radiation and all holes except the one spot to be exposed are covered with sheet lead. Expose the test spots in proper sequence down the two rows of holes, and place a small metallic marker on spot No. 1 during exposure to identify it later.

In using a timer do not vary its settings, as the scales are rarely calibrated with sufficient accuracy. Keep the timer set at 0.1 second and repeat the exposure the required

number of times. If the machine is not equipped with a timer capable of conveniently repeating 0.1 second exposures, time with a stop watch or by counting to full seconds instead of tenths. Increase considerably the target-plate distance in this case, if possible.

Do not develop test plates too far. Stop as soon as spots Nos. 1 to 5 show fairly well on the back of the plate. If the settings have been carefully made and exposures accurately timed, spots Nos. 1 to 5 should be approximately equal in density and Nos. 6 to 10 should run successively darker or lighter as the case may be.

When the finished plates are dry the spots should be numbered and all exposure data written on the emulsion side of the plate with pen and ink. The plate should then be turned in for inspection and credit.

Before commencing work read and understand the general instructions and precautions on page 6.

Distance-time Relation—Inverse Square Law

Test Plate 1. The *x*-rays travel out from the electron impact point on the target in straight lines, so that the amount in a cone of a given angle is spread over an increasing base area as we recede from the tube. A plate of fixed size intercepts more radiation in a given time when close to the source. If we move a plate to double its original distance from the target, the radiation received per second on a given area will be only $\frac{1}{4}$ as great; at ten times the distance, $\frac{1}{100}$ as great. In order to secure the same radiation effect, the time of reception must be increased four-fold in the first case and one hundred fold in the latter.

For *constant tube current and voltage* the plate blackening will be unchanged if we keep $\frac{\text{time}}{\text{distance}^2}$ constant for all exposures.

Set for 10 ma. at a 3 inch spark gap and expose spots as shown below. Or the bedside unit may be used, exposing seconds instead of tenths.

Spot No.	Distance, in.	Time, sec.	Spot No.	Distance, in.	Time, sec.
1	10	.1	6	10	.1
2	20	.4	7	20	.1
3	30	.9	8	30	.1
4	40	1.6	9	40	.1
5	50	2.5	10	50	.1

In the first row of spots we have compensated for the change in distance by a proper corresponding change in time, so these spots will have the same density. In the second row we have made no such compensation and the spots will not be equally dark. The target-plate distances ordinarily used in radiographic work vary from 15 to 36 inches. The sharpness of the radiograph increases with greater distance, but longer time is required. Assuming that 1 second is the correct exposure for a given object at 20 inches, plot a curve on cross section paper showing time required at various distances up to 36 inches to give the same density of plate.

Current-time Relation

Test Plate 2. The *x*-ray energy on a given plate area per unit time when the voltage is constant and the target-plate distance is fixed, increases in direct proportion to the current. Thus, we get the same radiation in *half* the time when using 50 ma. as when using 25 ma. Or, for equal photographic effect the product of milliamperes and seconds must remain constant.

To test this law expose a test plate as follows:
Voltage constant at a 4-inch gap.
Target-plate distance constant at 30 inches.

Spot	Current, ma.	Time, sec.	Spot	Current, ma.	Time, sec.
1	5	1.2	6	5	1.2
2	10	.6	7	10	1.2
3	15	.4	8	15	1.2
4	20	.3	9	20	1.2
5	30	.2	10	30	1.2

Notice that we have compensated by a decrease in time for the increase in current in the first row and that the second row is uncompensated.

Voltage-time Relation

Test Plate 3. The radiation leaving a given target as registered by a photographic plate is not fixed by the amount of current alone, but varies greatly with the drop in voltage through the tube. In fact, it increases very nearly in proportion to the *square* of the voltage. This means that on doubling the voltage, all other factors remaining unchanged, we get four times the photographically effective radiation per second and would then need but *one-fourth* the exposure time.

With an electrostatic high tension voltmeter it is easy to read voltage directly, but this instrument is not ordinarily available. The so-called primary "kilovoltmeters" with which many machines are equipped are not reliable indicators of secondary voltage, as they do not read the same for the same secondary voltage under different loads on the transformer. Parallel sparking distance between

blunt points is a guide to tube voltage. The relation between spark length and kilovolts is shown in Figure 13. It may be considered as reasonably true that under average conditions the kilovoltage is ten times the spark in inches plus ten, i.e., 3 inch gap = 40 kv.; 5½ inch gap = 65 kv., etc.

Exposures are to be made as follows:

Current constant at 5 ma.

Distance constant at 25 inches.

Spot	Gap	Time	Spot	Gap	Time
1	2 inches (30 kv.)	1.6 sec.	6	2 inches (30 kv.)	1.6 sec.
2	3 inches (40 kv.)	.9 sec.	7	3 inches (40 kv.)	1.6 sec.
3	4 inches (50 kv.)	.6* sec.	8	4 inches (50 kv.)	1.6 sec.
4	5 inches (60 kv.)	.4 sec.	9	5 inches (60 kv.)	1.6 sec.
5	6 inches (70 kv.)	.3* sec.	10	6 inches (70 kv.)	1.6 sec.

* These figures are fair approximations to the exact values.

The equality of density of numbers 1 to 5 as well as the great density difference of numbers 6 to 10 illustrate well the effect of increased voltage.

It must not be assumed that the quantity of radiation alone varies with the voltage at constant current and time. The ability to pass through material also increases to a great extent at higher voltage. The quality of negatives of the same average density made at high and at low voltage is quite different and a voltage (penetration) suitable for the case in hand should be chosen if the best results are to be secured.

It may be stated that the relation between voltage and time is only approximate.

Throughout the laboratory experiments the voltage is expressed as the effective value. In the tables for making *x*-ray films of different parts of the body the voltage is

expressed as the peak value, following the custom in vogue at the present time.

Summary of the Preceding Relations

Test Plate 4. Formulating the experience derived from the preceding experiments, we may conclude that for a given tube and machine, i.e., a fixed wave form, frequency, target, and absorbing glass wall, we may regulate the exposure, when no absorbing material is traversed, by control of (a) current, (b) voltage, (c) time, (d) distance.

Expressed in algebraic form, the photographic effect E is given by

$$E = \frac{K \times \text{Current} \times (\text{Voltage})^2 \times \text{Time}}{(\text{Distance})^2}$$

where K may change for various targets, glass walls, or wave form, but is fixed for a given tube and outfit. If this is true, one can readily compute from *one* set of conditions the length of time under other conditions that will give the same plate density.

To calculate the time for a given exposure use simple approximate methods, not long and involved computations. Thus, if a case is given as follows:

Exposure 1:

50 ma.—5-inch gap—18 inches—4 seconds.

Exposure 2:

15 ma.—4-inch gap—27 inches—time = ?

Decrease in current increases time $1\frac{0}{3}$ times.

Increase in distance increases time $\frac{9}{4}$ times.

Decrease in gap increases time $\frac{25}{16} = \frac{3}{2}$

Then the required time is

$$\frac{4}{1} \times \frac{\overset{5}{\cancel{10}}}{\underset{3}{\cancel{3}}} \times \frac{9}{4} \times \frac{3}{2} = 45 \text{ seconds.}$$

Start with 4-inch gap 10 ma. 20-inch target-plate distance, and .2 sec. Calculate and expose 11 spots so as to vary two or three of the above factors each time, but keep E constant. $E = \frac{(4)^2 \times 10 \times .2}{(20)^2} = .08$ arbitrary units for spot No. 1. Thus, if current is raised to 30 ma., this increase would give a time $\frac{1}{3}$ as great; but if the distance is raised to 30 inches the greater distance would require a time $\frac{9}{4}$ as great. Hence the correct time with the combined change is $.2 \times \frac{1}{3} \times \frac{9}{4} = .15$.

No.	MA.	Gap.	Distance	Time
1	10	4″	20″	.2 sec.
2	5	5″	25″	?
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

Do not work below a 2 inch gap on account of the absorption of the glass walls of the tube, or on the small instruction units above 5 ma. on a 6 inch gap or above 30 ma. on a smaller gap.

Use a variety of control buttons, and where the timer will not give exact results, get as near as possible or vary one or more factors to get exact tenths. The timer will not give smaller fractions with any considerable accuracy.

The exposures are to be computed before coming to the laboratory.

Enter your results as shown on page 125.

Change in Time of Exposure with Thickness

Test Plate 5. Exposure Factor. Find by trial the ratio of the time required to get the same density through *one* layer of a paraffin as when no absorber is present. To do this, expose a plate, using a machine setting of 10 ma., 3 inch gap; or use the bedside unit, exposing seconds instead of tenths and giving the plate much shorter development. Use 17 inch distance for all spots.

Spot No.	Layers of Paraffin	Time	Spot No.	Layers of Paraffin	Time
1	0	.1	6	1	.4
2	0	.2	7	1	.5
3	0	.3	8	1	.6
4	1	.2	9	1	.7
5	1	.3	10	1	.8

When the plate is developed compare other spots with Nos. 1, 2 and 3, and select the pair that comes closest to an exact match in density. If, for example, spots No. 1 and 5 are equally dark, the exposure factor is determined by the ratio of the time of exposure used—in this instance, 3.

This factor can be checked by comparing spots No. 2 and 8, which should match if the factor is 3.

Absorption of rays and scattering gives an explanation of the great increase in time of exposure with increasing thickness of absorbing layer. Thus, if experiment shows that a certain thickness of a given material will reduce the emerging radiation to $\frac{3}{5}$ the incident, then a spot exposed through this layer will require $\frac{5}{3}$ the time for the same phototgraphic density as the uncovered portion of the plate would require. For two such layers $\frac{25}{9}$ the original time will be required, for three layers $\frac{125}{27}$, etc.

Test Plate 6. Using the factor obtained from Test Plate 5 and the law indicated above, calculate proper exposure times and expose the plate as follows:

Machine setting constant at 10 ma., 3 inch gap, 30 inch distance; or use the bedside unit, if it was used for Test Plate 5, again exposing seconds instead of tenths and giving the plate short development.

Spot No.	Layer of Paraffin	Time	Spot No.	Layer of Paraffin	Time
1	0	.3	6	0	.3
2	1	..	7	1	.3
3	2	..	8	2	.3
4	3	..	9	3	.3
5	4	..	10	4	.3

The time for proper exposure in order to get the best plate does not work out from the simple law of absorption. The reason is clear when we consider scattering in tissue. Let AB, in Figure 60, be a small object in the body, relatively opaque to x-rays. If there were no scattering, the area S would be protected from radiation by an amount

fixed by the *increase* in absorption of AB over that of an equal amount of tissue. Thus, if volume represented by 1, 2, 3, 4 would absorb 95 per cent when AB is absent, then if

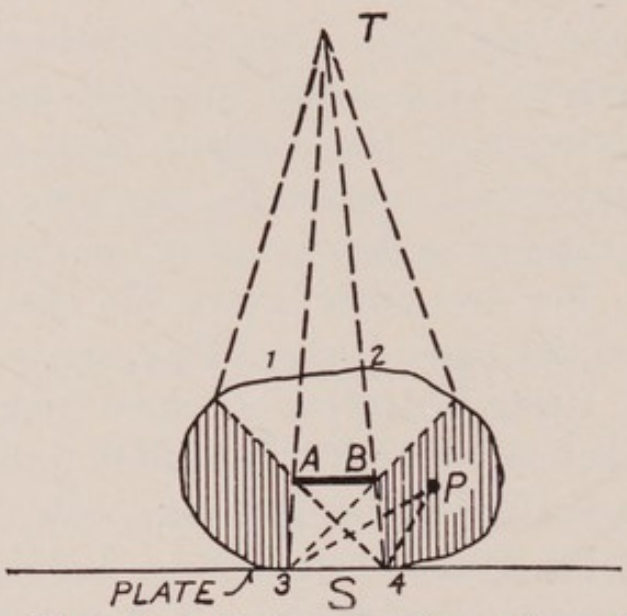


FIG. 60. Effect of scattering on undercutting of image.

the object were *entirely* opaque it could only reduce exposure by 5 per cent of that adjacent to it. In addition, all the shaded portions of the figure are sending scattered radiation in S in proportion to what each point receives. To reduce this scattering as much as possible no more of the body should be exposed than is necessary, and conditions maintained to give as high contrast as possible. The best plates of thick parts are rarely of high density as compared with those of extremities. Contrast is always better when the gap is made as low as possible, consistent with other operating conditions.

CHAPTER IV

FLUOROSCOPY

Definition. *Fluoroscopy* is the method of making studies of opaque objects by means of the *x*-rays and the fluorescent screen. It depends upon the fact that under the influence of the *x*-rays certain substances become highly fluorescent. The fluorescent screen consists primarily of a thin layer of this fluorescent substance spread upon cardboard. This cardboard or fluorescent screen in turn should be covered by lead glass having an absorbing capacity equivalent to 1 mm. of lead, and mounted in a frame. To this frame there should be attached convenient handles, and these handles should be so arranged that the hands will be protected from stray rays during the examination. When not working in a well-darkened room the screen must be covered by a hood so as to shut out other light. This hood is usually arranged in a pyramidal form. The depth of this pyramid must be at least the average focal distance for the eyes.

A fluoroscope for use in a lighted room has been described by Dr. Dessane[1] (Figs. 61 and 62). A spring attached across the hinge line will hold the fluoroscope down in its working position, or when tilted over it will be held by the same spring in position on top of the head.

Apparatus. If the apparatus is to be used solely for fluoroscopic work the exciting outfit needs to be capable of producing no more than 5 milliamperes with a voltage corresponding to from 3 inch to 6 inch parallel spark gap.

An outfit for *vertical fluoroscopy* is desirable. Its greatest use will be in the study of cavities containing fluid, such as

[1] Described by L. Ombredanne et R. Ledoux-Lebard, "Localization et Extraction des Projectiles," Librairies de L'Academie de Medecine, Paris.

cavities in the lungs, accumulations of fluid in the pleura or the study of opaque fluids placed in the stomach and intestines to render them opaque and visible. In this vertical

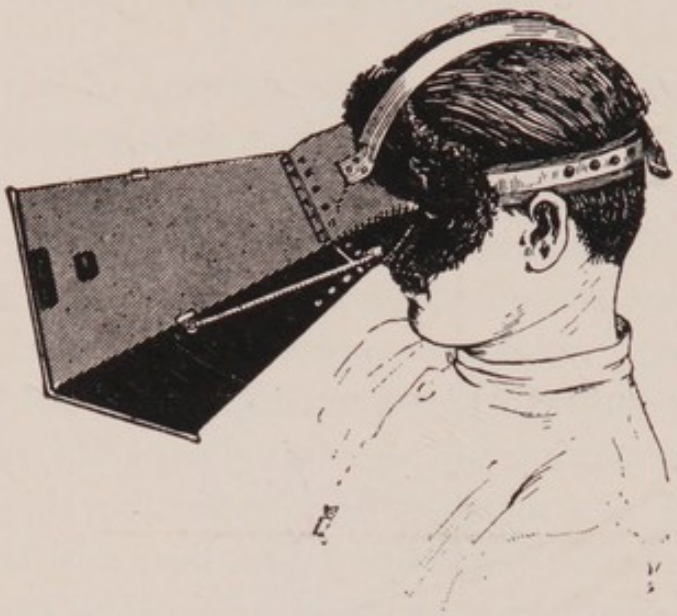


FIG. 61. Dessane's fluoroscope attached to the head ready for examination.



FIG. 62. Dessane's fluoroscope elevated to the top of the head after the fluoroscopic examination has been made permitting the operator to see by ordinary light without losing the sensibility of the retina because of a ruby glass which automatically drops in front of the eyes as the fluoroscope is elevated.

position one can often obtain the upper level of fluid and make an absolute diagnosis of a condition that, when studied

in the horizontal position, would give less evidence leading to a correct diagnosis.

Operating Switch. This switch should be adjusted: (1) so that the operator need not continuously stand on one leg; (2) so that it will accurately and quickly close or open the primary circuit; (3) and so that it will turn on and off the ruby light which is used for general lighting of the fluoroscopic room.

The Darkroom, Importance of Absolute Darkness. Too much emphasis cannot be laid upon the necessity of absolute darkness, especially if an open screen is to be used. The success in attaining absolute darkness will depend in great part upon the ingenuity of the operator. Black cloth or black paper is a cheap way of rendering cracks and light fissures dark. To cover windows and other openings, double black curtains running in grooves will be found satisfactory. Unless the room be absolutely dark the object under study will be dim in outline and in many instances not even visible. Lack of attention, therefore, to this detail may result in a prolongation of the fluoroscopic study, waste of time, injury to the patient and operator, nervous annoyance and very often absolute failure in the ultimate object of the work. If the room cannot be darkened, one must use the hooded screen or work at night.

Ventilation of the Fluoroscopic Room. See ventilation of developing room, page 165.

Time Required for Sensitizing the Retina. This will vary with the individual, and particularly with regard to the age of the individual, for the young can respond to this test more quickly than older people. In general, one should be in the dark for ten to fifteen minutes before beginning fluoroscopic study. If one begins in less time than this, there is likely to be unnecessary exposure of patient and operator, and inefficient and unsatisfactory results obtained.

The Light for the Darkroom. In general a ruby light is recommended on the theory that the retina becomes fatigued by the ruby light and is therefore more easily capable of appreciating the greenish white light of the fluorescent screen. It is most important, however, that so far as possible the dim lighting of the room should be well diffused.

Conditions for Fluoroscopy. It must be clearly recognized that the illumination on the fluoroscopic screen is entirely of local origin and that the relative luminosity is low. For this reason it is absolutely necessary, in order to observe the details on the screen, that is, the differences in illumination, to exclude light of every kind which does not originate in the excited portion of the fluorescent material. The *visibility* of a shadow on the screen increases with the difference of illumination between the shadow and its immediately adjacent brighter surroundings, and decreases with the *general* illumination of the screen. As a parallel we may mention the case of lantern slide projection, where line drawings, heavy markings, and things of great contrast and reasonable size may be projected satisfactorily in a moderately lighted room with a comparatively low power lantern. But when finer details are to be seen and more difficult gradations to be identified, it is desirable to increase to some extent the candle power of the projector and to exclude light from every source, such as windows, doors, etc., which has not passed through the optical system to produce the image. This principle is of even greater importance in fluoroscopic work because the small crystals excited to fluorescence emit light in every direction and always tend to illuminate portions of the screen which may have received no *x*-rays, so that we get a local cross-fire of true light spreading along the screen, reducing to a great extent the visibility of shadows. Screens will differ in

this respect to some extent according to the size of crystals used and the smoothness of the surface.

On account of this diminution of detail, owing to the nature of the screen, it becomes of increasing importance to secure as sharp shadows as possible by the use of a fine focus tube and by working at a suitable screen distance.

It should again be mentioned that the degree of contrast, irrespective of the illumination, is controlled exclusively, for a given target-screen distance, by the voltage of the working tube. The contrast will be higher the less penetrating the radiation, and, therefore, the lower the voltage consistent with proper illumination.

At a given voltage the only effect of increasing milliamperage through the tube is to increase the average illumination on the screen, so that contrast must be controlled by voltage, and brightness alone may be in part controlled by variation of the tube current. The effect of scattering is even more disastrous in fluoroscopic work with thick patients than it is in radiographic processes. Scattering may be greatly reduced by hanging a light Bucky grid between the patient and the screen. Even when using the grid, the diaphragm should be kept as small as possible.

As regards the preparation of the retina for fluoroscopic work, undoubtedly the ideal is to have the radiologist remain in total darkness for ten minutes before starting work, and to remain in as nearly complete darkness as is possible continuously during the period of fluoroscopic examinations. Instead of remaining in total darkness ten minutes, the radiologist may wear red goggles and be in a light room. The goggles are removed in the dark room and before fluoroscopy is begun, as no screen image can be seen through them. On leaving the room temporarily the red goggles are replaced.

In working with the surgeon it is absolutely necessary that *one* party keeps his eyes in condition for the best fluoroscopic vision. However commendable the desire on the part of the surgeon to see for himself, he should clearly understand that his selection of surgery as a vocation has not modified his optical organs so that he can see without taking the same precautions in fluoroscopic work as are prescribed for the *x*-ray operator. It, perhaps, ought also to be mentioned that for a person who is partially green blind fluoroscopy with the ordinary screens is quite impossible, and men having this visual defect ought not to attempt work in this field.

Summarizing, we may say that fluoroscopy demands (1) a fixed voltage corresponding to a 85 kv. peak, and a constant current of 3 to 5 milliamperes; (2) a fine focus tube; (3) as small a diaphragm as possible, (4) a good screen, and (5) eyes sensitive to screen light by preparation in the dark-room, or by wearing red goggles for a sufficient period to insure good vision.

Note that one accustomed to using eye glasses for reading should not remove them when doing fluoroscopic work, as the necessity for clear vision is even greater than in other cases.

If these conditions are attained with reasonable care, many things can be determined with the fluoroscope much more quickly than with films, and the information secured will be as accurate. The *x*-ray operator should read carefully the chapter on protection, and must assume responsibility for his own safety.

CHAPTER V

TECHNIQUE

The *X*-Ray Negative. The conditions which determine the distribution of shadows on an *x*-ray negative are extremely complex and vary with the physical condition, age, and weight of the patient even without any reference to pathological conditions. If there were no material between the target and the photographic emulsion, there would result, upon exposure and development, simply a uniform blackening of the film. The introduction of material in the path of the radiation between the target and the film results in absorption and scattering, with the result that portions of the emulsion are protected from the radiation, the resulting shadow showing as a white or lighter area by transmitted light through the negative. The amount of radiation failing to reach any area of the film as compared with that reaching the surface of the obstructing body depends upon two things: first upon the relative physical density of the material traversed as compared with its immediate surroundings and, second, upon the distance in this material of greater or lesser density actually traversed by the rays. As an illustration, the shadow cast by a thin, flat bone, placed with its surface parallel to the film will show little contrast as compared with the shadow of the surrounding flesh, whereas, if placed on edge, increasing the path traversed in the bone, there will be marked contrast.

In traversing the human body radiation passes through an aggregate made up of portions of decidedly different densities. Each of these portions absorbs the radiation in an amount depending both on its density and thickness. When we further take into account the physical nature of the action of the photographic film and the different absorbabil-

ity of the radiation under different conditions of tube, we may easily recognize the reason for the variety of negatives which it is possible to secure of the same anatomical region. Inasmuch as our diagnostic information must be acquired from a study of these areas, we must not forget that pathological conditions are liable to be inferred if based upon doubtful or imperfect data, and while we can not at present lay down complete rules for the guidance of the radiologist it is undoubtedly true that for each individual area there is a combination of factors of exposure, penetration, development, and position, that would give the best diagnostic film.

Consider the effect of varying (1) the quality of the *x*-ray beam, (2) the time of exposure when making a negative of any particular region. Assuming that we have proper development of the film after exposure, we may note that if the tube is energized by low power (by relatively few kilovolts) the majority of the radiation will be absorbed completely by even thin and non-dense portions of the patient, and that the exposure in order to have any effect on the film must be prolonged. For example, in the case of the hand, such a tube with proper exposure may bring out wrinkles or folds in the flesh, finger nails, and a very slight infiltration in the soft tissues, and only by prolonged exposure can even a moderate definition of bones be observed. When this is done the parts of the negative covered by soft tissue are greatly overexposed. If the kilovolts are too low nothing but a shadow of the hand such as would be cast by ordinary light will be observed. As we change the voltage with a suitable time of exposure we can secure quite different qualities of negative and, with moderate voltage and exposure, fair details in the bone and the soft tissue may be observed, but, with longer exposure, portions of the film beneath the thinner or softer regions still become overexposed, giving, on development, complete blackness with-

out details. At the same time the outlines of the thicker portions and of the bones may stand out very clearly, giving almost the appearance of a skeleton.

If the voltage is made too high the radiation reaching the film may be modified to only a slightly greater extent by the bones than by the soft tissue, and we get a characteristic film, lacking in contrast, which is generally described by the term "flat." In an extreme case, nearly all of the radiation might pass through the body with only a trifling amount of absorption, and there would be no differentiation with reference to density and thickness upon the film. Consequently, while no complete guide can be given, the general effect of increased voltage is to reduce the contrast, and the general effect of increased exposure with moderate voltage is to obliterate the details in the soft tissue or thin portions with an increase in the visibility of the shadows cast by the denser or thicker portions. If, for example, one desires a study of the thoracic vertebrae, one must expect that portions of the film receiving radiation through the air-filled lungs will be greatly overexposed and will indicate no shadows. With lower voltage, details of the spine and ribs will be less obvious, while the linear markings in the chest are rendered visible. It naturally follows that tube condition and exposure should be adapted to bring out the information desired. Mention may also be made of the fact that the overexposed and denser regions may frequently give valuable information if viewed with a sufficiently strong source of light, while a thin negative, or those portions in which the shadows are faint and the total blackening slight, are best observed in weak light.

Inference as to pathology can be safely made only when due account is taken of the variation in the shadows due to normal variation in human anatomy and the procedure followed in making the negative.

Certain terms are in common use when negatives are described, and should be understood.

Contrast refers to the amount of difference in darkening for a small difference of exposure. Thus, if rays pass through bone and flesh, there is a variation in the amount of radiation *reaching the film*, due to difference of absorption; when this results in a marked difference in darkening, the negative is "contrasty." Contrast depends on the nature of the film and the development, and to a great extent on the quality of the radiation used. If the beam is too penetrating, contrast is reduced, for if rays pass through bone and flesh equally well, there will be no contrast. Too "soft" radiation will fail to get through the denser portion and will give high contrast but poor detail in thick parts. The amount of contrast to be desired will vary with the work to be done. A film showing fine bone detail and contrast may show but little of the soft tissue.

Detail refers to the fineness of the marking of light and shade. Thus, a mastoid film should show minute structure, or lines of light and shade should show sharp gradation or density change. Detail depends on:

1. Breadth of tube focal spot.
2. Distance of target from film.
3. Distance of part to be radiographed from film.
4. Complete immobilization of patient.
5. Correct exposure and development.

The Bucky Diaphragm is a device that eliminates most of the scattered and secondary rays before they strike the film.

Essentially the diaphragm consists of an aluminum or bakelite support and under it a moving grid, with the grid plates radial to the focal spot of the tube. The grid moves at a constant speed for any desired time. The part to be taken is placed above the grid, the cassette below. During

the exposure the scattered and secondary radiations set up in the tissues proceed in all directions. That component that goes straight down in the original direction of the x-ray

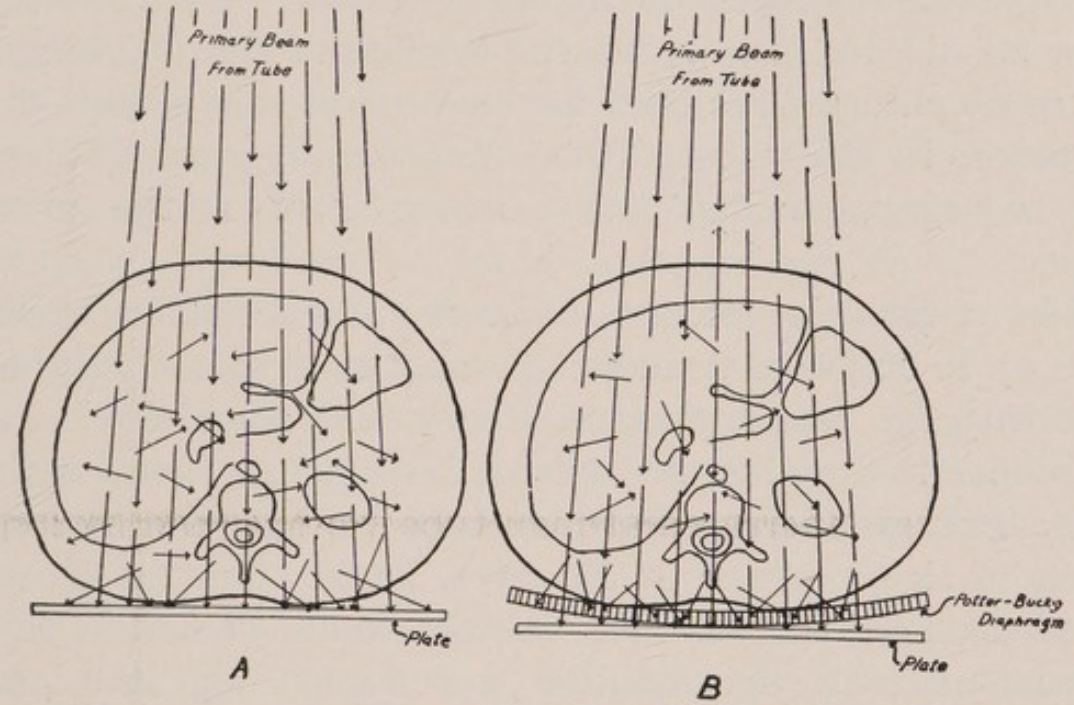


FIG. 63. Principle of the Potter-Bucky diaphragm. (From Weatherwax: Physics of Radiology.)

beam passes between the plates of the grid and strikes the film. Together with the x-ray beam they make the picture. Those components that go in other directions strike the plates of the grid and are stopped. (Fig. 63.) As the grid is moving at a steady rate no shadows of the grid plates appear on the radiograph. The resulting image is clear, as only those rays that come from the desired direction cast the shadow.

Most diaphragms are made as segments of a cylinder. It is the intention of the manufacturer that if the target of the tube is centered at a fixed distance (usually 25 inches) directly over the center line of the diaphragm every grid plate will be radial to the focal spot.

As the diaphragm is interposed, the object to be taken is farther from the film than usual. This increased distance

is least in the midline and greatest toward the sides. A radiograph made with the diaphragm is therefore distorted, the degree of distortion being least in the center line, increasing towards the periphery. The part under examination should be directly on the midline of the diaphragm. Some diaphragms are built flat, instead of as segments of a cylinder. In sizes up to 10 × 12 inches they are efficient, but in larger sizes may not be as satisfactory as the curved type.

The diaphragm removes scattered and secondary radiation up to 80 per cent under the most favorable conditions, and with the best apparatus. Every effort should be made to reduce the production of secondary and scattered radiation. Both are increased at high tube voltage, and by large areas of tissue struck by the rays. Even when the Bucky diaphragm is used the tube voltage should be as low as is consistent with the required penetration and the area exposed to the rays should be reduced with lead masks.

Detail in the *x*-ray film depends on the focal spot of the tube, just as in making radiographs without the grid. The exposure time must be doubled or trebled, as much of the radiation is stopped by the moving grid.

Diaphragms are heavy and are hard to handle. It is advisable to build the diaphragm into the table.

Intensifying screens are mounted in pairs in a cassette. The *x*-rays pass through one screen, called the front screen, before striking the film; then pass through the film and strike the back screen. Fluorescent light emitted by the screens thus affect both sides of the emulsion. Usually screens are made so that they may be used interchangeably either as a front or as a back screen. It is the constant endeavor of the manufacturer to reduce the absorption of radiation in the front screen, and in some instances screens are made so that one type is used for a front screen only,

and another type for a back screen. When this is done the screens are identified by the maker as "front" or "back."

Screens are easily damaged and readily soiled. They should be handled with the same degree of care that is shown appliances more impressive in appearance.

Cassettes are constructed so that the entire surface of both screens is pressed against the film. Usually the pressure is from steel springs on the back of the cassette; felt is interposed between the frame and the screens to ensure elasticity. Felt used in cassettes must be uniform in thickness, free from lumps, and radio-transparent. New felt may be fastened to the cassette with shellac. Intensifying screens may be fastened to the felt by applying a small piece of double faced adhesive linen at each corner, or a drop of tire patching cement.

It is sometimes advisable to test a cassette to determine if radiographs taken with it will show good detail. A convenient method is as follows: One inch above the entire surface of the cassette place a wire screen with a quarter or half inch mesh. Expose to *x*-rays and develop the film. The shadows cast by all the wires should be distinct. If any are blurred, the approximation of screens and film is not correct.

Speed. The speed of intensifying screens is fairly constant. Should variation between different cassettes be noted, it is a good plan to take one cassette as an arbitrary standard and grade the others by comparison with it. It may be noted that the effective speed of an intensifying screen can be judged only when some object is interposed. Such an object may be a block of paraffin or wax about 2 inches thick.

Care of Cassettes. Each time a cassette is loaded the surface of the screens should be brushed with a soft brush or wiped with a flannel cloth, to remove dust picked up from the films. Any particles of foreign matter show in the radiograph

as white specks. The screens may become soiled in other ways, for example, fingermarks of the technician may appear. From time to time the screens should be inspected in strong light. If necessary they may be washed gently with soap and water, followed with clear water, wiped dry, and laid aside with the cassette open until no trace of moisture remains.

Stereoscopy. A stereoscopic pair may be made as follows: One film is exposed; without moving the patient a second film is placed in the exact position of the first, the tube is shifted, and the second film is exposed. Usually the films are changed in a tunnel; special apparatus is required for the chest. The tube shift varies with the distance between the tube and the film.

Distance, focal spot of the tube from the film (inches)	Tube shift (inches)
25	2.5
30	3.
48	5.
72	7.

The stereoscopic pair of radiographs is placed in a stereoscope. A stereoscope is a pair of illuminating boxes and a pair of mirrors. The illuminating boxes should be 25 inches from the mirrors. By looking into the mirrors both films can be viewed simultaneously. The eyes are in the position of the tube at each exposure; the picture perceived is in three dimensions, just as any view seen by both eyes is in three dimensions.

If the tube shift has been in the long axis of the body, the films must be placed in the illuminating boxes so that the eyes will be in the long axis of the body. If the films are not thus placed, there will be no stereoscopic effect. If the films are placed askew, the eyes may attempt to correlate the images by rotating one or the other eye ball, and eye strain results.

When drawing conclusions from stereoscopic radiographs, it is well to consider the limitations of stereoscopic vision as we practice it in our daily lives. Stereoscopy is useful, but it is not accurate.

Immobilization. The slightest motion during exposure blurs the picture. The comfort of the patient must be kept constantly in mind, as a patient in a painful, constrained, or even awkward position is liable to move. Twitching of wounded muscles or the voluntary attempt of a patient to keep a part quiet will result in muscular tremor.

Immobilization can be obtained most easily by weighting the parts above and below the area to be examined by sandbags. These sandbags should not be completely filled. Cotton pads may be placed against a limb and the sandbags packed against the pads.

Immobilization of certain parts is secured by reducing the exposure time. The lungs should be exposed for one-fifth of a second or less, as the contractions of the heart shake the lower lobes; during the short exposure the heart may be at rest or in diastole. The stomach should be exposed for one second or less, because of peristaltic movement.

When making films of parts close under the diaphragm, such as the gall bladder or kidneys, the patient must hold the breath. This is more easily done at inspiration; but inspiration should be moderate, as at forced inspiration the diaphragm twitches. Some persons can hold the breath longer than others; a limit of exposure of ten seconds is usually safe, but four seconds is better.

Exposure Tables. Without doubt the best work is done when voltage, current, distance, and time are chosen with reference to the particular case in hand.

For the convenience of the operator two exposure tables have been prepared. In the first, only two values of voltage are given, and the exposure time is varied; this table is useful for *x*-ray apparatus not provided with a convenient

method of voltage control. In the second table the voltage is varied and the time is changed less; this table may be used for apparatus that has convenient methods for control.

The tables have been prepared for an average patient weighing 150 pounds. The technique should be varied for parts that are larger or smaller than the average. It may be noted that more radiation is absorbed in muscle than in fat; muscular individuals require more voltage or a longer exposure time.

Different types of *x*-ray machines produce different amounts of radiation when the same voltage is impressed upon the tube. Even the same machine, installed under different conditions of electric service, may give a different output. An *x*-ray laboratory should vary the suggested technique to conform to local conditions. An individual operator develops his own technique. It may be remembered that radiographs are often sent from one hospital to another, and are useful only when they are made under standard conditions of posture and target-film distance. This especially applies to films of the lungs.

X-ray tubes have a long life when they are used within the limits prescribed by the manufacturer. When used with excessively high voltage or current, they are liable to puncture or burnout.

On the same *x*-ray machine, the amount of radiation varies directly with the time of exposure and with the current in milliamperes, and inversely with the square of the distance. The amount of radiation varies decidedly with the voltage; unfortunately the change does not follow any convenient formula. This variation of radiation with different electrical conditions is fully described in pages 120 to 125.

The technique finally adopted for the individual laboratory should be well within the limit of power of the apparatus and of the tubes, and should be as simple as is possible. It is a good plan to post the technique near the exposure switch.

EXPOSURE TABLE, NO. I

Part	View	Gap	M.A.	Distance	Time			Bedside Unit Using 5″ Gap 10 ma. with 30″ Distance Time	
					Without Screens	With Screens	Bucky Diaphragm Screens	Without Screens	With Screens
Hand	P.A.	4″	10	30″	5	...	..	2	
Hand	Obl.	4″	10	30″	6	...	..	3	
Wrist	P.A.	4″	10	30″	5	...	..	3	
Wrist	Lat.	4″	10	30″	6	...	..	4	
Ulna & radius	A.P.	4″	10	30″	7	...	..	5	
Ulna & radius	Lat.	4″	10	30″	7	...	..	5	
Elbow	A.P.	4″	10	30″	7	...	..	5	
Elbow	Lat.	4″	10	30″	7	...	..	5	
Humerus	A.P.	4″	10	30″	7	...	..	6	
Humerus	Lat.	4″	10	30″	7	...	..	6	
Shoulder	A.P.	4″	10	30″	..	6	..	..	4
Clavicle	A.P.	4″	10	30″	..	6	..	..	4
Scapula	A.P.	4″	10	30″	..	6	..	..	4
Foot	A.P.	4″	10	30″	4	...	..	2	
Foot	Lat.	4″	10	30″	7	...	..	3	
Ankle	A.P.	4″	10	30″	7	...	..	3	
Ankle	Lat.	4″	10	30″	6	...	..	4	
Tibia & fibula	A.P.	4″	10	30″	10	...	..	6	
Tibia & fibula	Lat.	4″	10	30″	10	...	..	6	
Knee	A.P.	4″	10	30″	12	...	..	7	
Knee	Lat.	4″	10	30″	12	...	..	7	

EXPOSURE TABLE, NO. I. (*Continued*)

Part								Beside Unit Using 5″ Gap 10 ma. with 30″ Distance	
					Time			Time	
	View	Gap	M.A.	Distance	Without Screens	With Screens	Bucky Diaphragm Screens	Without Screens	With Screens
Femur	A.P.	4″	10	25″	..	...	15	..	5
Femur	Lat.	4″	10	25″	..	...	15	..	5
Hip	A.P.	5″	20	25″	..	...	10	..	6
Pelvis	A.P.	5″	20	35″	..	...	10	..	6
Cervical spine	A.P.	5″	20	30″	..	...	4	..	2
Cervical spine	Lat.	4″	100	72″	..	2	..	..	3
Dorsal spine	A.P.	5″	20	30″	..	...	15	..	6
Dorsal spine	Lat.	5″	20	30″	..	...	25	..	16
Lumbar spine	A.P.	5″	20	30″	..	...	15	..	6
Lumbar spine	Lat.	5″	20	30″	..	...	45	..	18
Skull	A.P.	5″	20	25″	..	...	10	..	8
Skull	Lat.	5″	20	25″	..	...	6	..	4
Mastoids	Lat.	5″	20	Cone	..	4			
Sinuses	Lat.	4″	20	30″	..	4			
Sinuses (antra)	P.A.	5″	20	Cone	..	6			
Sinuses (frontal)	P.A.	5″	20	Cone	..	6			
Nose	Lat.	4″	100	72″	..	1			
Stomach	P.A.	4″	100	25″	..	½			
Stomach	Obl.	4″	100	25″	..	1			
Heart	P.A.	4″	50	72″	..	2			
Lungs	P.A.	4″	100	48″	..	⅓	..	..	1

Cones are 5½ inches in length.

EXPOSURE TABLE, NO. II

Part	View	KVP	Pre-reading Voltmeter	MA.	Distance	Time		
						Without Screens	With Screens	Diaphragm Screens
Hand	P.A.	55	..	10	30	10		
	Obl.	55	..	10	30	10		
Wrist	P.A.	60	..	10	30	10		
	Lat.	65	..	10	30	10		
Forearm	A.P.	65	..	10	30	10		
	Lat.	70	..	10	30	10		
Humerus	A.P.	65	..	10	30	10		
	Lat.	65	..	10	30	10		
Shoulder	A.P.	85	..	10	30	10		
Clavicle	P.A.	85	..	10	30	10		
Scapula	A.P.	85	..	10	30	10		
Foot	A.P.	65	..	10	30	10		
	Obl.	65	..	10	30	10		
Ankle	A.P.	70	..	10	30	10		
	Lat.	70	..	10	30	10		
Leg	A.P.	70	..	10	30	10		
	Lat.	70	..	10	30	10		
Knee	A.P.	75	..	10	30	10		
	Lat.	75	..	10	30	10		
Femur	A.P.	85	..	10	25	..	..	10
	Lat.	85	..	10	25	..	..	10
Pelvis	A.P.	85	..	10	25	..	..	10

EXPOSURE TABLE, NO. II. (*Continued*)

Part	View	KVP	Pre-reading Voltmeter	MA.	Distance	Time		
						Without Screens	With Screens	Diaphragm Screens
Spine								
Cervical	A.P.	75	..	100	72	..	1	
	Lat.	75	..	100	72	..	1	
Dorsal	A.P.	60	..	10	25	..	...	30
	Lat.	60	..	10	25	..	...	30
Lumbar	A.P.	60	..	10	25	..	...	30
	Lat.	85	..	10	25	..	...	30
Head								
Skull	A.P.	80	..	20	25	..	...	10
	Lat.	70	..	20	25	..	...	5
Sinuses								
Nose-chin	....	80	..	20	Cone	..	5	
Nose-forehead	....	75	..	20	Cone	..	5	
Lateral	....	60	..	20	25	..	5	
Mastoid	....	70	..	20	25	..	5	
Heart	P.A.	70	..	50	72	..	2	
Lungs	P.A.	80	..	100	72	..	0.2	
	Obl.	80	..	100	72	..	0.5	
	Lat.	95	..	100	72	..	0.2	
Stomach	P.A.	90	..	60	25	..	...	1
	P.A.	80	..	60	25	..	0.5	
Colon	A.P.	80	..	60	25	..	...	2
Gall bladder	P.A.	60	..	100	25	..	...	3.5
Kidney	P.A.	60	..	100	25	..	...	4
Fetus	A.P.	85	..	60	..	..	...	4

Positions for Exposure. *Bones and Joints.* Place the patient so that the film will be as close to the patient as is practicable. Place the tube directly over the part to be examined. The entire length of the bone should be demonstrated. The films are made in two positions: one anteroposterior, and the second, lateral. When a lateral position is impracticable, as at the hip or shoulder, dependence must be placed on a stereoscopic pair. To meet the requirements of an individual case other positions may be added.

When there has been injury near a joint, the bones above and below the joint should be included; it may be necessary to demonstrate them on separate films if the extremity cannot be straightened.

Parallel bones are usually placed in such position that their shadows will not be projected one over the other; thus in side views of the hand or foot the best position is oblique instead of an exact lateral. An exception to this general rule is the lower end of the forearm; here the usual injury is a Colles' fracture, and an accurately made lateral film is required to demonstrate the important angle between the plane of the joint and the shaft of the radius.

The spine calls for particular care. The normal curvatures are shown in Figure 72. Anteroposterior films may be made as indicated in the diagram. Lateral films are indispensable. When these are made the spine should be straightened by packing cotton pads under the lumbar region.

Lungs. A uniform position is important, because repeated radiographs are often made of the same case. Should the position of the patient and the tube vary, the films are not comparable with films made weeks or months previously.

Adult. Posteroanterior. Stereoscopic films are recommended, although many observers are content with a single film. The tube should be not less than 4 feet from the film; 6 feet is preferable, and is the proper distance when the power of apparatus permits. Intensifying screens are always used.

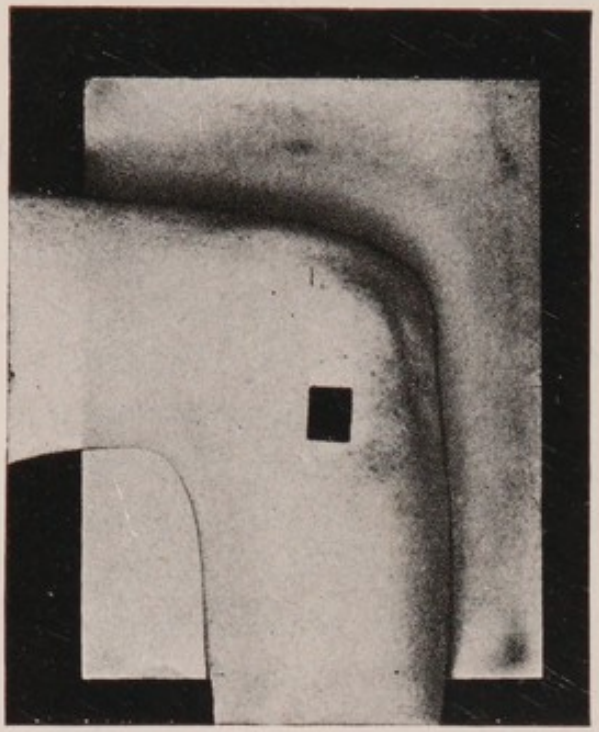


FIG. 64. Elbow, lateral view.

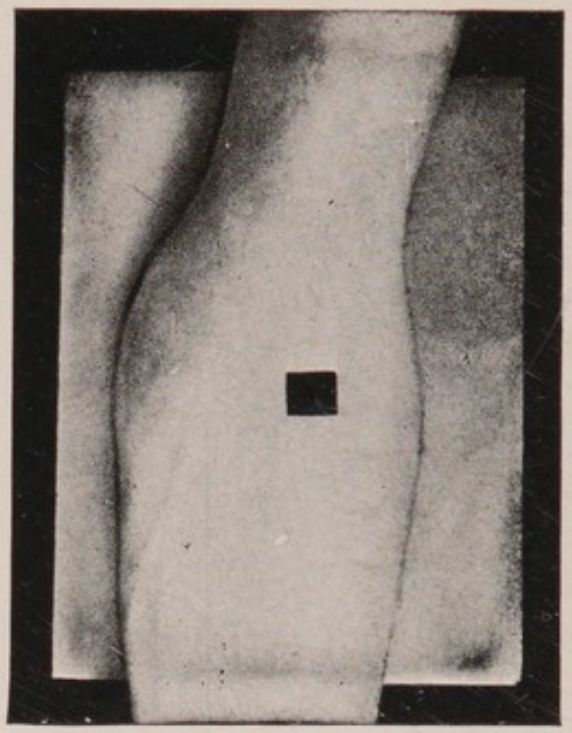


FIG. 65. Elbow, anteroposterior view.

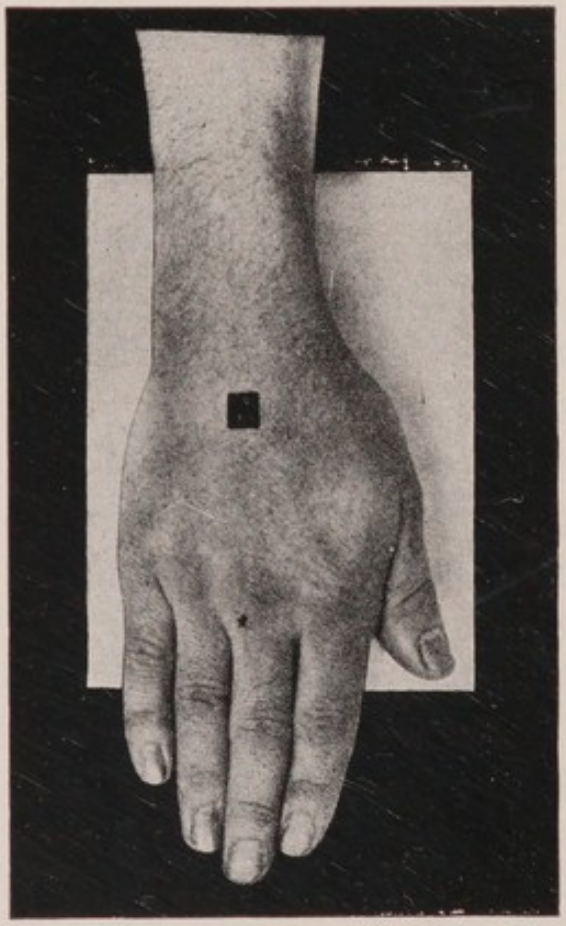


FIG. 66. Wrist, anteroposterior view.

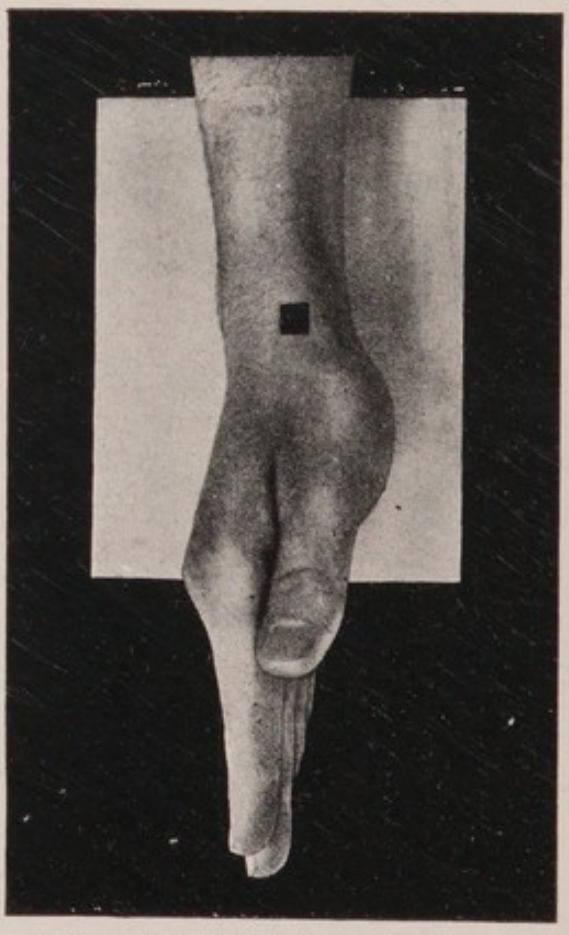


FIG. 67. Wrist, lateral view.

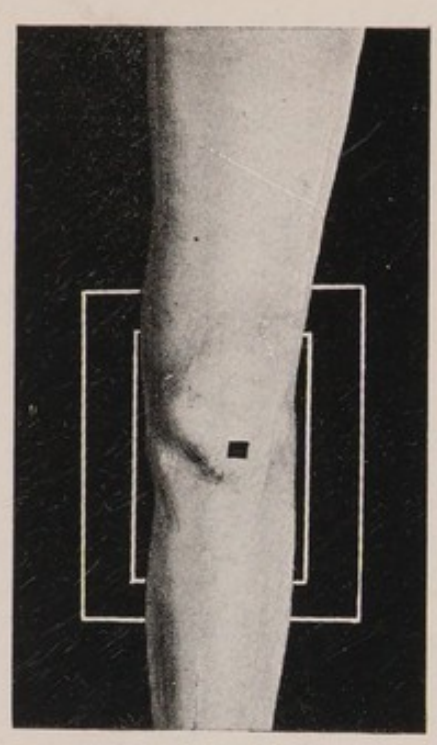


FIG. 68. Knee, anteroposterior view.

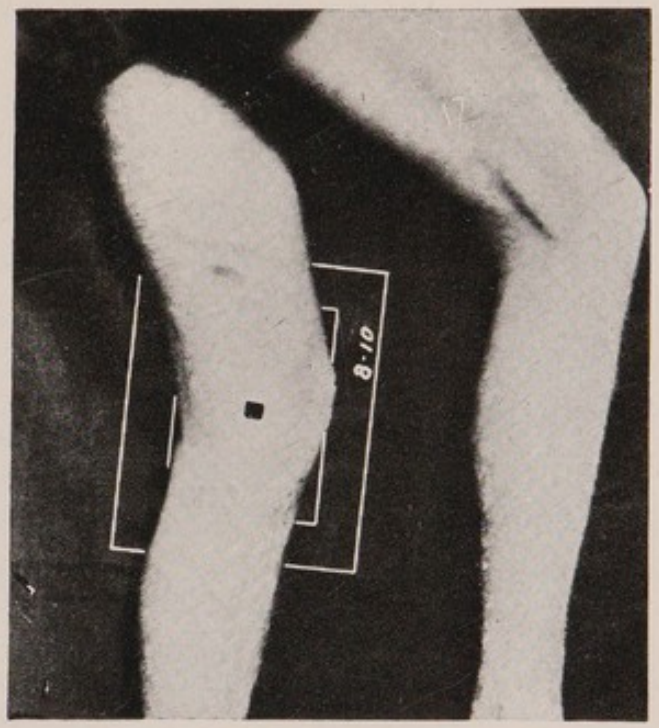


FIG. 69. Knee, lateral view.

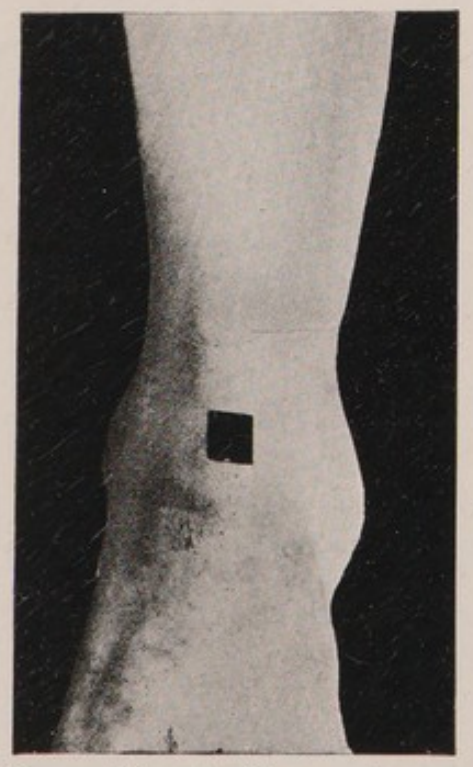


FIG. 70. Ankle, anteroposterior view.

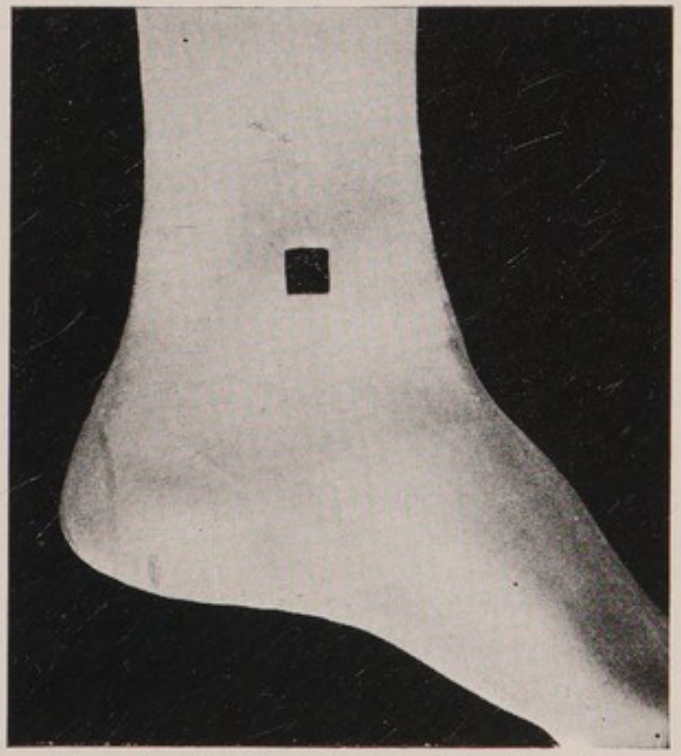


FIG. 71. Ankle, lateral view (marker over internal malleolus).

The patient is upright, the front of the chest squarely against the cassette changer. The neck is extended, and the cassette changer is brought up under the chin. The hands are

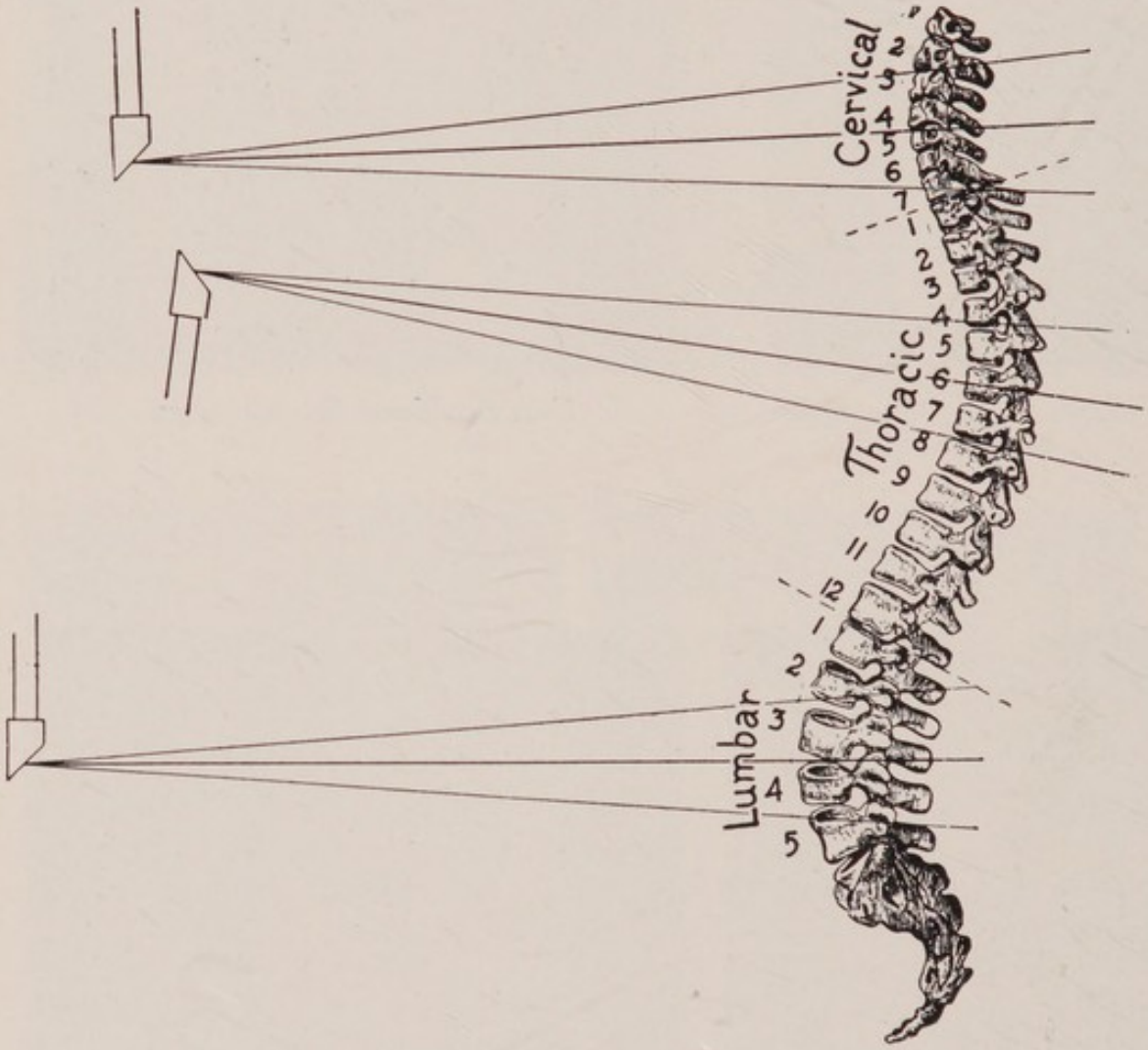


FIG. 72. The normal spine has general divisions into cervical, thoracic and lumbar. The projection lines from targets do not represent standard positions, but simply illustrate the projection, if the central rays are perpendicular to spinal column. The operator can vary opening of cone, size of plate and position so as to bring out special features desired.

placed behind the back and the elbows are brought forward, so that the scapulae will be forward and rotated.

The tube is centered on the center of the cassette.

The exposure is made at full inspiration. When a stereoscopic pair is made, the patient should hold the breath until after the second exposure. With proper apparatus for shifting the tube and changing the cassettes the entire procedure should not take longer than three seconds.

Lateral. The target-film distance should be 6 feet, as films made at a shorter distance are seldom informative. The Bucky diaphragm is recommended.

Oblique. The position that will determine the pathological condition the best may be determined by preliminary fluoroscopy.

Superlordotic. The patient stands facing the tube, the shoulders resting on the cassette, the feet and hips brought forward, the back arched until the direction of the ray coincides with the interlobar fissure between the upper and lower lobes, left, and the middle and lower lobes, right. This position is conveniently determined by preliminary fluoroscopy. The exposure time is the same as for a lateral position.

Children are more conveniently placed sitting, the back against the cassette; the knees should be drawn up, the forearms placed in the lap, the head straight forward. One film is made at full inspiration, and a second film at full expiration.

Infants are best examined recumbent, supine. One towel is placed over the lower chest, a second over the knees; both are weighted with sandbags to ensure restraint. The head is held exactly perpendicular to the cassette. One film is made at full inspiration, and a second film at full expiration.

Heart. The position of the patient is the same as for the posteroanterior view of the lungs. The target film distance is not less than 6 feet. The exposure time is not less than two seconds. The exposure time should be long enough to include one entire heart cycle. The size of the heart cannot be

estimated by the examination of films taken with the technique described for the lungs, as the exposure time is so short the heart might be either in diastole or in systole.

Mastoid. The position is described in page 309.

Sinuses. The positions are described in pages 298–304.

Urinary Tract (Kidneys and Ureters). Both right and left urinary tract should be included on the films, as a calculus may be found on the side opposite to that indicated by the symptoms. An examination of a single area is permissible only when done for verification. The right and left side of the patient must be identified by placing a lead R or L on the cassette at the time the radiograph is made.

The patient is supine, the knees flexed. Two 14 × 17 films are made: (1) The crest of the ilium is one inch above the midline of the Bucky diaphragm. (2) The iliac crest is one inch below the midline of the diaphragm.

The exposure is made at inspiration; the inspiratory effort should not be forced, as the diaphragm is liable to quiver.

Record System. Where a large amount of radiographic work is done, a well-organized record system is indispensable. In all cases the record should show on the negative.

When a patient comes to the laboratory for the first time, enter on a record card the name and such other data as may be required for identification.

Assign a serial number; enter it on the record card and on the report form. When the patient returns for further examinations the same number is assigned.

The number is set up in lead figures on a strip of adhesive plaster, or punched in a metal strip.

At the time the radiograph is made and before exposure, place on the cassette the identifying number, the date, and a lead R or L to denote the right or left side of the body.

Filing. Record cards in alphabetical order. Duplicate reports by serial number. Films by serial number; all films

of the same number are filed in one envelope regardless of date.

Small laboratories may conveniently substitute a book for the record cards, file the duplicate reports in alphabetical order, and the films by serial number.

X-ray films consist of a thin layer of gelatin containing a salt of silver, spread on both sides of a cellulose support. Light and *x*-rays cause a change in the silver salt such that suitable chemicals, called developers, act on the portions that have received the radiation, changing the silver compound to metallic silver, and thus rendering those portions more or less opaque to light. The opacity produced will depend on the amount of radiant action, on the sensitiveness of the emulsion, and on the development. Those portions receiving much light or *x*-rays, when fully developed, may be quite opaque; other portions may be entirely or nearly transparent.

After development the plate is washed and placed in a "fixing" bath which removes the unused silver salt, as shown by the disappearance of the cream color of the emulsion, rendering the parts not radiated and developed transparent.

All films sensitive to x-rays are also sensitive to ordinary light and hence they must be entirely protected from ordinary white light until finished.

The emulsion is an example of unstable chemical structure and may be injured by (1) moisture, (2) high temperature, (3) contact with other material, (4) exposure to light or *x*-rays, (5) bending.

Developing is an exact chemical procedure. A definite relationship exists between the time required for development and the temperature of the solution.

A correctly exposed film will be of proper density following five minutes' development in a freshly prepared solution

at 65° Fahrenheit. Variations of 2° or 3° are permissible. When it is not possible to maintain the temperautre of the solution at 65°, the developing time may be changed

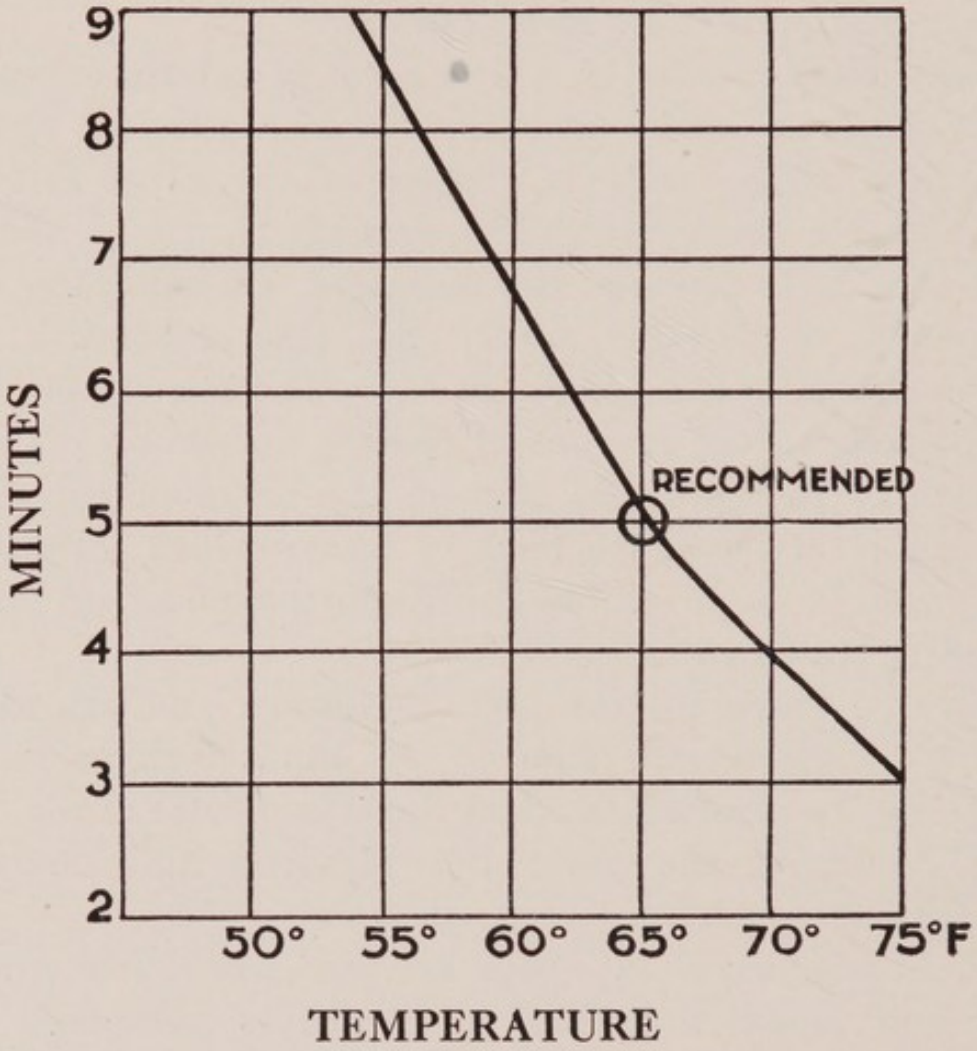


FIG. 73. Time-temperature chart.

according to the chart (Fig. 73).

The solutions may be maintained at the proper temperature by immersing the tanks in a water bath. Ice should not be added to the solutions as it would dilute them.

It is a safe rule that developing technique should not be varied to compensate for possible errors in exposure. Development by inspection is objectionable. When the film is removed from the tank the developing solution

retained on the surface becomes oxidized, causing chemical fog.

While five minutes' development is recommended for a freshly prepared developing solution, unfortunately the solution becomes weakened through use. This change is gradual, and depends on the size and number of films developed. The loss in strength is compensated by increasing the developing time. There are two methods for computing the proper developing time:

1. *Watkins' Constant.* Test strips are prepared by exposing a film partly covered with a strip of lead through the center. The film is then cut in strips, each strip having an exposed and an unexposed portion.

On the day the solution is freshly prepared, immerse one strip in the developing solution and note the time required for the image first to appear. Divide this time into the normal developing time (five minutes at 65°F.). This will give a number known as Watkins' Factor. Each day thereafter immerse one strip in the developing solution until the image first appears, and multiply the time by the factor. The result gives the proper developing time for the day. When the time exceeds eight minutes the solution should be discarded.

2. *Film Counting.* This method requires that the number of films developed be recorded, which can be done more easily by using cross-section paper. One square is crossed out for each 14 × 17 film; one square for two 10 × 12 films; and one square for three 8 × 10 films. After crossing out 80 squares, the developing time is increased to six minutes; after 40 more, to seven minutes; after 30 more squares the solution should be discarded. These figures are computed for a tank containing 6 gallons.

Fresh developing solution should be added at intervals to keep the level in the tank sufficiently high to cover the larger films.

Developing Solution. The prepared developing powders are convenient. Where prepared powders are not available the following formula is recommended:

	Avoirdupois	Metric
Metol or Elon	1⅔ oz.	50 gm.
Hydroquinone	6⅔ oz.	230 gm.
Sodium sulphite	4 lbs. 6 oz.	2100 gm.
Sodium carbonate	2 lbs. 3 oz.	1050 gm.
Potassium bromide	4¼ oz.	130 gm.
Water to make	5 gallons.	20 litres

Mixing developing solution: Enameled containers should be used. Under no circumstances should metal, other than monel or silver, come in contact with the solution. Copper even in minute quantities (1 part in 10,000) will produce chemical fog.

To 4 gallons of water (approximately 125°F.) add one pound of sodium sulphite; then add the metol (or elon) and hydroquinone; dissolve thoroughly; add the remainder of the sodium sulphite and the sodium carbonate. Dissolve the potassium bromide in a quart of water and add; stir thoroughly and add sufficient cold water to make up 5 gallons.

In certain localities, due to impurities, distilled water must be used instead of tap water.

The tanks and containers should be cleaned thoroughly before filling with fresh solution.

An additional gallon of developing solution should be at hand to maintain the proper level in the tank.

The tank should be covered when not in use, to prevent the developing solution from oxidizing. A wooden lid that will fit inside the tank may be treated with paraffin dissolved in gasoline; this makes a satisfactory floating lid.

After exposure the films are removed from the cassettes in the dark room and clipped into developing hangers. They are placed in the developing solution and raised and lowered several times to release air bubbles. The interval timer is set for the required time, and the film is removed from the solution on the signal from the timer.

It is quite important that the films be rinsed thoroughly before they are moved to the fixing bath. As the fixing bath is acid and the developing solution alkaline, unless the films are rinsed the fixing bath becomes neutralized; the hardening action of the fixing bath is then impaired, and the films may become stained.

Fixation removes from the film emulsion the silver salts unaffected by the developing solution, in order that the film will undergo no further change and become a permanent record. This is accomplished by immersing the film in a solution containing sodium thiosulphate (hypo).

A fixing bath, in addition to removing the unaltered silver halide, must also harden the gelatin coating without producing stain. Potassium alum and acetic acid or chrome alum and sulphuric acid are added to the fixing bath for this purpose.

Satisfactory fixing powders are available, or a solution may be prepared as shown on page 160.

Dissolve in the order given.

Mix solution A in the tank and solution B in a white enameled container.

After the sodium sulphite has been dissolved completely, add the acetic acid, then the alum, and stir until a clear solution is obtained.

When solution B has cooled, pour into A very slowly while an assistant stirs constantly. Sufficient water should be added to make 15 gallons. Unless the hypo is dissolved com-

FIXING SOLUTION (POTASSIUM ALUM)

	Avoirdupois	Metric
Solution A		
Water	10 gallons	40 litres
Hypo	30 pounds	14 kg.
Solution B		
Water	3 gallons	12 litres
Sodium sulphite	1.5 pounds	720 gms.
*Acetic acid (28 per cent)	2 qts. 10 ozs.	1250 c.c.
Potassium alum	1.5 pounds	720 gms.

* The acetic acid is given in liquid ounces. To make 28 per cent acetic acid from glacial acetic, take 3 parts of glacial acid and add 8 parts of water.

pletely before adding solution B, a yellow precipitate of sulphur is likely to form.

The temperature of the fixing bath should be the same as that of the developing solution.

The film should be left in the fixing bath twice the time apparently required to clear. To secure maximum hardening the film should remain in the solution at least fifteen minutes.

Washing. The purpose of washing is to remove from the film the chemical products formed during fixation. In order to insure permanency of the radiograph, it is not only necessary that fixation be complete, but that all traces of the fixer be removed.

The temperature of the wash water should not vary more than 10°F. from the temperature of the developing and fixing solutions.

The time required for washing depends on the rate at which the hypo and soluble salts formed during fixation

diffuse out of the gelatin emulsion. This depends on the rate the water in the washing tank changes, and how freely the water circulates over the surface of the films. Ordinarily twenty-five to thirty minutes are required.

The film and the hanger in which it is clipped should be completely submerged, so that every trace of fixing solution will be removed from both. If hypo remains on the hanger it will contaminate the developing solution when the hanger is used again.

Drying. The drying rack should be so constructed that the films hang end-on toward a fan, but cannot swing far enough to touch each other.

The rate of drying may be expedited by fitting the drying cabinet with an electrical heating arrangement. As a safety measure the heating element should be so arranged that the current cannot be applied without the fan operating.

Developing at High Temperatures. Success in processing *x*-ray film at high temperatures depends upon the following factors: Short time of development, so that the gelatin does not have time to swell excessively; thorough rinsing between developing and fixing; agitation of the film in the fixing bath for at least fifteen seconds after immersion; the use of a special hardening fixing bath; and limiting the time of washing to fifteen minutes.

Dissolve the constituents of solution A and *bring to the temperature of the supply water.* Then mix solution B by adding the chemicals in the order given and *cool to the same temperature.* Then add solution B to solution A while stirring the latter thoroughly.

If the solutions are mixed in a deep tank and the hypo bath is not adequately stirred, the chrome alum solution will tend to float on top of the hypo solution, and sulphurization is likely to occur. Solutions A and B must be cool when mixed, otherwise the bath will sulphurize.

HARDENING FIXING BATH FOR HIGH TEMPERATURES
(Small Tank or Tray)

	Avoirdupois	Metric
Solution A		
Hypo	20 oz.	600 gm.
Sodium sulphite (desiccated)	1 oz.	30 gm.
Water to make	48 oz.	1½ liters
Solution B		
Water	10 oz.	300 c.c.
Sodium sulphite (desiccated)	⅓ oz.	10 gm.
Sulphuric acid 5 per cent*	2½ oz.	80 c.c.
Potassium chrome alum	2 oz.	60 gm.
Water to make	16 oz.	500 c.c.
(Tank)		
Solution A		
Hypo	15 lb.	7 kg.
Sodium sulphite (desiccated)	10 oz.	200 gm.
Water to make	4½ gal.	18 liters
Solution B		
Water	1 gal.	3½ liters
Sodium sulphite (desiccated)	4 oz.	120 gm.
Sulphuric acid 5 per cent	32 oz.	960 c.c.
Potassium chrome alum	26 oz.	770 gm.
Water to make	1½ gal.	6 liters

* To prepare 5 per cent sulphuric acid, add one part by volume of concentrated sulphuric acid to 19 parts by volume of cold water and mix carefully with stirring. The acid must be added to the water and not vice versa, otherwise an explosion is liable to occur.

It is not desirable to store the solution B as a stock hardener because it loses its hardening properties on keeping.

Procedure. Develop for times not exceeding the following values: at 75°F., three minutes; at 80°, two and one-half minutes; at 85°, two minutes.

After development, rinse the films in water for at least fifteen seconds.

Immerse the films in the fixing bath and agitate them for at least fifteen seconds. If the films are not agitated, streaking is likely to occur.

Fix the films for at least fifteen minutes; the hardening increases with the time of fixing.

Wash the films in running water for a time not exceeding fifteen minutes; prolonged washing tends to soften the gelatin, even after thorough hardening in the fixing bath. To wash the films adequately in fifteen minutes, the hourly flow of water should be at least eight times the volume of the washing tank. The fixing bath should be renewed when its hardening power has diminished noticeably; it cannot be safely used after twenty $8'' \times 10''$ films, or the equivalent, per gallon have been fixed, and its hardening power cannot be depended upon to last longer than about two weeks, regardless of how little it is used.

Tray Development. Tray development is satisfactory only when the number of films to be developed is small. Three trays are required, one for each operation: developing, fixing and washing. They should be marked distinctly, since the tray used for washing should not be used for developing.

Compounding developing and fixing solutions from bulk chemicals is not economical. It is more satisfactory to employ prepared developing and fixing powders. Solutions will keep for a long period if kept cool in bottles fitted with glass stoppers.

Developing solution, at a temperature of 65°F., should be poured into the tray to a depth of at least ½ inch. In a darkroom, illuminated by a safelight only, remove the film from the cassette and immerse into the solution by a quick, sliding movement without pause. The film should be

turned over immediately and three or four times thereafter to liberate any airbells that might form on the under side of the film. Only one film is developed at a time. The tray should be rocked continually to ensure a constant change of solution over the film.

At the completion of development, approximately four minutes at 65°F., the film is removed, rinsed thoroughly, and placed in the fixing solution for twice the time required for apparent complete removal of the undeveloped silver salts (cream-colored substance). The white light may be used when the film has been immersed in the fixing solution for one minute.

On completion of fixation the film is placed in the tray for washing. A gentle stream of water is kept flowing into the tray. While one film only should be placed in the tray for developing or fixing, several films may be washed in the same tray. It is important, however, that the film be turned over several times. To remove all traces of the fixing solution from the film, washing should be for twenty minutes and the film should be then hung up to dry.

Always rinse and dry the hands after handling the film in the fixing bath. The slightest trace of fixing bath carried over into the developing solution will result in contamination.

Reducing Dense Radiographs.

Solution No. 1

Water	16 oz.
Potassium ferricyanide	1 oz.

Solution No. 2

Water	16 oz.
Hypo	1 oz.

Place the film in a solution made up of two parts of solution No. 2 and one part of solution No. 1, sufficient to cover

it, rock the tray, and watch the film carefully. If it reduces too slowly remove film while adding more of solution No. 1.

Wash films in running water at least a half hour after reducing.

Weights and Measures. In photographic practice solids are weighed and liquids measured either by the avoirdupois or the metric system.

Weight		Volume	
437½ grains	1 ounce	60 minims	1 fluid dram
16 ounces	1 pound	8 drams	1 fluid ounce
		16 ounces	1 pint
		128 ounces	1 gallon

When a formula is expressed in ounces and grains it may be converted into a metric formula by taking each gallon as 4 liters, each ounce fluid as 30 c.c., and each ounce solid as 30 gm. Actually one ounce solid equals 28.35 gm., but the round figures are sufficiently accurate.

Darkroom. The modern darkroom has a generous supply of fresh air and is painted in colors which reflect and distribute the illumination provided by the safelights. It has been found that the technician makes fewer mistakes and does better work in rooms where accommodations are ample and attention has been given to efficient arrangement. Each laboratory has its individual problems, but the following general considerations are applicable to all:

Fire Hazard. All partitions must be of fire-resistive construction. An adequate exit is required by fire laws. A fire extinguisher must be available, and there should be a metal container for waste. Smoking is prohibited. The best protection against fire is absolute cleanliness and order.

Ventilation. To prevent fogging of film all white light must be excluded when the room is in use. The most satisfactory method of ventilation is to force the air through ducts; it may be noted that the architect's estimate is

rarely sufficient. Air from the darkroom should not be expelled into other rooms because of its odor. If dependence is placed on light proof ventilators, they should be provided with fans. Entrance to the room should be by a labyrinth (maze). This improves ventilation and provides easy access. If there is a window, it should be fitted with an inside light-tight sash.

Protection from Radiation. Walls facing radiographic or treatment rooms should be protected from both direct and scattered radiation. This is accomplished best by lining such walls with sheet lead $\frac{1}{16}$ inch in thickness. In laboratories having high-voltage treatment equipment the thickness of the lead should be increased. Plaster impregnated with commercial barium is not recommended, as the plaster is liable to crack and the radio-opacity may be uneven. Ordinary wooden partitions offer no protection against radiation. Walls of brick or concrete are not adequate protection since they are rarely of sufficient thickness.

A simple method to determine whether radiation is penetrating through the darkroom walls is to place films loaded in exposure holders in different parts of the room. On each holder a strip of lead is fastened. Films left in position four days, and then developed, should show no image of the lead strip. Should a shadow of the strip be present, it is indicative that the walls are not sufficiently protected.

Color of Walls and Ceiling. The entrance maze should be painted flat black, while the walls of the room should be light in color, for example, light sage-green, light buff, or gray. The ceiling should be white. Black or red walls are depressing and unnecessary.

Illumination. It is recommended that the general illumination of the darkroom be indirect. An indirect light box fitted with a safelight may be suspended from the

ceiling. Other safelight lamps of the conical or direct illuminating type should be suspended from the ceiling directly over the loading and unloading table, while a wall or bench-type safelight lamp should be placed at the rear of the developing tank.

A safelight is safe only for a given length of time, depending upon the sensitivity of the film, intensity of the illumination (wattage of the lamp used must always follow the manufacturer's instructions) and the distance between the films and the source of light. The standard of safety adopted by the manufacturers of safelights permits the dry film to be handled without fogging for one-half minute at a distance of 3 feet from the light. When the film is wet it becomes less sensitive.

An illuminator should be provided for interpreting wet films. This illuminator should be placed at the rear of the washing compartment in order that the hypo solution from the film will drip into the wash water and not into the developing solution, for should this occur, the developing solution would become contaminated. The light switch on the illuminator should be the chain-pull type. A thumb switch is dangerous as it might be grasped with wet fingers.

A white ceiling light should be provided for illuminating the room when films are not being handled. Bright illumination tends toward keeping the room clean.

Darkroom Equipment. 1. A table or bench for loading and unloading cassettes or film holders. It should be fitted below with compartments for holding cassettes and film holders, and a light-tight bin for the film. Racks should be placed above the bench for holding the developing hangers; a separate rack should be provided for each size of the hangers.

2. Tank System. If possible there should be an outer water jacket fitted with four compartments to accommodate

containers for developing solution, fixing solution, rinsing, and washing. The tank should be so designed that water for cooling will circulate freely around the solution containers.

3. A sink, fitted with hot and cold water faucets.

4. An adequate drying cabinet, fitted with a fan and heating element.

5. White enameled containers for mixing the developing and fixing solutions.

6. Two wooden paddles, one each for stirring the developing and fixing solutions.

7. A thermometer for determining the temperature of the solutions.

8. An interval timer.

9. Safelights.

There should be no shelves, lockers, or closets except for the purposes indicated above. No chemicals, either in bulk or in packages, should be stored in the darkroom. The quantity of film kept in the darkroom should be limited to approximately one day's supply.

CHAPTER VI

FIELD UNIT

***X*-Ray Table.** The *x*-ray table consists of the following principal parts (Fig. 74):

1. Two aluminum end castings.

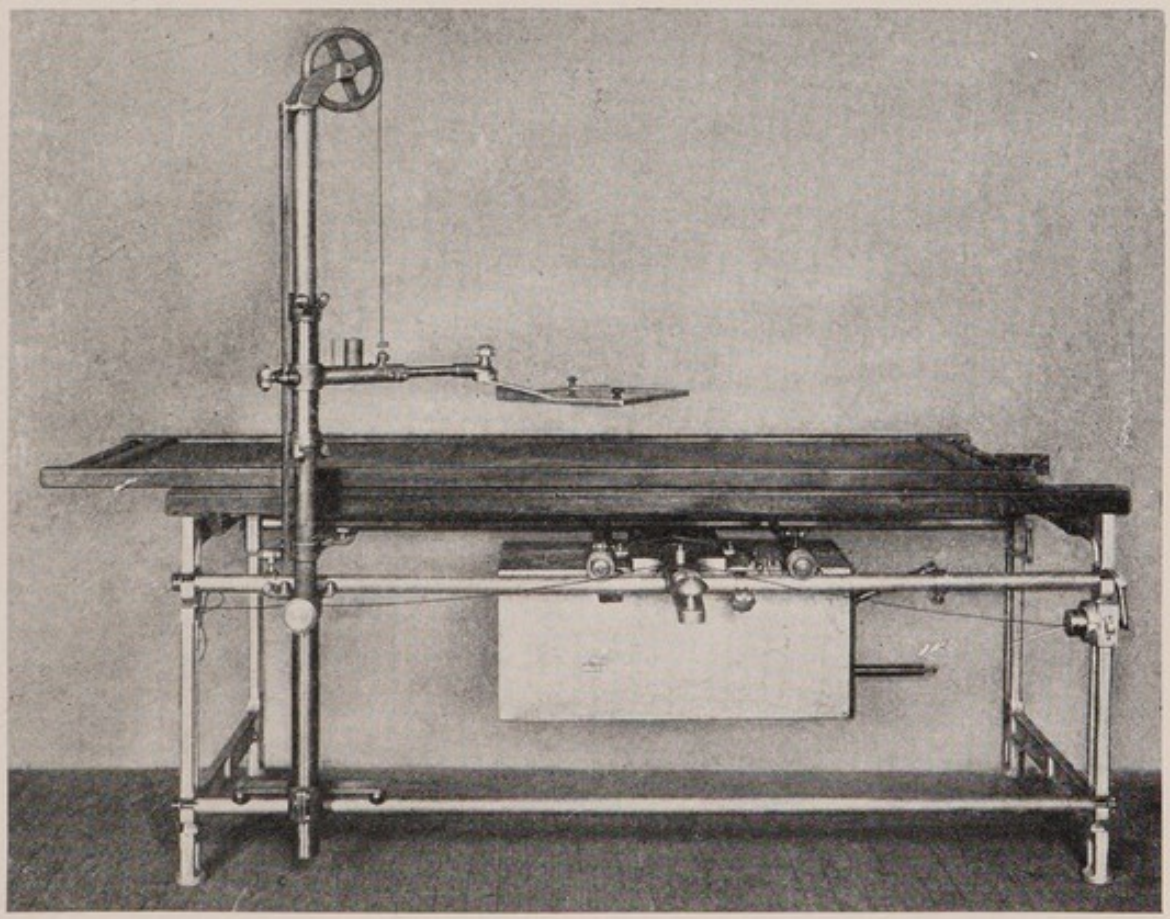


FIG. 74. Standard U. S. Army *x*-ray table complete with box for radiator type tube.

2. Three steel side rails.
3. A rectangular frame as a tube-box cradle.
4. A lead-covered tube box.
5. A special detachable shutter.
6. A rectangular wooden frame supporting a stretcher type top.

7. An operating switch.
8. A special screen carrier.
9. High tension vertical insulators.

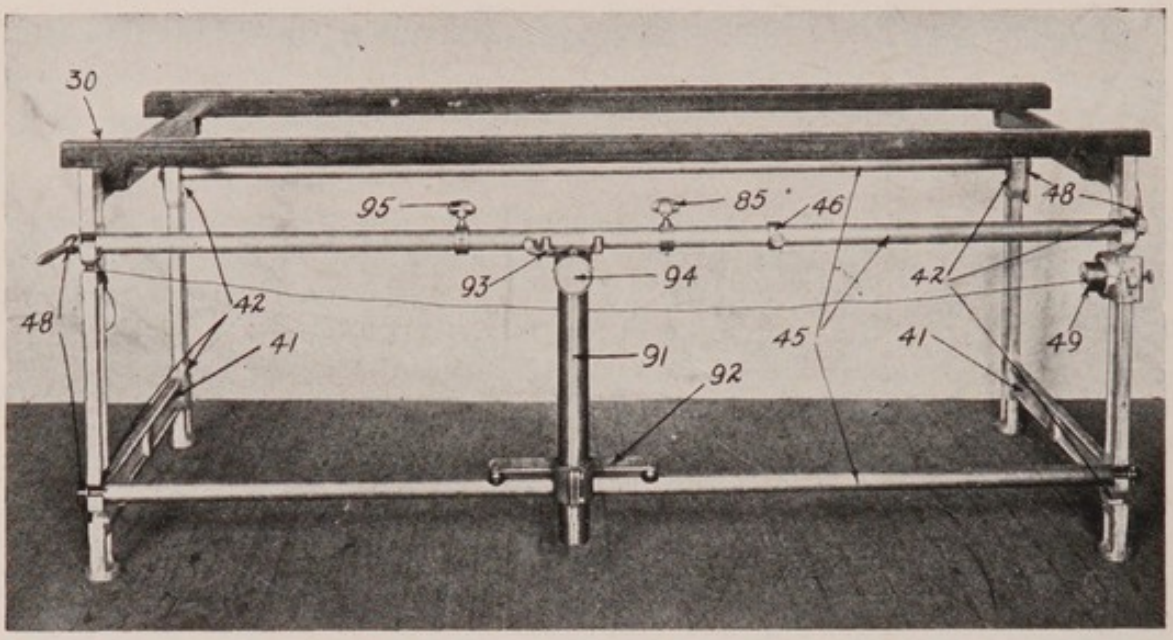


FIG. 75. Framework of standard Army *x*-ray table and operating pull switch (49).

10. A tube holder for working above the table.

When the table is to be used with the portable outfit a tube box designed for the radiator type of tube must be used. Any or all of numbers 8, 9, and 10 may be omitted in special cases.

In the description following, numbers in parentheses refer to the figures in the text, *not* to manufacturers' stock or replacement numbers.

End Castings (Fig. 75). The end castings (41) have four slots (42) on each side. These take the ends of the steel side rails. *Two* rails (45) are used on the operator's side of the table and *one* on the other side. When using the regular top the rails should be placed in the upper of each pair of slots. If one must use an army litter, use the lower slots. Holes are provided to mount the masts for overhead work.

Rails (Fig. 75). The round rails have tightening screws (48) with permanently attached handles. Sliding on one of these rails are three rings (46, 85, 95). The one at the

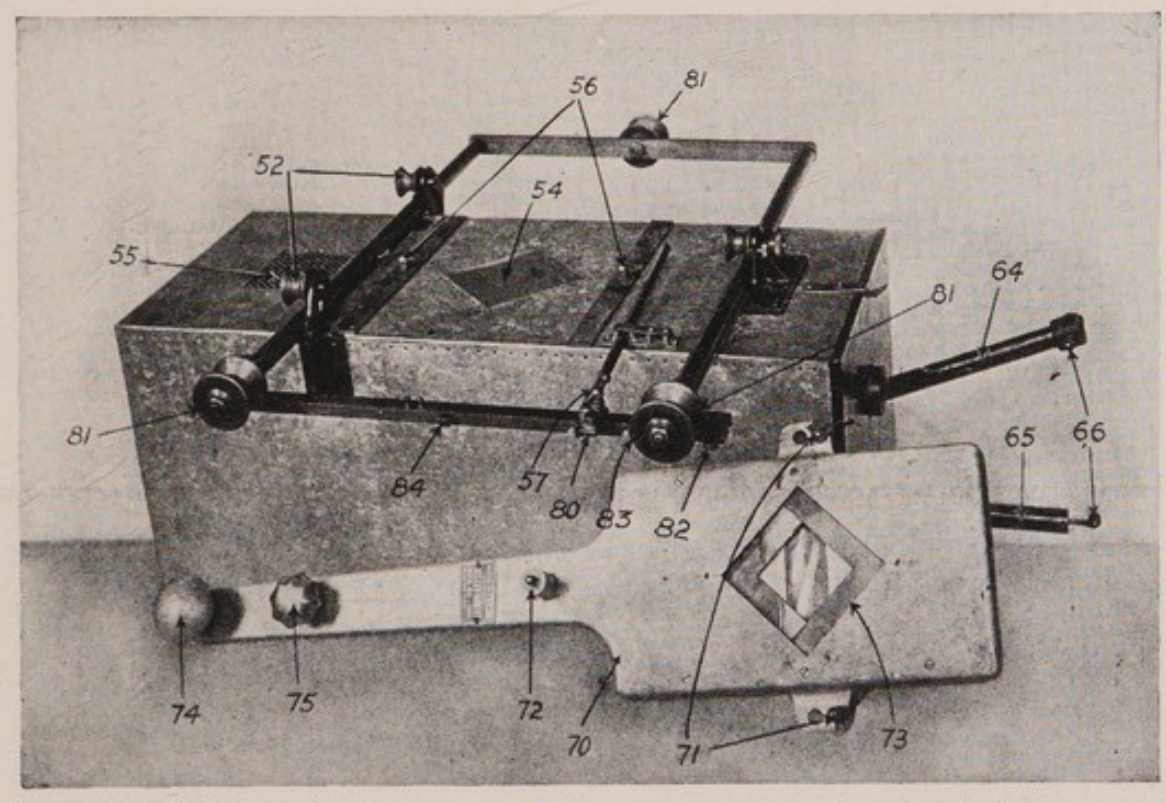


FIG. 76. Details of tube box, cradle and shutter, standard Army *x*-ray table.

left serves to lock the screen carriage, the center one locks the tube box against longitudinal run and also may be used to secure a tube shift of either 10 or 15 cm. The right-hand ring serves in measuring any desired tube shift. These should always be placed on the rail in the order shown.

Cradle (Fig. 76). The cradle has three roller-bearing wheels (81) to give longitudinal run on the side rails. The single roller in the right has a screw brake to be used when lifting the box. The cross piece on the operator's side carries a tube box brake (57) for lateral locking when in use, also three stops for tube shift measurement. The one near the center (84) is permanently attached, as is also the

one at the right (82). The third (83) is placed close to the roller and when the ring (85) is placed between (83) and (84) we have a 15 cm. shift; by changing the position of the

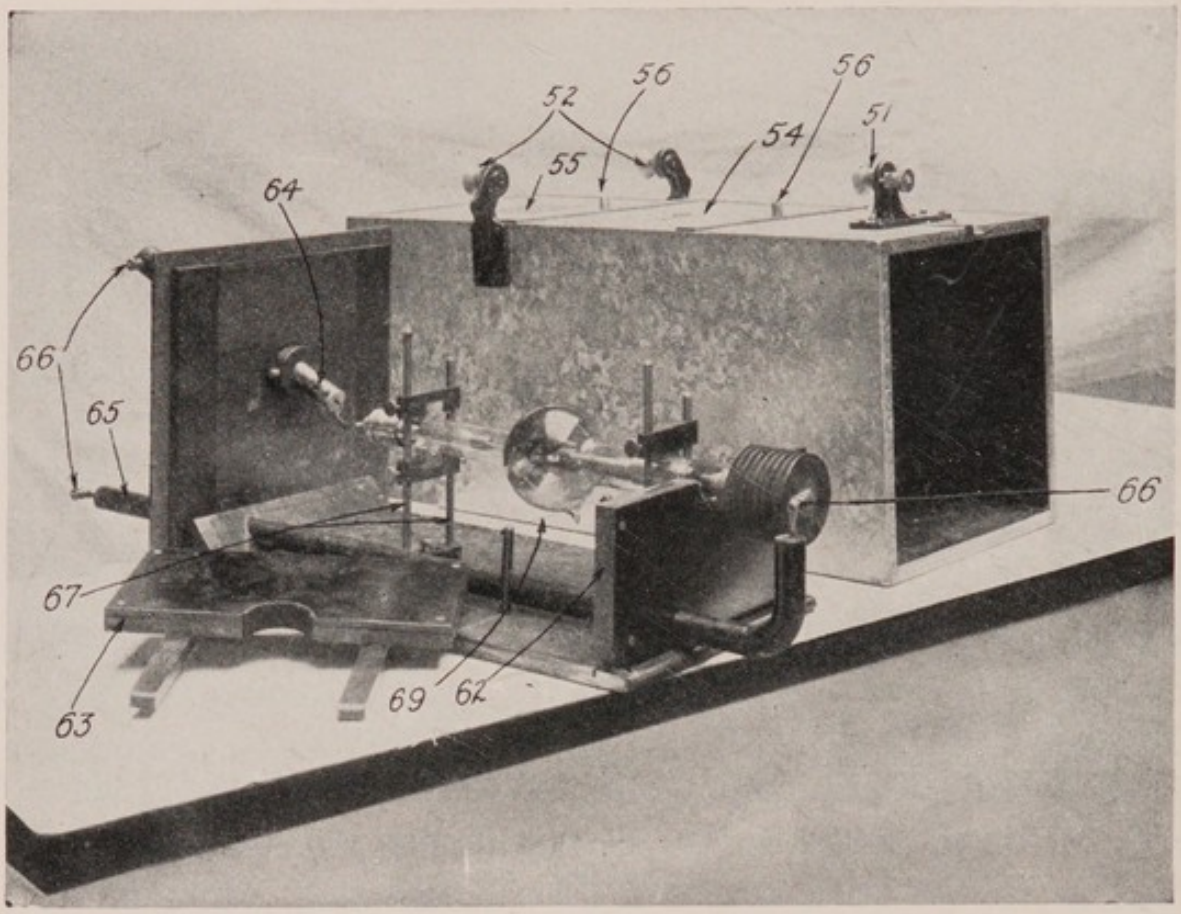


FIG. 77. Tube box and mount for radiator type tube, standard Army *x*-ray table.

screw (57) of the cross run brake, we may secure a 10 cm. shift between stop (84) and the stop (80) on the brake.

