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Contributors

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W. L. Harris

SURGERY OF THE LUNG

BY

C. GARRÈ
Professor of Surgery at the University of Bonn

AND

H. QUINCKE
formerly Professor of Medicine at the University of Kiel

SECOND EDITION

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DAVID M. BARCROFT, M.D.

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PREFACE.

SINCE the publication of the first edition of our "Sketch" (1903) the surgery of the lung has made considerable progress. Not only, by constant and careful elaboration of the old methods of procedure, have the operations then in vogue been more frequently, and, on the whole, more successfully carried out, but new methods have been invented and new indications laid down. Above all must be mentioned the method of maintaining difference of pressure, which has enlarged the sphere of surgical operation to an extent hitherto unimagined; also the methods, at that time only in their infancy, of artificial pneumothorax and thoracoplasty, and the surgical mobilization of the thorax by the bisection of the costal cartilage.

This increase of material has necessitated altering and re-writing to a very great extent, and the addition of a great many illustrations. We hope, by this means, to have done justice to the progress made in the surgery of the lung and to the actual condition of affairs.

GARRÈ. QUINCKE.

BONN AND FRANKFORT-ON-THE-MAIN,
May, 1912.

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SURGERY OF THE LUNG.

CHAPTER I.

ANATOMICAL TOPOGRAPHICAL INTRODUCTION.

For the modern surgery of the lung a summary acquaintance with the thorax and its contents no longer suffices. New operations, more delicate in their technique, presuppose an exact knowledge of the region in which the operation is to take place. Thus, only to mention a few, the technique of anæsthesia by loss of nerve conduction is based upon a detailed knowledge of the course of the peripheral sensory nerves, Freund's operation rests upon a proper understanding of the mechanics of the thorax, Trendelenburg's operation, Sauerbruch's ligature of the branches of the pulmonary artery, bronchotomy and bronchoscopy, &c., demand, besides the steady hand of the surgeon, an anatomically trained eye. So it seems to me that a topography treated from these points of view will not be unwelcome to the surgeon.

Both lungs are surrounded for the greater part of their upper and practically their only accessible surface, by a uniformly articulated structure—the thoracic wall. It is important to know thoroughly not only the structure of the thoracic wall and the lungs, the position of the lungs and pleura, but also the boundaries of the lungs and pleura.

On the lower boundary of the thoracic cavity the conditions are also simple, as here only the diaphragm comes into consideration.

More complicated are the conditions at the cardiac surface of the lung and the dome of pleura, as here large blood-vessels and nerves have to be taken into consideration. But here an operation on the lung can only rarely take place.

The bony framework of the thorax is the chest-wall. It is generally cone-shaped, somewhat flattened posteriorly, and slightly contracted inferiorly. In women the thorax, which is generally smaller, is rather barrel-shaped than cone-shaped, owing to the shortness of the sternum and the greater length of the upper ribs. The female thorax, in form, more nearly resembles the inspiratory type; the male, the expiratory.

The bony thorax is composed of the dorsal vertebræ, the twelve pairs of ribs, and the sternum.

The dorsal vertebræ form, as it were, a slightly movable staff.

The sternum, consisting of the manubrium, gladiolus, and ensiform process, has in its lower section a slight convex curve to the front; when there is a sternal angle (angulus Ludovici) between the manubrium and gladiolus the arch is more pronounced. At this spot, which is easily palpable, the 2nd rib is inserted. The upper margin of the manubrium is opposite the 2nd and 3rd dorsal vertebræ. The sternum has a thin cortical layer which encloses a loose spongiosa with bone-marrow, rich in blood. It is worthy of note that the flexible connection between manubrium and gladiolus (the region of the sternal angle) becomes ossified in old age; it must also be noticed that the gladiolus is composed of several individual parts, and that frequently holes (defects in ossification) occur, especially in the lower section of the gladiolus.