Tube Box. The tube mount slides into the box at the end. Figure 77 shows the mounting with insulators for the radiator type of tube. The partition (62-63) is covered with lead rubber and the upper portion is removable for insertion of the tube. The tube may be raised or lowered or shifted longitudinally for centering. The insulating posts with the transverse wire (69) are used in adjusting the target position. All connections to the tube are to be made *before* inserting the slide in the box.

Shutter (Fig. 76). The shutter has double slides; one pair controlled by the outer knob (74) gives a diamond-shaped opening; that controlled by the inner knob (75) gives a slit parallel to the length of the table. The shutter is attached to the box by the pins (56) and clamps (71), as shown, and these must be closed before using.

Top (Fig. 75). The rectangular frame (30) is narrower than the supporting ends of the table, permitting a slight lateral shift of the patient without disturbing him on the stretcher. A raised ridge projects on one side to engage a groove in the stretcher type of top. This allows a certain amount of longitudinal shift. A little paraffin as a lubricant on the ridge will serve to make the top move readily, even with a heavy patient.

Switch (Fig. 75). When using the "Delco" engine to operate the portable outfit the switch may open and close *two* circuits; in this case the *usual foot switch cannot be used.* A special pull switch (49) operated by a string running along the rail is supplied.

Screen Support (Fig. 78). The screen support was designed to enable the screen to be carried to any working position parallel to the table top without having any portion obstructing the work of the operator. For localization work it may be locked in any desired position.

It has the following features:

1. It runs freely on the two side rails.
2. It is counterbalanced so as to run up and down with ease.
3. It may be rotated about two vertical axes, enabling the pierced center of the screen to be brought easily into position.
4. It may be locked against each motion separately.
5. It may be locked as to up and down motion and yet rotate.

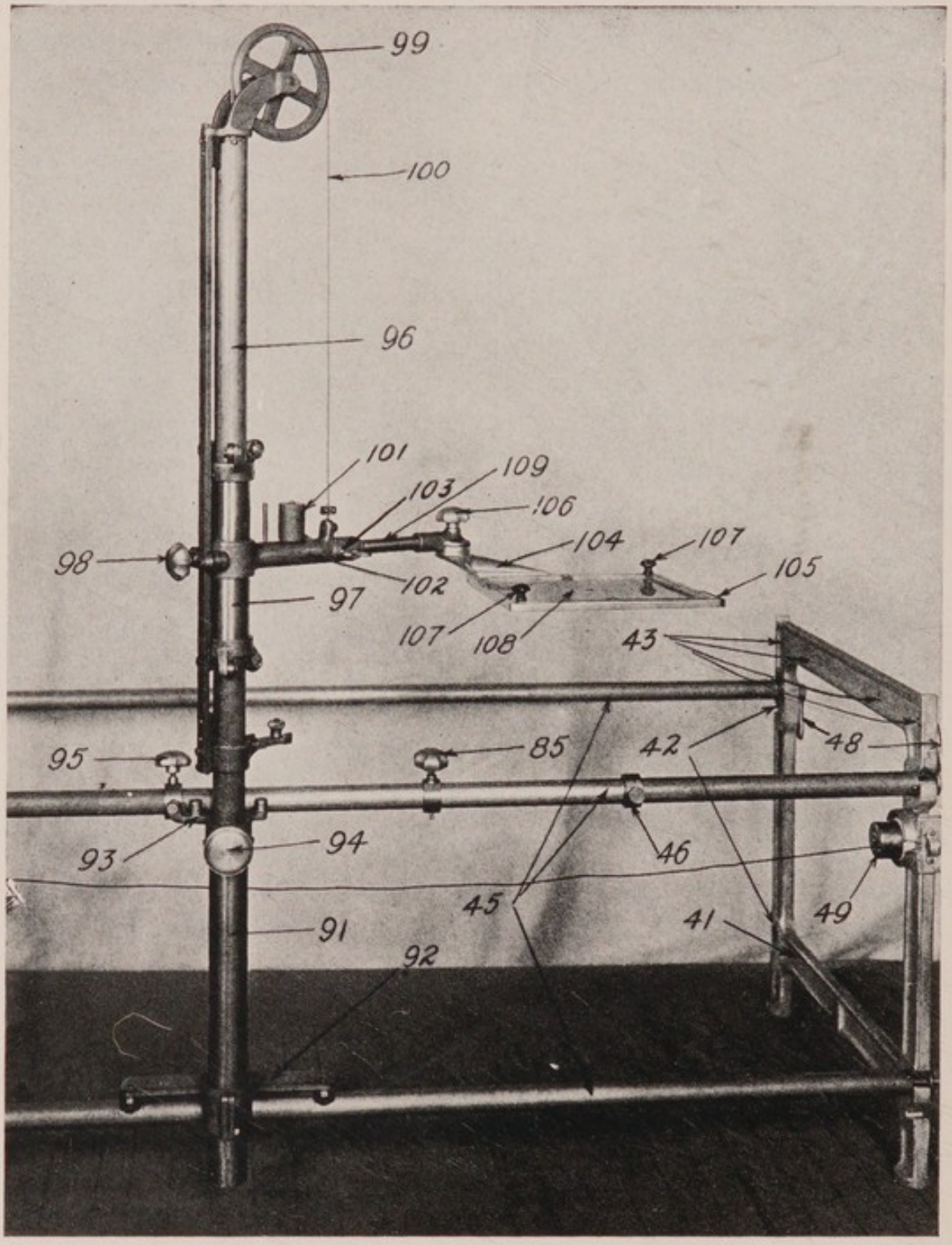


FIG. 78. Screen-carrying mechanism, complete standard Army *x*-ray table.

6. The screen may be inclined if need arises. The carrier is mounted in a tube (91) with bearings running on the lower rail, and three rollers (93) on a vertical axis hold it in line on the upper rail. (96) is a heavy tube fitting into (91) and turns on a cone bearing at the base. (109) is an adjustable rod to which is attached the screen clamp (106). (98) is the clamp for vertical motion; (95) for longitudinal run; (94) for rotation in the tube; (106) for rotation about the corner of the screen.

Setting Up Table.

1. Unpack all of the outfit and check list to ensure that no parts are mislaid.
2. Decide on position for the table and instrument box, and which shall be the operating side of table.
3. Lay two rods (45) down on the side to be used by the *x*-ray operator; one of these must have locking and stop rings.
4. Place end frames (41) in position and drop rods into notches. Use all upper notches unless army litter is to be used.
5. Place screen roller carriage (91) in position and tighten end screws on all rods. Run (91) to left of operator's position.
6. Hook cradle under rollers on tube box with the two roller ends of cradle on the operator's side of the table. *Lock cross brake* (51) and set cradle on rails, then release brake (51). Attach working cross lock and be sure it is in proper position. (See Fig. 76.)
7. Attach diaphragm (70) to box and lock in position.
8. Set (96) into (91), then attach screen and clamp with screw (103).

9. Unlock (98) and put on enough small weights to counterbalance the screen.
10. Attach pull switch to the end of the table toward the instrument box.
11. Pull out the drawer from the tube box and place on a good support.
12. Place the tube in the position shown in Figure 77. Make the cathode connection by turning the tube in the holder before tightening. Then, approximately center and tighten the holder. Connect to the radiator by means of a short piece of wire. Do not use the screw as a binding post.

NOTE. Be sure to retain the box in which the tube is shipped.

Cautions.

1. Do not bend, bruise or jamb parts.
2. Do not remove screen without first locking (98), as the counter weight may cause damage.
3. Do not turn screws so tight that threads are stripped.
4. Do not fail to set the cross run brake (51) before lifting the tube box off or on.
5. If the supporting side rails are slightly bent the tube carriage will run hard or bind. Place the box in the middle of the run and, loosening the end nuts (48), rotate the upper rods about their own axes until the single back roller is free on both sides, i.e., does not rub on its support.
6. Always remove the screen from its holder before removing screen carriage.
7. Note the cone bearing on the lower end of the carrier post. Do not stand the carrier on this, as it may easily be roughened.

8. If the screen carrier does not run freely or is too loose at the top, the eccentric mounting on the inside of the roller bearing should be loosened and adjusted so that there is very little play between these rollers and the rail. If tightened in this position the carrier will run freely.

Also, note that the ring (95) has a hole 90° from the handle into which a small thumb nut projects, making the attachment with the movable carrier; while (85) has a projection intended to engage a slot on the under side of the cross piece of the cradle, to serve as a lock for longitudinal run of the tube box.

Some Operating Points. After the table is set up and made reasonably level and all adjustments have been made, it is strongly advised that the operator practice manipulation until he can instinctively and certainly grasp the locking devices whenever necessary for his work.

There are, then, six knobs to be operated, three controlling the screen carrier and three the tube box and diaphragm.

Number 106 will usually be set according to the operator's idea of using the screen and need not generally be unlocked.

It is expected that the operator will stand between the screen carrier and the diaphragm control, using the right hand to control the screen box and its locks. It may be suggested that if the operator will acquire the habit of grasping the rod (109) in order to control the screen position, the left hand need never be in the radiation, and the right hand can remain free to control shutters and rail lock (Fig. 79).

Fluoroscopic Room Illumination. It is strongly urged that the lighting of fluoroscopic rooms be properly arranged. One should have a dim light for use in placing patients, etc.,

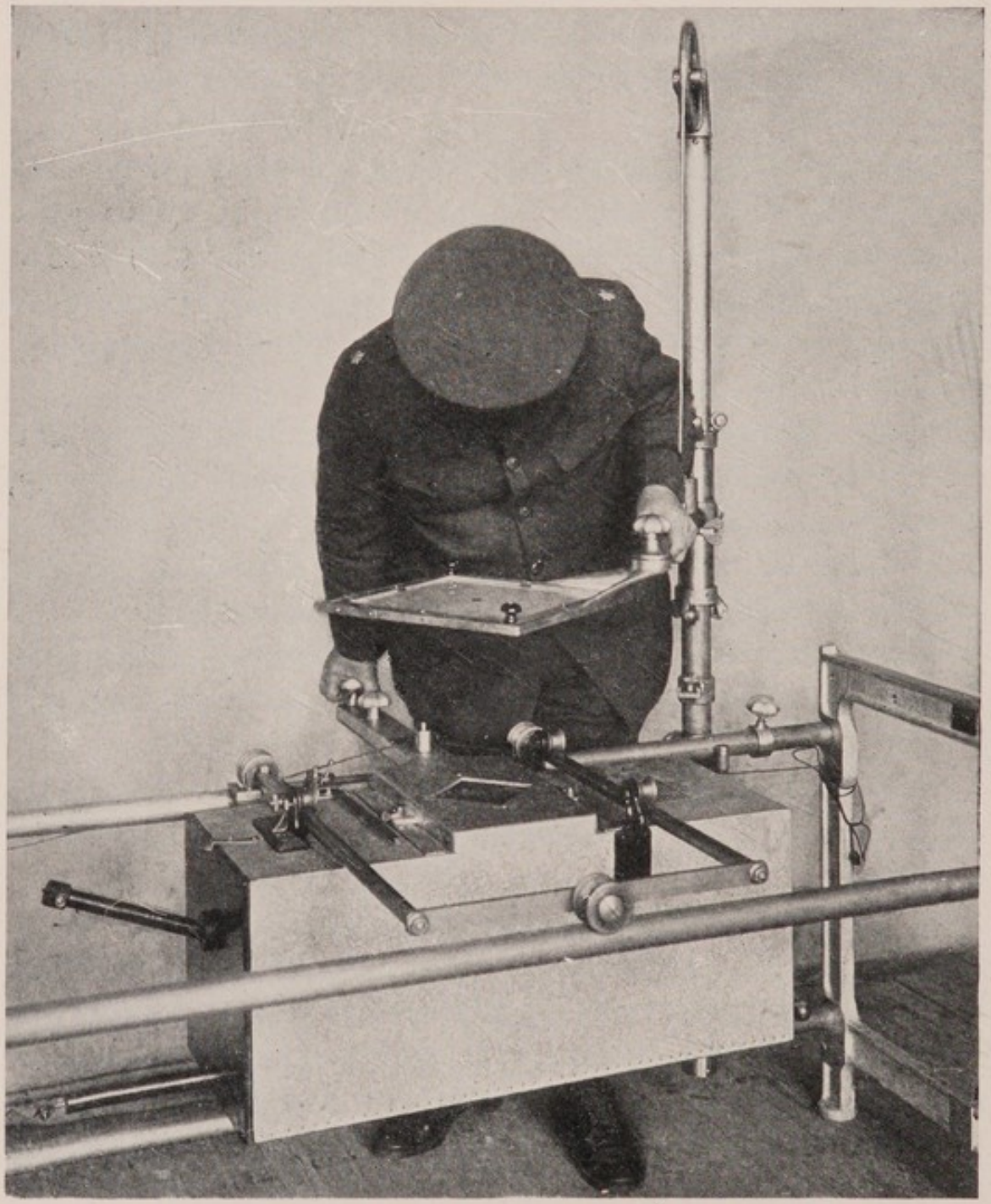


FIG. 79. Method of handling screen and shutter on all standard Army *x*-ray tables. Litter top removed.

List of Numbers Referring to Illustrations of Standard Tables

Numbers refer to the illustrations and *not* to manufacturers' stock or replacement numbers.

Part	No.
Top	
Rectangular frame	30
Bakelite stretcher	31
Frame	
End frames	41
End frame slots	42
Holes for mast support	43
Rods (side rails)	45
Ring stop	46
Screw handles on rods	48
Switch	49
Tube Box	
Roller with cross run lock	51
Rollers without lock	52
Aluminum window	54
Ventilation opening	55
Register pins for shutter	56
Lock, cross run	57
Partition (lower half)	62
Partition (upper half)	63
Insulator (cathode)	64
Insulator (anode)	65
Binding Posts	66
Tube support posts	67
Tube clamp	68
Tube centering wire	69
Shutter	
Shutter complete	70
Shutter clamps	71
Screen carrier connecting post	72
Diaphragm opening	73
Diamond-opening control	74
Slit-opening control	75

Part	No.
Tube Box Cradle	
Stop position for 10 cm. shift	80
Rollers	81
Stop for variable shift	82
Stop for 15 cm. shift	83
Stop	84
Lock to rail	85
Screen Carrier	
Socket bearing	91
Lower rail carriage frame	92
Upper rail bearing rolls	93
Clamp against rotation	94
Clamp against longitudinal run	95
Main post	96
Sliding sleeve	97
Clamp (vertical position)	98
Pulley	99
Wire cord	100
Balance weights	101
Socket for horizontal arm	102
Clamps (screw)	103
Screen holder frame	104
Screen holder latch	105
Screen clamp	106
Knobs to lift screen	107
Screen	108
Rod to screen frame	109
Additional High Tension Insulators	
Vertical masts	21
Frame for supporting masts	22
Short insulator for keeping high tension wires away from frame	23

and no light when fluoroscoping. The portable outfit provides for operating the needed light from the Delco generator. When the operating switch is closed the lights go out, and on opening this switch they are automatically lighted. It is advised that a ruby lamp be used intended for operation on a circuit above 110 volts. The connection used with the portable unit is shown in Figure 85 and a similar connection can be made for other outfits.

Centering Tube in the Box beneath the Table. The focal spot of the target should be vertically below the center of the diaphragm. In order to determine whether this is the case, proceed as follows:

1. Close up the diamond-shaped opening of the shutter to about ½ inch.

2. Lock the tube box in position and bring the opening of the screen so that the illumination shows symmetrically thereon.

3. Suspend a small metal ball, *B*, by a string passing through the center of the opening, and observe when this ball comes to rest whether its shadow falls symmetrically upon the projection of the diaphragm. If not, or if on narrowing the diaphragm still further, the narrow beam of rays passes by the ball so that it does not cast a shadow on the small illuminated area of the screen, it is evident that the tube is not properly centered, and the position of the shadow also gives an indication of the direction of tube movement required. (Fig. 80.)

An approximate idea of whether the tube is properly centered or not may be gained by bringing the perforation in the center of the screen to the center of the projection of the small diagonal opening of the shutter. When the screen is down close to the table with the carrier locked against longitudinal motion and against rotation, raise the screen by the vertical movement of the carrier and see

whether it retains its symmetrical position. An idea of the amount by which the tube needs to be shifted may be obtained in this way.

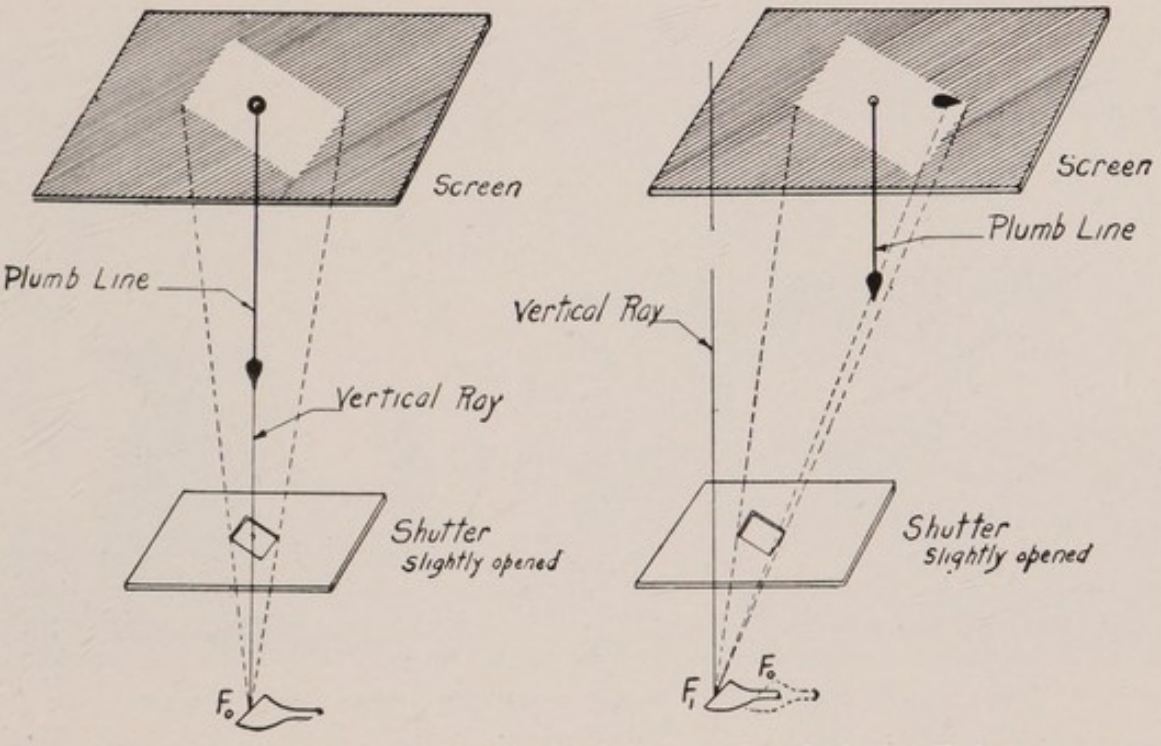


FIG. 80. A. Correct position of shadow of plumb bob. Tube properly centered.
B. Projection of plumb bob on fluorescent screen, incorrect position.

It is also suggested that, if the tube needs to be moved in the direction in which the holder slides out of the box, one can slide the holder itself out and test for correctness, measure the distance, and finally shift the tube the same amount.

The electric generator and x-ray machine designed during the World War are described in the following pages. The assembled unit as used is shown in Figure 81 and diagrammatically in Figure 82.

The important features of the outfit are the portable power plant, the self-rectifying Coolidge tube, and the special table. Having the complete generating equipment, it is admirably adapted to service in strange territory

where the electrical supply is not suitable for standard machines or is likely to fail because of war conditions.

The gasoline engine is direct-connected to a generator

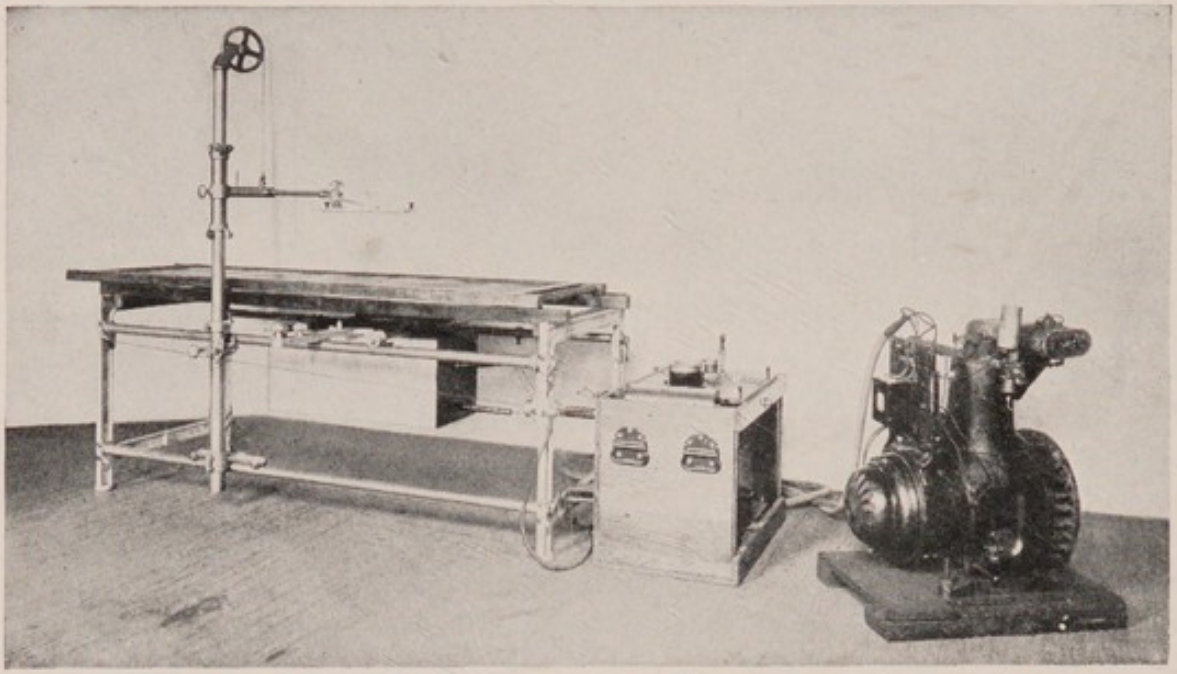


FIG. 81. United States Army portable *x*-ray unit complete.

which supplies power for the *x*-ray and filament transformers (a.c.) and a small amount of current (d.c.) for the control circuit. The primary circuit requires no control resistance, regulation for the two working settings being made by shifting the throttle by means of the d.-c. control circuit, changing the speed and thereby the voltage of the generator. The secondary circuit contains no rectifying device since the tube allows only each alternate half wave to pass. (See page 18 for a description of the tube.)

Fluoroscopic work is done at 5 ma. and all radiographic work at 10 ma. The maximum operating gap is about 5 inches, but may be reduced if desired by control of the machine speed.

Owing to the drop in line voltage upon closing the operating switch, it is necessary to secure a uniform filament current by inserting a "booster" in the primary circuits of

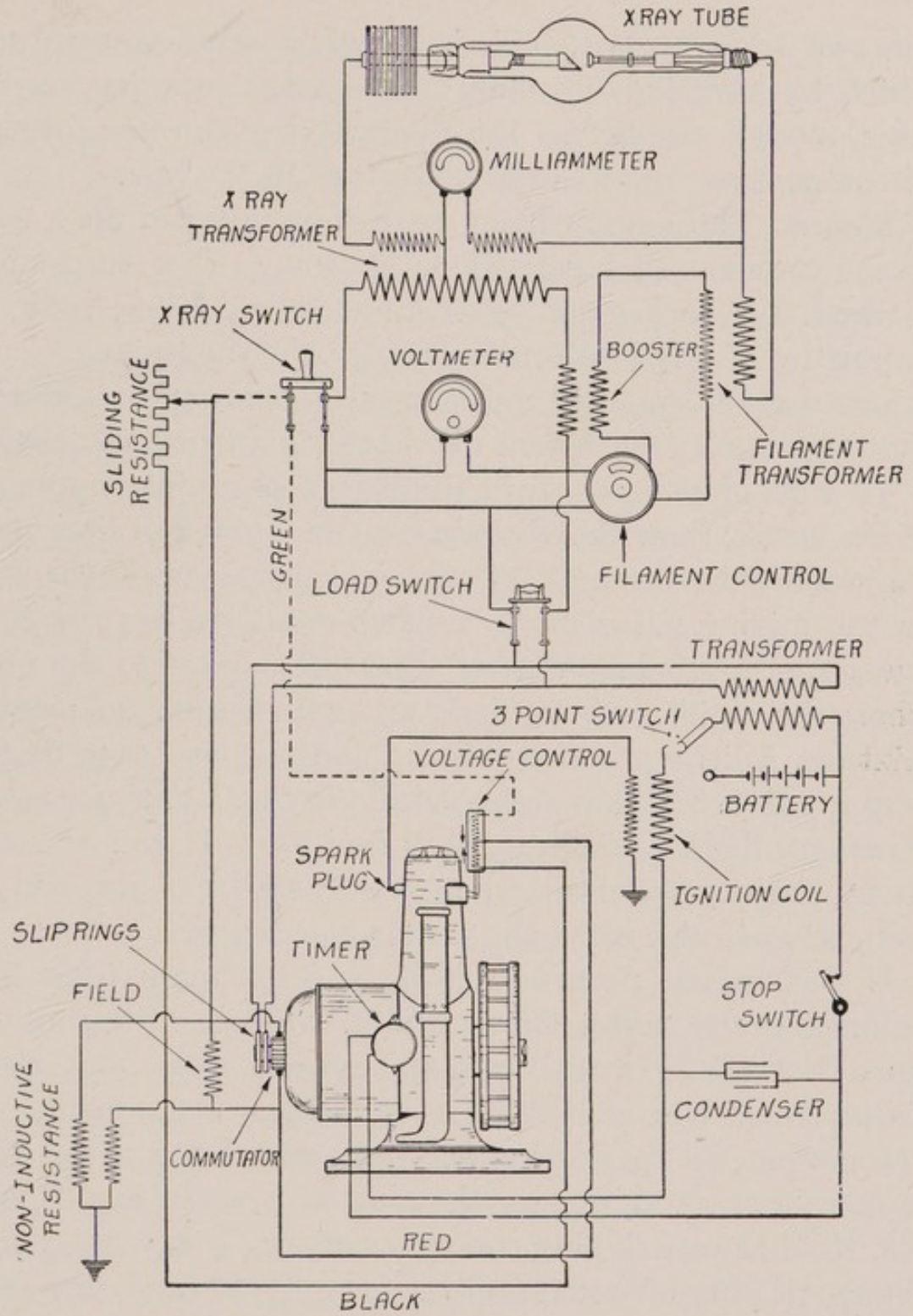


FIG. 82. Wiring diagram for United States Army portable *x*-ray unit. Dotted lines show connections for those machines having special control. In other cases these wires are omitted.

the two transformers. This is merely a small transformer, which by carrying the main transformer primary current adds enough voltage to the filament transformer primary to compensate for the drop of voltage in the line.

Engine. The engine must be firmly fastened to a solid base by means of lag bolts or by some other convenient method. All fuel must be strained when filling tank, as impurities of any kind are certain to clog fuel pipes.

Use a good grade of medium oil and always make sure that the crank case is well filled before starting the engine.

To start the engine, turn the fly-wheel rapidly by means of the crank, immediately remove the crank and then press the starting button and cut off the air by means of the lever on the mixing valve body. When the engine has run for a few seconds, advance the air adjustment lever to the point where the engine runs regularly and with the leanest possible mixture. A little practice will enable the operator to do this very quickly. This adjustment will vary with climatic conditions and the kind and grade of fuel used. It will be found to be slightly different when the engine has warmed up from what it was when the engine was started.

If the engine does not start, a few simple tests may determine the cause. Go carefully over all wiring and be sure that all electrical connections are tight and clean. Test to make sure that the starting battery is not exhausted.

Examine the spark plug carefully and if the porcelain is broken or cracked, replace the plug with a new one if possible. Hold the spark plug connecter about $\frac{1}{8}$ inch away from the spark plug terminal and turn the fly-wheel over several times by means of the crank and see if a good spark is obtained in this manner. If not, the plug may be greasy or dirty; remove and clean thoroughly with gasoline and adjust the distance between the points to about $\frac{1}{32}$ of an inch, or until a dime can be just passed between them.

Next, look at timer contacts to see that they are properly adjusted and are making good contact every time they close. If necessary, clean these contacts with a piece of fine sand paper. To adjust the distance between the points turn the engine over until the points open to their full extent. In this position a dime should just slip between the points. If necessary, adjust them by turning the contact screw in or out until the proper distance is obtained.

Next, examine commutator and brushes. The commutator may be dirty or greasy. It should never be allowed to remain in this condition, if the generator is to operate at maximum efficiency. Hold a piece of clean cloth soaked in a little kerosene against the commutator while the engine is running. Never use oil other than kerosene on the commutator and always wipe it dry with a piece of clean cloth afterwards. Examine brushes to see that they are in good condition and are making good contact.

To test your fuel line, fill the priming cup from a small oil can with gasoline, and crank. If the engine will run when using gasoline from the can, and will not run otherwise, it indicates that fuel connections are loose or that the fuel hole in the mixing valve body is clogged. Be sure there is no water in the gasoline tank. The fuel hole in the mixing valve body or line may be cleaned out by blowing through it or by means of a fine wire. These few tests will usually locate the trouble. Now look at the cable leads which are all stamped with a corresponding number on the engine switch board. Be sure that they are properly connected to both engine and transformer unit. The amount of gasoline on *continuous* fluoroscopic work will be about 1 gallon per hour. On intermittent work, as is usually the actual case, a gallon will last about 3½ hours.

The Transformer Unit. The *x*-ray transformer unit contains the apparatus needed to transform and control the

currents necessary for energizing the radiator type Coolidge tube used with these outfits. It consists of the following parts (Figs. 83 and 84):

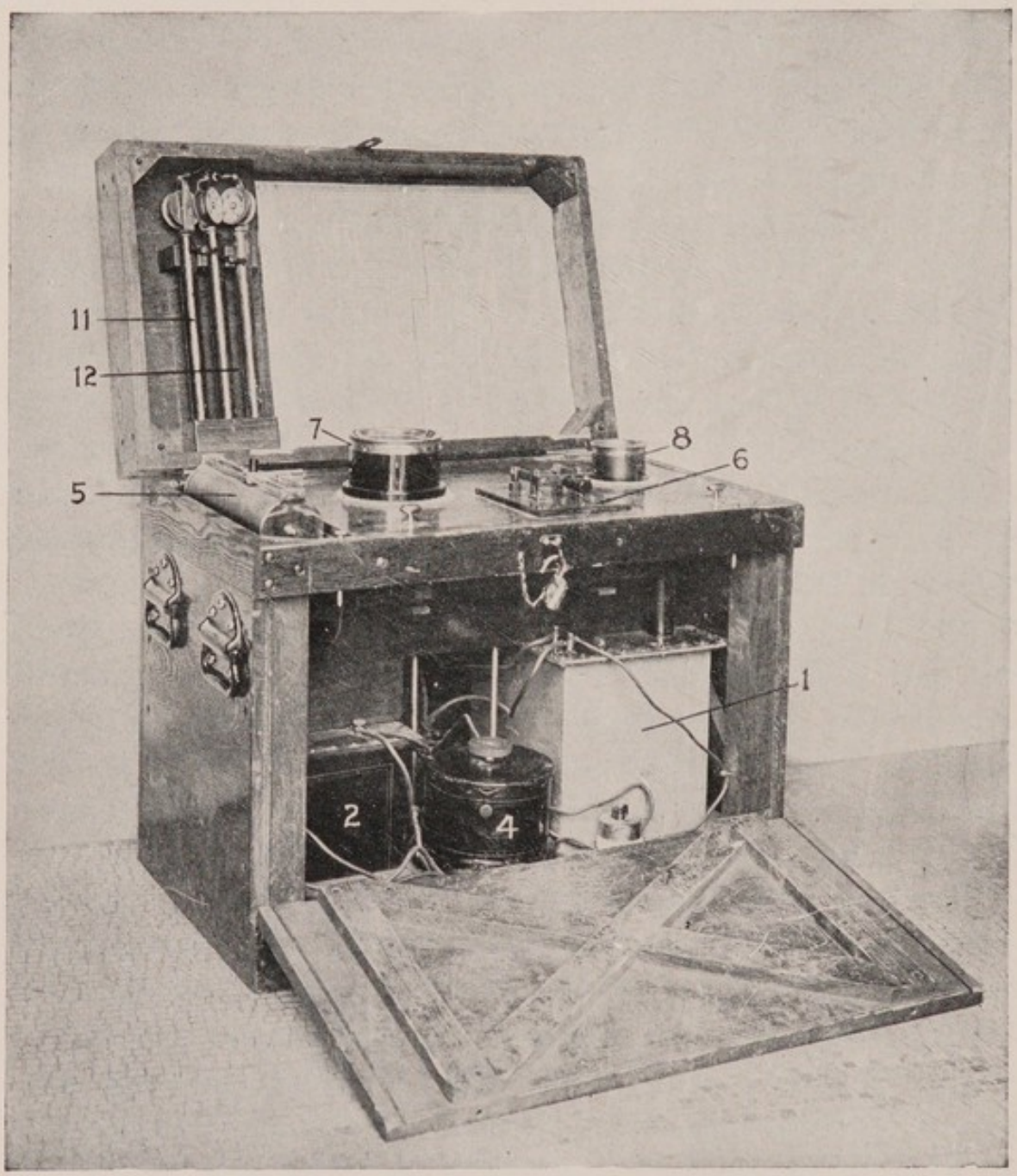


FIG. 83. Instrument box for portable unit, front view.

The *x*-ray transformer (1) transforms the low tension alternating current from the gasoline engine generator unit into suitable high tension current.

The filament transformer (2) supplies the low tension current for heating the filament of the x-ray tube.

The booster transformer (3) keeps the filament of the

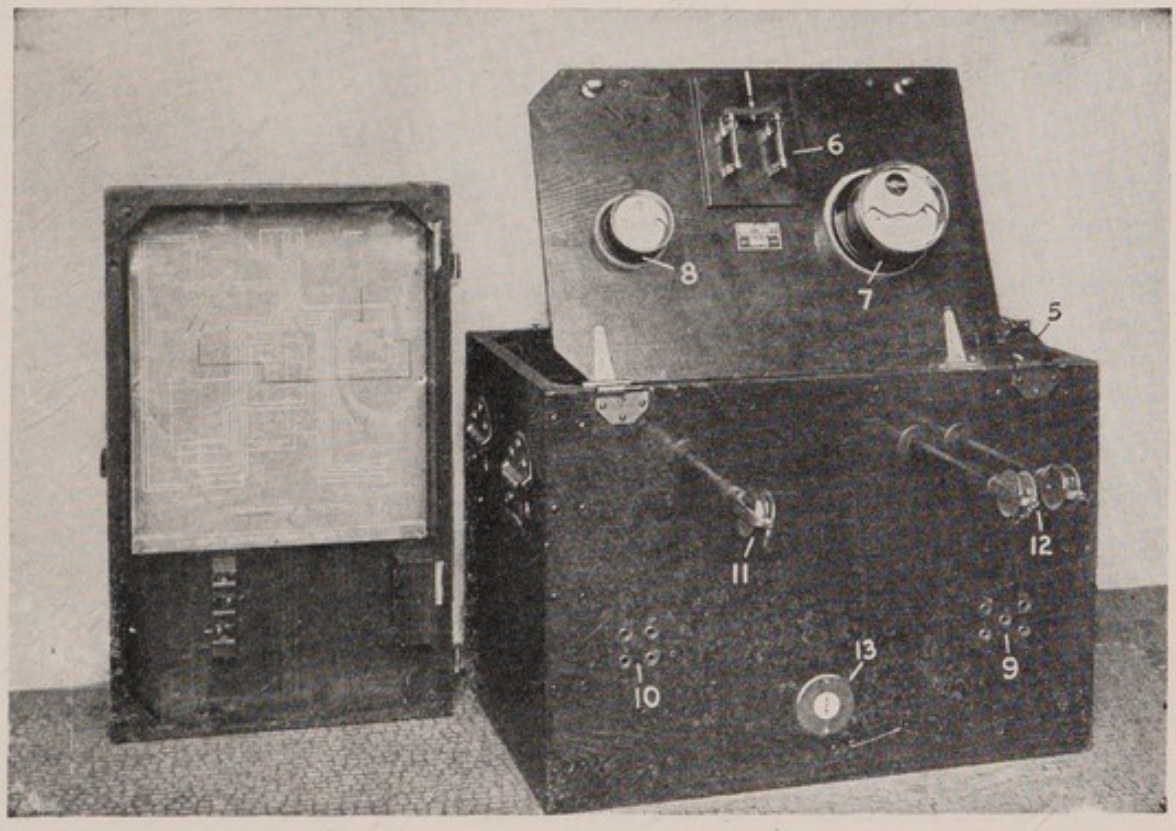


FIG. 84. Instrument box for portable unit showing instruments, high tension terminals, and openings for connections.

x-ray tube constant.

The filament control (4) varies the amount of current passing through the x-ray tube. A small knob will be found projecting from the side of this regulator—this is to open and close the circuit through the primary of the filament transformer. When pushed in it is closed, as it should ordinarily remain.

The engine rheostat (5) serves as a means for controlling the speed of the gasoline engine. Moving the contact toward the front of the box increases the speed of the engine and thus raises the voltage of the generator.

The *x*-ray switch (6) opens or closes the circuit to the primary of the *x*-ray transformer and to the auxiliary throttle control.

The voltmeter (7) measures the voltage of the generator.

The milliammeter (8) measures the amount of current passing through the *x*-ray tube.

The main terminal board (9), whose five terminals project from the rear side of the case, provides a means for connecting the *x*-ray transformer unit to the gasoline engine generator unit by means of the cable.

The pull switch terminal board (10) is, as the name indicates, for the purpose of attaching a pull switch to the apparatus. The split lugs at the end of the switch cable are to be inserted into the sockets in this terminal board to connect the pull switch in circuit. These connections put the pull switch in parallel with the *x*-ray switch and permit the closure of the circuit by either independent of the other.

After the engine and *x*-ray table are set up, place the *x*-ray transformer unit in position, *close* to the end of the table and so that the high tension outlets are equally spaced between the legs of the table. This is very important and and should not be forgotten.

Unlock the box, raise the lid to an angle of about 45° from horizontal, and slide the cover of the box slowly to the left until the two hinge sections have been disengaged one from the other. The cover can now be removed from the box.

Pull out the two door bolts. The door in front can now be let down so that work can be done readily in the interior of the box. This door should be kept open at all times when the unit is in operation to avoid damage by corona, etc.

Push the split terminal lugs at one end of the cable into the sockets on the main terminal board. These lugs are of

different sizes so that they will only fit one way in the terminal board, and no mistake should be made. Connect the numbered lugs at the other end of the cable to the correspondingly marked connection posts on the switch board of the engine. Connect pull switch, if one is to be used, by inserting the split lugs on the switch cable in the sockets in the pull switch terminal board.

The high tension terminals (11) and (12) will be found held in place in the cover by means of a clamp device. These terminals should be removed and screwed into the sockets.

These sockets and terminals are provided with different sized threads at their ends so that the terminals can only fit into their proper socket. The high tension terminal (11), provided with the spring hook terminal, screws into the single socket. The remaining terminals (12) can be screwed one into each of the remaining sockets.

Attach the cord from the positive terminal to the positive terminal of the tube box and the cord from the two negative terminals to the two binding posts on the negative terminal of the tube box.

Open the *x*-ray switch, the pull switch, and the line switch on the board of the engine; move the sliding contact of the engine-rheostat as close to the hinge side of the box as it will go. Start the engine and close the switch on the switch board of that unit. The filament of the tube should now be incandescent. Slowly move the contact on the engine rheostat toward the front of the box. The voltmeter should indicate higher and higher voltage. Continue until the voltmeter indicates about 160 volts.

For radiographic work, having adjusted the engine speed by means of the engine rheostat until the voltmeter reads 160 volts, set the filament control at 1.9, close the *x*-ray switch and readjust the engine rheostat and filament control

until the milliammeter reads 10 ma., when the voltmeter should read from 110 to 115 volts.

Now open the *x*-ray switch and read the voltage generated at no load, leaving the rheostat set in the 10 ma. position. Hereafter, whenever radiographic work is to be done, simply adjust the engine rheostat until the voltmeter indicates the voltage thus found.

To obtain the opening point for fluoroscopic work, viz., 5 ma. at from 110 to 115 voltmeter reading, reduce the speed of the engine by means of the engine rheostat until the milliammeter indicates 5 ma. Upon examination of the voltmeter, it will be found to read from 110 to 115 volts. Open the *x*-ray switch and read the voltage generated at no load, leaving the engine rheostat set at 5 ma. point.

Hereafter, whenever fluoroscopic work is to be done, adjust the engine rheostat until the voltmeter again reads the voltage thus found.

In order to save fuel and wear and tear on the engine, it may be advisable to run the latter on reduced speed, except when making a radiograph, or during a fluoroscopic examination, or when it is desirable to use red room lamps designed for this unit. For this reason an adjustable stop is provided on the engine rheostat. This stop is set to bring the engine to proper speed for the work in hand, so that during the interval between making radiographs or fluoroscopic examinations, the engine speed can be reduced and reset for the next operation by merely running the contact against the adjustable stop.

This *x*-ray transformer unit should, as far as possible, be kept dry inside and out, and should be kept covered with a tarpaulin when not in use. Care should be taken to prevent sudden jarring and rough handling generally, to minimize the danger of putting meters, etc., out of adjustment.

The filament control must be adjusted carefully to give the proper current and primary voltage, and once adjusted it will stay fixed. Make sure the filament is lighted before

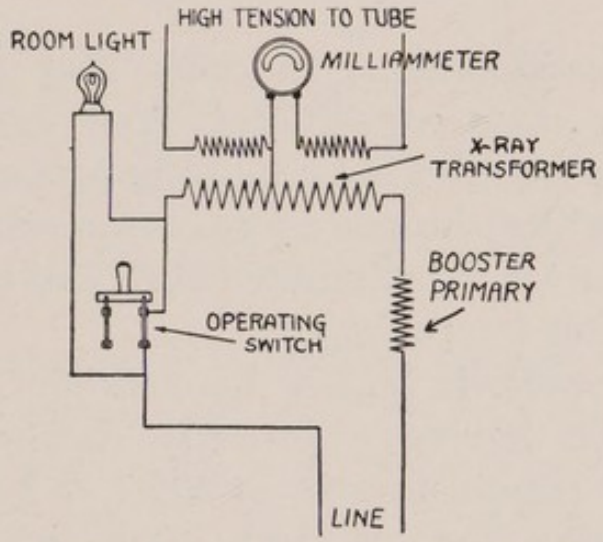


FIG. 85. Connections for red lamp over the fluoroscopic table, when used with portable unit.

throwing on power: this may easily be forgotten with an enclosed tube.

Should a spark pass in the secondary circuit when the operating switch is closed, it may be due to a temporary surge. Unless an "arc" results, do not open the operating switch. Keep secondary wires well apart and well away from other objects to prevent corona and leakage. It is a good plan to connect the frame of the table to any convenient "ground."

Red Light for Fluoroscopic Room. The generator may readily serve to give the reduced red light needed in fluoroscopic work. Figure 85 shows how this is done; and either a high voltage ruby lamp or two 16 candle power, 110 volt ruby lamps in series are required. Do not connect in except as shown and do not attempt to load the generator with additional lights or apparatus. Pulling the string switch alternates x-ray excitation and darkroom illumination. The extension cord and light connect onto the box at 13 (Fig. 84).

CHAPTER VII

LOCALIZATION

General Considerations. In order that this important work may be done expeditiously and with the desired degree of accuracy, it will be quite important for the radiologist to consider the matter from the standpoint of the greatest service for the minmum effort, and with the fullest consideration for the patient.

Where the work is largely fluoroscopic the radiologist must insist on having a properly darkened room and be allowed to remain therein in order to keep his eyes in proper condition for his work. The patient should be prepared outside of this room. Before any patient is placed in position the radiologist should see that the apparatus is in satisfactory working condition, that the accessories necessary for the localization he intends to make are conveniently at hand, nor should he fail to train his assistants during slack periods in order that they may act promptly and efficiently.

After the patient is placed on the table it is desirable to bring the affected part which is to be examined somewhere within the middle third of the movement of the tube box. A rapid, but nevertheless careful, survey should be made of the regions at some distance from the point of entrance and emergence of the projectile, as it is well known that projectiles often follow tortuous paths, and are at considerable distances from the point of entry, and very often split into fragments, each of which may take lodgment in points remote from the main path.

Having located the projectile whose presence is sought, it will often be found that by use of parallax, on moving the tube slightly, one can readily determine whether the

projectile is above or below certain bony landmarks, and sometimes a slight manipulation of muscle will indicate position with reference to important soft tissues.

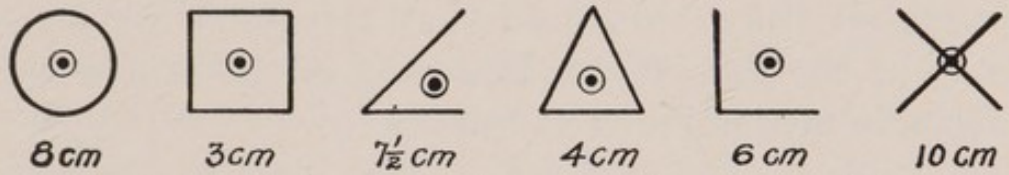


FIG. 86. Method of distinguishing between skin marks and denoting depth of foreign body from skin marker.

Care in Marking and Recording. Inasmuch as conference between the surgeon and the radiologist is likely to be the exception rather than the rule in military radiology, great care must be taken in recording observations. In addition to the written report, we must, in the case of multiple foreign bodies, identify each skin mark and the corresponding depth. This may be done in either of two ways: One may number each dot on the skin and write a depth number beside it. There is some danger in this case of confusing the depth of the projectile with the localization number. The following is suggested as an alternative:

Place around each skin mark an indicating symbol that also appears on the record, as indicated in Figure 86.

The numbers signify that 8 cm. below the dot in the circle there is a projectile; 3 cm. below the dot in the square there is another; and so forth.

Reports. Reports may be made in part on anatomical charts if these are available. The written portions should be brief, but exact and explicit.

They should include:

1. The designating symbol and the depth, *corrected* for screen position.

2. The approximate position of the patient when examined.

3. Anatomical information.
4. Approximate size of projectile.
5. Condition of injured bones.

For marking the skin in connection with localization operations, it has been found that the Finzi ink meets a majority of the tests better than any of the others tested. The formula of this ink is as follows:

Pyrogallic acid	1.0 gm.
Acetone	10.0 c.c.
Liquid chloride of iron	4.0 c.c.
Wood alcohol q.s. ad	20.0 c.c.

This ink is rather thin; it can be used with a pen, but is not very satisfactory in this respect. It makes a black mark and dries in from thirty to forty-five seconds, depending on the amount used. It will smudge slightly during the first fifteen minutes after applying, but leaves a permanent mark. The color carries from gray to intense black according to the amount used. It is visible for forty-eight hours to a week, depending on whether it is subjected to rubbing in contact with solid objects or with clothing, etc. It can be seen through iodine stain and resists alcohol. The standard skin inker will make from ten to twenty successive marks without replenishing.

With proper care as to the amount to be taken on the wick, this ink will be found to give satisfaction in use. Too much ink will cause the mark to run into the surrounding skin crevices, and the center of the mark will not be easily gauged. Too little ink will not make a sufficiently black or permanent mark.

Standard Methods. Experience in military service during the World War has served to emphasize the importance of rapid and reasonably accurate methods for the localization of foreign bodies. The ordinary practice of

radiology, as a rule, has little to do with this phase of the subject.

It would be desirable, and may even be regarded as necessary, that all of the injured should have the benefit of an *x*-ray examination; since it has been found that there are many cases where foreign bodies split off after entry, or are in such unexpected or peculiar positions that they can hardly be successfully handled without the evidence available from such an examination.

In order to work on such an extensive scale it is necessary to consider very carefully the relation of *x*-ray work to surgery, and to analyze the methods which are to be employed with reference to simplicity and certainty, and to pay particular attention to the reports and information needed by the surgeon in order to facilitate his work. In this connection it may be remarked that there is a distinction between the *x*-ray requirements in evacuation hospitals and base hospitals. In the former, speed is essential and simple apparatus must suffice. In the latter, a more complete equipment would be expected. It may be well to recognize that time will not permit the use of films in the evacuation hospitals, and dependence must be put almost entirely upon fluoroscopic work. Consequently, all arrangements in hospitals near the front must conform to the conditions imposed by fluoroscopy.

It must also be remembered that the operator is an essential part of the localizing apparatus. Among the operations giving opportunity for error even in ordinarily competent hands we may note:

1. Reading of fine scales.
2. Reading any scale in bad light.
3. Making arithmetical computations.
4. Drawing diagrams.
5. Changing from bright light to read scales and back to fluoroscopic work.

It may well be pointed out that refined mathematical accuracy is not generally a requisite for good service in this connection. As was remarked by Lt. Col. James T. Case, Senior Consultant in Roentgenology of the American Expeditionary Forces, "This war is not being fought with bird shot, and a localization, as a rule, to 0.5 cm. will be entirely satisfactory." In a few cases—such as bodies in the eye, or where a small foreign body is in a particularly dangerous and troublesome place—greater accuracy may be required, but it is necessary for the surgeon to keep in mind the fact that because of the incision and the introduction of retractors there may result a considerable displacement of the projectile and it is often difficult to connect its position with displaced skin marks. It may also be remarked that in the majority of cases a definite anatomical localization should be given by experienced and well-trained radiologists, which in many cases may be of greater value than a simple depth determination. Whether or not this is well done will determine to a considerable extent the value of the *x*-ray service, and every opportunity should be given the radiologist to ascertain the landmarks used in surgery and to adapt his work to the requirements of the surgeon using his data.

It is generally assumed that a skin mark was made at the place of emergence of the beam which formed a shadow of the projectile and that the tube focus was adjusted vertically beneath the projectile. A vertical line drawn later through the skin point can only strike the projectile if the body of the patient is placed in the same position on the operating table as it occupied during the *x*-ray examination, and careful distinction must be made between a vertical line so described and a line perpendicular to the surface of the skin at the marked point. The amount by which the surgeon may miss the projectile by failure to get a correct sight line increases

materially with increased depth of the projectile and with decreased dimensions, and some idea of the size of the body sought should always be given. Much greater care will surely be needed in the localization of the smaller bodies.

Definitions. *Central Ray.* The ray passing through the center of the limiting diaphragm, which, when the tube is fixed with reference to the diaphragm holder, will change its direction with each tilt or movement of the tube and its mounting.

Vertical Ray. The central ray when the tube is beneath the table, and the target is so adjusted that the line joining the focal spot of the target with the *center* of the diaphragm opening is vertical.

Strohl Method. This method was proposed by Professor Strohl of the French Roentgenological Service during the World War. It is extremely rapid, reasonably accurate, and requires a minimum of manipulation; it is the method of preference for mobile hospitals.

Attached to the top of the tube box of the standard table described in Figure 76 (p. 171) is a substantial brass frame, carrying two wires attached across two opposite corners, and protected by a thin sheet of aluminum (Fig. 87). When the distance between the wires is 5 inches, the *x*-ray tube must be adjusted in the tube box until the focal spot is 7½ inches below the wires. Thus in the triangle ACF_0 (Fig. 89) the relation between the altitude and the base is as 3 is to 2. It may be noted that the essential is the proportion between the altitude and the base. The actual distance between the Strohl wires is a matter of convenience. As the position of the tube is highly important, it is a good plan to check by localizing an object a known distance from the screen.

The Strohl wires cast their shadows on the screen; when the tube box is moved, the shadows move with it.

The operator brings the shadow of the projectile to the center of the screen, and marks the skin through the hole

in the screen. He places in position a small celluloid strip with two sliders (Figs. 87 and 89). He then shifts the tube box until the shadow of one of the wires coincides with the

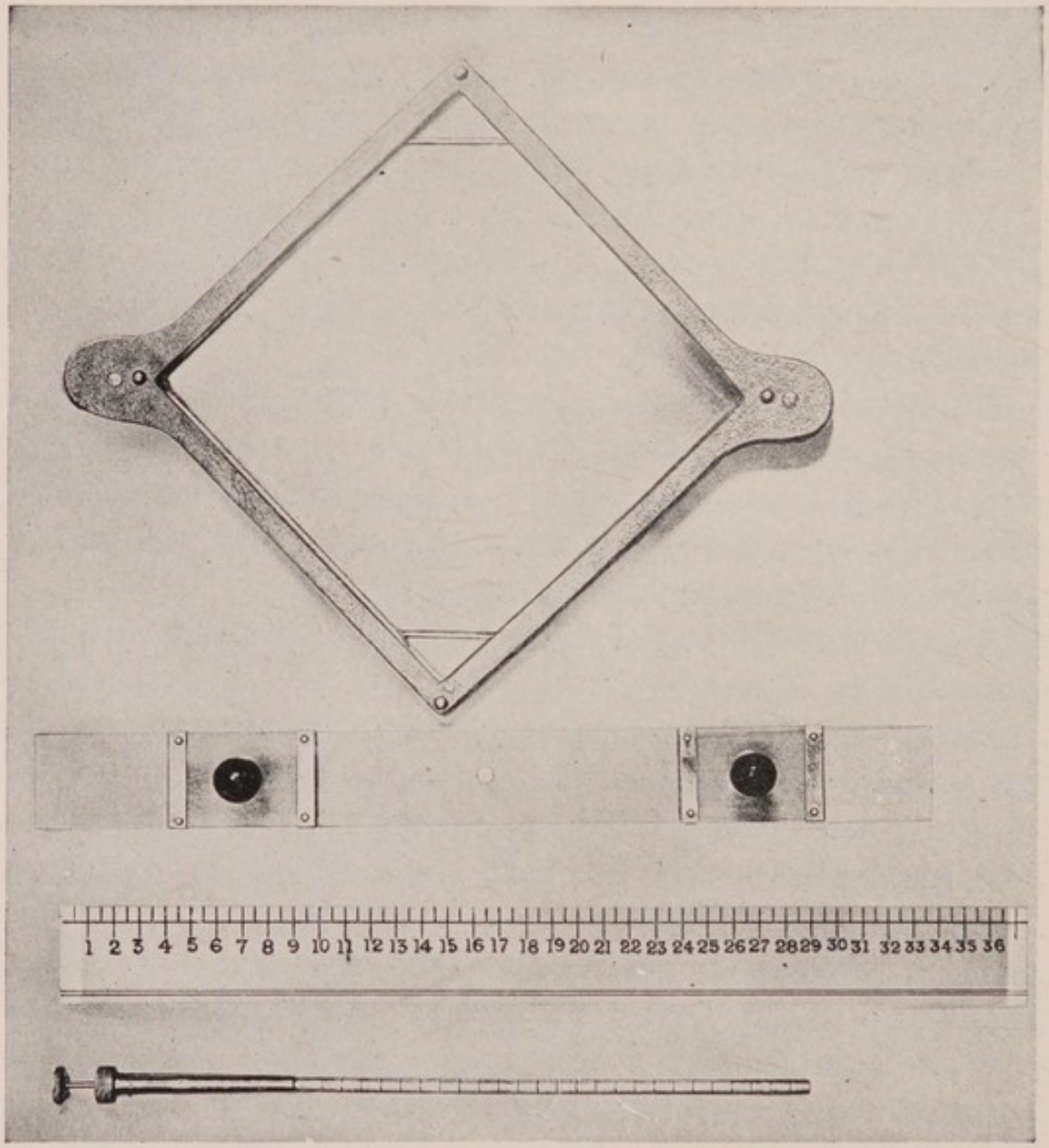


FIG. 87. Apparatus consisting of cross wire holder, double slider, and special rule.

shadow of the projectile (Fig. 88), and adjusts one of the sliders to mark this position; then, shifting in the opposite direction, he brings the shadow of the other wire to coin-

cidence with that of the projectile, and adjusts the second slider. The distance between the two sliders is two-thirds the distance between the fluoroscopic screen and the

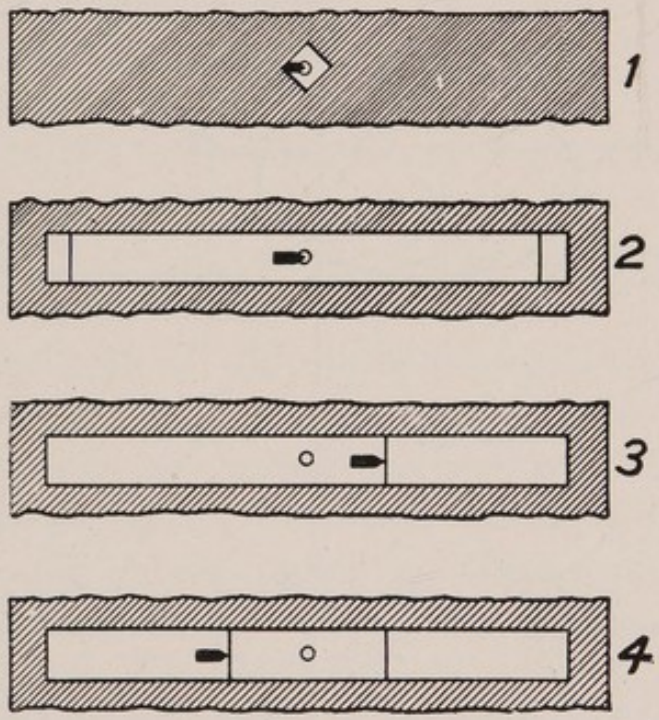


FIG. 88. Successive appearances on fluoroscopic screen. (1) Shadow of projectile with small diaphragm at central point of screen. (2) Rectangular diaphragm replaced by slit opening shadow of wires at right and left. (3) Tube has been shifted to the left, bringing shadow of projectile and right hand wire to coincidence. (4) Reversed shift of tube, bringing left wire and projectile shadow to coincidence.

projectile.

Figure 88 shows screen shadows in steps of this method. In (1) is seen shadows in central ray; (2) shows open slit and shadows of wires; (3) shows coincidence of shadow and right hand wire, and (4) points for measurement. The principle is shown in Figure 89. On the table is a cross section of a body containing a projectile, P. Beneath the table is the x-ray tube, with the focal spot marked F_0. To begin, the screen is brought directly over one end of the projectile, the rays from F_0 stricking vertically upward so that P_0 the hole in the screen; P, the projectile; and F_0, the focal spot,

are in one vertical line. The screen is locked in place against movement and the skin is then marked at *s*.

Above the focal spot, F_0, is drawn a triangle. *A* and *C* of

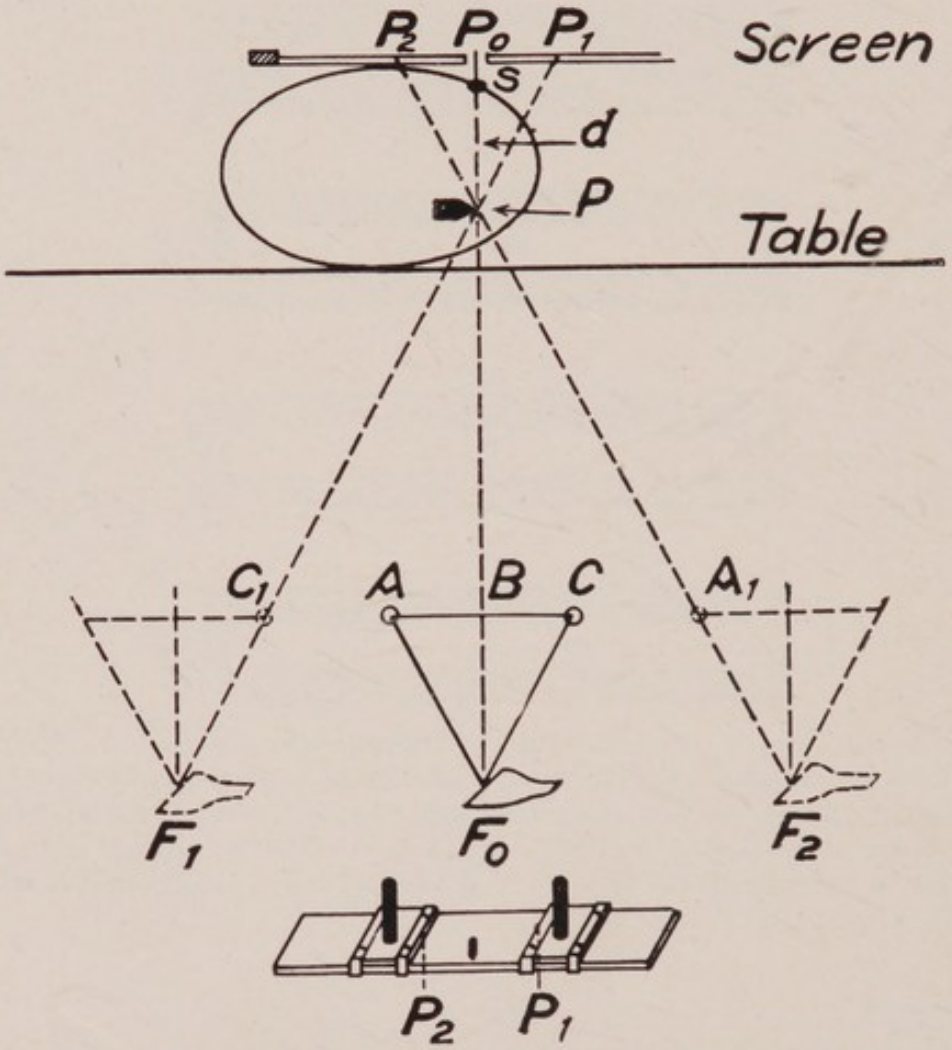


FIG. 89. Principle of the Strohl method. Simple slider for measurement of the distance between the two images shown below diagram.

the triangle represent the cross section of the wires illustrated in Figure 87.

The tube box is shifted to the left, until the shadow of wire *C* and projectile *P* coincide on the screen. This spot is designated P_1.

The tube is then shifted to the right until the shadow of wire *A* and the projectile coincide on the screen. This is designated P_2.

There is thus formed a triangle P_2P_1P its base on the screen and its apex at the projectile. The sides of this triangle are parallel with the triangle ACF_0. The two triangles are therefore similar.

In similar triangles, the relation between the altitude and the base is similar.

In triangle ACF_0 the proportion between the altitude and the base is as 3 is to 2. It was made that way.

Therefore in the upper triangle the proportion between the altitude and the base is as 3 is to 2.

Measure the base of the upper triangle, multiply by $\frac{3}{2}$ and we get the altitude, that is, the depth of the projectile below the screen. To avoid bothersome calculations, a special rule is provided, that automatically multiplies by $\frac{3}{2}$. When the distance between the sliders on the screen is measured with this rule, the correct distance from the screen to the projectile is read directly.

Measure the distance between the screen and the skin. When the measurement is taken from the top of the glass covering the screen, deduct 0.5 cm.

Subtract this from the distance between the screen and the projectile, and we have the depth of the projectile below the mark *s*.

Operating Instructions. 1. Make a general survey of the region to be examined, noting the number and approximate position of the projectiles, and the condition of the bones as to fracture.

2. Bring the shadow of the projectile which is to be localized, using a small shutter opening, upon the perforation in the screen, and lower the screen until it is in contact with the body.

3. Using the special skin marker, mark the skin carefully through the perforation, and observe whether the skin point is in contact with or at some distance from the under

side of the screen. If the latter, immediately note the correction needed.

4. Open the diamond-shaped shutter fully, and close the slit to a convenient width.

5. Insert the pin of the small celluloid double slider in the perforation in the screen, the screen to be locked against all movement. Shift the tube to the right or left, watching the shadows of the cross wire, which is initially seen at the extreme edge of the slit opening, until these shadows become coincident. Leave the tube at rest, and adjust the inner edge of the slider to coincidence with the shadow. Reverse the shift of the tube, and do the same for the second slider.

6. Remove the slider attachment, and, by means of the special boxwood scale provided, read the distance between the inner edges of the two sliders, and record this reading as depth in centimeters.

7. Identify this skin mark, provided more than one localization is to be made, and immediately enter everything on the record.

Nearest Point Method. Owing to the enormous pressure of work on the radiologist in an advance hospital during periods of great activity at the front, it is necessary to utilize the simplest and most rapid method of localization consistent with working accuracy. One method that has met with considerable favor in rapid approximate determination of location and depth, is the so-called "nearest point" method.

This method consists in palpating, under fluoroscopic observation, the soft tissue surrounding the projectile. The instrument used for this palpation is a wooden rod about 10 inches long with a metal screw or some similar piece of metal at the end. Under the screen the wood is almost invisible and the only plain shadow is that cast by the metal. By the movement of the projectile under pressure on the

tissue surrounding it, and the amount of pressure used, the operator is able to judge with fair accuracy what point on the skin is nearest the projectile and the depth from that point. Obviously, palpation at a very near point will ordinarily cause much greater movement of the projectile than will palpation at a more remote part of the skin surface. Likewise, palpation will cause greater displacement in the very soft tissues than it will in the firmer tissues.

Skill in this method increases with continued use, and a sense of pressure is developed that proves a valuable aid to speed and accuracy. It is well to check the observation by shifting the tube carriage. When the shadows of the projectile and the pointer traverse to the same degree, the projectile and the pointer are at the same level below the screen.

The nearest point method is applicable to localization of projectiles in the soft tissues of the extremities, the axilla, scrotum, and buttocks, but not to the more vital and less palpable regions of the head, thorax, and abdominal cavities. By practice one becomes accustomed to palpating the soft tissues around the foreign body, and by what are termed light and deep palpation to determining the depth of the projectile from the nearest point on the skin surface. Even if the foreign body cannot be displaced by pressure with the palpating stick this information is often of great value, showing that the projectile must be in a joint, against the bone, or embedded in deep tissue.

This method is, in brief, adapted to localization in the extremities and soft parts of the body under advance hospital conditions, where rapid examination of the patients is a matter of prime importance.

Radiographs at Right Angled Planes. This, the oldest method of localization, is also the simplest. One film is made in the sagittal plane, a second in the coronal plane. When the target-film distance is not less than 48 inches, the

position of a metallic foreign body can be determined with reasonable accuracy.

The position of the foreign body is located with reference to a bone. The radiographs should include a sufficient area so that the bone can be easily identified from the films, in the operating room. A foreign body in the torso may be located by the aid of a cross section anatomy.

Operative Removal under Fluoroscopic Control. Occasionally, when time permits, it may be necessary to remove the foreign body on the fluoroscopic table.

The radiologist is a member of the operating team. He wears a hooded fluoroscope fastened to his head, as it is not practicable to bring the usual fluoroscopic screen into the neighborhood of the operative field without interfering with aseptic technique. When called upon the radiologist indicates the direction of the foreign body.

Certain precautions are necessary. These are described under "Reduction of fractures under fluoroscopic control," page 228.

Depth of Anatomical Landmarks beneath the Skin. The following paragraph and table are taken from an article by J. Metcalfe and Keys-Wells.*

Surgeons will find the table given below of value in determining the exact position of a foreign body in relation to points on the skeleton. In their article published in connection with this table, the authors state that the surgeon often experiences many difficulties when operating for the removal of a foreign body even after the radiologist has made an accurate localization. Previous to the war, the surgeon studied the ultimate depth of his operation only with regard to certain surrounding anatomical landmarks, and not in terms of centimeters or inches beneath a point on the skin. If the radiologist reports a projec-

* Metcalfe, J., and Keys-Wells. *Lancet*, May 27, 1916.

tile as being 4.5 cm. from a point on the skin of the back overlying the transverse process of the 12th dorsal vertebra, the surgeon has little knowledge as to where this depth will lead him. If, however, the surgeon knows that the average depth of this structure is less than 4 cm. from the skin, he appreciates the fact that the projectile must lie in or just anterior to the transverse process. The objection is, of course, that individuals vary greatly in thickness of various parts, but the authors call attention to the fact that the soldier is selected after rigid examination and, as a result, the extremely thin and extremely obese are not present.

TABLE[1]

HEAD: LATERALLY *Incision*	DEPTH OF ANATOMICAL POSITION
Just above zygoma	2.5 cm. to sphenosquamosal suture
Just below zygoma	4 cm. to sphenoidal bone
To coronoid process or condyle of mandible	2.5 cm.
NECK: ANTEROPOSTERIORLY	
Through center of larynx	5 cm. to body of vertebra
3 cm. to side of center of larynx	4 cm. to transverse process of cervical vertebra
3 cm. to side of center of larynx	7.5 cm. total depth of neck
Through middle line of trachea just below cricoid	4 cm. to body of vertebra
3 cm. to side of center of trachea	4 cm. to transverse process of vertebra
From center of suprasternal notch	3 cm. to posterior border of manubrium
NECK: LATERALLY	
From center of middle of neck.	4 cm. to transverse process of vertebra
From center of middle of neck.	6 cm. to body of vertebra
From just below tip of mastoid process	6 cm. to body of 1st cervical
CHEST: SUPERIORLY	
From a point midway between root of neck and tip of acromion	5 cm. to apex of pleura, downwards
From a point midway between internal and external extremities and just behind posterior border of the clavicle	5 cm. to apex of pleura, downwards

[1] Depths were given in inches in the original table, but have here been converted into centimeters.

TABLE. (*Continued*)

CHEST: ANTERIORLY	DEPTH OF ANATOMICAL POSITION
From center of lower border of clavicle backwards to subscapular fossa just clear of ribs	7.5 cm.
From a point just over tip of coracoid to subscapular fossa backwards	7.5 cm.
From a point 2.5 cm. external to sternoclavicular joint just below clavicle	3.5 cm. to 1st rib
From a point 2.5 cm. external to sternoclavicular joint just below clavicle	2 cm. to pleura
From a point 5 cm. external to sternoclavicular joint just below clavicle backwards	3 cm. to 1st rib
From a point 5 cm. external to sternoclavicular joint just below clavicle backwards	4.5 cm. to pleura
From a point 5 cm. below center of clavicle	5 cm. to pleura
CHEST: POSTERIORLY	
To supraspinous fossa	2.5 cm.
To infraspinous fossa	2 cm.
To transverse process of 7th cervical vertebra	4 cm.
To pleura level of 7th cervical vertebra	5 cm.
To anterior level of body of 7th cervical	7.5 cm.
To transverse process of 12th dorsal vertebra	3.5 cm.
To pleura level of 12th dorsal vertebra	5 cm.
To anterior level of body of 12th dorsal vertebra	8.5 cm.
ABDOMEN: THICKNESS OF WALL FROM FRONT	
1 cm. to either side of middle line just above umbilicus	2.5 cm.
1 cm. to either side of middle line just below umbilicus	3 cm.
Just internal to anterior superior spine to iliac fossa	7.5 cm.
Midway between anterior superior spine and pubic crest to front of acetabulum	5 cm.
ABDOMEN: THICKNESS OF WALL FROM SIDE	
On level of tip of 12th rib in line upwards from anterior superior spine	2.5 cm.

TABLE. (*Continued*)

ABDOMEN: THICKNESS OF WALL FROM BACK	DEPTH OF ANATOMICAL POSITION
To transverse process 3d lumbar	4.5 cm.
To anterior level of body of 3d lumbar	11 cm.
To anterior level of psoas muscle	13 cm.
HIP AND THIGH FROM FRONT	
8 cm. below anterior superior spine to head of femur	6 cm.
8 cm. below anterior superior spine to neck of femur	5–7 cm.
15 cm. below anterior superior spine (level of lesser trochanter) to front of femur	4 cm.
To greater trochanter	11 cm.
To lesser trochanter	9 cm.
Brim of pelvis 2.5 cm. in front of sacroiliac synchondrosis	9.5 cm.
To anterior inferior spine	3 cm.
To spine of ischium	12.5
To ischial tuberosity	13 cm.
To anterior surface of line of junction of ascending ramus of ischium and descending of pubis	7 cm.
HIP AND THIGH FROM BACK	
To ischial tuberosity	6 cm.
To spine of sacrum on level of posterior superior spines of ilia	3 cm.
To sacral groove	5 cm.
To head of femur	5 cm.
To greater trochanter	9 cm.
To lesser trochanter	7.5 cm.
To brim of pelvis 25 cm. in front of sacroiliac synchondrosis	10 cm.
To anterior inferior spine	15 cm.
To spine of ischium	5 cm.
To posterior surface of junction of ascending ramus of ischium and descending ramus of pubis	11 cm.

Eye Localization. In the case of foreign bodies in the eye very accurate localization is necessary, as knowledge of the exact position of the foreign body may mean the saving of an eye or the preservation of vision.

The simple Sweet-Bowen apparatus consists of two general parts: the base or head rest, as illustrated in Figure 90 and the localizer, as shown in outline drawing, Figure 91.

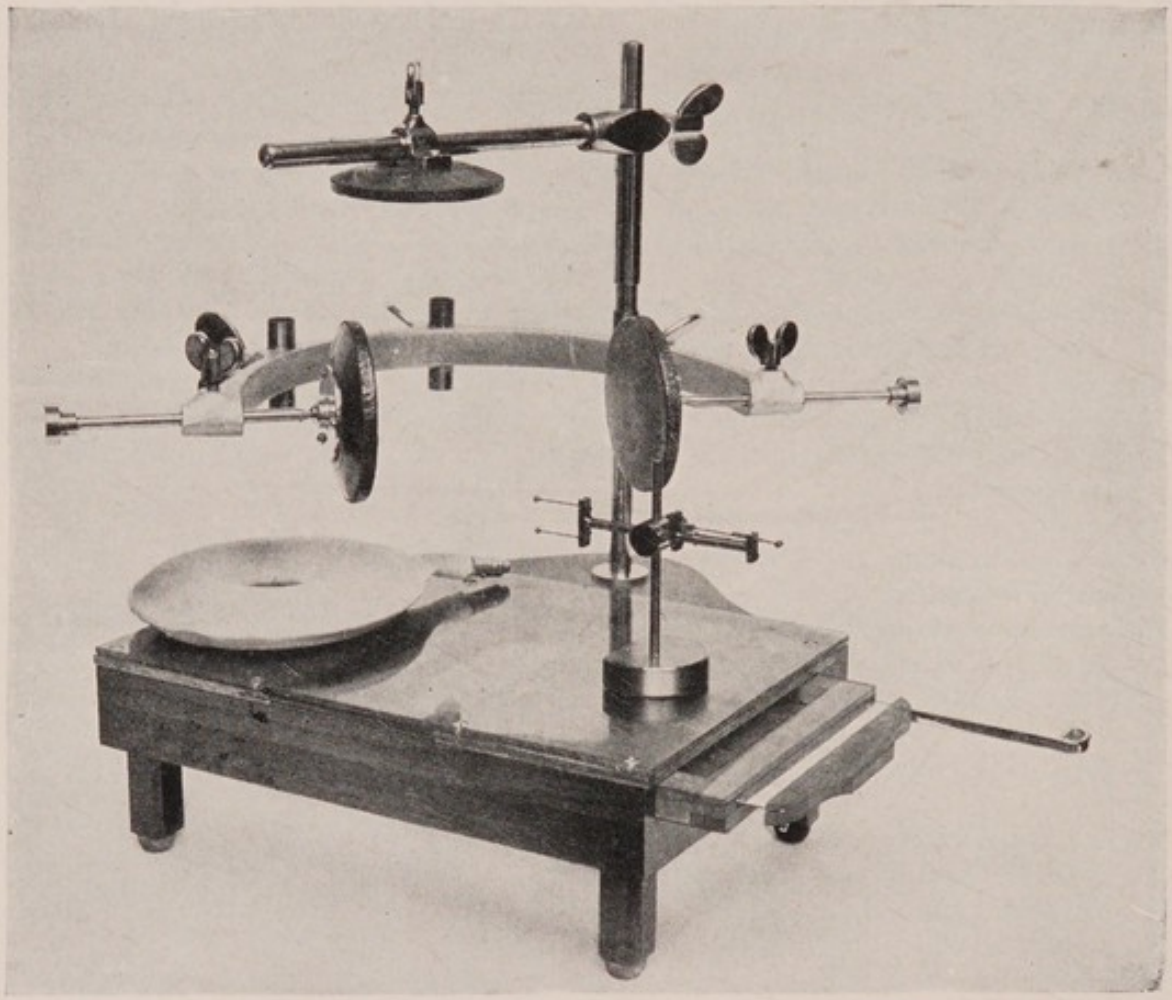


FIG. 90. Head rest for use with the eye localizer.

The head-rest base is composed of the following parts:

1. A plate-slide tunnel, so constructed as to protect one-half of a 5 × 7 radiographic film while the other half is being exposed, and to protect the exposed half while the second exposure is being made.

2. Four rubber-tipped legs to raise the tunnel so that it will act as a pillow to hold the patient's head level when lying on his side.

3. A plate holder having a slide that will protect the film from the ordinary light, but offer no resistance to the x-ray.

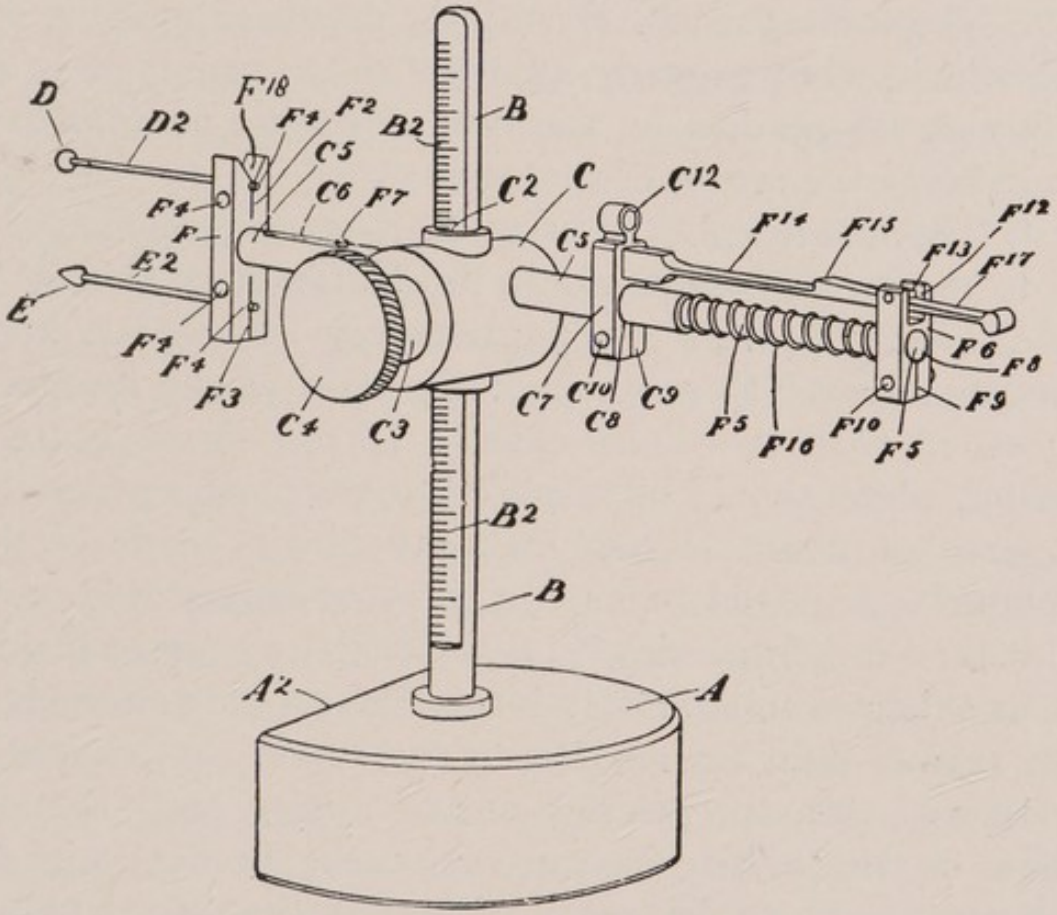


Fig. 91. Sweet eye localizer.

4. An arm or handle attached to the plate-holding slide to enable the operator to shift the film the correct distance for each exposure, and to withdraw the same when both exposures have been made.

5. A pneumatic cushion for the comfort of the patient.

6. A double clamp to hold the patient's head and to prevent any horizontal movement.

7. A single vertical clamp to press the head downward upon the pneumatic cushion.

The localizer consists of:

1. A heavy metal base, Figure 91.

2. An upright standard, B, to support the localizer and permit the same to be adjusted and held firmly at any desired height.

3. The indicator-ball D with its needle-supporting stem D^2, which, when properly adjusted to the center of an eye, will cast its shadow on the film and serve as a landmark to indicate the center of the cornea.

4. The metal tip E, of stem E^2 is made cone-shaped, so as to more easily differentiate its shadow from that of ball D. These indicators are permanently adjusted a known distance apart (15 mm.), and the base of the localizer is provided with two holes exactly 15 mm. from center to center, which should be employed to verify this adjustment in case of doubt. When an x-ray film is made of them obliquely, adjusted to an eye as previously stated and as indicated in "front view" on the chart, we are enabled by their shadows to definitely locate the source and course of the rays of light (in relation to the chart) that caused the shadows. Also, the position of any foreign body that may show on the same film can very easily be determined by the position of its shadow in relation to that of the ball and cone, because the exact position of the latter with reference to the chart is known and indicated (front view).

5. Tube C^{12} and notch F^{18} are sights similar to those used on a rifle, with which the operator can accurately align the center of the cornea of the afflicted eye with ball D and its supporting step D^2. F^{14} is a spring trigger which presses upwards against pin F^{13}. F^5 is the end of the rod to which the indicator-ball and cone D and E are attached by bracket F, the whole being supported by passing through tube C^5. Spring F^{14} being attached to stationary tube C^5 by means of bracket C^7, rod F^5 with bracket F^6 can be pressed forward until pin F^{13} is engaged by notch F^{15}.

6. By loosening set-screw C^4 the bracket C can be raised or lowered until ball D with its supporting stem D^2 is in exact alignment with the center of the cornea of the affected eye, and the screw is then tightened.

7. The patient is instructed to close his eyes, and the entire instrument with its base is slid forward until indicator-ball D presses into the eyelid approximately its thickness. The trigger F^{17} is then depressed to disengage notch F^{15} from pin F^{13}, when spring F^{16} will cause the rod F^5 and indicator-ball D and cone E to rebound exactly 10 mm., being restricted by knob F^7 in slot C^6. The subject and localizer are now in correct position for making the two necessary exposures.

First Exposure. Place the patient's head, affected eye downward, on the plate-holder base, with inflated cushion in position, as shown in Figure 92, being careful that the inflated cushion does not extent over the marked lines on the cover; otherwise it will cast a shadow on the film.

If the subject shows a tendency to move about, the horizontal clamp, as shown in Figure 90, must be adjusted to the base of the head and forehead, otherwise the vertical clamp, as shown in illustrations herewith, will be sufficient. The double horizontal clamp can be adjusted for either eye by means of its two off-center holes and clamp screws.

Place the diaphragmed tube in position so that its central rays will exactly parallel the front vertical plane of the patient's eye, as shown in Figure 92.

A film, having previously been placed in the plate-holder, is now placed in the tunnel with the outer flange protruding, as shown in the illustration. This will expose one-half of the film to the action of the rays, while the other half will be protected for the second exposure.

The localizer (Fig. 91) is now placed on the stand in front of the affected eye; its trigger is "set" as already described and, after the indicator-ball has been adjusted to the plane

of the cornea, the entire instrument is pushed forward on its base until the ball presses into the patient's closed eyelid approximately its thickness; the trigger spring is

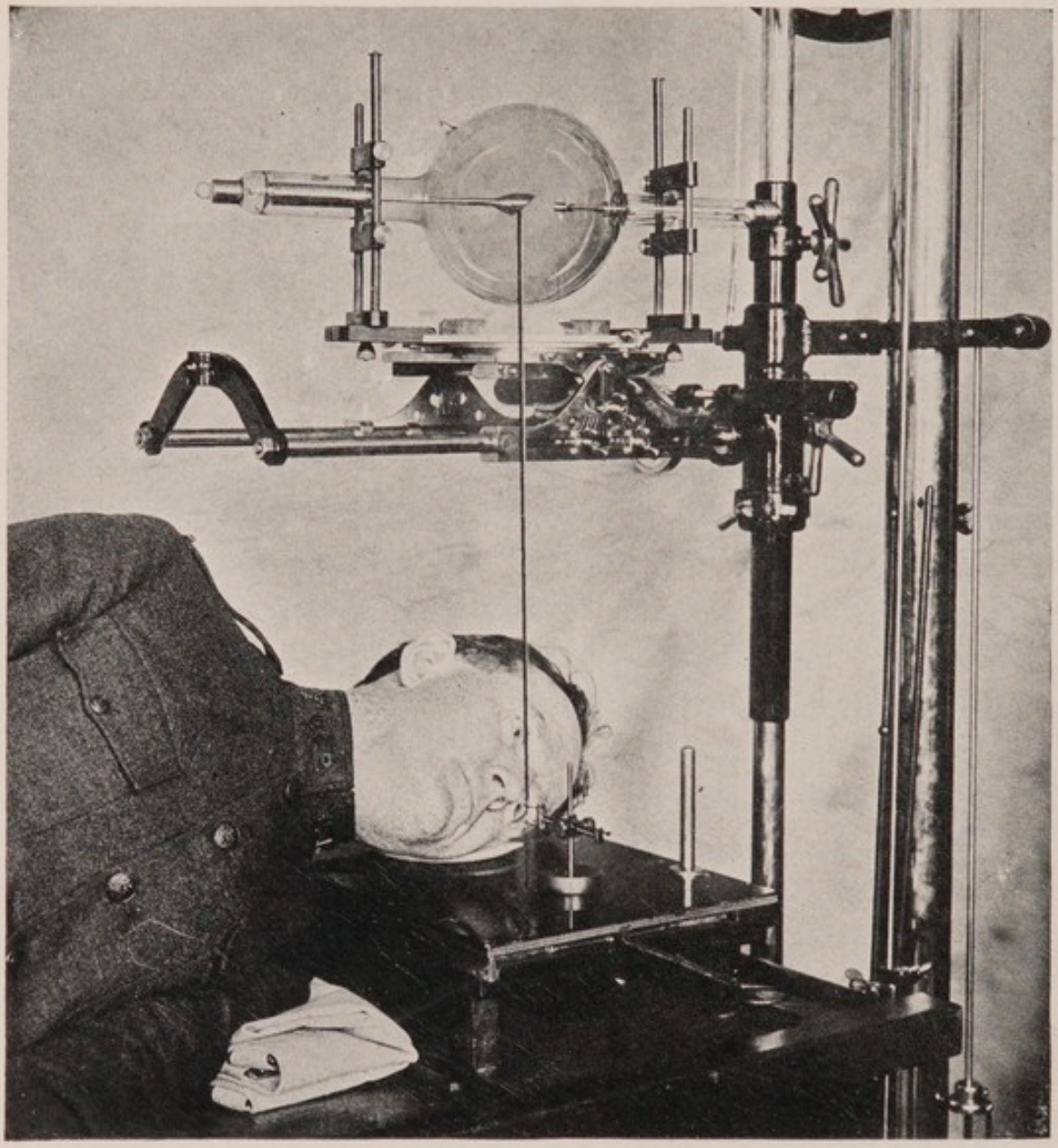


FIG. 92. Position for first exposure in localization of projectiles in the eye. Be certain that the tube is centered accurately over the cone so that both ball and cone will be superimposed.

then released and the indicator-ball and cone recede exactly 10 mm., thereby permitting the patient to open his eyes and wink them in a natural manner. By referring to the localizer

chart you will observe that due allowance of 10 mm. has been made by placing the indicator-ball and cone just that far from the front plane of the cornea. It should also be

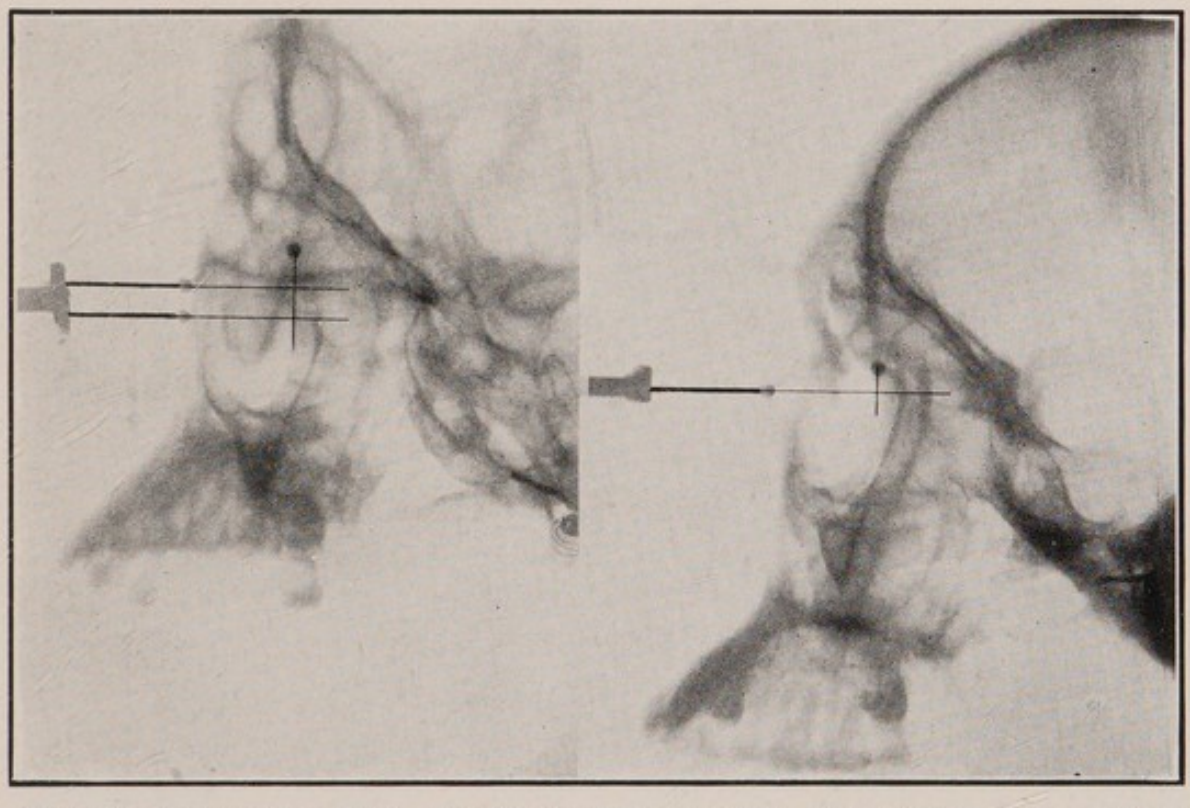


FIG. 93. Specimen plate of projectile in the eye illustrating the method of measurement.

borne in mind that the front of the cornea is 10 mm. in front of the shadow of the indicator-ball, as shown in your negatives. The tube is now centered over the localizing ball and cone so that the shadows of the two will coincide (Fig. 92).

Some object, such as a candle or a piece of white paper, that can readily be seen by the patient, should be placed in alignment with the sights of the indicator, but several feet removed therefrom, and the patient should be instructed to look constantly at this object while the two exposures are being made.

Second Exposure. The first exposure having been made with the rays perpendicular to the plane of the film

and parallel to the patient's eye, thereby superimposing the shadows of the indicator-ball and cone and their supporting stems, as shown in the right-hand half of Figure 93,

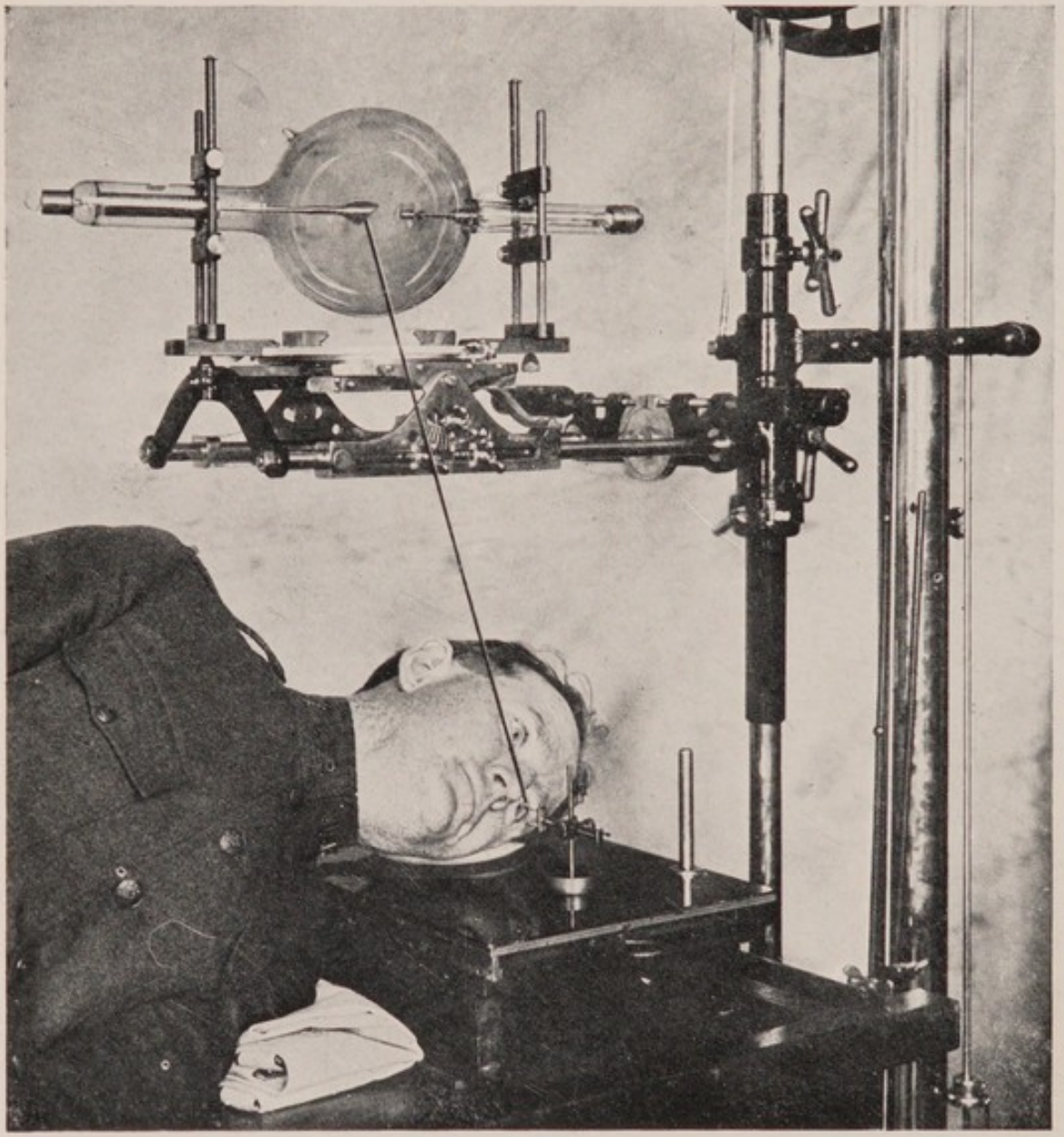


FIG. 94. Second exposure for localization of projectiles in the eye. Notice shift of tube in order to separate the shadows of ball and cone. Be careful not to produce any lateral shift. The tips of ball and cone must be kept in alignment.

the *x*-ray tube is then shifted toward the patient's feet 4 or 5 inches and tilted so that the indicator-rod points to the

ball of the localizer, thereby causing the central rays to pass obliquely through the center of the cornea of the patient's affected eye, as shown in Figure 94. The radiographic film must now be shifted by pushing the plate-holder inward, by its handle, as far as it will go, thereby protecting that portion that was acted upon by the rays in the first exposure and bringing its unexposed half in proper position to receive the rays from the second exposure. In this position the second exposure is made with the rays falling obliquely upon the indicators, thereby separating their shadows, as shown in the left half of Figure 93.

It should be remembered that it is not essential that the exposures be made with the tube at any specific distance from the film, or even that it be the same distance for the two exposures. Neither is it important that the tube be shifted an exact or known distance for the second exposure, as by the use of the charts and Dr. Sweet's method the course of the ray is automatically established. This is shown by the line *A-D* through P^1 and P^2 of outline drawing (Fig. 95).

Charting the Films. In charting the films the following method is pursued: Upon the negative (right-hand half of the illustration) which represents the first exposure, a line is drawn through the horizontal axis of the indicator-ball and cone which are here superimposed, thereby projecting their supporting stems and establishing the visual axis of the eye. (Fig. 93.)

A second line is drawn at right angles to the first through the center of the foreign body's shadow.

With a small pair of dividers step the distance from the edge of the indicator-ball to the intersection of the horizontal and vertical lines that you have just drawn. Then step this distance off on the diagram chart, making a dot with a pen, or a very sharp, hard pencil, to represent the exact distance (distance *R*, Fig. 95).

EXPOSURE NO. 1

R, distance from ball *B* to projectile shadow F^1, 22½ mm.
V, distance of projectile shadow F^1 above horizontal plane, 9 mm.
M, distance of ball *B* from anterior surface of cornea, 10 mm.
N, distance of projectile posterior to anterior surface of cornea, 12½ mm.

EXPOSURE NO. 2

X, distance from ball *B* to projectile shadow P^2, 10½ mm.
Y, distance from cone *C* to projectile shadow P^1, 15½ mm.
O, distance from center of ball *B* to center of cone *C*, 15 mm.
A-D, line of central ray passing through true position of projectile and its projected shadows P^1P^2.
Intersection of plane F^1F^2 with plane P^1P^2 is the position of projectile in front view at F^2.
F^1, position of projectile in side view.
F, position of projectile in horizontal section.
Average diameter of eye, 24 mm.

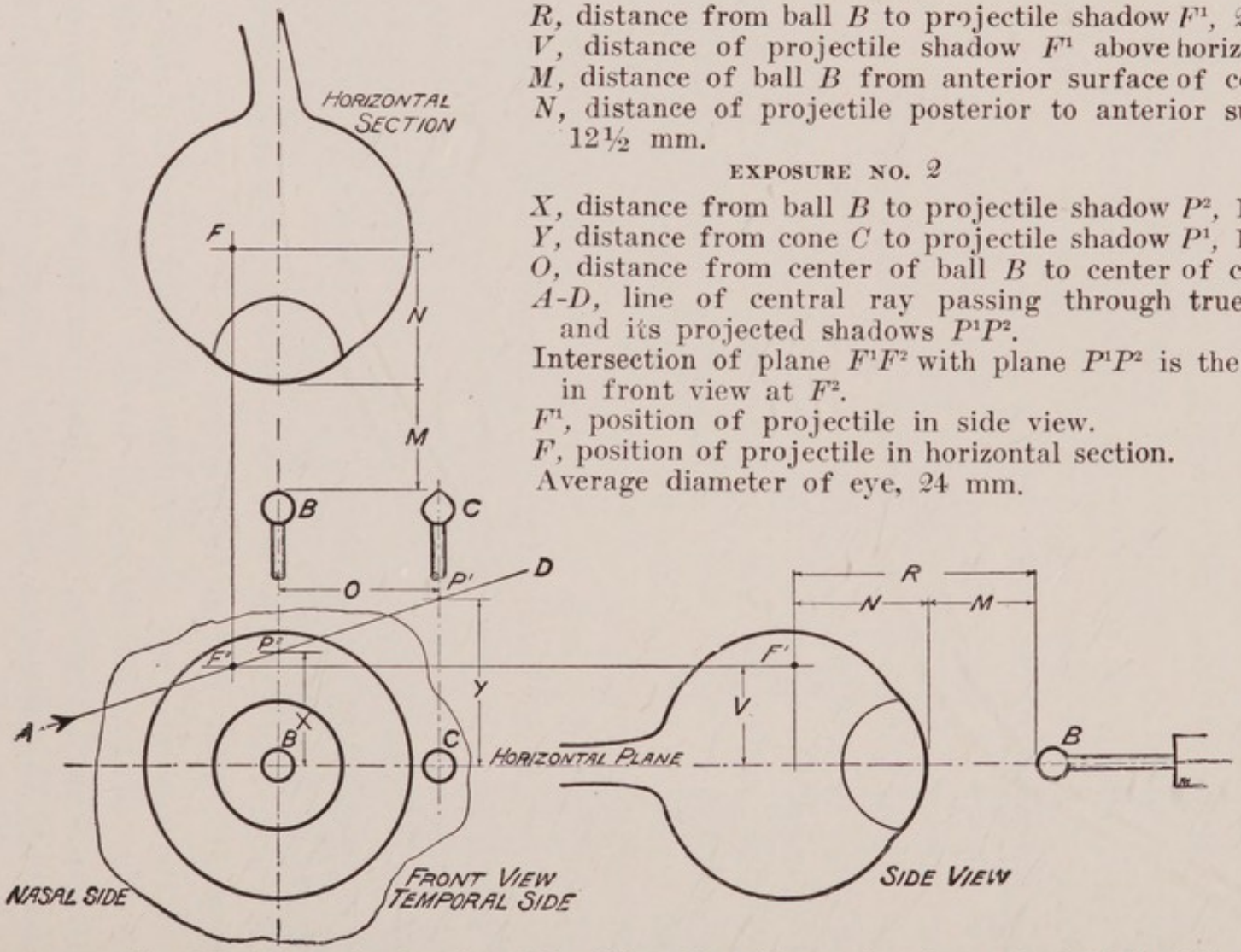


FIG. 95. Schematic drawing of localizing chart illustrating the method of obtaining measurements.

On the vertical line that has been drawn through the shadow of the foreign body (right-hand half of Fig. 93) measure the distance of the foreign body above or below the horizontal line and indicate the same on the chart above or below the axis, distance *V* locating dot F^1.

Place another dot on the same horizontal plane and draw a line through these two dots, parallel to the axis, projecting into the front view as shown.

Since the position of localizer-ball *B*, as shown on the chart, side view, is the same as when the first film was made, the location of the foreign body must be at point F^1. We have yet to establish its location to the nasal or temporal side.

Project a line vertically through point F^1 to the 45° angle (see Fig. 96), thence horizontally through the horizontal section.

Upon the negative (left-hand of Fig. 93) which represents the second or oblique exposure, a line is drawn through the horizontal axis of both the ball and the cone, thereby projecting their supporting stems and establishing the relation of their horizontal planes to that of the foreign body.

A third line is drawn at right angles to the first two through the center of the foreign body shadow.

With your dividers measure the distance of the shadow of the foreign body above or below the horizontal plane of the shadow of the ball, and mark the same by a dot on the front view of the chart just above or below the center *B*, as indicated by distance *X*, because that was the relative position of the indicator ball when it cast the shadow. Measure the distance of the shadow of the foreign body above or below the horizontal plane of the shadow of the cone, and mark the same on the chart at the point above or below *C* indicated by distance *Y* because that was the

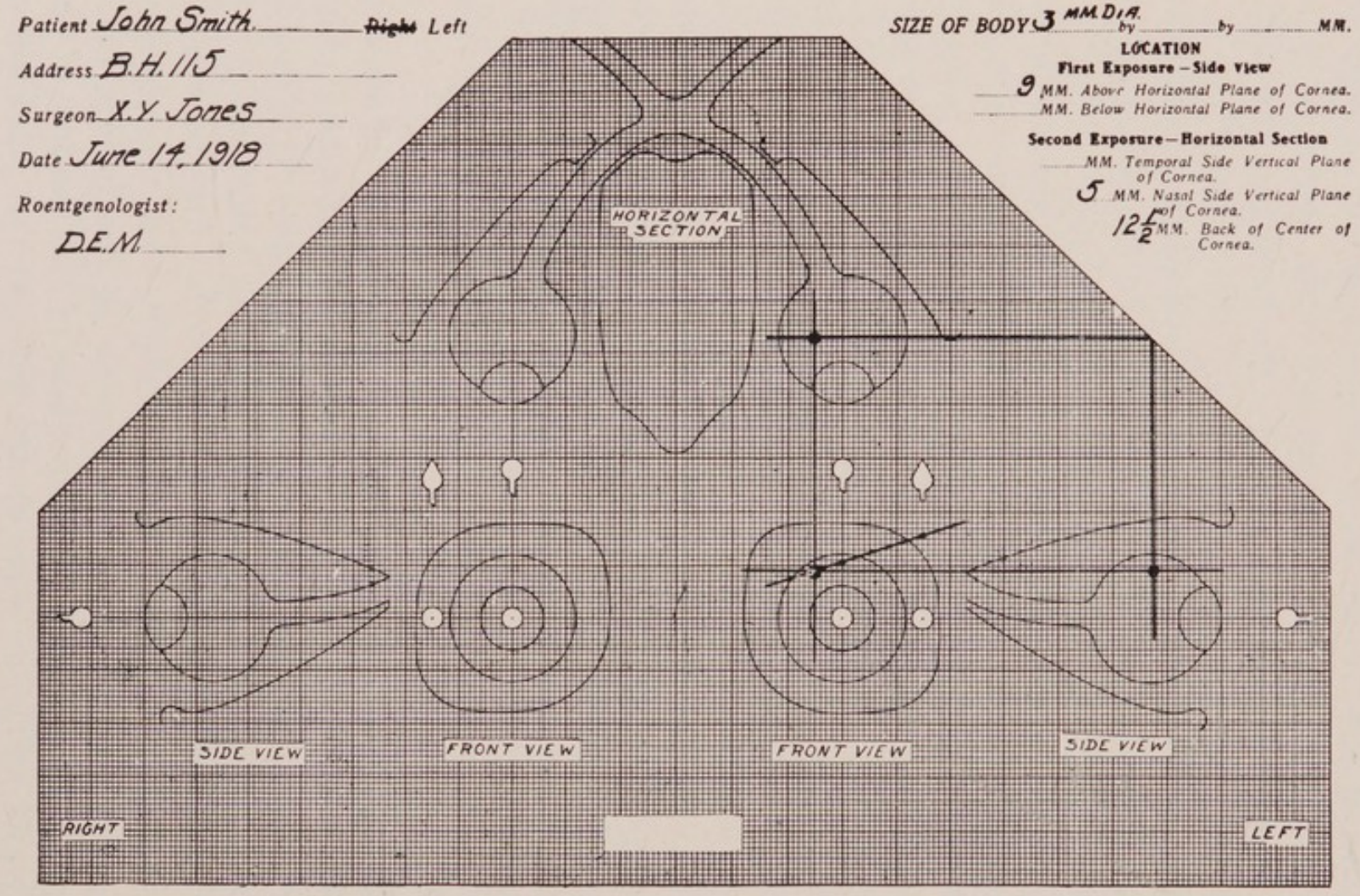


FIG. 96. Chart used in eye localization.

relative position of the indicator cone when it cast the shadow.

A line drawn through dots P^1 and P^2 will represent the true course of the rays in the second exposure, and its intersection with the projected line from the side view through the point F^1 will be the position of the foreign body when viewed from the front, while a vertical projection through the horizontal section shows the position of the foreign body to the nasal or temporal side at point F.

In these eye localizations a source of error is the fact that this is a schematic eye, constructed to correspond to the average eye which is about 24 mm. in diameter, but this may vary 3 mm. from the average.

Sometimes the variation can be measured with an ophthalmoscope and corrections made, but ordinarily the eye is so injured that this is impossible, and we must assume that the eye corresponds to the schematic eye. This error, of course, would interfere only in those cases where the foreign body is located 1 or 2 mm. inside or outside the sclera. In that event one would not be certain whether the foreign body was within or without the globe of the eye.

This point may often be determined in the following manner: Place the patient on his side with the affected side next to the film and center the tube over the eye. Fix the vision of the good eye on a spot in a plane parallel to the film, so placed that the eye is rotated toward the top of the head. Make an exposure of ½ the correct amount, then shift the vision to a point well toward the feet, still keeping the head fastened securely in place, and expose for the remainder of the necessary time.

If there are two images of the foreign body, it is certain that the foreign body moved with the eye and therefore must be in the globe.

It is barely possible for the foreign body to be in an ocular muscle and move, thereby giving two images, but its position near the exterior and anterior portion of the globe would help differentiate this.

In an acute case where a localizing apparatus is not available, this method may be all that is necessary.

Other methods of localization are: the Beguet and Gascan formula, stereoscopy, triangulation, parallax, ring localizer, chain, Hirtz compass, Caldwell's pointed rods, grid, malleable metal bands, calipers, harpoon, telephone probe, cardboard cut-outs, Baese device, and the bell ringing forceps. These methods have been elaborated, modified, or combined by many keen minds to a number of different techniques. Space does not permit even an adequate summary, although it is recognized that by each of them large numbers of foreign bodies were localized successfully.

CHAPTER VIII

BONES AND JOINTS

Fractures. A fracture may be defined as a break in the texture of a bone or, more briefly, as a solution of continuity.

The study of fractures with the aid of the *x*-ray enables us to decide: first, whether a fracture is present or absent; second, the number and relation of the broken fragments, so that the best mechanical measures can be selected for replacement. After a retentive dressing has been applied, it is easy to study the results of treatment without waiting for the test of healing and restoration of function.

Fractures may be classified as:

I. Simple: where there is no external communication.

II. Compound: where there is external communication. A compound fracture may communicate with the exterior by a bone fragment perforating the skin, or by the path of a projectile.

Bone damage from fracture may be listed as:

1. Incomplete (subperiosteal; green-stick): the periosteum is traumatized but not broken; the fracture line may not cross the entire width of a bone.
2. Linear: a crack in bone, as in linear fracture of the skull.
3. Transverse: across the long axis of the shaft.
4. Oblique.
5. Longitudinal: in the long axis of the shaft.
6. Spiral.
7. Butterfly.
8. Comminuted: many fragments at a single location.
9. Drill hole: by perforation of a bullet, without fragmentation.

10. Impacted: one fragment is driven into an adjacent fragment. Refers to long bones; seen especially in the shoulder, lower end of the radius, and hip.
11. Compression: a cancellous bone is squeezed into smaller bulk; encountered frequently in the spine.
12. Multiple: a bone is broken in more than one place, for example in the upper third and also in the lower third. This term may refer to the skeleton as a whole, as when more than one bone is broken.

Fractures from Projectiles. A high speed bullet striking bone may cause widespread shattering of osseous tissue. This shattering effect is especially evident in the shaft of the long bones. When the bullet strikes a cancellous end, or cancellous flat bone, it may perforate (drill hole fracture) or it may shatter the bone. The effect cannot be predicted, and varies with the speed of the bullet and its angle of yaw.*

A high speed bullet striking the skull may give up so much of its energy to the encased contents as to cause an action of explosive type, shattering the calvarium; or the bullet may perforate the skull without shattering bone. The difference in effect may be due to the speed of the bullet, to its angle of yaw, or to variation in the fluid content of the brain.

Bullets of very high velocity always cause shattering; the shock may be communicated to adjoining bones, and fracture them.

Shrapnel and shell fragments cause effects varying with the mass and velocity of the missile. There is often comminution, but seldom as extensive as is caused by the impact of a high velocity bullet.

* Angle of yaw: a bullet in flight may not travel with its long axis accurately in the line of flight; the end of the bullet pendles to a varying degree. The amplitude of the swing is the angle of yaw.

Small lead bullets of low velocity usually cause only slight injury to bone.

The report should include the location of opaque foreign bodies.

The radiograph of a fractured bone shows a dark line indicating the solution of continuity; displacement of the fragments; abnormal alignment; and alteration in shape or contour. The dark line is not seen when the fracture is impacted. The displacement is mainly caused by the contraction of the traumatized muscles; it may not appear for a day or two, especially where severe or crushing injuries cause temporary paralysis of the muscles. Abnormal alignment may be prevented by a parallel bone splinting its injured fellow. Alteration in shape and contour is especially important evidence when there has been an incomplete fracture of a long bone, or a compression fracture of cancellous bone.

Incomplete fractures are often found in the long bones of children; while there is no separation of the fragments, the fine tracery of the haversian canals is wrinkled, the bone is widened at the fracture line, and the alignment is altered.

Incomplete fractures are frequent in the cancellous bone of adults; the bone is compressed, so at the fracture line there is more bone tissue rather than less, and the fracture line if seen at all appears as a white line instead of a dark line. There is change in shape and contour. The alignment may be altered.

Artefacts. Scratches upon the films have been mistaken for solutions of continuity; artefacts due to air bubbles have been confused with foreign bodies. Difficulty in interpretation may arise from dressings impregnated with salts of the heavy metals, such as bichloride of mercury or magnesium sulphate, or the application of adhesive plaster. These substances cast a white shadow, obscuring bone

detail. Occasionally there is air in an interspace or ridge of the dressing that casts a comparatively dark shadow, that might simulate a fracture line. The planes of fascia may carry a deposit of fat, as at the margin of the psoas muscle. As the fat is less dense than surrounding structures a dark line appears on the radiograph. While dark lines crossing bones may resemble fractures to an annoying degree, they are readily differentiated, because the line due to an artefact passes the bone and enters soft parts.

Epiphyses. An epiphyseal cartilage casts a dark linear serrated shadow similar to the shadow of a fracture. The epiphyseal line most commonly mistaken for fracture is at the crest of the ilium, which does not ossify until the age of eighteen or twenty. After the epiphyseal cartilage is completely replaced with bone there may be a white line resembling the shadow of a compression fracture; this white line is often seen in the lower end of the radius.

When there is doubt whether a linear shadow might be due either to an epiphyseal cartilage or to a fracture, a film of the uninjured limb may be made for comparison.

Epiphyseal separations are rare. Not uncommonly an epiphysis may appear to fit so badly on the end of a bone that it is thought to be displaced; a comparison with the opposite side will show this not to be true. Some epiphyses are segmented; this is often seen in the posterior epiphysis of the calcaneus. Occasionally a fracture line may involve an epiphysis, but it nearly always runs into the shaft at some point.

A table showing the time the epiphyses appear and the time of their ossification is appended at the end of the chapter. This table represents the average. As is well known, normal individuals vary both in the time the epiphyses appear and in the rate of their growth; there is even some difference between opposite sides of the same person. For

this reason it is not safe to estimate the growth of the entire skeleton from the appearance of a single bone; as the one bone might indicate retarded growth, but the other bones show development at an average or normal rate. In female children the process of ossification is more rapid than in the male. The centers of ossification appear one to two years earlier and the epiphyseal line is closed by ossification at a younger age.

Extra bones are the cause of occasional controversy. A table is appended at the end of the chapter. The list includes only the extra bones more commonly encountered.

Sesamoid bones are clearly shown on the radiograph. They are often divided into two or more parts and may simulate a fracture. Divided sesamoids are often seen opposite the head of the first metatarsal, and the head of the first metacarpal.

When a sesamoid has been fractured the opposing surfaces are uneven; the size and shape of the fragments are usually not similar. When a sesamoid has developed in two parts, the opposing surfaces are smooth; the size and shape of the two parts are similar.

Compact islands are small dense shadows, usually oval, about the size of a pea. They may appear in the ends of long bones, and occasionally are found in the pelvic bones; they are especially common in the upper end of the humerus and in the carpal bones. They are usually solitary, only one appearing in a given location. Near the old epiphyseal line they may occur as white streaks approximately parallel with the ossified epiphyseal cartilage. They are thought to develop from misplaced bits of epiphyseal cartilage. There is no pathological significance.

Fractures of more than one bone are often encountered. Thus with fracture of the lower end of the radius there may be injury to the scaphoid and dislocation of the semi-

lunar. Impacted fracture of the neck of the femur may be associated with fracture of the acetabulum, or fracture of a pedicle of the fifth lumbar vertebra. A break in the anterior

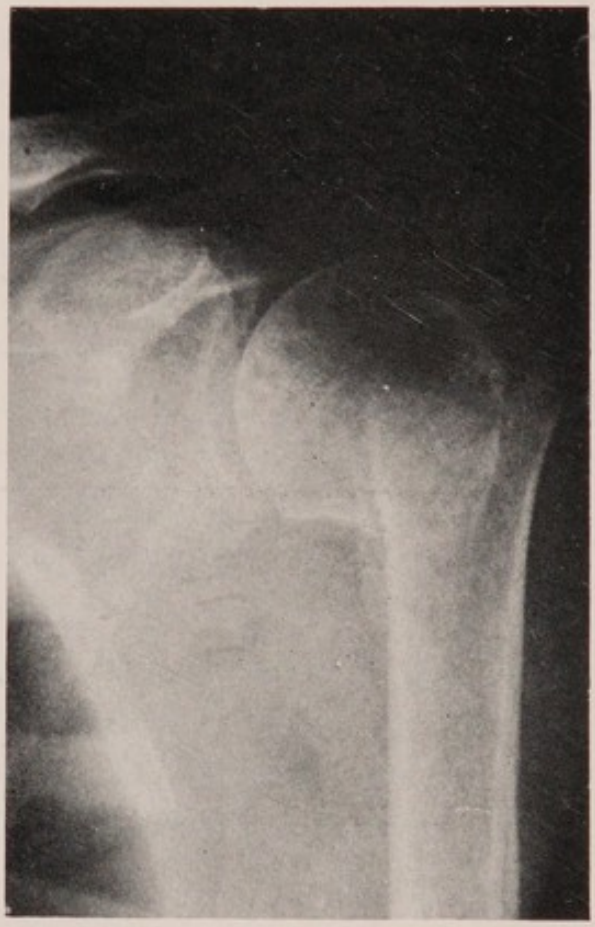


FIG. 97. Fracture of neck of left humerus. (From Forrester: Imperative Traumatic Surgery.)

portion of the pelvic ring is usually associated with fracture of the posterior portion. A spiral fracture of the lower third of the tibia must of necessity cause the fibula to give way in its upper third.

Gas in the tissues casts a dark shadow. If the gas collects in the intermuscular septa there are dark streaks arranged along the course of the muscles. If the gas forms within a muscle there are dark spots and blotches grouped where the muscle is the thickest. The shadows are not clear cut, smooth in contour, or regular in arrangement, as are the

radiotransparent lines due to a normal deposit of fat, but are splotchy, with indefinite margins, uneven in shape, and have no definite arrangement. If a wound is infected with any of the gas producing organisms, these changes may become manifest within a few hours after the injury is received.

Reports. In writing reports of *x*-ray films for fractures, it is essential to describe *first* the area shown by the film with the anatomic parts of the bone examined; *second*, to give a description of the traumatic pathology shown; *third*, a statement as to the condition of the bone, or bones, and of the soft parts outside of the area described in the second heading. In the report the manner in which the film is made should be described so that this can be taken account of in considering the interpretation. For example, if a lateral film is made, this fact should be mentioned at the beginning of the description. A description of the traumatic pathology should embrace, first of all, the part of the bone involved; second, the type of fracture, whether transverse, oblique or longitudinal; third, whether comminution is present and the number and size of the fragments. In all cases the relative position of the fragments should be described. If the fracture is complicated by the presence of a foreign body, this should be stated, with the size, shape and position, and its relative position to the bone fragments.

Particular attention should be paid to the question as to whether the fracture line involves joint surfaces. Prognosis and treatment are materially affected in this type of injury.

If it is doubtful after an examination of all the films whether a fracture is present or absent, this doubt should be plainly stated and the reasons for it given. If the uncertainty is based on lack of penetration or blurring due to movement, a second exposure should be made. If splints

were present at the time of examination, their appearance should be described and special note made as to whether the shadow of the splint complicates the interpretation.

Negative Reports. If the examination does not reveal the ordinary *x*-ray evidences of fracture, this should be stated with a definite description of the area shown by the film. For example, a negative report stating that there is present no fracture of the tibia or fibula should not be made unless the film shows the entire length of the tibia and fibula. If the limb is rayed in only one direction, note should be made of this and the conclusion should be stated that no disturbance of the outline of the bone is shown in this *one* view.

Reduction of Fractures under Fluoroscopic Control. The recommendations of the American College of Surgeons are as follows:

1. A room should be prepared for the reduction of fractures under fluoroscopic control. Shades or shutters should be provided in order to exclude all light. Provision should be made for adequate illumination during the application of retentive appliances. The floor area should be large enough to accomodate the *x*-ray fracture table, apparatus, casual tables for anesthetist, dressing, etc., and there should be sufficient space remaining to accommodate the personnel without confusion. Ventilation must be adequate when the room is darkened.

2. The *x*-ray fracture table when chosen must satisfy both the radiologist and the surgeon.

3. The apparatus must be so designed that no sparks will occur, and no part of the high tension circuit can by any possibility come within 6 inches of patient, operator, attendant, or casual visitor. Protection from stray radiation must conform to the standards accepted by the International Congress of Radiology.

4. The surgeon must avoid any possibility of *x*-ray dermatitis of his hands. He should wear rubber operating gloves. He should limit himself to not more than two

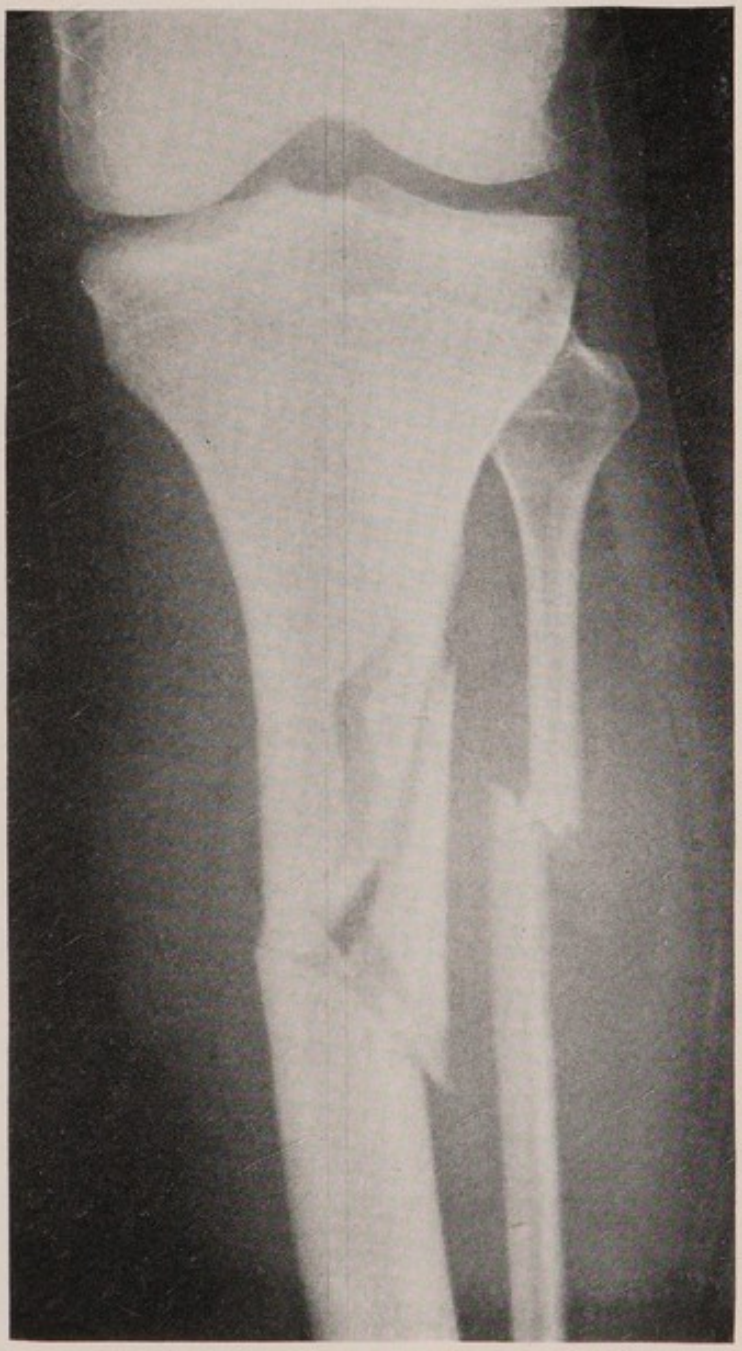


FIG. 98. Fracture of tibia and fibula.

fluoroscopies a week. He should wear red glasses for ten minutes before beginning fluoroscopy, that he may thereby prepare his eyes to see the bones clearly and immediately.

He should remove the red glasses after the room is darkened, and resume the glasses during periods of illumination.

5. The exposure of the patient should be limited to a total of seven minutes, using not more than 5 milliamperes of tube current. Each single observation should be as short as possible.

6. The anesthetist should be provided with a flash light.

7. Fluoroscopy should never be done with portable apparatus. Progress during suspension—traction treatment should be estimated by the use of radiographs. The fluoroscope is useful for checking up immediately after reposition of fragments and for adjustments of fractures about joints.

8. A radiographic film should be taken of every case, as a check for fine detail and as a medicolegal record.

Repair of Fractures. It is the usual practice to make radiographs shortly after reduction, to determine if the position of the fragments is satisfactory. In certain classes of cases, such as fractures of the femur and tibia, reduction is attained slowly, and films are required frequently. These progress examinations should define the changes that have taken place. This can be done accurately if the tube is at least 25 inches from the film, and directly opposite the known location of fracture: and if the radiographs are truly anteroposterior and lateral. The possibility of an *x*-ray injury from repeated examinations may be absolutely avoided if the total of all exposures does not exceed 60 ma. minutes at a 25 inch distance. If intensifying screens are used, the average single exposure is less than 1 ma. minute (see p. 104, Dangers and Protection). The report should be made after a comparison with the films taken previously.

Callus should cast a shadow in ten days if the fracture is in a phalanx, six weeks to two months if the broken bone

be the adult femur. The time of first appearance of the callus, and the rate of its increase in density, may be a guide to treatment in some cases, but as a general rule the clinical evidence of repair is sufficient without *x*-ray examination. The time of appearance of the callus is shortened in the young; when mechanical irritation is great; when the bones are not in accurate apposition; and when the blood supply can be maintained by massage or other methods. The appearance of callus is delayed in the aged; when the bones snap with little tearing of periosteum; when anatomical reduction is nearly attained; when blood supply is impaired, as by pressure on or injury to blood vessels; in certain bones, such as the lower third of the tibia, the scaphoid of the wrist and the inner malleolus of the tibia; and for utterly unknown reasons. Syphilis undergoing treatment does not delay the formation of callus. In certain bones, such as the cranial vault, no callus may be evident long after the clinical recovery is satisfactory.

Fractures of cancellous bone, particularly compression fractures of the vertebrae, may be watched for further reduction in substance. Unless weight bearing is completely removed, a fractured vertebral body tends to collapse further.

Radiographs Made through Splints or Casts. In radiographing parts of the body enveloped in splints or casts, there is presented, oftentimes, a difficult problem. For purposes of exact diagnosis it is always best, when possible, to remove any splints or casts. If the examination is made for determining the position after reduction, the dressing should be left on. The length of exposure is to be increased so as to compensate for the extra amount of material which has to be penetrated. Some splint materials, for example, yucca board, contain particles of extra density which, when superimposed on the shadows of the bone, render the

detection of subperiosteal fractures difficult. It often occurs that the radiologist has to decide whether callus is present or absent in a limb enveloped in a plaster splint. It can be stated that this is oftentimes impossible to be decided, as the varying densities of the folds of plaster induce shadows which may simulate the appearance of callus. Sometimes when a limb has a splint on one side only, the rays can be directed so that the shadow of the bone can be wholly or partly isolated from the shadow of the splint. In elbows confined with a right-angle metallic splint, the metal may cast a shadow over the part especially interesting, and here in the interest of exact diagnosis it is best to secure permission to remove the splint. Dry plaster is more easily penetrated by the ray than moist plaster, so that it is always best to *x*-ray a limb in a plaster cast after the cast has become thoroughly dry. The position of the fragments of long bones of course can be accurately told even when enveloped in a wet plaster cast, but it is not to be expected that fine detail and the presence or absence of callus can be made out without the removal of the cast. Where the examination has to be made in only one direction the films should be stereoscopic.

Splints, casts, dressings, bandages, etc., should never be disturbed by the radiologist. If they have to be removed, this should be done by, or under the direction of, the surgeon.

While each case presents its own problems, in some instances there are fractures that are distinctive either because of the shape of the bones or their function. A brief summary may conveniently call to mind a few of the more interesting features.

Humerus, upper extremity. Intracapsular fracture may be associated with avulsion of the greater tuberosity (Fig. 99). The greater tuberosity may be torn off by muscular action (strap-hanger's fracture). In all fractures through

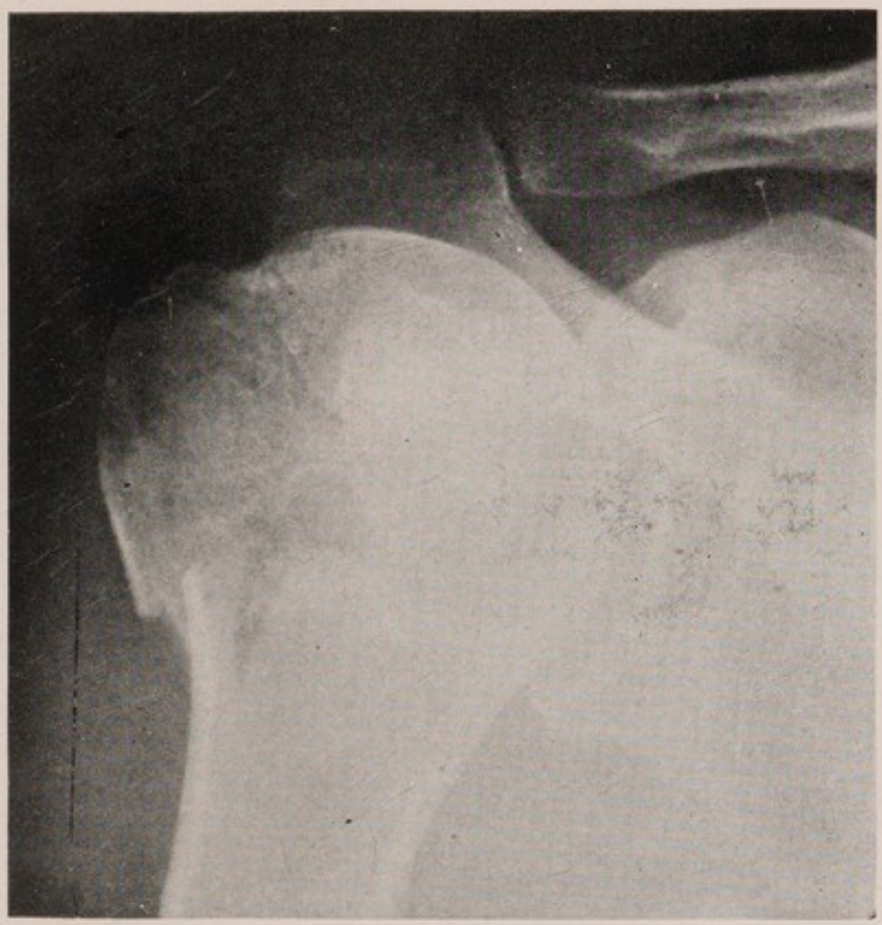


FIG. 99. Intracapsular fracture of head of humerus. (From Forrester. Imperative Traumatic Surgery.)

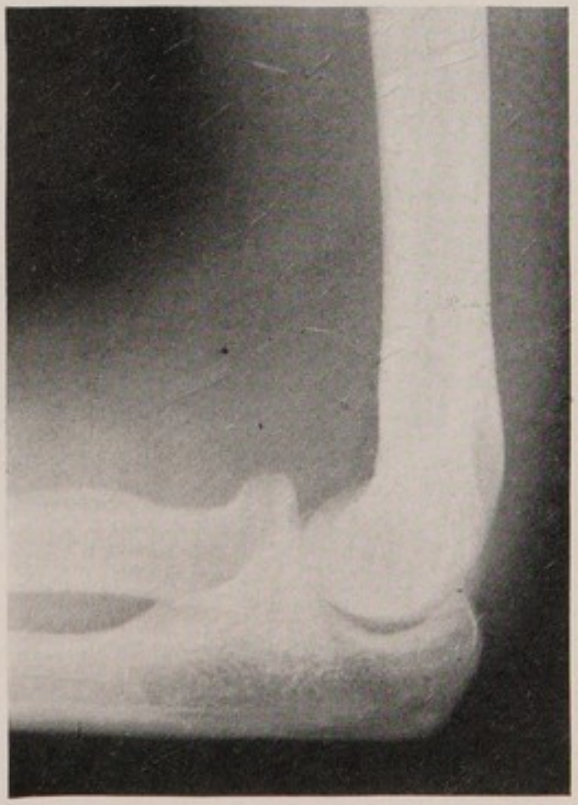


FIG. 100. Normal elbow, showing angle of shaft of humerus with elbow joint.

the upper extremity the position of the head with reference to the shaft must be demonstrated. It is often necessary to place a film in the axilla, the arm abducted, and direct

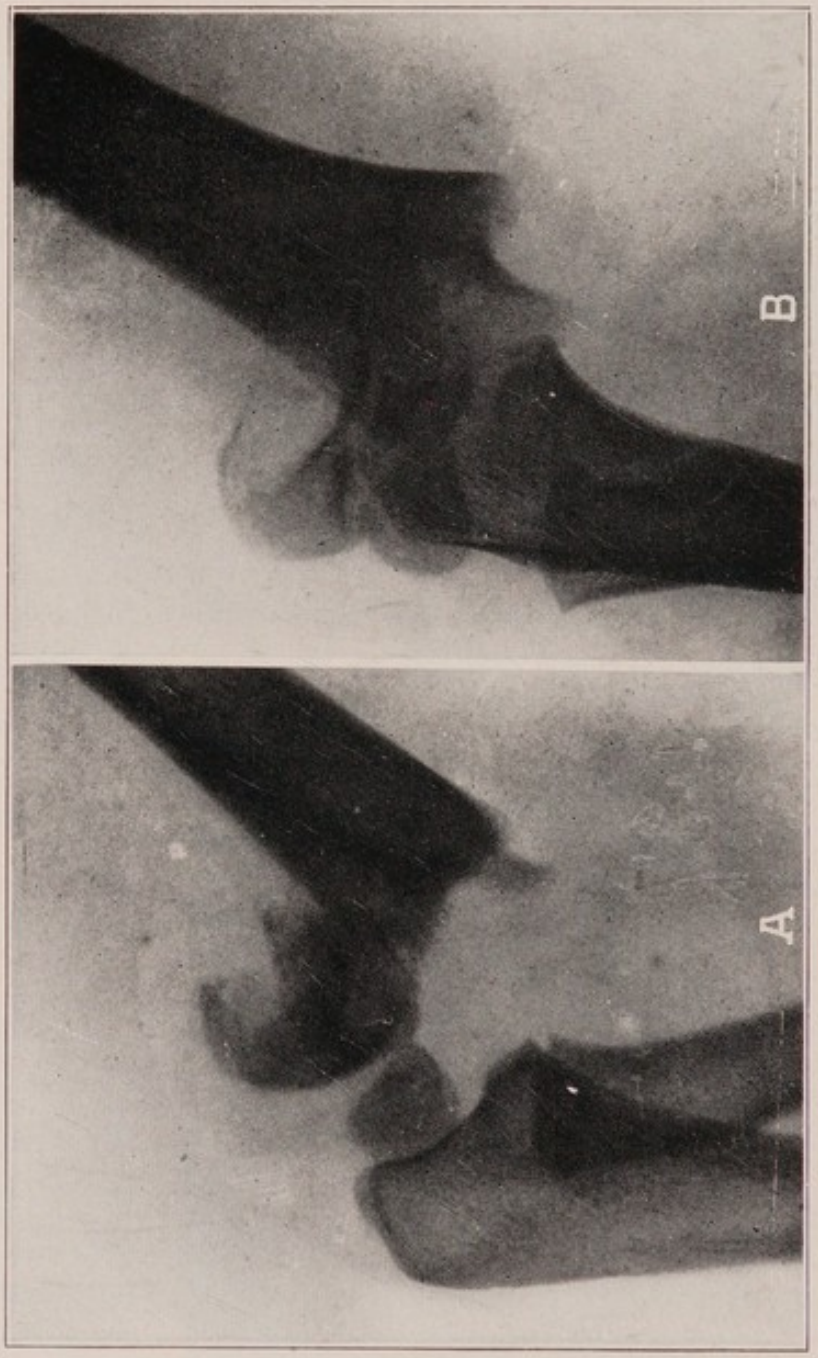


Fig. 101. Fracture, elbow. (From Cohn: Normal Bones and Joints An als of Roentgenology, Vol. IV.)

the ray longitudinally from the head toward the feet.

Elbow. The lower fourth of the humerus is inclined forward (Fig. 100). The carrying angle of the forearm varies between flexion and extension, but is always inclined out-

ward. While the anteroposterior view demonstrates the fracture line, it is the lateral view that is of the greatest interest to the surgeon. A troublesome fracture about the

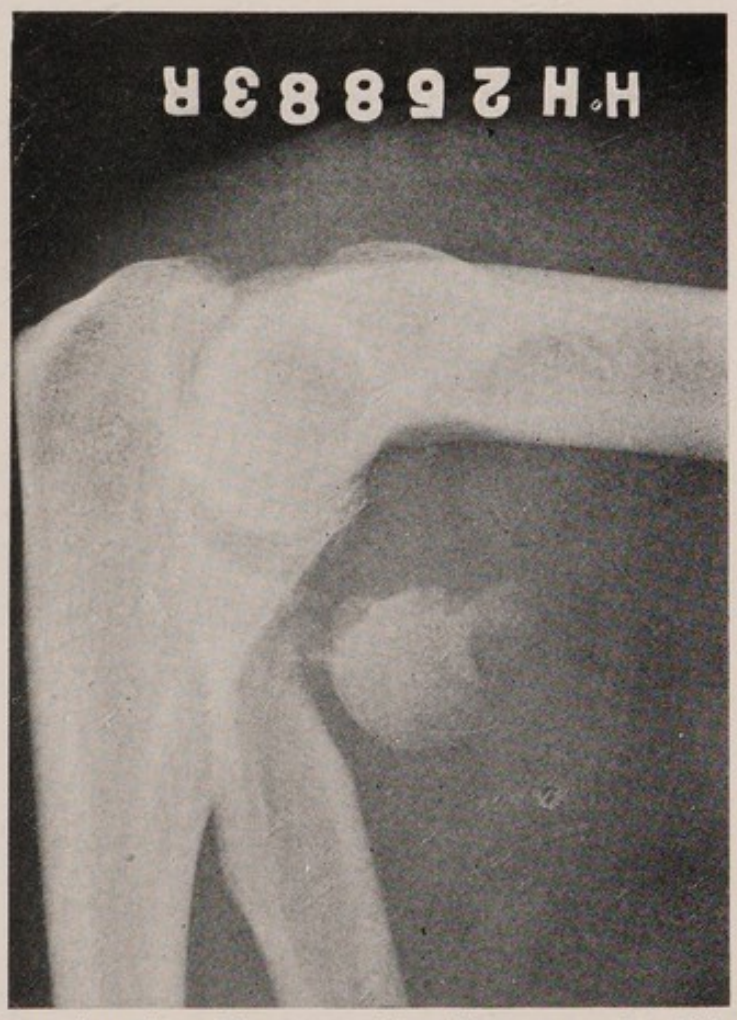


FIG. 102. Comminution, fracture of radius at neck, dislocation of fractured head of radius. (From Forrester: Imperative Traumatic Surgery.)

elbow joint is an incomplete line through the head of the radius. Normally the head is asymmetrical, the anterior and outer lips being more prominent. When fracture occurs, a fine black line can be demonstrated in an oblique view, and a segment of the head is depressed 1 or 2 mm. Dislocation of the head of the radius may be determined by observing its relation with the capitellum.

Lower Extremity of the Radius and Ulna. The radiocarpal joint is normally inclined to the front 10 degrees. As in

most of these fractures the impaction is especially in the posterior aspect, the plane of the joint is displaced backward, carrying the carpus with it. This causes the silver

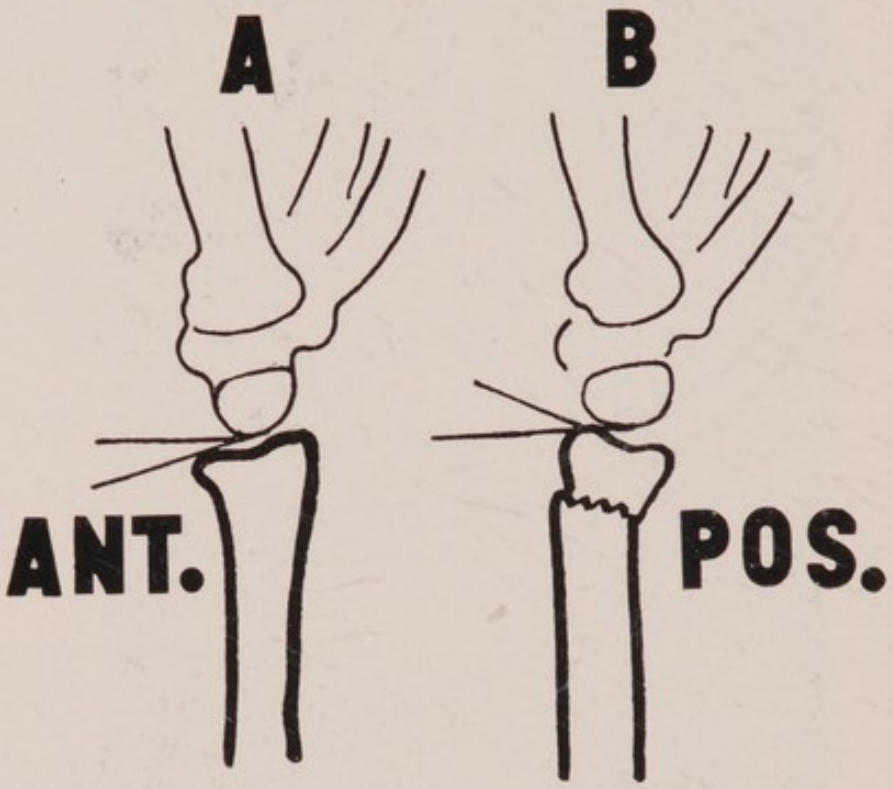


FIG. 103. Diagram showing, *A*, the plane of the radiocarpal joint; *B* changed position after fracture.

fork deformity. (Fig. 103.) The carpus is chiefly attached to the radius. If the radius is shortened, the carpus is carried up with it, wedging against the ulna on the inner side. The radioulnar joint is usually injured, which may interfere with pronation and supination.

Fractures of the hip are usually quite evident, but occasionally a case presents difficulty. Careful positioning is very important, as the entire length of the femoral neck must be demonstrated. These cases may be complicated by fracture of the 5th lumbar vertebra (often a pedicle) or of the pelvis. Callus appears slowly, and may not be manifest for six months or longer. Sometimes radiographs are

asked for frequently; it is a good plan to keep a record of the number and the length of the exposures.

Dislocation of the *acromio-clavicular joint* is best shown in the upright position. Anomalies of the joint are common, and the opposite side should be taken for comparison. Usually it is possible to demonstrate a rupture of the coraco-clavicular ligament, which gives way at its insertion, carrying off a flake of bone or stimulating callus.

Fracture of the Skull. The shape of the skull and its elasticity, the close fitting covering of skin, muscle, fascia and periosteum on the outside, and the pressure of the intracranial contents and the dura on the inside, tend to immediately replace and maintain fractures in position. For this reason, we find fractures indicating only slight bony injury, the grave lesion being to the blood vessels, intracranial nerves, dura and brain substance and the secondary conditions arising therefrom; the presence or absence of fracture, in such cases, fades into insignificance except as a clue to the site of the injury and a guide for surgical procedure.

Varying from this class, we have the other extreme; namely, those having an extensive bony lesion, as in depressed or perforating fractures, with or without injury to the underlying structures. In such cases, the location and character of the fracture must be considered. Here the force is consumed in breaking bone at the point of impact, the effect being dependent upon the amount of force, the point of injury and the character of the body producing the fracture.

Between the two definite forms above mentioned, there is much variance in the importance of the bony injury.

Fractures of the skull may be divided into those of the vault and those involving the base. In over 50 per cent

of the cases examined radiographically there is found a combination of both. Fracture of the vault may be due to direct or indirect violence or it may be an extension from the base. There have been various theories advanced relating to these fractures, such as Aran's theory of irradiation, the bursting theory, fractures by contrecoup and the Rawling theory of direct violence. It would seem as though each applied, as a causative factor, to certain classes of fracture of the skull. Experience shows that cases which are able to reach the radiologist present a fairly constant effect of direct violence, the point of impact receiving the maximum amount of bony injury; from this point, we have radiating fracture lines which seek the weaker parts of the skull in the immediate neighborhood.

The common fractures of the skull are described as: fissured, comminuted, diastasis of the sutures, depressed and perforated. The frequency with which these fractures are mistaken for various other conditions, especially in cases of coma, calls for a method which will make a rapid and positive diagnosis. On account of the many difficulties which are encountered in the correct diagnosis of head lesions the routine *x*-ray examination of the skull is of the greatest importance in all head injuries. It offers an actual visual demonstration of the presence or absence of fracture, its location, character and extent.

Traumatic skull injuries should have systematic *x*-ray examination when the condition of the patient permits. In every case of skull fracture accompanied by shock, the *x*-ray examination should, if possible, be deferred.

When a case of head injury is referred to the radiologist for examination, the patient is often in an irritable, semiconscious or comatose condition. Extreme patience and perseverance are required. In skull examinations, the patient's head must be absolutely fixed. If the objective

symptoms, such as bleeding from the ear, nose or mouth, laceration of the scalp, hematoma or paralysis be present, they are a clue to the possible site of the fracture, and attention is naturally directed toward that area; this must not mislead one, however, for every examination should cover the frontal, the parietotemporal, the occipital and basilar regions.

Fractures of the vault of the skull show best in stereoscopic films exposed in the true lateral, anteroposterior, and posteroanterior positions. Fracture lines must be differentiated from suture lines and from the grooves of the meningeal vessels. The suture lines are recognized from their constant position and their serrated margins. Both the lines of the vessels and the lines due to fracture are black; both are branching; neither show any constancy in arrangement or direction. There are three means of differentiation: (1) The blood vessel line is straight or an even curve; the fracture line may be jagged, with a sharp angulation. (2) The position of the main stem of the anterior, middle, and posterior meningeal vessels is known; their branches may usually be traced back to the main stem; the fracture line cannot be traced back to a known blood vessel and may cross a blood vessel. (3) Any displacement of plates of bone renders the diagnosis easy; remembering that in the anteroposterior view the plate of the temporal bone overlaps the parietal and may show a niche in the skull contour. Healing of skull fractures to the degree that solid bone obliterates the fracture line may not occur for many months after clinical recovery is satisfactory. The report should include the exact location of every fracture line, the size of each displaced fragment, and the amount of displacement. As fractures of the base usually evade the most searching radiographic examination, an eliminative conclusion, that no fracture is present, should never be ventured.

Arthritis. A normal joint is composed of three parts, namely, cartilage, synovial membrane and the synovial fluid. There is no free bone in the joint proper; the consequence is that in attempting diagnosis of joint conditions we do so by means of the changes in one or more of these three parts.

We may divide arthritic conditions into two classes. First, the acute, and second, that large group which we may class as arthritis deformans. Under the first group would come acute polyarticular rheumatism. This type comes nearer to being a distinct clinical entity than any of the other forms of this disease.

In acute polyarticular arthritis the *x*-ray indications are rather indefinite. We find that there is an increased amount of fluid in the joint, and the synovial membrane and periarticular tissues are swollen. There is no destruction of cartilage, as we can tell by the fact that the joint space is of normal width. The cartilage itself is not visible by means of the *x*-ray, so we have to judge its presence or absence by indirect evidence, namely, the width between the bony surfaces that compose the joint. Since, in this condition, there is no destruction of cartilage we may expect the joint to come back to its normal condition, and, after the disease has subsided, the *x*-ray examination will show an absolutely normal joint.

When we take up conditions in rheumatoid affections we meet very considerable difficulties. The classifications of the various types under this head are very unsatisfactory, and then, too, these so-called chronic rheumatisms have so many names for the same condition. For example, we see the terms chronic rheumatism, arthritis deformans, rheumatoid arthritis, osteoarthritis and spondylitis used indiscriminately by different individuals and yet meaning the same condition. There is no classification which is

absolutely satisfactory, but that adopted by Goldthwait many years ago is, taken as a whole, probably the best. Of course, many men take exception to his classification

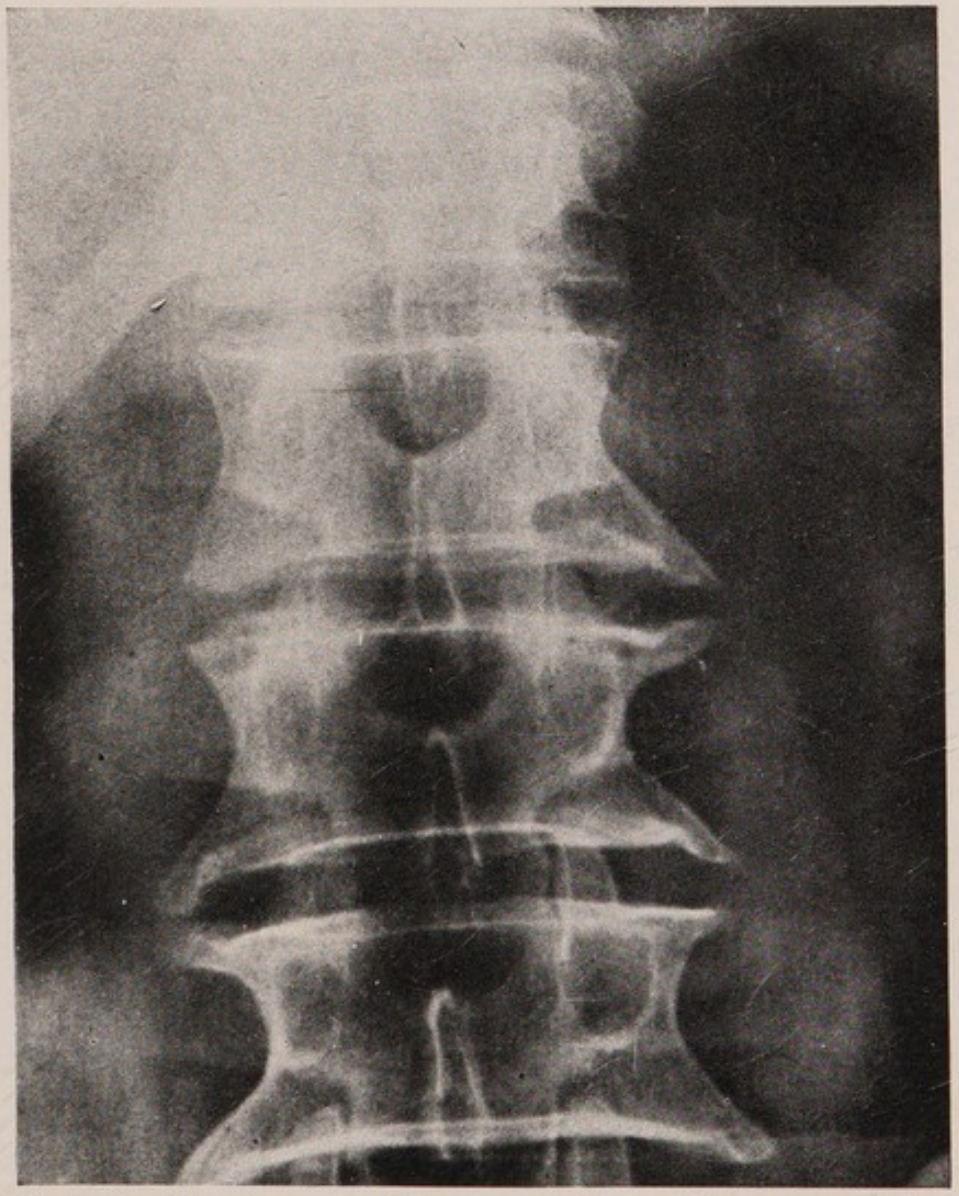


FIG. 104. Arthritis, hypertrophic type. (From George and Leonard: The Vertebrae, Annals of Roentgenology, Vol. VIII.)

and do not agree with it as a whole, but its simplicity and the great number of cases which can be classified according to it makes it seem generally the most useful. He divides chronic arthritis into:

1. The infectious type. This includes tuberculosis, gonorrhea, syphilis, pneumococcic infection and those types of arthritis which have the same clinical manifestations, but where the etiological factor is unknown.

2. Those cases designated as atrophic.

3. The hypertrophic cases.

Infectious arthritis, from an *x*-ray standpoint, presents three different appearances, according to the stage of the disease at the time of examination. For example, in the first stage we have an acutely inflamed joint, and a marked amount of fluid present with periarticular swelling. There is no cartilaginous destruction and consequently no bone destruction. This stage gives the same *x*-ray appearance as an acute polyarticular rheumatism or an injury to the joint without fracture, because in these conditions we also get fluid, periarticular swelling and no cartilaginous changes. In the second stage the disease probably reaches its maximum intensity and, in time, the following changes take place in the joint and bone. In the first place, on account of the disuse of the joint, we begin to get a generalized atrophy of the bone, the swelling has partially disappeared and the fluid may be partially absorbed. The cartilage is now eroded, as shown by the fact that the joint space is narrowed, but there is no new bone formation. The soft tissues may have even atrophied somewhat. Occasionally we may see punched-out areas. The punched-out areas are best seen when the layer of bone is thin, as in the phalanges, wrist, or sacroiliacs. In the third stage, or we may term it the stage of repair, the active infection has disappeared and the patient is beginning to use the joint, consequently, the atrophy is disappearing or will have completely disappeared. The soft tissues are resuming their normal appearance, and, where the cartilage has been destroyed, it is replaced by proliferation of new

bone. In other words, we get the formation of bony exostoses. The extent of these exostoses depends entirely upon the severity of the lesion, and in some cases cartilage has been so completely destroyed that we have a true bony ankylosis. This type of infection is seen in all ages of life, that is, from early adult life up to and through old age.

Atrophic Arthritis. Atrophic arthritis is generally seen in early middle age. There is marked atrophy of both soft tissues and bone. The joints are frequently partially subluxated, due to the contraction of the tendons, and there is limitation of motion; the latter is not due to bony ankylosis, however, but to fibrous changes and muscle contracture. The *x*-ray examination shows marked atrophy of the bone. There is extensive absorption of cartilage and its complete destruction in certain areas, but there is apparently no attempt at new bone formation. From this description one can readily see that the atrophic arthritis simulates very closely the second stage of infectious arthritis. The only differential point is that at no stage in this disease is there any fluid or periarticular swelling, while in the second stage of infectious arthritis one is apt to find a small remaining amount of swelling and fluid. Many clinicians think that atrophic arthritis is not a distinct clinical entity but probably one of the stages in an infectious arthritis.

Hypertrophic Arthritis. Hypertrophic arthritis is a disease almost invariably associated with people of middle life and old age. One rarely sees this type under thirty-five and it is most pronounced in patients in the neighborhood of fifty and over. The *x*-ray examination shows that there is practically no atrophy, in fact, there is condensation of bone so that the bone shadows are even a little denser than normal. When the age of forty-five is reached there is always a certain amount of atrophy in the bone, due to

what might be called a senile change. This is completely absent in the hypertrophic type. Besides the condensation of bone there is a marked formation of exostoses, due to small areas of cartilaginous destruction and marked lipping at the edge of the articulating surfaces. Frequently little, bony, loose bodies may be present in the joint (joint mice). There may be ankylosis of the joint, but this is not a true bony ankylosis but simply one due to the mechanical locking of these bony exostoses. This type simulates the third stage or the stage of repair in an infectious arthritis. In hypertrophic arthritis, if the condensation of bone is absent, it is extremely difficult and, at times, impossible to differentiate between the third stage of infectious arthritis and hypertrophic arthritis, particularly if the patient is in the neighborhood of fifty.

Great care must be taken not to confuse the slight arthritic changes which are always present in people over fifty with an acute active process. It has been definitely established that practically all of us when we reach the age of forty-five show small exostoses in and around the joints, and yet there may be no clinical manifestations of an arthritic process. It is particularly in these joints that we get such marked symptoms following a slight injury, symptoms out of proportion to the extent of the injury. In this condition we must remember that the injury has simply lowered the resistance of the joint and has allowed this quiescent arthritis to flare up into an active process, so that the marked clinical manifestations seen in such joints are really the result of the arthritis and not of the trauma.

We have mentioned the subdivisions under infectious arthritis where the etiological factor is known. The question naturally arises, do any of these give such definite *x*-ray changes that we can actually determine the specific type of the infection with which we are dealing. Unfortunately,

the majority of them give the same *x*-ray indication. Some, however, give fairly constant appearances so that they can be readily recognized.

In *tuberculosis of the joint* we have a marked hazing so that the *x*-ray shadows are very indistinct. In fact, it suggests that we have a very poor film, but in this same film one will note that the bones adjacent to the affected joint come out sharply and distinctly. It is only the joint itself that is hazy and indistinct. This is due to the thickening of the synovial membrane. Upon close inspection we will find that the bone contour, that is, the bone beneath the cartilage, is very indistinct, irregular and eaten out. In the active process fluid is present and there is marked periarticular thickening. When the disease subsides this haziness and indistinctness of the joint disappears, but we still have an irregular and eroded joint surface, indicating that there has been some destruction of cartilage and slight destruction of the bone beneath. There is very little tendency to new bone formation, and the ankylosis, if present, is generally fibrous in nature. Since these joints when untreated so frequently form sinuses, there is a great chance of having another infection besides the tuberculosis in the joint. It is in these mixed infections that we see marked new bone formation. Other conditions may deform a joint and should be considered. For example a hip may be deformed by Legg's disease (p. 270); a vertebra may be deformed by an old fracture or by a neuropathy (p. 257).

Gonorrheal arthritis does not give us distinct *x*-ray appearances. It varies according to the severity of the lesion. In only one joint do we have fairly definite characteristics, namely, the knee joint. In that particular joint, for some reason, the greatest severity of the lesion seems to take place in the cartilages beneath the patella, and early bony

ankylosis occurs. In a knee joint in which we find ankylosis between the patella and the femur gonorrheal arthritis must be borne in mind. Exostoses and ankylosis are quite common in this disease.

Syphilitic arthritis shows marked periarticular swelling, thickening of the synovial membrane and fluid in the joint. This type does not go on to cartilaginous destruction, consequently, when the disease subsides we have a perfectly normal joint. The *x*-ray appearance is identically the same as that of an acute polyarticular rheumatism. Fortunately, this type is generally accompanied by bone change. While this change is not present in the joint itself at the same time it is fairly characteristic, namely, a small area of periostitis forming just at the point where the cartilage of the joint ceases and the periosteum of the bone begins. This periostitis in conjunction with periarticular swelling and fluid in the joint is fairly characteristic of a syphilitic lesion.

The *Charcot joint* must not be confused with this acute syphilitic joint, since the changes in the former are neuropathic rather than infectious and are characterized by great destruction of the joint with splitting off of large fragments of bone, which lie free in a swollen joint filled more or less with fluid. In addition, there is marked eburnation of the remaining ends of the bones. Upon glancing at such a joint one is struck by the marked degree of disorganization that it has undergone and instinctively feels that such a joint could not possibly be used. On the other hand, there is absolutely no atrophy of the bones, indicating that the joint has not been at rest. Joints which undergo any degree of disorganization are always extremely painful and remain at rest. They consequently show marked atrophy, so that when one sees a markedly disorganized joint without any atrophy of the bone at all one should

seriously consider the possibility that the condition is not an ordinary infection but a Charcot joint.

Occasionally, but not frequently, one runs across a joint giving the clinical symptoms of an infectious arthritis, but the *x*-ray examination shows a rather remarkable condition. There is marked destruction of the cartilage of the joint, slight new bone formation, and a hazy joint, simulating tuberculosis; but in the joint cavity itself there is a blood clot which has undergone either fibrous or bony change. When such a condition is present it is invariably the result of hemophilia.

The remaining forms of infectious arthritis do not give any definite *x*-ray appearances. In joint diseases, as in other conditions, the clinical aspect of the case must be taken into consideration in order to arrive at a diagnosis.

Loose bodies in a joint are found most frequently in the knee. Loose bodies may be demonstrated by injecting air into the joint space. Occasionally loose bodies become calcified, and are then demonstrable by films made in the routine manner.

Spine. The various conditions that may affect the spine are grouped together in the following pages, as their demonstration forms such a large proportion of all radiographic examinations.

Abnormalities of the Spine. Before discussing the pathological changes in the spine it is well to remember that it is the seat of more abnormalities than any other part of the bony structure. Certain of these abnormalities while not pathological in the sense of disease yet may produce symptoms. For convenience it is well to consider them according to their locations, namely, cervical, dorsal, and lumbosacral.

In the cervical region the most common abnormality is the presence of extra ribs. They generally spring from

the seventh cervical; may be either unilateral or bilateral, the former being the most common. They frequently produce pain and numbness in the arm and sometimes atrophy

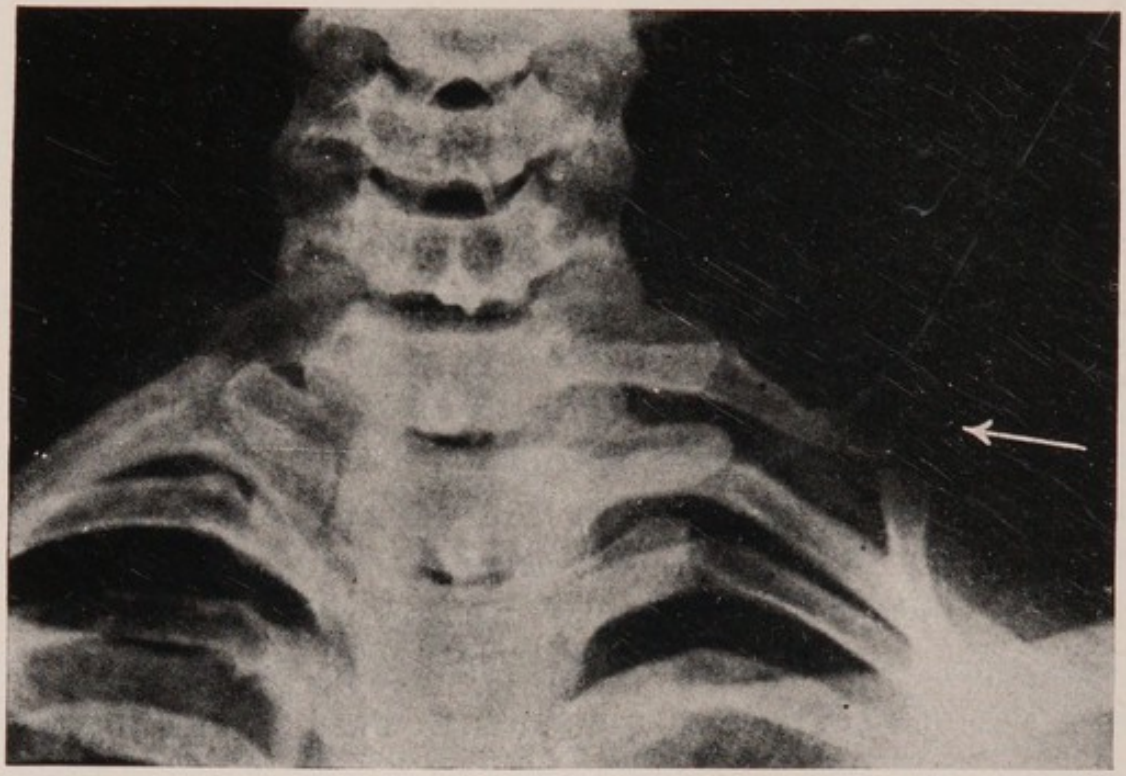


FIG. 105. Cervical rib. (From George and Leonard: The Vertebrae. Annals of Roentgenology, Vol. VIII.)

of certain muscles. The symptoms usually lead to a diagnosis of neuritis which, if due to pressure from one of these ribs, will not yield to medical treatment, as removal of the ribs is the only cure. When unilateral the diagnosis is easy, as one will note that the corresponding rib on the opposite side is absent. When there are two cervical ribs the diagnosis is more difficult, as they may be mistaken for the pair of normal first dorsal ribs. This can be determined only by examination of the entire dorsal spine to ascertain whether twelve or thirteen pairs of ribs are present. If there are thirteen, we know we are dealing with an extra pair of cervical ribs. The seventh cervical vertebra, from the radiological appearance, is so similar to

the first dorsal that no conclusions can be drawn as to whether the ribs arise from the seventh cervical or first dorsal vertebra. The fact that there may be six cervical

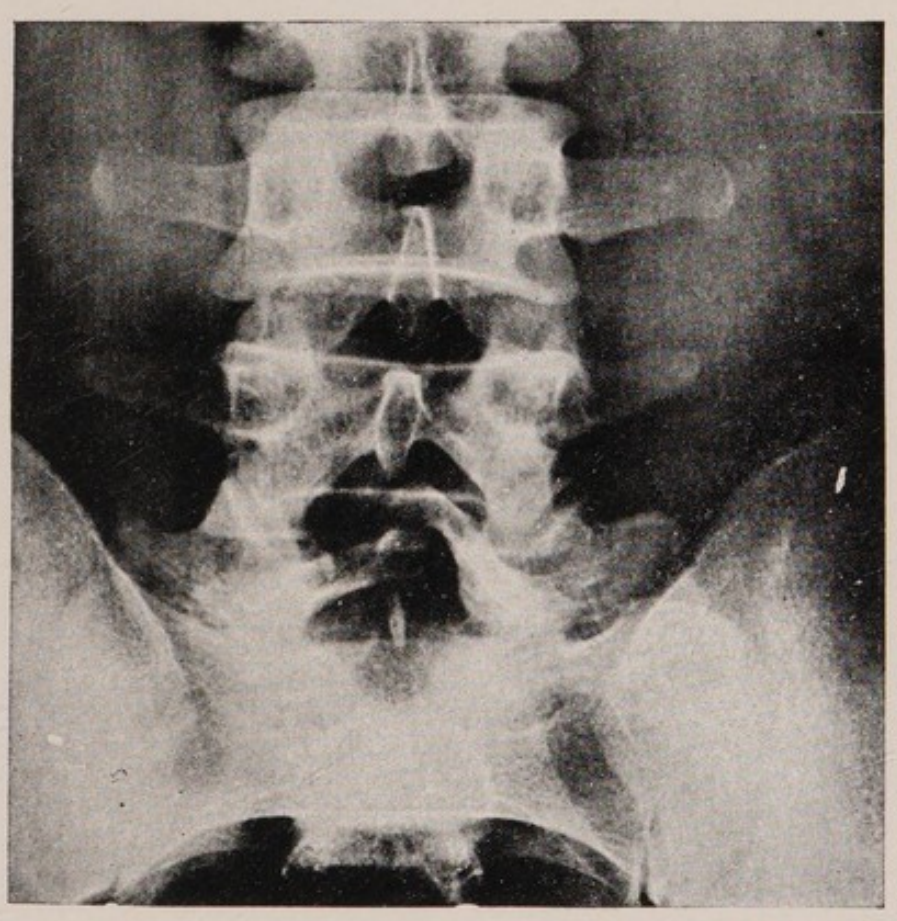


FIG. 106. Congenital non-union of the laminae. (From George and Leonard: The Vertebrae. Annals of Roentgenology, Vol. VIII.)

vertebrae does not mean that we are dealing with an extra pair of ribs, as the attachment of the ribs is variable. Sometimes they are attached one vertebra too high or one vertebra too low. It is quite common to find six cervical, twelve dorsal and six lumbar vertebrae, or eight cervical, twelve dorsal and four lumbar vertebrae.

While these extra ribs nearly always spring from the seventh cervical vertebra, it is well to remember that on very rare occasions they may be attached higher up.

Congenital non-union of the laminae that form the spinous processes is quite common in the seventh cervical. On account of the narrow space between the laminae this



FIG. 107. Partial dislocation of the second cervical vertebra. (From Forrester: Imperative Traumatic Surgery.)

is often mistaken for a fracture.

In the dorsal vertebrae we may also have congenital non-union of the laminae, generally confined to the upper two or three. Rudimentary vertebrae, triangular in shape, are sometimes seen inserted between the vertebrae. Since they are triangular in shape and inserted on one side scoliosis invariably results. This is important, as such a condition will not yield to the ordinary treatment for scoliosis.

Fractures of the spine may be simple or comminuted, due to either direct or indirect violence.

Cmopression fracture of the body of a vertebra (Fig. 108) is the most common, and occurs more frequently in the lower thoracic, upper lumbar, and midcervical regions.

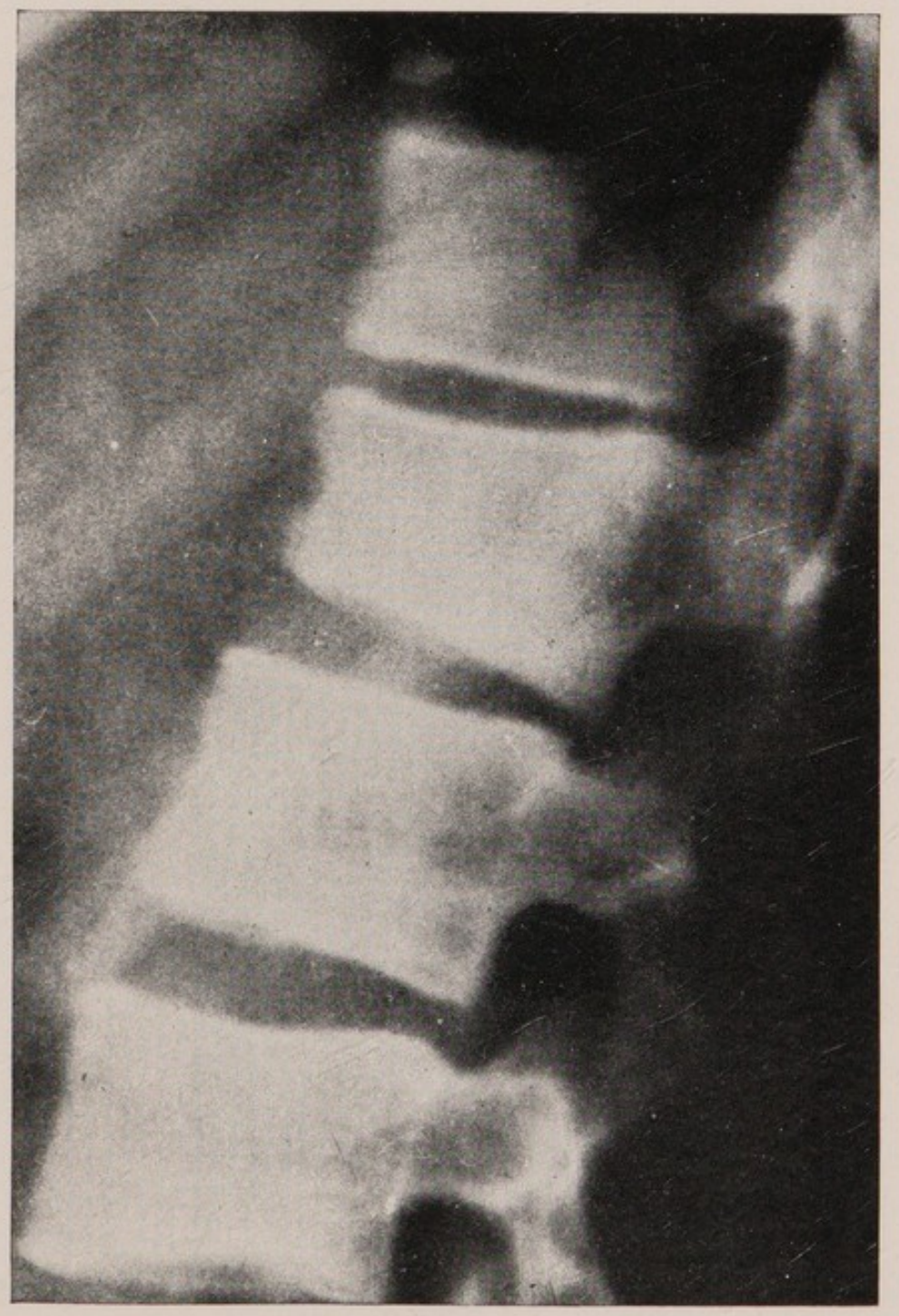


FIG. 108. Compression fracture, spine. (From George and Leonard: The Vertebrae. Annals of Roentgenology, Vol. VIII.)

The vertebra collapses anteriorly, as the posterior portion is held intact by the more resistant bones of the neural

arch. There is no destruction of the intervertebral disc. More than one vertebra may be involved, but of these the damage to a single one is predominant. Even slight

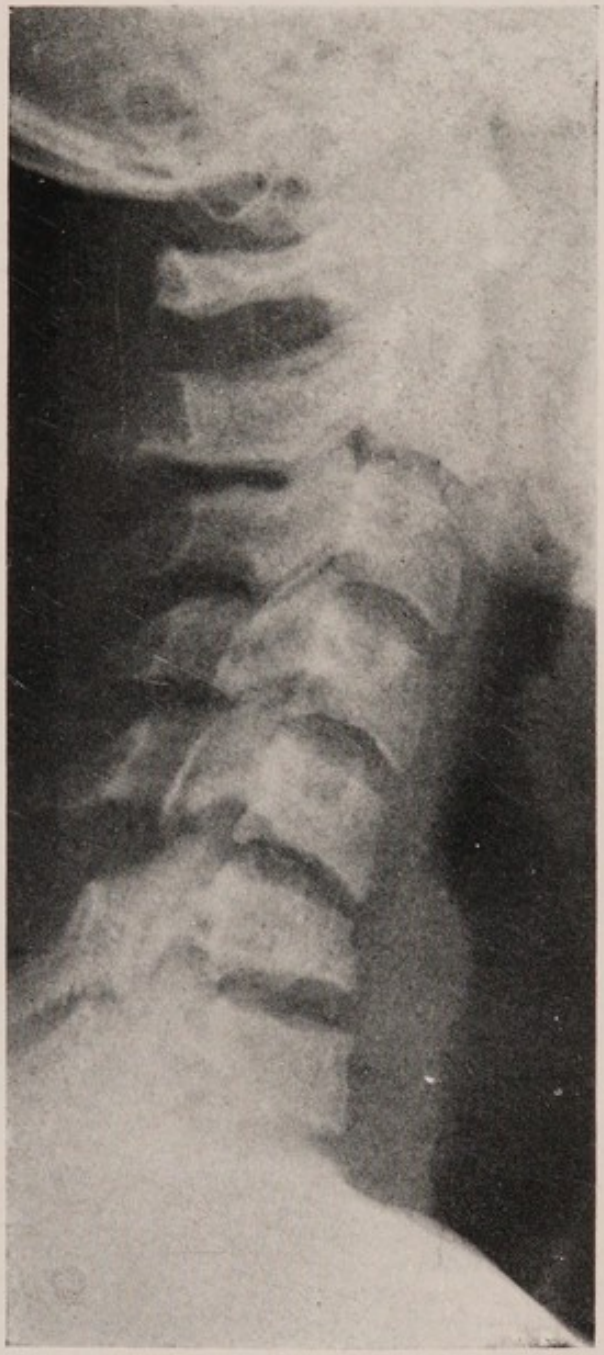


FIG. 109. Compression fracture, 6th cervical vertebra. (From Forrester: Imperative Traumatic Surgery.)

degrees of compression are important, as the normal architecture of the spine is damaged. These cases may come

to the radiologist months after the injury, when persistence of back pain leads to the investigation of damage caused by trauma thought to be trifling.

Compression fractures are demonstrable only in the lateral view (Figs. 108 and 109). The radiograph shows that the width of the anterior surface of the body of the vertebra is lessened as compared with the width of the body above and below. The anterior surface may be wrinkled, or one corner thrust forward as a lip. These changes are more easily recognized when the film is examined at a distance, as from 6 feet, where the comparative width of the vertebral bodies is sensed more readily. It will be remembered that the width of the body of the fifth cervical is normally less than the body of the fourth.

Comminuted Fracture (Fig. 110). The vertebra is split as well as compressed; the fracture lines are multiple; the neural arch is involved. The intervertebral disc is damaged. The body of the vertebra is somewhat flattened longitudinally and may show a wedge-shaped deformity. The fractured vertebra is often dislocated. Several vertebrae may be involved, but the damage affects one to a predominant degree.

Old fractures of the comminuted type may resemble tuberculosis (p. 256). There is the same wedge-shaped deformity, the kyphosis, and at least partial destruction of the intervertebral disc; in fracture there is development of new bone from callus, in tuberculosis there is none; in fracture there is no localized bone destruction, in tuberculosis small irregular areas of lessened density demonstrate the tuberculous destruction of bone tissue.

Fractures of a pedicle are more common in the lower lumbar spine, especially in the fifth lumbar. They not infrequently complicate fractures about the pelvis or hip. The fracture line is near the shadow of the articulations,

but may be differentiated by stereoscopic films. The fragments of the pedicle are commonly displaced 2 or more millimeters; the demonstration of the displacement is the

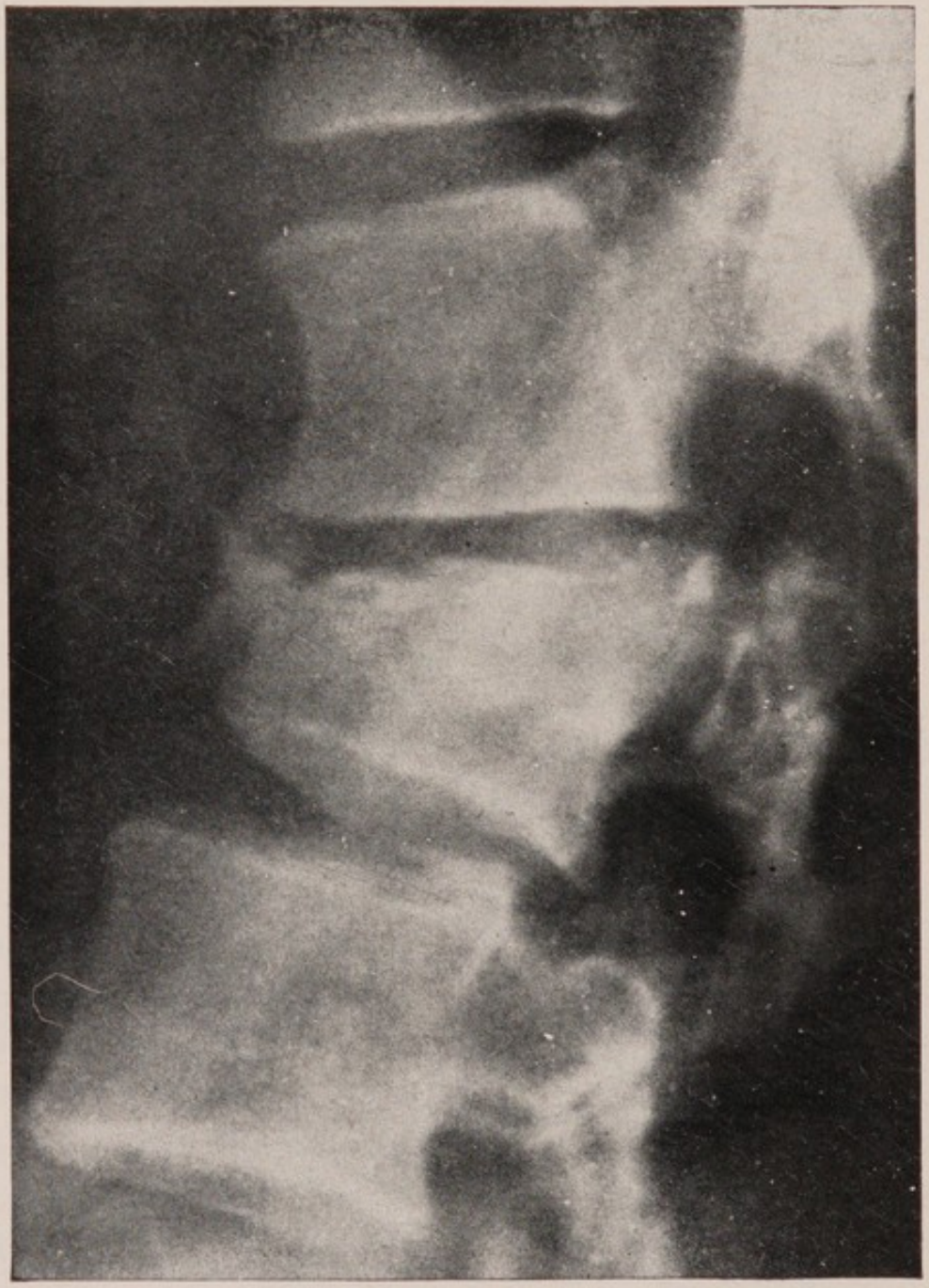


FIG. 110. Comminuted fracture, spine. (From George and Leonard: The Vertebrae. Annals of Roentgenology, Vol. VIII.)

most convincing evidence of fracture.

Fracture of the transverse process of a lumbar vertebra usually occurs by muscular action. These fractures are

commonly multiple, but are limited to one side of the body. The distal fragment is always displaced, usually upward. The displacement of the broken end is more important evidence than the demonstration of a fracture line; fat in the aponeurosis of the psoas muscle normally casts a dark linear shadow which crosses the transverse processes and may simulate a fracture line. Fracture of a transverse process in the upper cervical region is readily demonstrable; in the lower cervicals it is more difficult to see and may require stereoscopic films taken at many angles.

Fracture of the odontoid process of the second cervical may be demonstrated by a film taken through the open mouth.

Dislocation without demonstrable fracture may be found in the cervical region. The dislocation is forward. These dislocations are readily interpreted when the film is taken in the true lateral position; but if the head is rotated on the cervical spine and the shadows of the vertebrae are not truly comparable, the appearance of the film may be misleading.

Dislocation of the lumbar vertebrae is described on page 261.

Pathological Processes in the Spine. In dealing with the pathological processes incident to the spine we have practically the same changes as seen in the other bones with certain modifications. For convenience of classification the lesions are divided according to their origin as follows:

1. Joint lesions. Lesions arising from and involving the articulating surfaces.

2. Transitional lesions. Lesions arising from the articulating surfaces and involving the body of the vertebrae.

3. Bone lesions. Lesions arising from the body and not involving the articulating surfaces.

In class one will fall the various types of arthritis, namely, infectious, atrophic and hypertrophic, and the first stage of tuberculosis.

In class two we have the destructive stage of tuberculosis, fractures, and the neuropathic conditions such as Charcot and syringomyelia.

In class three we have the new growths and occasionally osteomyelitis, though this may come under class two, according to whether the joint is involved or not.

Spinal Joint Lesions. In dealing with class one, the joint infections, certain changes seen in the joints of long bones are not present, that is, we do not see any periarticular or fluid changes, so our diagnostic points rest entirely upon the cartilaginous destruction and bone production.

In the arthritic cases, non-tuberculous, we seldom see any narrowing of the joint space, but at the edges of the vertebrae, particularly where the lateral ligaments attach, the edge will first become sharpened and then exostoses will form, growing toward the joint space, and finally will unite with the exostoses from the other surface of the joint and produce a true bony ankylosis at that point. This may be so extensive that all the vertebrae will become ankylosed. There is no change in the body of the vertebrae. We cannot differentiate the various types of arthritis. In the early stages of tuberculosis we get destruction of cartilage and some narrowing of the joint, but the disease proceeds to attack the body of the vertebrae and then we get the second class, or the transitional type, where joint and body are involved.

In *tuberculosis* the anterior portion of the body of the vertebra becomes softened and then from pressure gives way, assuming a characteristic appearance, namely, the body becomes triangular in shape with the apex anterior and the base of the triangle posterior. (Fig. 111.) This gives us

the characteristic angulation or knuckle, the true tuberculous kyphosis. Active tuberculosis is a destructive process, not a bone producer, and always involves the intervertebral

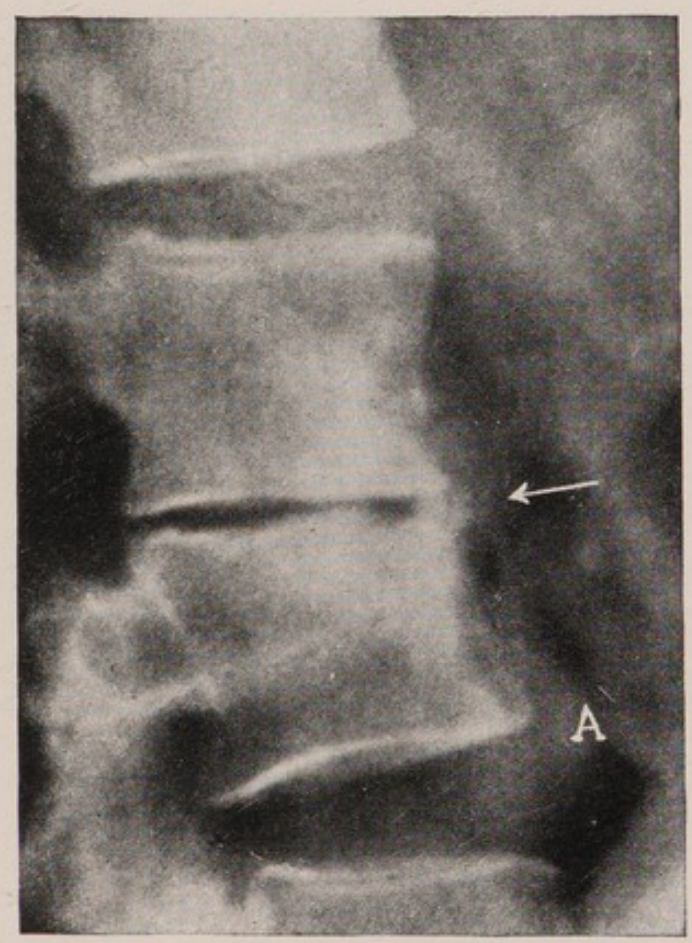


FIG. 111. Tuberculosis, spine. (From George and Leonard: The Vertebrae. Annals of Roentgenology, Vol. VIII.)

disc.

In the *neuropathic conditions*, namely, Charcot's, there is always the lateral crushing of the joint, and the body is involved with the formation of bony detritus, seldom new bone formation. The three differential points are (1) angulation; (2) deformity, lateral; (3) seldom new bone formation, but generally bony detritus present.

Tuberculosis, neuropathic joint, and comminuted fracture resemble each other in bone loss, wedge-shaped deformity, and kyphosis. They differ from each other in the following particulars: (1) Necrosis: tuberculosis, always

present, shown as ragged, irregular areas of lesser density found most frequently near the remnants of the intervertebral disc; neuropathic joint, none; fracture, none.

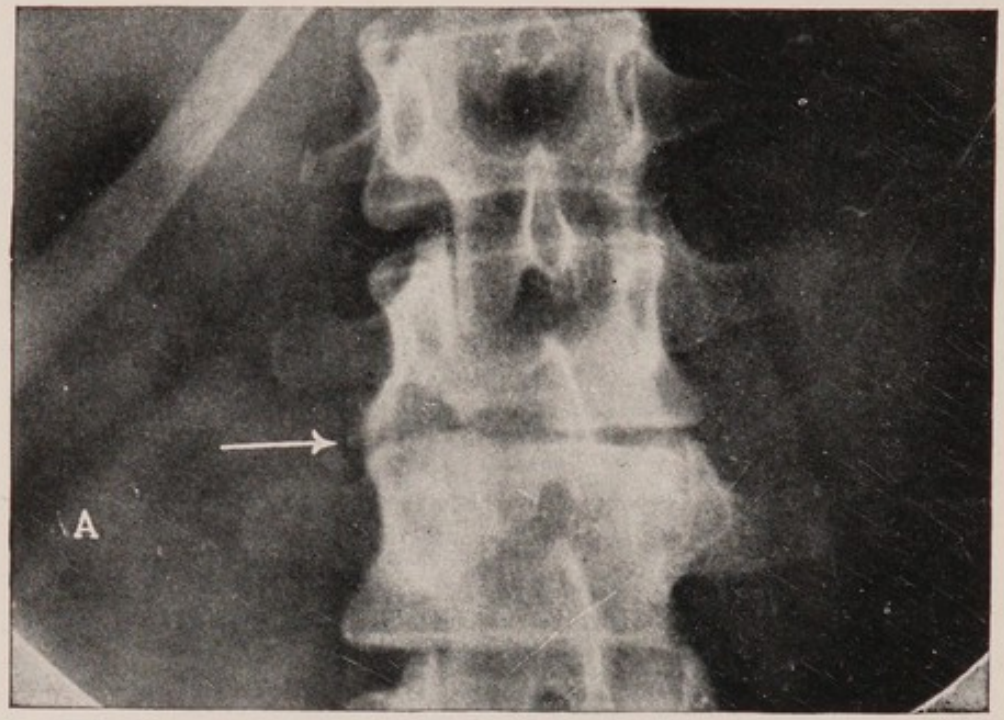


FIG. 112. Compare with Figure 111. In the anteroposterior view the destruction of bone might have been overlooked. The lateral position is essential. (From George and Leonard: The Vertebrae. Annals of Roentgenology, Vol. VIII.)

(2) Bone production: tuberculosis, none; neuropathic joint, seldom; fracture, always present. (3) Bone fragments and bone detritus: tuberculosis, minimal or absent; neuropathic joint, the predominant feature, often present to such degree as to convince the examiner that were the lesion caused by trauma it must have been fatal; fracture, fragments are present, but are smoothed off and joined by callus. The common fracture of the spine, the compression fracture of the body of a vertebra, causes no difficulty in interpretation, as there is no destruction of the intervertebral disc, no bone necrosis, and no bone fragmentation. Tuberculosis in the spine of children must be differentiated from Scheuermann's disease (p. 269).

Tumor. The most common bone lesions are the new growths, and the same system of differentiation applies here as in growths of the long bones. When the growth arises from the edge of the vertebra and there is bone production outside, the condition may simulate fracture and dislocation, but the striking point is that in growths the joint is not involved.

In sarcoma and carcinoma a portion of the vertebra may be completely absorbed, but, on account of the density of the growth, crushing of the body takes place slowly and equally. The body will become narrowed, but the joint spaces will be intact and clearly seen.