Only the seven upper ribs are attached to the sternum. The 8th to the 10th ribs are connected at the anterior end with the cartilage of the 7th. The 11th and 12th ribs are free. Not infrequently the cartilage of the 8th rib reaches the sternum. The two first and two last ribs tend in their whole length to incline downwards from the back to the front. The others at first follow the same course, but before their insertion in the sternum, or in the cartilage of the 7th rib, they turn upwards in such a way that the lowest point of the 7th rib is in the nipple line; whilst that of the ribs above it is more mesially, that of those below is more laterally placed. TILLAUX has ascertained by sagittal sections of the thorax in the nipple line that the 1st rib corresponds anteriorly in the horizontal plane with the 4th rib posteriorly. For the time being the 2nd to the 7th ribs in front correspond with the 6th to the 11th ribs behind in the scapular line. The knowledge of this simple fact should make the comprehension of X-ray photographs easier. The mechanism of the thorax will be treated of in the chapter on "Emphysema."

As anomalies of the ribs may be mentioned fissures at the anterior end. The rib may end by means of two cartilages in the breast bone, or, if the bifurcation ends before this insertion in the sternum, roundish or oval holes may arise, generally situated at the border of the bony cartilage. Of the supernumerary ribs, the cervical ribs have a certain practical importance. "If the subclavian artery with the brachial plexus passes over a cervical rib, then this is also reached by the dome of the pleura, which is not now hindered from rising so high." (Merkel, "Text-book of Topographical Anatomy," vol. i, p. 326.)

The cortical substance of the ribs is firmer and the medullary spaces are smaller than those of the sternum; the powerful periosteum is, in contrast with the outer side, very firmly attached to the inner surface of the ribs.

The breadth of the intercostal space is the greatest in the three first, especially at the border of the bony cartilage. When the

vertebral column is extended the intercostal spaces attain their greatest dimensions. After severance of the pectoral and intercostal muscles, the ribs, especially in children, move apart, so that in the case of children a wide opening of the pleural cavity can be achieved without excision of ribs.

The bony structure of the thorax is covered externally by various strong muscular substances and the skin with the subcutaneous tissue. Besides these are superimposed posteriorly from the 3rd to the 8th ribs downwards the shoulder-blades and anteriorly the mammary glands, the base of which extends from the 3rd to the 6th or 7th ribs.

Concerning the muscles of the thorax, the following should be remembered. In front of the thorax lie the pectoralis major muscle, beneath this to the side the pectoralis minor muscle, more to the side beneath the serratus anticus major. To these adhere the processes of the obliquus externus abdominis muscle, so that the processes of the two muscles are intermingled.

In the dorsal region of the thorax lies on the surface the large trapezius muscle and beneath as a second layer the rhomboidei and latissimus dorsi muscles, the inferior fasciculi of which interdigitate with fasciculi of the obliquus externus abdominis muscle. Lower than the trapezius lie as a third layer the unimportant serratus posticus superior and inferior muscles.

The two splenii muscles (dorsi et cervicis) belong already to the region of the nape of the neck. Still lower than the so-called superficial muscles lie in the sulci dorsales, in the two spaces formed on the one side by the spinous processes, and on the other side by the angles of the ribs, the long and short muscles of the back.

Between the ribs, filling up the intercostal spaces, is the double layer of the intercostal muscles. The outer muscles run obliquely down from back to front and reach from the levatores costarum muscles to the bony end of the ribs. They are interspersed with shining tendinous fibres, which are continued between the cartilage of the ribs and form here the external intercostal ligaments. The inner muscles take an opposite direction. They spring from the inner surface of the rib at the upper margin of the sulcus, cover the vessels therein and adhere to the upper edges of the rib next beneath. The internal intercostal muscles extend in front as far as the sternum, but at the back only to the angle of the rib.

On the inner surface the thorax is covered in front at both sides of the sternum by the oblique processes of the transverse thoracic anterior muscles (triangularis sterni muscle of older writers), behind by the irregular fasciculi of fibres of the transversus thoracis posterior muscles. The fibrous fasciculi of both masses of muscles pass over the inner surface of the ribs.