A vertebra that is much smaller in width with joint spaces intact should always be viewed with the possibility of growth in mind. The characteristic points are (1) no angulation; (2) no displacement; (3) narrowing of body with or without bone production, according to type of tumor.

Sacroiliac Joints and the 5th Lumbar Vertebra. The lower lumbar spine, sacroiliac joints and the posterior portion of the pelvic ring are so intimately bound together as to justify their inclusion as a single assembly. They present certain well-known anatomical features that are particularly important, and bear on the interpretation of some cases of "lower back pain." The sacrum is an inverted keystone, the narrow part directed upward. The upper half of the sacrum is nearly horizontal. The 5th lumbar vertebra is applied by an intervertebral disc, which is thicker anteriorly than behind. The body of the 5th lumbar vertebra is also thicker anteriorly. Thus the forward and upward curve of the lumbar spine is begun: the upper surface of the 5th lumbar vertebra is directed at an angle of only 45°, whereas the upper surface of the sacrum is nearly vertical. The 5th lumbar vertebra, sacrum,

and posterior pelvis are held in position by an exceptionally strong ligamentous sling, and by heavy ligaments running between the transverse processes and the adjacent borders of the ilium. A stress applied to the spine and stopped at the pelvis places this group at a disadvantage, but so long as the assembly is well formed any usual stress can be handled without difficulty.

Anomalies of shape and position are common. The articulation between the 5th lumbar vertebra and the sacrum varies widely between different individuals, and on opposite sides of the same person. The articulation may be in the sagittal plane, in the coronal plane, or at any angle between. Spina bifida occulta is an incomplete fusion of the neural ring, affecting one or more segments of the 5th lumbar vertebra and sacrum. The spines are absent or represented by small knobs; this condition is found in 10 per cent of all persons, most of whom have no symptoms.

Sacralization of the 5th Lumbar Vertebra. On one or both sides the transverse process is wide, thick, and shaped like a wing; it articulates with the sacrum below and sometimes with the ilium at the side. In these cases there are usually six lumbar vertebrae, and it becomes an academic point to decide whether the lowest should be classed with the sacral or lumbar regions. The anomalous joints may be poorly built and are prone to give trouble, especially where unilateral.

Transverse Process Impinging on the Ilium. Rarely, the tip of a transverse process of the 5th lumbar vertebra comes close to the ilium when the body is rotated, pinching the soft parts. Normally the posterior and inner portion of the wing of the ilium lies from ½ to 1 inch anterior to the transverse process of the 5th lumbar vertebra; the shadow of one is cast on the other. Mere apparent juxtaposition of these shadows tells nothing. If there is a true shortening of

the normal gap between these bones the opposing surface of the ilium will show change, usually the facet of an anomalous joint.

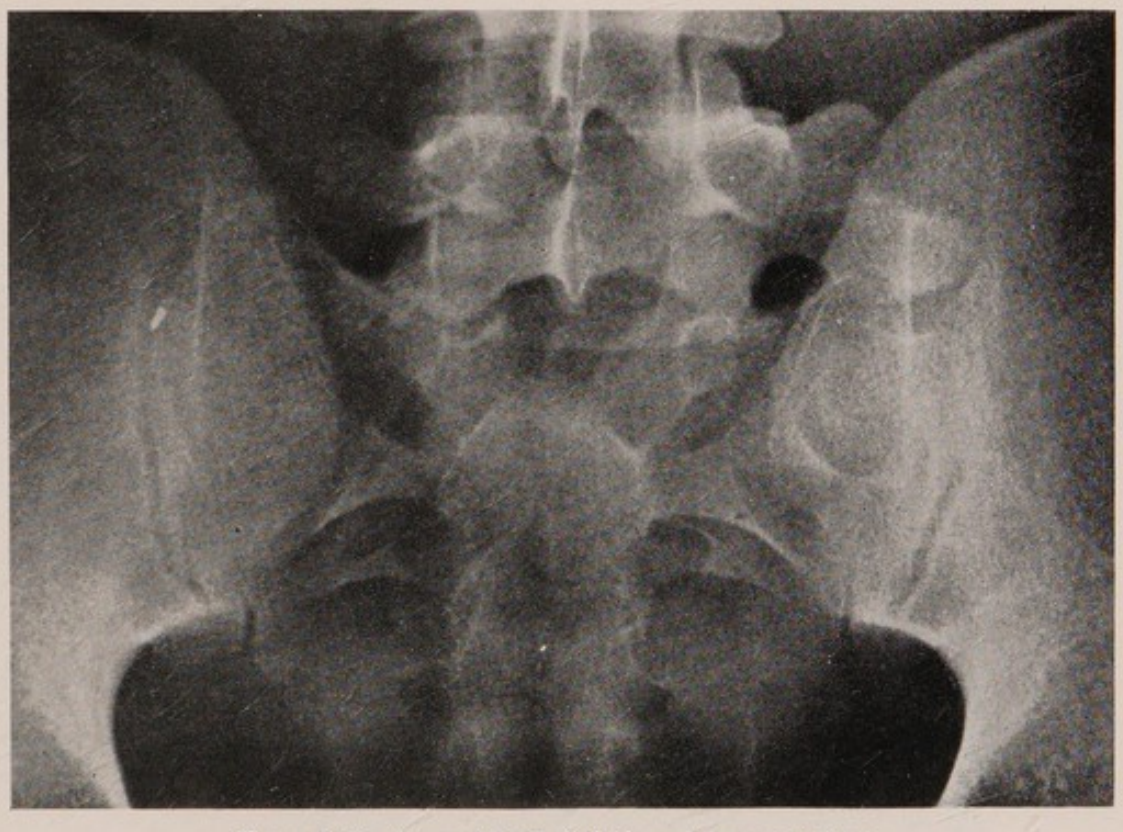


FIG. 113. Sacralized 5th lumbar vertebra.

Fracture. Elsewhere in the vertebral column the body of the vertebra or a transverse process gives way, but injuries to the pedicles are not often seen. The reverse is true in the 5th lumbar vertebra. The body of the bone escapes injury, as there can be no counter-thrust either above or below. An articulation, pedicle, or transverse process is liable to fracture if a twisting stress is applied to the spine. In every injury to the hip or pelvis, fracture in the 5th lumbar vertebra should be suspected. When fracture does occur, the basal support of the spine is structually weakened and permanent disability may ensue.

Dislocation of the 5th lumbar (*spondylolisthesis*) is either unilateral or bilateral. It is commonly caused by a shearing

stress. When one articular process dislocates or ruptures, and one side of the binding ligaments gives way, that side of the vertebra slides forward (downward) and slews around



FIG. 114. Spondylolisthesis. (After Kleinberg, *Am. J. Surg.*)

on the side that continues to hold. When both sides give way, the vertebra slides forward without rotating. The body in either case may jut forward (downward) in relation with the sacrum for 1 cm. This condition is demonstrated in a true lateral view. (Fig. 114.) When examining the film it is best to note the relation of the posterior aspect of the vertebral bodies, rather than the anterior.

With every care, an exact true lateral may not be obtained, and the alignment of the front of the vertebrae may be misleading.

Arthritis of the sacroiliac joints is a common cause of lower back pain. In the acute stage the clear outline of the joint is lost; it is hazy and murky. Fine, dark, pin-point sized areas of bone destruction underlie the cartilage, making the joint line roughened and uneven. Beyond is a zone of bone condensation whiter than the shadow cast by normal ilium. As the disease progresses, the necrotic areas become larger and more numerous, and the zone of reaction wider. Later still the cartilage is thinned, and finally is completely replaced by bone. The changes take place slowly. If the natural course goes on unhindered for five or six years, the joints are replaced by bone.

Tuberculosis gives the same appearance as in other joints, except that the usual haziness is not so noticeable. There is bone and cartilage destruction, but bone condensation is practically lacking. This condition is encountered as a complication in tuberculous disease of the lung.

Slip of the sacroiliac joint is not demonstrable in the *x*-ray films. In rare cases one or both sides of the sacrum shift position in relation to the ilium for 2 to 5 mm.; these cases should be regarded as true dislocation and should not be classed as a "slip," which is a clinical entity not demonstrable radiologically.

Dislocation of the sacrum on the ilium may follow injuries such as dislocation of the symphysis pubis, or rupture of the pelvic ring. It is usually associated with fracture through and into the sacroiliac joints.

Rickets (rhachitis) is a metabolic disease chiefly manifested by abnormal ossification. It occurs usually in the first two years of life, but may be seen as late as the twentieth year.

Bones grow in length by the production of bone in the epiphyseal cartilage. They grow in thickness from the inner layers of the periosteum. At the same time the medul-

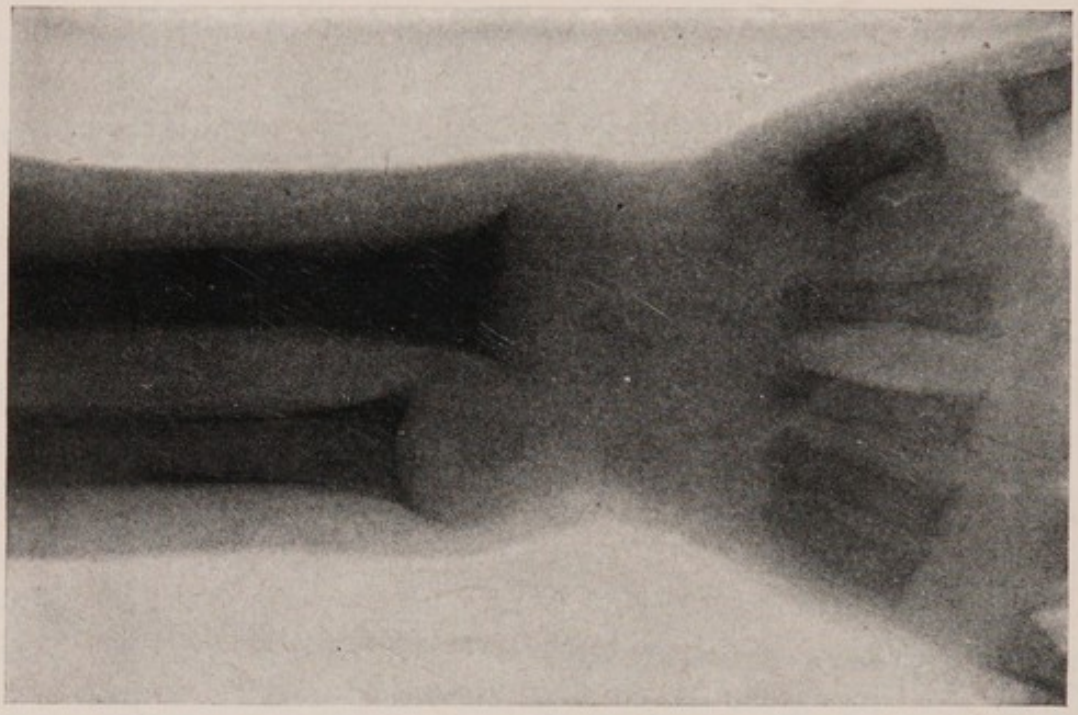


FIG. 115. Rickets. (From Baetjer and Waters: Injuries and Diseases of the Bones and Joints.)

lary canal enlarges by the disappearance of the inner layers of bone. In rickets the cartilaginous and subperiosteal cell growth goes on with increased rapidity and in an irregular manner, and the ossification is imperfect, irregular, or wanting. The lime salts of previously ossified bone may be removed. The dilatation of the medullary cavity is irregular and often excessive.

As a result the growing ends of the bone are deformed, and the increased growth between the epiphysis and the shaft produces knobby swellings. The shaft lacks solidity and may bend from weight bearing or muscular tension. Incomplete fractures often occur.

In the radiograph the formed epiphysis casts a white shadow that differs but little from the normal; its edges

may be slightly blurred. The epiphyseal cartilage casts a dark shadow larger than the normal; it is irregular; it is convex toward the shaft instead of a transverse line; and its margins are indistinct. The lower end of the shaft flares out widely, is ragged, and appears cupped. The diaphysis does not show the fine tracery of the haversian canals, and its alignment may be altered if the softened bones have bent.

The changes in the epiphyses are best demonstrated in the lower end of the radius and the lower end of the tibia. The bending deformities are most often seen in the ribs and in the weight-bearing bones.

If fracture has occurred callus is produced in excess.

The flaring, cupped end of the diaphysis, with a blurred, ragged outline, and the increased width of the epiphyseal cartilage present an appearance that is characteristic. Slight grades of rickets produce changes that vary little from the normal; these changes are best demonstrated by comparison with a radiograph of a like normal bone taken at approximately the same age. Advanced rickets may simulate scurvy.

Scurvy is more frequently found in infants. It is convenient to divide the disease into three stages. These are arbitrary, as the changes are due to a progressive development in the pathological condition.

First stage. The earliest radiographic change is found in the shaft; the fine tracery of the haversian canals is lost or obscured, giving a "ground glass" appearance. At about the same time the epiphysis shows a dense ring, especially at the joint side; at the opposing end of the shaft there may be a similar dense line.

Second stage. If the case progresses, a line of lesser density appears in the shaft, just beyond the dense line. The cortex thins from atrophy.

Third stage. Hemorrhages occur under the periosteum. While no shadow is cast at first, calcium salts are soon deposited, first as small projections near the end of the shaft, later as definite opacities marking out the entire hemorrhagic area. When this stage is well established there may be epiphyseal separations. In the stage of repair the hemorrhages absorb in breadth and in length. The periosteal thickening may persist long after the clinical signs have abated and healing has begun. These evidences may persist for several years.

Rickets and scurvy may be present at the same time. As the *x*-ray appearance of rickets resembles mild or early scurvy, the differentiation might be in doubt, except that scurvy does not show the flaring ends of the shafts, the cupping, or the widening of the epiphyseal line. Both show the blurring of the haversian shadows, but this is more marked in scurvy than in slight degrees of rickets. Acute osteomyelitis resembles scurvy clinically but produces no bone changes. Sarcoma can scarcely be confused, as it induces bone destruction and gives rise to metastases. Syphilis may show very similar changes, but does not show the dark line just beyond the white line in the end of the shaft.

Periostitis may be a simple inflammatory lesion or luetic in origin. It is sometimes very difficult to differentiate these two conditions. The simple inflammatory periostitis lays down the periosteal bone parallel to the shaft. Luetic periostitis also generally lays down bone parallel to the shaft, but occasionally the new periosteal bone may be laid down perpendicular to the shaft very similar to that seen in certain bony malignancies. In the luetic periostitis, however, the amount of bone is small and closely confined to the shaft, not extending out into the soft tissues, so that a mistake can probably seldom arise. In luetic perios-

titis more than one bone is frequently involved, while the simple inflammatory type generally affects only one bone.

Syphilitic changes in bone are so diverse, and mimic other conditions so faithfully, that a serological test should always be made in every case of bone disease.

Osteomyelitis ordinarily implies the changes caused by the pyogens, although it is proper to speak of tuberculous and syphilitic osteomyelitis.

As the result of the infective agent the bone dies. After an interval varying from ten days in the small bones, such as the phalanges, to several months in large bones, such as the cortex of the femur, the dead bone becomes separated from the living. This dead and separated portion is the sequestrum. The separation is caused by osteoclasts destroying the bone at both the living and the dead margins. Osteoclasts are found in granulations springing from bone. Their action is more rapid when the granulations are close to living bone, and slower when further from living bone or when retarded by pus. The destructive effect continues after separation is complete, but rarely goes on until the dead bone vanishes. Usually the action is incomplete, and fragments remain until removed by operation. While this sequence of events is taking place the living bone undergoes atrophy from disuse.

The radiological appearance of osteomyelitis affecting cortical bone depends on the pathological process. The dead bone, deprived of its blood supply, retains its original density. The living, atrophied bone, loses density. Thus sequestrum is denser than living bone and casts a whiter shadow. The granulations that have attacked bone leave a radiotransparent edge. Thus surrounding the sequestrum there is a dark line. The action of the granulations is not uniform, and some portions of the sequestrum are destroyed more than others, so that the contour is uneven. These

changes have been vividly summarized by Phemister in three words: "density, demarcation, and contour." The sequestrum casts a denser shadow than living bone, it is demarcated, and has an uneven contour.

The living bone reacts with the formation of new bone by osteoblasts. The new bone is found surrounding the dead, and in some cases may extent for long distances up and down the shaft. When the new formed bone surrounds the dead shaft it is called the involucrum.

In cancellous bone the changes are different. In such bone the granulations may grow in many directions, the osteoclasts causing destruction in irregular areas and islands. While the sequestrum retains its original density, the difference in color from the living bone is less distinct. Because of irregular lines of absorption, the demarcation is less evident. The bone casts an irregular, "moth-eaten" shadow, with dark areas from 2 to 10 mm. in diameter, some of the larger showing a slightly denser center. None of the changes have clean cut edges, but are indefinite, the density fading out from the gray toward a black.

Sequestra are usually multiple. At operation more are found than were demonstrated on the film. After operation, and after gun shot injuries, there may be small islands of bone formed anew from displaced periosteum. These islands cast a shadow that is nearly circular, with indefinite, fading out margins. They are usually located in the soft parts. The differentiation is important, in that sequestra, being porous, harbor the infective bacteria, whereas the islands of new formed bone are solid and are not responsible for persistence of the disease.

Acute osteomyelitis does not produce radiographic changes. The *x*-ray examination is of no value in assisting at a diagnosis in time to be of use. Later, if the disease becomes chronic, the changes develop as outlined above.

Localized osteomyelitis of the os calcis occurs not infrequently, at the insertion of the long plantar ligament. The radiograph shows at the insertion of the long plantar ligament an area of lesser density 2 to 5 mm. in diameter; the outline of the area is indefinite; bone detail near the area is blurred. The process heals with bone formation to excess, causing a spur projecting from the under surface of the os calcis in line with the long plantar ligament. Bone spurs in this location may form from other causes, and are not due to localized osteomyelitis solely.

Localized bone abscess (*Brodie's abscess*) casts a dark, circumscribed shadow. Outlining the shadow is a dense white zone of bone condensation, which may be 2 mm. or more in thickness. There may or may not be a sequestrum in the center of the abscess.

Scheuermann's Disease (Vertebral epiphysitis; Vertebral osteochondritis; Juvenile kyphosis; Adolescent kyphoscoliosis; Kyphosis dorsalis juvenilis; Kyphosis osteochondropathica). This condition affects the bodies of the vertebrae, especially in the dorsal region. The end result may be scoliosis and sometimes kyphosis.

Infants and Young Children. The radiograph shows that the bodies of several vertebrae are mottled, and their contour is irregular. The intervertebral disc is not affected. The involved vertebrae become wedge-shaped and deform laterally, causing scoliosis or kyphosis. Later the mottled appearance decreases, and eventually bone texture becomes normal.

At puberty the marginal epiphyses may be affected. A lateral radiograph of a normal child at puberty shows the epiphyses at the front of the vertebra as small, well defined, triangular bodies at the upper and lower corners; the outline of the vertebral bodies clear cut and distinct; and the intervertebral spaces uniform in density throughout the

spine. In Scheuermann's disease a number of vertebrae show changes. The epiphyses are enlarged and irregular; the margins of the vertebrae are indistinct; and the intervertebral spaces in the affected region are cloudy and ill defined. The affected vertebrae become wedge-shaped, with irregular borders, and may deform laterally.

These cases may be differentiated from tuberculosis (p. 258) because Scheuermann's disease affects many vertebrae, whereas tuberculosis, starting in or near one intervertebral disc, involves one vertebra only, or two adjoining vertebrae. Healed cases may resemble healed tuberculosis. Although Scheuermann's disease originally affected many vertebrae, the process may have been predominant in one, with wedged-shaped deformity and kyphosis. Differentiation is by the demonstration of intact intervertebral discs, and evidence of the changes in other vertebrae characteristic of Scheuermann's disease.

The differentiation from rickets cannot be made from the appearance of the spine alone. Rickets must be excluded by the demonstration of normal bones elsewhere, especially the lower ends of the radius and ulna, and the lower ends of the tibia and fibula, favorite location of rickets, and by clinical evidence.

Legg's Disease (Perthes' disease; Legg-Calve-Perthes' disease; Osteochondral tropopathy). This hip joint disease begins at any age between three and thirteen, terminates spontaneously, and may cause a deformity of one or both hips that persists throughout life. In the early stages the epiphysis of the head of the femur is flattened, widened, and slips downward. The neck of the femur becomes wider and may bend, reducing the normal angle with the shaft. The joint cartilage is unaltered. For several months the changes progress, and then become stationary. In the terminal stage the head of the femur has lost its globular shape, is wider

and uneven in contour. The neck is wider and is set on the shaft at an angle approaching 90°, in some cases even less. The joint cartilage remains unaltered. The acetabulum adapts itself to the altered shape of the femoral head. There is no excess of joint fluid, and no edema in the surrounding tissue, so that the radiograph is always clear and distinct.

Later in life, especially when the joint is used excessively, arthritic changes are added. The joint cartilage becomes thinned, and new bone is formed both at the margins of the cartilage and in the bone underlying the joint cartilage.

The radiographic appearance is characteristic. The flattened, mushroomed head seated in a malformed acetablum, the clear joint space, and the widened, bent femoral neck present a picture that is not shown by any other disease.

The paucity of symptoms is striking. For ordinary locomotion there is no pain and no disability. Abduction and excessive use of the joint do cause pain.

A few cases show areas of bone rarefaction 0.5 to 1 cm. in diameter in the neck of the femur. It is still uncertain whether these cases may properly be ascribed to Legg's disease, or should be grouped with the cystic diseases of bone.

Osgood-Schlatter's disease affects the tubercle of the tibia during childhood or adolescence. The lateral view of the normal tubercle shows a tongue-shaped process of bone extending from above downward, demarcated from the shaft by the dark line of the epiphyseal cartilage. In the normal tubercle the outline is clear and distinct, the tongue-shaped piece of bone continuous from its base. When this disease is present the outline is blurred and indistinct, the dark line widened and uneven. The tongue-shaped process of bone may be segmented.

Subdeltoid Bursitis (Subacromial Bursitis). There may be a deposit of a radiopaque substance in this bursa, which casts a definite shadow. The location of the shadow is



FIG. 116. Diagram showing the location of the opacities in subdeltoid bursitis. (After Koehler.)

usually just above the greater tuberosity, but may be posterior. The shadow is differentiated from arthritis in that it is separate from the joint; from sprain-fracture of the greater tuberosity in that the tuberosity has lost none of its substance.

The suprapatellar bursa may show an opacity, usually at its upper end, varying in size from 0.5 to 3 cm., spherical or ovoid in shape. This opacity is similar to the opacity described in the subdeltoid bursa.

Osteochondritis dissecans is localized bone necrosis that may occur in any joint, but is most frequently encountered in the knee. When the knee is involved the usual site is

the internal condyle of the femur close to the insertion of the posterior crucial ligament, in the intercondylar notch. The radiographs show a dark line marking off a piece of bone about 0.5 by 1.5 cm., ellipsoidal in shape, the edges smooth and even. The area of bone thus demarcated is a sequestrum, probably caused by the failure of an end artery. In some cases the sequestrum drops into the knee joint, becoming a "loose body."

Acromegaly. In acromegaly the cranial bones are very much thickened; the head seems to be elongated anteroposteriorly and the lower jaw projects markedly forward. The sella turcica is frequently enlarged and deepened. The bones and soft tissues of the hands and feet are very much enlarged, and the tufting of the terminal phalanges is materially increased.

Osteitis fibrosa cystica is encountered occasionally in children and adolescents, seldom in adults. In one or more bones there are multiple cyst-like formations. The bone is softened and bending deformities occur; the structure is weakened and fractures easily. The changes are more readily demonstrated in the long bones, but the flat bones may be affected as well.

The radiograph shows the bending deformities, and possibly a pathological fracture. The affected portion of the bone shows multiple areas of lesser density in the cancellous ends, in the diaphysis, or both. In the cancellous ends the areas may have any shape or arrangement; in the diaphysis the areas are elongated and are disposed with their long axes in line with the long axis of the shaft. The areas are clearly demarcated; the outline is regular, smooth, and even; their size varies from an abnormality that is barely perceptible to one or more centimeters; the texture is homogeneous, but may be crossed by lines suggesting trabeculations. The cortex is expanded but never perforated.

The impression given the examiner is that the whole or a part of the bone is badly constructed, rather than the site of a tumor growth.

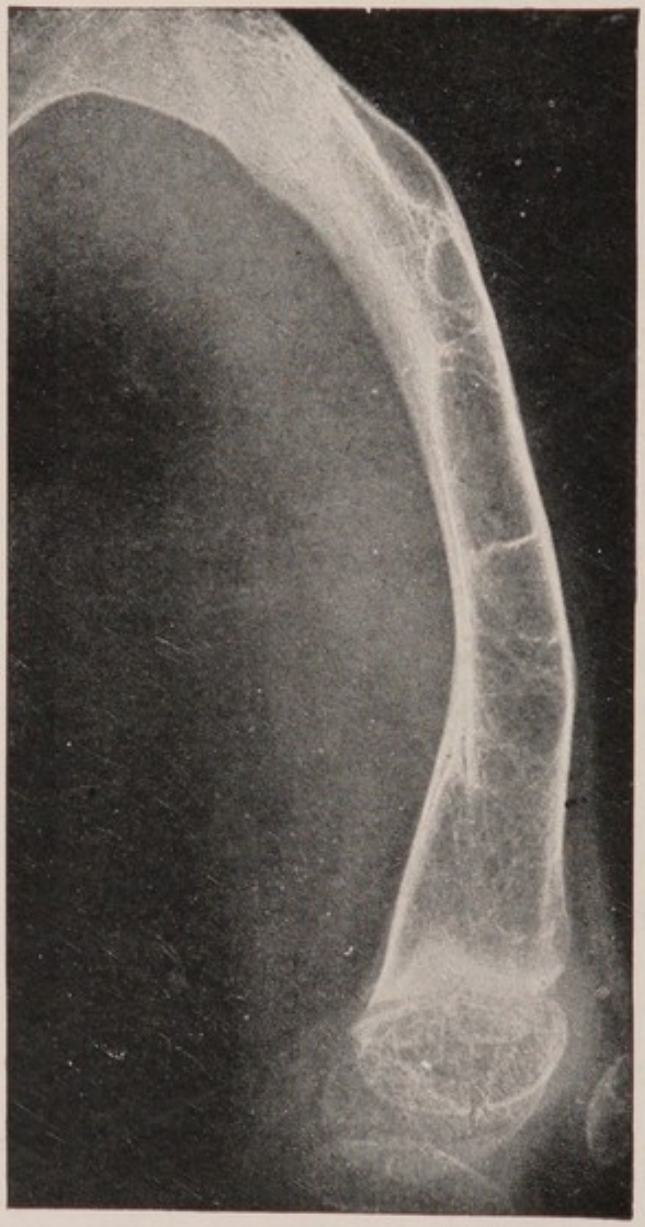


FIG. 117. Osteomalacia. (From George and Leonard: The Vertebrae. Annals of Roentgenology, Vol. VIII.)

Radiographs of many bones show that while most of the skeleton is normal, the condition is manifest in more than one bone; that osteitis fibrosa cystica is a generalized condition rather than a local bone disease.

Osteomalacia is a rare condition, characterized by extreme softening of the bones, with remarkable bending distortions. The medullary canal is wide, and the cortex

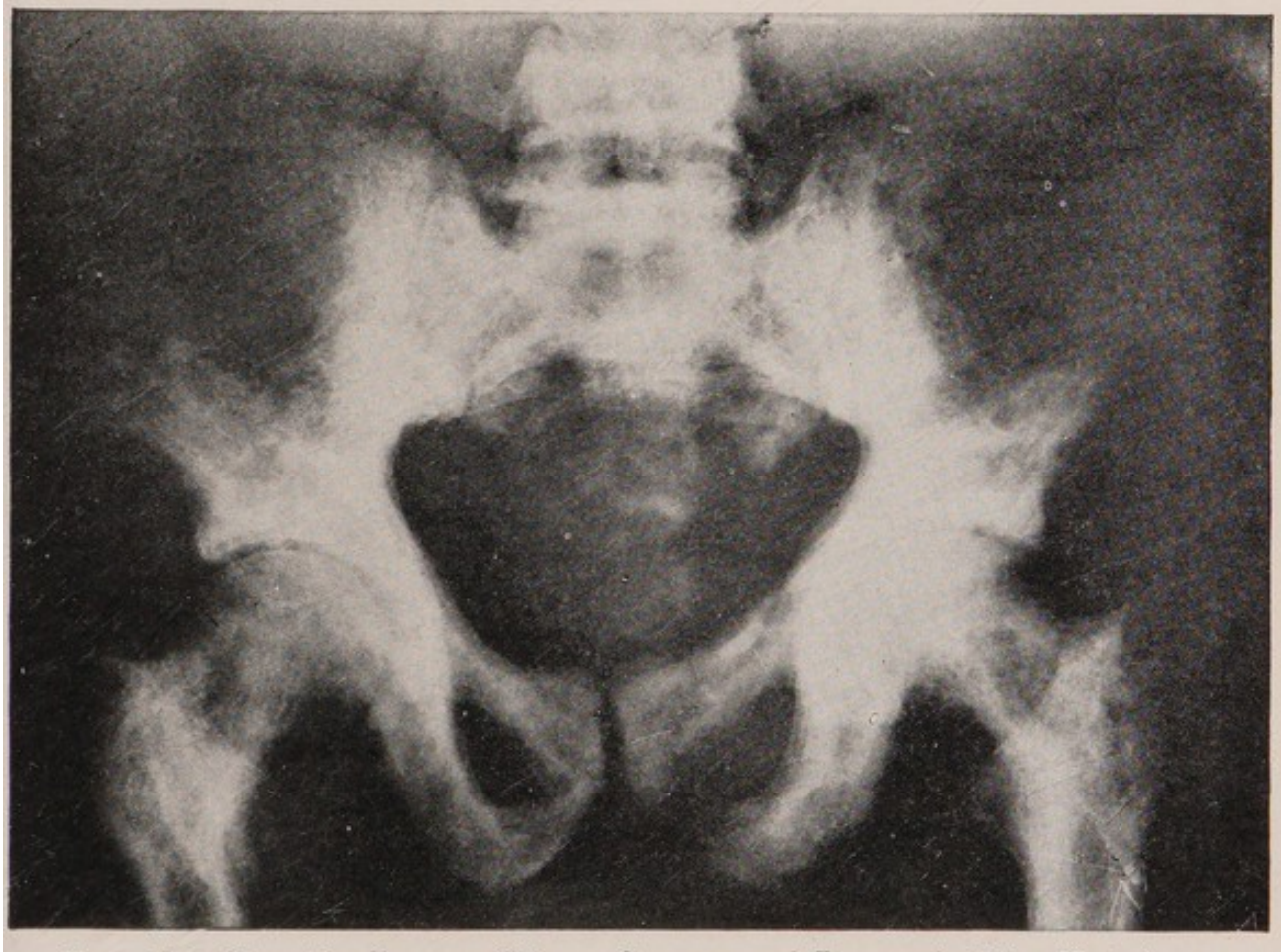


FIG. 118. Paget's disease. (From George and Leonard: The Vertebrae. Annals of Roentgenology, Vol. VIII.)

thin. The bones resemble osteitis fibrosa cystica, but the cystic formation is not so definite, and the softening is greater. This disease usually begins in the spine or pelvis, but all the bones may be affected.

Paget's disease presents the same picture as osteitis fibrosa cystica, plus the deposit of newly formed bone. It is a generalized condition affecting many bones, the weight-bearing elements the most. Of the long bones, the femur and tibia are most frequently implicated. Of the cancellous bones, the pelvis and spine are often involved

at some part. The skull may show changes that are clearly demonstrable. Bending deformities are common.

Paget's disease affects persons over fifty years of age, as contrasted with osteitis fibrosa cystica, which is typically found in the young.

The radiograph shows the areas typical of osteitis fibrosa cystica. Near these areas of lesser density is a white deposit of new bone. In some parts of the skeleton the bone loss is especially notable, but in most parts the deposit of excess bone is predominant. Here are areas of bone that are densely white, the normal texture of bone replaced by an amorphous sclerotic mass, through which the spots of cystic degeneration show but faintly. In the long bones the cortex is unevenly thickened; this is especially evident along the concave border of the bowed femur and tibia. In or near the medulla are spots and patches of sclerosis. In the pelvis and skull amorphous deposits of new bone cast densely white shadows. The entire pelvis or skull may be affected, but more commonly there are large irregular patches, the edges ill defined and shading toward normal bone texture, the contour uneven, the texture white, amorphous, fuzzy, the normal bone texture lost to view. When the skull is involved the calvarium is thickened with irregular deposits of dense bone; where the surface is seen in profile the shadow is uneven.

In the spine a vertebra involved to a greater degree than its fellows is densely white and widened slightly.

The interpretation rarely gives difficulty if enough of the skeleton is examined. The appearance of a single bone is often open to doubt.

Ten per cent of all persons affected with Paget's disease acquire osteogenic sarcoma, although that tumor ordinarily occurs only in adolescents.

Bone Cyst. The radiograph shows a single area, even in contour, with sharply defined margins. The cyst may be lobulated. The cortex may be expanded if the cyst is large, but is always intact. The single cyst is generally medullary, and is usually located close to the end of the bone. Pathological fracture is common. Solitary cysts occur in childhood, but may not be discovered until later in life. Of all the conditions classed as tumors, bone cysts are by far the most numerous. The sharply outlined cyst within an intact cortex cannot be mistaken for a malignant condition.

Ossification in the Soft Parts (sometimes called Myositis ossificans). Bone may develop in the soft parts following trauma, with or without fracture. The new bone is believed to arise from bits of periosteum which have become separated from the shaft. The new bone is first demonstrable several weeks after the injury; it may continue to increase in bulk for several months and then show no further increase in size, the condition becoming stationary. The bone is laid down in amorphous areas, usually parallel with the shaft. The individual areas vary in size; some may be barely visible; others are larger, even up to 0.5 cm. in thickness and several centimeters in length.

The radiograph shows one, two, or many opacities in the soft parts adjacent to a bone. The shape of the opacities is elongated, the long axis parallel to the shaft. The density is the same as bone. The outline is sharply demarcated. The contour is irregular. The texture may be smooth, amorphous, or striated. Films taken at many angles may show in one that the new bone is separated from the shaft and does not arise from it. Occasionally in an extensive case the areas of new-formed bone are numerous and surround the shaft.

Differentiation is from osteogenic sarcoma; in this tumor there is bone destruction, in benign ossification there is

none; in sarcoma the excess bone is connected with the shaft, in benign ossification it is usually separated from the shaft; in sarcoma there is tumor mass, in benign ossification no soft tissue tumor surrounds the hard, easily palpable new-formed bone.

Ossifying hematomata, while quite common, are at the same time often mistaken for malignant growths clinically. The *x*-ray appearance, however, is quite different. This lesion is caused by some trauma to the periosteum which causes the formation of a hemorrhage beneath the periosteum and it, in turn, is raised up by the hemorrhage. When this first takes place the *x*-ray appearance does not help us, as it reveals nothing, but at the end of about three weeks the periosteum will lay down new bone and the hemorrhage beneath it will undergo organization with a deposition of calcium salts. The calcium salts, however, are laid down parallel to the bone, and the periosteum, of course, makes a definite border to the growth. In adult life this is most commonly seen in the thigh; in children it may occur in any bone but only in connection with scurvy.

Osteochondromatosis. Multiple spherical loose bodies varying in size from 0.5 to 1 cm. occurring in the bursae about the shoulder, elbow, or knee. These bodies are densely opaque and resemble the picture one would expect from a handful of marbles.

Benign Osteogenic Tumors of Bone. The term "osteogenic" means that the tumor is derived from bone-forming tissue; it does not mean bone producing, as a few of these tumors show no evidence of bone within them. This group includes *exostosis*, *osteoma*, and *chondroma*. They all form a single group, the members of which vary in appearance, in distribution, and in their age of incidence.

Exostoses have the same character of bone formation as the shaft; they spring from the shaft at an angle and always

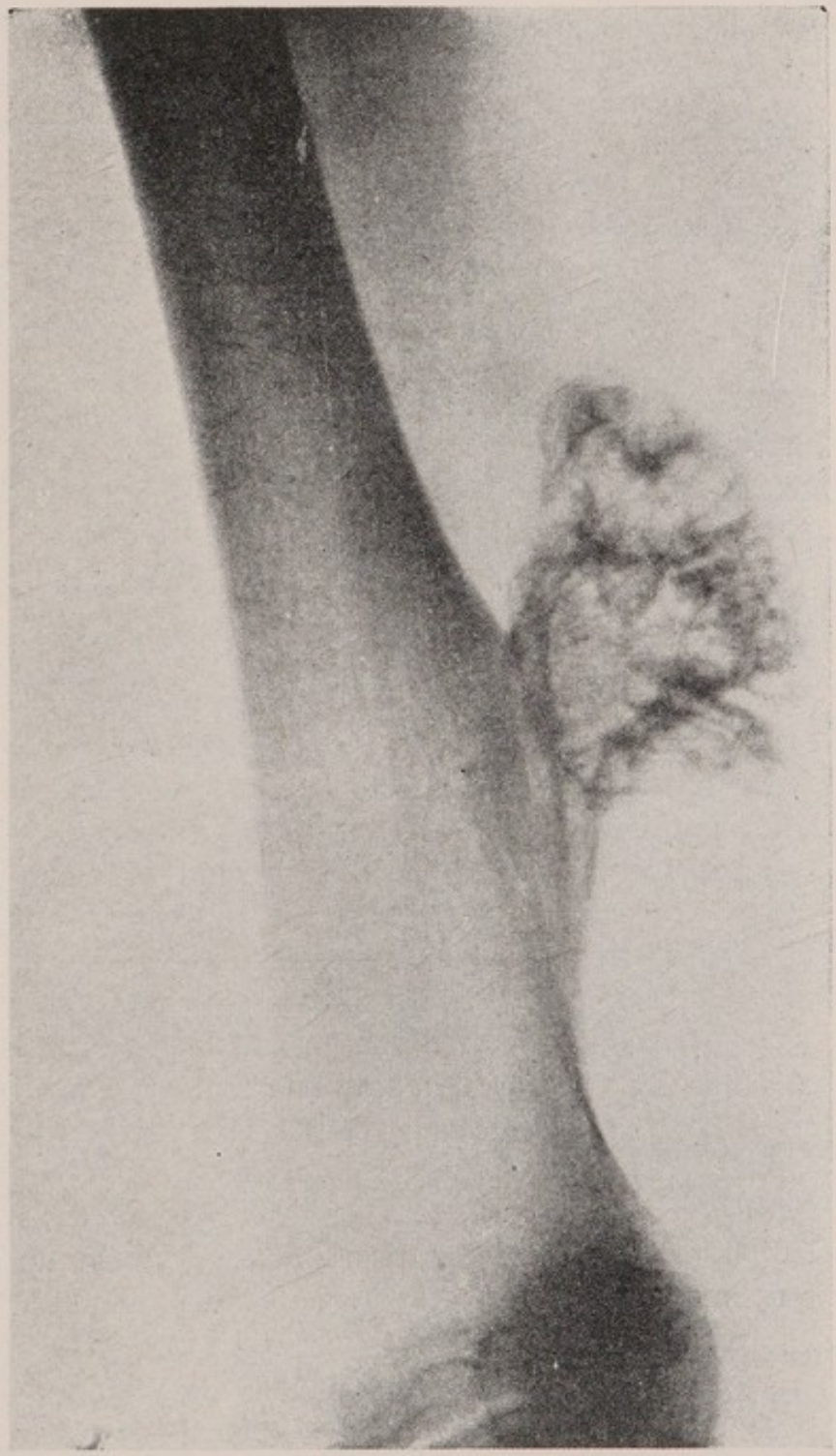


FIG. 119. Benign osteogenic tumor. (From Codman: Bone Sarcoma.)

point away from the nearest epiphysis. Occasionally one may see such an exostosis with an osteoma forming at the tip. Occasionally exostoses are multiple, occurring in practically all the long bones.

Osteoma arises from the cortex and, as its name implies, is a dense bony tumor. The growth extends out into the soft tissues, the bone being laid down very symmetrically, and has the typical cauliflower appearance. It is frequently lobulated, has a very definite outline, and no sign of invasion. These growths are generally multiple at the point of origin, are seen most commonly in the young, and are generally perpendicular to the shaft. The bone in these growths is much denser than the shaft and does not have the same bony structure.

Chondroma, as its name implies, is cartilaginous in origin and is generally seen before the epiphyses have united. The early recognition is probably due to the fact that fractures take place through this growth quite readily; the patient comes in for the fracture and the tumor is then discovered. The growth is situated near the ends of the bones in the region of the epiphyseal line, seldom extending beyond this line into the epiphysis proper. It is generally multiple and the growth is cystic in character; one growth may contain several cyst-like formations. It extends up and down the shaft; the cortex is expanded in a spindle-shaped manner but intact. There is no new bone formation unless there has been an injury. It may arise either from the medullary portion or the cortex. Any of the long bones in the body may be involved, the phalanges of the hands being probably the most common. These usually occur between the ages of seven and fifteen years.

Benign giant cell tumor destroys bone; there is no bone production in the tumor itself. It develops in the cancellous tissue at bone ends and grows equally in all directions, but

is commonly placed in an eccentric position in the shaft. The cortex is expanded and may be reduced to a thin shell, but is usually intact. Occasionally the cortex is perforated,

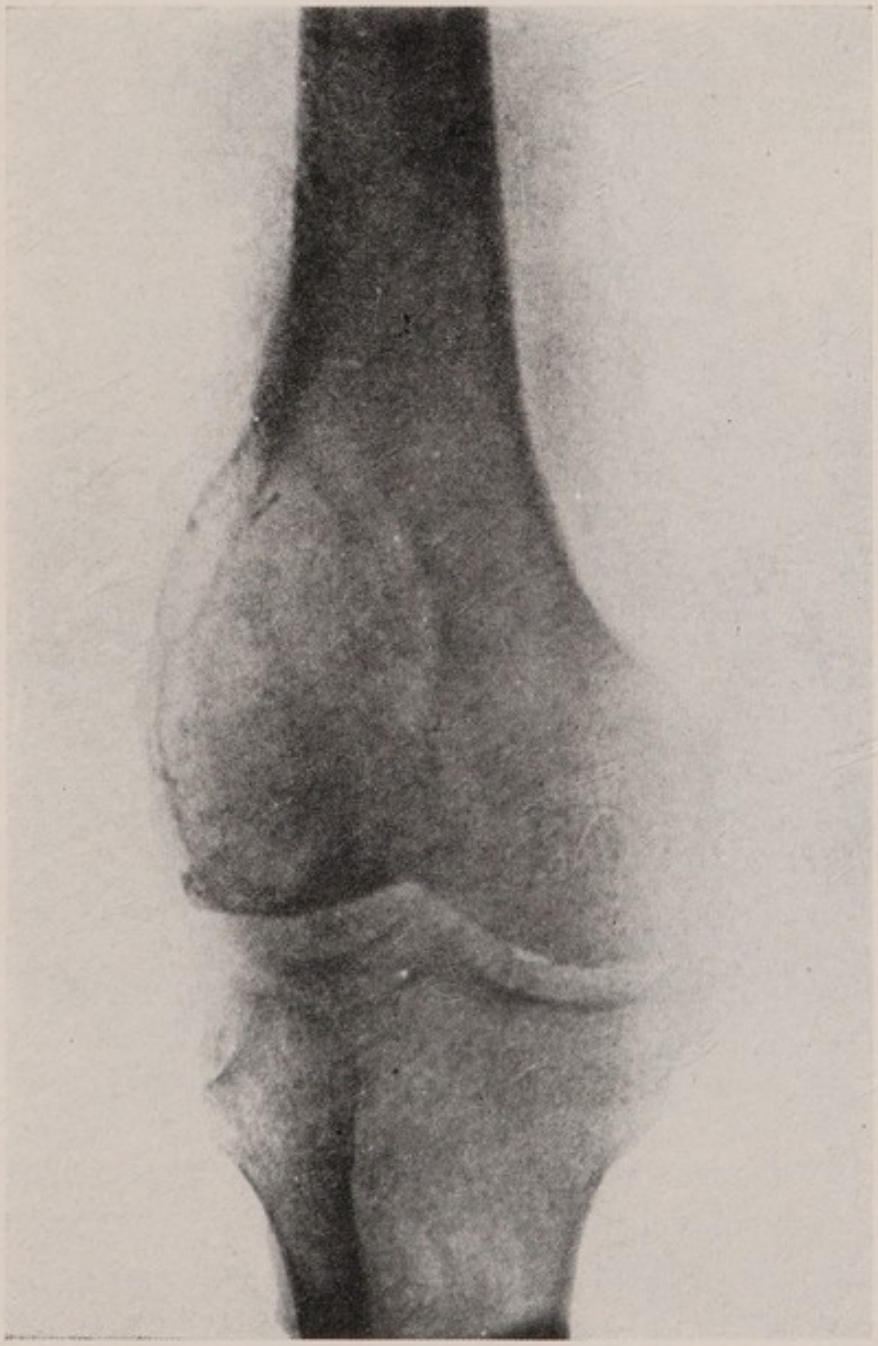


FIG. 120. Benign giant cell tumor. (From Codman: Bone Sarcoma.)

and the tumor grows out between the planes of fascia. When two bones are bound together by interosseous ligaments, the tumor may grow from one bone through

the ligament and invade the opposing bone. In spite of the possible invasion of soft parts, these tumors are not malignant, as they do not form metastases. The tumor is single,

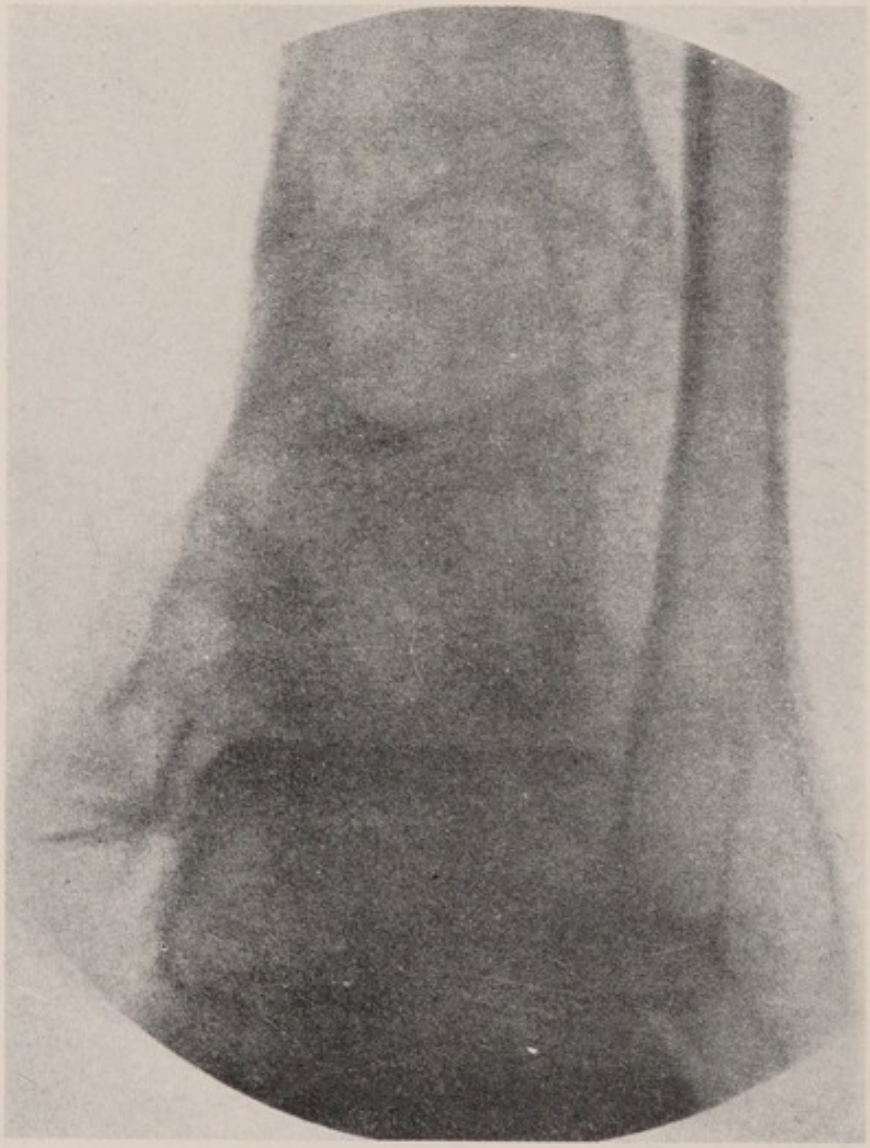


FIG. 121. Benign giant cell tumor which has invaded the fibula through the interosseous ligament. (From Codman: Bone Sarcoma.)

only one location in the skeleton being affected in any given individual. Pathological fracture has not been reported.

The radiograph shows the expanded, thinned cortex, and the bone destruction within. Crossing the radiotransparent area are lines suggesting that the tumor is lobulated; these lines are cast by ridges in the inner wall of the bone

shell and are not due to septa dividing the tumor substance. It is a characteristic feature that the tumor may grow right up to the cartilage of the joint. This is in contrast with osteogenic sarcoma, which ordinarily is stopped by the epiphyseal line.

The average age of incidence is between twenty and thirty. The usual locations are the lower end of the femur, either extremity of the tibia, and the lower end of the radius and the ulna. The location helps to differentiate this condition from osteogenic sarcoma, which has never been reported in the lower end of the radius or the lower end of the tibia.

The tumor grows month by month. It is susceptible to improvement or cure by radiation therapy.

Metastatic Tumors of Bone. Carcinoma is the most common invader. The tumor cells may enter the bone by the lymph vessels, along with the nutrient artery, or may arrive from the primary growth by extension along a muscular aponeurosis. When a bone is invaded the focus of growth is often in or near the medullary cavity, but may be cortical, at a ligamentous insertion. The tumor grows in all directions, destroying bone tissue in its path. The cortex is destroyed, not expanded. When the cortex is perforated the soft parts are invaded. The lesions are usually multiple, occurring either in a number of different bones or several in one bone.

There is predilection by certain tumors for particular bones: carcinoma of the breast: to the greater trochanter, spine, ribs, humerus, and ilia; carcinoma of the pelvic organs: to the lumbar spine; carcinoma of the prostate: to the pelvic bones and lumbar spine; carcinoma of the lips and tongue: to the mandible. Carcinoma typically does not cause the production of bone; the lesions are purely destructive. In the long bones the destruction may

so weaken structure as to cause pathological fracture. However, the metastases from prostatic carcinoma do cause production of new bone as a thin shell just beyond the

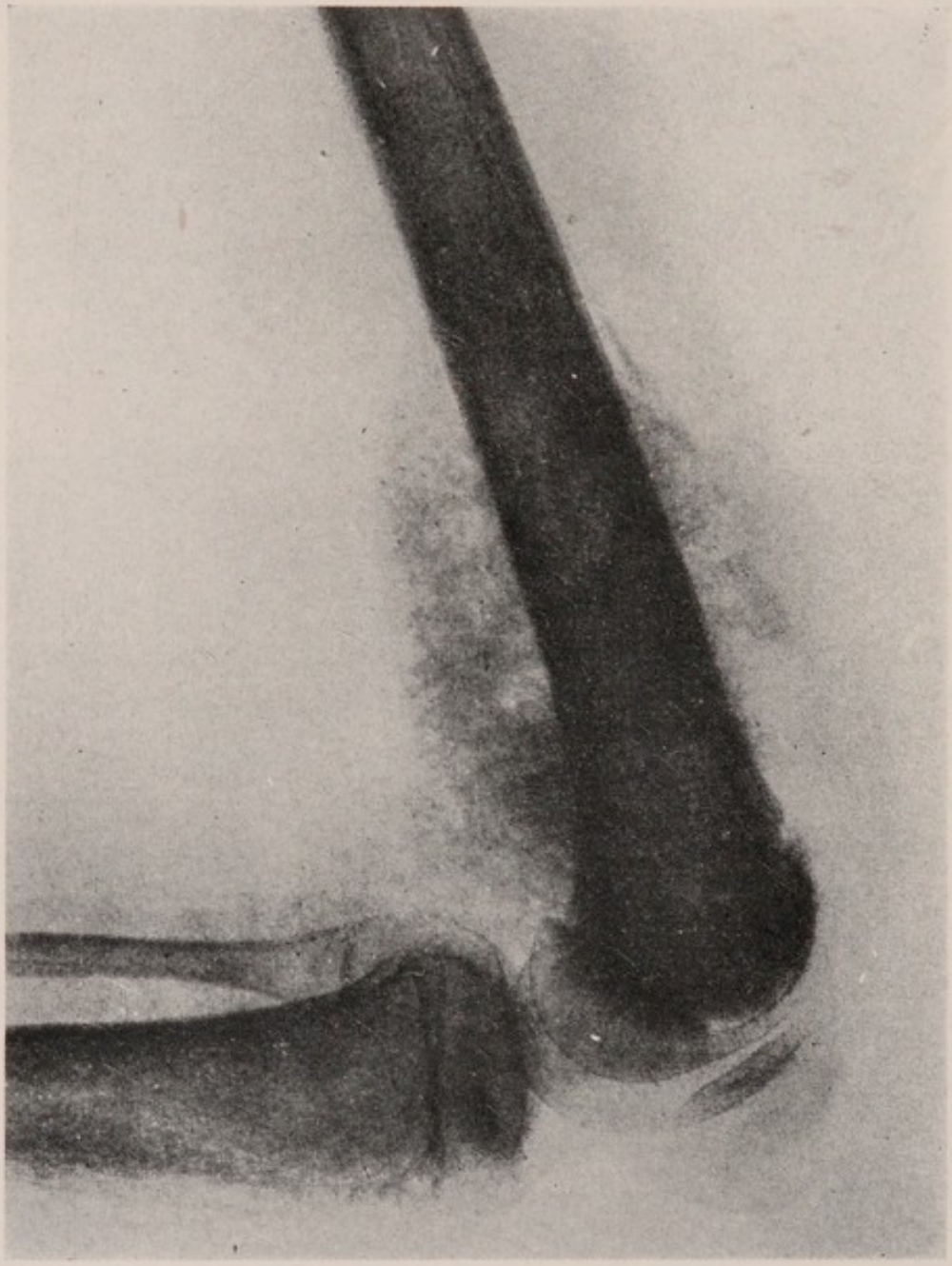


FIG. 122. Cuff of elevated periosteum and the formation of tumor bone. (From Codman: Bone Sarcoma.)

edge of the growth. Bone production may also be seen in metastases from other neoplasms, though rarely.

The radiograph shows in the long bones a dark area, punched out, sharply demarcated, irregular in outline, located in the medulla, in the cortex, or in both. Examination of many bones demonstrates that the condition is multiple. In the flat bones there is at first an uneven, mottled, indefinite loss in density; the spongy texture of bone is no longer well demonstrated. As bone destruction progresses, the shadow of the bone shows clear dark radiotranslucent areas, as though a pencil sketch were carelessly erased. This shows best where the bones are thin; in thick bones the demonstration is not as satisfactory. Thus in the spine an involved vertebra casts at first the same shadow as the normal; the tumor cells replace the destroyed bone and permit no loss in substance. As bone destruction progresses the vertebra becomes softer, collapses partially, and shows mottled areas of decreased density.

Metastases cause pain, especially when the spine is involved; pain may be present early, even before the metastasis is demonstrable in the radiograph.

Osteogenic Tumors, Malignant (Osteogenic Sarcoma). These tumors both destroy bone and produce bone: they are both osteolytic and osteoblastic. The appearance of the radiograph varies with the preponderance of one or the other feature. Thus, if the tumor is osteolytic in type, the bone is nearly completely destroyed; if osteoblastic, there is a bony mass; there is every gradation between the two extremes. The radiographs differ, but the tumor is the same; unfortunately the prognosis is equally bad in all. Five main characteristics have been described by The Registry of Bone Sarcoma.

(1) Combined central and subperiosteal involvement. This differentiates these growths from the benign forms, which are either inside or outside the shaft, never both. To determine this point it is often necessary to make

radiographs at many angles. Occasionally the only evidence of extracortical involvement is a cuff of elevated periosteum at the upper margin of the tumor. Such a cuff is positive

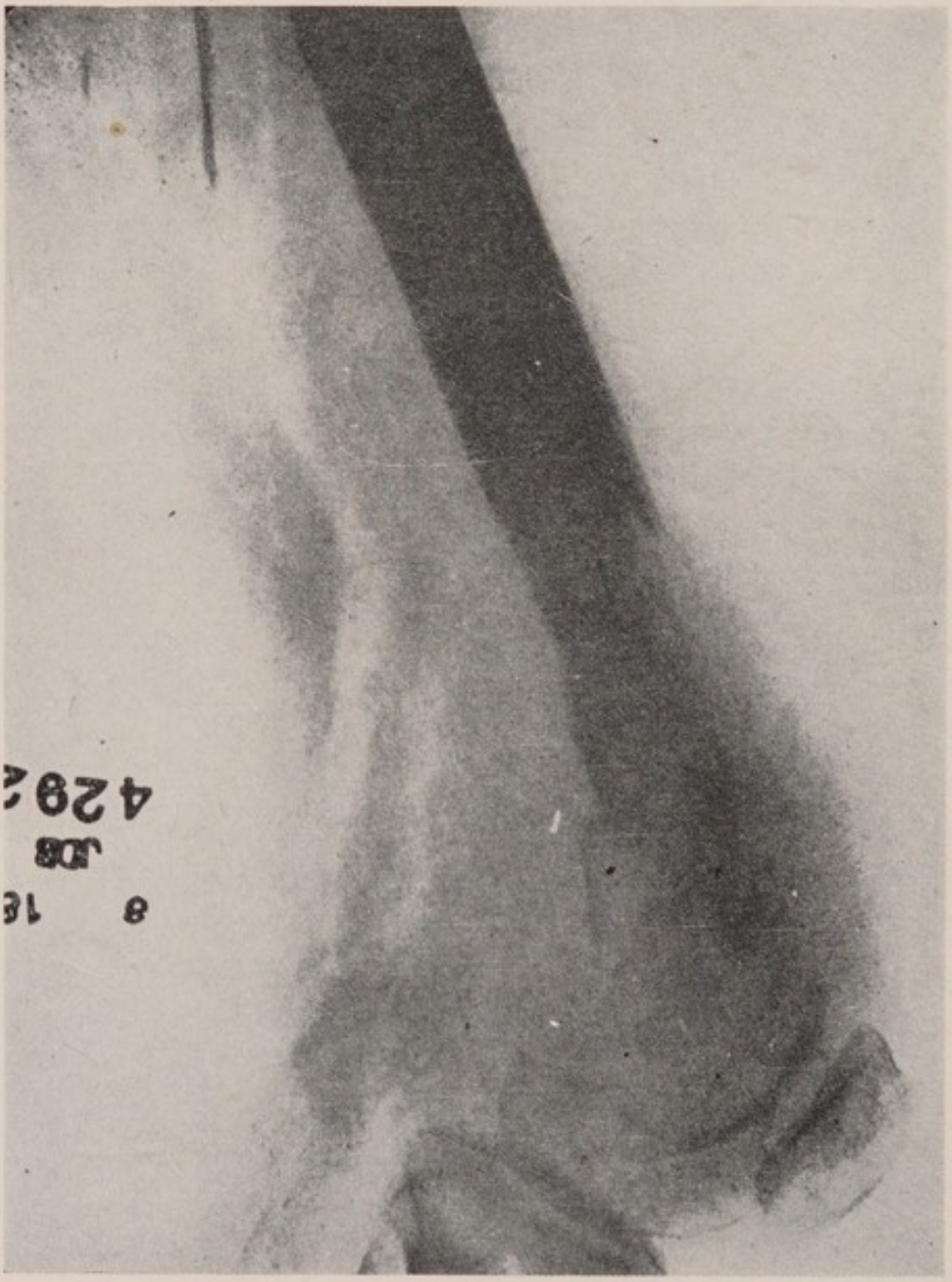


FIG. 123. Osteogenic sarcoma, osteolytic in type. (From Codman: Bone Sarcoma.)

evidence that a condition within the bone has perforated the cortex. It may be noted that inflammatory conditions

or subperiosteal hemorrhage may cause the appearance of this cuff, which is not indicative of tumor formation solely.

(2) Presence of the old shaft. The shaft remains in its normal position; it is not expanded. The destruction may have progressed so far that portions are completely separated, but these fragments continue in their former alignment. Even in the purely osteolytic types the remaining bits of shaft are seldom displaced. The cortex is perforated radially; bone is laid down in the tumor columns, which give an appearance of spicules arranged perpendicularly with the shaft. When this arrangement of new bone is present, it is characteristic of sarcoma, as it is rarely encountered in other conditions. The absence of the spicules does not disprove the existence of sarcoma.

(3) Invasive character in spongy bone. The advancing edge is irregular. Giant cell tumors and a few vascular metastases have a rounded, smooth outline; these advance by pressure atrophy due to their pulsations.

(4) Osteolytic or osteoblastic or both. As a rule both processes coexist. Rarely, a tumor may be wholly osteolytic or wholly osteoblastic. If the condition is wholly osteolytic there is a striking resemblance to carcinomatous metastasis.

Osteolytic tumors are found more frequently in adults; osteoblastic, in children and adolescents.

A tumor that is osteolytic in type may at a later stage in its growth become osteoblastic.

(5) Involvement of soft parts. Unless the tumor is of the osteoblastic type, and has progressed sufficiently far, this feature may be difficult to demonstrate in the *x*-ray film. It has been shown that a tumor may have invaded soft parts without demonstrable evidence by *x*-ray. The cuff of raised periosteum is a help.

The diagnosis of a well-defined case of malignant osteogenic tumor may present little difficulty, but as so many

cases occur when all the five characteristics are not demonstrable, or when other findings cast the diagnosis in doubt, it is well to consider the probabilities as to age, location,

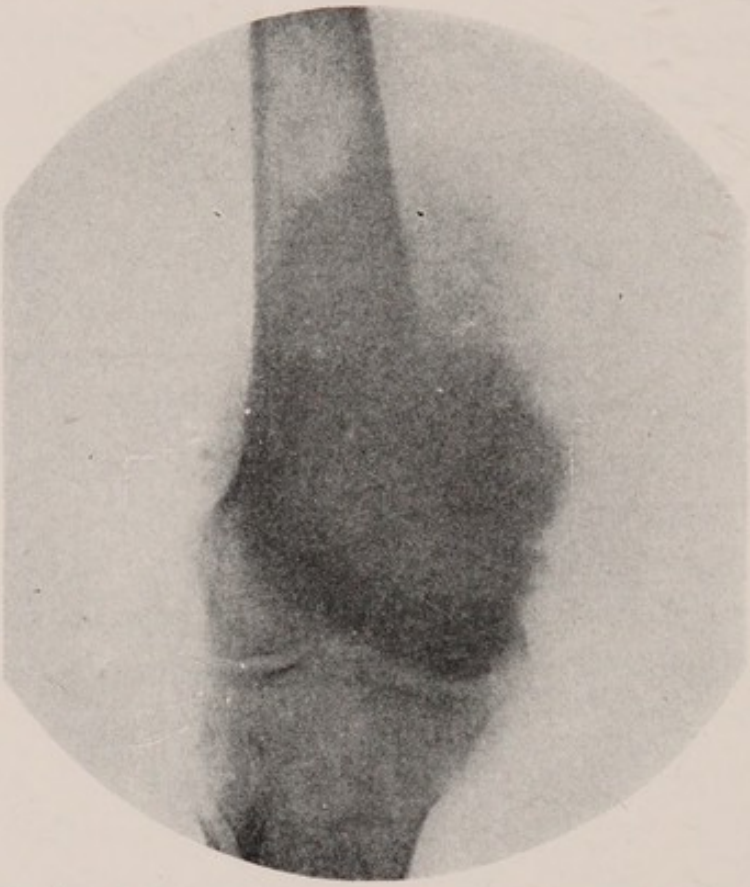


FIG. 124. Osteogenic sarcoma, osteoblastic in type. (From Codman: Bone Sarcoma.)

size and rapidity of growth.

This disease is one that primarily affects the healthy young adult. Most of the cases have occurred around the age of twenty. None has been reported in which the patient was over fifty, except in those instances of Paget's disease that later develop sarcoma; these may be older. Half the reported cases have occurred in the femur, a fourth in the tibia, and half the remainder in other long bones, except the phalanges which appear to be exempt. More particularly, if the femur is involved, the lower fourth of the shaft is affected four times out of five; of the remaining fifth,

half appear in or near the great trochanter and half are distributed through the shaft. If the tibia is involved, the seat is in the upper end nine times out of ten, and is never in the lower end. If the humerus is involved, the seat is in the upper third; osteogenic sarcoma below the deltoid tubercle is a curiosity. The lower end of the radius and the lower end of the tibia appear to be exempt; this is in contrast with benign giant cell tumor, which commonly appears in one of these locations.

The location is at the end of the bones rather than the middle of the shaft. The growth is large when the patient first seeks medical advice; a small or pedunculated tumor is presumably benign. Increase in size is generally noticed month by month. Benign osteogenic tumors have an exceedingly slow growth; while they may show periods of increase this occurs year by year. Inflammatory conditions usually enlarge noticeably week by week, and often day by day.

Pulmonary metastases are frequent; from the lung the dissemination may follow throughout the osseous system and parenchymal organs. Lymphatic metastases are less common.

Ewing's tumor destroys bone; there is no bone production in the tumor itself. The cortex is infiltrated and thickened, and may be split into layers sufficiently definite to be recognized in a radiograph. The cortex is expanded slightly. As the disease progresses the cortex is destroyed. The periosteum is elevated; there is a reactive proliferation of bone that is irregularly disposed, so that the outline of the shaft is beaded and irregular. As in other reactive conditions the new bone is parallel to the shaft. The tumor is large when the patient first seeks medical advice, and frequently implicates half of the shaft. At first the tumor is single. Later metastases occur in other bones and in the lungs.

The radiograph shows the thickened, irregular, nodular cortex, that is unevenly expanded; the medulla is ill defined, the bone destruction masked by the shadow of the cortex that covers it.

The average age of incidence is under thirty. The usual location is in the middle of the shaft of a long bone. The tumor is susceptible to improvement by radiation.

Other bone lesions may be similar in radiographic appearance; it may be convenient to consider a brief summary of the more striking points of difference. Osteomyelitis resembles Ewing's tumor; the radiographic appearance of the two may be identical. In such cases there are no differential points that would serve to determine whether the shadows of the involved bone are cast by one or the other condition. Ewing's tumor should always be borne in mind and in every case of apparent osteomyelitis, where the clinical features or progress are doubtful or unusual, a search should be made in other bones and in the lungs for metastases; and radiotherapy should be tried. Malignant osteogenic tumor may resemble Ewing's tumor that has gone on to destruction of the cortex, but differs from Ewing's tumor in that the cortex is fragmented but not thickened or displaced; malignant tumor has a cuff of periosteal bone at the upper end, while Ewing's tumor shows no cuff; malignant tumor shows bone of tumor origin unless purely osteolytic; and does not respond as well to radiation. Metastatic tumors of bone differ in the appearance of the cortex and in the age of incidence: they are more common after the age of forty.

Myeloma causes multiple areas of bone destruction, and involves a number of bones simultaneously. There is no bone production by the tumor itself, but occasionally there is a reactive proliferation of bone near a slowly growing nodule. Most of the lesions are in the medulla but the cortex

may be involved as well. It is customary to find some bones extensively involved, and others free from apparent manifestations of this disease.

The radiographs show many bones riddled with small, discrete, clean-cut areas of lesser density. The spine and pelvis are nearly always affected. In the spine the vertebrae cast faint shadows, and may be reduced in size. The age of incidence is usually over forty. Metastasis to the lungs occurs infrequently.

The differential diagnosis of a bone tumor that runs true to type may present little difficulty. Even cases that are not true to type may be diagnosed if the period of observation is extended long enough to determine the manner of growth, and the development of bone destruction and bone production. Unfortunately the physician in charge of the case is often hard pressed for a diagnosis, particularly as the public has been educated to believe that any malignancy is curable if taken in time.

There are tumors that vary from the average so far that the combined efforts of clinician, radiologist and pathologist may fail to determine their nature.

This is especially true of angioma, which has not been diagnosed as such during the life of the patient, and periosteal fibrosarcoma, which presents little or no evidence of bone involvement.

Two working classifications have been evolved, the first by The Registry of Bone Sarcoma in 1925, and the second a modification suggested by Kolodny two years later. These classifications are appended at the end of the chapter. They are often exceedingly valuable in the analysis of a particular case.

Rare Conditions. The following conditions are so rarely encountered that an extended description is not justified.

Myositis Ossificans. Sheets of bone tissue are laid down in the substance of muscle in many parts of the body.

Hereditary cleidocranial dystosis is characterized by partial or complete absence of one or both clavicles, abnormalities of dentition, and variations in the shape of the skull.

Madelung's deformity is spontaneous dislocation of the wrist.

Sprengel's deformity is unilateral elevation of the scapula, associated with decided anomalies of the ribs and sometimes with defective formation of the clavicle.

Osteogenesis imperfecta (osteopsathyrosis) occurs in fetal life or infancy. There are multiple fractures resulting in deformity. Callus forms rapidly. If the infant lives there may be recovery.

Achondroplasia. The epiphyseal line is condensed and sclerosed, with early union. The ends of the bones are widened, the shafts narrowed and frequently distorted, giving the "drum-stick" deformity.

Dyschondroplasia. The normal outline of the haversian canals is distorted. It is stated that bits of cartilaginous tissue are present between the layers of bone.

Osteopoikilia (Osteitis condensans generalisata; Osteopathia condensans disseminata; osteosclerosis fragilis generalisata; Albers Schönberg disease). Numerous dense spots the size of a bean are scattered through all the long bones placed with their long axes in the long axis of the affected bone. They are most numerous in the cancellous ends.

Osteochondritis Deformans (Juvenile deforming metatarsophalangeal osteochondritis; Freiberg's infraction of the metatarsal head). The head of one metatarsal, usually the second, is wide, the end flat or slightly cupped. The base of the proximal phalanx alters in shape to correspond. This disease is considered comparable with Legg's disease of the hip.

Koehler's disease of the scaphoid is a similar condition, except that the affected bone is smaller and denser than normal, instead of larger and less dense. There is no change in adjoining bones.

Osteochondritis of the Os Calcis (Apophysitis). The epiphysis at the posterior aspect of the os calcis is enlarged and irregular; the epiphyseal cartilage is blurred and indistinct.

APPENDIX

Ossification and Epiphyses

Bone		Appearance	Union
Clavicle	Shaft	6 wk. int. ut.	
	Sternal end	18–20 yr.	25 yr.
Scapula	Body	7– 9 wk. int. ut.	
	Coracoid process subcoracoid and glenoid 10 yr.	12–18 mos.	15 yr.
	Acromial process (2–3)	14–16 yr.	20–25 yr.
	Base of scapula	16–18 yr.	25 yr.
	Lamina of coracoid and glenoid	16–18 yr.	
Humerus	Shaft	8 wk. int. ut.	
	Head	3 –4 mo.	20 yr.
	Great tuberosity	2½–3 mo.	
	Small tuberosity	3½–5 yr.	
	Internal condyle	4– 5 yr.	18 yr.
	Trohlear	10–13 yr.	19 yr.
	Capitellum	1– 2 yr.	
	External condyle	12–14 yr.	
Radius	Upper end	5– 6 yr.	16–18 yr.
	Shaft	8 wk. int. ut.	
	Lower end	2– 3 yr.	20 yr.
Ulna	Upper end (olecranon)	10 yr.	17 yr.
	Shaft	8 wk. int. ut.	
	Lower end	4– 5 yr.	20 yr.
Carpus	Os magnum	1 yr.	
	Unciform	12–18 mos.	
	Pyramidal	2½– 3 yr.	
	Trapezium and semilunar	4– 5 yr.	
	Scaphoid	5½–6½ yr.	
	Trapezoid	6– 8 yr.	
	Pisiform	8–12 yr.	

Ossification and Epiphyses. (*Continued*)

Bone		Appearance	Union
Carpus (*Continued*)	Shaft of metacarpals and phalanges.	10–12 wk. int. ut.	
	Heads of metacarpals and bases of phalanges, except epiphysis at *base* of metacarpal of pollex, though latter sometimes has distal epiphysis at 7–8 yr.	3– 6 yr.	18–20 yr.
Os innominatum	Ilium, ischium and pubis (3).....	2, 4, 4½ mo. int. ut.	7– 8 yr.
	Acetabulum begins to ossify 12–15 yr. finishes 17–20 yr.		
	Crest of ilium; symph. pubis; ant. inf. il. spine; isch. tub.....	15–16 yr.	18–25 yr.
Femur	Upper end (head).....	1– 2 yr.	18–19 yr.
	Shaft.....	7– 8 wk. int. ut.	
	Great trochanter.....	3– 4 yr.	18 yr.
	Small trochanter.....	13 yr.	17 yr.
	Lower end.....	8 mo. int. ut.	20–21 yr.
Patella	Center.....	3 yr.	15–18 yr.
Tibia	Upper end (sometimes separate center for tubercle 13 yr.).....	Birth	19–22 yr.
	Shaft.....	7– 8 wk. int. ut.	
	Lower end.....	1–2 mos.	17–19 yr.
Fibula	Upper end.....	3– 4 yr.	19–24 yr.
	Shaft.....	5 wk. int. ut.	
	Lower end.....	2 yr.	19–21 yr.
Tarsus	Os calcis: center.....	6 mo. int. ut.	
	post. extremity.....	10 yr.	15–18 yr.
	Astragalus.....	7 mo. int. ut.	
	Cuboid.....	8 mo. int. ut.	
	External cuneiform.....	1 yr.	
	Internal cuneiform.....	3– 4 yr.	
	Middle cuneiform.....	3– 4 yr.	
	Navicular.....	3– 5 yr.	
	Shafts of metatarsals and phalanges	10–15 wk. int. ut.	18–20 yr.
	Heads of metatarsals and bases of phalanges except epiphysis at *base* of metatarsals of hallux, though latter sometimes has distal epiphysis at 7–8 yr.....	3– 8 yr.	18–21 yr.
	(Sometimes traces of a proximal epiphysis in 2nd metacarpal, or 5th metatarsal)		

Extra Bones

Extra bones are found in the hands, feet, and hips. In themselves, only one has known pathological significance, the tibiale externum. This bone may make a projection on the inner side of the tarsus that interferes with the wearing of a shoe. An extra bone may be mistaken for fracture, arthritis, or even a foreign body. They are tabulated as follows:

Hand.

1. Os centrale, on the dorsal aspect, posterior to the os magnum. Usual size 1 × 3 mm.
2. Os trigonum, a minute bone at the tip of the ulna styloid.
3. Os radiale externum. Lies just external to the scaphoid.
4. Os vesalii. At the base of the 5th metacarpal, on the inner side.

Divided scaphoid. As this bone is developed from two centers of ossification, the two halves may not unite, simulating fracture.

Foot.

1. Os trigonum. At the posterior aspect of the astragalus, opposite the tubercle.
2. Os peronei. On the outer side, below the cuboid.
3. Tibiale externum. On the *inner* side of the scaphoid, and applied closely to it like a cap. May be 1 × 1 cm. in size.
4. Os astragalo—scaphoid. At the upper and posterior lip of the scaphoid, triangular in shape, 1 to 2 mm. in size, close to the articular margin.
5. Secondary os calcis. Lies between the astragalus and the os calcis.
6. Secondary astragalus. Lies just above the neck of the astragalus.

Divided sesamoid, opposite the head of the 1st metatarsal. Normally there are two sesamoids. Frequently one of the two is divided, making a total of three.

Hip.

1. Os acetabuli. At the superior margin of the actetabulum. Seen in profile in the standard position; gives an appearance similar to a chip of bone torn from the acetabular margin.
2. Os trochanteri major. Just above the upper margin of the great trochanter.
3. Os trochanteri minor. Just above the tip of the lesser trochanter.

Knee.

Sesamoid in the long head of the gastrocnemius. Variable position, usually just posterior to the condyles. Occurs in 70 per cent of all cases.

Divided patella. The patella is divided into three, with no separation of the pieces, edges smooth, lines wavy or straight. Seen only in the posteroanterior view.

Divided tubercle of the tibia. As seen in the lateral view, the epiphysis is long and pendulous. At times the tip is separate.

Classification of Bone Lesions

Registry of Bone Sarcoma, 1925.*

1. Metastatic tumors
2. Periosteal fibrosarcoma
3. Osteogenic tumors
   a. Benign
   b. Malignant

* Codman, E. A. Bone Sarcoma. An Interpretation of the Nomenclature used by the Committee on the Registry of Bone Sarcoma of the American College of Surgeons, N.Y., Hoeber, 1925.

4. Inflammatory conditions
   a. Osteoperiostitis
   b. Myositis ossificans
   c. Osteitis fibrosa
5. Benign giant cell tumor
6. Angioma
   a. Benign
   b. Malignant
7. Ewing's tumor
8. Myeloma

Definition: Osteogenic—a tumor derived from bone forming tissue; does not connote that the tumor itself necessarily produces bone.

Changes Suggested by Kolodny, 1927.*

1. Osteogenic sarcoma
2. Ewing's sarcoma
3. Myeloma
4. Unclassified.

Under group 4, Unclassified, come Periosteal Fibrosarcoma (Class 2, above) and Angioendothelioma (Angioma benign and malignant, class 6, above). Both of these conditions are separate entities but are rare and are practically never diagnosed during life. These tumors should not be included in a working classification until further knowledge adds the means for establishing their diagnosis early enough to assist in treatment and prognosis.

Metastatic tumors (class 1 above) the "Inflammatory" group (class 4 above) and the benign tumors (class 3, a, class 4) are excluded in Kolodny's modification of the original classification established by The Registry of Bone Sarcoma.

* Kolodny, A. Bone sarcoma; primary malignant tumors of bone and giant cell tumor. *Surg. Gynec. Obst.*, 44: 1, 1927.

CHAPTER IX

SINUSES, MASTOIDS AND BRAIN

Technique for Accessory Sinuses. In order to obtain a satisfactory posteroanterior image of all the accessory sinuses at one exposure, it is necessary that the rays pass through the head at a certain angle. If this angle is not observed, the petrous portion of the temporal bone obstructs the view of the ethmoids or antrum, or the sinuses are so distorted that the information given is not correct.

Of the many positions that have been suggested, three are in ordinary use; these may be called the nose-forehead, the nose-chin, and the Granger's positions. It is customary to make radiographs in at least two of these positions, in order that the condition of the sinuses may be verified. A lateral view is always made.

Nose-forehead Position. The proper angle is one which will cause the shadow of the petrous portion to cut across the lower one-third of the orbit and upper one-third of the antrum, leaving the lower two-thirds of the antrum free and also the upper two-thirds of the orbit clear. (Fig. 125.) The superior portion of the antrum is not so important, as any condition affecting the antrum to the extent of an *x*-ray diagnosis will involve the inferior portion as well.

The position described shows clearly the frontals, ethmoids, and antra on a single film, and the sinuses in their proper relation and size.

To obtain this position the principal ray must be directed through the head at an angle of 23° from a line extending from the external auditory meatus to the glabella.

This angle may be obtained by a pair of dividers or a permanent triangle set at an angle of 23°. (Fig. 126.)

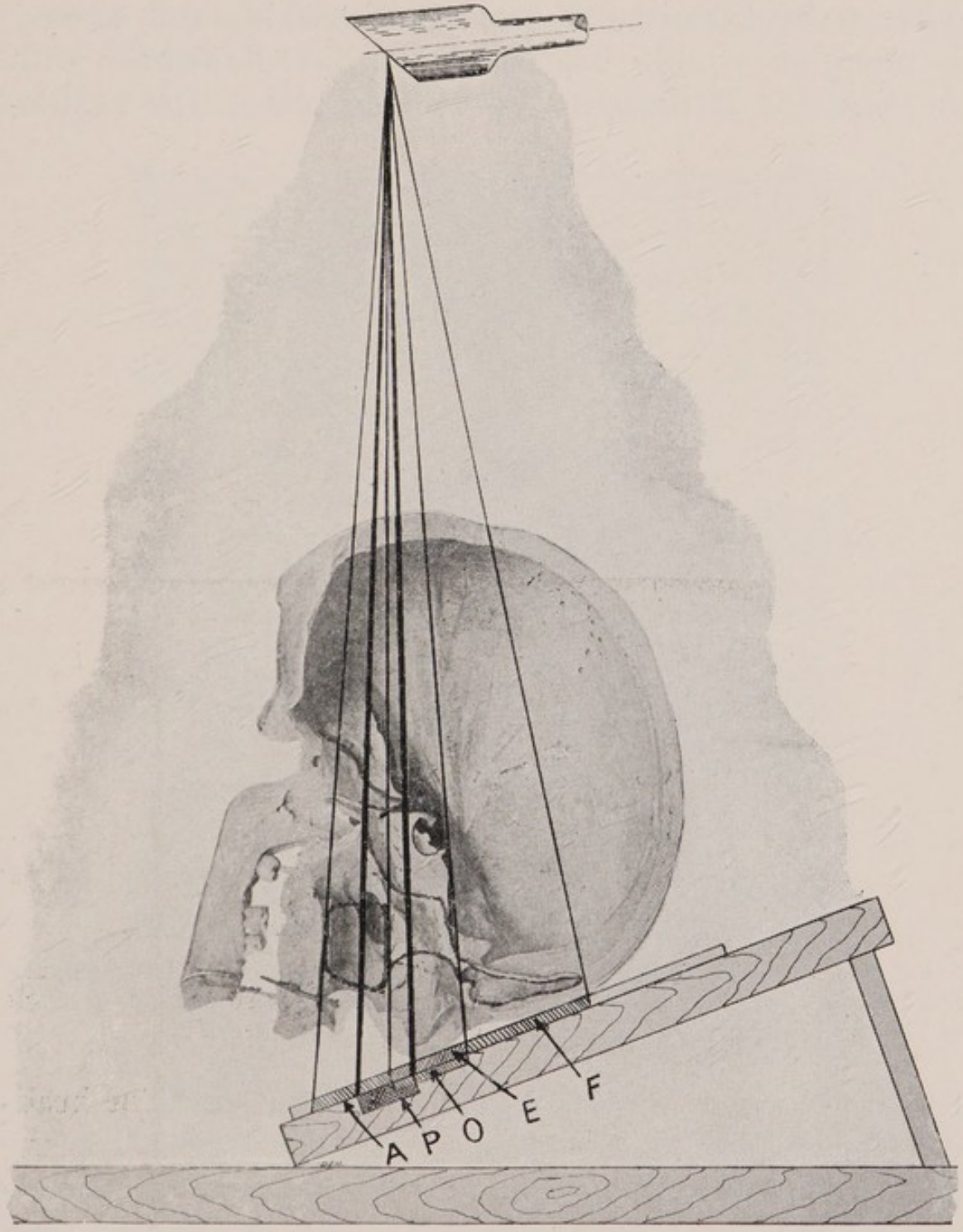


FIG. 125. Schematic drawing illustrating correct angle for postero-anterior accessory sinus examination. The heavy lines indicating projection of petrous portion of temporal bone on to the film *A*, antrum; *E*, ethmoids; *F*, frontal; *P*, petrous; *O*, orbit.

The patient is seated before an adjustable stand, or may lie prone on a table. The head rests face downward with the nose and forehead on an inclined plane. The inclina-

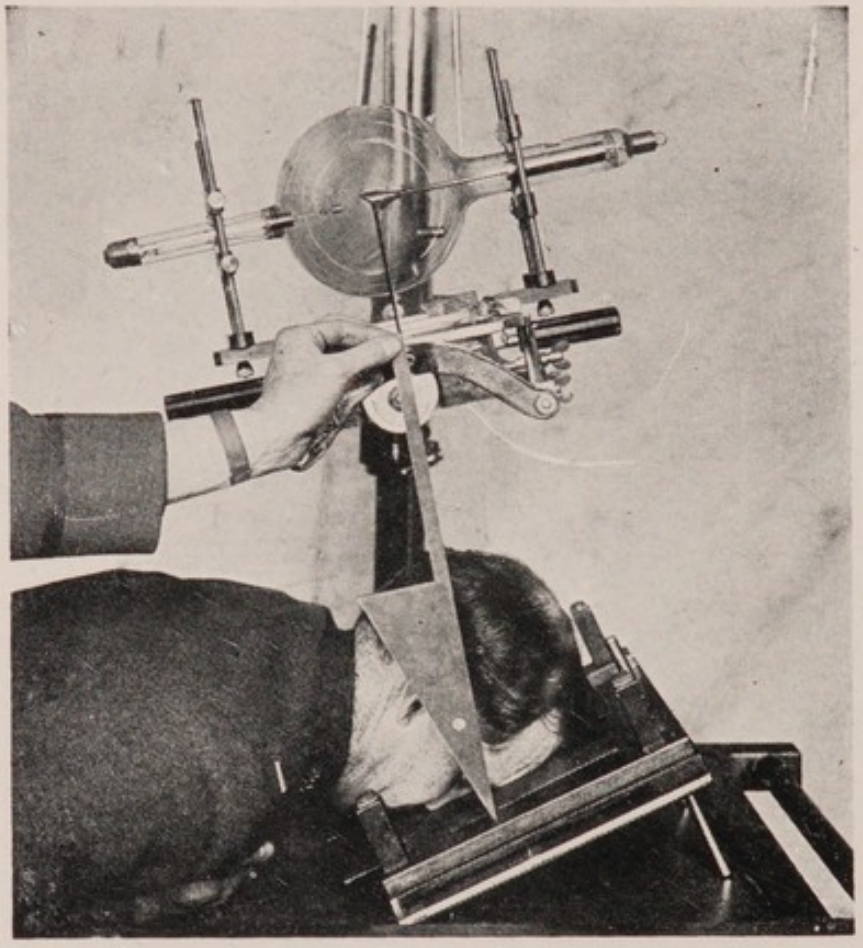


FIG. 126. Position for posteroanterior examination of accessory sinuses, head resting on nose and forehead, central ray entering head at angle of 23° from a line from external auditory meatus to glabella.

tion is such as to be comfortable to the patient. The headrest shown in the illustration has an angle of 20°. If the patient is sitting, an adjustable rest is necessary to accommodate for the difference in the length of the neck and shape of the head.

The tip of the angle finder is placed opposite the glabella, the short arm passing across the external auditory meatus, the long arm extending upward alongside the cone and representing the direction of the principal ray. The cone

is now brought into alignment with the arm of the finder and adjusted at the proper height.

Technique. Without Bucky diaphragm:

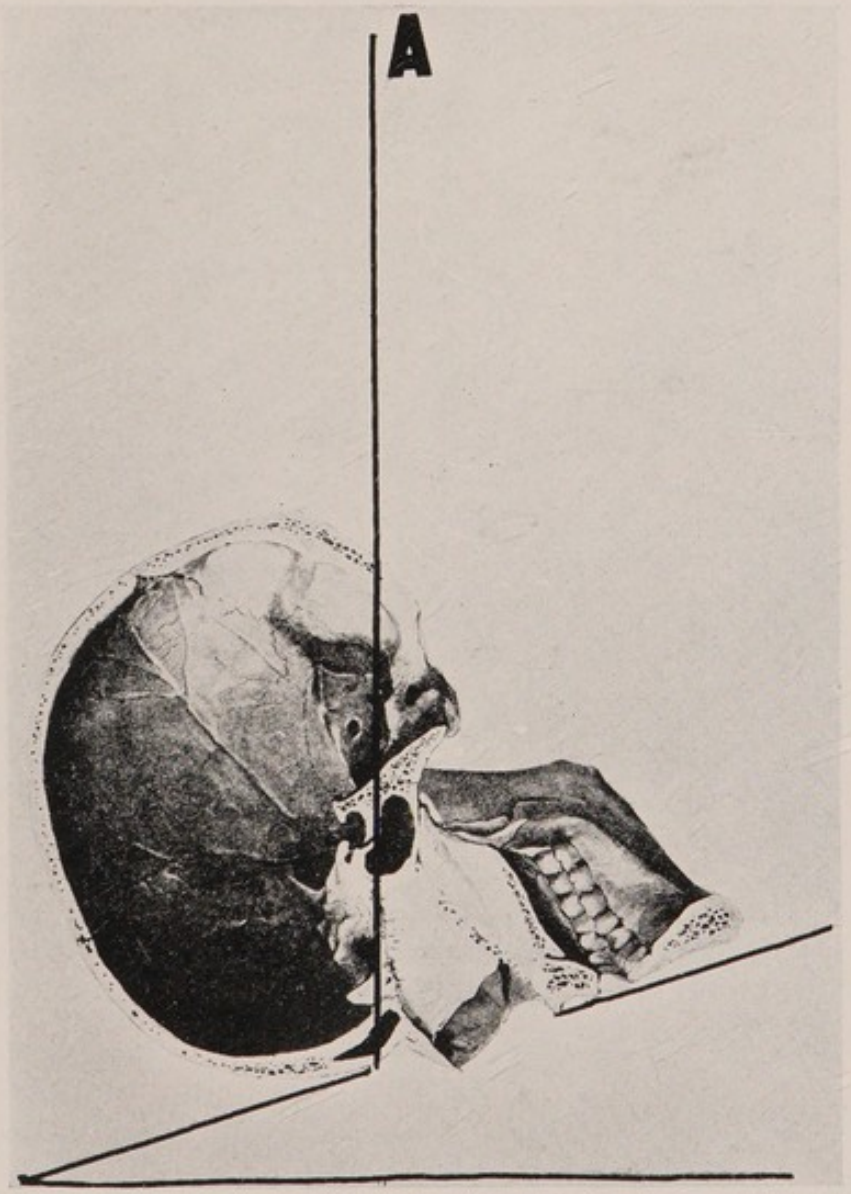


FIG. 127. Granger's position. *A*, direction of the *x*-ray beam.

Kv. 85. Ma. 20. Distance 25 in. Time 3 sec. Screens.

With Bucky diaphragm:

Kv. 85. Ma. 20. Distance 25 in. Time 10 sec. Screens.

Nose-chin Position. The inclined plane is removed. The chin is placed on the cassette, the head inclined forward

until the end of the nose is half an inch above the cassette. The direction of the ray is vertical. The antra are well demonstrated, but the frontal and ethmoid sinuses are so

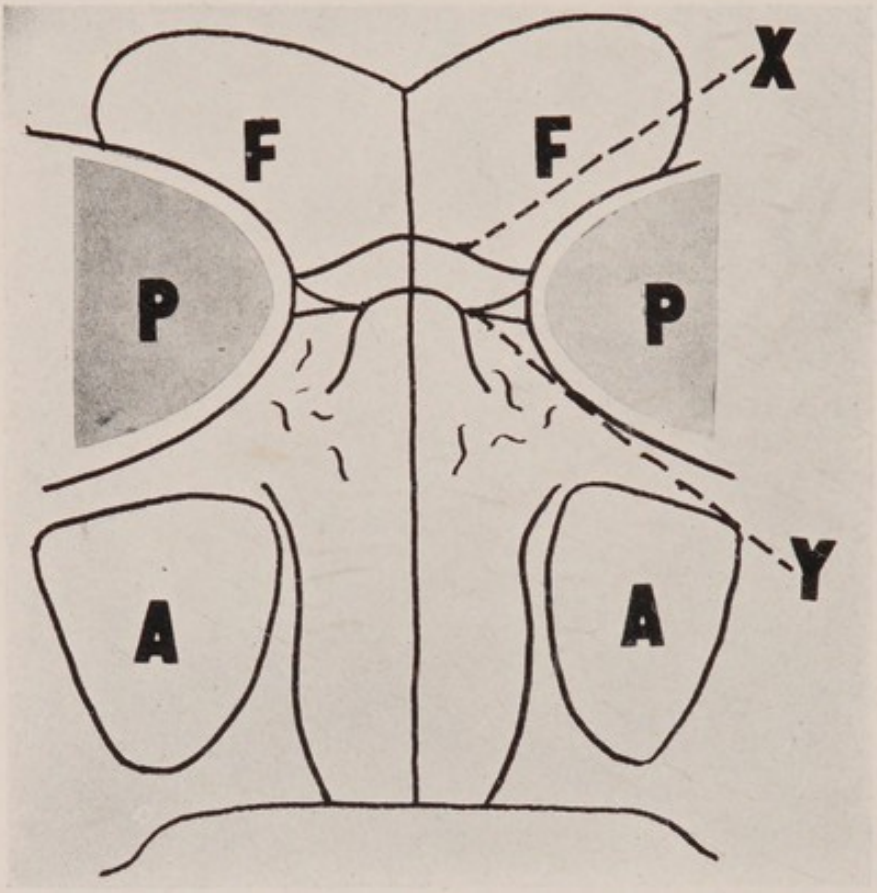


FIG. 128. Granger's position. Diagram showing the projection of the sinuses. *A*, antrum; *F*, frontal sinus; *P*, petrous portion of the temporal bone; *X*, upper limit of the sphenoid, the optic groove; *Y*, horizontal plate of the frontal bone.

far from the film that their shadows are not distinct.

Technique. Without Bucky diaphragm:

Kv. 85. Ma. 20. Distance 25 in. Time 5 sec. Screens.

With Bucky diaphragm.

Kv. 85. Ma. 20. Distance 25 in. Time 10 sec. Screens.

Granger's Position. Flex the head and place on an angle board provided with a slot for the nose. The angle is 17° from the horizontal. (It will be noted that in the preceding position the head is extended, instead of flexed.) The gla-

bella and the upper jaw press equally against the angle board. The central ray is directed vertically, centered just posterior to the external auditory meatus (Fig. 127). When the position is correct the shadow of the petrous portion of the temporal bone falls exactly within the shadow of the orbits. The shadow of the sphenoid sinus falls across the lower portion of the shadow of the frontal sinuses, between the lines *X* and *Y* (Fig. 128). The line *X* is often referred to as "Granger's line." The ethmoid cells fall below the line *Y*. As the relative position of the component parts of the skull occasionally varies, it should not be expected that the sphenoid sinus will always be projected as indicated by the diagram.

Technique. The use of the Bucky diaphragm is preferable.
Kv. 85. Ma. 10. Distance 25 in. Time 10 sec. Screens.

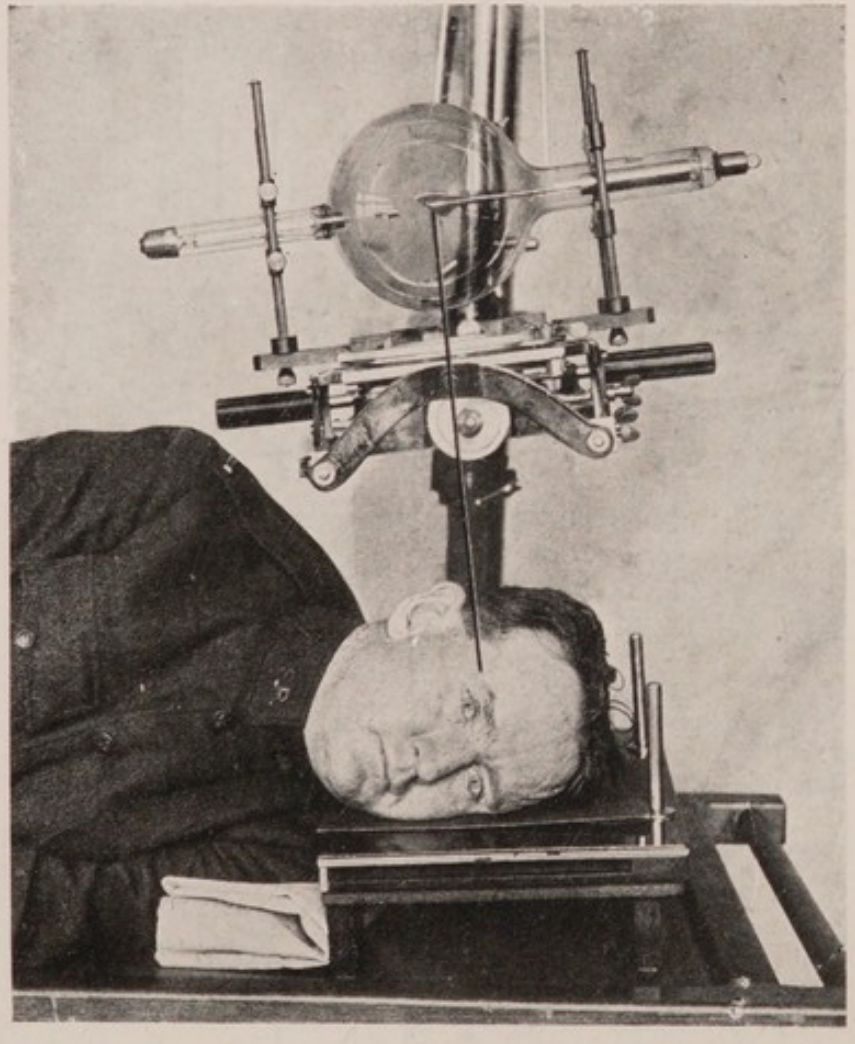
If the Bucky diaphragm is not used:
Kv. 85. Ma. 10. Distance 25 in. Time 5 sec. Screens.

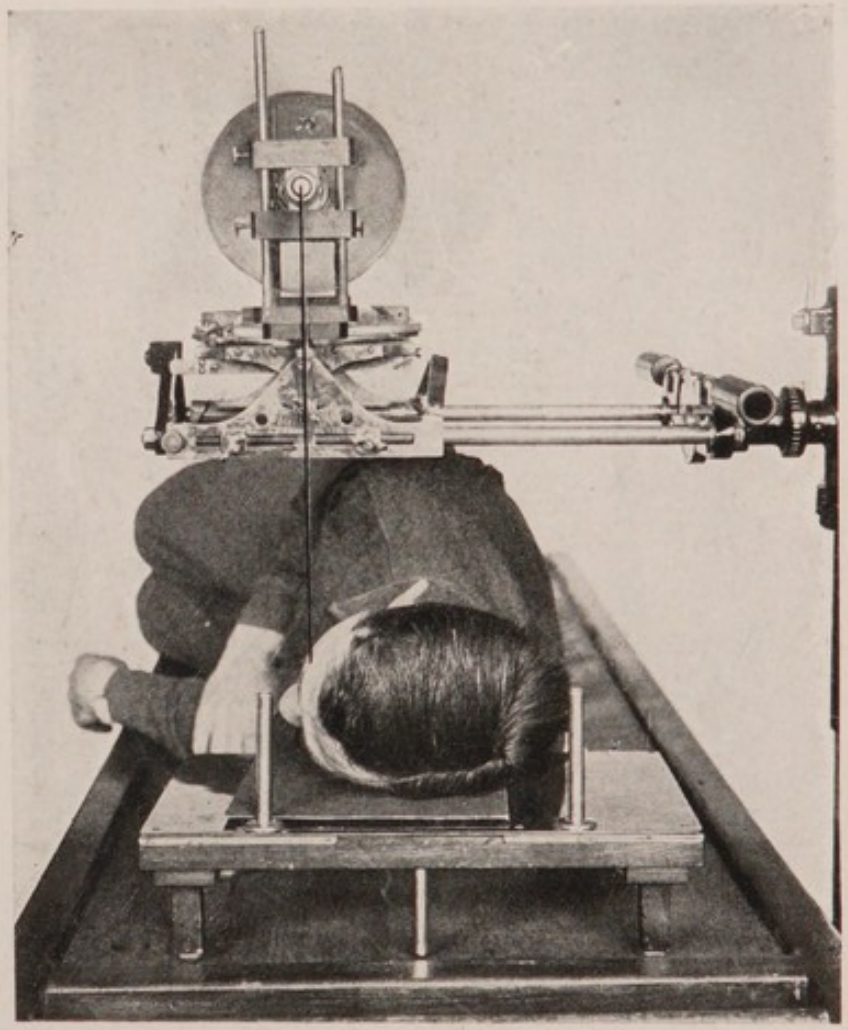
Lateral Films. For lateral films the patient places the side of the head on the platform holder, the head is leveled so that the sagittal plane is parallel to the film and the tube is centered so that the principal ray passes directly through the frontal sinus. This is to obtain a true representation of the depth of the sinus and the thickness of the anterior wall. The head is clamped firmly in place. (Figs. 129 and 130.)

Technique. Without Bucky diaphragm:
Kv. 75. Ma. 10. Distance 25 in. Time 3 sec. Screens.

A lateral view that demonstrates a possible fluid level is made as follows: Place the head in the nose-forehead or nose-chin position; clamp firmly. Place the cassette against the side of the head and direct the ray horizontally, from the opposite side.

Interpretation of Accessory Sinuses. The pneumatic cavities in a normal condition allow the rays to produce





FIGS. 129 and 130. Position for lateral examination of accessory sinuses, head resting on side and central ray passing directly through floor of frontal sinus.

dark areas on the film. When pathological material is present the transparency is reduced, depending on the extent of the involvement.



FIG. 131. Nose-chin position. Normal sinuses.

In the examination of the frontal sinuses a very important factor to be considered is the depth of the sinus and the thickness of the anterior wall, as viewed on the lateral film. A sinus with a thick wall will naturally show less transparency than the same sinus with a thin wall. Hence a sinus with a thin wall and containing granulations or thin pus will cast the same transparency as the same sized sinus

with a thick wall but clear of pathological material. A deep sinus will normally be more transparent than a shallow sinus. One must remember that one or both frontal sinuses

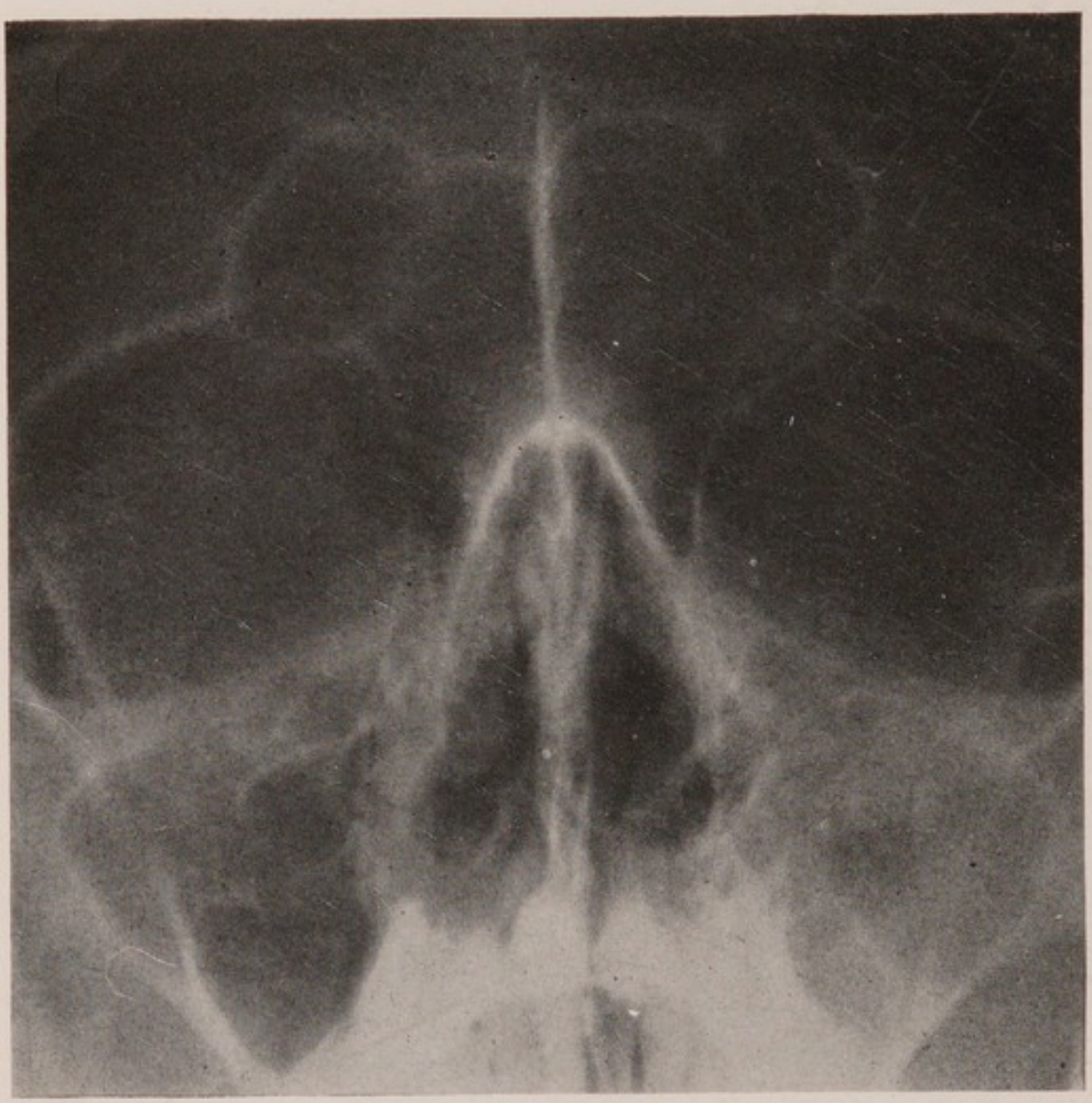


FIG. 132. Involved antrum.

may be absent. In the case of absence of frontal sinuses, the lateral film will reveal solid bony detail in the frontal region, while a single frontal sinus will reveal bony detail through the transparent area of the sinus which is present.

It is impossible to distinguish between the shadow cast by pus or by dense granulations in the sinuses. The diag-

nosis must be made of occlusion of the sinuses by some dense material. The case history will help to a great extent.

The ethmoid region must be studied in both the antero-



FIG. 133. Pan-sinusitis, unilateral.

posterior and lateral positions, the diagnosis resting on the density of the region and the degree of obliteration of the septa. Films made in the vertical position will indicate the affected side and show whether the anterior or posterior cells are involved.

The ethmoid cells are sometimes very extensive and show above, behind and below the orbit. In the examination of

the maxillary antrum the degree of obliteration of the fine lines of the walls determines the amount of involvement, although mucoid material will cause practically no change in the shadow. It may be necessary to puncture the antrum through the nose to clear up the diagnosis between granulations and pus.

The *sphenoid* sinus is located deep in the skull. Attempts to demonstrate it by films placed in the mouth, under the chin, and by oblique views have been successful occasionally. Granger's position is preferable. When the angles are correct the shadow of the sphenoid is cast between the lines *X* and *Y* in Figure 128. A normal sinus casts a dark shadow; an involved sinus is opaque. The shadow of the sphenoid is small; occasionally the lines *X* and *Y* coincide, and no shadow of the sphenoid is demonstrated. The interpretation is made easier by comparison with a series of films taken of normal cases. Whatever the method employed, the interpretation of disease of the sphenoid sinus should be based on changes that are definitely demonstrable.

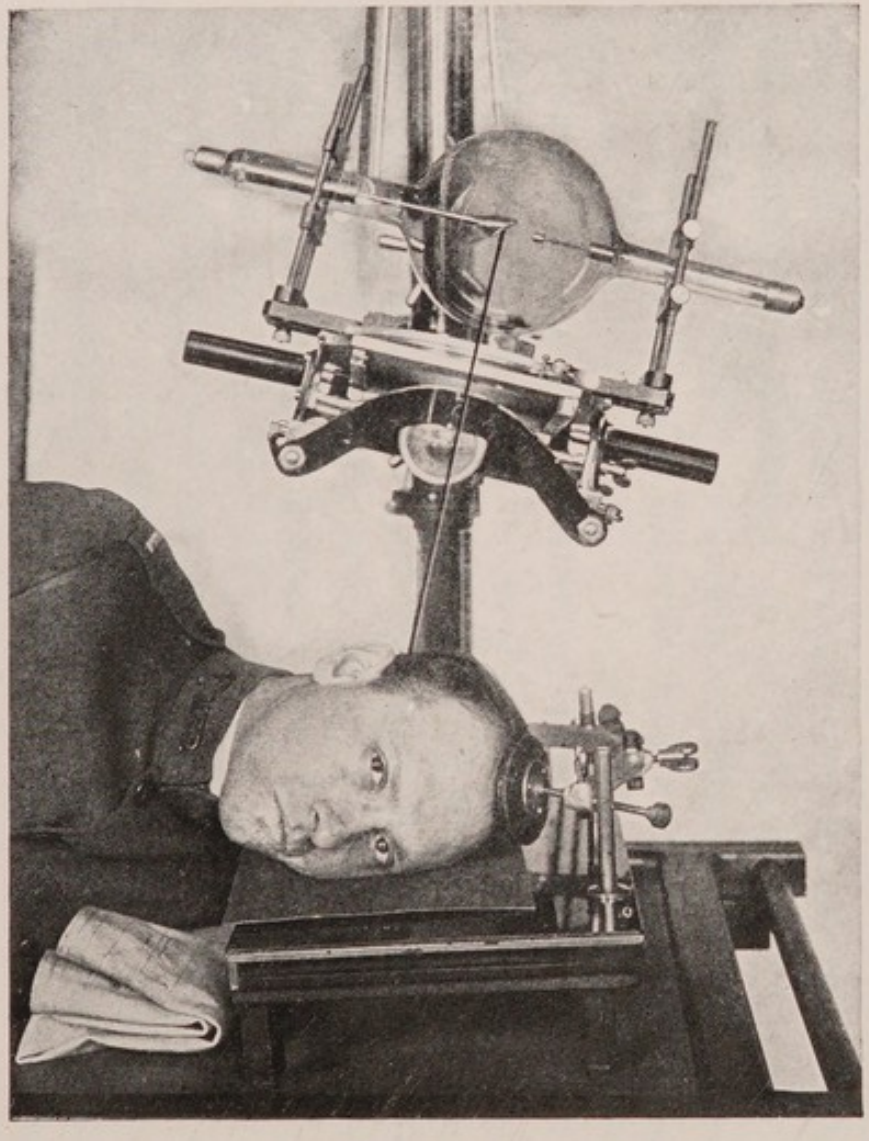
Contrast Injections with Iodized Oil. The ordinary strength of iodized oil (42 per cent iodine) is more opaque than is necessary; the oil may be diluted with two parts of liquid petrolatum or olive oil, reducing the iodine content to one-third. The antrum may be filled as follows: Puncture the antrum with a 16 gauge needle; irrigate; remove the fluid by air pressure if the ostium is open, otherwise by suction; fill with the contrast medium. During evacuation incline the head toward the opposite side; during filling and until the pictures are made, toward the affected side. If the antrum should contain fluid too tenacious for evacuation through a 16 gauge needle, a trocar with a 2 mm. bore must be used; this is not as satisfactory, as the opening is so large the contrast medium may run out before the radiography.

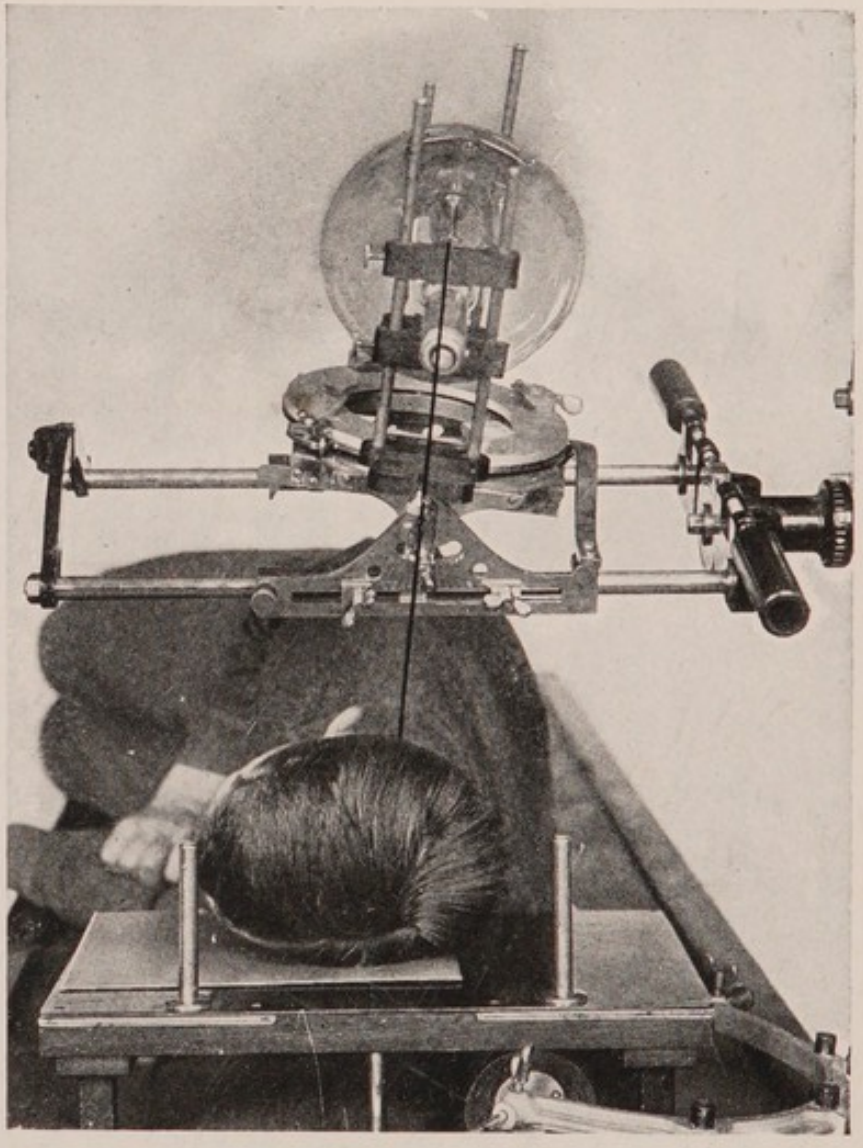
Radiographs should be made in the lateral position, sitting; lateral, recumbent; and lateral in the nose-chin position.

Other sinuses may be filled completely or partially by dropping iodized oil into the nares, the head thrown back and inclined toward the affected side; the patient closes the nares with the fingers, closes the mouth, and attempts to blow, increasing the air pressure in the nose and forcing all fluid that may be in the nasal passages into the sinuses. This method is undesirable as infective material may be forced into uninvolved spaces.

Technique for Mastoids. It is necessary to make an examination of both mastoids. This may be done on one 8 by 10 film, by covering one-half of the film with a thick piece of lead and making one exposure on the uncovered portion, then changing the lead cover to the exposed side and making the second exposure on the side which had previously been covered. It is necessary to compare one mastoid with the other, and placing both on the one film makes comparison of the two sides much easier than if separate films are made.

The patient lies on a table with the head on a small raised platform, the affected ear next to the film with the pinna folded forward. There should be a clamp on the platform with adjustable pads to press on the occiput and forehead, but not so as to obstruct a clear view of the mastoid cells. The head is placed so that the sagittal plane will be parallel to the film. The tube is centered over the head in such a way as to direct the central ray downward and forward toward the opposite ear. An angle of 15° from behind forward toward the face and 15° from above downward toward the feet will in the majority of cases be correct. In case the shape of the head is such that the sagittal plane cannot be placed parallel with the film,





FIGS. 134 and 135. Position for mastoid examination, head resting on side of affected ear, central ray entering head at angle of 15° toward face and 15° toward feet.

without raising the mastoid area above the film, the angle of the tube must be altered to accommodate it. The central ray should enter the head above and behind the external auditory canal, and emerge at the external auditory meatus next to the film.

The tube stand should be supplied with a small cone. Stereoscopic films may be made by shifting and tilting the proper distance on each side of the angle. (Figs. 134 and 135.)

It may be found more convenient to place the head on the angle board, and obtain in this manner the 15° angle toward the feet. The patient lies prone.

Technique. Without Bucky diaphragm:

Kv. 75. Ma. 10. Distance 25 in. Time 5 sec. Screens.

With Bucky diaphragm:

Kv. 85. Ma. 10. Distance 25 in. Time 5 sec. Screens.

Anatomical Landmarks. On a radiograph made by the technique described the landmarks may be identified from Figure 136.

Interpretation. In case the pinna cannot be folded forward, due allowance must be made for the increased density over the mastoid cells caused by the shadow of the pinna. Postauricular edema will cause a haze over the cells, which must not be mistaken for inflammatory exudate. Inspection of the ear before radiographic examination will prevent this error, as allowance may be made for the increased density. Furunculosis in the canal is often accompanied by a slight cloudiness of the cells, which must not be mistaken for exudate.

The mastoid, being a pneumatic cavity, will show normally as a honeycombed structure with the cell partitions clearly outlined, so that the degree of the involvement will be determined by the sharpness of these partitions. A simple congestion or thin fluid will produce a general haze over

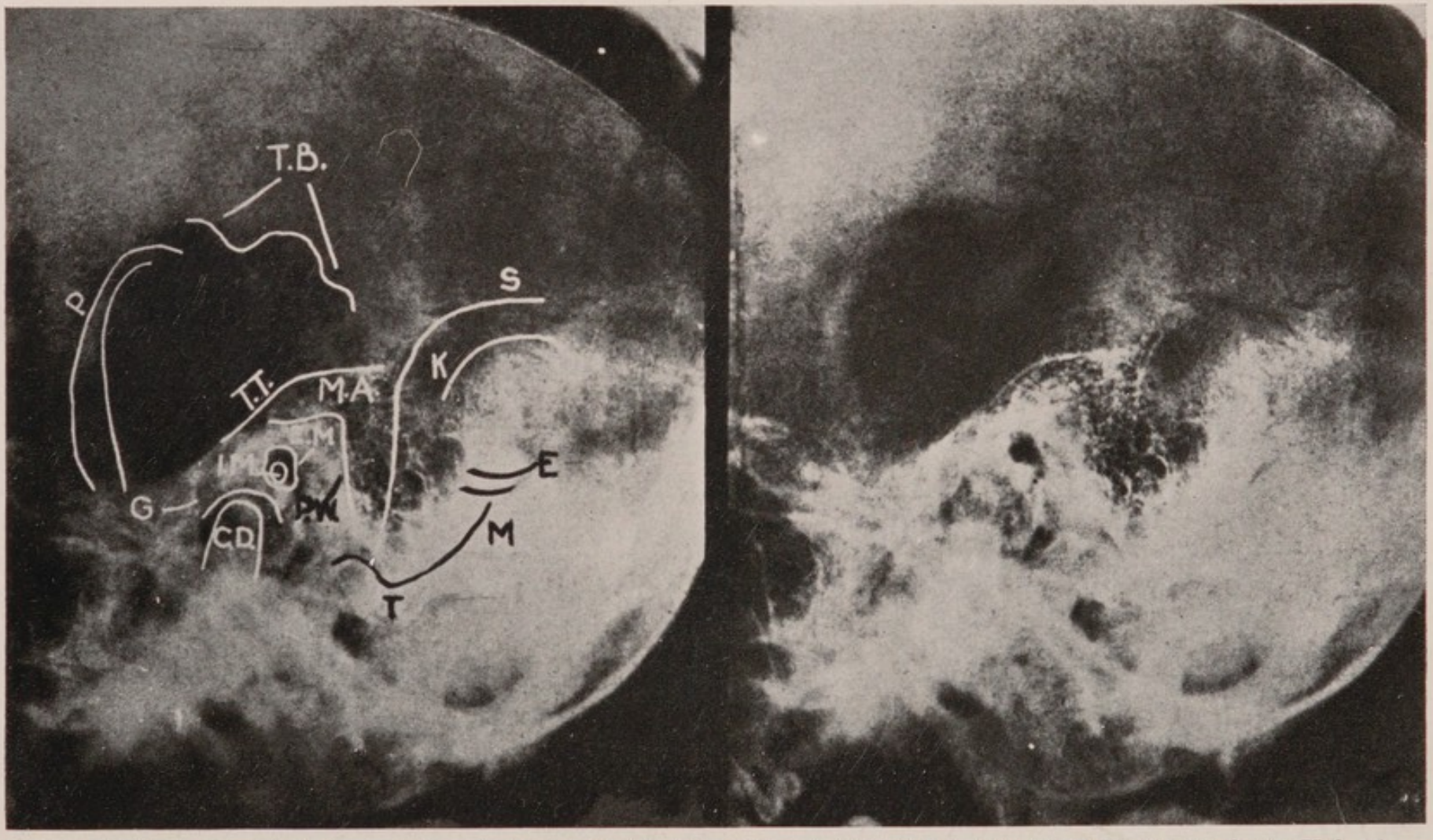


FIG. 136. Anatomical landmarks of the mastoid. (From Law: Mastoid's Annals of Roentgenology, Vol. 1.) *T.B.* The superior limit of the thin portion of the temporal bone. *P.* Pinna. *T.T.* Tegmen tympani. *S.* Anterior wall of sinus groove. *K.* Knee of the sinus. *P.W.* Posterior wall of the auditory canal. *E.* Emissary vein. *M.* Limiting border of mastoid process. *M.A.* Mastoid antrum. *E.M.* External auditory meatus. *I.M.* Internal auditory meatus. *G.* Glenoid fossa. *C.D.* Condyle of jaw. *T.* Mastoid tip.

the mastoid structure, but the cell walls will be clearly outlined. As the disease progresses and pus accumulates, the degree of obliteration of the cell walls will determine the extent of the disease or the amount of pus. If the condition has reached the point of bone destruction the necrotic area will show through the white blur of the cell involvement as a dark area. This usually occurs over the line of the tegmen tympani, representing an epidural abscess, or over and below the knee of the lateral sinus as a perisinus abscess.

This dark area must be distinguished from a large cell in the midst of a group of small cells. This can usually be done by comparison with the opposite mastoid. As a rule the two mastoids are similar in structure. When there is a large or small cell on one side there is usually a corresponding cell on the opposite side. Then, too, a necrotic area will have hazy edges while a clear cell will be sharply outlined.

Complete obliteration of the cell area must be differentiated from sclerosis. This is a condition caused by replacement of the cell structure by dense bone, and the shadow on the film will therefore be structureless. The area resembles the bone in the rest of the skull, with a clear-cut outline of the sinus showing through. This process can be so extensive as to involve the entire area including the region of the antrum, thus showing no detail at any point.

A condition may arise in which necrosis has occurred in the sclerotic area, a cholesteotoma. This will show as a dark spot within the sclerotic area. Usually there is a lighter area in the dark portion which represents a mass of débris in the necrotic cavity.

In the event of a fracture or injury extending through the mastoid structure stereos are necessary. These cases

nearly always show mastoid change due to the presence of blood or infected material.

In the event of the involvement of both mastoids dependence must be placed on the history and clinical evidence.

The size of the cells plays an important part in the prognosis. A large pneumatic mastoid with large antrum cells is more likely to clear up without operation than one with small cells, as the smaller cells are more apt to clog and stop drainage.

Many cases which have been operated upon and have not properly cleared up will reveal cells remaining in the mastoid process. These contain granulations which keep up the discharge and prevent healing.

In the case of children; the mastoid process does not usually develop until about the age of five years, but large dural cells are present which may be affected by middle ear disease. These cells have been found involved in an infant of eight months.

Brain. *Calcifications.* In stereoscopic lateral views small opacities are often seen in the interior of the skull. Of these the most common is a solitary or double opacity 2 to 5 mm. in diameter, located in the midline posterior to and above the sella turcica. This opacity is due to calcification in the pineal gland, and has no known significance. Occasionally there may be a cluster of minute opacities located at the site of the choroid plexus; these are due to calcifications in the plexus and have no significance.

Hypophyseal tumors are enclosed within the sella turcica. They are readily demonstrable as follows: (1) The sella turcica is expanded; the distance between the anterior and the posterior clinoid processes is increased, and the floor of the sella is pushed down into the sphenoid sinus. (2) Bone erosion, demonstrated by definite areas of bone loss. It may be remembered that the size and thickness of

the walls of the sella turcica vary widely between different normal individuals; walls apparently thinner than normal are not evidence of bone erosion. (3) Calcified areas within the tumor are seen occasionally.

Other tumors can only be demonstrated by ventriculography. As an exception, a tumor may contain areas of calcification, which may be demonstrated by ordinary methods. Advanced cases may show evidence of bone erosion in the calvarium.

Ventriculography is the radiographic demonstration of the ventricles by replacing the cerebrospinal fluid with air. Each lateral ventricle is tapped separately through trephine openings. All possible fluid is withdrawn, measured, and replaced by a lesser quantity of air. Withdrawal is fractional, that is, a small amount of fluid is withdrawn, air is admitted, then more fluid is withdrawn and more air admitted; the process is repeated until all the fluid is replaced with air. The amount of air introduced is less than the fluid withdrawn, because the air expands as its temperature rises. It is customary to operate immediately after localization of the tumor by ventriculography, when the result indicates that operation is feasible. When it is decided that the case is not suitable for operation the ventricles are again tapped and the air is withdrawn.

Radiographs are made anteroposterior, posteroanterior, and stereoscopic lateral on each side. In the anterior views the head should be flexed to throw the shadow of the ventricles above the shadow of the frontal sinuses. The lateral radiographs show the air in the ventricles more clearly when the tube is beneath and the cassette above the head.

Cerebrospinal fluid passes into the lateral ventricles by way of the choroid plexus. The fluid passes out of the lateral ventricles by the foramen of Monro to the third ventricle;

by the aqueduct of Sylvius to the fourth ventricle; from the fourth ventricle by the foramen of Magendie and the foramina of Luschka to the subarachnoid space, where it is absorbed by the blood stream. When the circulation of the cerebrospinal fluid is blocked the spaces back of the block are distended.

Interpretation is based on changes in the size, outline and position of the ventricles. Any variation from the normal must be constant in all views.

A tumor in a frontal lobe may obliterate the anterior horn.

A tumor in a cerebral hemisphere may reduce the size and deform the outline of the lateral ventricle on the same side, and may shift its position, usually toward the midline. The opposite ventricle is commonly unaltered in shape, but may be changed in size or location.

A tumor above the tentorium may press upon the third ventricle, obliterating or deforming its shadow, and block the circulation of cerebrospinal fluid, causing internal hydrocephalus. Both lateral ventricles are distended.

A tumor in the posterior fossa may press upon the fourth ventricle, and cause distention of the ventricular system above the fourth ventricle.

Disease may block the foramen of Magendie and the foramina of Luschka, causing internal hydrocephalus and distention of the entire ventricular system.

Encephalography is the radiographic demonstration of the ventricles by replacing the cerebrospinal fluid with air, but in this method the fluid is withdrawn and the air introduced by lumbar puncture. The cerebrospinal fluid is withdrawn and the air introduced by the fractional method, with the patient sitting. The patient maintains the sitting position until after the radiographs are made.

As in ventriculography, the tube and the head must be placed in position carefully, to ensure true shadows, as the

interpretation often depends on the evidence of slight displacement of the ventricles from the midline.

The interpretation is based on the same principles as are established for ventriculography, except that the air is introduced from below instead of from above. When there is a block in the ventricular system the air may not pass by it and demonstrate the ventricles above the block.

CHAPTER X

TEETH AND MAXILLAE

Placing the Film. Observe the following hints in placing the films in the mouth. To prevent gagging, the patient is told to breathe deeply through the mouth while the film is being placed in position. This causes the tongue to be carried far back into the pharynx where it need not be pressed upon. In very troublesome cases spraying the palate and pharynx with camphor water, in addition to the foregoing precaution, adds greatly to the chance of success. Be sure that the film is far enough into the mouth to include all of the root structure. The position of the film should be carefully noted after the patient's thumb or forefinger is in place to hold the film, as the patient's hold may relax as the operator removes his hand. There is no better film holder than the patient's left thumb for the upper teeth on the right side, and the right thumb for those on the left side. The pressure of the thumb must be firm, and the fingers should rest on the opposite side of the face to prevent unintentional motion of the hand. In all instances the operator must mold the film to the contour of the maxillae and denote by the firmness of his own pressure how the patient shall hold it.

For the lower jaw it is absolutely essential that the patient's tongue be completely relaxed in order that the film may be carried back far enough to reach well beyond the third molar, and deep enough to reach well below the apices of the roots. The palmar surface of the index finger of the opposite hand is preferred for holding the films against the lower teeth.

A dental film is enclosed in a light tight and moisture proof envelope. The side that must be placed against the tooth is marked.

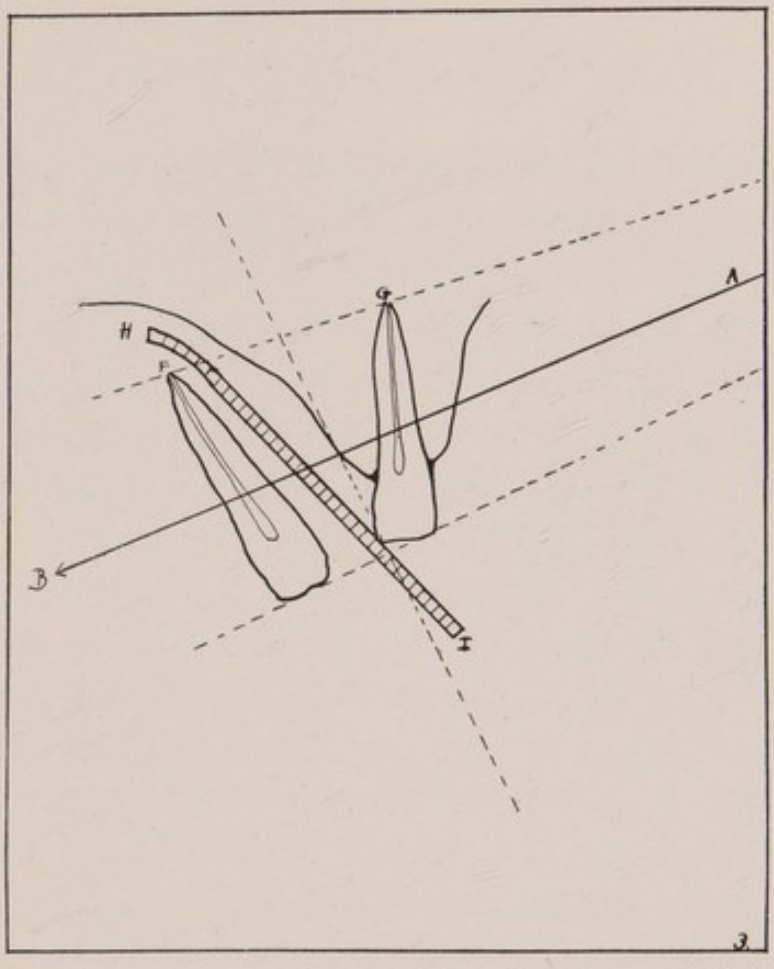


FIG. 137. Film *HI* is nearly flat. Shadow, *F*, of tooth, *G*, is proper size (From Osgood: Teeth and Jaws. Annals of Roentgenology, Vol. v.)

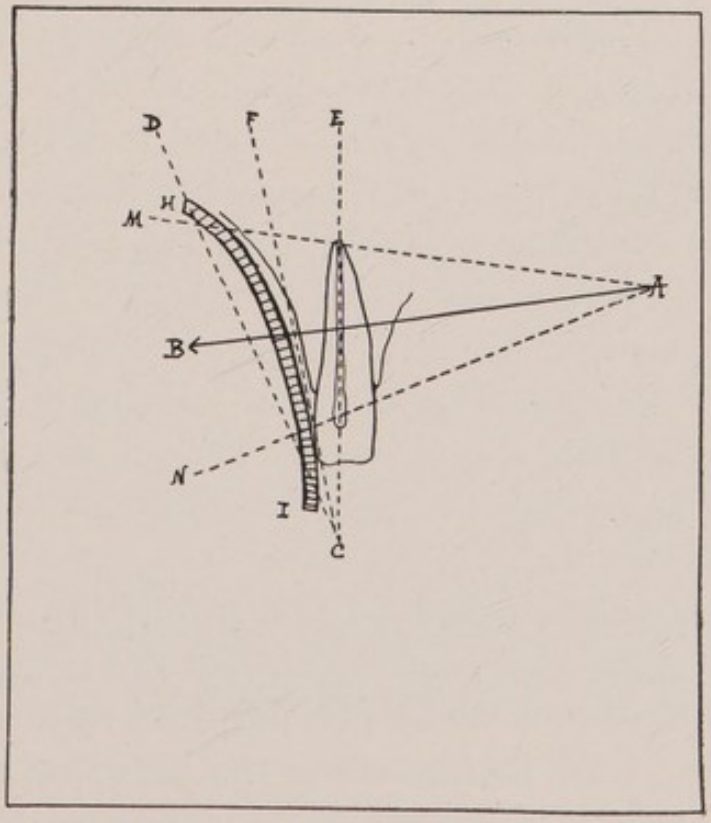


FIG. 138. The film *HI* is pressed against a curved surface. The ray *AB* is perpendicular to the line *FC* bisecting the angle *DCE*. (From Osgood: Teeth and Jaws. Annals of Roentgenology, Vol. v.)

Technique. The tooth shadow should be approximately the same length as the tooth (Fig. 137). Correct shadows are secured when the *x*-ray bisects the angle between the tooth and the film (Fig. 138). The patient should be sitting. The head should remain in a fixed position, as follows: Upper teeth; the head erect, an imaginary line from the lobe of the ear to the nostril horizontal. Lower teeth; the head erect, thrown back slightly so that when the mouth is open the lower jaw is horizontal.

Ordinarily 14 films are required to show a full set of teeth. The position of the tube is changed for each radiograph; four of the positions are shown in Figures 139 to 142.

The *x*-ray film should show the tooth structure, the pericementum, and the bone structure in the alveolus. Unless all three are demonstrated, the *x*-ray film has failed to give the information required.

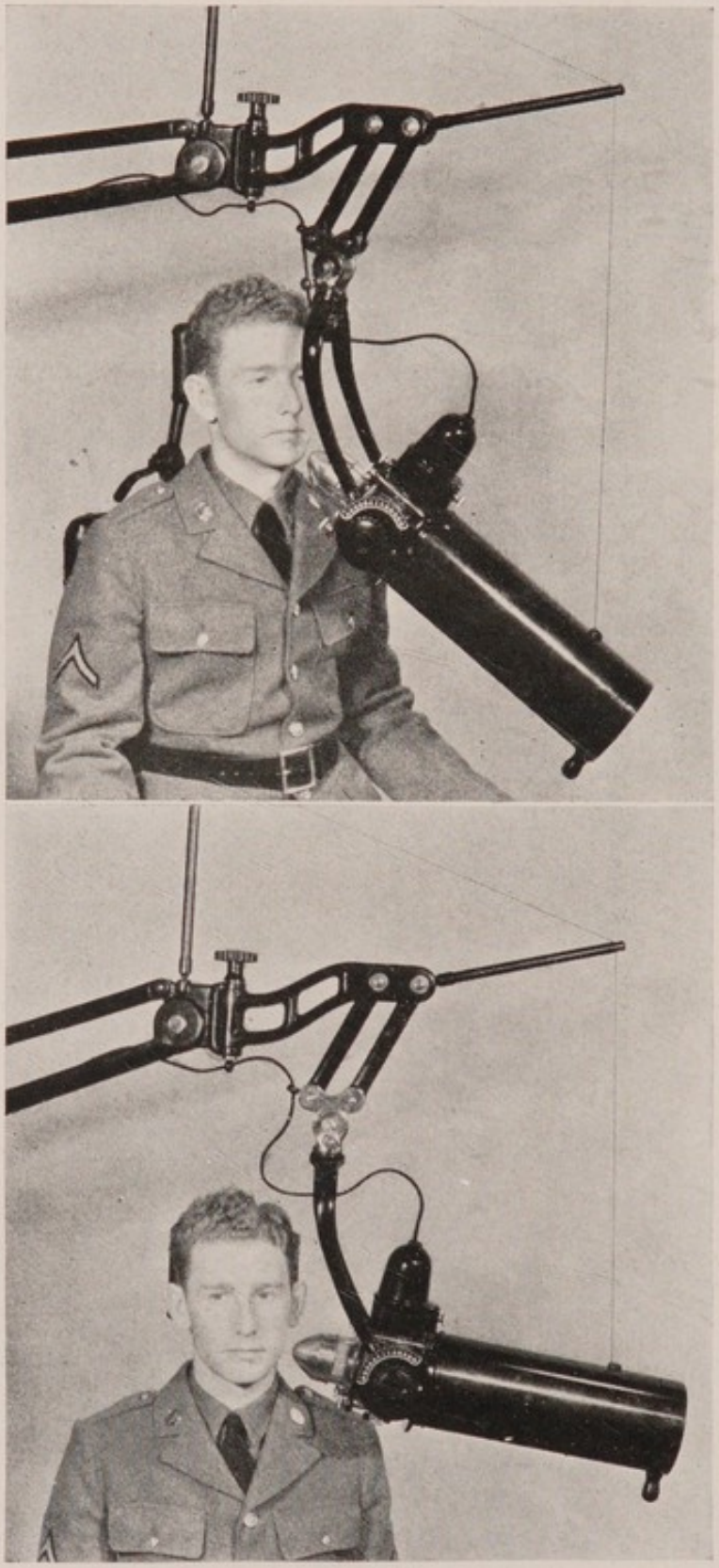
Occlusal Bite Film. In the dark room cut down an *x*-ray film to the desired size; enclose in paper impervious to moisture until light tight. Place in the mouth, and direct the ray as indicated in Figures 143 and 144.

Protection of the Patient. Each end of the tube must be not less than 6 inches from the patient. While the exposure is made the operator should watch the patient, and open the switch if the patient starts to move in the direction of the tube. *X*-ray machines made especially for dental radiography have safety devices, so that the danger of accidental electric shock is minimized or absent. This apparatus varies in type; the instructions of the manufacturer should be followed.

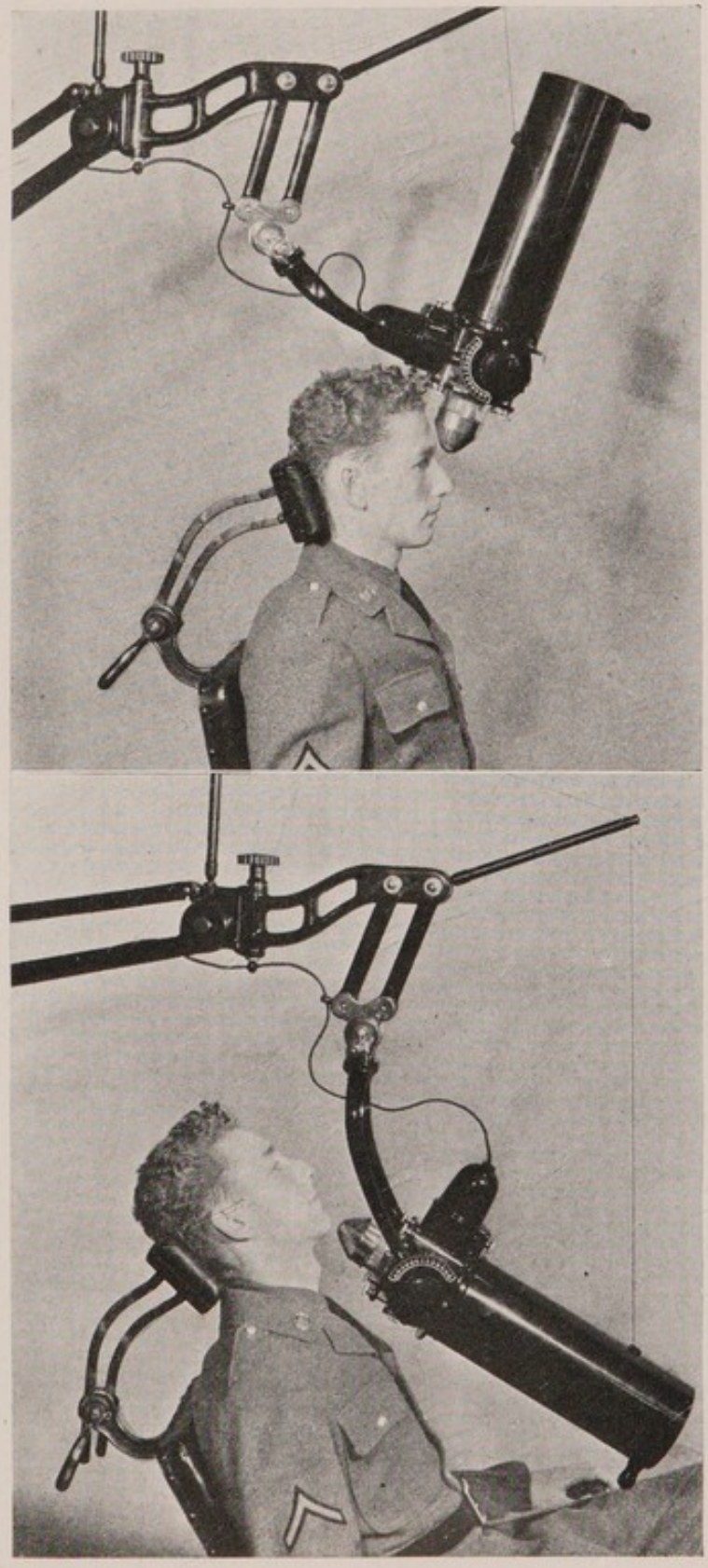
X-ray burns of the face may be avoided by the following rule: the total *x*-ray exposure striking any part of the face should not exceed 7 ma.-min. when the target of the tube is 10 inches from the skin, or 30 ma.-min. when the target of the tube is 20 inches from the skin. A



FIGS. 139 and 140. Two of the positions for films of the upper teeth.



FIGS. 141 and 142. Two of the positions for films of the lower teeth.



FIGS. 143 and 144. Positions for occlusal bite films.



FIG. 145. Normal teeth except for unerupted canine upper right. Note the firm attachment of the teeth to the alveolar process, and also the cancellous structure of the alveolus. The numbers from 1 to 10 show the order in which the films have been exposed. There is slight resorption of the alveolar margin in the lower incisor region.



FIG. 146. Localized areas of destruction of the alveolar margin, or subgingival abscess, second bicuspid upper right, first bicuspid upper left, first molar lower left, canine lower left, second bicuspid and first molar lower right. Hypercementosis of roots of first molar lower left.

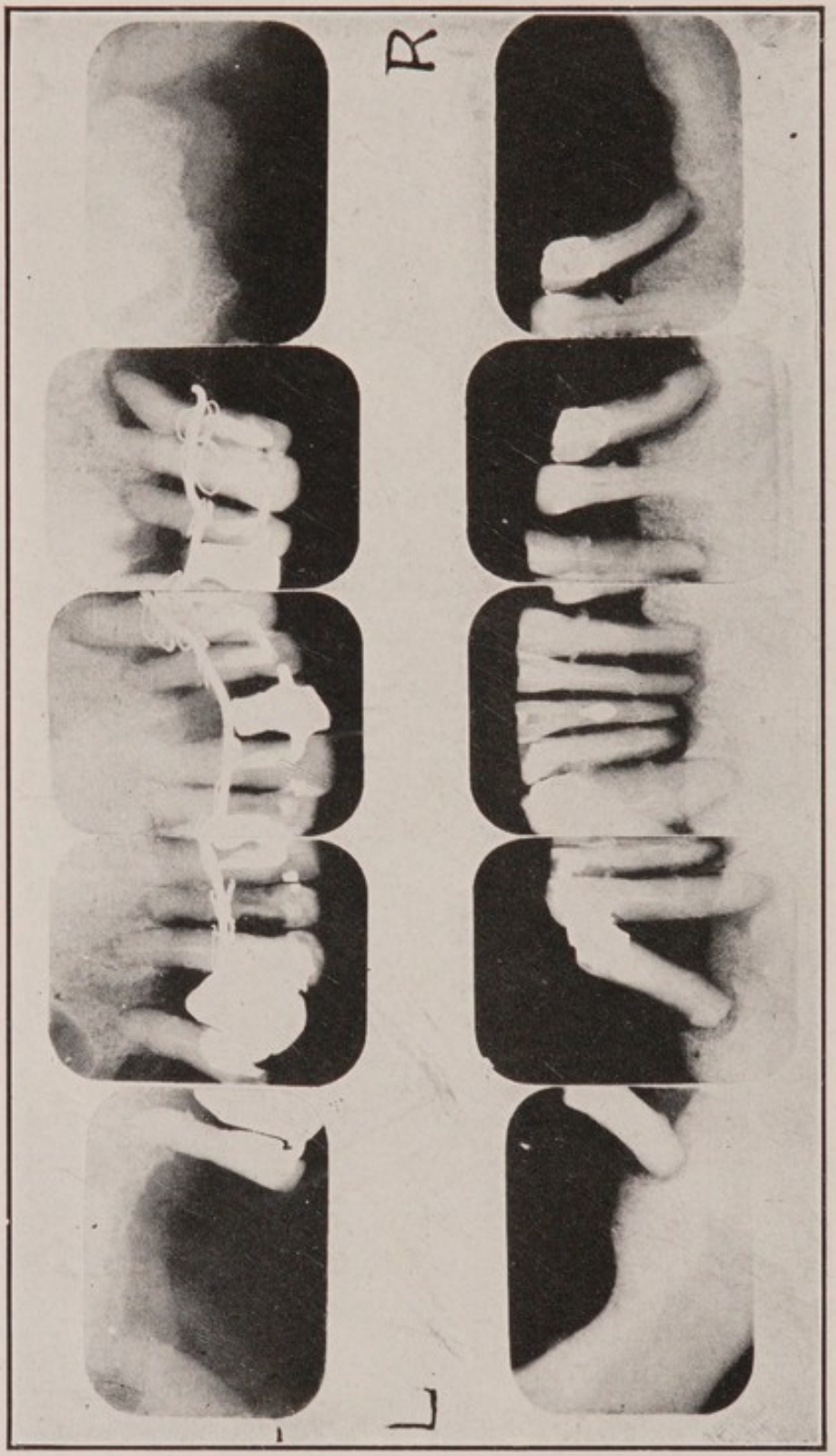


Fig. 147. Advanced pyorrhea.

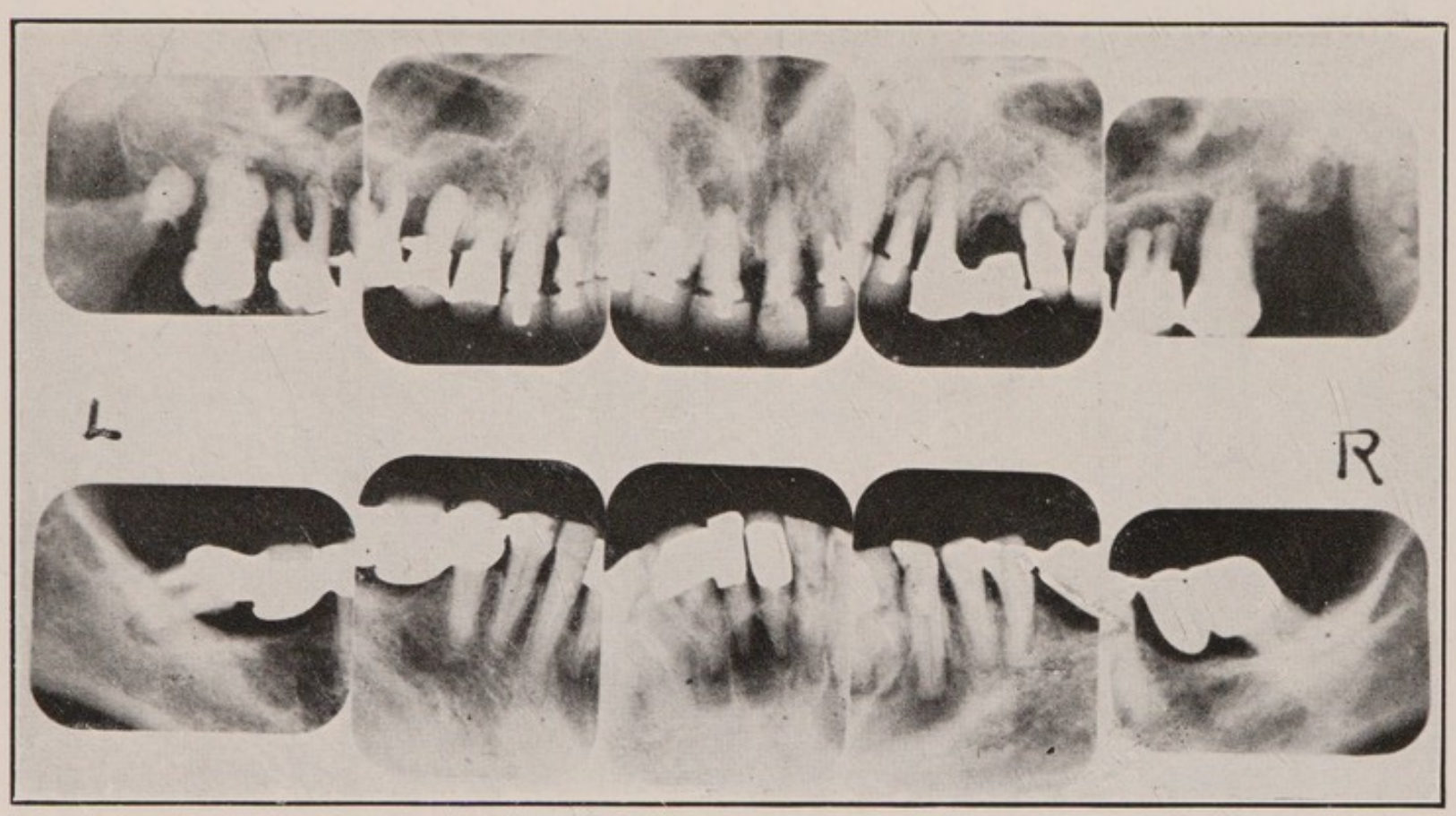


FIG. 148. Multiple chronic apical abscesses, with areas of extensive destruction of the alveolar margin. Unextracted root third molar upper left.

milliampere-minute is the product of the milliamperes through the tube and the time of exposure. For example, 10 ma. of tube current for three seconds is 30 milliampere-seconds, or 0.5 milliampere-minute. The *x*-ray effect on the skin is cumulative, so that if a patient has had an *x*-ray exposure on one day, the effect of the *x*-rays is still present in the skin on the next day, and further exposure is additional. The effect diminishes slowly, and does not disappear for three weeks.

If the patient has had an *x*-ray examination of the sinuses or head, reduce the exposure allowable in the dental laboratory to one-half: to 3.5 ma.-min. at 10 inches, or 15 ma.-min. at 20 inches.

Protection of the Operator. Never hold the film in the mouth during the *x*-ray exposure. If the patient cannot hold the film, and no mechanical device for that purpose is practicable, it is better to forego the *x*-ray examination.

Identify right from left. The observer imagines he is inside the patient's mouth. The films are held with their lingual aspect toward the observer; the patient's right side and the observer's right side are the same. When using single emulsion films the shiny side is the lingual aspect. Double emulsion films have two dull sides; these films are marked by the manufacturer to denote the lingual aspect.

Interpretation. The *x*-ray study of the teeth and maxillae is to be considered from the viewpoint of dentistry without injury, and from the viewpoint of wounds incident to war. The former has more to do with the general health and efficiency of the soldier, while the latter involves the repair and restoration of these parts after injury.

The reader is advised to acquaint himself with the structural and regional anatomy of the teeth and maxillae, and also to study some recognized authority on the pathology of these structures. The accompanying illustrations show practically all of the types of pathological lesions.



FIG. 149. Sarcoma of mandible involving median incisors and left lateral incisor.



FIG. 150. Acute abscess right upper central and lateral incisors. Note that abscess is not sharply defined. Acute abscesses sometimes do not cast definite shadows.

The examination of the films should follow a definite method. One method is as follows:

Place the films in a holder and view in strong transmitted

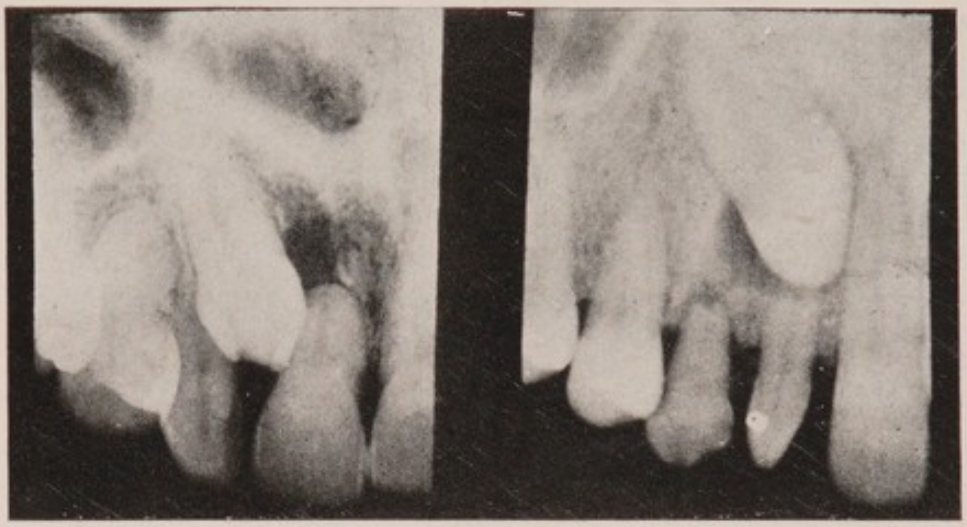


FIG. 151. Abscesses involving unerupted teeth.

light. Examine each tooth by observing:

1. Tooth structure. Note defects indicating cavities, often encountered under fillings. Pulp stone. The presence of filled root canals.

2. Pericementum. Shows as a dark line outlining the root from just below the cervix; beyond the dark line is the white line of compact bone outlining the alveolar socket. Trace these lines completely around each root. If the line is broken, it suggests granuloma or abscess. If the line is uneven or widened, it suggests pericementitis.

3. Bone structure in the alveolus should show clearly. If it does not, a pathological process is present. Especially note bone structure near an apparent break in the pericemental line. If bone structure is blurred, indistinct, then suspicion of granuloma or abscess is confirmed. If bone structure is normal, the apparent break in the pericemental line may be due to pericementitis, but probably is not. Repeat the radiograph of this tooth at differing angles; check against the clinical findings.

Abscess will show changes in the radiograph after sufficient time has elapsed for bone destruction. Depending on the virulence of the infection, this may be days, or weeks. The abscess is shown then as an area of lesser density, and is darker in the radiograph; bone detail is blurred or lost.

Granuloma may show the same changes as abscess, or more commonly, less definite changes. The area occupied by the granuloma may have the same density as bone, but bone detail is lost, and there is always an associated break in the pericemental line.

Confusing Shadows. Normal structures may cast a dark shadow.

The anterior nares may cast a shadow over the upper centrals.

The anterior palatine foramen casts a small, circular, dark shadow above and between the upper centrals.

There is a thin area of bone at the canine fossa, lying above and mesial to the apex of the upper cuspid. As the bone is thin it is more radiotransparent, and the shadow of the alveolus is darker.

The antrum wall is in the form of a more or less distorted W. The middle of the W usually lies between the first and second molars. The shadow of the antrum is often thrown across the roots of the upper bicuspids and molars.

The mental foramen lies opposite the lower bicuspid; it casts a small circular black shadow, with well-defined borders.

The beginning of the inferior dental canal shows as an area of lesser density about ½ inch distal to the last molar. Should the angle of the ray be directed from behind forward, the shadow may be cast on the root of the last molar.

Artefacts. These are three classes:

1. Position. Displacement or distortion of the shadows of normal structures so that they occupy unusual positions on

the film. For example, the anterior palatine foramen is readily recognized in a true picture of the upper centrals; but if the angle of the ray was oblique, the shadow of the foramen may appear opposite the root of a central incisor, and be mistaken for abscess. The coronoid process of the lower jaw has been mistaken for a tooth root.

2. Physical. The curvature of the film may elongate an apex. Cancellous bone detail may be lost by over-exposure, and simulate bone resorption.

3. Developing Errors. Carelessness in the dark room is responsible for most of the failures in radiographic laboratories, dental as well as clinical. A drop of water falling on a film while the film is drying may blur bone detail in a circumscribed area and simulate bone destruction. To eliminate this error view the film by reflected light; the defect is seen on one side only; view the film obliquely, and the surface is seen to be uneven at the site of the water-drop.

Accuracy. A carefully made and properly developed dental film gives information that is definite and accurate. Exceptionally a tooth that shows no abnormality in the *x*-ray film may be the seat of disease.

The Dental Service should make the dental radiographs. The dental surgeon should interpret them in the light of his clinical findings.

Localization. It is frequently necessary to identify the relative position of an impacted cuspid or molar. There are three methods.

1. Occlusal bite film, as already described.

2. Parallax (shift-sketch). Place a film, expose, and identify the film by puncturing through the envelope with a pin. Place a second film in the exact position of the first, shift the tube 2½ inches to the right and expose. Develop, and compare the films. The relative position of two objects

changes as indicated in Figure 152. It will be noted that the object further from the film shifts its position a greater distance, in a direction opposite to the tube shift.

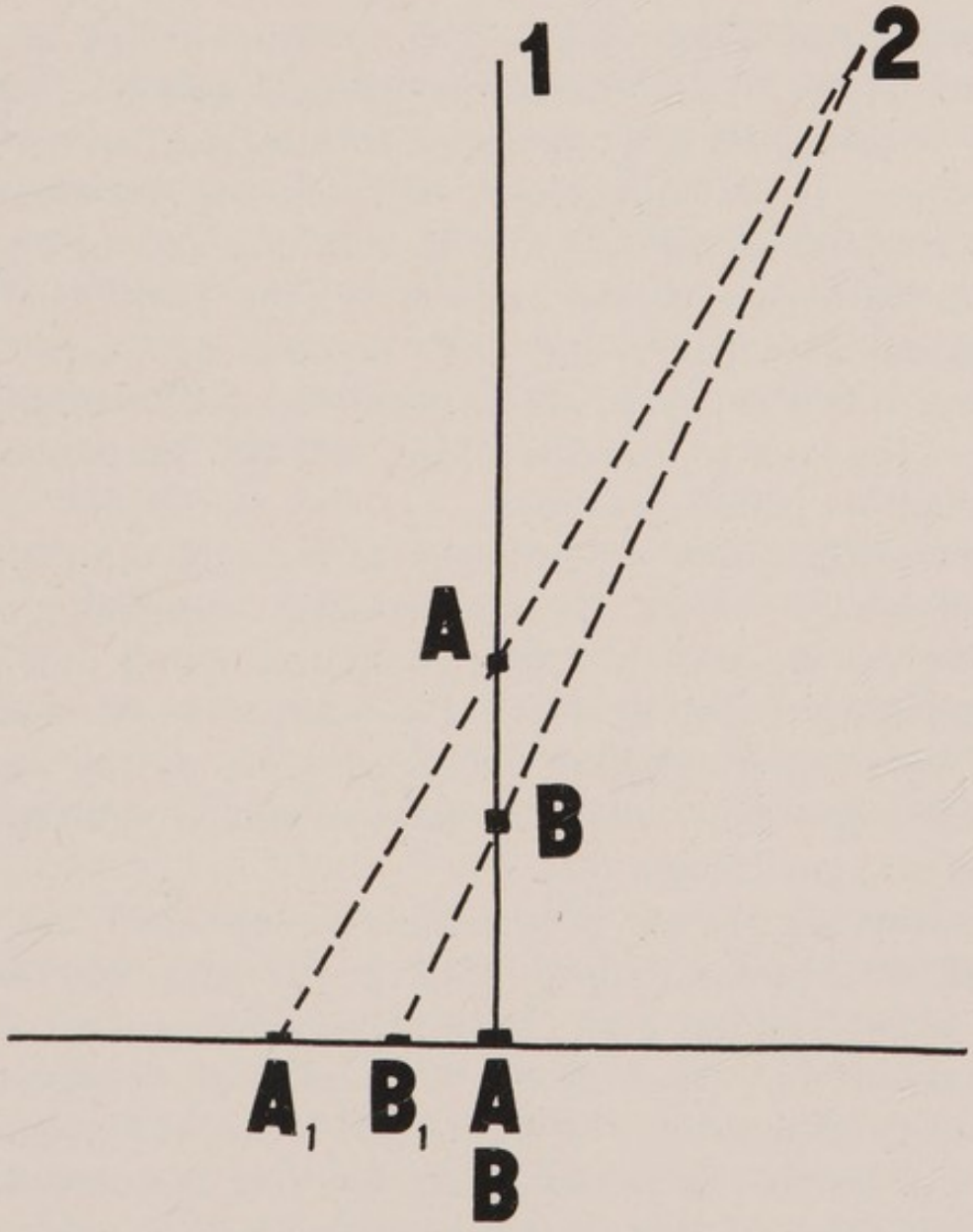


FIG. 152. Parallax (shift-sketch) method of localization.
1. Position of the tube at the first exposure. 2. Position of the tube at the second exposure. *A*, *B*, Objects. A_1 B_1 Shadows of the objects at the second exposure.

3. Stereoscopic. Make two films as described in the parallax method, develop, and place in a stereoscope. When the two films are observed by both eyes in the stereoscope, the picture perceived is in three dimensions.

CHAPTER XI

THORACIC VISCERA

Methods of Examination. The thoracic viscera may be studied either by fluoroscopy or by radiography. Fluoroscopy is useful for a preliminary orientation, to view the movement of the diaphragm, to study the movement of fluid levels in the pleura and in the lung and to observe the mediastinum in the various oblique positions. It is indispensable in the *x*-ray study of heart and aortic conditions. It is of uncertain value in the recognition of infiltration in the lung as in tuberculosis. For this purpose a film examination is indispensable.

Stereoscopic films are of value to indicate the depth of a pulmonary lesion. In tuberculosis, especially, they resolve the shadows into their components and, thus, give a truer idea of the density of the infiltration. Stereoscopy can, however, usually be dispensed with, as the data it furnishes does not materially differ in character from that found in a good single film.

Fluoroscopy is done in a completely darkened and well-ventilated room equipped with an upright fluoroscope. The *x*-ray tube has a fine focus; the power applied to the tube should have a range up to 85 kv. peak voltage and 5 ma. of tube current. The radiologist wears red goggles or remains in the darkened room for ten minutes before beginning fluoroscopy, in order that his eyes may perceive faint changes in shadow.

The patient is examined standing. A rapid survey of the entire chest with the diaphragm of the fluoroscope wide open discloses the general nature of the problem. The diaphragm is then closed to a small aperture and each lung is inspected from above downward. The aperture is changed to a horizontal slit and the movements of the diaphragm are

studied, the two sides observed simultaneously for comparison. The aperture is changed to a vertical slit and the mediastinum is examined, first in one and then in the other oblique position.

Any variation from the normal is then re-studied at different phases of respiration, at differing angles, and if indicated, by changes in posture. The position that best demonstrates a pathological change is noted.

A protracted study of the chest might incur the risk of undue exposure to radiation (p. 104). The fluoroscopic study is a moving picture of functioning organs, but not an exposition of the finer detail; the interpretation is based mainly on radiographs.

The radiograph must be made with careful and uniform technique (see p. 149). The interpretation of the film is frequently based on minor changes in line or shadow that must be shown so clearly that no doubt may exist as to their presence; in no other department of radiology is there so much temptation to read into the film changes that are not there.

Anatomy. The following brief summary may conveniently recall the salient points of interest.

The alveoli open into thin-walled spaces, the atria, and these again open into a ductulus alveolaris. This communicates with one of the terminal branches of the bronchi. The assembly of a single ductulus alveolaris, the atria budding from it, and the alveoli opening from the atria, comprises one histological unit, called a primary lobule. (Fig. 153.) The size of a primary lobule is microscopical.

The lung is built up of the primary lobules, held in position mostly by sheets of connective tissue which cross and intersect at many angles. Toward the periphery the connective tissue framework resembles a number of irregular pyramids, their bases directed toward the pleura. Each encloses from 50 to 200 primary lobules. The pyramids are visible when the cut surface of the lung is viewed at



FIG. 153. Scheme of primary lobule with its blood vessels and lymphatics. *B*, pleura; *Br.*, bronchiolus respiratorius which divides into two ductuli alveolares (*d.al.*), only one of which is carried out in detail; *a.a.a.*, three atria, each having a number of sacculi alveolares (*s.al.*) opening into it, around periphery of which are alveoli pulmonis (*c*). Alveoli are also connected with bronchiolus respiratorius, ductulus alveolaris and atria. *A*, pulmonary artery which divides into three atrial branches and each atrial branch into branches distributed to sacculi alveolares; latter branches give origin to capillary network in walls of air spaces. *L*, lymphatics; *V*, pulmonary vein and its branches of origin; 1, 2, 3, 4, 5, key points at which lymphoid deposits occur. Bronchial artery does not extend as far as primary lobule. (After Miller, from Sante: The Chest. Annals of Roentgenology, Vol. XI.)

autopsy, and have been called anatomical lobules. The connective tissue septa subdivide the entire lung, as well as the periphery, and are important as they tend to restrict the

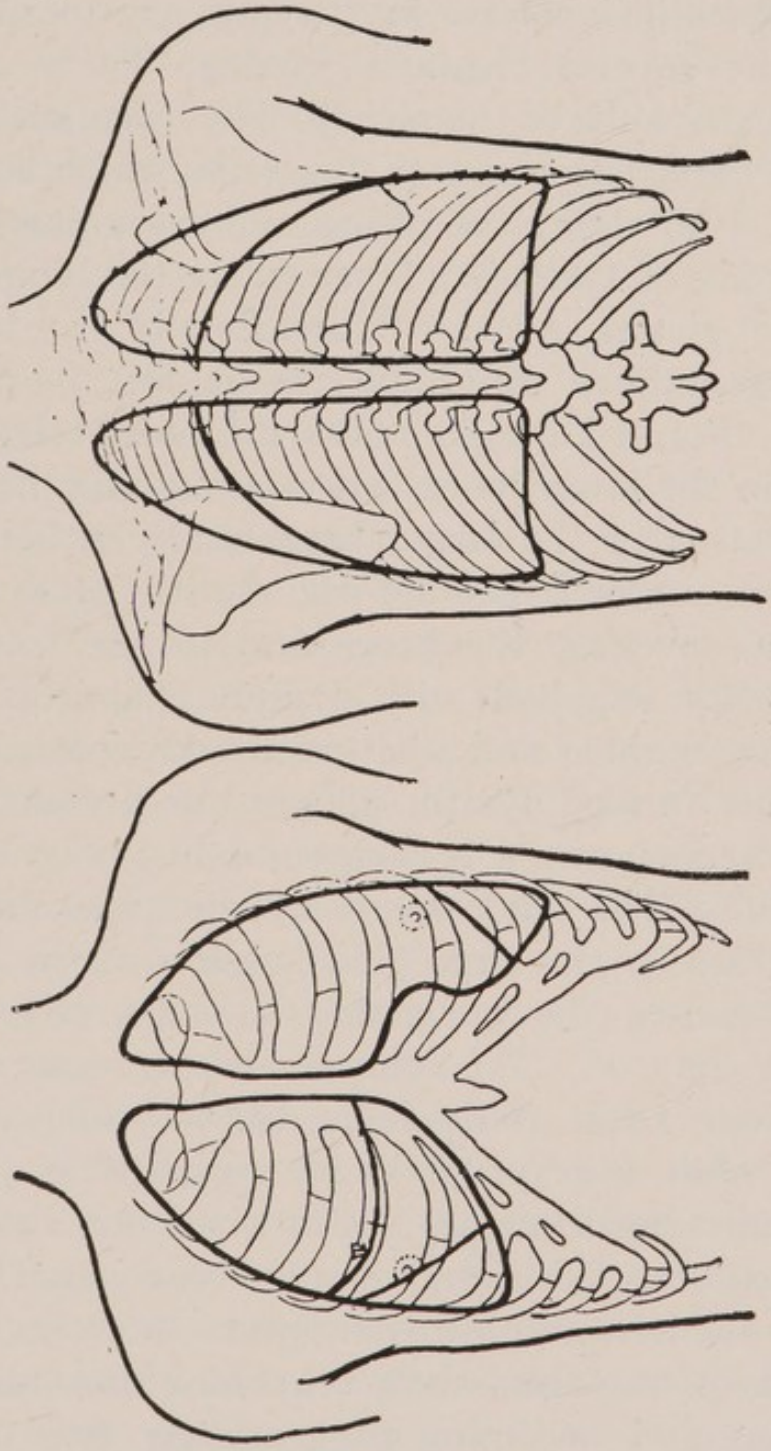


FIG. 154. Diagram illustrating position of interlobar septa. Position of these septa is very important in localizing pathology in various lobes. Anterior and posterior views. (From Sante: The Chest. Annals of Roentgenology, Vol. XI.)

progress of some forms of disease, such as tuberculosis.

The blood vessels of both circulatory systems follow the bronchi closely, throughout all the subdivisions.

The lymph channels accompany the blood vessels, as they do elsewhere in the body; there are additional channels in the walls of the bronchi. They reach as far as the distal end of the ductuli alveolares in the primary lobule, and there end, the several channels joining. There are no lymphatics in the walls of the alveoli. The direction of flow is toward the hilus, except for that portion which lies close to the pleura. Underlying the pleura and extending inward to a depth of about 1 cm. is a layer where the lymph flow is toward the pleura. At the bifurcation of the bronchi there are aggregations of lymph tissue, but no formed lymph nodes. Formed lymph nodes are absent from the lung, except in the lower lobes, where a few may be found at the bifurcation of the larger bronchi. Even here they are seldom encountered beyond the fourth subdivisions.

The pleura covering the lungs and in the interlobar fissures is richly supplied with lymph channels; nodes occur, but their number and position are not constant.

At the hilus formed lymph glands are present; their number is not constant nor is their combined mass similar, in normal adults. The shadow cast by the nodes added to the shadows cast by the large blood vessels at the root of the lung comprises the conglomerate mass referred to as the "hilus shadow." The comparative size and density among different adult individuals varies widely within the limit of what may properly be regarded as normal. In a given individual changes in size with time are of the utmost importance. The right hilus is less covered by the heart than is the left, and always appears to be the larger.

Radiographs of the chest show branching lines radiating from the hilus and becoming progressively finer toward the periphery. These lines are the shadows of the pulmonary blood vessels which follow closely the course of the bronchi. As the bronchus is an air-filled tube, it cannot cast a shadow unless caught end on, and then as a perfectly circumscribed

ring. Because of the close association between the blood vessels and the bronchi, these shadows have been called "bronchial markings," a misleading term that has gained acceptance in usage by reason of the appearance of the cut surface of an autopsied lung, where the rigid bronchi are better seen than the collapsed blood vessels. While lymphatic channels accompany the blood vessels, they are too narrow to add materially to the width of the shadows. The thickness of the linear markings largely depends on the state of the blood channels. Thus if the patient is erect the markings in the lower lobes are heavy, as the dependent blood channels distend; in the upper lobes they are narrow and finely circumscribed, as the blood drains from those vessels readily. When the patient is supine or prone, the distinction between the size of the shadows of the lower and upper lobes is not as great. When the patient is placed on his side, the dependent side is engorged, and the upper side drains readily; all the lines in the lower lung are thick, in the upper lung narrow. As age advances, blood vessels sclerose and become larger; the thickened vessel wall no longer diminishes its caliber readily. So in the aged, the linear markings are everywhere more noticeable, and those of the upper and lower lobes tend to approximate in size.

Types of X-ray Chest Films. No two chest films, even of normal individuals, are alike. Many different physical conditions are imposed by the conformation of the chest and all may be within normal limits. Variations in the technique of the examination may give unusual appearances that must not be mistaken for abnormalities. It is therefore necessary, in deciding whether the shadows on the film are due to pathological lung conditions, to take into account these normal variations. Failure to do this accounts for most of the disagreement among radiologists in the interpretation. It is not possible to describe adequately the

characteristics of the normal. They must be seen and studied. The following suggestions are made.

The Healthy Lung. There is, strictly speaking, no such thing as a normal or typical lung film. The size, shape and graphic appearance of the lung fields vary with the age of the individual, the shape of the thorax and with previous pulmonary disease. As far as the *x*-ray is concerned the lungs consist, on the one hand, of the great mass of air-containing vesicles and, on the other, of a network of bronchi, blood vessels and lymphatics. The former do not cast any shadows and are responsible for the aerated lung fields. The latter intercept the ray and produce a shadowy network throughout the lung radiating from the root, decreasing in distinctness and width toward the periphery where they are barely visible. It is the difference in the prominence of these markings in different individuals, or even in the same individual when the technique is varied, that gives rise to diverse types of normal chest films.

Localization of the bronchi is not generally possible and such a localization is probably of little importance.

Localization of the lobes of the lungs has a greater value and is to a certain extent feasible. A knowledge of the topographical anatomy of the fissures is essential. On the left side the fissure between the upper and the lower lobes begins behind at the level of the third dorsal vertebra, extends obliquely down to the axilla and then almost transversely across the chest to the sternal end of the sixth costal cartilage. On the right side the upper interlobar fissure runs across the chest to the sternal end of the fourth cartilage. By means of these landmarks it is to a certain extent possible to refer shadows to individual lobes. This must, however, be done with caution because, in the middle area of the lung, the lobes overlap. To localize shadows in this region, stereoscopic examination and the lateral positions

are of value. In a fair proportion of cases the right interlobar fissure is sharply outlined due to pleural thickening, thus serving as a guide in this region.

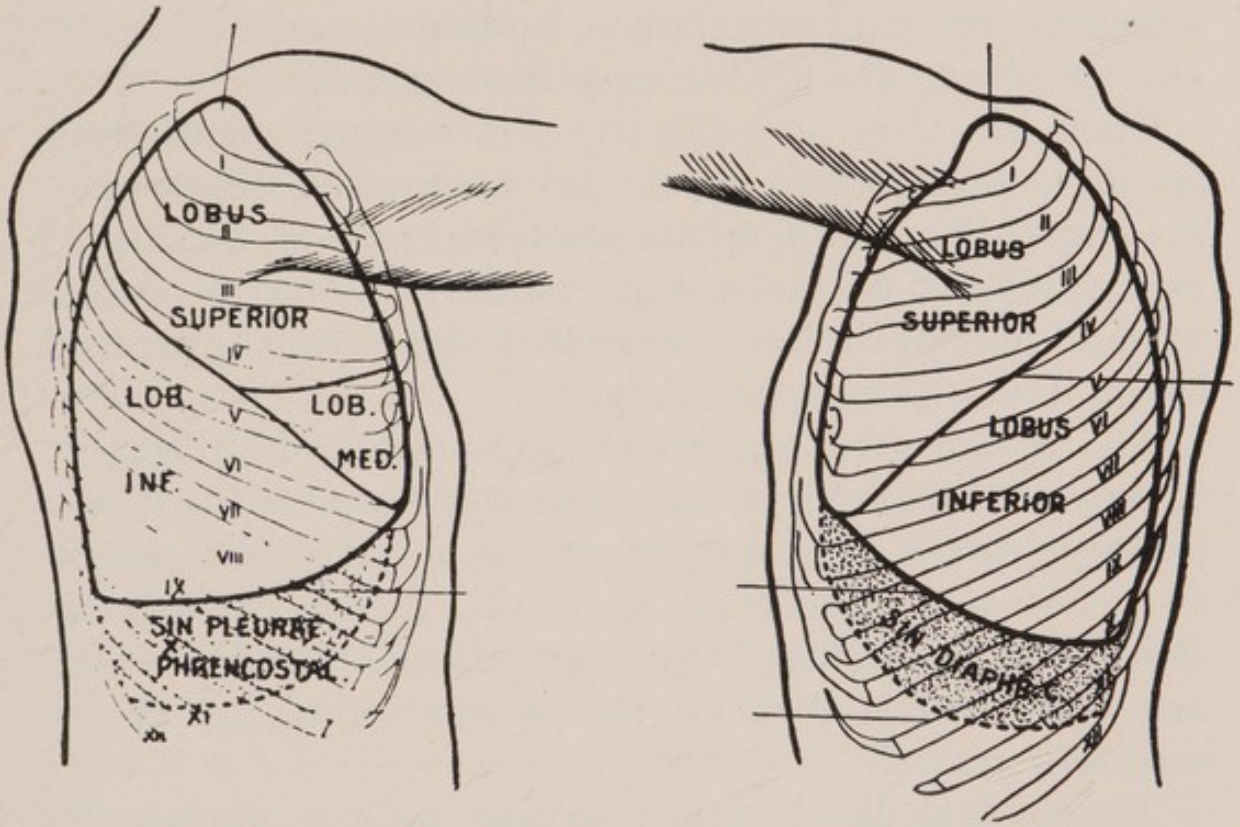


FIG. 155. Diagram illustrating the position of the interlobar fissures, lateral views. (After Assmann from Sante: The Chest. Annals of Roentgenology, Vol. XI.)

An azygos lobe is occasionally present; on the right side a fine white line curves upward and outward from a point opposite the upper pole of the hilus to the apex.

The *hilum or root* of the lung shows as an ill-defined mass of shadows which are produced by the blood vessels, large bronchi and lymph nodes near the mediastinum. It is irregular in shape and varies considerably in size and density, depending upon the age of the individual and previous respiratory infections. Here again there is no normal type. Usually the shadow does not extend laterally more than an inch beyond the spine and is of moderate

density. However, in estimating the significance of the hilum shadows it should be remembered that in nearly all adults pathological changes have occurred. Thus the bronchial nodes, as a result of infection, tuberculous or otherwise, are usually enlarged, indurated and calcareous, and the tissues about them may be thickened.

They are only an evidence of the usual adenopathy found in adults, and should be disregarded unless they are very marked. The hilum shadows are more prominent in the aged and in cases of emphysema. If the heart is median in position or hypoplastic, more of the hilum will be exposed and will, therefore, appear larger.

The *trachea* takes an almost median course through the upper mediastinum and bifurcates at the level of the fourth dorsal vertebra. It is usually well seen and a deviation in its course or a constriction are readily noted. The bifurcation and the outlines of the larger branches of the bronchi are often visible through the denser structures of the mediastinum.

The shadows cast by female breasts and pectoral muscles should be noted, and inferences as to the aeration of the lungs must not be drawn from a wrong interpretation of them. The same is true of the scapula, the shadow of which overlaps the axillary portion of the chest if the arms are not brought forward or rotated inward during the examination. The upper limit of the apex of the lung is usually at the level of the lower border of the second rib posteriorly. If for any reason the apex is depressed, as in cases of chronic tuberculosis, a shadow may be seen just below and parallel to this rib.

Previous diseases leave their mark. An old pneumonia, clinically cured, may leave localized patches of fibrous tissue —merely a tracery, but enough to distort the normal course of the blood vessels in the lung septa. An old and completely

healed tuberculous infection may leave behind one or more calcareous nodules, a silent reminder that disease has formerly been present. The pleura at the base may be adherent from an old and healed process, restricting the excursion of the dome of the diaphragm. Such changes cannot be considered as disease, as they do not affect the life of the individual.

The right dome of the diaphragm is usually higher than the left, the average difference being 1.5 cm. The curve of the upper surface is ordinarily smooth, but may be wavy. The wavy curve is due to unequal levels of attachment, and is not evidence of any pathological process.

Certainly no inference should be drawn from slight alterations in the normal structure unless the entire history of the patient is known to the examiner; and then only with the greatest caution.

Reliability of Conclusions Drawn from a Chest Film. A radiograph of the chest is a picture of the morbid processes in the lungs. It is comparable with a post mortem examination, except that the examiner is deprived of the sense of touch, of resistance, and of color. In many instances a disease is so well marked, its features so definite and characteristic that any skilled pathologist could venture a diagnosis on merely viewing the cut surface of the lung. Similarly the radiologist can draw positive inferences when the case under consideration is average, well marked, and definite. But just as the pathologist would refuse an opinion on any but the most definite case, so the radiologist should confine himself to indicating a number of possibilities, and leave any decision to a conference between himself and the clinician. Taken in this way, as a means of securing information, and not as a direct and exclusive method of diagnosis, the *x*-ray film of the chest surpasses all other clinical methods in value.

An opinion should be expressed clearly and in unmistakable language. Particularly apt are the well-known words of Montaigne: "There is more ado to interpret interpretations than to interpret things themselves." It is not enough for the radiologist to describe the shadows, even in meticulous terms. It is not sufficient for the clinician to himself view the film and draw his own conclusions. The radiologist and the clinician must have perfect team work, each contributing his knowledge. It is as unjust to expect the physician to evaluate the importance of shadows, and differentiate them from the normal, as it is to expect the radiologist to establish the diagnosis without the history or physical examination. Inasmuch as the majority of cases follow well-defined and characteristic lines, the necessity for such a conference is not frequent. The unusual or aberrant case may require repeated examinations, protracted observation, and many consultations before a decision is formulated.

Tuberculosis has a characteristic appearance, but no single typical picture. The interpretation of a condition from a radiograph as definitely or probably tuberculous depends upon logical deduction from all the evidence at hand, and not upon a comparison between the radiograph on the view box and other similar pictures that resemble it more or less closely. Fortunately the pathological changes in the lungs show clearly in comparison with the air-filled spaces that surround them.

As is well known, the typical tuberculous nodule is built up from a number of microscopical tubercles, each surrounded by its zone of exudative reaction, forming an asymmetrical, conglomerate mass from 2 to 20 mm. in diameter. Usually it is the exudate that casts the shadow. The exudative zone varies in width, in demarcation, and in density depending on the degree of the reaction. Thus if

the disease is limited in extent and in virulence the nodules are discrete, definite, and clearly seen. But if the infection is massive or virulent the zone of reaction may be extensive, with no trace of its nodular points of origin: or if the nodules are closely set, neighboring zones may overlap to form a confluent mass. This relation between exudate and virulence is so close that it has been considered evidence for or against activity; as evidence it is not as reliable as other sources of information, secured clinically.

There are many conditions that may cause the appearance of small opacities in the lungs, but tuberculosis has certain features that are characteristic when considered together, and in the sequence of their development.

Calcium salt deposit changes the appearance of a nodule from a gray shadow to white. It is evidence that the particular nodule is healing, but is not proof that the nodule is completely and permanently healed. The amount of calcium salt deposit varies from a slight change where the process is beginning, to the dense clear white shadow of the "lung stone."

Cavities. Some nodules caseate at their center. The density remains the same as before, and the shadow cast is not altered unless further changes occur. But if the caseated mass is liquefied by the action of pyogenic or tubercle bacteria, it usually opens into a bronchus. The liquid mass is expelled and a cavity is formed. Air enters the cavity; as the air is radiotransparent and the walls of the cavity are opaque, a definite shadow is cast on the film. The cavity shows as a dark space completely surrounded by a white shadow that is elliptical or circular. Surrounding the white line is a narrow band of increased density, irregular in contour, representing tuberculous granulation tissue and fibrous tissue. Surrounding this again is a zone of lesser density fading out toward the surrounding lung,

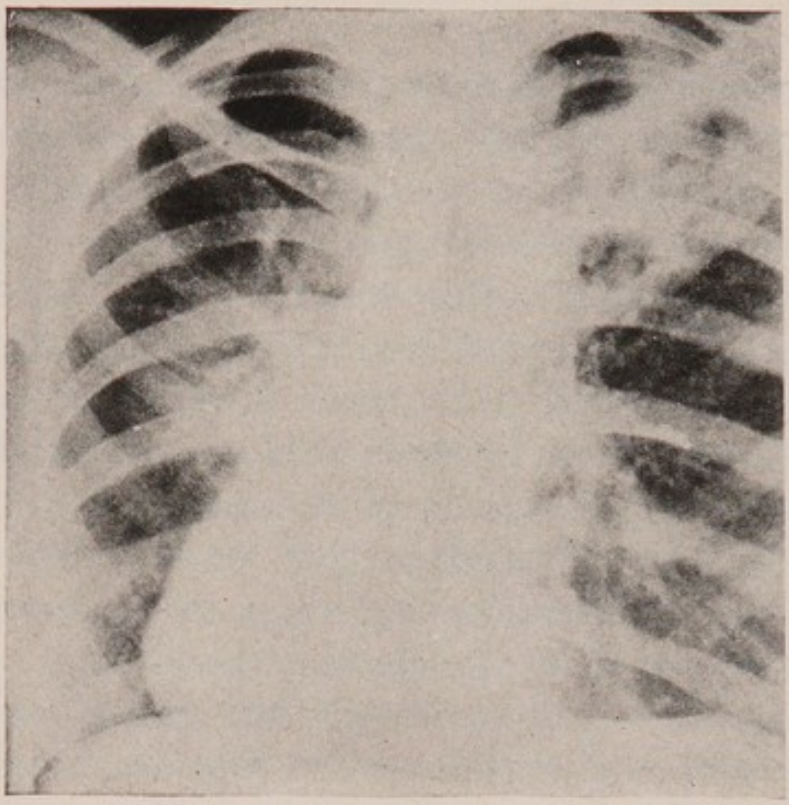


FIG. 156. Pulmonary tuberculosis. (From Sante: The Chest. Annals of Roentgenology, Vol. XI.)

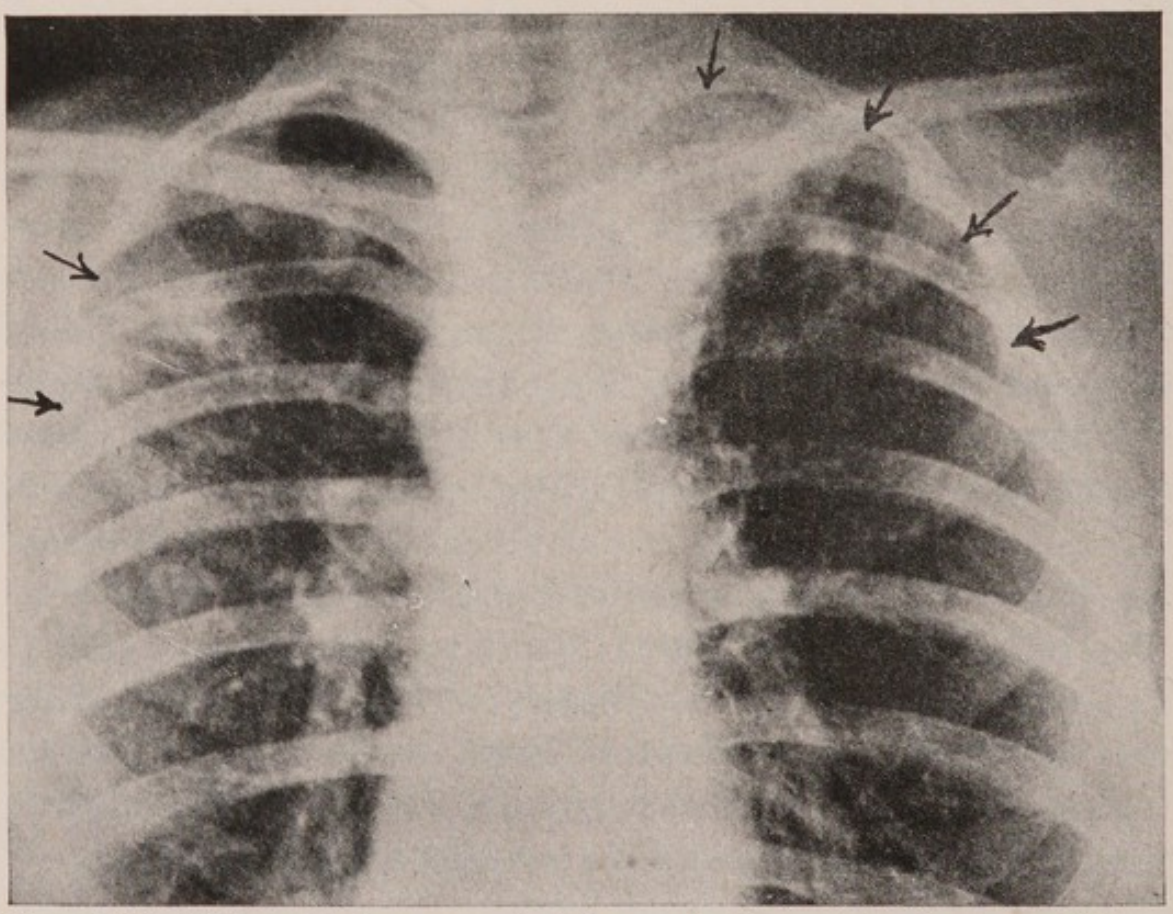


FIG. 157. Tuberculosis, somewhat beyond the minimal stage. (From Sante: The Chest. Annals of Roentgenology, Vol. XI.)

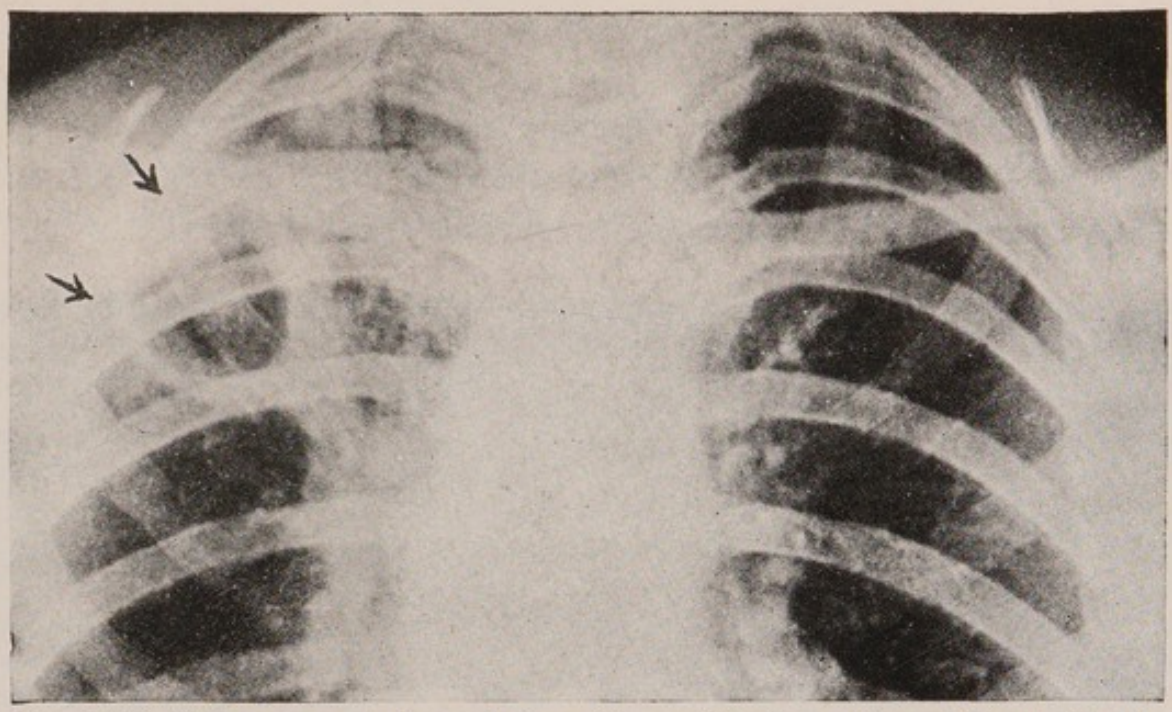


FIG. 158. Pulmonary tuberculosis with cavity formation. (From Sante: The Chest. Annals of Roentgenology, Vol. XI.)

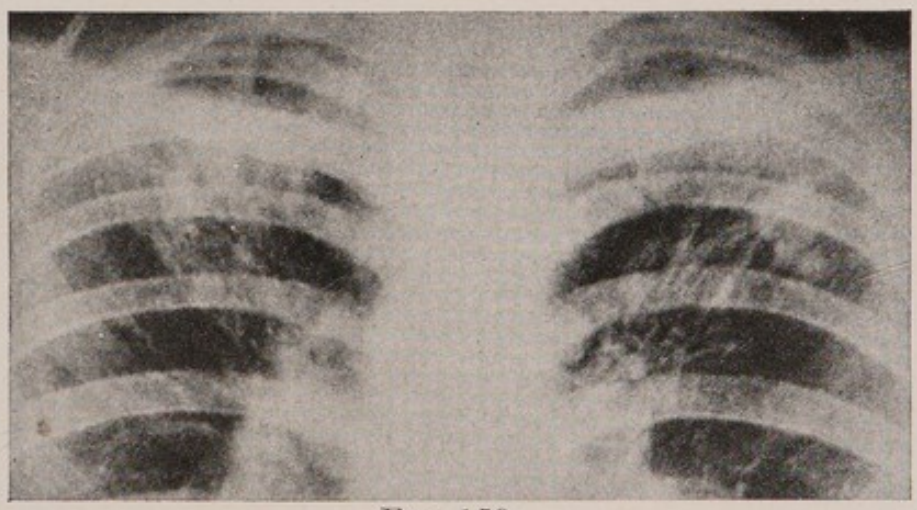


FIG. 159.

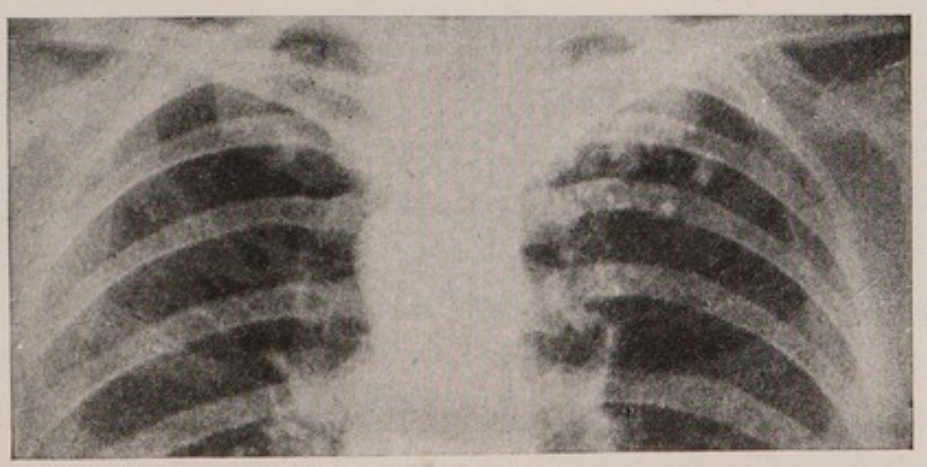


FIG. 160.

FIGS. 159 and 160. Tuberculosis. Fibrosis and calcification. (From Sante: The Chest. Annals of Roentgenology, Vol. XI.)

representing the zone of exudative reaction. If the cavity is 1 cm. or more in diameter, and the zone of reaction is thin, there is little difficulty in the interpretation. But if the

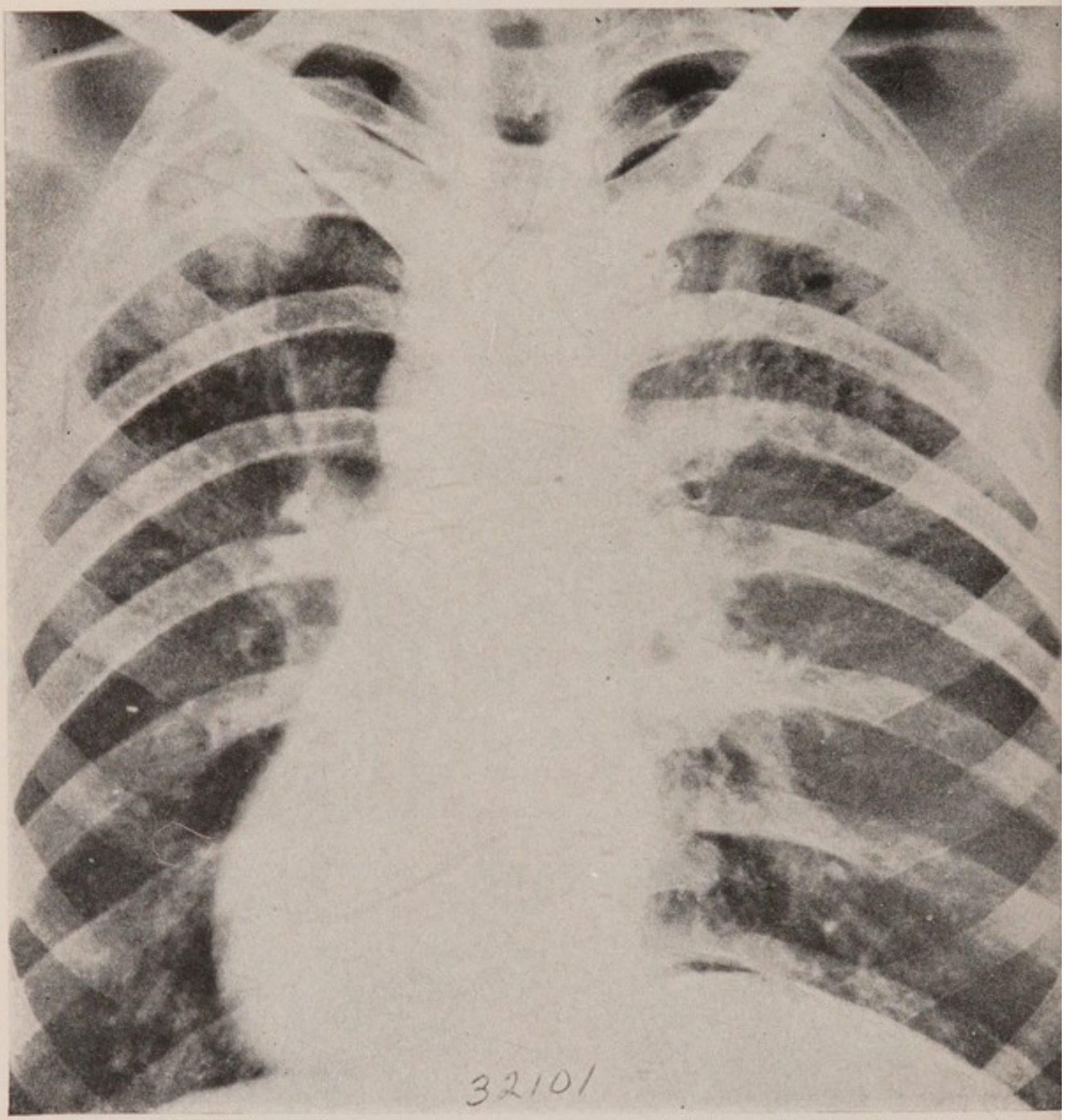


FIG. 161. Tuberculosis, moderately advanced. (From Sante: The Chest. Annals of Roentgenology, Vol. XI.)

cavity is less than 1 cm. in diameter or the zone of reaction is broad, it may escape detection. A cavity may be so large

as to completely excavate an entire lobe. If located close to the lateral wall it may simulate a pneumothorax. The size, location, and number of cavities affords an important

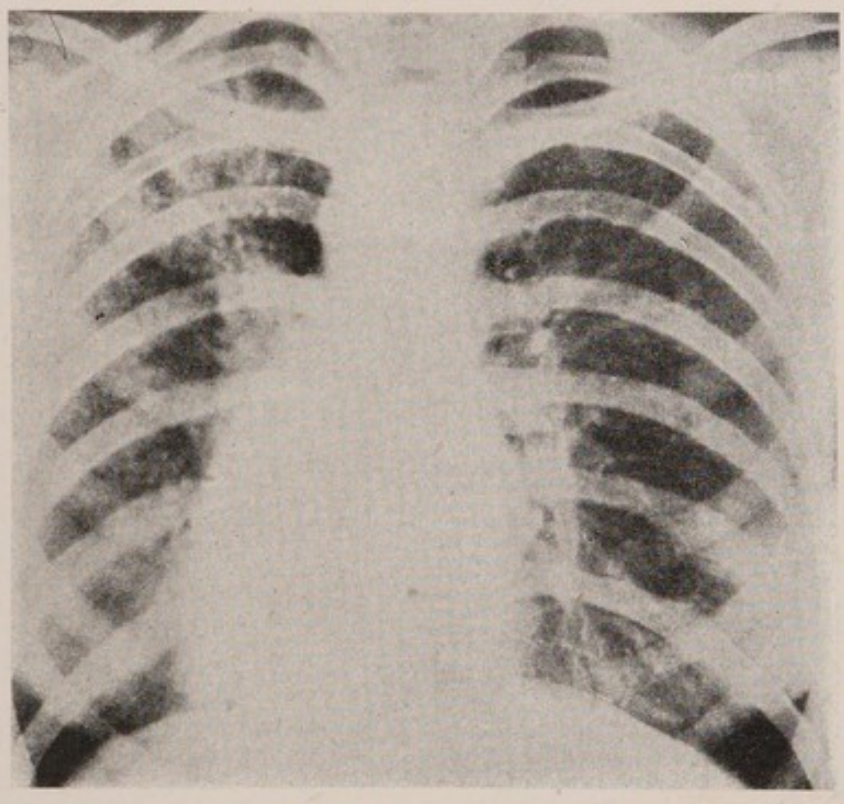


FIG. 162. Pulmonary tuberculosis. (From Sante: The Chest. Annals of Roentgenology, Vol. XI.)

guide in the treatment of the patient.

Connective tissue formation is stimulated by the tubercle bacilli. The amount varies with the degree of the infection, the type of bacilli, and the resistance of the individual. The least grades are shown only by distortion of the linear markings. More extensive deposit of fibrous tissue displaces the trachea toward the affected side, displaces the base of the heart, displaces the hilum upward, and narrows the intercostal spaces. Where the reaction is extreme there are bands and sheets of fibrous tissue traversing the lungs in all directions. When the pleura is involved fibrous tissue may bind the parietal to the visceral layers, forming small or large adhesions.

There is *predilection* for certain definite parts of the lungs. The upper lobes are first invaded in a majority of cases, and in the upper lobes the tuberculous nodule is usually seen in the periphery, about 1 cm. from the pleura. The extreme apex may show one or several nodules directly on the pleura, forming the "puckered scar" so often encountered in all autopsies. More commonly the visible lesion is lower than the extreme apex, in the second interspace opposite the axilla. As the disease advances the number of nodules increases, so that extensively invaded lungs may show multiple lesions in all lobes.

Pleural involvement is always present to some degree. This may be so slight that no evidence is present in the radiograph. There may be a "pleural cap," a sheet of fibrinous pleurisy extending over one or both upper lobes, diminishing in thickness from above downward; in the affected area the film is shaded, and the linear markings obscured. The shading caused by thickened pleura is slight; it is comparable in density with the shadow of a well-developed pectoralis major. The thickened pleura may extend between the lobes; when this occurs between the upper and middle lobes the direction of the ray is such that the sheet of thickened pleura is caught on edge and a dense white shadow is seen. But when it occurs between the middle and lower, or between the left upper and lower lobes, the thickened pleura is caught diagonally and no shadow appears on the film as taken in the usual postero-anterior position. Thickened pleura above the lower lobes may be demonstrated by placing the tube so that the ray will fall in line with the interlobar septum (see lateral view and superlordotic position, p. 153). Associated with the fibrinous pleurisy there may be fluid. Usually this collects by gravity in the most dependent portion. As the radiograph is made while the patient is upright, there is a

dense, white, homogeneous shadow extending from the diaphragm upward, the upper border curved upward and outward toward the lateral wall. The quantity varies from

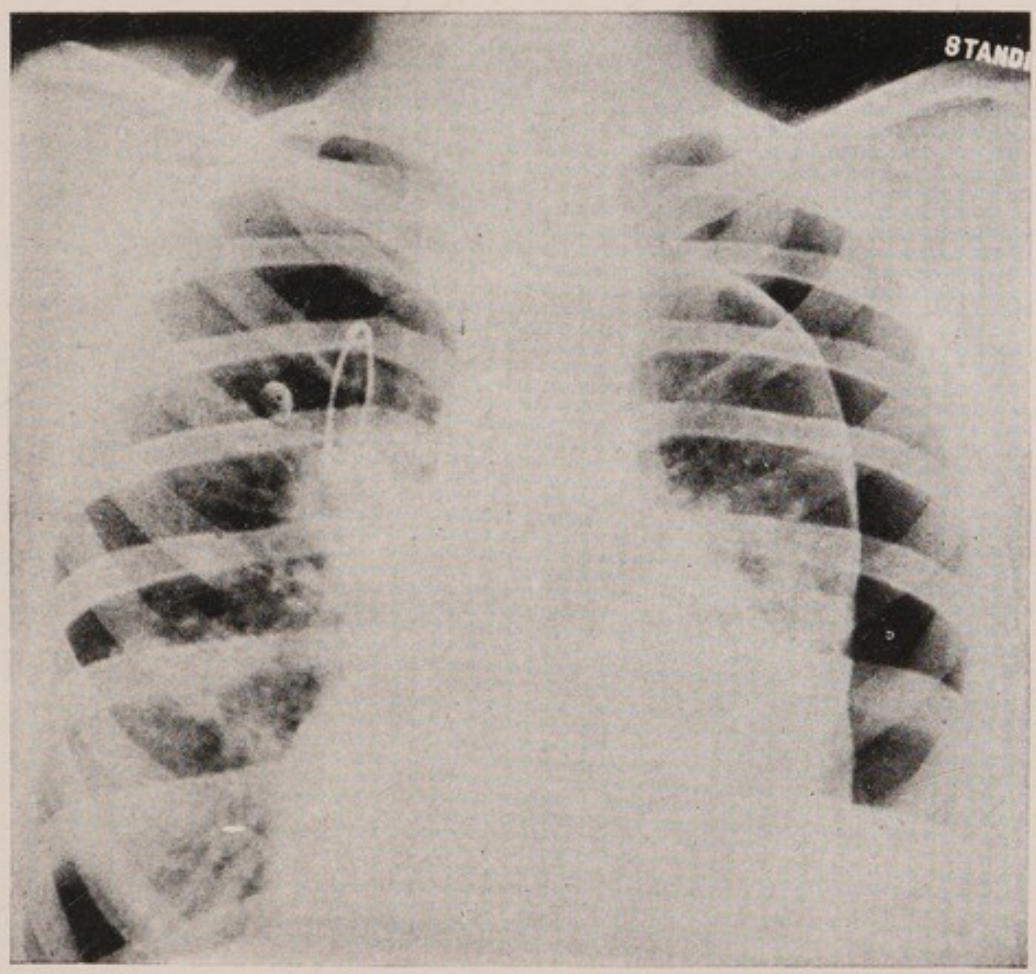


FIG. 163. Pneumothorax. (From Sante: The Chest. Annals of Roentgenology, Vol. XI.)

an amount just sufficient to fill the costophrenic angle, to a quantity that displaces the heart toward the opposite side. The fluid in the pleura may even rise past the lung and blot out all distinguishing landmarks, converting that side of the chest to a white, homogeneous density.

Pneumothorax. Air may be present instead of fluid, if a nodule on the pleura ruptures into a bronchus. The lung then collapses as far as it can. If the degree of tuberculous pleurisy be slight and adhesions absent, the entire lung

collapses to a dense mass lying against the mediastinum. The film shows particularly clean-cut shadows of the ribs, and in the area formerly filled by lung, a dark space devoid

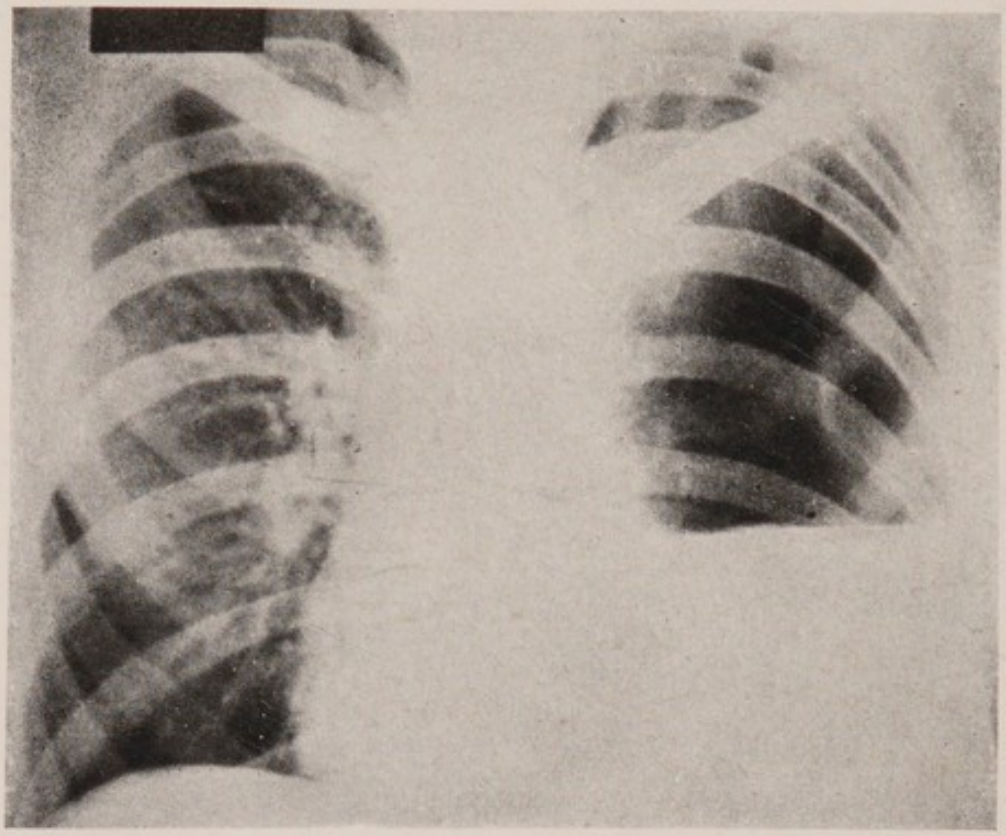


FIG. 164. Pneumothorax with hydrothorax. (From Sante: The Chest. Annals of Roentgenology, Vol. XI.)

of the linear markings: the heart may be displaced to the opposite side. After the perforation seals over, the lung re-expands to its former position. If adhesions are present, the lung is fastened to the chest wall at certain points; collapse is incomplete at these points. Later the adhesions stretch and fibrous bands are seen, traversing the air-filled chest cavity.

Fluid and pneumothorax may coexist. The fluid casts a dense, homogeneous shadow as before, but its upper limit is horizontal, parallel with the ground, instead of curved upward and outward. By fluoroscopy ripples and waves

may be seen when the patient is moved about. Above the fluid level is the dark area of air-filled chest cavity, devoid of the linear markings of normal or pathological lung tissue. In some cases adhesions may localize the fluid, which is then said to be "encapsulated." Air is seldom localized.

Sequence of Events. There is a tendency for this disease to remain stationary or regress in some areas, and increase and extend in other parts of the lungs. In the same patient some nodules may be old, and others recent. So when in a given film there is one group of nodules that cast shadows which are discrete, definite, some white from the heavy salts of calcium; and when the intercostal spaces are narrowed, the trachea or heart displaced, the inference is obvious that a definite time has elapsed since the process began—as it requires time to lay down the salts of calcium, and for connective tissue to form and then contract. Where there is another group of lesions that cast shadows less distinct, with ill-defined, blurred, indefinite borders, without evidence of connective tissue formation, the deduction may be made that these lesions are comparatively recent. So in one patient there may be a group of lesions that are remaining stationary or are healing, and another group that are increasing in number and possibly extending in area.

This sequence of events serves to differentiate tuberculosis from other lung diseases that are not as chronic, or do not have an interrupted, remitting, irregular course.

Activity cannot be safely estimated. While the radiologist may state that certain lung changes are of tuberculous origin, he cannot determine whether or not those changes are active. The determination of activity must be left to the clinician. It is especially in these cases of lung disease that a true ethical code demands that the report should go to the clinician who referred the case, and never to the

patient himself. A completely arrested tuberculous process may interfere little with the life of an individual.

Unusual types of tuberculosis result from variations in the infection, or in the resistance of the individual. Thus if the infection is massive or the resistance is low, there may result the exudative type. If the seeding be through the blood stream, the miliary type may result. In childhood (p. 355) the tissue reactions differ from those found in the adult.

Exudative Tuberculosis (tuberculous pneumonia). At times the exudative reaction overshadows the usual nodular distribution. This may be local, in a part of one lung, or may prevail generally throughout an entire lobe as does the exudate of lobar pneumonia. Inasmuch as the air cells are filled to the practical exclusion of air, the shadow cast has a smooth, even density. When in the lower lobes, fluid in the pleural cavity might be suspected, were it not for the fact that movable organs are not displaced, and the upper limit of the shadow has not the characteristics of a fluid line. A true lobar consolidation casts the same shadow, be it caused by the tubercle bacillus or any other organism; consequently the differentiation from lobar pneumonia is frequently impossible until the tuberculous consolidation breaks down to form cavities. In these cases little asistance is given the clinician, as by the time cavitation is established tubercle bacilli may be readily demonstrated in the sputum. Fortunately tuberculous lobar pneumonia is uncommon in adults.

Miliary Tuberculosis. If the infection is hematogenous in origin the tubercles form simultaneously in a large part of the lung field, sometimes in all parts of both lungs. Dissemination may be incomplete, when a part of one lobe is seeded from a focus in the same lung. The tubercles break into the air passages only late in the disease. Consequently there is at first no expectoration, no excretion of bacilli, no râles,

and no physical signs. The *x*-ray film shows innumerable small opacities which slowly increase in size as the case progresses. If the individual has acquired a certain amount

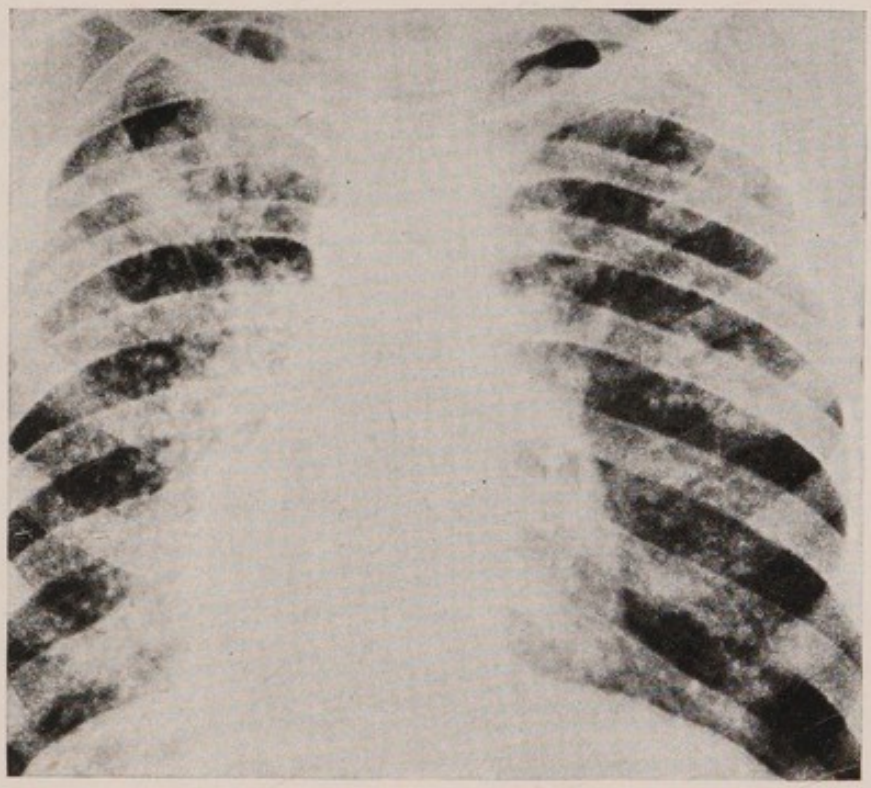


FIG. 165. Pulmonary Tuberculosis, miliary type. (From Sante: The Chest. Annals of Roentgenology, Vol. XI.)

of resistance, as when the dissemination is from a focus in a tuberculous kidney, development may be slow, lasting six months or more. When the resistance is lower, the termination will occur in less time. Exceptionally, if the seeding is sparse or the resistance high, there may be clinical recovery.

Childhood Tuberculosis. It is accepted that nearly all children acquire tuberculosis of the lungs. The infection is usually minimal, the resistance high, and the child may recover without medical advice. A less benign course causes many grades of pulmonary pathology.

Tubercle bacilli gaining access to the lung cause tubercle formation and an exudative reaction. Almost immediately the regional lymph nodes are involved and enlarge. The

primary focus in the lung parenchyma may be demonstrable, but is frequently so small as to escape detection. The enlargement of the lymph nodes is the dominant feature. There is often pleurisy, which may be plastic or fluid. The process may extend directly from a tuberculous node to adjacent lung and cause secondary involvement of lung tissue.

The typical pathological change differs from the adult case. In older individuals involvement of the lymphatic system is minimal or absent, as the existence of an antecedent infection confers a partial immunity and alters the characteristics of the disease.

The interpretation of the radiograph should be conservative. The dominant feature is the enlargement of the lymph nodes. As is so well known, the lymph nodes of children enlarge from many causes: they are engorged in pertussis, in the exanthemata, in bronchitis of any etiology, in fact, from any infection or irritation of the lungs.

The enlarged lymph nodes cast a dense shadow, the contour smooth and rounded, the outline sharply demarcated. The location of the enlarged nodes may be demonstrated by films taken at various angles; for example, the nodes at the bifurcation of the trachea show best in the oblique view.

Adenopathy alone merely indicates that some infection is present, or has existed previously. If in addition there is the shadow of a definite lesion in the lung parenchyma the suspicion of tuberculosis is heightened; if there is associated pleural involvement, it is more definite.

The characteristic course may be disclosed by repeated examinations. When the disease is being overcome, the adenopathy decreases; the exudative reaction about the parenchymal focus diminishes; and the pleural involvement is less. During an exacerbation, the adenopathy becomes

larger; the exudative reaction is more extensive; and pleural involvement is greater. The deposit of the salts of calcium, the formation of fibrous tissue, or the development of cavitation may clarify a previously doubtful diagnosis.

When the disease progresses unfavorably, extension, widespread dissemination, and cavitation may lead to a fatal termination before those changes occur that require time for development.

The miliary type differs from the adult case only in its more rapid course. The number of the opacities may be greater than in the adult, and by summation of overlapping shadows give the appearance of larger areas of involvement.

The interpretation should be particularly guarded in those instances where the film shows enlarged and calcified lymph nodes and beaded, accentuated bronchial markings leading to a limited portion of the lung. It is granted that such a patient has a tuberculous process; it rests with the clinician to evaluate its importance to the patient.

It is evident that in childhood a case should be diagnosed pulmonary tuberculosis only after consultation with the physician in charge, that the evidence as shown on the film may be correlated with the clinical findings. The *x*-ray evidence alone is not sufficient to establish a diagnosis.

Follow up examinations, used as a guide to treatment, are made every three months for cases that are undergoing active medical care, every six months for those that have apparently healed, unless some physical sign or symptom indicates the necessity for earlier investigation. Inferences should be drawn from a comparison with all films taken previously, rather than from a comparison of the film with written reports. The clinician is interested in an accurate description of all changes that may have occurred, described as changes, rather than a complete description of the present condition.

Classifications are of great value in assisting the study of this disease. Of the many excellent ones, two have acquired numerous adherents. For convenience of reference they

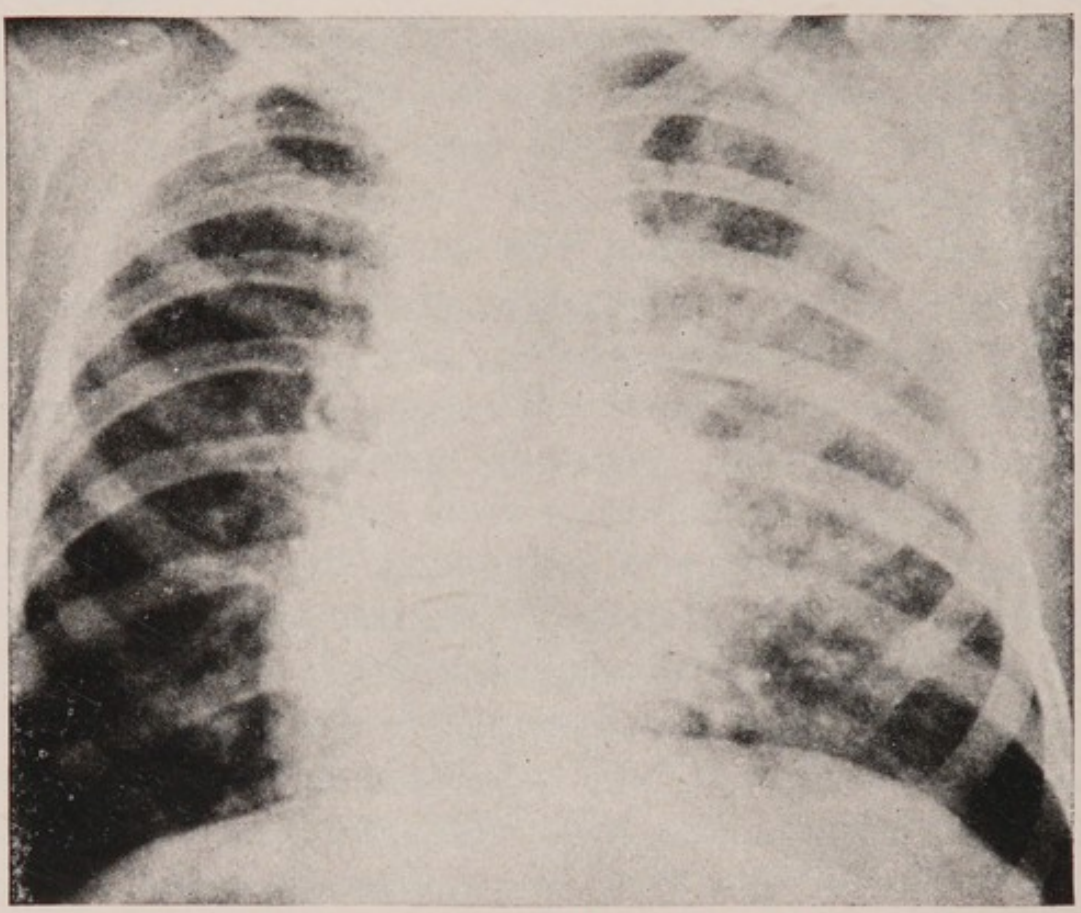


FIG. 166. Bronchopneumonia, child. (From Sante: The Chest. Annals of Roentgenology, Vol. XI.)

are appended at the end of the chapter.

Bronchopneumonia. Each consolidated area casts a separate shadow on the film. Thus there are scattered opacities, varying in size from 2 mm. to 2 cm., their color a light grey. The number depends on the degree of involvement; the distribution varies widely. Opacities appear in an upper lobe, others in a lower; both lungs are usually affected. The number and size of the lesions may vary from day to day. Occasionally the disease is limited to a single lobe, and may for a time resemble tuberculosis. When the

pleura is involved, the excursion of the diaphragm may be inhibited.

In childhood bronchopneumonia is a common disease.

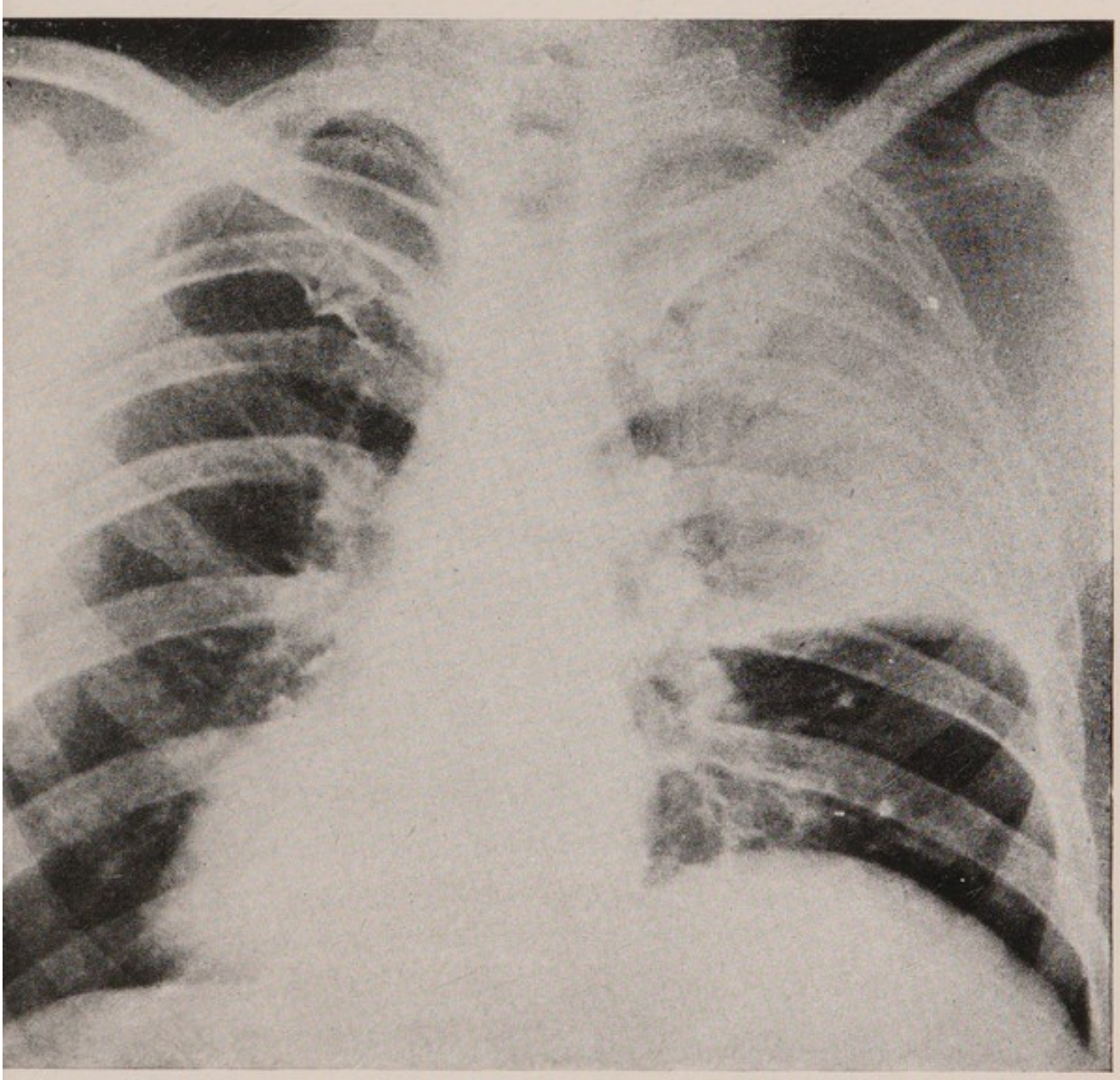


FIG. 167. Pneumonia, right upper lobe. (From Sante: The Chest. Annals of Roentgenology, Vol. XI.)

The appearance of the shadows is similar to those found in the radiograph of the adult case, but they are often more extensive and less well defined. At this age the condition may be associated with localized patches of atelectasis that

confuse the picture by their extensive and poorly demarcated shadows. The lesions may be so thickly set as to imitate the shadow cast by a lobar pneumonia; in such

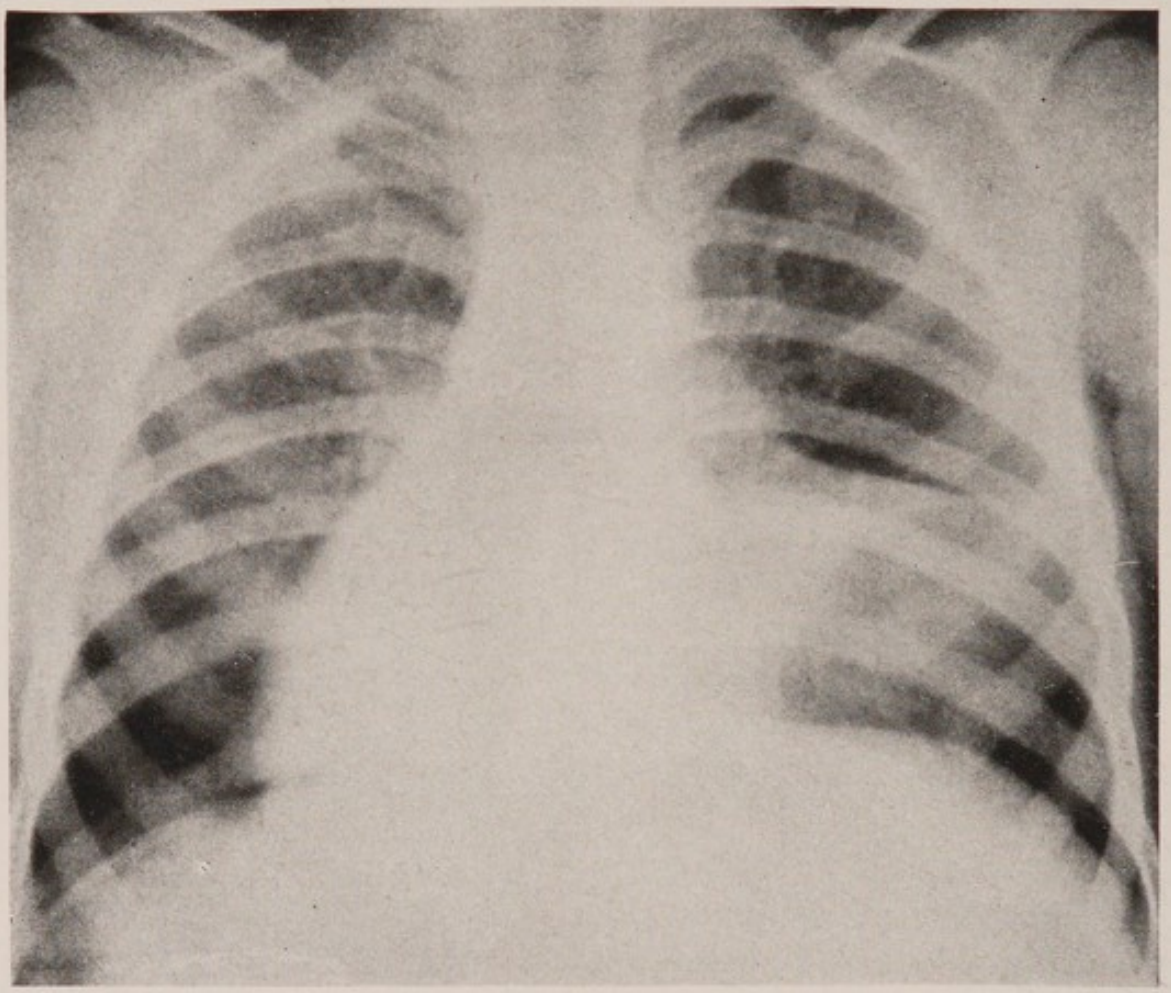


FIG. 168. Pneumonia, right middle lobe. (From Sante: The Chest. Annals of Roentgenology, Vol. XI.)

instances the occurrence of small opacities in other lobes clarifies the situation. Radiographs often show small patches of consolidation that were not suspected clinically. Occasionally the film fails to demonstrate lesions that certainly exist.

Lobar Pneumonia. An entire lobe or a large portion of a lobe casts a homogeneous shadow; the density is similar to the heart shadow. More than one lobe may be affected, either simultaneously or after an interval of a day or two.

The density is so uniform, and the boundaries of the shadow are so definitely lobar that the diagnosis is seldom in doubt. Pleural involvement is the rule; on the affected side the diaphragm rises higher than its normal position in the thorax. A lower lobe consolidation may resemble fluid in the pleural sac.

Pneumonia may be differentiated from fluid because in pneumonia the heart is not displaced, while fluid usually pushes the heart toward the opposite side; in pneumonia the shadow of the costophrenic angle is only slightly shaded, whereas fluid casts a denser shadow, approaching a clear white color.

After the crisis the density of the shadow of a pneumonia is very little decreased. For several days thereafter the affected lobe is mottled, with grey patches and streaks indicating the location of clearing lung tissue. When the exudate is entirely cleared thickened pleura may remain for weeks, and may continue to show a faint shadow, shading over the previously involved area.

Clinically, lobar pneumonia is justly called "frank" and radiographic assistance is not often sought until complications arise or are suspected. These are especially empyema and suppuration.

Empyema. When the consolidation was in the upper or middle lobes the presence of fluid is readily determined; even after lower lobe involvement it is not difficult. It may be borne in mind that at nearly all autopsies of pneumonia cases about 50 c.c. of clear or cloudy straw-colored fluid is found in the pleural sac, so that a slight density in the costophrenic angle should not lead to the conclusion that purulent fluid is present. Larger quantities, as are found in empyema, cast a dense, white, definite shadow; the outline of the costophrenic angle is obliterated, and an upper level can be determined. Fluid in still larger quantity rises

past the involved lobe, and is shown by an increase in the density of the shadow. This is more easily recognized as empyema occurs as a rule at a time when the lung density

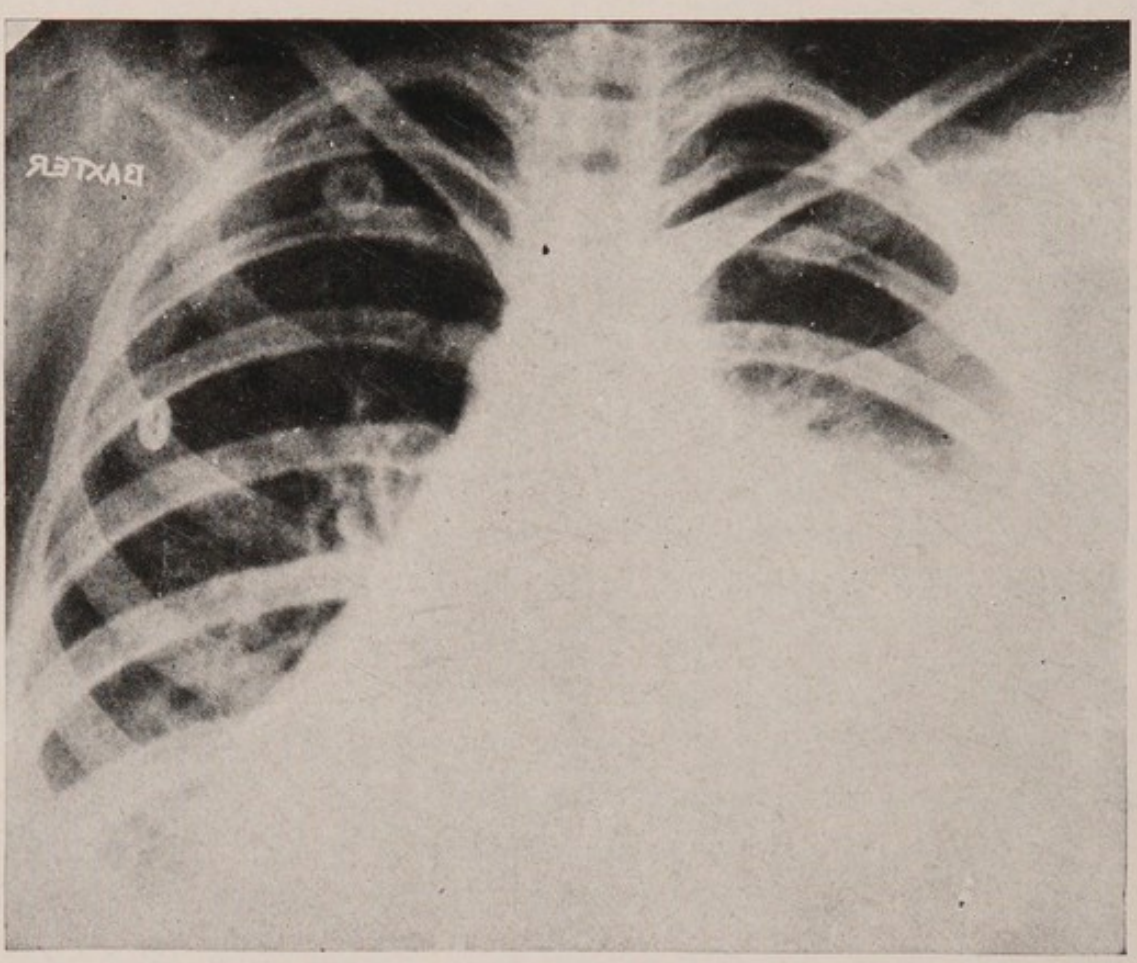


FIG. 169. Empyema. (From Sante: The Chest. Annals of Roentgenology, Vol. XI.)

is decreasing, and has become mottled. The fluid shadow is whiter and more homogeneous than the shadow of the affected lobe. The characteristic crescentic curve of fluid is usually absent, as the lung is solid and cannot be floated up from below; for the same reason the clearly defined upper level is not seen. The heart is usually, but not invariably, pushed to the opposite side.

Lung suppuration (p. 369) is harder to detect and may not be identified. The suppurative area is an irregular density that resembles the mottled, uneven densities charac-

teristic of the resolving exudate in an uncomplicated case. Later in the course of the disease the characteristic appearance of lung abscess becomes manifest.

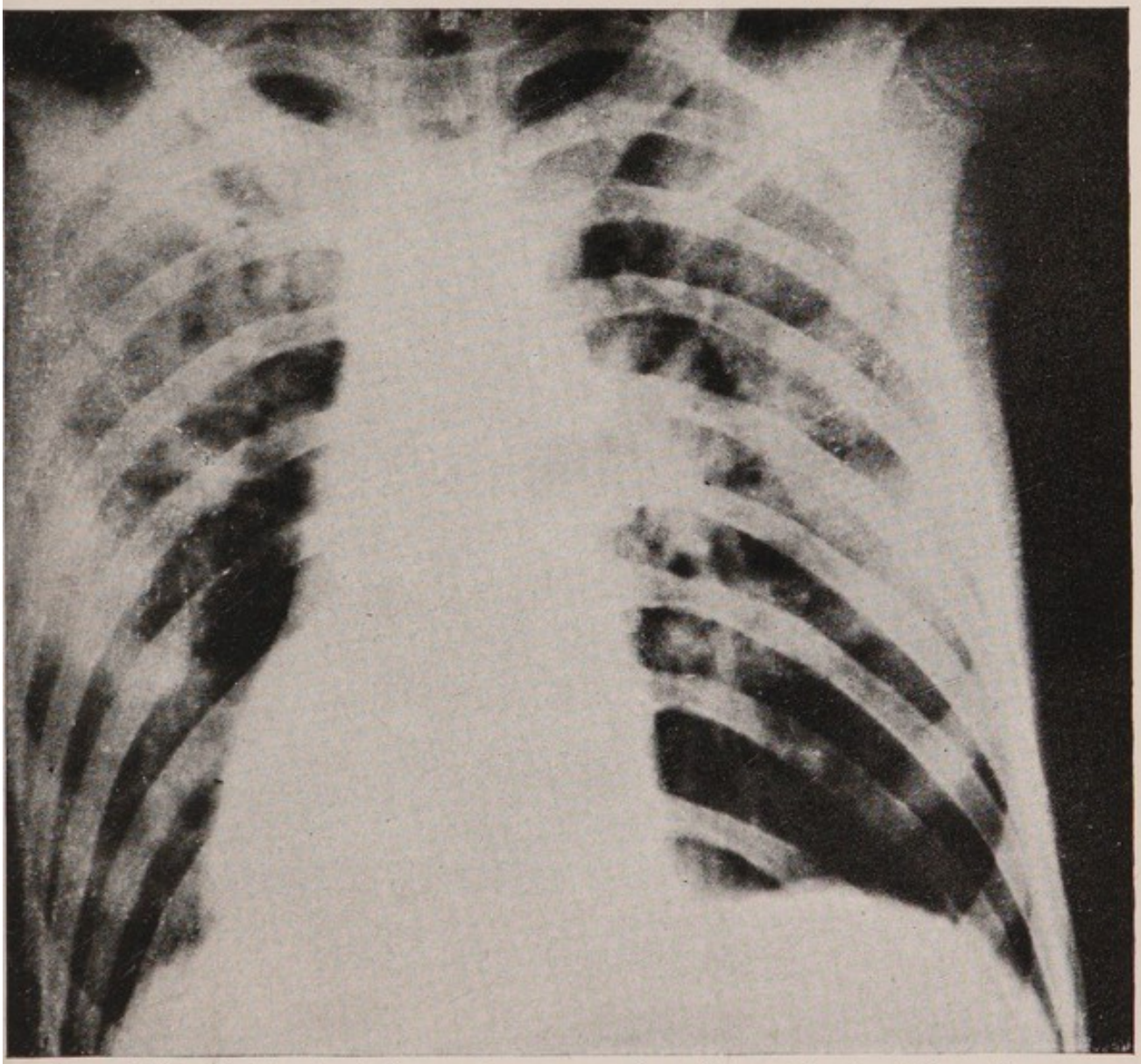


FIG. 170. Epidemic influenzal pneumonia. (From Sante: The Chest. Annals of Roentgenology, Vol XI.)

In children the first appearance of the consolidation of a lobar pneumonia may be peripheral, and the spread is toward the hilus; the point of origin may be central.

Central Pneumonia. Close to the hilus and continuous with it appears a haze, homogeneous in density, fading out

at its margin, until exact differentiation is no longer possible between the diseased and the normal lung. The size of the process varies from a relatively narrow zone

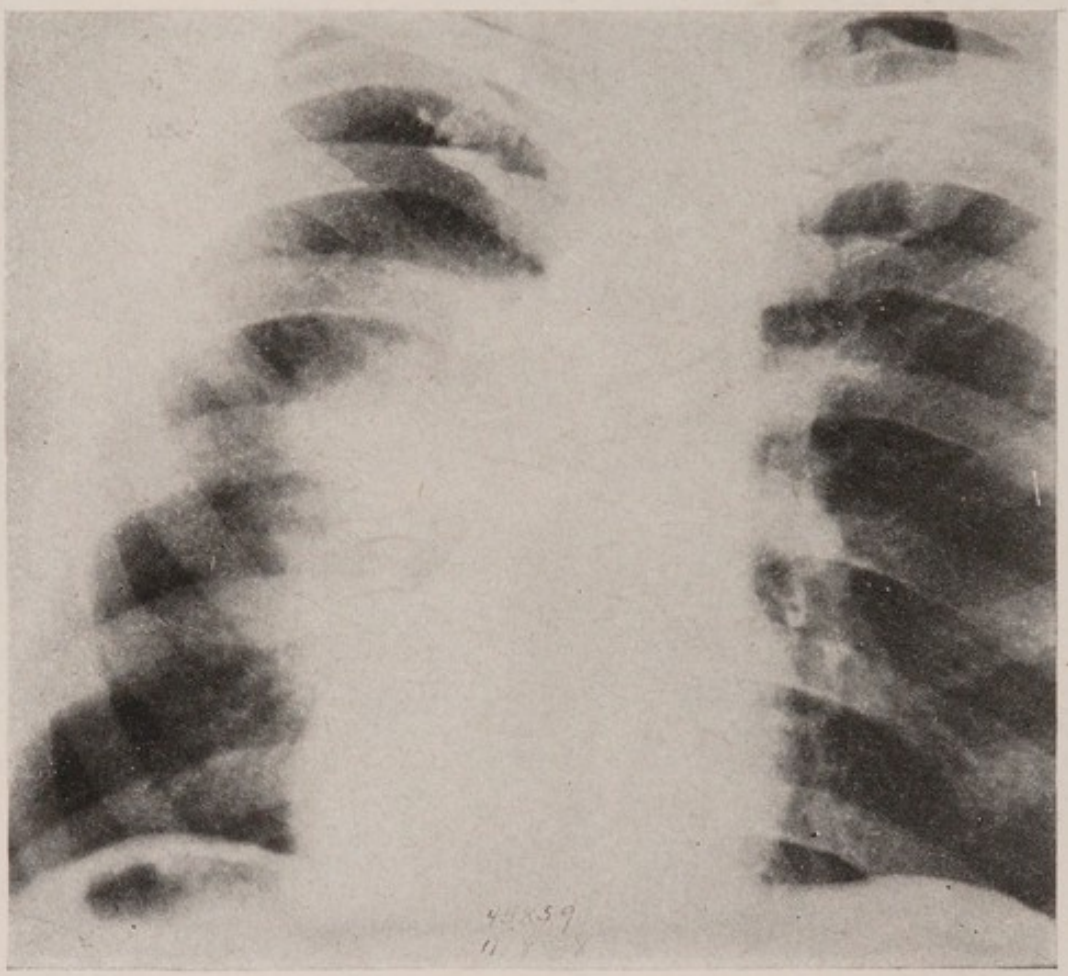
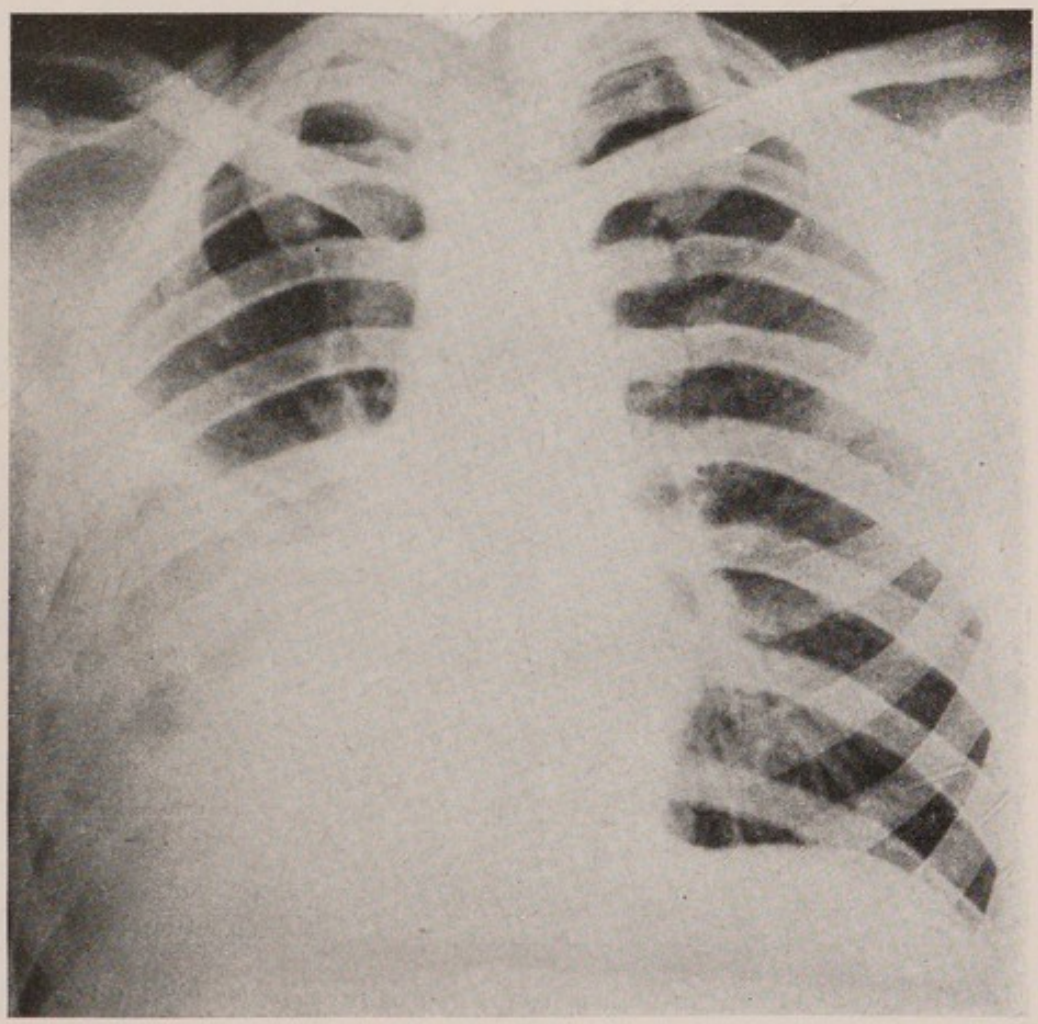


FIG. 171. Central pneumonia. (From Sante: The Chest. Annals of Roentgenology, Vol. XI.)

obscuring and blurring the hilus contours, to an irregular area, that may be 10 cm. in diameter. Within a few days the haze may extend peripherally and involve an entire lobe, becoming a lobar pneumonia, or it may begin to resolve. A special type starts at the hilus and affects more than one lobe simultaneously. These cases are seen during influenza epidemics. When a central pneumonia first appears, there is no evidence that may indicate whether

it will develop into a frank lobar pneumonia, or remain central in type.

Chronic interstitial pneumonia (indurative pneumonia;



B

FIG. 172. Fluid (hemorrhage) in pleural sac. (From Sante: The Chest. Annals of Roentgenology, Vol. XI.)

chronic diffuse interstitial fibrosis) is a descriptive term implying that fibrous tissue is present in excess in one or more lobes; it is a pathological condition rather than a disease entity.

The common causes are pneumonia, when associated with a suppurative process; plastic fibrinous pleurisy, usually associated with a purulent exudate; and lung suppuration that has gone on to healing.

Tuberculous disease of the lung is associated with fibrous tissue production, but cases of pulmonary tuberculosis are not included in this classification.

A

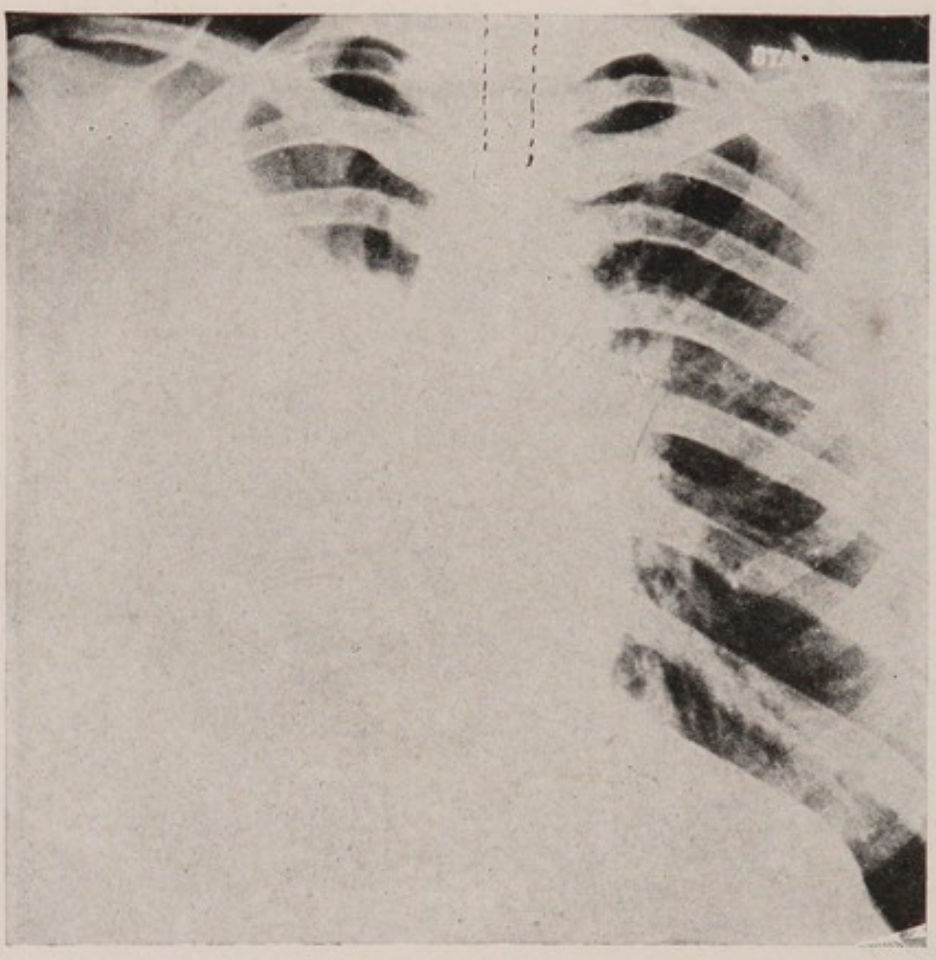


FIG. 173. Large pleural effusion. (From Sante: The Chest. Annals of Roentgenology, Vol. XI.)

Infarct in the lung rarely casts a shadow; the *x*-ray should not be expected to assist in diagnosis. If the infarct is large (over 5 cm. in diameter) there may be a faint triangular shadow based on the periphery.

Pleural Effusion. A transudate, an exudate, pus, or blood, casts the same dense, white, homogeneous shadow. The fluid will drop to the most dependent portion of the chest, unless prevented by adhesions. Minimal amounts are seen in the costophrenic angle. Larger amounts float the

lower lobe of the lung upward; the upper fluid level is sharp, distinct, the line running in a curve from the mesial aspect upward and outward to the lateral chest wall. The

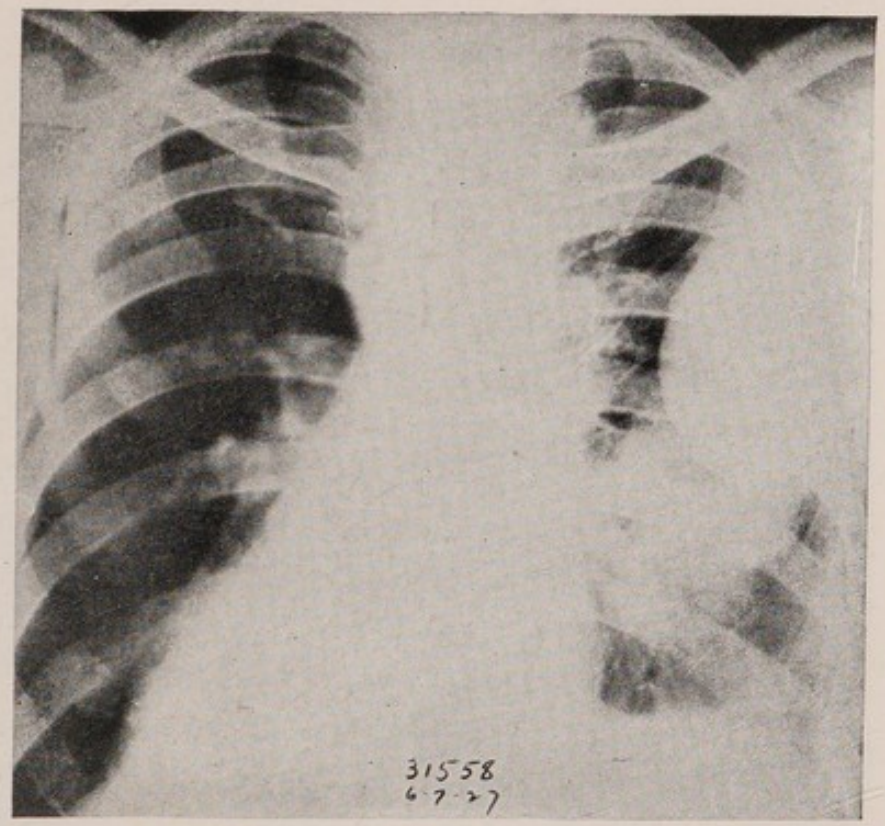


FIG. 174. Localized pleural effusion, lateral chest wall.
(From Sante: The Chest. Annals of Roentgenology, Vol. XI.)

level shifts with change of posture. The heart may be displaced toward the opposite side. When the fluid increases it cannot push the lower lobe farther, as the attachment of the lung at the hilus prevents, but rises past the lung laterally, in front, and behind. The fluid line is no longer curved; there is no sharp line of demarcation, the dense white shadow below fading out to an indeterminate upper limit. The heart is displaced to the opposite side, the lung pushed upward and compressed.

Displacement of the heart and mediastinum by large amounts of fluid is the rule. But when the mediastinum has been rendered immobile by a disease process, it must

remain stationary whatever the quantity of fluid in the pleural cavity; or if the lung volume is reduced as by atelectasis, there is space enough to accommodate the fluid

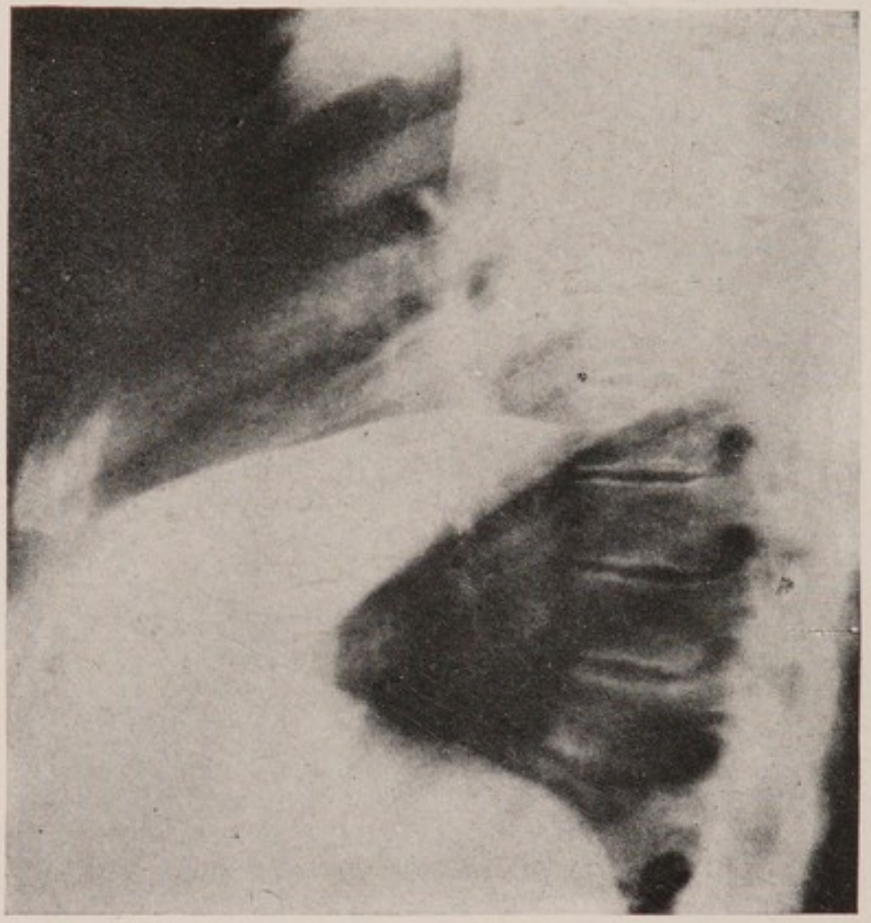


FIG. 175. Localized pleural effusion between upper and middle lobes. The lateral position is more informative than the posteroanterior. (From Sante: The Chest. Annals of Roentgenology, Vol. XI.)

in the pleural cavity, there is no thrust upon the mediastinum, and no displacement. Loculated effusion occurs when dense adhesions prevent movement from the place the fluid is formed. The more frequent locations are the lateral chest wall and the interlobar fissures.

Pleural thickening shows on the film as a haze, less in density than fluid. The density of the shadow varies with the actual thickness of the pleura, but usually permits a view of the lung structure. The heart is not displaced to

the opposite side, unless by other pathology, such, for instance, as adhesions. If fibrous tissue is laid down, it contracts; the heart is drawn toward the affected side, the

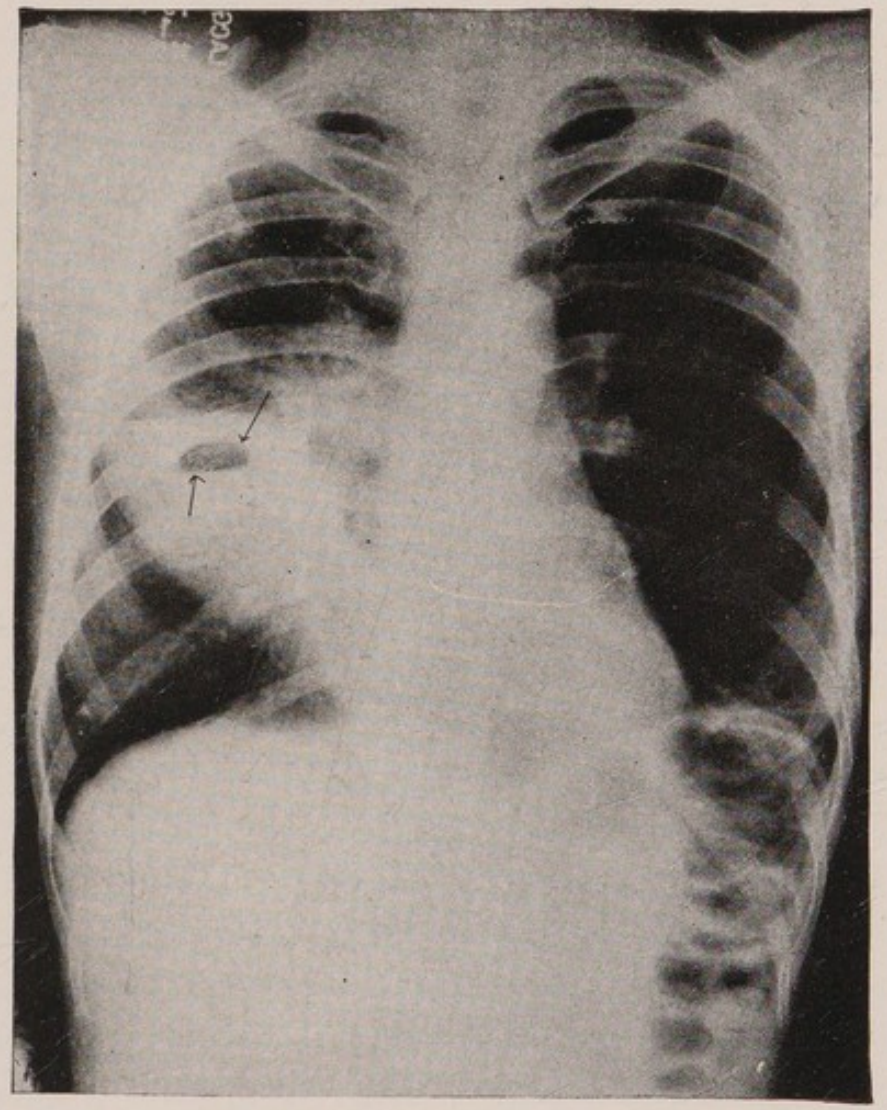


FIG. 176. Suppurative lung with abscess cavity. (From Johnson. *Am. J. Surg.*, 8: 1238, 1930.)

intercostal spaces are narrowed, and the thorax is constricted. The density of the shadow is not a reliable guide to the actual thickness of the involved pleura.

Lung Suppuration. The more common causes are:

1. Pneumonia; indurative pneumonia.
2. Aspiration of foreign material during operations under general anesthesia.

3. Accidental aspiration of foreign bodies, especially in children.

4. Septic emboli from remote suppurative lesions.

5. Bronchiectasis.

A septic process in the lung causes an exudative reaction in surrounding lung. If the process is active the area increases in size. There is necrosis, liquefaction, eventually a bronchus is opened and the liquefied mass is expelled. The cavitation is often multiple. A cavity thus formed fills and empties. Until the process has been long established there is not time for fibrous tissue formation; the cavities are irregular in outline and are poorly demarcated from the adjacent consolidated lung tissue. Eventually fibrous tissue forms and walls off the cavity. In another type the focus is in a bronchiectatic dilatation rather than in lung parenchyma.

The condition tends to improve and relapse. During an intermission the cavity remains air filled and may decrease in diameter, the zone of reaction becomes thinner, and the process occupies a smaller part of the lung. When the disease gains the ascendant the cavity tends to remain filled and fails to cast its black shadow, the zone of reaction becomes wider, and the process involves a larger area. Spontaneous cure is possible and not infrequently occurs; the cavity shrinks, collapses, and the elastic lung closes in upon a scar. Occasionally the process goes on favorably for a time, the disease is apparently cured, the patient becomes clinically well, but the focus remains and a relapse occurs.

The type of shadow cast by the involved area varies with the stage of development. At first there is the shadow cast by the exudate. It is similar in appearance to a pneumonic exudate, but has an irregular, blotchy, poorly defined distribution. Later, when tissue breaks down but is not

extruded through a bronchus, there is an increase in the area affected but otherwise no change in the radiograph; the filled cavity casts the same shadow as does the exudate. Later still, when the liquefied portion is expelled and replaced by air, there is a contrast between the air-filled cavity and the surrounding consolidation. Still later fibrous tissue forms about the cavity and the familiar three zones appear: the dark air-filled center, the white line of fibrous tissue, and the zone of exudative reaction shading off toward normal lung structure.

Usually the clinician suspects lung suppuration and asks for the radiograph with that thought in mind; the film is taken to determine the extent and stage of the process. In the cases originating during convalescence from lobar pneumonia the clinical differentiation is more baffling, as the persistence or recrudescence of symptoms may suggest equally well an empyema or an indurative pneumonia. Here the radiological diagnosis also is difficult. A lung clearing from a lobar pneumonia always casts a shadow that is mottled and blotchy on a grey background. The area occupied by the suppurative process is ill defined, but does cast a shadow that is definitely denser than the remainder of the lobe. Fortunately immediate diagnosis is not essential; a second examination in a few days may show that the suppurative area has increased in size and in density. Even then the differentiation from indurative pneumonia may continue in doubt until the demonstration of cavitation makes the diagnosis certain.

Clinically and radiographically there is a resemblance between lung suppuration and pulmonary tuberculosis. Both are chronic diseases and both are associated with lung destruction and cavitation. They may be differentiated, as tuberculosis affects the upper lobes, lung suppuration typically the lower; tuberculosis has a multiple distribution

and commonly affects both lungs, lung suppuration is localized in one lobe; tuberculosis is manifested by characteristic nodules at some point, lung suppuration is not. While both diseases may exist in the same individual the chances are against it. The history, the character of the sputum and the clinical course should be taken into account. Lung suppuration is a disease highly important to the individual, and a consultation between the clinician and the radiologist is essential. The treatment depends on the cavitation, which may be single or multiple. For this reason the diagnosis is frequently expressed as lung abscess.

Lung abscess seldom empties completely, as does the tuberculous cavity. Fluid may usually be demonstrated within the abscess as a white shadow, its upper level horizontal, its lower limit conforming to the shape of the cavity. Radiographs taken in various postures show shifting of the fluid within the abscess, and are pretty demonstrations, of interest to all. When surgical intervention is contemplated the abscess must be localized. The radiologist must use his utmost ingenuity, as no set procedure is applicable to every case. The following suggestions may be found useful. Whatever the method, all radiographs should be made immediately after postural drainage.

1. A true anteroposterior, and a true lateral film. If the abscess is positively identifiable in the lateral view, this may give all the information necessary. Often the shadow of the abscess merges with the shadow of the heart or mediastinum, and the method fails.

2. Direct the ray in line with the interlobar fissure above the lower lobe (superlordotic position p. 153). The interlobar pleura may be thickened and its relation to the abscess determined. As the position of the interlobar fissure is known (see diagram, p. 341) the location of the abscess can be plotted.

3. Films taken in an oblique position. By fluoroscopy note which oblique position is the best; determine the angle accurately. Place an opaque marker over a rib in front and another over a rib behind, located so that their shadows will be nearly in line with the abscess. Make a radiograph at a 6 foot distance. Plot the location of the abscess by referring to a standard cross section anatomy. *Caution.* In the radiographic rooms and also on the operating table the patient's arm is moved about, and a marker on the skin moves with it; when the radiographs are made the markers must be over bony landmarks that are easily identifiable.

4. Run in a small quantity of lipiodol near the abscess. The contrast medium will not enter the abscess; it is obvious that were the opening to the cavity patent the need for surgical intervention would be unlikely, as the abscess would drain itself. Exceptions are uncommon. The failure of the abscess to fill may be utilized, as the lipiodol may enter the bronchi in front and behind, leaving the abscess cavity as an unfilled portion. The quantity of the contrast medium should be small, certainly not over 10 c.c. Take a lateral film.

5. In stereoscopic films, determine the relation between the abscess and an identified bronchial trunk. This method is valuable when the abscess is near the hilus, where the bronchial trunks are large and constant in position.

Bronchiectasis is local dilatations of bronchi, resulting in multiple small dead spaces that tend to accumulate fluid. The contained fluid is usually purulent. Bronchiectasis more commonly affects the mesial aspect of either lower lobe, but may occur anywhere. Typically, the affected area shows multiple ring shadows and small opacities varying in size from 3 to 10 mm. in diameter. The opacities are the same average size as the ring shadows and represent

bronchial dilatations that have not emptied. Usually bronchiectatic cavities empty readily, the zone of exudative reaction is thin, and the process is clearly demonstrated.



FIG. 177. Lipiodol injection, bronchiectasis. (From Sante: The Chest. Annals of Roentgenology, Vol. XI.)

Occasionally the dilatations do not empty or the process in the adjoining lung is more active and the lesions are concealed. Especially in such cases bronchiectasis must be differentiated from multiple small abscesses in the lung parenchyma. The differentiation may be made by the thoughtful use of lipiodol. If a sufficient quantity

of this contrast medium is run in to demonstrate a portion of the bronchiectatic dilatations, they will show as fusiform enlargements of the bronchial tree. Multiple abscesses of the parenchyma may not show at all, or as irregular, blotchy, nondescript opacities that have no arboreal distribution. When the quantity of lipiodol is in excess, a large mass of overlapping and conflicting shadows may confuse the most experienced examiner.

Gangrene of the lung occurs when anaerobic bacteria gain access. Lung destruction is extensive and the sputum has the characteristic fetid odor.

Lipiodol is iodized oil, so prepared that iodine is bound chemically with the oil. Bromine may be substituted for iodine. There are many trade names. These preparations obstruct the passage of *x*-rays, and when placed within any space cast a dense shadow, defining structure. They are not irritating, and may be used to demonstrate any lung condition that is not tuberculous. The administration may cause coughing sufficiently severe to endanger a tuberculous patient, and therefore lipiodol should not be used when tuberculosis is even suspected. Most of the oil is expelled in one day.

The opaque oil should be applied to the part of the lung that is under investigation. So far as possible the quantity of oil should be no more than is necessary to give the information desired. If large parts of the lung are filled, or if a locality is filled to excess, the mass of overlapping shadows blots out the area that is being studied and may baffle the observer.

There are two methods of administration: by gravity and bronchoscopic.

1. Gravity. (a) The pharynx and larynx are anesthetized. The warmed oil is deposited on the base of the tongue a drop at a time and allowed to trickle through the larynx;

or, a cannula is passed through the mouth, pharynx, and larynx, and the oil is dropped into the trachea. (b) Under local anesthesia a needle is passed through the cricothyroid membrane and the warmed oil is dropped into the trachea. A needle that will not break is essential. This method is the easier and is less time consuming.

The oil dropped into the trachea by either method flows into the dependent portions of the bronchial tree. The posture of the patient is shifted so that the part of the lung under investigation is the most dependent.

2. Bronchoscopic. A bronchoscope is passed and the oil is slowly injected into the bronchus which leads to the part under examination.

As is obvious, the oil will not enter a space already full, or pass through a bronchus that is occluded.

Massive Collapse of the Lung (Massive Idiopathic Atelectasis). When the main stem bronchus to a lobe is completely plugged, the air in the lobe is absorbed and the lobe collapses. At the same time the blood vessels are engorged and transudate is poured into the air cells. As the collapsed lobe occupies less space than formerly, the uninvolved lungs expand, displacing the heart and trachea. The diaphragm comes up into the affected side. The chest is retracted, the intercostal spaces on the involved side are narrowed. Frequently the collapse affects an entire lung. The bronchial plug is usually mucus.

A common cause is an abdominal operation, regardless of the anesthetic, or a rectal operation. Infrequently, cases occur in postdiptheritic paralysis of the diaphragm, after poliomyelitis, after acute meningitis, and following trauma to the chest, abdomen, buttocks, or femur.

The typical history is a sudden respiratory embarrassment during recovery from an abdominal operation. Clinically there is resemblance to pneumonia.

The radiograph shows an opacity in the entire involved area, equalling the density of lobar pneumonia. As in pneumonia, the shading is smooth, uniform, and massive.



FIG. 178. Massive collapse. (From Sante: The Chest. Annals of Roentgenology, Vol. XI.)

The heart and trachea are displaced toward the affected side; the diaphragm is high in the chest cavity; the intercostal spaces are narrowed; and the chest wall on the affected side is retracted.

Differentiation from other conditions is rarely difficult if the possibility of lung collapse is borne in mind. A lobar pneumonia does not displace the heart or trachea, and the upward displacement of the diaphragm is not as extreme. A pleural effusion displaces the movable structures away from the affected side. Lung tumor may cast a shadow that is similar, but has a totally different onset.

The progress of the case is typically toward rapid resolution and complete restitution to normal in a few days or even in a few hours. When the bronchial obstruction is persistent or repeated, the lung clears more slowly; lung suppuration may ensue.

Non-opaque foreign bodies, such as peanuts, beans, coffee berries, etc. may lodge in a bronchus and set up an intense reaction. A partial obstruction of the bronchus follows. At inspiration the bronchus dilates, admitting more air; at expiration it contracts, retaining the air pumped in. The affected lung is emphysematous. Radiographs should be taken at full expiration, and at full inspiration. The child must be absolutely four-square with the cassette, the *x*-ray beam exactly in the midline, as the diagnosis depends on the comparative size of the lungs, and the position of the heart and diaphragm. A fluoroscopic examination is desirable, but the evidence from the film taken at expiration is more informative. On the affected side the lung is darker than the normal lung; the diaphragm is pushed down and is relatively immobile; and the heart is displaced toward the normal side. Within a few hours after removal of the foreign body all these anomalies have disappeared. Should the foreign body be permitted to remain there may be an exudative reaction, purulent in type, which may progress to abscess formation. Occasionally there is pulmonary edema. These complications are more apt to arise in children two years old or younger. At five years and over the foreign body is better tolerated. Occasionally a foreign body, usually a melon seed, lodges in the trachea, producing partial emphysema in both lungs. The radiological signs are less clear cut. If the obstruction is of sufficient grade, there is paradoxical movement of the diaphragm, which becomes lower at expiration than at inspiration.

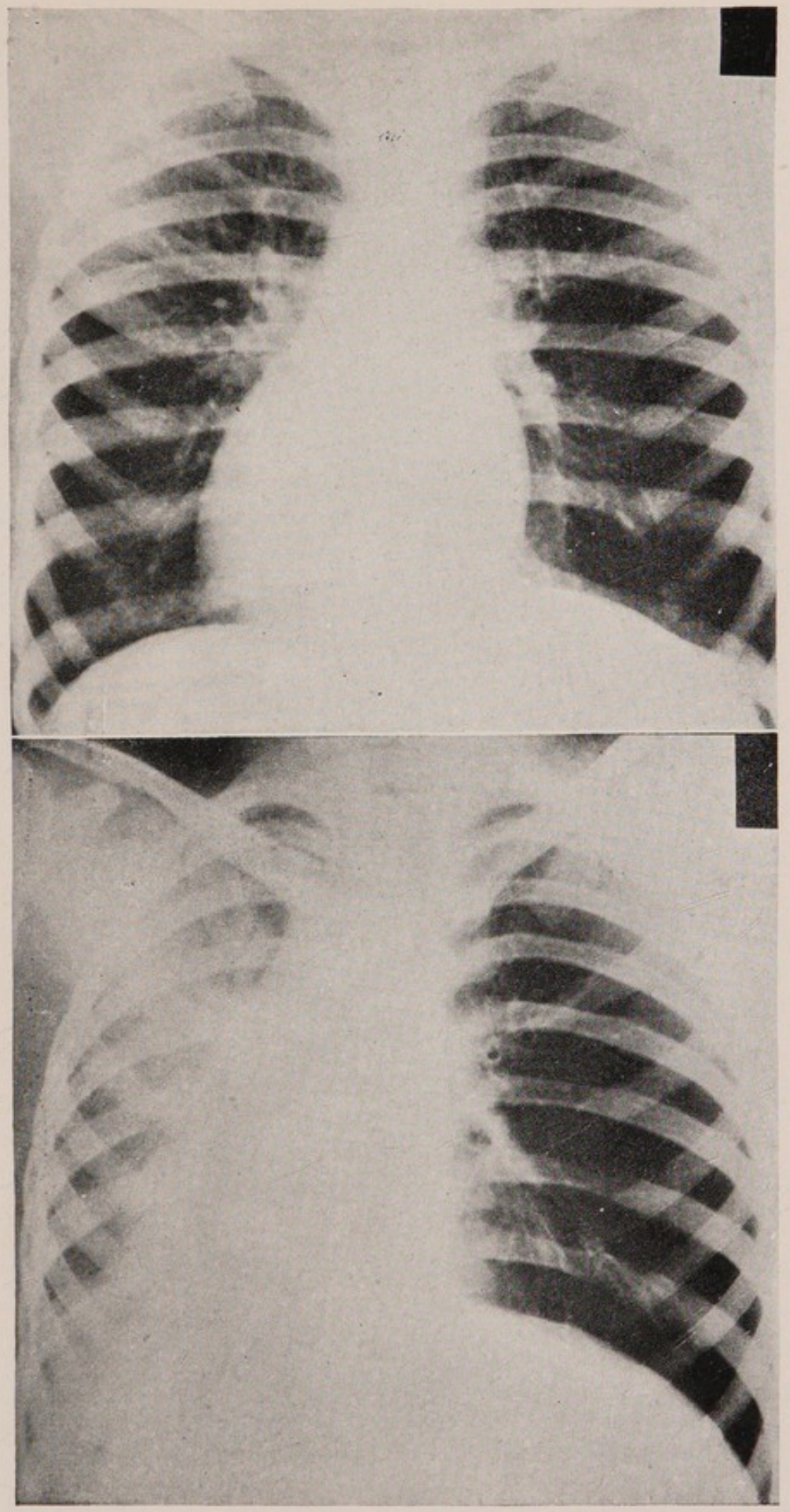
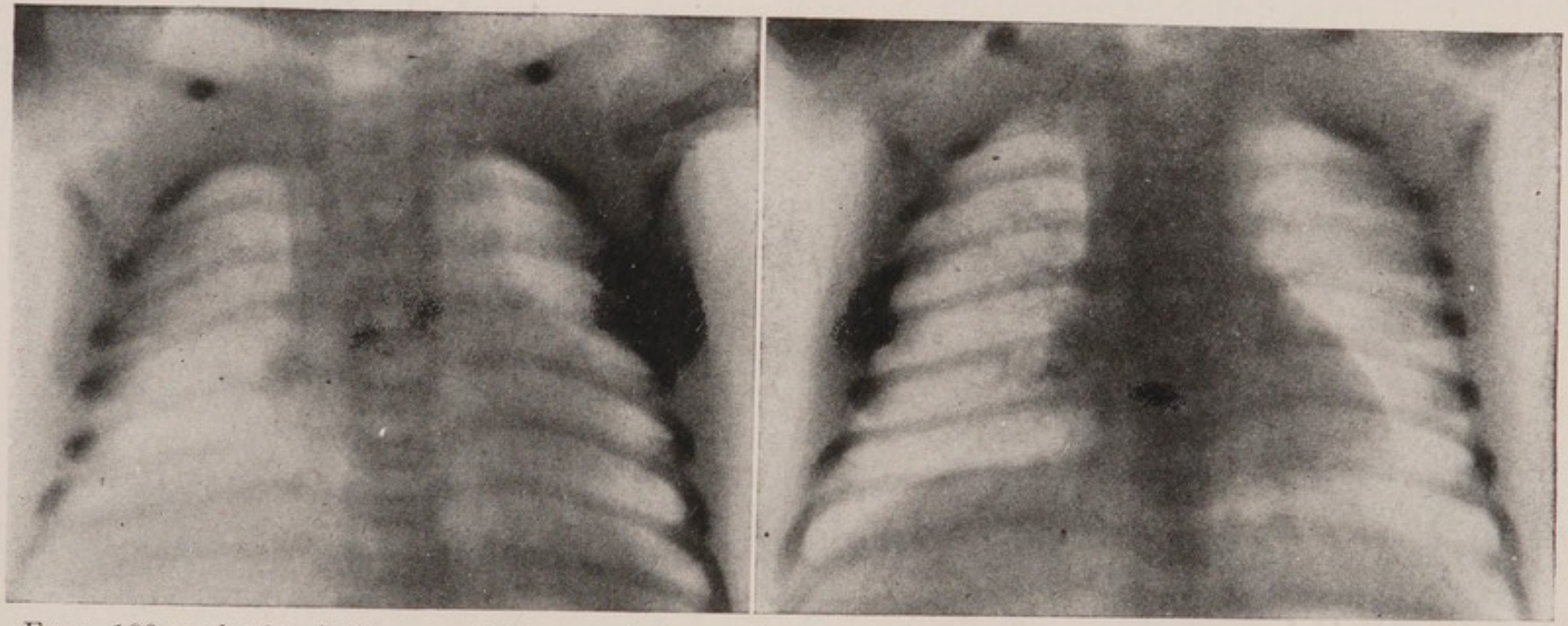


FIG. 179. Non-opaque foreign body; Manges' sign. *A*, taken at full inspiration, shows no abnormality *B*, taken at full expiration, demonstrates the lung condition. (From Sante: The Chest. Annals of Roentgenology, Vol. XI.)



FIGS. 180 and 181. Influence of the respiratory phase on the width of the superior mediastinum. In the expiratory phase the superior mediastinum appears widened; in the inspiratory phase the superior mediastinum appears normal. (From Stoloff. The Chest in Children. Annals of Roentgenology, Vol. XII.)

When the foreign body is to be removed by the transbronchial route, an *x*-ray examination should immediately precede the bronchoscopy. Not infrequently a violent fit of coughing displaces the foreign body to the opposite side.

Thymus Enlargement. The thymus begins to grow at birth, increases in size up to twelve months, and then regresses, disappearing as a demonstrable organ at twenty-six months. There is a wide variation in the time of growth, extent of growth, and time and extent of regression. When the film is taken the infant must be four-square with the cassette, the head exactly in the sagittal plane. The exposure should be at the instant of full inspiration.

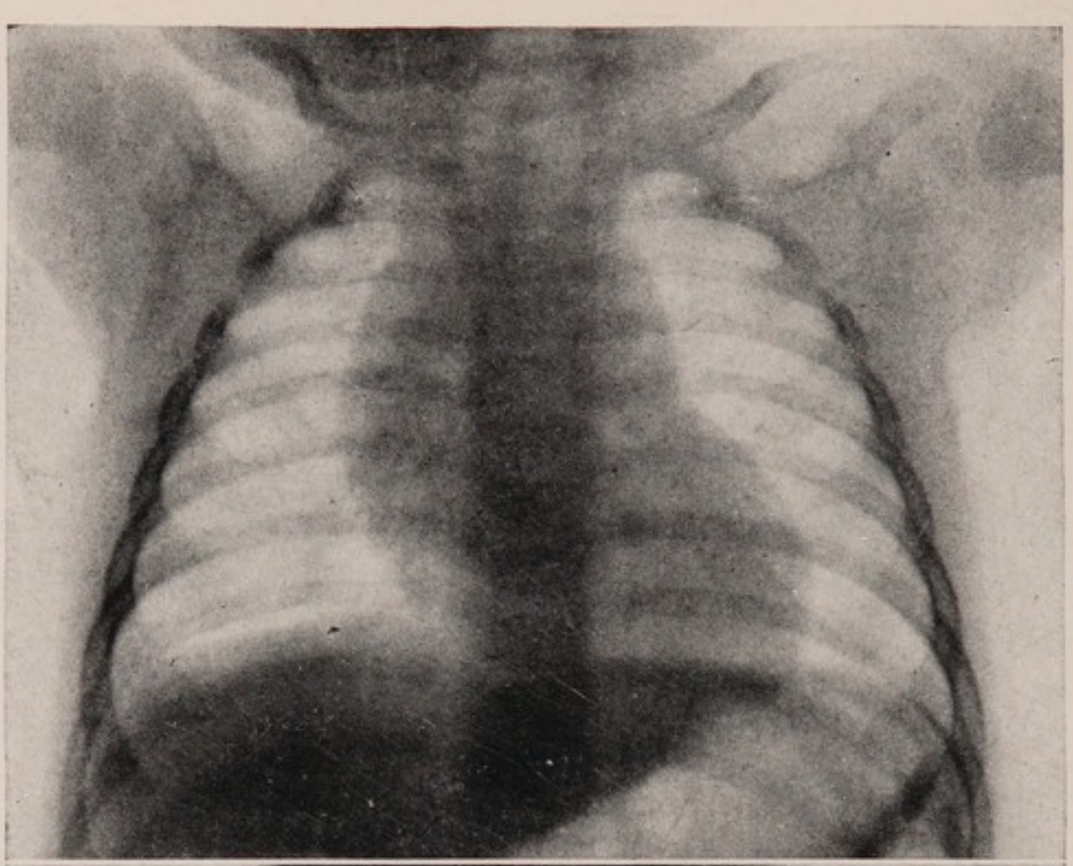
The shadow cast by the thymus is in the superior mediastinum, extending from the clavicles downward to the heart, which it overlaps laterally. The density is slightly less than the heart shadow. The outline is clean cut, sharply demarcated from the lungs, and is wider below than above. A lateral view may show a thick narrow thymus pressing upon the trachea.

The shadow cast by an enlarged thymus is not distinctive. A similar picture is caused by enlargement of the mediastinal lymph nodes. These nodes may enlarge in tuberculosis, as a response to near-by suppuration, or when the patient incurs one of the group of diseases classed as lymphoblastoma.

Differentiation depends on the law of probabilities. When the patient is under two years of age thymus enlargement is common, the other conditions that might cause widening of the mediastinum infrequent or rare. A patient over two years old is not likely to have an enlarged thymus, and is liable to incur the other conditions, especially tuberculosis of the mediastinal lymph nodes.

When the thymus is enlarged and is the cause of symptoms the response to *x*-ray therapy is immediate. One-

A.



B.

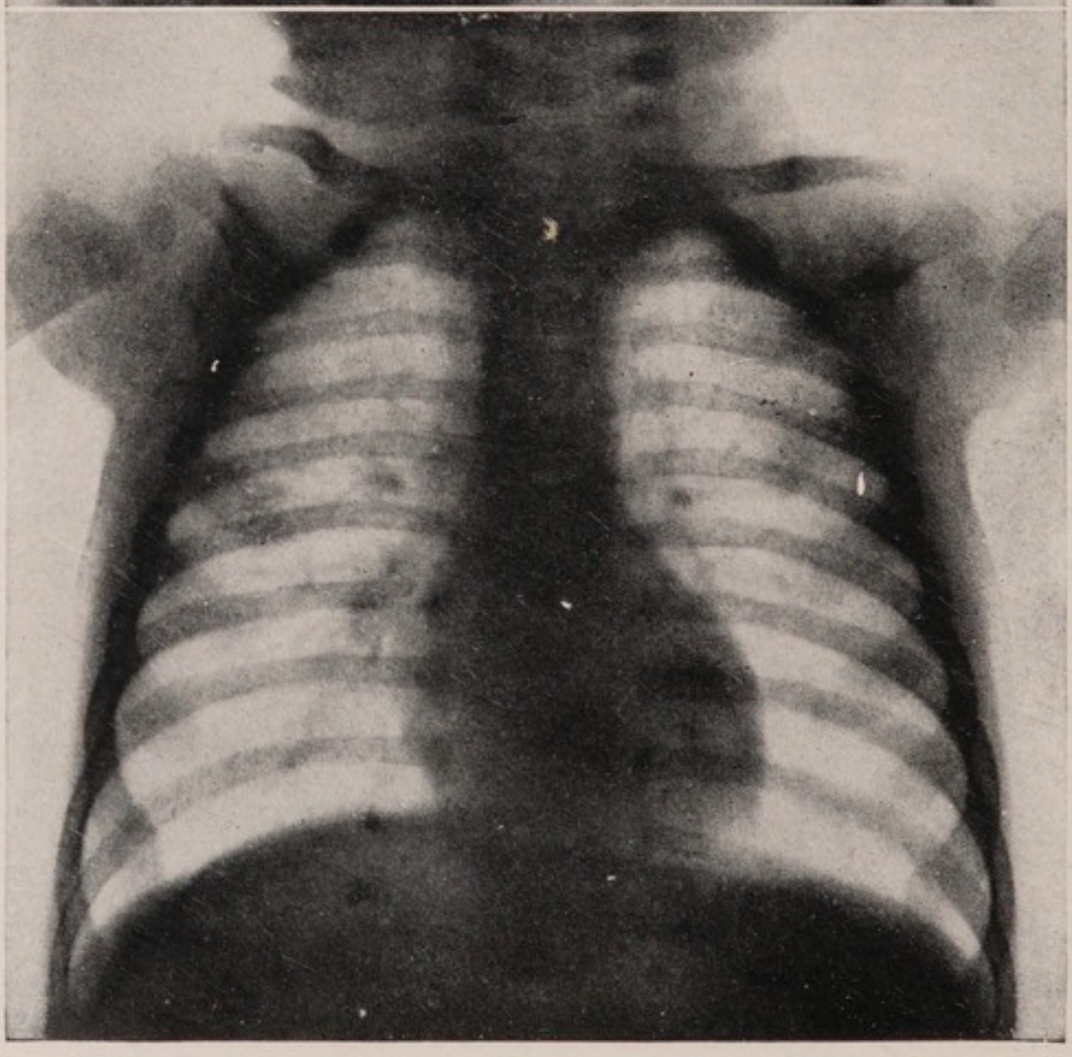


FIG. 182. A. Enlarged thymus: infant, aged four and one-half months. B. Same patient, three weeks following *x*-ray therapy; widening of thymic shadow is absent. (From Stoloff: The Chest in Children. Annals of Roentgenology, Vol. XII.)

tenth of a unit skin dose applied to the anterior chest will cause the symptoms to subside within a few hours; the size of the thymus may become less at a later date. This favorable response must not be considered a therapeutic test for diagnosis, as the same dose may give equally immediate results in other diseases associated with a widened mediastinal shadow.

Intrathoracic thyroid casts a shadow in the superior mediastinum that is slightly less dense than the heart. The shape is nearly triangular, with the base of the triangle upward and continuous with the shadow of the thyroid in the neck. The trachea or the esophagus may be pushed to one side or compressed.

Silicosis (pneumoconiosis, anthracosis) is a disease caused by the inhalation of free silica (SiO_2). It is found in hard rock miners, granite cutters, anthracite coal miners, and to a lesser extent among soft coal miners and coal handlers. The lung changes are slowly progressive, the rate of change depending on the quantity of inhaled silica, and on the individual. Three stages are described.

First Stage. The hilus enlarges; small densities, varying in size from 2 to 5 mm., appear at the bifurcation of the bronchi; the interlobar septa and the linear markings are beaded. These changes affect the center of the lungs more than the periphery, the right side more than the left.

Second Stage. As the silica inhalation continues, the small densities increase in number and in size, but the hilus density decreases. The distribution continues to be central, both the number and the size of the lesions are less toward the periphery; the apices are usually clear, as is the extreme base. Unless the individual is withdrawn from his exposure to silica the process continues to advance and a haze appears over the upper lobes.

Third Stage. Fibrous tissue is laid down, which distorts lung structure, renders the lung inelastic, displaces the contents of the mediastinum, and contracts

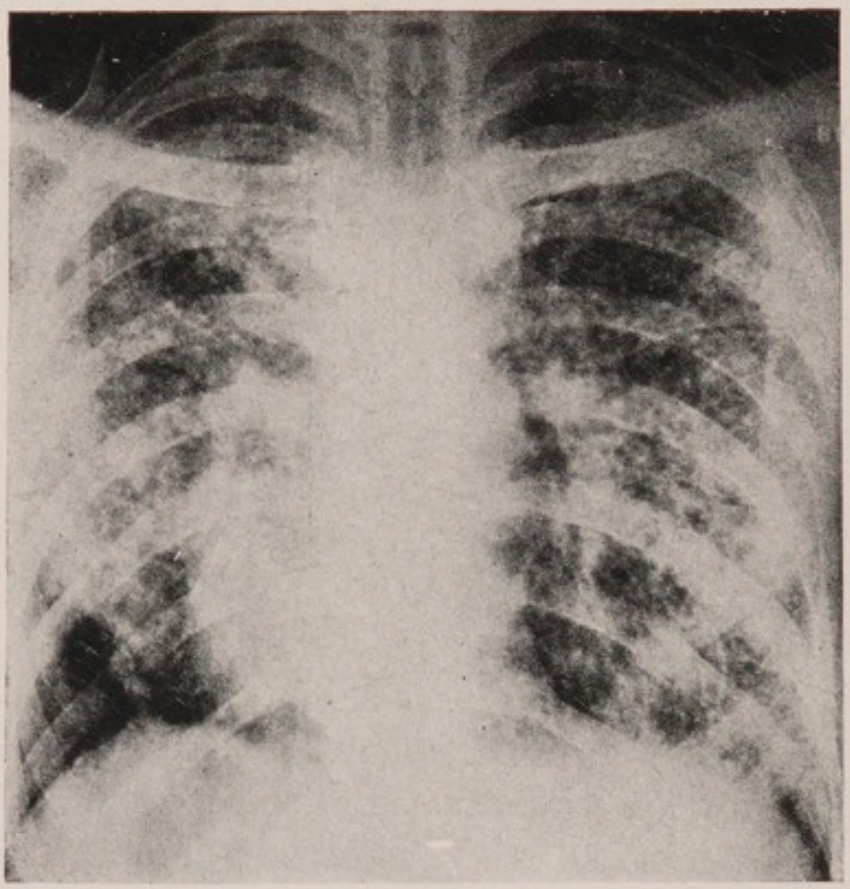


FIG. 183. Silicosis, third stage. (From Sante: The Chest. Annals of Roentgenology, Vol. XI.)

the thorax. Up to this stage relief from exposure to the inhalation of silica is followed by regression in the lung changes.

Silicosis is frequently complicated by pulmonary tuberculosis. Uncomplicated silicosis seldom affects the upper lobes or the periphery of the lung; lesions occurring in these places are likely to be tuberculous in origin. The differentiation is difficult, uncertain, and not to be relied upon. In the later stages silicosis and tuberculosis may present an identical appearance on the film.

Other mineral dusts, and even inorganic dusts in heavy doses, are said to cause changes resembling those due to silica, although less in degree.

Tumors in the chest are metastatic or primary. Metastases to the lungs may complicate malignant disease in any part of the body, and are often found in cases of bone sarcoma, carcinoma of the breast and hypernephroma. Primary tumors of the chest are less frequently encountered. They comprise 1 per cent of all carcinomas.

Whatever the class of malignant disease: carcinoma, sarcoma, hypernephroma, thyroid tumor, or other, the shadow of the growth on the film is similar, and differentiation by the appearance of the radiograph is unreliable.

It is convenient to describe metastatic malignancy separately from the primary lesions, but it is evident that a solitary metastasis may run a similar course and give the same picture as does the single primary focus.

Metastatic malignancy occurs in three forms, depending on whether the route is by the blood stream, by the lymphatics, or by direct extension to the pleura.

When the seeding is by the *blood stream,* multiple nodules appear particularly where the blood supply is largest: in the central zone and the lower lobes. At first minute spots are seen; slowly the spots increase in size until they may reach a diameter of 2 to 3 cm.—the size of the nodules depends on the stage of the process. The appearance also depends on the rate of growth.

Some types of malignancy grow rapidly; there is a grey line of growth fringing the mass, and around this a narrow zone of exudative reaction. Other types grow slowly; their outline is circumscribed and there is no zone of reaction. Some forms may break down at the center and may be evacuated, with cavity formation.

This nodular type may resemble tuberculosis. It differs in that there is no deposit of fibrous tissue and all the nodules have the same general appearance—are the same

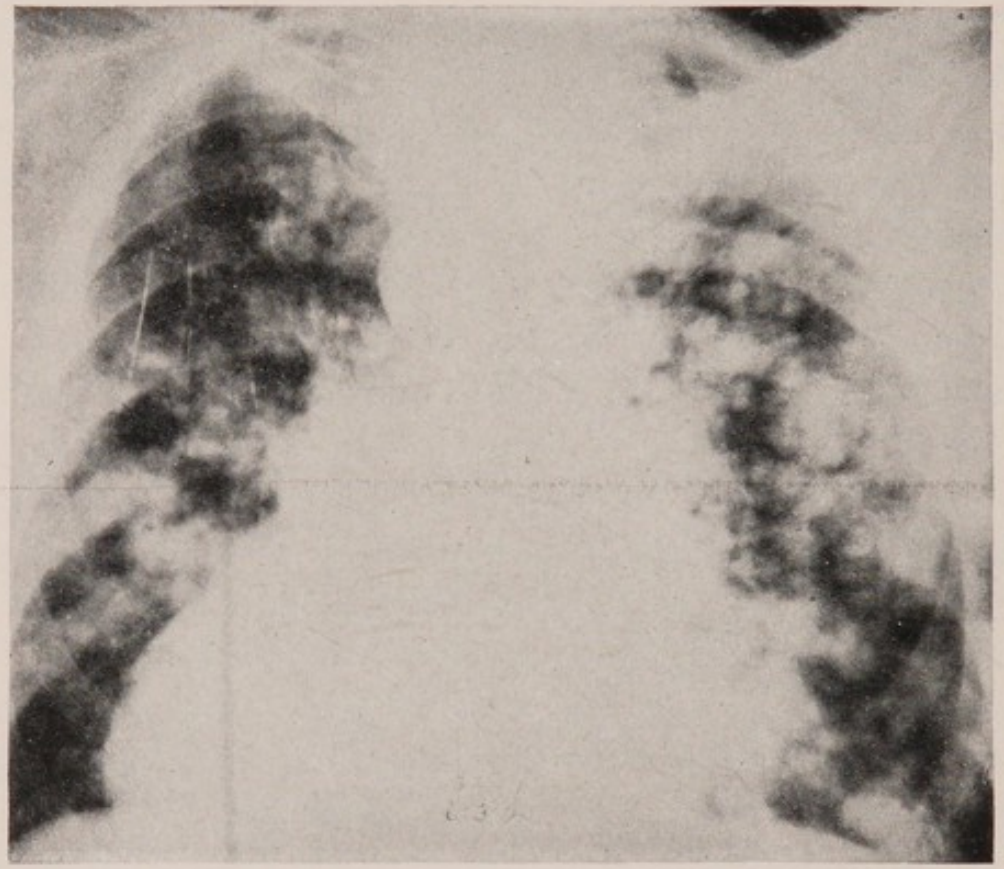


FIG. 184. Metastasis to lung following sarcoma of bone. (From Sante: The Chest. Annals of Roentgenology, Vol. XI.)

age. Tuberculosis lays down fibrous tissue, and in all forms except the miliary the nodules present diverse appearances. It is true that miliary tuberculosis occurs, as does metastatic malignancy, by a hematogenous seeding to all parts of the lungs simultaneously; but the tuberculous lesions are smaller, less definite, and less circumscribed than are the nodules of malignant metastasis.

Metastasis by the lymphatics involves the mediastinum and the glands at the hilus. The shadow cast by the mediastinum is wider, the hilus on one or both sides more prominent. At first the changes are too slight to warrant

any conclusions, unless previous radiographs of the patient are at hand. Later the growth in the glands attains definite size, and columns of tumor cells extend along the lymphat-

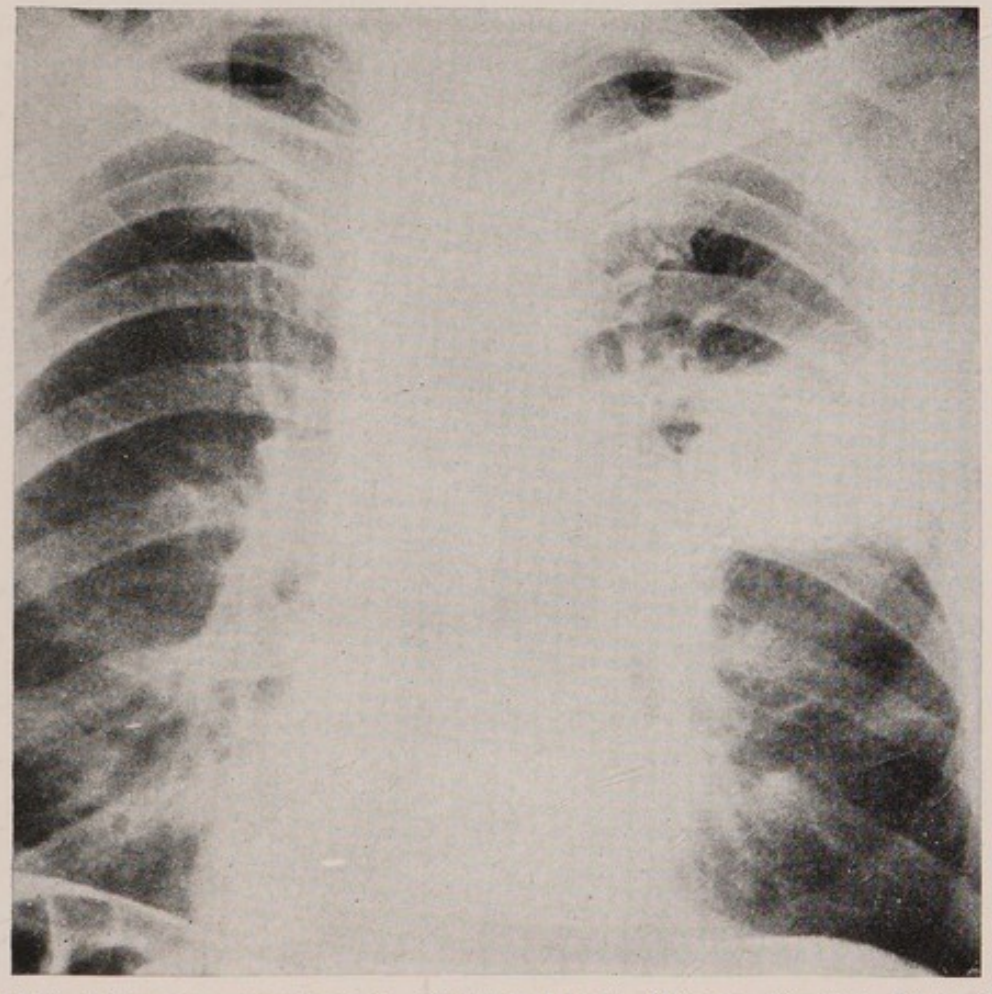


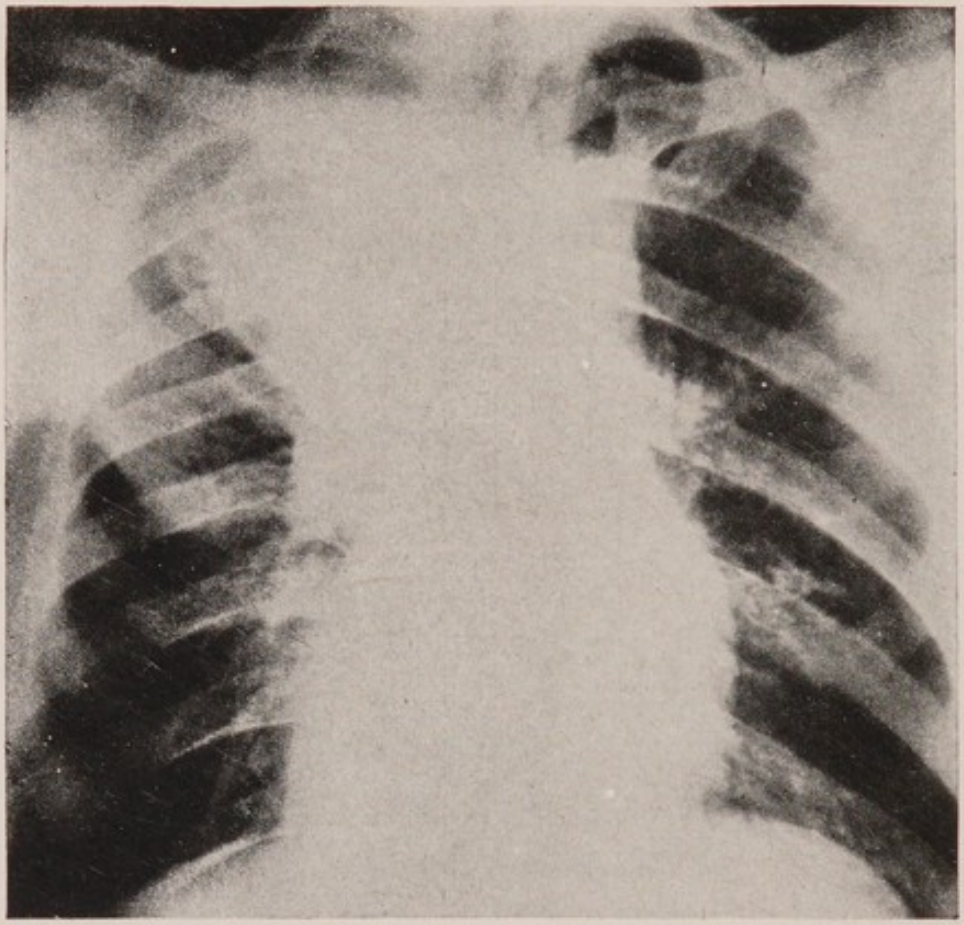
FIG. 185. Primary carcinoma of the lung. (From Sante: The Chest. Annals of Roentgenology, Vol. XI.)

ics into the lung fields. The film shows the masses at the hilus and definite enlargements of the linear markings close to the hilus. Because of its appearance, this type of malignancy is called "infiltrative."

Metastasis by direct extension to the pleura is from disease primary in a breast. The pleura is thickened; the radiograph shows a faint shading so indistinct as to cause doubt as to its presence. Later fluid forms in the pleural sac. In the

presence of known carcinoma of the breast the suspicion of malignant disease of the pleura is then justified.

Primary malignancy usually arises in a bronchus close to



A

FIG. 186. Bronchial carcinoma. (From Sante: The Chest. Annals of Roentgenology, Vol. XI.)

the hilus, but may begin in the parenchyma or in the pleura.

When the point of origin is in a bronchus the growth may enlarge en masse or it may extend along the wall, along the lymphatics, or bud into the lumen. Thus the growth may be lumpish and massive, or infiltrating, columns of tumor cells extending in rays from the focus of origin. Metastases may appear either in the same lung or in the opposite side. The pleura may be invaded. There is a form of multiple origin affecting a large part of the lungs simultaneously; this type is called miliary.

Secondary changes occur. When a bronchus is completely occluded there is atelectasis with its familiar sequence: absorption of air, collapse, increased density, and displacement of structures toward the collapsed area. Blood supply may be impaired; there follows necrosis, liquefaction, extrusion of the liquefied portion and cavitation. There may be an infectious pneumonia in the whole or a part of a lobe. Interference with lymph channels or direct seeding on the pleura may cause an exudate that is usually serosanguinous but is occasionally purulent.

Because of this varied course and the sequelae that may ensue, the radiograph may show a wide range in the shape, density, and distribution of shadows. The disease may be conveniently considered according to the location of the point of origin.

Hilus Malignancy. On one side the hilus is denser; the density is not uniform. The area of the hilus density is enlarged. The outline is better circumscribed, and the usual crescentic curve is replaced by an outward bulge. The contour varies; when the tumor grows massively the contour is clean cut, sharply demarcated, but when the growth is infiltrative the contour is not sharply defined but is indefinite, rays of tumor casting their shadows as an irregular fringe about the hilus.

Such a radiograph leads to the suspicion of malignancy but is not definitive evidence. Decision depends on the course as shown both clinically and on the film. Further extension along lines characteristic of tumor growth, atelectasis, or a pleural effusion may satisfy the examiner that malignant disease of the lung is present.

Parenchymal Malignancy. The radiograph shows a solitary opacity, circular or oval, the density of any grade, the shading uniform, the contour smooth and rounded, and the demarcation from adjoining lung complete.

Pleural malignancy usually causes no symptoms until well advanced. At this time the radiograph shows on one side the flat white characteristic of a large effusion with little or no displacement of the heart or trachea. Thoracentesis withdraws serosanguinous fluid that may contain tumor cells. A second radiograph taken after fluid is withdrawn continues to show the same density, as the tumor plastered on the lung casts a dense shadow.

Miliary carcinomatosis shows multiple pinhead-sized opacities; later the minute densities increase in size and coalesce.

Differentiation is from those conditions that most nearly approximate the picture at the moment. The radiologist rarely sees the patient when malignant disease of the lung is in its early stages; usually the patient experiences no discomfort at first, and seeks medical advice only after the tumor has attained considerable size or one of its sequelae has developed. It is seldom advisable to make a diagnosis on the evidence given by the films taken at any one time; dependence may be placed on repeated examinations, correlated with the clinical findings.

Among the conditions that may imitate the radiographic appearance of lung tumor, hilar adenopathy, tuberculosis, lung suppuration, and chronic interstitial pneumonia are the most troublesome.

Mediastinal or hilar adenopathy, whether caused by tuberculosis or lymphoblastoma, is usually bilateral; malignancy is unilateral. An adenopathy is sharply demarcated throughout its entire outline; malignant disease, even the massive type, shows an area at some point where the delimitation is not well defined.

Tuberculosis is rarely confined to one lung. Cavitation may be present in both tuberculosis and malignant disease, but in the tuberculous lung there is associated fibrosis, in

malignant consolidation there is not. The tuberculous lung may be reduced in size, as may the lung the site of malignant disease associated with atelectasis; but the tuberculous lung is irregularly puckered, the malignant growth is evenly collapsed. In the terminal stages of a malignancy the two conditions may be exactly similar and differentiation must rest upon the history. In miliary tuberculosis the lesions are multiple, small, and discrete; in miliary carcinomatosis they are also multiple, small, and at first discrete, but later coalesce. Acute pleurisy with effusion may give an identical clinical onset and closely resemble the picture of malignancy with pleural involvement. In cases of malignant disease thoracentesis withdraws bloody fluid, and the radiograph taken afterward continues to show the same density. Chronic tuberculous pleurisy with thick caseous masses casts the same dense shadow as does the pleura thickened by tumor, even in the absence of effusion.

Lung suppuration, especially when of long standing, may closely resemble a broken-down tumor with cavitation; but an old lung abscess is smooth and rounded; the cavity in a necrotic tumor is uneven and nodular.

Chronic interstitial pneumonia may resemble malignancy with areas of atelectasis, but runs a different course and has not the same clinical history.

Benign tumors of the lung may exactly resemble a parenchymal lesion; but benign tumors are rare, and may be diagnosed only after the progress of the case has definitely excluded malignancy.

Echinococcus cysts of the lung are definitely circumscribed spheres which displace lung tissue.

Mediastinal tumors usually originate in the superior or anterior mediastinum. They may be sarcoma, lymphoblastoma, or dermoid. Some are benign but most are malignant. The tumor casts a definite shadow on the film, over-

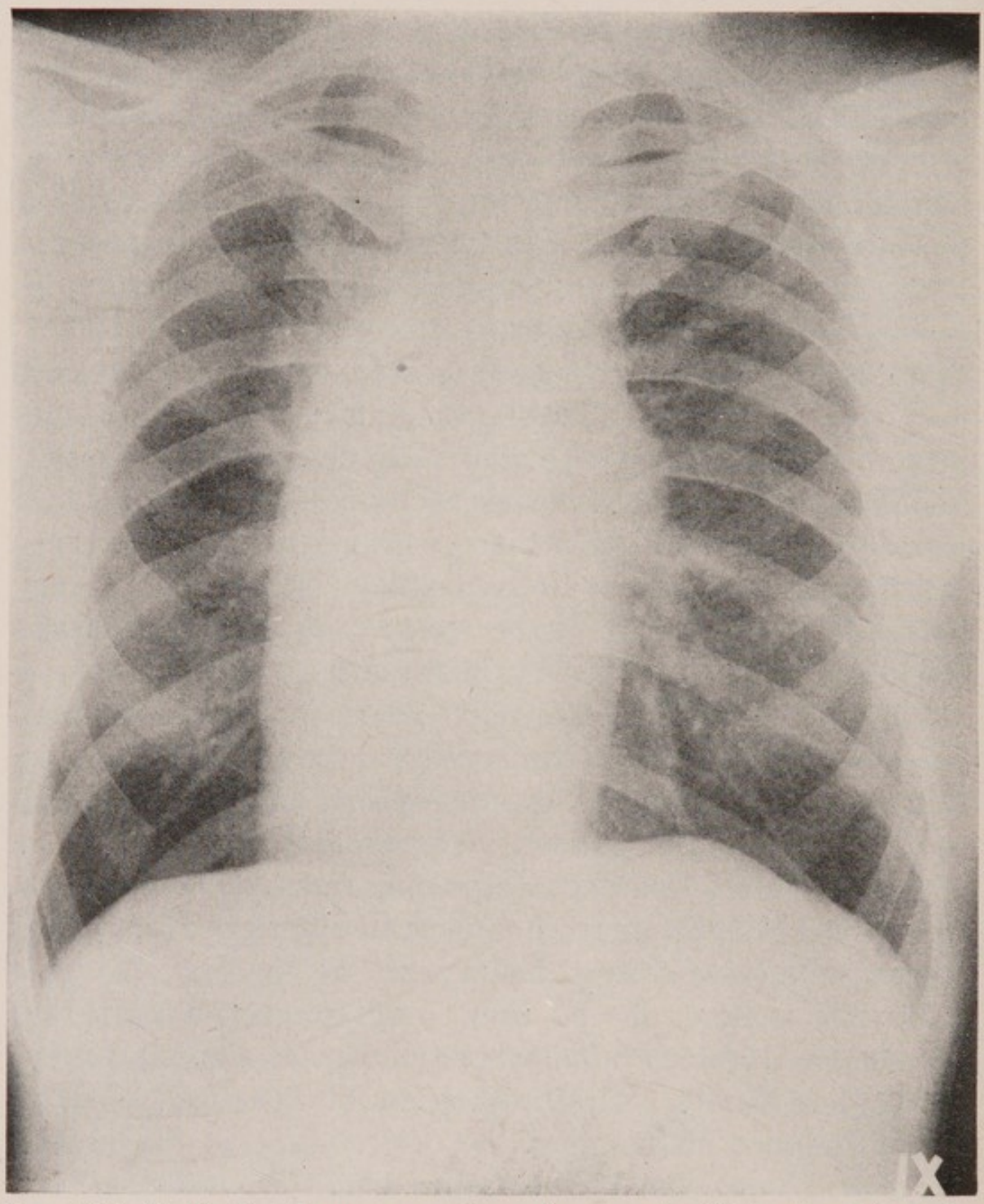


FIG. 187. Mediastinal tumor; massive enlargement of intrathoracic nodes.

lapping the great vessels or the heart, extending farther to one side than to the other. The density is usually less than that of the heart; the outline is distinct. The exact position in the chest is determined by a fluoroscopic examination, supplemented by films taken at such angles as the fluoroscopic study shows to be the most informative. When the tumor is not in close contact with a large artery it does not pulsate. But when a tumor is in intimate contact with the aorta it does pulsate, each expansion of the artery causing a definite excursion in the tumor outline. Tumors of the mediastinum are apt to cause varicosities in the superficial veins of the thorax.

Of all the tumors that may arise in the mediastinum, lymphoblastoma is the most frequent and is the most important. This term includes Hodgkin's disease and lymphosarcoma. In this form the shadow of the mediastinum is widened, the outline distinct but wavy. The hilus shadows on each side are enlarged, nodular, the crescentic outline replaced by a bulge. *X*-ray therapy is followed by immediate though temporary regression.

The other types resemble each other closely. It is not easy to determine whether the condition be benign or malignant, as even the malignant types may grow slowly. An effort should be made to differentiate tumor from aneurysm.

Aneurysm of the Thoracic Aorta. In the diagnosis of aortic aneurysm fluoroscopy is far superior to radiography because we are dealing with an organ in motion. The film merely furnishes a permanent and graphic record for comparison with later examinations. The patient should be fluoroscoped in several directions. The dorsoventral position furnishes the most information. The oblique positions show the encroachment upon the posterior mediastinum by an aneurysm of the descending aorta; or brings out more clearly an aneurysm in the ascending aorta and may

show the extent of an aneurysm of the descending aorta. A true lateral view is of value in determining the antero-posterior enlargement.

Though pulsation is not an absolutely reliable sign in all cases, its presence or absence, its character, whether expansile or transmitted, will aid in the diagnosis. Expansile pulsation (pulsation in all directions) suggests aneurysm, especially of the fusiform variety. Transmitted pulsation (pulsation in one direction) occurs when a mediastinal tumor is in close contact with the aorta. In this condition the excursions of the aorta move the tumor, thus giving the appearance of pulsation. On the other hand, very slight pulsation or even its complete absence does not exclude aneurysm. This is especially true of the sacculated variety on account of the thickening of the sac.

Aneurysms may involve any portion of the aorta, but in their order of frequency are seen as follows:

1. Aneurysms of the ascending aorta cast their shadows almost entirely to the right of the spine and lie near the anterior chest wall.

2. Aneurysms of the arch lie in the upper part of the mediastinum, generally in the midline, but may extend to the right or left according to the portion of the arch that is involved. They also are nearer the anterior chest wall.

3. Aneurysms of the descending aorta are almost entirely to the left of the midline and lie nearer the posterior wall.

The shadow of the aneurysm is of necessity confluent with that of the aorta. It is even in contour, rather convex and usually shows no lobulations.

The shadow cast by an aneurysm of the ascending aorta and arch is as dense as that of the heart, because both are situated in the same vertical plane. The shadow cast by an aneurysm of the descending aorta is less dense in the dorsoventral position because it is not in the same verti-

cal plane as that of the heart shadow, being situated more dorsally.

The large aneurysms are usually fusiform. The smaller ones are either sacculated or fusiform. As a general rule, those of the arch are more frequently sacculated; those of the descending and, to a lesser extent, those of the ascending, are more frequently of the fusiform variety. It is important to remember, however, that there are dilatations of the aorta which are not aneurysms in the true sense of the word. This fact must be borne in mind when examining adults beyond middle age, because in them a moderate enlargement and lengthening of the aorta are common. This is shown usually by an increased prominence in the upper part of the chest to the left of the spine, as the aorta turns downward and backward. In cases of atheroma, the aorta may be uniformly dilated throughout its entire course. In such cases it extends to the right of the sternum, the arch is prominent and the descending portion may be seen as a faint shadow to the left of the spine. This condition is frequently associated with hypertrophy of the left ventricle and aortic insufficiency. On the other hand, enlargement of the heart is generally not associated with aneurysm.

The most common difficulty encountered is the differentiation between aneurysm and mediastinal tumors. The following points may be helpful:

The shadow caused by an aneurysm is usually denser than that of a tumor.

Large aneurysms of the aorta, especially of the first portion, displace the heart downward and often to the left. Tumors nearly always displace the heart laterally.

Large aneurysms of the arch and descending aorta displace the trachea and esophagus, while tumors, except intrathoracic thyroid, envelop them.

Fluoroscopy in the oblique positions will help to establish the relation of the aneurysm to the heart, aorta and the other thoracic organs, which cannot otherwise be done. In this manner, we can sometimes recognize the normal contour of the aorta within a shadow which is suspicious of aneurysm and thus establish the diagnosis of tumor rather than of aneurysm.

Growth of the aneurysm may produce changes in the adjacent viscera or in the spine. These changes are entirely mechanical and due to pressure.

Pressure upon the esophagus may cause displacement and obstruction, which is at times almost complete. In case an aneurysm is very large, it is advisable to examine the esophagus with the aid of a barium mixture so as to determine the presence of esophageal obstruction, or compression. Often the fluoroscope would show pressure upon the esophagus long before the patient noticed difficulty in swallowing.

Pressure upon a bronchus may cause bronchostenosis or even atelectasis. In such cases the fluoroscope shows in the lung field supplied by the bronchus a darker area which does not become lighter upon deep inspiration. Occasionally the severe spinal symptoms associated with aneurysm are due to actual erosion of one or more vertebrae from pressure.

X-Ray Examination of the Heart. The method of choice in the roentgen study of the heart is fluoroscopy. The reason for this is that the heart is an organ in continual motion, and a study of its movement is essential to a proper interpretation of the shadows. The film gives such a distorted image of the heart that it may give rise to entirely erroneous deductions. Of all the methods, orthodiagraphy, combining as it does direct observation and a true graphic image of the heart, is most valuable.

The cardiovascular shadow is composed of a number of curves, two on the right side and three or four on the left, which represent the following parts:

The right upper curve represents superior cava or, occasionally, the ascending aorta.

The right lower curve represents the right auricle.

The left upper curve represents the arch of the aorta.

The left middle curve represents the pulmonary artery.

The left lower curve represents the left ventricle.

Occasionally the curve of the left auricle is seen between the middle and lower curves. (Fig. 188.)

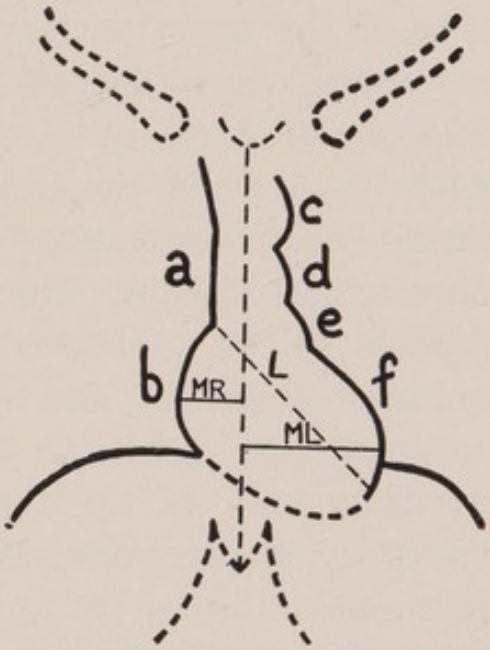


FIG. 188. Normal heart (orthodiagram).

a, Vena cava superior. *b*, Right auricle. *c*, Descending arch of aorta. *d*, Pulmonary artery. *e*, Left auricle (occasionally seen). *f*, Left ventricle. The right ventricle is never seen in this position.

MR, Longest distance between the median line and the right border. *ML*, Longest distance between the median line and the left border. *L*, Longitudinal diameter. *ML* + *MR* equals the transverse diameter, *T*.

The shape and extent of these shadows which form the contour of the heart are more or less constant though they are subject to slight physiological variations. At times these shadows are ill-defined and a study of their pulsations may be necessary to distinguish them. The latter differ both as to their amplitude and their time phase. Thus the right lower curve of the auricle shows a very faint pulsation presystolic in time. The curve of the left ventricle has the widest pulsation systolic in time. The aortic and pulmonary curves show a moderate expansion synchronous with the contraction of the ven-

tricles. The left auricular appendage is poorly seen in the ordinary position and shows only a slight presytolic undulation.

Normal Variations of the Heart Shadow. The configuration of the heart shadow is determined to a considerable extent by the obliquity of its long axis. But this is frequently affected by extrinsic factors. Thus it will vary with the type of the thorax, being more horizontal in the broad-chested and more oblique or vertical in the narrow-chested or asthenic individual. Adiposity or gaseous distention of the intestines may rotate the heart into a more horizontal position and may mold it so that it will simulate a hypertrophy. In the aged the heart is less oblique in position and its apex becomes blunted. There is some variation in the prominence of the individual curves. The pulmonary artery is at times abnormally large without any evidence of cardiac disease. The arch of the aorta, especially in persons beyond the age of forty, is frequently prominent, and this should not be looked upon as evidence of serious disease. It is, therefore, important in estimating the significance of a particular cardiogram to keep in mind these normal variations.

Dilatation and Hypertrophy of the Heart. A dilatation of the cardiac cavities results in an increase in the size and prominence of the contour together with an increase in the values ML and MR. In the case of the left ventricle this results in a more horizontal position of the heart, so that it acquires a shape which has been compared to that of an egg. The ventricular border formes a sharp angle near the pulmonary curve and the apex is blunted. A dilatation of the right ventricle by itself produces no enlargement of the heart, but it changes its conformation by dilating in an upward direction, so that the conus arteriosus and its right auricular attachment are displaced upward.

The heart thus acquires a more vertical and globular aspect. A marked enlargement to the right is usually due to a coincident dilatation of the right auricle. It is well to

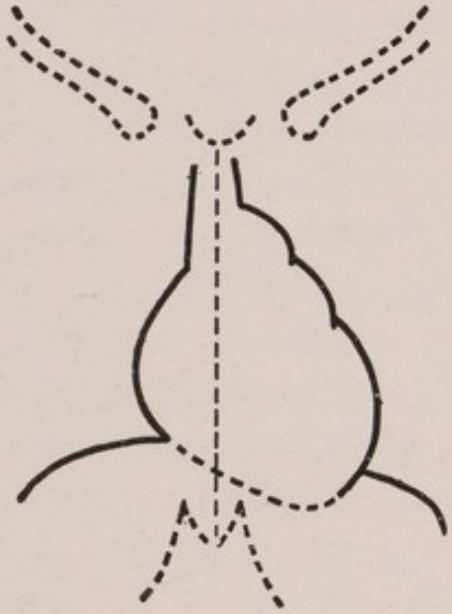


FIG. 189. Mitral insufficiency: Entire cardiac shadow enlarged (except right vena cava). The prominence of the pulmonary artery is not due to enlargement of the artery itself but to displacement by the enlarged heart.

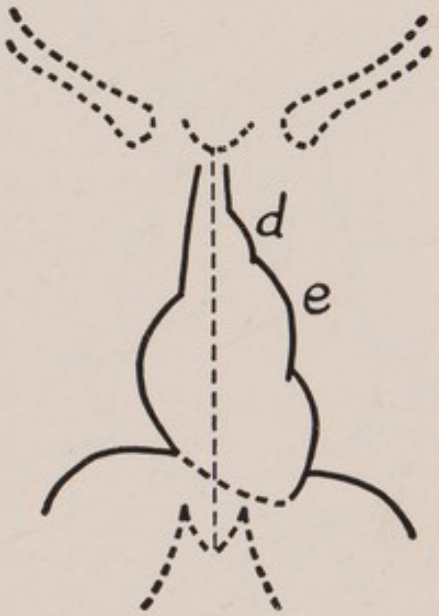


FIG. 190. Pure mitral stenosis: Marked enlargement of the left auricle (*e*). Heart otherwise not enlarged. Pulmonary artery (*d*) may be slightly enlarged. Aortic arch not shown on this sketch.

bear in mind, however, that whereas clinically a distinct increase in absolute heart dullness to the right may be found, the *x*-ray frequently in such cases shows the right heart border to be in its normal position.

The greatest enlargement to the left is found in cases of aortic insufficiency, in the hypertensile form of chronic nephritis and in advanced mitral disease; enlargement to the right is most often found in all forms of decompensation and in congenital heart disease.

Displacement of the Heart. This is readily recognized. One of the most frequent causes is chronic tuberculosis in which the heart is usually drawn over by pleural or medias-

tinal adhesions to the side containing the oldest lesions. Pleural effusions frequently displace the heart to the opposite side. This, however, is not an invariable rule, as the heart may occasionally be in its normal position even in the presence of a large effusion. In kyphoscoliosis the heart is frequently displaced and rotated; on the other hand this does not invariably result, as the heart may be normally situated in spite of marked thoracic deformity. In emphysema and asthma the heart is often hypoplastic and its apex depressed below the sixth interspace so that it acquires the shape of a drop heart. The most extreme displacement may be found in eventration of the diaphragm, so much, in fact, that a dextrocardia is closely simulated, when the eventration is on the left side, a more frequent position than on the right.

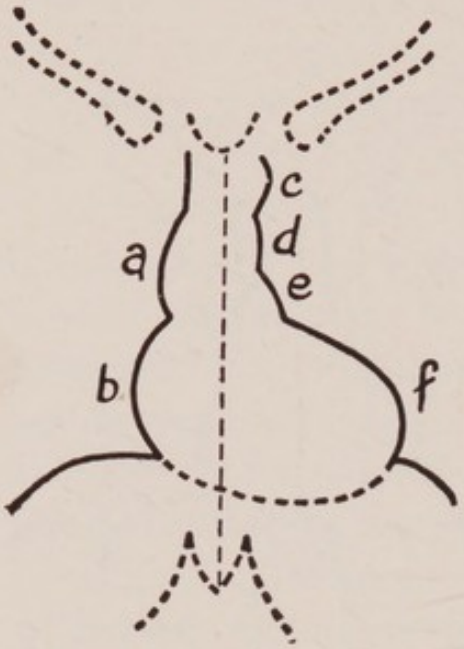


FIG. 191. Aortic insufficiency: Left ventricle (*f*) markedly enlarged. Left auricle (*e*) and pulmonary artery (*d*) little affected. Aortic arch (*c*) more prominent. (*a*) in this case, represents ascending aorta masking vena cava superior. *a* and *c* are actually enlarged in advanced stages. In the early stage they are more prominent because of the increased volume of blood they have to carry.

The transverse position of the heart is characteristic of this condition.

Valvular Lesions. The mechanical changes produced by valvular lesions and the resulting alterations in the cardiac cavities are faithfully reflected in the heart shadow. Each cardiac lesion or its combination with others has a more or less characteristic silhouette. Some of these are represented in Figures 189–191. Of particular importance is the recognition of the early stages of mitral disease. The earliest signs

noted are a slight enlargement to the left, an increased prominence of the pulmonary artery and of the left auricle, and a tendency toward globular shape.

Nephritis and Arterial Hypertension. In their early stages these two conditions produce a hypertrophy of the left side of the heart with little or no dilatation. The appearance on the screen is characteristic. The heart is horizontal, egg-shaped, and is blunted at the apex. As these conditions are frequently combined with atheroma of the aorta, the latter is usually seen to be dilated and irregular in outline. (Fig. 192.) These cases are frequently confused with aneurysm, owing to pulsation of the aorta; this error can be avoided by noting the diffuse character of the aortic dilatation and the enlargement of the left ventricle. In the later stages of chronic nephritis we see evidence of failure of the left ventricle, namely, enlargement to the right and prominence of the left auricle and of the pulmonary artery. The amplitude of the pulsation as noted on the screen bears no relation to the amount of hypertrophy or dilatation nor to the muscular strength of the

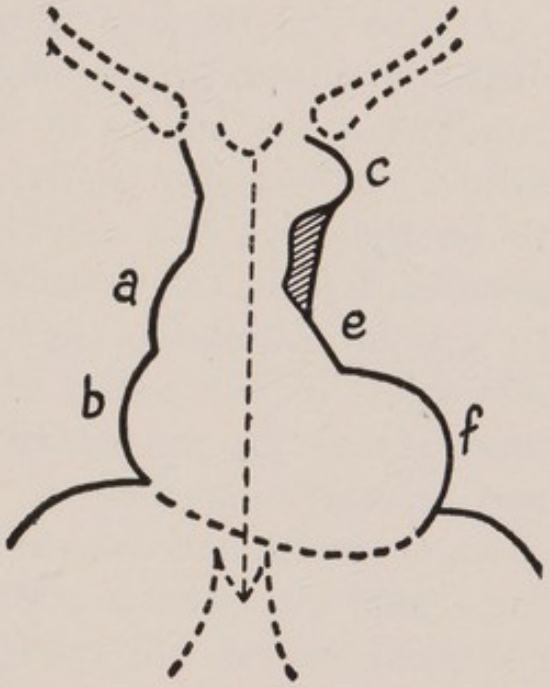


FIG. 192. Atheroma of the aorta: (Arterial hypertension, chronic nephritis). Aortic arch (*c*) and ascending aorta (*a*) enlarged. Pulmonary artery not seen on account of actual dilatation of aorta to left (shaded area). In this illustration enlargement of heart is due to chronic nephritis.

While aortic dilatation is frequently associated with cardiac enlargement from various conditions, it may occur unaccompanied by heart changes in individuals beyond middle age. In young individuals, on the other hand, it is invariably associated with cardiac changes.

ventricle. The largest hearts may show practically no pulsation, and inferences as to cardiac failure should not be drawn from its absence.

Angina Pectoris and Anginoid Pains. Precordial pains, anginoid in type, are found in a variety of heart and arterial conditions, the nature of which may be disclosed by the *x*-rays. In younger individuals they are usually found to be based on the valvular diseases, particularly aortic insufficiency. In the latter, especially when it is consecutive to syphilitic aortitis, the examination will show a slight dilatation of the aorta at its origin. In older persons, angina may be associated with atheroma of the aorta and arterial hypertension. The aorta is seen to be thickened, tortuous, and dilated throughout and frequently contains lime placques. A study of the ascending aorta in an oblique position will reveal an enlargement of the conus arteriosus.

A large group of cases of angina pectoris in adults is primarily due to sclerosis or thrombosis of the coronary artery. There is no change in the size or shape of the heart, and the aorta is little, if at all, dilated. In these cases the examination has only a negative diagnostic value in excluding the conditions previously mentioned. It is important to emphasize that in these cases there may be an infarction of the heart muscle with extreme fatty and fibrous degeneration, but with no evidence of enlargement of the heart even shortly before a fatal termination.

So-called Functional Heart Disease. There is a fairly large number of individuals in whom systolic murmurs at the apex of the heart are heard and in whom no other evidence of heart disease is found. The question will always arise whether these persons have valvular lesions or whether the murmurs are so-called functional or accidental ones. In such cases, the most important factor to determine is an

enlargement of the heart. Examination may be of decisive value in these cases. In a case of such a doubtful heart murmur, if no enlargement of the heart or change in its configuration are shown, it may be fair to assume that the murmur is not valvular in origin.

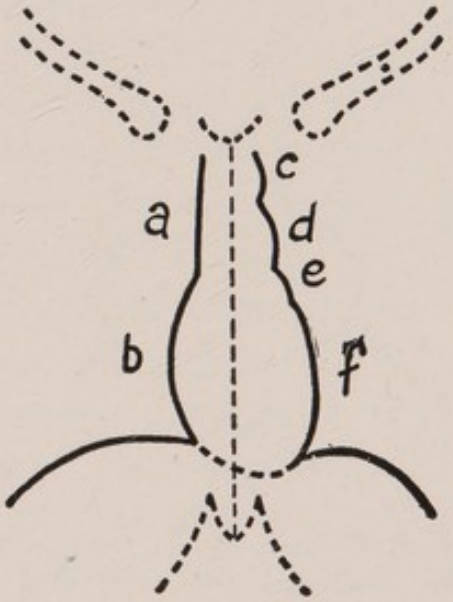


FIG. 193. Drop heart.

In a similar way we may have recourse to the *x*-ray in a study of the various functional disturbances resulting from excessive work or nervous excitement incidental to a soldier's life. The marked cardiac overaction in these cases makes accurate percussion difficult, and frequently gives the impression of an enlargement of the heart. This enlargement is only apparent and is due to the so-called irradiation of the apical impulse. Whatever the mechanism of the cardiac weakness in these cases, the *x*-ray examination shows that it is not due to a dilatation of the heart. On the contrary, the asthenic individuals who are especially prone to these functional disorders under stress frequently have hypoplastic or drop hearts (Fig. 193).

Heart Function. Little, if any, deduction of value as to the function of the heart muscle can be drawn from the *x*-ray examination. The amplitude of contraction of the left ventricle is no index of its muscular power. Normally two types of contraction may be seen, a strong and a weak. The former is commonly noted in nervous or erethic individuals and in the asthenic or drop heart. The latter is noted in subjects who are less influenced by the excitement induced by the novel examination. Fluoroscopic tests of function have been barren of results. The heart in all

individuals reacts to muscular work by a decrease in its size, which is closely related to the degree of tachycardia. The heart responds in a similar manner to a change from the recumbent to the upright position. Cases of organic disease react to these maneuvers pretty much as normal hearts do. As far as is known, dilatation of the heart after exertion cannot be used as a test of function, as it rarely if ever occurs under experimental conditions. Little change is noted in the size of the heart after treatment, even though there be marked improvement of the symptoms. In cases which show a marked recession of the cardiac borders after treatment the possibility of the resorption of a moderate pericardial effusion should be considered.

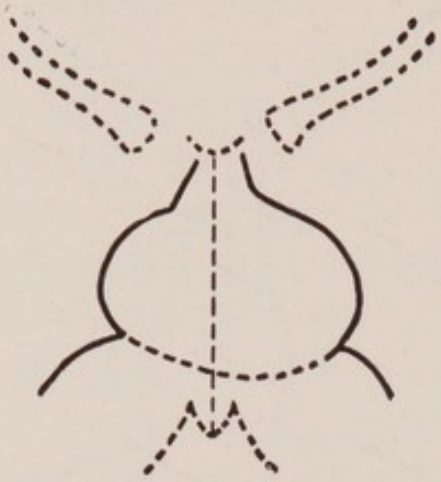


FIG. 194. Large pericardial effusion. Heart shadow is enlarged laterally and upward, encroaching upon aorta. Contour divisions are absent.

Pericarditis. A pericardial effusion, if moderate in amount, results in a general increase in the size of the heart shadow. Under these conditions the diagnosis cannot be made. It is only when the pericardial sac is distended with fluid that it produces a characteristic appearance (Fig. 194). The heart assumes a flask shape and extends upward to the first or second rib and also into the right chest, where it frequently occupies as much space as in the left. The heart contours are long; the pulsations are usually not visible, although occasionally a diffuse impulse may agitate the whole mass.

In advanced myocarditis the cardiac shadow is somewhat similar to that of pericardial effusion. The distinguishing features in this condition are that the cardiac silhouette

is more triangular in shape, does not extend as much to the right, and does not encroach upon and obliterate the aortic shadow.

Adhesions between the pericardium and pleura are frequently seen as small pointed projections extending out to the surface of the heart. An obliteration of the pericardium can only be diagnosed if, in addition, there are pleuropericardial adhesions. Under these circumstances, on deep inspiration, with each contraction of the heart the left diaphragm may be pulled up forcibly. This corresponds to what is clinically known as Broadbent's sign.

Heart Measurement. Various attempts have been made to correlate heart measurements with pathological conditions. Considerable caution may be advised for two reasons; first, there is no definite relation between the size of an organ and its functional condition; second, the errors due to unusual position of the heart or bad apparatus adjustment are such as to make the measurements themselves unreliable. Measurements expressed in centimeters or inches connote mathematical accuracy that is untrue and misleading.

A fair estimate may be made by comparing the transverse diameter of the heart and the greatest diameter of the thorax as taken from the inner aspect of the ribs. A comparative study of many individuals has shown there is a fairly constant and simple ratio: the heart diameter should not be greater than one-half the thorax diameter.

APPENDIX

Classifications of Tuberculosis. 1. Pathological—Anatomical. *Fibrous.* Discrete shadows with well-defined borders (fibrous or calcified nodose lesions) band-like and linear markings, sharply outlined stellate shadows, diffuse shadows of irregular density, but with clear-cut margins.

Shrinkage of the part of lung involved, as determined by displacement of the interlobar fissures, approximation of the ribs, lifting of the hilus, elevation of the diaphragm, and displacement of viscera such as the trachea, heart, and aortic arch.

Nodose Productive. Irregular cloverleaf-shaped shadows, with well-defined margins and of medium density, through which the outline of the ribs or of the heart can be seen. These shadows give the film a discrete or diffusely mottled appearance. At the apex or upper part of the lung they are diffuse, with a ring or rarefied area if a cavity is present. In the lower lung fields they become smaller or scattered.

Exudative Lobular or Lobar Pneumonic. Opaque shadows of wide extent with washed margins fusing into the normal lung tissue. The shadows usually spread from the central part of the lung outward in all directions. If cavities form they have ragged, blurred margins.

Miliary. A fine mottling, with small regular shadows equal in size and evenly distributed.

II. National Tuberculosis Association. *Minimal.* A total area involved (parenchymatous) not greater than the area to the upper level of the second chondrosternal junction on one side (both sides may be involved) in the form of scattered mottling or an intense shadow interpreted as pleuritic. No tuberculous complications.

Moderately Advanced. To show an intense shadow, not interpreted as pleuritic, of no greater extent than the area above the upper level of the fourth chondrosternal junction on one side; or areas of rarefaction interpreted as cavities, limited to one interspace; or scattered mottling over a greater area than under Minimal, but not greater than the area of one entire lung and to the level of the second chondrosternal junction on the opposite side. No serious complications.

Far Advanced. To show an intense shadow, not interpreted as pleuritic, of greater extent than the area above the level of the fourth chondrosternal junction of one side, or areas of rarefaction interpreted as cavities larger than one interspace, or scattered mottling greater in extent than under Moderately advanced.

Miliary Tuberculosis.

CHAPTER XII

URINARY TRACT

Preparation of the Patient. To obtain satisfactory results it is necessary to eliminate confusing shadows of substances found in the gastrointestinal tract and to get rid of accumulations of gas in the colon which tend to obscure the kidney shadows and may obliterate small calculi. For that reason it is a condition precedent to every examination of the urinary tract to prepare the patient by thorough catharsis. The patient should be given a vegetable cathartic on the evening before, and an enema two hours before the radiography. The enema should be tap water warmed to the temperature of the body; salt is added, one teaspoonful to the quart, but no soap. The enema should be given with the patient lying down, and slowly, so that one or more quarts enter the colon—sufficient to flush out the entire length of the gut, and bring out fecal residue and gas. Breakfast should be given. Many patients swallow air if deprived of their breakfast; food need not be omitted, as it is non-opaque. The bladder should be emptied immediately before the examination is begun.

If it can be avoided, the patient should not be examined during or immediately following an attack of colic. During an attack he is usually too sick for such an examination. Besides, at that time and immediately after, he is invariably under the influence of an opiate or similar drug which interferes with efficient catharsis and almost always causes the accumulation of gas in the colon.

Pyelography (urography) is the demonstration of the urinary tract by substances opaque to *x*-rays. The demonstration of the renal pelvis and calices is called a pyelogram;

of the ureter, a ureterogram. There are two methods of pyelography: intravenous and retrograde.

Intravenous Pyelography (Fig. 195). Rowntree and his

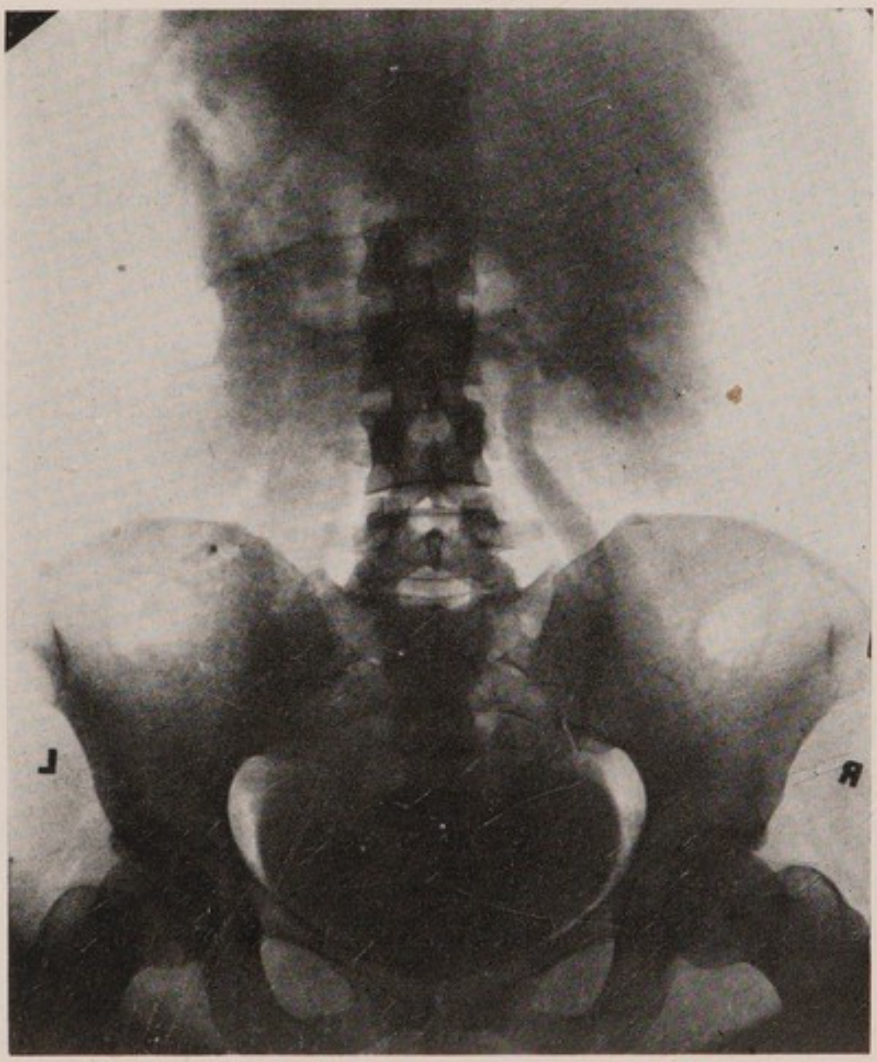


FIG. 195. Normal pyelogram (intravenous pyelography). Right kidney is lower than left. Comparative level varies in different individuals. (After Lubash. *Am. J. Surg.*)

collaborators discovered dyes that would demonstrate the kidney pelvis when introduced intravenously; these dyes caused kidney irritation and were not suitable for clinical use. Roseno, in June, 1929 found a combination of sodium iodide and urea that gave good shadows and caused less irritation. Swick, in November, 1929, discovered a better dye, which he named Uroselectan.

Uroselectan is an iodine-pyridine combination with an iodine content of 42 per cent. It is not toxic and is not irritating. After intravenous administration about three-fifths is eliminated by a normal kidney in the first two hours, one-fourth in the third hour, and practically all the remainder during the next four hours. Kidneys that have impaired function excrete the dye more slowly.

Uroselectan is now named iopax. Any substitute must be non-toxic, not irritating, and cast a satisfactory shadow when introduced intravenously.

Technique. The patient is given the catharsis and enema as already outlined. No fluids are allowed for nine hours before the examination. The dye is introduced intravenously, following the technique usual for the introduction of any fluid intravenously; no special precautions are necessary. After the dye is administered, radiographs are made at the following intervals: fifteen minutes; thirty-five to forty-five minutes; fifty to sixty minutes. When inspection of the films shows that the dye is being excreted more slowly than usual, more radiographs are made at one or two hour intervals.

The radiographs must be made at the time the concentration of the dye in the urine is at the maximum. It has been found advisable to apply compression over the lower abdomen for ten minutes before the radiograph is made, and to continue the compression during the *x*-ray exposure.

As a rule the pyelogram is not as dense as the shadow of dye introduced through the ureter by the retrograde method, but gives a truer picture as the kidney pelvis is not artificially distended. When the urinary tract is normal the shadow may be particularly faint, as the dye is excreted rapidly, the flow of urine is increased, and the concentration in the urinary passages may be insufficient. When there is partial obstruction to the ureter the dye remains in the

kidney longer and the shadow is denser. In some cases associated with impaired function excretion of the dye is delayed, and the pyelogram is dense and clear; in these

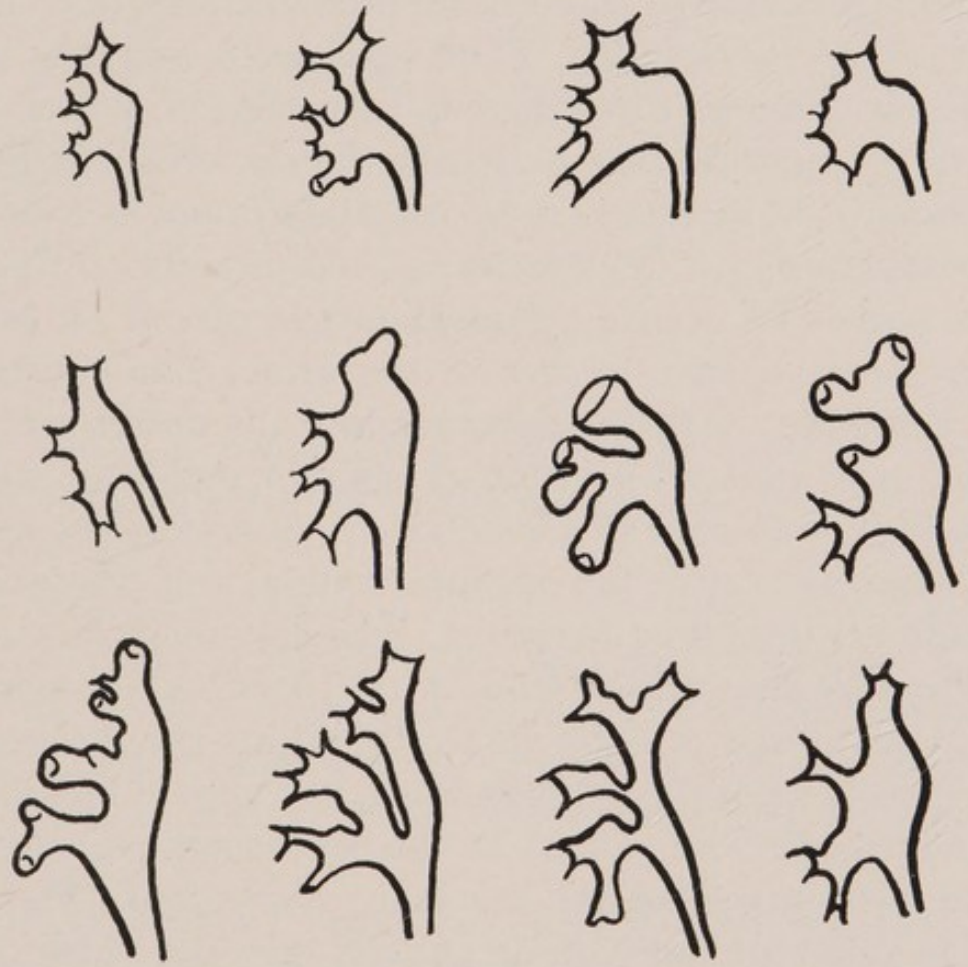


FIG. 196. Diagram showing the more usual variations in outline that may be found in normal kidneys.

cases the entire kidney outline may stand out especially well, due to the presence of dye in the uriniferous tubules. Kidney function may be impaired to the degree that excretion of the dye is lessened; in such cases the shadow is faint or even absent.

The shadow cast by the ureter is variable. It is remembered that the ureter is a muscular tube; if peristalsis is active or muscular tonus high, the dye-containing urine may

pass so rapidly and in such small quantity that no shadow of the ureter appears on the film.

The intravenous method is applicable when cystoscopy is not indicated, and when pyelography by the retrograde method is inadvisable. It is the method of choice in children.

Retrograde Pyelography. Fluid opaque to *x*-rays is introduced by gravity through the catheterized ureter. The shadow cast on the film is denser than is obtained by the intravenous route, and is more certainly found as a definite quantity of opaque medium is applied directly to the part to be visualized, and no dependence is placed on an unknown concentration of dye in the urine. The substances most commonly used for injecting into the ureter are 10 to 20 per cent aqueous solution of sodium iodide or sodium bromide. Uroselectan or a similar dye is preferable, as it is non-irritating; both the sodium iodide and the sodium bromide cause kidney irritation. The amount tolerated by a normal kidney varies from 4 to 10 cc. A pathological kidney may take a larger quantity. Films should be made immediately after the pelvis is filled, and should include one film taken with the patient in the semirecumbent posture.

The normal pyelogram has many variations (Fig. 196) both in different individuals and on opposite sides of the same person. In addition to the variations due to anatomical structure, the appearance changes if the quantity of an injected solution is insufficient. The pelvis may vary in size and in shape, but it is always smooth in contour. The major calices are distributed, one to each pole of the kidney and one between; often only two are present, and of the two one, commonly the lower, soon subdivides; there may be four or even five major calices. Although the number and distribution of the major calices is subject to such wide variation, their appearance in the normal kidney is characteristic: they are smoothly outlined, and are either of

the same diameter throughout their length or taper toward the cortex. The minor calices branch from the major stems; their distribution is not regular or orderly. The end of the



Fig. 197. Hydronephrosis.

minor calyx is smoothly cupped, with sharp or evenly rounded edges; the neck of the minor calyx is straight if it is seen at all.

The ureter is straight or smoothly curved. The diameter varies with the muscular tone, and may approach 1 cm., and still be within normal limits. The normal ureter is devoid of local constrictions, sacculations, sharp angles or kinks, and shows no point where its filling is abruptly terminated.

Hydronephrosis (Figs. 197 and 199). The pelvis is enlarged and appears ballooned out. The tips of the minor calices are rounded, and have lost their normal cup-shaped appearance. There are all grades of distention; the pelvic enlargement may be anywhere between one and one half up to ten times its normal diameter, or even more. Associated with the changes in the kidney there is always evidence of obstruction in the ureter, either from stone, kink, or cicatrix. Hydroureter is often associated with hydronephrosis; the diameter of the ureter is increased, it is commonly longer than normal and the usual curves are accentuated.

Pyonephrosis (Fig. 200). The pelvis is enlarged, though not to the degree encountered in cases of hydronephrosis. The tips of the minor calices are rounded and have lost

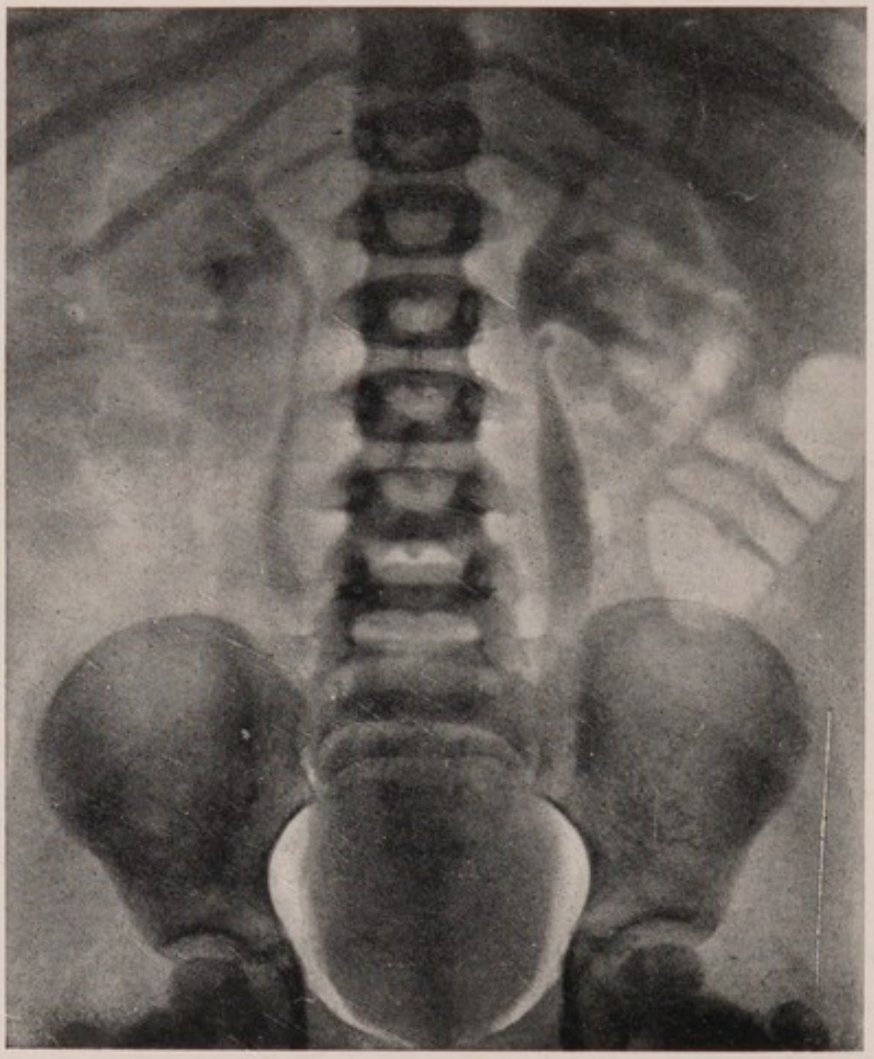


FIG. 198. Intravenous pyelography, patient a child five and one-half years old. Ureteral twist just below the ureteropelvic junction, and dilatation of the pelvis and ureter. (After Swick. *Am. J. Surg.*)

their normal cup-shaped appearance. The changes in the pelvis and calices are the same as are seen in hydronephrosis, but the relation between them is different; in pyonephrosis the change in the calices is predominant, in hydronephrosis the pelvis is most affected. As the disease progresses fibrous tissue forms, contracts, and distorts the contour of the pelvis and the calices. In those cases where the infection

has produced tissue necrosis, the outline of one or more calices is irregular, the contour blurred, and indistinct.

The ureter shows changes in pyonephrosis. It may be

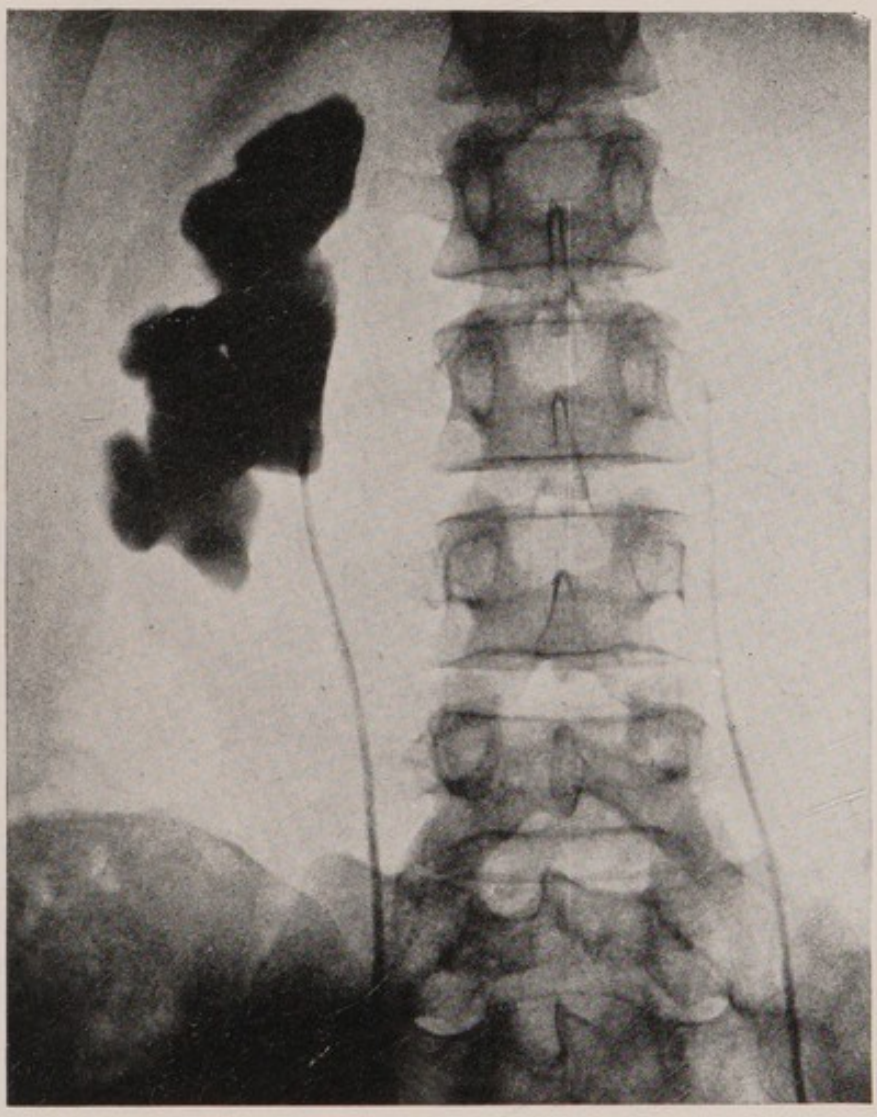


FIG. 199. Hydronephrosis (retrograde pyelography). (After Lower and Belcher. *Am. J. Surg.*)

dilated at the ureteropelvic juncture, may show dilatations throughout its length, and may show spastic contractures, illustrated on the film as narrowed areas separated by dilatations.

Tuberculous kidney is more safely demonstrated by other methods than by pyelography. If the retrograde method is used in these cases, care should be taken to avoid kidney irritation. The appearance is the same as found in pyonephrosis, plus the evidence of greater tissue destruction.

Displaced Kidney. The pyelogram definitely locates the kidney. Films should be taken both supine and semi-reclining, to determine the effect of posture.



FIG. 200. Pyonephrosis.

Horse-shoe kidney or fused kidney may be shown. Unilateral kidney may be proved.

Tumor. The changes due to tumor (Fig. 201) are diverse and may be difficult to interpret. Fortunately clinically important tumors of the kidney are rare. In general it may be said that definitely new formed or positively elongated calices indicate that an abnormal amount of kidney tissue is present. Circumscribed tumors may press upon the outline of the pelvis or distort the course of the calices.

Cystic Kidney. If the cysts communicate with the pelvis the injection fluid fills them, and casts dense, lobulated or spherical shadows. If the cysts do not communicate, an hemispherical encroachment on the pelvis may indicate the presence of a cyst; a calyx may be elongated.

Demonstration of Calculi. Calculi are demonstrable to a greater or lesser extent according to their chemical composition. The oxalates and the calcium carbonates give the best shadows; the phosphates are next in density; the urates may be shown very faintly but generally not at all.

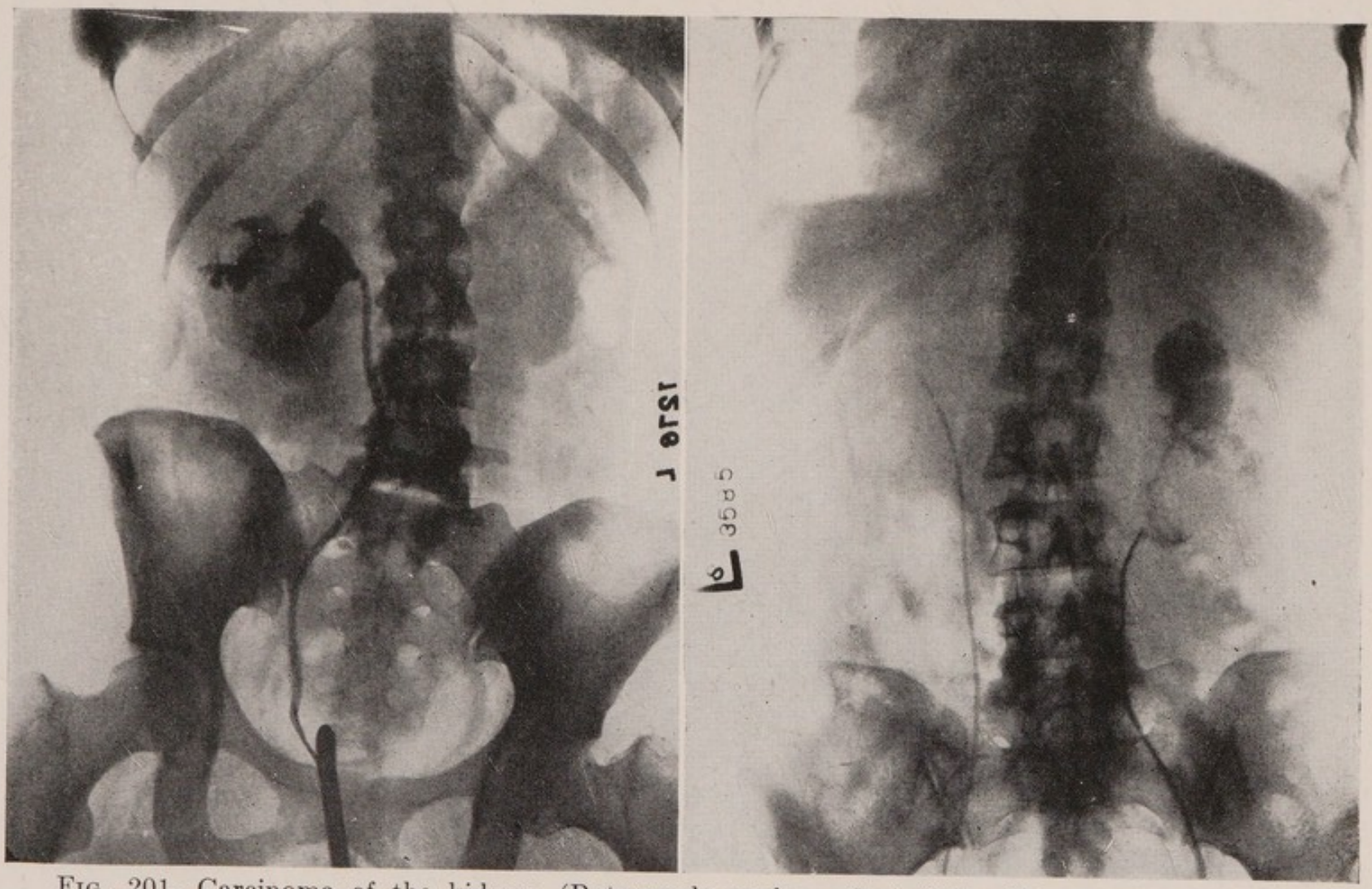


FIG. 201. Carcinoma of the kidney. (Retrograde pyelography.) (After Hyman. *Am. J. Surg.*)

Fortunately, the latter are infrequent in the ureter and quite rare in the kidney. In the bladder, where they occur most often, cystoscopy comes to our aid in locating them. At the first inspection of the film there are a few sources of error that have sometimes occasioned inconvenience. Often there is calcification in the tip of a costal cartilage. This may be recognized without difficulty when the shadow is in the cartilage of the free border, but may cause confusion when the twelfth rib is short, as the calcified spot then falls within the shadow of the kidney. Calcification in the tip of a transverse process of the lumbar vertebrae is directly opposite the bony process, and occurs in relation with many of the processes. Another condition that gives little trouble is a placque of sclerosis in an abdominal artery; similar placques outline the course of the artery. It is needless to comment on extraneous sources of error, such as buttons in clothing, spots of barium on a gown, or knots of adhesive plaster on the skin.

Renal calculi may be small and located in the pelvis or in a calyx. They are often large, sometimes occupying two-thirds or more of the kidney. They are often bilateral, and frequently are multiple in one kidney. Occasionally a calculus represents a complete cast of the renal pelvis and all the calices.

The position of the kidney may be abnormal, and opacities away from the usual kidney location may nevertheless be renal calculi.

Opacities from other causes may simulate renal calculi, for example, gallstones, calcified mesenteric glands, intestinal contents in the hepatic flexure.

The appearance of the shadow may be so characteristic of renal stone that it may be interpreted as such without further investigation. More often it is necessary to demonstrate that the cause of the opacity is within the kidney.

This is done by a pyelogram. When kidney damage is slight the intravenous route is satisfactory; but when the secretory activity of the kidney is lessened the retrograde method is necessary. Occasionally a non-opaque stone may cause a negative shadow—an area of lessened density in the pyelogram.

If the original shadow is caused by a renal stone it will be included in the pyelogram. Films should be taken both in the anteroposterior and the lateral positions, as the shadow of other objects, such as a gallstone, might be superimposed on the shadow of the pyelogram in the anteroposterior view.

The condition of the kidney is an essential part of the diagnosis; it bears no relation to the size of the stone. A large stone nearly filling the pelvis may cause no noticeable kidney pathology; a small stone may occlude the ureteropelvic orifice and cause hydronephrosis; a small stone in a calyx may be associated with tissue destruction. Secondary infection with pyonephrosis may be demonstrable. When the exact location within the kidney can be determined it may suggest the best route for surgical removal.

Ureteral calculi vary in size from a minute stone 2 mm. in diameter to a mass 10 mm. thick and 20 mm. long. They are usually found opposite the body of the fifth lumbar vertebra or at the ureterovesical orifice, but may occur anywhere along the length of the ureter. It is remembered that the ureter may not be located in its usual position.

In the lower part of the urinary tract, especially near the bladder, there are encountered frequently a number of small concretions whose shadows are dense, circular in outline, distinct in contour, which are not calculi; they are called phleboliths. A small calculus may be mistaken for them.

Ureteral stone may cast an indistinct shadow and is often difficult to see; the stone may be overlooked entirely

in many cases. The presence of a stone that failed to cast a definite shadow may be demonstrated by a ureterogram.

Even when a small opacity is seen in the usual location

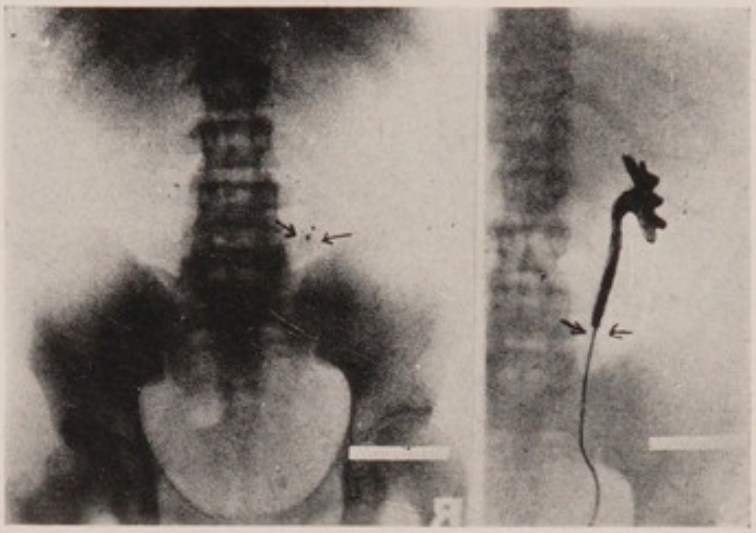


FIG. 202. Calculus in ureter. Retrograde pyelography, showing dilatation of ureter above calculus, and slight hydronephrosis. (After Moots and Magoun. *Am. J. Surg.*)

of the ureter, the shadow may not be so characteristic that a positive diagnosis of stone is justified; in these cases confirmatory evidence is given by the ureterogram (pyelography). Intravenous pyelography is better than the retrograde method in all cases where the kidney function permits.

The ureterogram (Fig. 202) demonstrates that the shadow under investigation is cast by a stone in the ureter by the following evidence:

(1) The original shadow is completely included in the ureterogram.

(2) At the site of the shadow the ureterogram shows a localized enlargement.

(3) The outline of the ureter is enlarged (a) above the shadow; or (b) below the shadow.

(4) The ureter is outlined below the shadow, but no opaque fluid has passed it (as demonstrated by the retrograde method of pyelography).

One or more of the foregoing points should be present.

Vesical calculi are encountered less often than stone elsewhere in the urinary tract. Their demonstration is generally more difficult and less satisfactory than that of other calculi. The reason is first, that the majority of them are composed of pure uric acid or of a combination of urates; secondly, they occur largely in individuals with prostatic disease, with thickened bladder walls, and retention of urine, all of which add to the difficulty in demonstrating them by the *x*-ray.

Ordinarily a vesical calculus is demonstrable by cystoscopy, and the aid of the *x*-ray is not sought; but calculi may be present in a diverticulum, or hidden behind a prostatic bar, and escape detection by cystoscopy. If the routine *x*-ray examination is negative, the bladder may be catheterized and pumped full of air. When the radiograph is taken the voltage at the tube should be reduced to a 3 inch gap (kv. peak 50) and the time increased to fifteen seconds, milliamperage remaining the same (see p. 147). Even a uric acid stone may be demonstrated by this method, as it will cast a shadow outlined against the air-filled bladder. Especial care must be taken that no fecal residue remain in the rectum, as extraneous matter might cast a shadow that would be mistaken for stone.

CHAPTER XIII

GASTROINTESTINAL TRACT

In the *x*-ray examination of the gastrointestinal tract we must remember that we are not dealing with fixed organs, but with those that vary greatly in size, shape, position and motility according to conditions. It is therefore difficult to differentiate between supposedly abnormal indications, either congenital or temporary, and those that are pathological. The most definite of the latter are as follows:

1. Interference with function.
2. Irregularities in outline, such as,
   - Filling defects,
   - Projections,
   - Niches,
   - Diverticula,
   - Hourglass deformities,
   - Spasms.
3. Extreme changes in position.

Technique. Since the gastrointestinal tract is not directly demonstrable by the *x*-ray, it is necessary to introduce some opaque substance which should not interfere with function and must be harmless.

"Barium sulphate for *x*-ray diagnosis" is the agent employed. Barium sulphate sold under this name is free from contamination with the soluble barium salts, which are active poisons. While the constituents of the barium meal vary with many operators, it is well to emphasize that, whatever meal is used, it should be adhered to in all examinations, as different meals may cause marked differences in function, especially of the stomach.

In studying the lesions of the esophagus, a thick paste made of barium sulphate and mucilage of acacia should be

employed. A barium water mixture should be used first, as a very narrow stricture may be present.

For the study of the stomach 4 oz. of barium sulphate are added to 12 oz. of water and agitated in a mechanical shaker. The same quantity of barium may be mixed with malted milk or buttermilk and made into a satisfactory suspension by stirring, without a mechanical shaker.

The opaque enema is composed of 8 oz. of barium sulphate and 32 oz. of water with sufficient mucilage of acacia to make an emulsion. Other vehicles, such as buttermilk or a mixture of equal parts of condensed milk and water, may be used.

Preparation of the Patient. For the examination of the esophagus and the stomach by an ingested meal, the patient should present himself with an empty stomach but *without* previous catharsis. When the opaque enema is to be used the colon is prepared by the administration of a cathartic on the evening before, followed by a tepid water enema two hours before examination. All drugs which have a stimulating or inhibitory effect upon the digestive tract should be withdrawn at least twenty-four hours before the examination.

Method of Examination. In making an examination, a combination of the fluoroscopic and radiographic methods should be employed. Both methods give information as to size, position, shape and contour. Films give full detail, especially in contour, and form a permanent record. The screen has the great advantage of permitting the observer to study the tract in motion and to palpate individual organs. It is therefore indispensable.

The fluoroscopy and the radiography are done with perfect safety to both the patient and the radiologist by observing the simple rules established by The International Congress of Radiology (p. 108). The annoyance occasioned

by beginning the fluoroscopic examination before the operator's eyes are ready to perceive the faint shadows on the screen may be readily avoided by wearing red or amber goggles for a full ten minutes before commencing the examination of the first case; and thereafter by replacing the goggles when in the presence of illumination. It is needless to comment that an attempt to study the gastrointestinal tract in an improperly darkened room is dangerous to the patient and disastrous to the operator.

Progress of the meal through the alimentary tract may be observed by two methods. (1) A motor meal of barium and porridge is taken six hours before the patient comes to the *x*-ray laboratory. (2) The barium meal is given in the laboratory to the fasting patient, and the *x*-ray study is made; four to six hours later the patient returns to the laboratory, the progress of the meal is noted, and the first observations are checked by a repeated examination. In both methods no food is allowed until the emptying time of the stomach has been noted. The first method is applicable to large clinics, or when the radiologist is sure of his own accuracy; the second is advisable when the number of patients is small, or the radiologist prefers to check his observations by repeating the fluoroscopic study.

The stomach empties normally in about four hours. But if the barium is retained up to six hours it is still considered within normal limits. A retention after six hours of about one-eighth or more of the ingested quantity is distinctly pathological. On the other hand, perfectly normal stomachs have been seen to empty in about two hours. In these cases, however, one should remember that achylia gastrica is characterized by very rapid emptying time. The cecum begins to fill about four hours after the meal; the head of the barium column is at the hepatic flexure at six hours after

the meal, in the midportion of the transverse colon at eight hours and in the lower portion of the descending colon at twelve hours. Part should be discharged about twenty-four hours after the meal and a complete evacuation ought to be accomplished in forty-eight hours.

The Esophagus. This should be examined for the following lesions: Diverticula, benign strictures, malignant growths and spasm.

Diverticulum is usually found just below the jugular notch. Since it may lie anteriorly, posteriorly or laterally it should be viewed from various angles. It manifests itself by a shadow outside that of the esophagus and is generally pouchlike in appearance and persists after the esophagus is empty (Fig. 203).

Benign strictures and malignant growths are similar in appearance; in both there is a constriction at the seat of the lesion which is usually conical in shape, the apex pointing downward, accompanied by a varying degree of obstruction. An etiological diagnosis between these two conditions cannot always be made but when the edges of the stricture are serrated it is more likely to be malignant (Figs. 204 and 205). In malignancy little dilatation, if any, is observed, and it is usually found at the level of the bifurcation of the trachea and in the cardiac end. When the latter obtains, the adjacent part of the stomach is frequently involved. A lateral or oblique view of the thorax may show the mass in the mediastinum. Benign strictures may be found in any portion of the esophagus. Age will frequently aid in the determination of the condition.

Spasm is intermittent in character, may occur in any part and is usually transitory. The most common form is *cardiospasm*. It is more or less persistent and results in a dilatation of the entire esophagus to a degree not seen in any other conditions (Fig. 206).

Stomach. The size, position and shape of the stomach depend upon the habitus of the individual.

Roughly speaking, the high transverse stomach is found

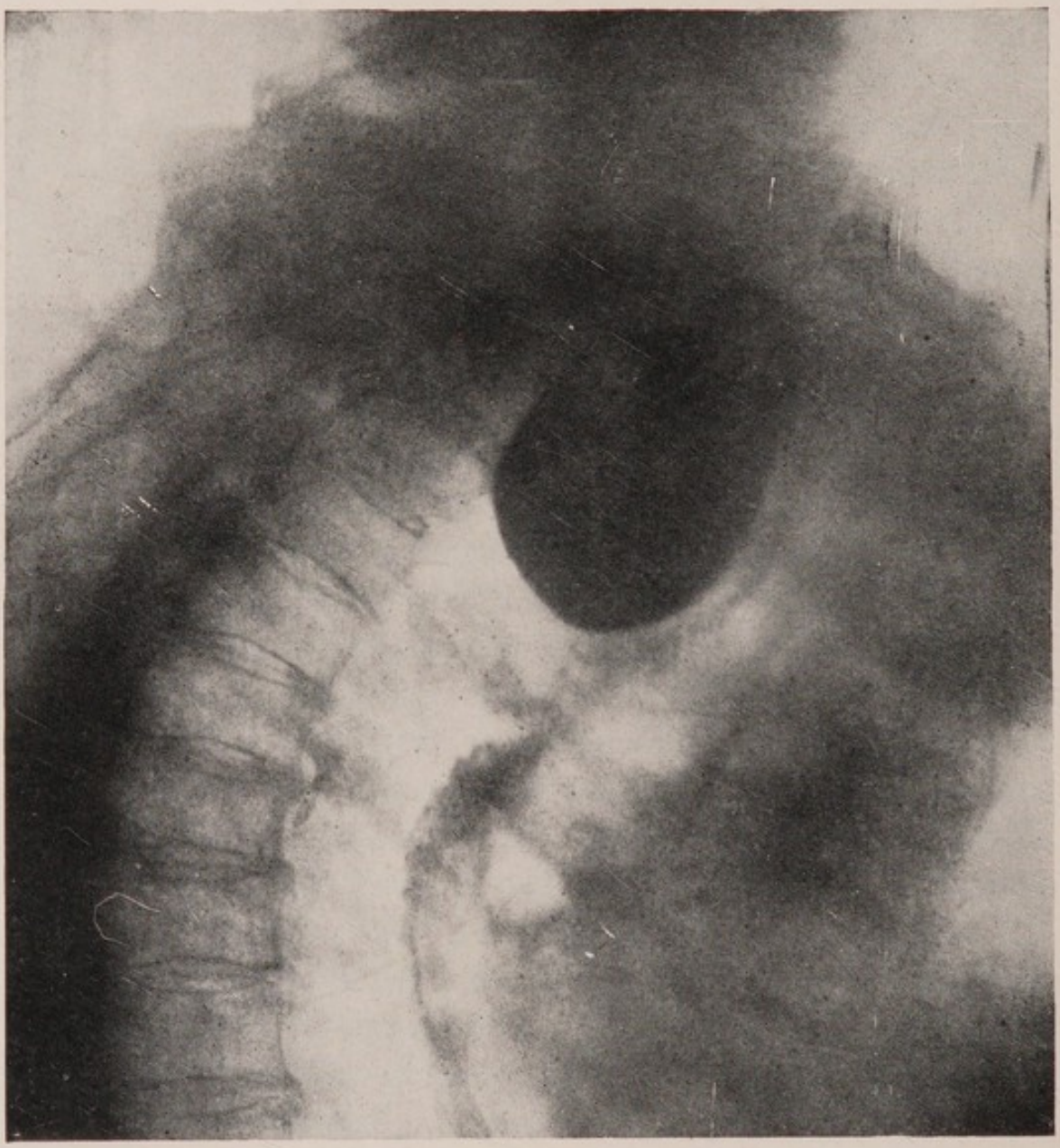


FIG. 203. Diverticulum arising from posterior wall of esophagus.

in fat people, the cow-horn type in the medium weight individuals, the fish-hook type more frequently in thin individuals, but variations from these accepted positions are common. These positions are well worth remembering

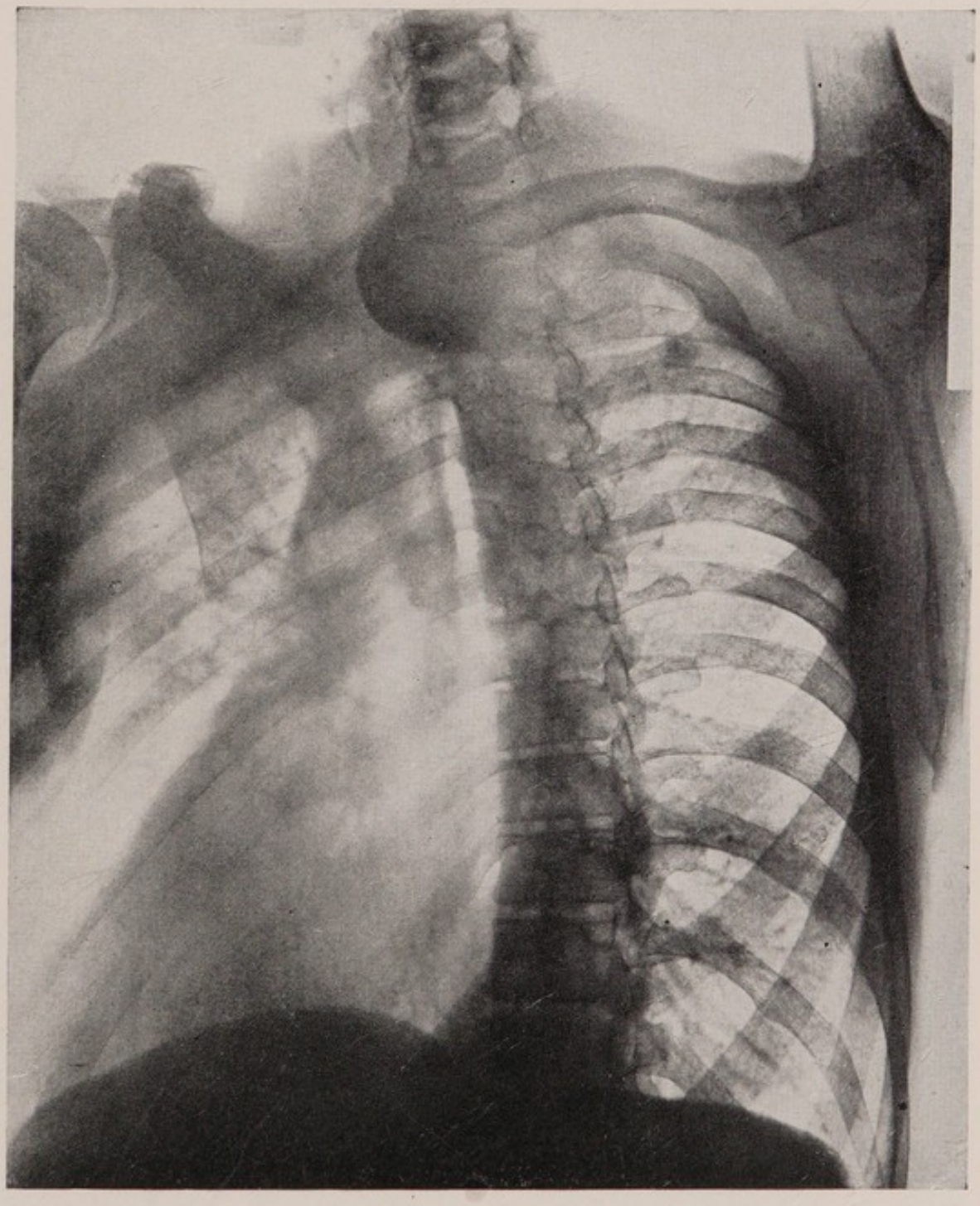


FIG. 204. Benign stricture of esophagus.

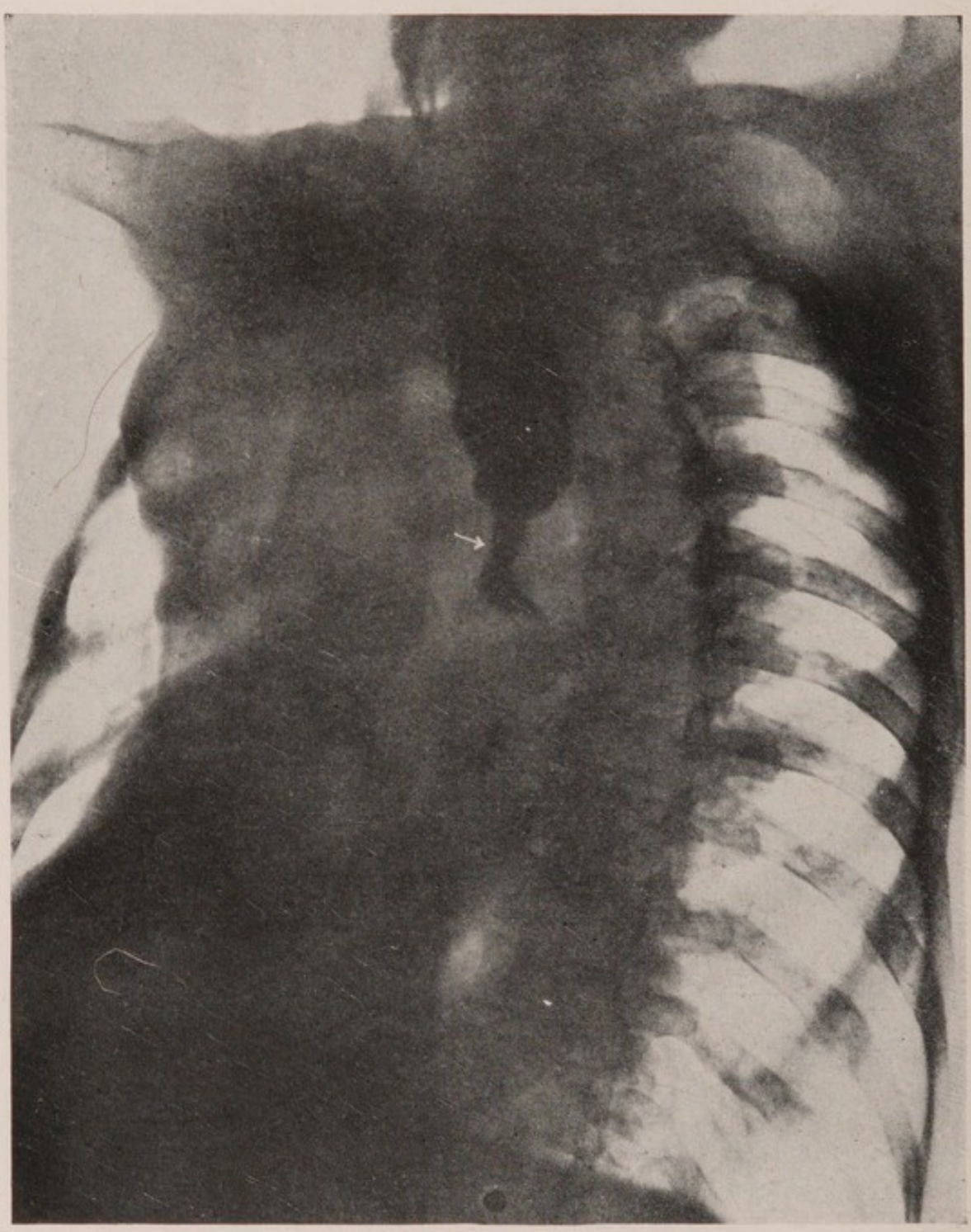


FIG. 205. Carcinoma of esophagus at level of bifurcation of trachea.

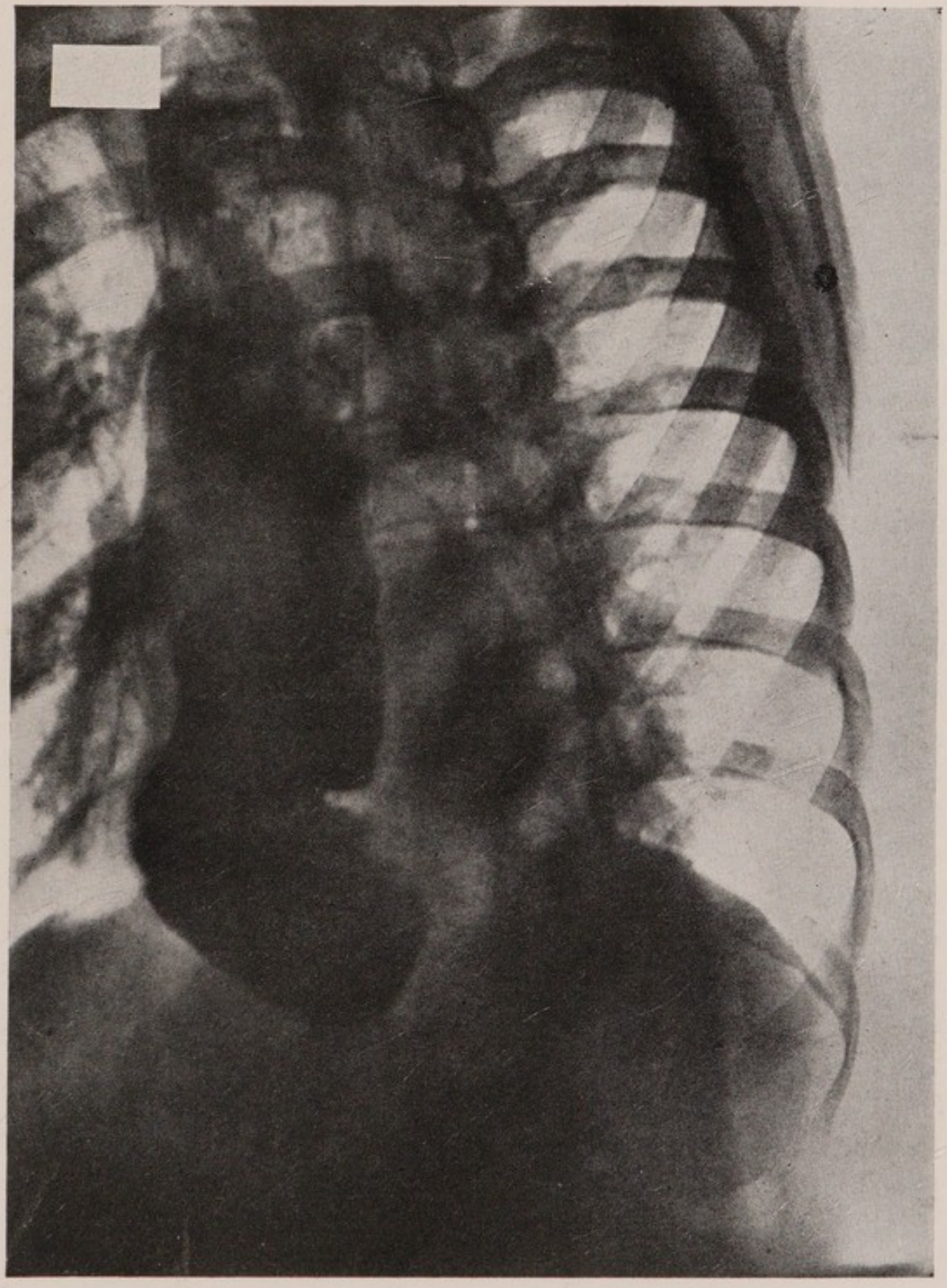


FIG. 206. Cardiospasm; note marked dilatation of esophagus.

as they play an important part in motility. As a general rule the high normal stomach empties more quickly than the normal fish-hook type.

The mere position of the stomach is of little importance; a stomach may be located far down in the abdomen and yet empty normally and cause no symptoms. Function is more important than position.

While the patient is standing an *air bubble* appears in the fundus, distending the cardiac end. The lower limit of the air bubble is horizontal; it is sharply demarcated. When the stomach contains residue or recently ingested food, there are three layers: from above downward, the non-opaque air bubble, below that the less radio-transparent residue, at the bottom the densely opaque barium meal. In the prone position the air bubble remains in the cardia. In the supine position the bubble rises to the pyloric end, and may so distend the antrum as to stop gastric peristalsis. The size of the air bubble varies with the quantity of air taken in while the opaque meal is swallowed.

Peristaltic waves are circular constrictions that pass at a constant speed from the cardia toward the pylorus. A wave indents the lesser and the greater curvatures simultaneously, and arrives at the pylorus at the same time; to traverse the greater distance, the wave moves more rapidly on the greater curvature. The waves usually arrive at the pylorus at the rate of three a minute. From three to four waves may be seen in the stomach at the same time. The depth of the constriction varies with different individuals and at different times in the same person. Peristaltic waves are best seen when the patient is prone, the hips elevated on a sand bag, the chest supported. In this position a wave may be observed from its first appearance at the cardia to its arrival at the pylorus. In the

upright position the waves are usually seen only in the dependent portion of the stomach.

Hyperperistalsis is a gastric state where the peristaltic waves move at an abnormally rapid rate, or indent the stomach more deeply than normal. Hyperperistalsis may be due to nervous, physiological, or mechanical causes. For example, hyperperistalsis may be found in neurotic persons; when there is ulcer of the stomach or duodenum; or in the early stages of pyloric obstruction.

Ulcer of the stomach has the following signs:

1. The niche and accessory pocket. The niche is an excavation in the stomach wall caused by the ulcer. Niches vary in appearance from the most shallow detectable to a deep excavation that penetrates through the entire stomach wall, and forms a bulge or bud on the serous coat. Sometimes an ulcer may form a pocket near the stomach into which gastric contents may flow. This is called the "accessory pocket." The niche shows well if it is on the lesser curvature. But if it is on the posterior wall the demonstration requires careful study. The most reliable method is to give only one swallow of a thick opaque meal, and push it around the stomach by palpation. The barium adheres to the ulcer cavity and also outlines the rugae, which are distorted or flattened. When ulcer is discovered or suspected, films should be taken immediately, without changing the position of the patient or the pressure applied by the gloved hand. By reducing the size of the beam of rays, and keeping the hand below their direct path, the procedure is safe for the operator. A more convenient method is to use a compression cylinder provided with an inflated rubber bag; the degree of compression can be gauged more accurately. This apparatus should be provided with a method for exposing films without changing the position of the apparatus or the degree of pressure applied. It may be noted that the stomach

containing the small quantity of barium mixture does not have active peristalsis, and an exposure for three or four seconds will produce a satisfactory radiograph. After the full

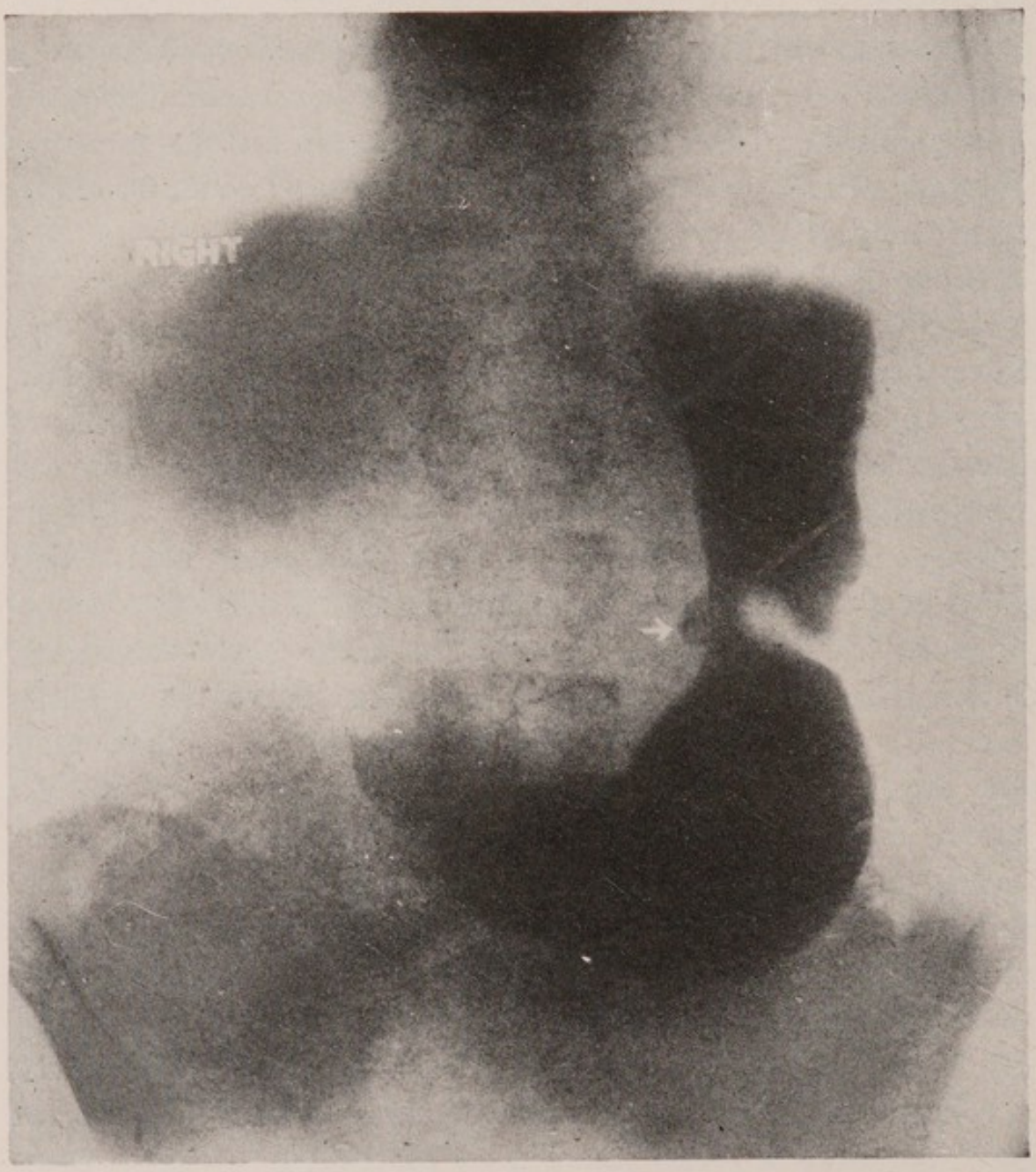


FIG. 207. Penetrating ulcer on lesser curvature of stomach. Spastic hourglass contraction opposite on greater curvature.

meal is taken the ulcer niche is lost to view unless it happens to lie on the lesser curvature. Chronic ulcers have wide, indurated borders (Fig. 208). Their size is exaggerated in

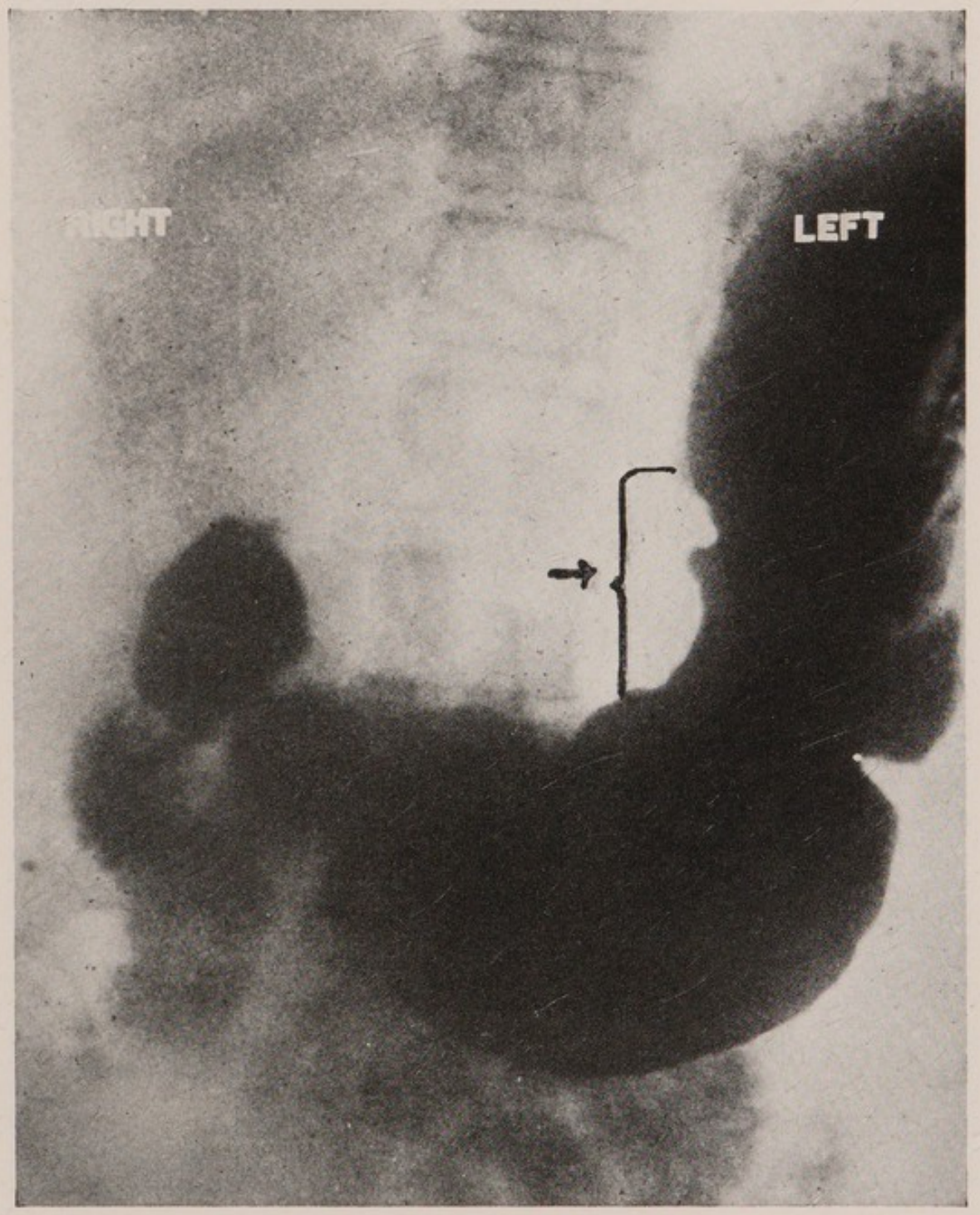


FIG. 208. Excavating ulcer of lesser curvature, indicated by bracket.

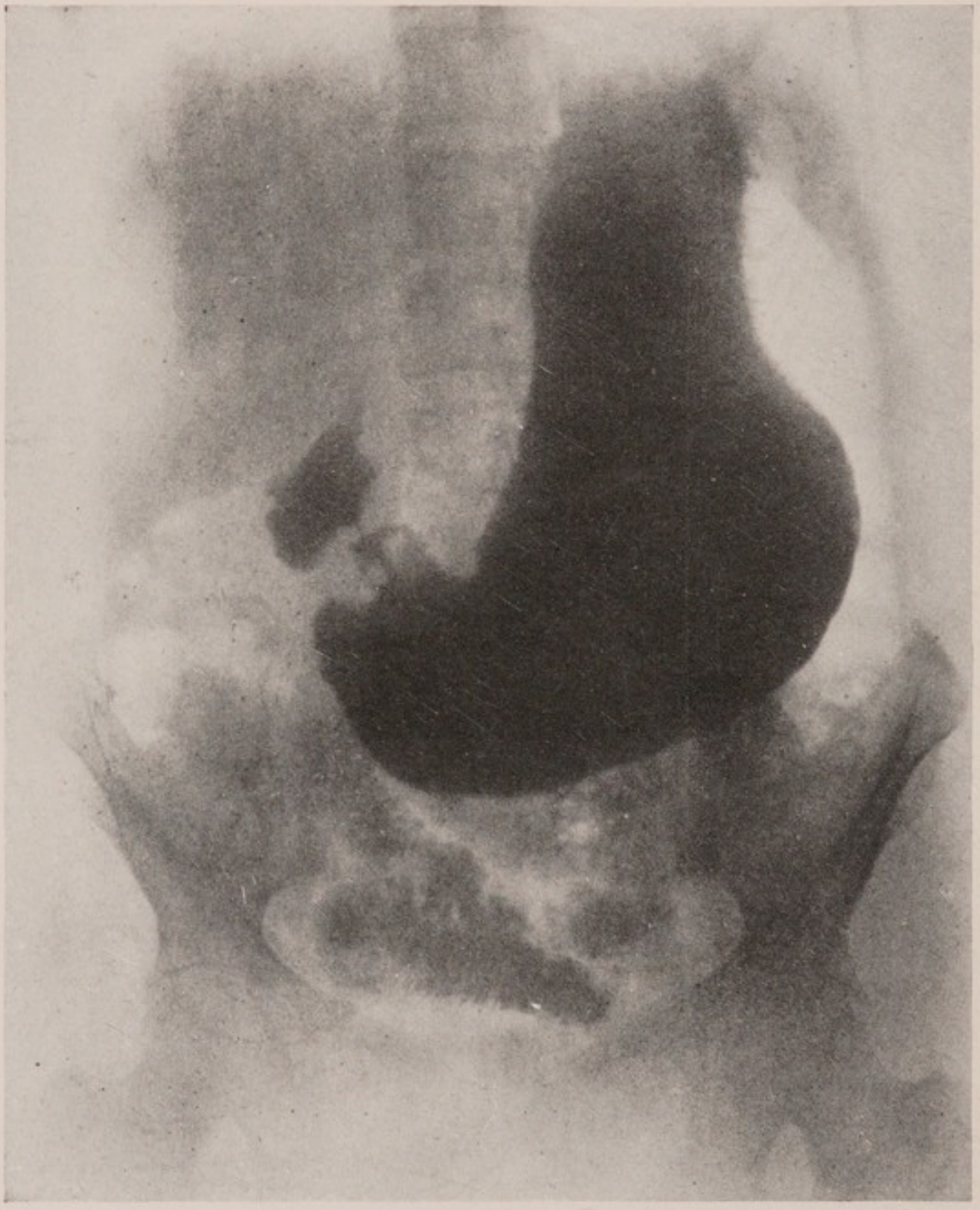


FIG. 209. Marked dilatation of stomach due to obstruction at pylorus (prone position).

the x-ray film, as some of the defect is caused by the mucosa piling up around the edges. The majority of ulcers occur on the lesser curvature within 2 inches of the pylorus.

2. When the wave of peristalsis arrives at an ulcer, it hesitates, and then recommences at the far side. This can be demonstrated when the ulcer is seen in profile.

3. Incisura. Opposite the ulcer, on the greater curvature the stomach wall may be indented deeply. (Figs. 207 and 208.) This "incisura" is smooth, sharply defined, and persistent; peristaltic waves pass by without appreciably affecting its depth or location. The incisura may be called a spasmodic hourglass.

4. Modified peristalsis. There is usually hyperperistalsis, especially in the early part of the examination, associated with spasm of the pylorus and consequent delay in emptying time. The spasm at the pylorus is especially found with ulcers in or near the pyloric canal. Eventually the stomach may tire, spasticity and hyperperistalsis are lost, and the stomach becomes atonic and dilated. (Fig. 209.)

5. Hourglass stomach, as its name implies, indicates that the stomach is divided in two portions connected by a short, narrow channel. If organic, it is the result of cicatrization.

6. Spasm. There are two varieties: general and local. The local simulates organic hourglass stomach in contour and location, but is evanescent in character. General spasm affects the entire stomach so that there is an absence of peristaltic waves. Both can be overcome by paralyzing the musculature by physiological doses of atropine, and this is the only method by which the spasmodic hourglass is differentiated from the organic.

Every case will not show all the changes enumerated above. The diagnosis rests on the demonstration of the ulcer cavity, and is supported by the corroborative evidence of some or all of the other changes.

Carcinoma may be situated in any portion of the stomach, but the most frequent location is at the pyloric end. Unlike ulcer at the pylorus it may be quite extensive with-

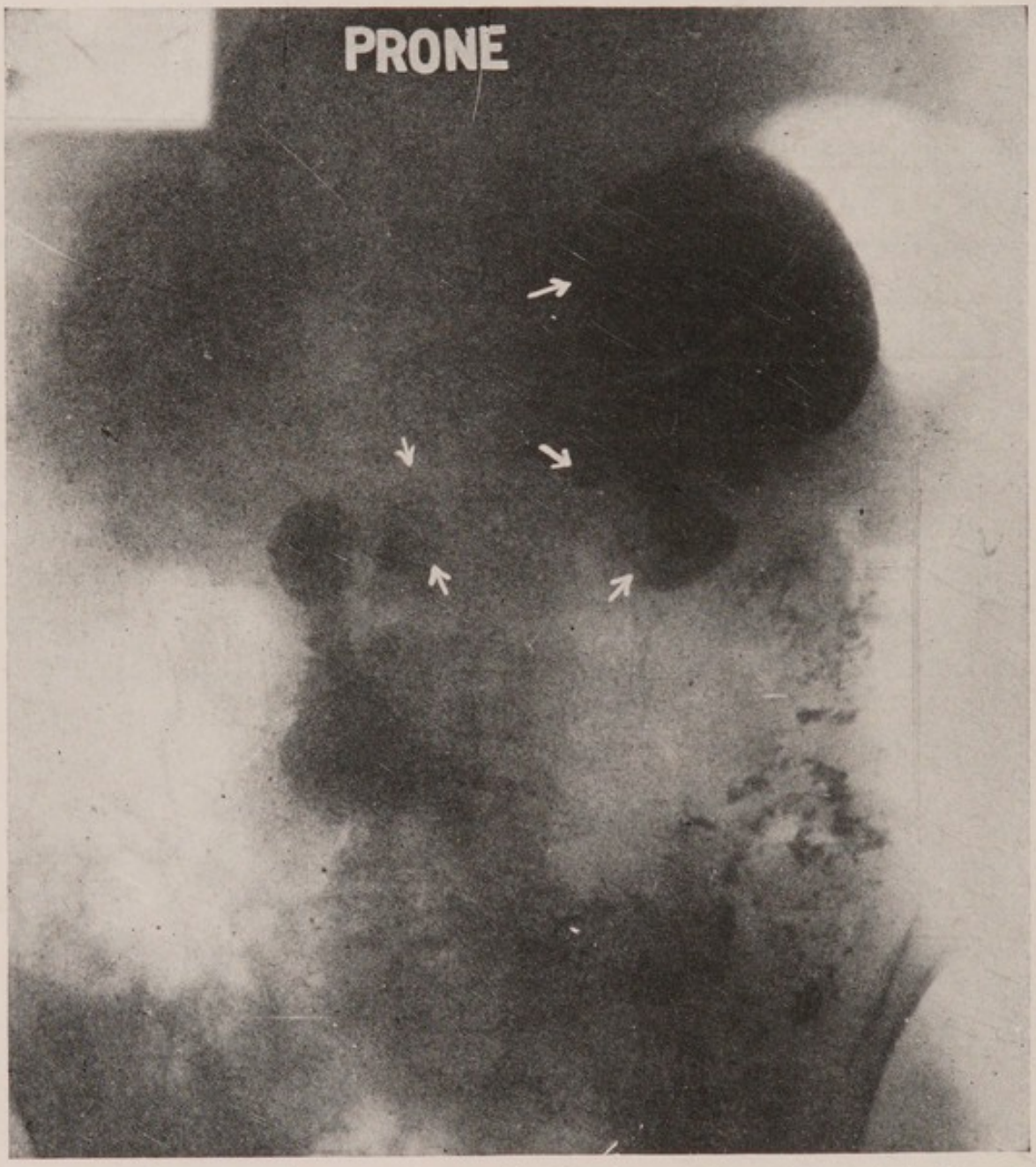


FIG. 210. Large carcinoma of stomach. The large filling defect is indicated by arrows.

out producing obstruction.

The chief signs of malignancy are:

1. The filling defect is irregular, serrated or rounded. It is due to the projection of the growth into the lumen of the stomach. If the growth is on the greater curvature



FIG. 211. Carcinoma of stomach, moderate size, indicated by bracket.

the defect resembles fingermarks in putty. If on the posterior wall there is an area of lesser density where the opaque meal is thinned. (Figs. 210 and 211.) On the lesser curvature the

picture resembles ulcer, but the niche is broader, and the stiffening of the adjacent stomach wall is more extensive; a niche ¾ inch or more in diameter is presumptive evidence of carcinoma rather than simple ulcer. At the pylorus the defect may be funnel shaped, the pyloric canal elongated and frequently tortuous. The filling defect is consistently and accurately duplicated on all the films. It may be remembered that a filled colon may press upon the greater curvature and imprint a series of small notches on the stomach outline.

2. Palpable tumor. It is often possible to palpate a tumor mass that coincides with the observed filling defect. Growths on the greater curvature disturb the function of the stomach so slightly, and are so painless, that an early clinical diagnosis is often impossible. At the time these patients come to the radiologist for their first *x*-ray examination, the tumor has usually grown to such a size that it is readily palpable.

3. Modified peristalsis. The infiltration of the gastric wall causes a diminution, or even absence, of peristalsis in the involved area.

4. Emptying time. When obstruction is present, the time varies according to the degree of occlusion. On the other hand, it may happen that the pyloric ring is so infiltrated that it does not obstruct, but, on the contrary, cannot contract, and then there is rapid clearance.

Carcinoma of the cardiac end may restrict the esophageal opening or cause spasm, with pain and dysphagia. These growths at the cardia are difficult to demonstrate, as the upper third of the stomach is behind the ribs, preventing palpation, and the meal drops away from contact with the stomach walls when the patient is standing. It is a good plan to place the patient on his back, in which position the cardia is better outlined. When observed in the upright

position the outline of the air bubble should be evenly rounded; a mass may deform the outline and suggest the presence of carcinoma. The "small meal" technique may be tried, as described on page 431.

Benign tumors of the stomach are infrequent. They show as masses that project into the lumen and displace the opaque meal. Benign tumors are differentiated from malignant by their smooth hemispherical contour; malignant tumors are uneven and nodular. Peristaltic waves pass the benign tumor readily; the waves are thrown out of their normal timing by the malignant tumor. In the presence of benign tumor, the adjacent stomach wall is pliable; carcinoma infiltrates the wall and may cause recognizable induration. A benign tumor may be pedunculated, and the movable mass may be pushed about by palpation; malignant tumors are fixed. As a mass in the stomach is more often malignant, carcinoma must be excluded before a diagnosis of a benign growth is justified.

Syphilis of the stomach does occur, and may present exactly the same appearance as carcinoma. More commonly syphilis causes gastric retention, and no defect in the stomach outline. A stomach showing retention at twenty-four hours, without *x*-ray evidence of abnormality except for the absence of any demonstrable duodenal bulb, is usually syphilitic. The probability is strenghtened if the patient is free from pain and is fairly well nourished. The retention in these cases is not mechanical, but is due to interference with peristalsis. As has been pointed out by many observers, the stomach does not empty by gravity.

Linitis plastica (leather bottle stomach). The stomach wall is thickened, the stomach size reduced to one-third or less. The meal passes through the stomach rapidly. Peristaltic waves are seen faintly or are absent.

Hernia of the stomach through the diaphragm. The stomach filled with the opaque meal is found to lie above the diaphragm, displacing the heart and lung. The hernia may implicate the greater part of the stomach; a loop of colon may be included. In most instances the hernia is through the esophageal hiatus.

Thoracic Stomach. As a congenital defect, the diaphragm is missing or rudimentary on one side. The stomach and other abdominal contents lie in the thorax. These cases must be differentiated from hernia, as they are inoperable.

Duodenum. The first portion is called the "bulb" or "cap." The bulb fills with the opaque meal, hesitates several seconds, and then contracts. The meal passes out of the first portion in separate masses, aptly called "finger-lengths." These masses are serrated in contour, and vary in diameter with the tonicity of the walls of the gut. They move toward the jejunum rapidly, but from time to time delay momentarily.

Usually the opaque meal flows readily into the duodenum and distends the bulb. There are numerous instances when it does not, and the examiner may doubt whether he is viewing a bulb poorly filled with an insufficient quantity of opaque medium, or whether it is an abnormal bulb deformed by intrinsic disease. The bulb may be filled during the fluoroscopic examination, by manipulating the stomach with the gloved hand on the abdomen. Occasionally the stomach may be inert when first filled and no bulb is visible. It is a good plan to allow these patients to rest fifteen minutes or so; the muscular activity becomes established, the pylorus relaxes, and the bulb fills well.

When a normal bulb is filled its contour is smooth; the outline is evenly rounded except at the upper left corner, where there may be a slight indentation; the density of the shadow is uniform; the size and shape vary widely (Fig. 212).

The most common abnormality in the duodenal bulb is ulcer. Diverticulum is occasionally seen. Carcinoma is so rare that it may be considered only after all other

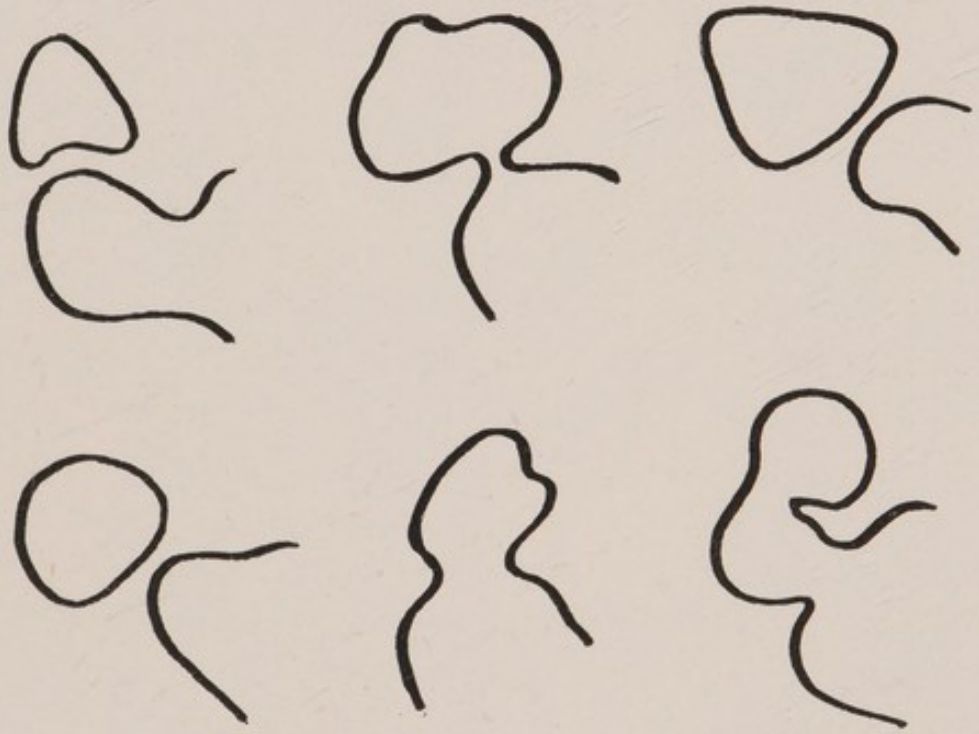


FIG. 212. Variations in outline of normal duodenal bulbs.

possibilities have been ruled out.

Ulcer. The signs of ulcer are as follows:

1. Deformity, caused by the exacavation of the ulcer, by spastic contraction of the muscular wall from the stimulation of the ulcer, and by the contraction of scar tissue.

The excavation of the ulcer deforms the outline the least; it is remembered that a duodenal ulcer may be only a few millimeters in diameter, or even a mere erosion in the mucous membrane. The spastic contraction of the muscular wall of the bulb deforms the outline the most, except in the old cases, where scar tissue has formed. The deformity of the bulb may take any shape; some of the more common types are shown in Figure 213.

As the diagnosis is often based on the appearance of a hollow organ deformed mainly by muscular contracture

it is obvious that dependence may be placed only on deformities that are constant. Occasionally there are slight variations in successive films, as are shown in Figure 216, but



FIG. 213. Types of deformity caused by duodenal ulcer.

in such cases the radiographs resemble each other closely. When viewed from the same angle the old dictum applies: "One normally outlined bulb discounts any number of irregular forms." When the bulb is viewed from many angles a normally rounded bulb may be found in the presence of deformity. This may be illustrated by indenting a ball; held in one position the indentation is seen, but the ball may be turned so that its profile is perfectly rounded.

Usually the deformity caused by ulcer is characteristic. Occasionally the duodenal bulb is the site of spastic contracture caused reflexly by irritation elsewhere in the alimentary tract, and the appearance of the bulb may simulate ulcer. These cases may be differentiated by administering an antispasmodic, such as belladonna or



FIG. 214. Duodenal ulcer. Niche formation, size of pea, on retracted lesser curvature side level with deep defect from major side. Small basal prestenotic diverticulum. (After Akerlund. *Am. J. Surg.*, 11: 514, 1931.)

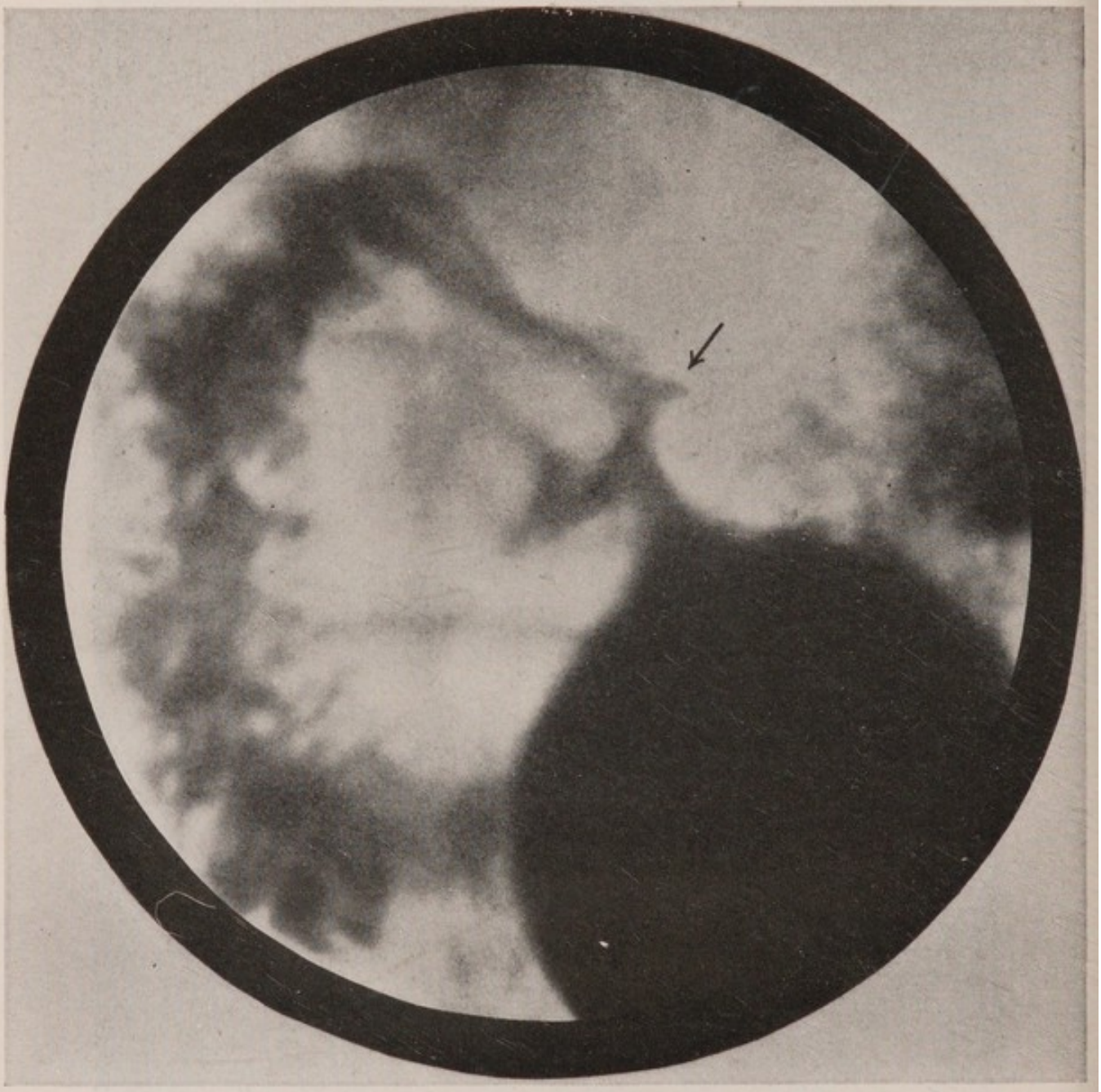


FIG. 215. Niche and puckered arrangement of the folds of mucous membrane are demonstrated by applying compression. (After Akerlund. *Am. J. Surg.*, 11: 511, 1931.)

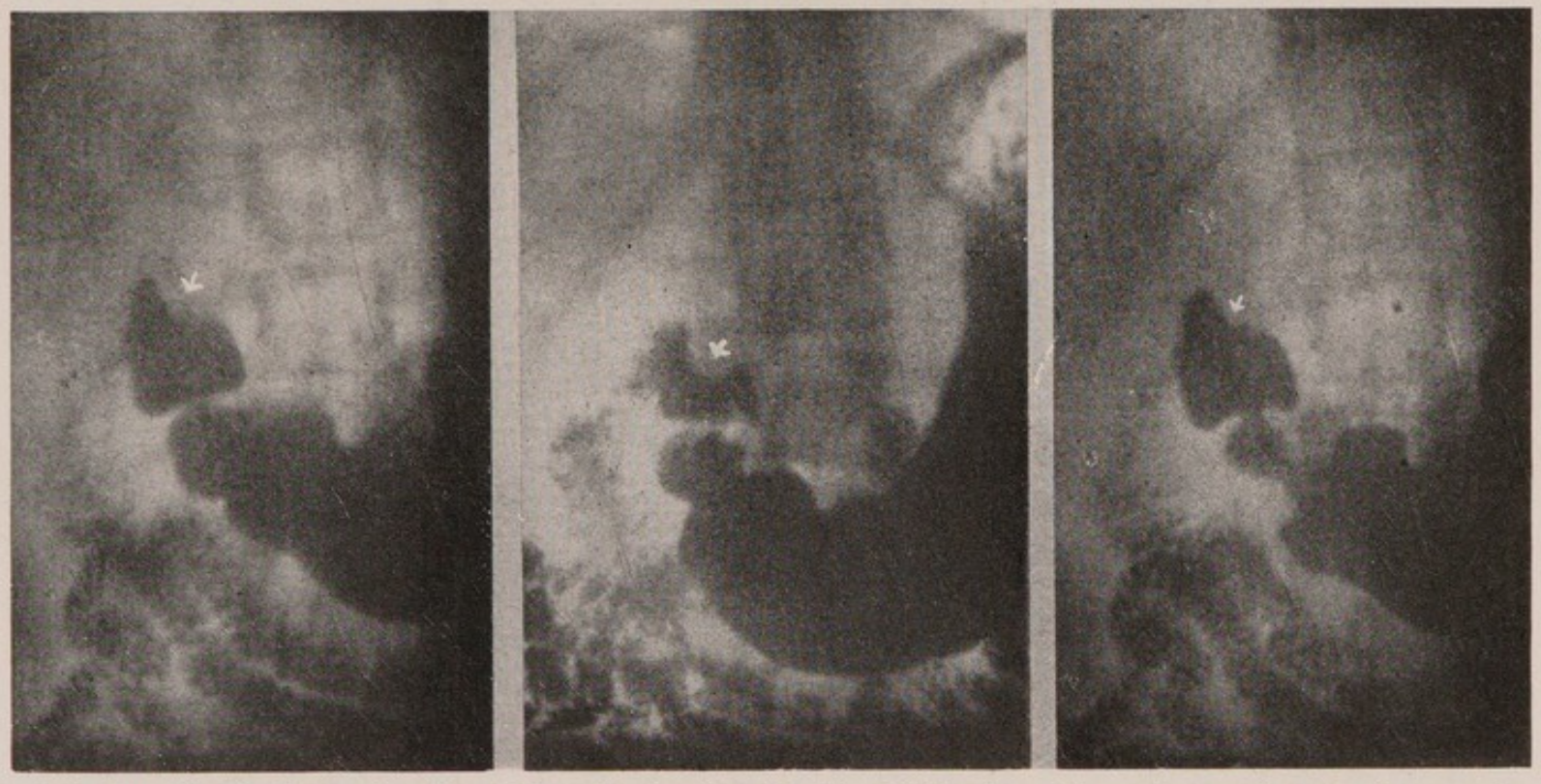


FIG. 216. Duodenal ulcer, showing defect in duodenal bulb which, though persistent, is not always of same size. Arrows indicate the defect.

atropine. Spasm due to extrinsic causes is relaxed by belladonna, but the spasm due to ulcer persists, although modified in degree.

An ulcer may be demonstrated by the small meal technique (p. 431). The appearance of the rugae is dependent on the degree of pressure.

2. Tender point exactly at the ulcer. This evidence is purely confirmatory. Usually, pressure over an ulcer causes pain. On the other hand, some persons have tender points in the upper abdomen, and have no ulcer. In others ulcer may be present, but there is no complaint of pain when it is palpated.

3. Functional abnormalities. In simple uncomplicated ulcer there is always evidence of gastric hyperperistalsis and of hypermotility. In chronic cases there may be delay in the emptying time of the stomach. The functional evidence is purely corroborative. Hyperperistalsis and hypermotility may occur from a number of causes. Delay in the emptying time of the stomach may be consequent to other conditions, such as a diseased appendix.

Ulcer of the stomach may coexist with ulcer of the duodenum.

Progress examinations. An ulcer that is active stimulates the muscular wall and causes contraction, with deformity in outline of the bulb. An ulcer that is healing causes less stimulation and the spastic contracture is less. When a duodenal bulb has been examined and found deformed, and at a later date the deformity is less, the inference is justified that the activity of the ulcer is less; when the bulb casts a shadow normal in contour, that the ulcer is quiescent. A statement that an ulcer is healed is seldom justified, unless the radiologist knows that the period of quiescence has been so protracted that the possibility of relapse is unlikely. Obviously, a bulb deformed by cicatricial tissue will show less change in outline.

A *diverticulum* is a smooth-walled sac, that buds from the duodenum. Barium enters the sac readily, and is often retained after the gut is empty. A diverticulum may form in the duodenal bulb as a sequence to ulcer of the bulb; the favorite location is from the lower right surface of the bulb. Elsewhere the most frequent site is in the neighborhood of the papilla of Vater.

Duodenal obstruction is seldom seen. Dilatation of the duodenum, resulting from a change in muscular tonicity, is not uncommon. In true obstruction the entire length of the duodenum above the point of constriction is enlarged, retains barium longer than it should, shows reverse peristalsis, violent peristalsis, and retention at the six hour examination. In dilatation of the duodenum the gut is wider than usual, but shows none of the other features. Dilatation may be due to a gut that grew to be larger than usual, or it may be due to alterations in the physiological gradient, as from an ulcer of the first portion.

Jejunum. *Gastrojejunal Ulcer following Gastroenterostomy.* The radiographic examination is made when the patient is standing, and while the opaque meal is being ingested. The meal passes out of the stomach within a few minutes. The stoma should be smooth; the jejunum distal to the stoma should fill sparsely, with no local dilatations. An ulcer at the stoma shows as an irregular area, deforming the smooth outline. An ulcer distal to the stoma, as an excavation budding from the jejunum; associated with this, the jejunum is dilated either above or below the ulcer. In studying a stomach that has been operated upon, it may be remembered that a stomach does not empty by gravity; the contents are squeezed out by muscular action. Unless the pylorus was closed at operation, the ingested meal may leave by the pylorus as well as by the artificial stoma. No deductions can be drawn from altered peristalsis in an operated stomach.



FIG. 217. Angulation at duodenojejunal junction, causing marked dilatation of third portion of the duodenum.

Ileum. *Stasis* may be reported when any portion of the opaque mixture remains in the ileum eighteen hours after the meal is taken. This condition may be found in cases of appendicitis, of colitis, in obstructive lesions of the colon, and in low placed cecum; but at times no abnormality can be found to account for it. Ileal stasis should be reported, as in the opinion of many gastroenterologists it is a functional defect important to the individual. The terminal ileum may show apparent kinks and adhesions at the radiological examination that are not demonstrable when the abdomen is opened.

Ileus. (Intestinal obstruction.) *Acute Ileus.* A postoperative case should be radiographed at the bedside in the supine position; if a lateral view is necessary the patient may be rolled on the side, the cassette placed against the abdomen.

The diagnosis depends on the demonstration of loops of small intestine distended with gas.

The radiograph shows gas areas in the center of the abdomen. The gas-filled loops may be identified as small intestine by the following:

1. Kerkring's folds may be outlined by the gas, causing a feathery appearance at the margins of the loop. (Note the appearance of the small intestine in Fig. 211, p. 437.)
2. The distended loops may lie parallel with each other (ladder arrangement).
3. The colon is identified by its position; by the demonstration of the haustrations; and by the position of the diaphragm, which is usually elevated by gas in the colon, but not by gas in the small intestine.
4. The stomach is identified by its position; gas in the stomach may push up the diaphragm.

Usually the appearance of the radiograph is characteristic; should there be doubt whether the observed gas

areas are in the small intestine or not, the following procedures are recommended:

1. An opaque enema defines the position of the colon and identifies the location of gas areas within it.

2. Ten to 20 grams of barium sulphate in lactose water may safely be given by mouth. The barium outlines the margins of the stomach and the intestinal loops.

3. A side view may show gas pockets and fluid. If the gas pocket and fluid line are narrow, the distended gut is probably small intestine; if broad, probably colon.

The size of the distended loops of small gut defines the gravity of the condition. For example, when the distention is so great as to produce the ladder arrangement, operative interference is urgently required.

The position of the distended loops suggests the location of the obstruction. A few areas in the upper abdomen indicate high ileus; many gas areas in the lower abdomen or in the pelvis indicate low ileus.

In all cases where the presence of ileus is doubtful, a second radiographic examination should be made within a few hours.

Chronic Intestinal Obstruction. The patient should be examined standing. Scattered along the small intestine are dilated loops containing gas and fluid. The gas pockets are broad. The fluid shows the characteristic horizontal fluid line, which shifts with change of posture. The intestinal wall is not usually shown, but when it is, Kerkring's folds are visible. The position of the dilated loops may be defined with a small amount of barium given by mouth.

The appendix is best examined eighteen to twenty-four hours after the opaque meal is taken. The appendix may fill with the opaque mixture by its peristalsis, unless retained contents prevent the barium from entering. The appendix is readily recognized (Fig. 218) although an incompletely filled terminal ileum has been mistaken for it.

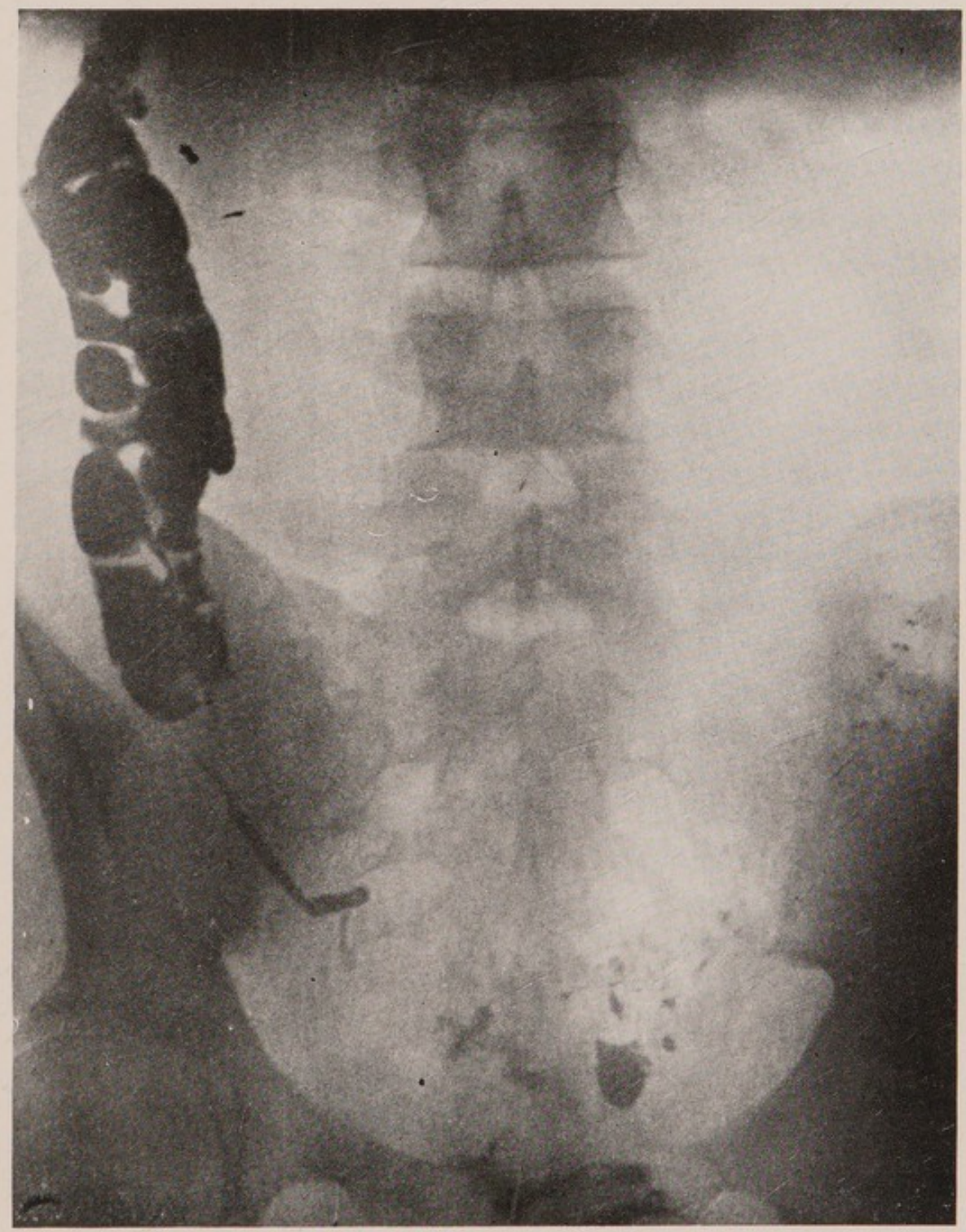


FIG. 218. Appendix. (Appendix filled with barium.)

As is well known, the appendix has no constant position in the body. The following points indicate a pathological condition.

1. Point tenderness, definitely located at the appendix. The examination should be made on the horizontal fluoroscope, the patient as relaxed as possible. To elicit point tenderness, the radiologist should first locate the appendix, either by actually seeing it, or by its relation to the tip of the cecum. He should then stop the *x*-ray exposure and palpate the observed spot with his bare hand. The degree of tenderness and of muscular resistance is as important in the radiological examination as elsewhere. Many normal persons have a definite sensation of pain when the appendix is pressed upon.

The radiological examination is valuable in that it determines the relation between the tender point and the appendix.

Acute appendicitis cases, which may be tender over a considerable area, do not come to the radiologist for examination.

2. Ileal stasis.

3. Irritable cecum. Normally the cecum is well filled eighteen to twenty-four hours after the meal is taken. An irritable cecum is incompletely filled.

4. Reflex spasm at the pylorus or the duodenal bulb. If the spasm is at the pylorus, there may be gastric retention; if at the duodenum, the bulb fills poorly and evacuates its contents with increased rapidity.

Point tenderness localized at the appendix is definite evidence; the other signs are corroborative.

Sometimes the appendix is adherent to adjoining structures; this indicates that disease has been present at some time past, but does not prove that an active process is going on at the time of examination.

A retrocecal appendix is best seen by rolling the patient to the right, until the shadow of the appendix is separated from the shadow of the cecum. The tip of the cecum is turned on itself, and points up, toward the liver.

A retrocecal appendix is a developmental anomaly that should be reported; but merely because the appendix is retrocecal does not imply that it is necessarily the site of an inflammatory process.

Colon. The shape and position depend especially on embryological development. The following brief summary may be found convenient in calling to mind a few of the well-known facts:

Development. The primitive gut is a straight tube. In embryonic life the abdominal portion elongates, forming a loop. The loop migrates into the umbilicus, and later returns to the coelom (which is to become the abdominal cavity). At first the colon lies entirely on the left side. It is later pushed up into the right upper quadrant; at this stage the small intestine is entering from the right and above. In the next stage the gut rotates so that the small gut enters from the left and below. In the later months of fetal life and the first month after birth the cecum grows downward, carrying the appendix and opening of the small gut with it. After this is complete, the ascending and descending colon and the rectum become fixed to the back wall. In this position the colon grows to keep pace with the individual. There are thus five phases, migration, rotation, descent, fixation and growth. Any of these elements may be varied.

1. Migration. Delay causes congenital hernia.

2. Rotation. Rarely the small gut may enter from above and to the outer side.

3. Descent. On the average the cecocolon grows down to the right iliac fossa and stops there. In about 10 per cent

of all females, less often in men, the cecum continues to descend and may reach the true pelvis. As another anomaly the tip of the appendix may adhere before descent is begun. As the cecum grows down, the appendix stretches out behind the colon, pointing up toward the liver. On fusion, the appendix becomes retrocecal.

4. Fusion. Both the ascending and descending arms of the colon may retain a mesentery, either as a whole, or in part. In these cases the hepatic and splenic flexures fall to the level of the iliac crests in the upright position, resuming their usual location when the patient is horizontal. There are many variations. The flexures may retain their mesentery and the colon be fused lower down: and this is the usual anomaly. Or the hepatic flexure may be fixed and the cecocolon swing on a mesentery, forming the "mobile cecum."

5. Growth. Any one of the four component parts: ascending, transverse, descending and sigmoid, may be produced in excess. The ascending colon has already been considered under "descent." The transverse may be in loops across the abdomen, or fall into the true pelvis as a festoon. The descending portion may be tortuous. The sigmoid may fill the lower half of the abdomen. Growth to excess may affect the diameter and not the length. Enlargements of the cecum beyond the average are not uncommon. Rarely the colon is of such caliber that even in the infant it may measure 3 or more inches in diameter (Hirschsprung's disease).

Position. The usual arrangement (the cecum in the right iliac fossa, hepatic flexure under the liver, splenic flexure under the left leaf of the diaphragm, junction with sigmoid in the left iliac fossa) is thus liable to minor or greater changes depending on embryonic development and on growth. Other factors influence position, as the individual

attains adult life. These are especially habitus and mobility of the diaphragm.

Function. It is the function of the colon to extract water from the fluid chyme and expel the unused residue. The colon urges its contents onward by "mass contraction," a general, slow, tonic contraction affecting 3 to 6 inches of the gut nearly simultaneously. The impulse to contract is more active in the cecal end, less so in the rectal, or expressed in the terms enunciated by Alvarez, the gradient is higher at the cecum. The difference in gradient is not considerable.

The ingested meal should arrive at the cecum in five hours, fill the entire colon at twenty-four, and be nearly completely expelled within forty-eight hours. When definite delay is found it may be reported as *stasis.* In these cases the musculature, especially of the descending portion, is nearly always spastic. It rests with the clinician to determine whether the reported delay in emptying time is important to the health of the individual.

In the rectal type, known as *dyschezia,* the meal rapidly passes through the colon into the rectum, and stays there for days, gradually producing dilatation of the rectum (Fig. 219). Spasm is characterized by the absence of a continuous shadow of the barium, by a diminution in the size of the haustral segments and by an increase in the depth of the sulci.

Technique. The ingested meal gives much information, but does not demonstrate the entire outline of the large gut, as fecal masses may prevent the barium from coming in contact with its wall. It is often necessary to clear out the colon by catharsis followed by thorough flushing with a warm cleansing enema, and then administer an opaque clysma. This may be prepared as follows:

Barium sulphate	125 gm. (¼ lb.)
Mucilage of acacia	250 gm. (½ lb.)
Warm water to	1500 c.c. (1½ qt.)

(The mucilage of acacia may be kept indefinitely by adding 0.5 per cent phenol.) Insert the tube just past the sphincter ani, and allow the solution to flow in slowly.

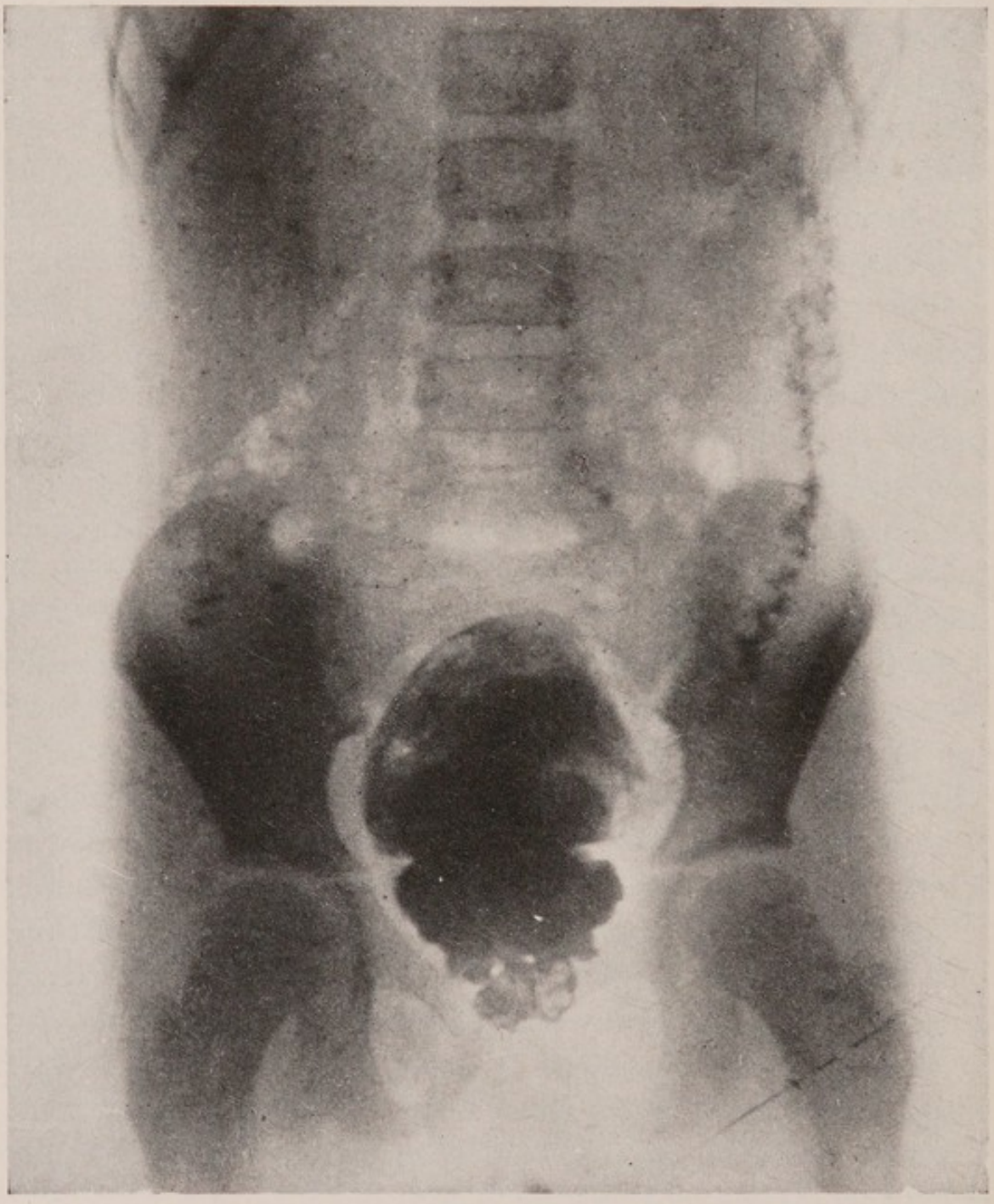


FIG. 219. Dyschezia; note dilatation of rectum (ingested meal).

As the enema enters it distends the rectum to a diameter of 3 to 4 inches. This raises the gradient and by a

series of short rushes the enema passes through the sigmoid, descending colon, transverse colon, ascending colon and cecum. If allowed to continue, the enema passes the ileocecal valve and enters the ileum. The entire procedure requires from three to five minutes. The colon distended by enema is nearly twice as large as that seen following the ingestion of the opaque meal. This is thought to be the result of the antiperistaltic wave which overcomes the usual tonic contraction of the musculature.

Obstruction. Acute. The bowel above the lesion is distended with gas and contains fluid.

In addition to the anteroposterior position, the patient may be turned on the side and a cassette placed against the abdomen. Only the portion of the colon that lies uppermost will be shown; the ascending and the descending colon must be demonstrated separately, by turning the patient on the left and on the right side, respectively. The administration of an opaque enema is contraindicated.

In the anteroposterior projection the distended colon is outlined by gas. In the lateral films the distended colon shows a broad gas-filled area, and below the gas, a horizontal fluid line.

Chronic. The colon above the lesion is distended with gas, and may contain fluid. Neither gas nor fluid is present to the degree encountered in acute obstruction. The patient should be examined standing. The gas-filled colon and any local collections of fluid in the colon are readily demonstrated, and are distinctive. An opaque enema may define the exact location of the lesion.

Carcinoma. The common positions are the cecum, the hepatic flexure, and the junction of the descending colon with the sigmoid, but no part of the large bowel is immune. When the mass is sufficiently large it projects into the lumen, disturbing the normal contour. If the mass is small

and located either on the anterior or the posterior aspect, it may escape detection.

In all cases where carcinoma is suspected an opaque



FIG. 220. Carcinoma of hepatic flexure (enema). Arrow indicates growth.

enema should be administered. In the presence of carcinoma of sufficient size, the enema flows in up to the point of

constriction, and stops there: the block is due to the raised gradient. After the bowel below has been stretched sufficiently, the enema flows past the mass, which is visualized



FIG. 221. Carcinoma of ascending colon (ingested meal). Arrow indicates growth.

as an unfilled portion, the "filling defect" (Figs. 220, 221, and 222). The rectosigmoid junction should be examined



FIG. 222. Carcinoma of cecum (enema). Arrows indicate growth.

with particular care. A loop of the sigmoid may drop over this area, and filling defects may be visible only in radiographs made in the oblique and lateral positions.

Diverticula are characterized by small circular shadows beyond the lumen of the colon, seen during the progress and after the evacuation of the barium meal (Fig. 223).

Tuberculous ulcers are indicated as follows:

1. The ingested meal reaches the splenic flexure or further in six hours, and is evacuated within twenty-four hours.

2. An enema flows in with difficulty, stopping at every ulcer until the gut below has dilated sufficiently to raise the gradient. The cecum is especially irritable, and although barium can be made to enter, it is promptly expelled. A radiograph will show numerous rings of contraction, and when the ulcers are closely set, a ragged, uneven contour of the gut wall.

Ulcerative Colitis. The haustrations are lost, the colon appearing as a smooth tube. There are local areas of constriction with ring contraction of the musculature. This disease has a very high mortality: fortunately it is not of common occurrence.

Cholecystography is the demonstration of the gall bladder by the administration of a dye. The process was discovered by Graham and Cole in 1923, and published by them in 1924. The dye in common use is tetraiodophenolphthalein sodium, or its isomer, phenoltetraiodophthalein. The dose of the former is 3.5 grams for an adult; of the latter, 2.5 grams. The dye is sold under a variety of trade names, shortened for the convenience of the customer. They are not the only chemicals that will demonstrate the gall bladder, but are the most practical of the ones discovered up to the present. Either dye deteriorates with age, on exposure to light, and when in solution. Dye that is deterio-

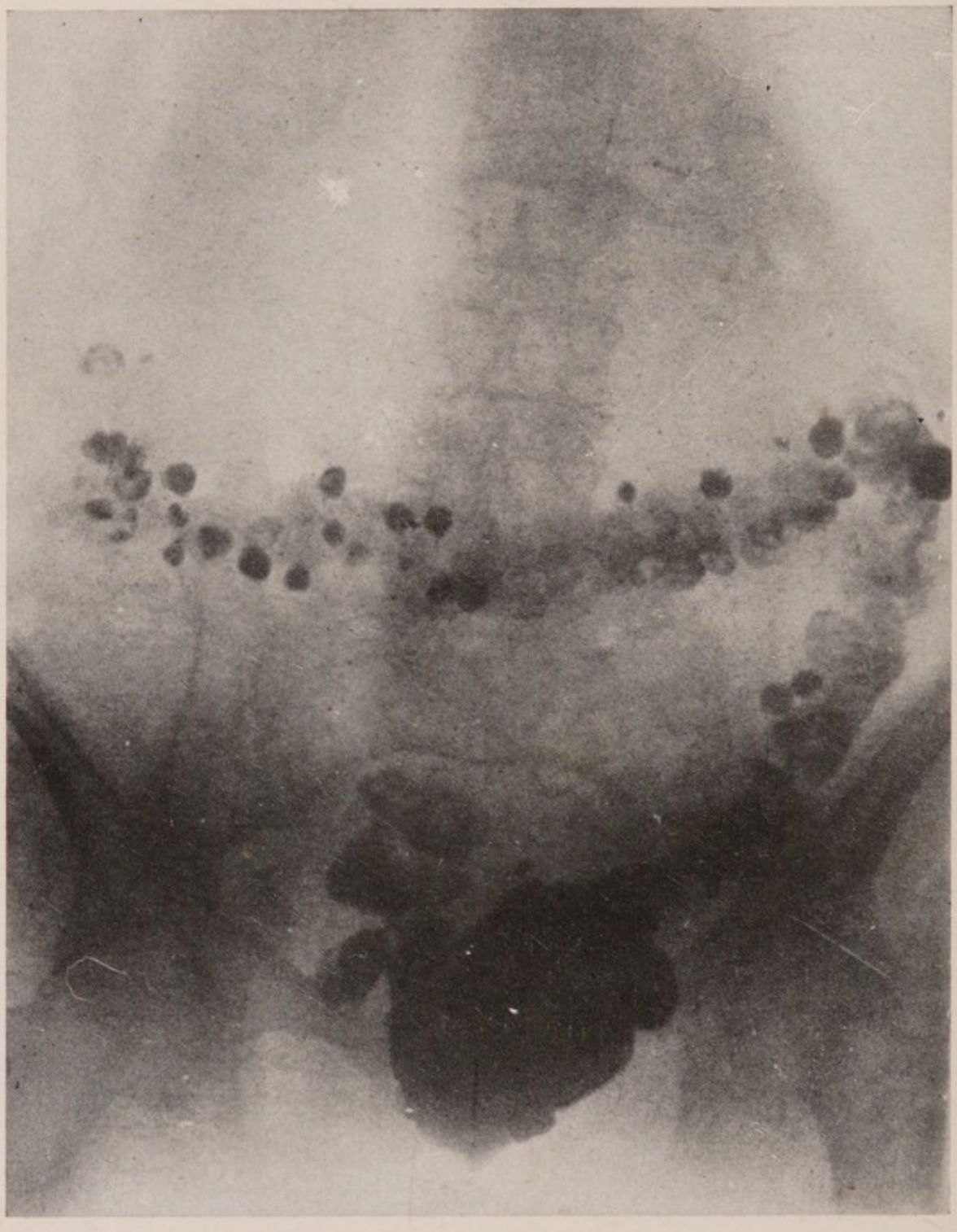


FIG. 223. Diverticula; note nearly circular shadows seen in transverse and descending colon.

rated is unsafe. Even the fresh dye may irritate the mucosa of the alimentary tract, or the blood vessel walls when given intravenously. There are two methods of administration: (1) intravenous, and (2) oral.

1. *Intravenous.* Fifteen to eighteen hours before the administration, the dye is dissolved in 30 c.c. freshly distilled water, sterilized over a water bath, filtered, and resterilized. If any precipitate forms it should be filtered and sterilized again. There are many approved methods of administration; the one given below follows closely the technique described by Case.*

About five minutes before giving the dye, inject ¼ grain ephedrin subcutaneously. A salvarsan apparatus is sterilized and filled with 100 c.c. warm Ringer's solution. The patient is recumbent. A tourniquet is placed around the arm to distend the veins. Under aseptic precautions an 18-gauge needle attached to a glass syringe is inserted into a vein; the plunger is withdrawn to make sure that blood flows. The tourniquet is removed. The needle is twisted off the syringe and attached to the salvarsan apparatus. Ringer's solution is then allowed to run into the vein. As soon as the flow is established the assistant pours the dose of dye into the burette. The injection proceeds as rapidly as gravity permits, usually requiring four to five minutes. The dye is followed immediately by 15 to 20 c.c. Ringer's solution which washes out the needle and vein. The needle is then withdrawn. One dose is given, not a divided dose. The patient remains recumbent for fifteen minutes. No food is allowed. Films are made four and eight hours later. If a definite shadow of the gall bladder is seen a fatty meal is then given and two hours later another radiograph is made. The examination is then complete. If no shadow of the gall bladder is found at four or eight hours no fatty meal is given and there is a third

*Case, J. T., *Am. J. Roentgenol.*, 16:239, 1926.

examination at twelve hours. It is convenient to administer the dye at 5 P.M., allow a fruit meal in the evening, and begin the radiographic examination the next morning before breakfast. The interval of fifteen hours' resting corresponds approximately to eight hours of ordinary activity.

Lately Case has advocated dissolving the dye in only 40 c.c. of distilled water; the filtering and sterilizing are done in the same manner. The solution is placed in a 50 c.c. syringe and injected into the vein through a 22 gauge needle; it is convenient to interpose 5 or 6 inches of rubber tubing between the syringe and the needle. The injection is followed with 4 or 5 c.c. of Ringer's solution.

2. *Oral.* (a) As advocated by Stewart.* The dye is removed from the sealed container and put up in 8 plain gelatin capsules not more than six hours before it is to be taken. At 6 P.M. a meal is given containing fat, usually in the form of eggs and butter. At 9.30 P.M. the patient takes two capsules containing dye, and one capsule containing 10 grains sodium bicarbonate, with half a glass of water; the dose is repeated every fifteen minutes until all the dye is taken. No breakfast is allowed. A radiograph is made at 9.30 A.M. the next morning, which should show the greatest gall bladder distention. Still no food is allowed and another radiograph is made four hours later, when the gall bladder should have contracted slightly and show the greatest concentration of the dye. A fatty meal is given, and two hours later a radiograph should show that the gall bladder has partly emptied, decreasing to about one-half its former size. The patient eats the usual meals and is again examined the following morning, when the gall bladder should be found to contain no dye. (b) Grape juice or carbonated water method. The fresh dye is dissolved in

*Stewart, W. H., *Radiology*, 11:271 1928.

1 oz. of water and filtered into an 8 oz. bottle; the bottle is filled with grape juice or carbonated water. The patient takes the same meal as in method (a) and drinks the mixture at 9.30 P.M. Thereafter the method of examination is the same as in method (a).

Contraindications. Extensive liver damage, cardiac decompensation, threatened uremia, common duct obstruction, acute abdominal conditions, and all those conditions associated with jaundice. In pregnancy after the thirty-second week technical difficulties make the procedure inadvisable.

Reactions are few. These are nausea, vomiting, chill, circulatory depression, fever, abdominal cramps, and urticaria. When the route is intravenous, phlebitis; oral, diarrhea. Treatment for reactions: for circulatory depression or urticaria, epinephrin; for all the others, rest recumbent. All the reactions are transitory, and even when severe disappear in an hour or two. No deaths have been reported although many thousand patients have received the dye.

The *demonstration* of a gall bladder shadow depends on:

1. Sufficient concentration of dye in the blood stream.
2. A liver capable of excreting the dye.
3. Patent common and cystic ducts.
4. A gall bladder capable of receiving and discharging the dye.
5. A gall bladder capable of concentrating the dye.

Some of these requisites are structural, and some functional. The dye may not enter the gall bladder because the ducts are stopped, or because the gall bladder is full of stones or inspissated bile. The dye given orally may not be absorbed into the blood stream in sufficient quantity, the liver may not be competent to remove the dye from the blood stream and deliver it to the bile, or the gall

bladder wall may be the seat of disease and not be able to accomplish the necessary concentration of the dye.

It is obvious that the radiographic technique must be excellent. The diagnosis is based mostly on negative evidence: a shadow that should be found is absent, or faintly portrayed. Non-opaque stones are demonstrated by slight changes in density within the cholecystogram.

The *normal* gall bladder fills, concentrates, alters in size, and empties. The radiograph shows a definite shadow at the proper time interval; the density is uniform without filling defects, the contour smooth and rounded; the size reduces after the fatty meal, and no shadow is seen at twenty-four hours.

Cholecystograms may be classed as follows:

1. Stone positive. (a) Calcified stone demonstrated without the dye. In every case a radiograph should be made before the dye is given. Rarely, these stones may not interfere with function; the shadow cast by the dye in the gall bladder may be dense and conceal the shadow of the stone. (b) Stone demonstrated by the use of the dye. As is well known, most gallstones are largely formed of cholesterin and are non-opaque. When the dye is given these stones show as areas of lesser density. Their shadow may be faint, barely perceptible. Shadows cast by small bubbles of gas in the duodenum or colon may be differentiated, because when films taken at the successive time intervals are examined, the shadows cast by the gas move from the gall bladder area, whereas the shadows of calculi always remain within the cholecystogram. The density of shadow of the cholecystogram is usually less than normal, but if function is little disturbed it may approach the normal density.

2. Absence of shadow. This is definite evidence of pathological change; it is not certain evidence that the pathology is in the gall bladder. Thus the absence of the shadow may

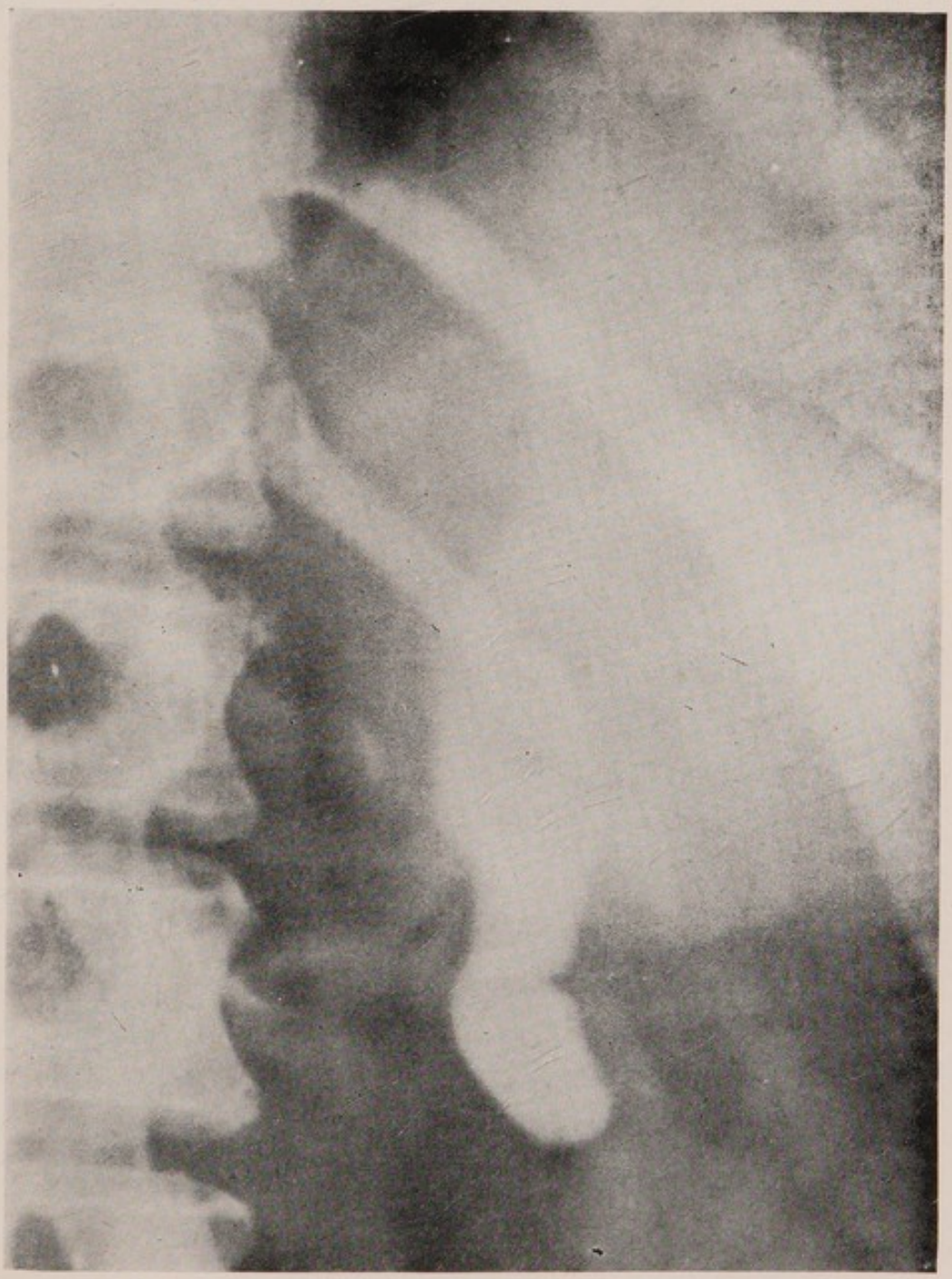


FIG. 224. Gall bladder shadow, "normal" type.

be due to occlusion of the cystic duct, or to the circumstance that the gall bladder lumen is packed full of stones, filled with inspissated bile, or obliterated from disease. On the

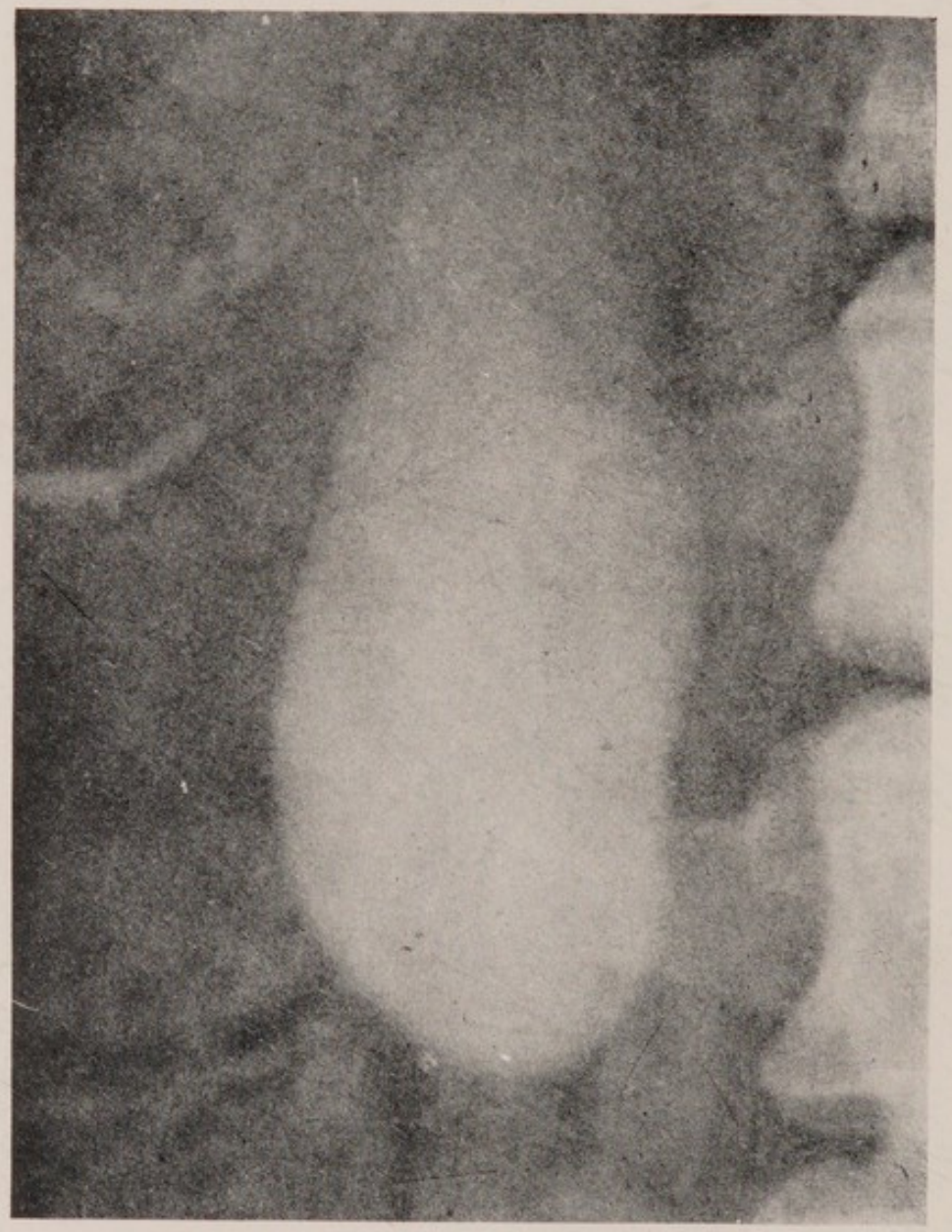


FIG. 225. Gall-bladder shadow, "normal" type.

other hand, the absence of the shadow may be due to the failure of the liver to excrete the dye.

No dye may be found in the gall bladder in the presence of acute abdominal conditions, or in diseases associated with jaundice. There are certain individuals classed as the

"asthenic type" who may show no dye in the gall bladder. It is well to question the patient and make certain that unauthorized food has not been eaten.



FIG. 226. Gall bladder shadow, "normal" type.

3. Normal. This implies that the shadow is characteristic of that cast by a normal gall bladder. It does not mean that the gall bladder of the patient examined is necessarily completely free from disease, as the test is not perfect. However,

a gall bladder casting a "normal" shadow is free from disease at least nine times out of ten.

4. All others. This is a general class that includes the

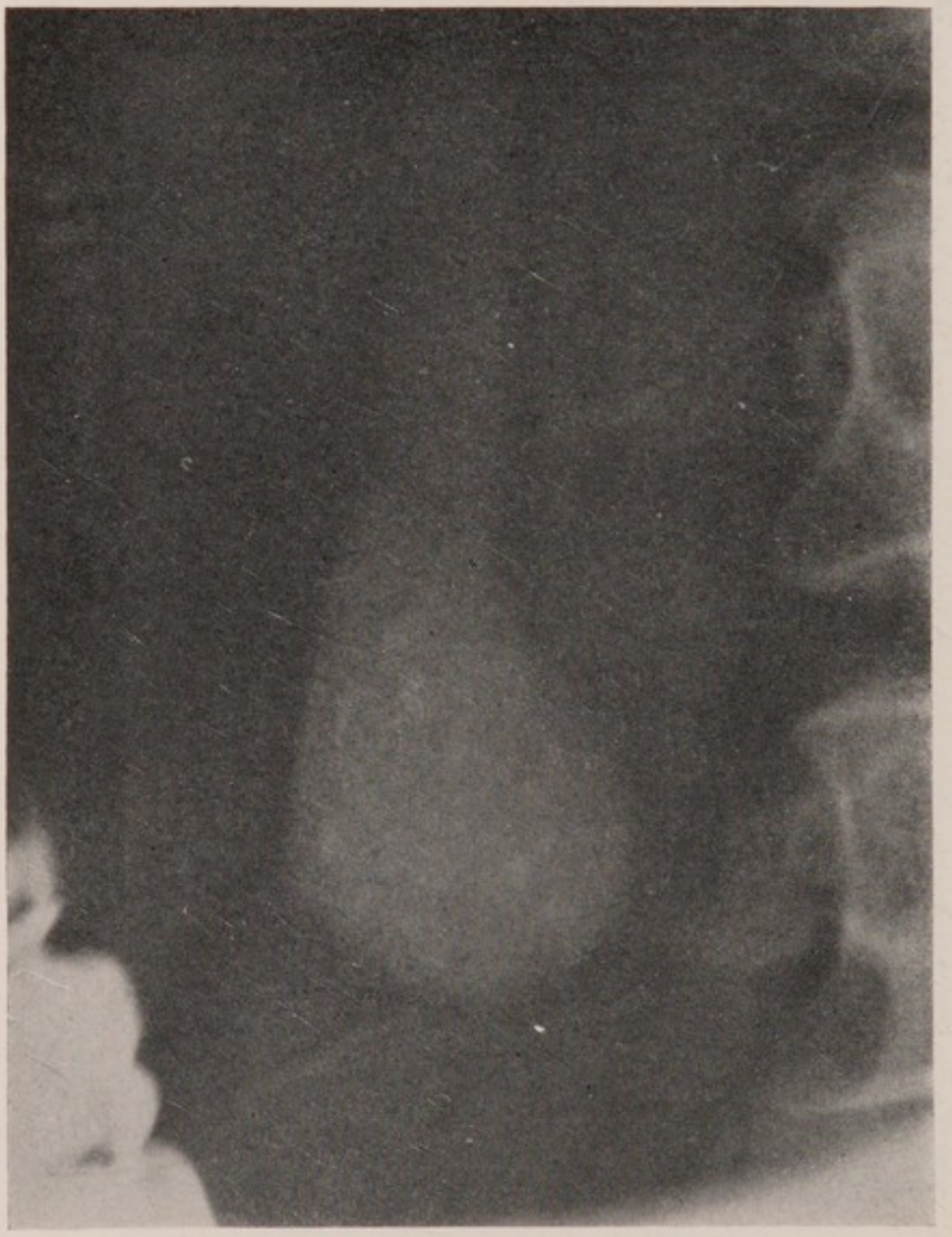


FIG. 227. Enough dye is concentrated in the gall bladder to cast a shadow of "normal" density. Within the shadow of the gall bladder are the dense shadow of calcified gall stones.

following abnormalities of density, shape, or the time the shadow appears.

(a) Faint shadow. At no time does the shadow attain the density that may be considered "normal." The condition of the stomach and duodenum should be re-checked and

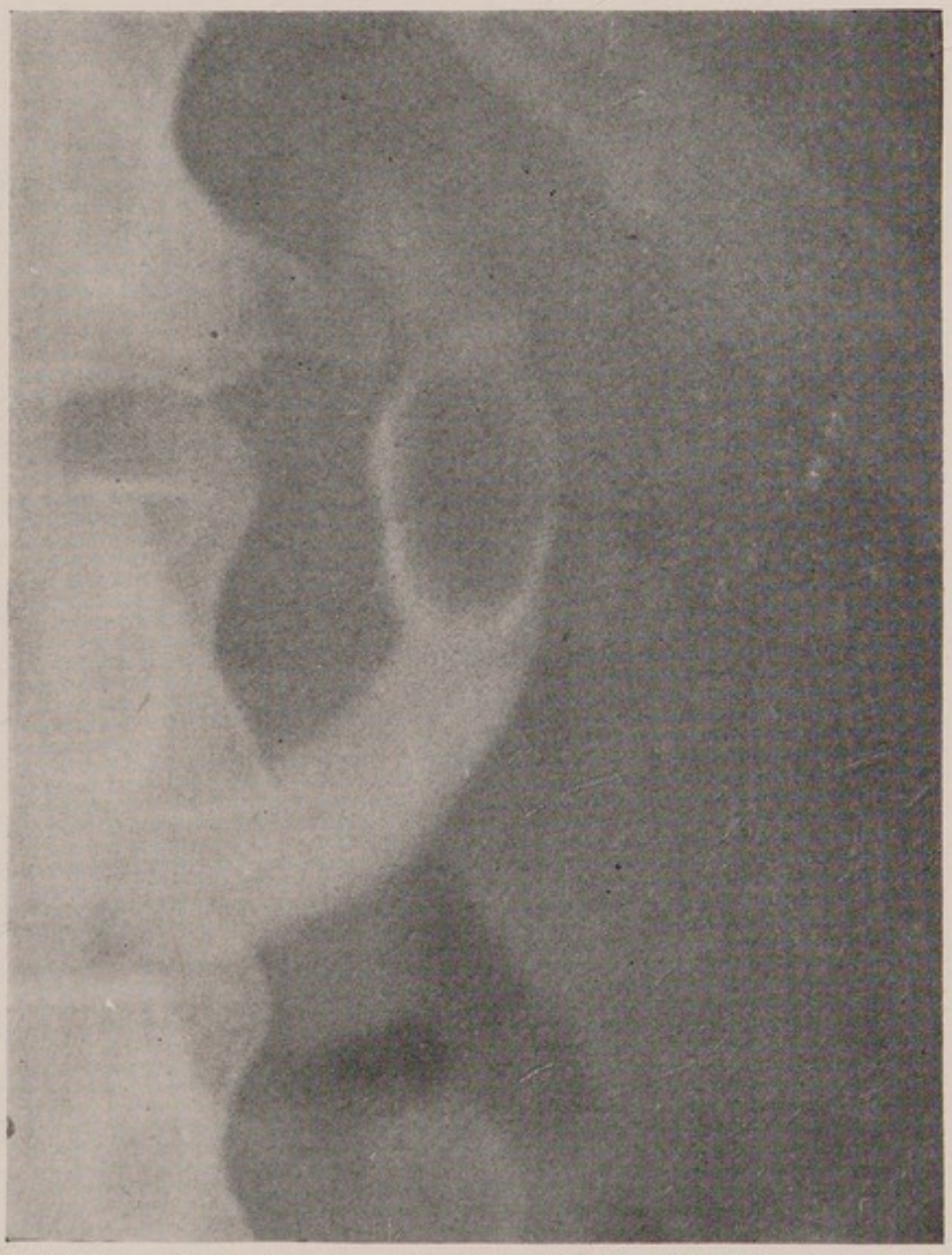


FIG. 228. Enough dye in concentrated in the gall bladder to cast a shadow of "normal" density. Within the shadow of the gall bladder is the negative shadow of a solitary non-opaque gallstone.

disease of these organs eliminated. The test should be repeated, and atropine given. If the shadow continues to be faint, there must be some break in the five link chain: dye

in the blood, liver function, duct patency, gall bladder reception, and dye concentration. The films taken at the different time intervals should be compared. If there is little or no variation in the size of the gall bladder, the cause may be disease of the gall bladder wall, which has lessened its ability to withdraw fluid and concentrate the dye.

(b) Persistent shadow. Dye given by mouth may be absorbed more slowly than usual; the dye excreted by the liver and emptied into the intestine may be reabsorbed and again excreted. It is rare that persistence of the shadow is important evidence.

(c) Deformed shadow. The normal gall bladder may take queer shapes, especially if it is elongated and folded on itself. Irregular shadows are usually due to stone within the gall bladder, which can be demonstrated by a better radiograph. Occasionally the irregular shadow is due to adhesions about the gall bladder. Commonly adhesions if present do not deform the gall bladder outline.

(d) Abnormal position is rarely important.

The success of the radiologist depends on careful technique and rigid adherence to the same method of examination. Whether the dye shall be given intravenously or by mouth depends largely on individual preference. As a rule the *x*-ray examination of other parts of the body may be assisted by knowledge of the history and clinical findings; here it is not. The case that is clinically definite rarely needs radiologic confirmation. The case that is usually sent for examination of the gall bladder is the type where the symptoms and clinical findings are vague, uncertain, and indefinite, but so persistent and aggravated that the possibility of gall bladder involvement arises. The radiologist will do well to err on the side of ultraconservatism. Often he can assist with a definite statement. If he cannot, his report should be summarized as "inconclusive."

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