The inner surface of the thorax is also covered by the fascia endo-thoracica, a thin layer of fascia, which unites the outer surface of the pleura costalis with the inner surface of the muscles of the ribs or the intercostal muscles, and passes over the posterior surface of the sternum as well as the convex surface of the diaphragm.

The various layers of the wall of the thorax are shown in transverse section in fig. 1. The superficial layer of muscle is seen, enclosed by two layers of fascia, the superficial and deep fascia thoracica. Then come the ribs and between them the double layer of the intercostal muscles. Between them lie on the lower edge the ribs, one by one, and here, embedded in the sulcus costalis, nerves and blood-vessels. Further inwards there follows a thin layer of fascia, which, in coalescence with the inner surface of the ribs, spans the intercostal spaces, the fascia endo-thoracica. It forms the foundation for the innermost layer, the pleura.

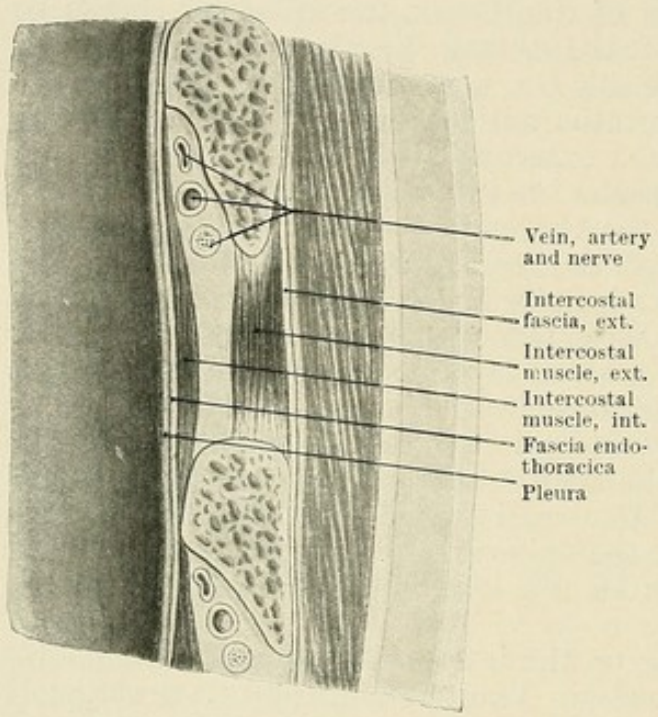

FIG. 1.—Transverse section through the chest wall. According to TILLAUX.

The wall of the thorax proper receives its provision of blood through the posterior intercostal arteries and the internal mammary artery (fig. 2).

The intercostal arteries (posterior) spring, with the exception of the two first, which proceed from the truncus thyreocervicalis of the subclavian, from the posterior wall of the thoracic aorta. Each intercostal artery (posterior) runs—those on the right side after they have passed over the bodies of vertebræ—from the costovertebral articulation to the lower edge of the rib in question. From the angle of the rib it lies at a distance of about 8 cm. in the sulcus costalis inferior protected by the rib. This part, therefore, the region between the middle and posterior third of each rib, is the most suitable for puncture and incision (TERRIER and REYMOND). From each intercostal artery there proceeds in the posterior section of the intercostal space a branch which runs along the upper edge of the rib next below towards the front.

The internal mammary artery, a branch of the subclavian artery, runs behind the sterno-clavicular articulation straight down at the side of the sternum. As both edges of the sternum are convexly curved, the mammary artery is, like the various intercostal spaces, some distance (11 to 20 mm.) from the breast-bone.

SANDMANN[1] gives the average extent of the distance of the artery from the breast-bone as follows:—

[1] Inaugural Dissertation, Königsberg, 1894.

In the 1st intercostal space, 11 mm.
In the 2nd to 4th intercostal space, 15 to 16 mm.
In the 5th intercostal space, 17 mm.
In the 6th intercostal space, 20 mm.
Deviations occur.

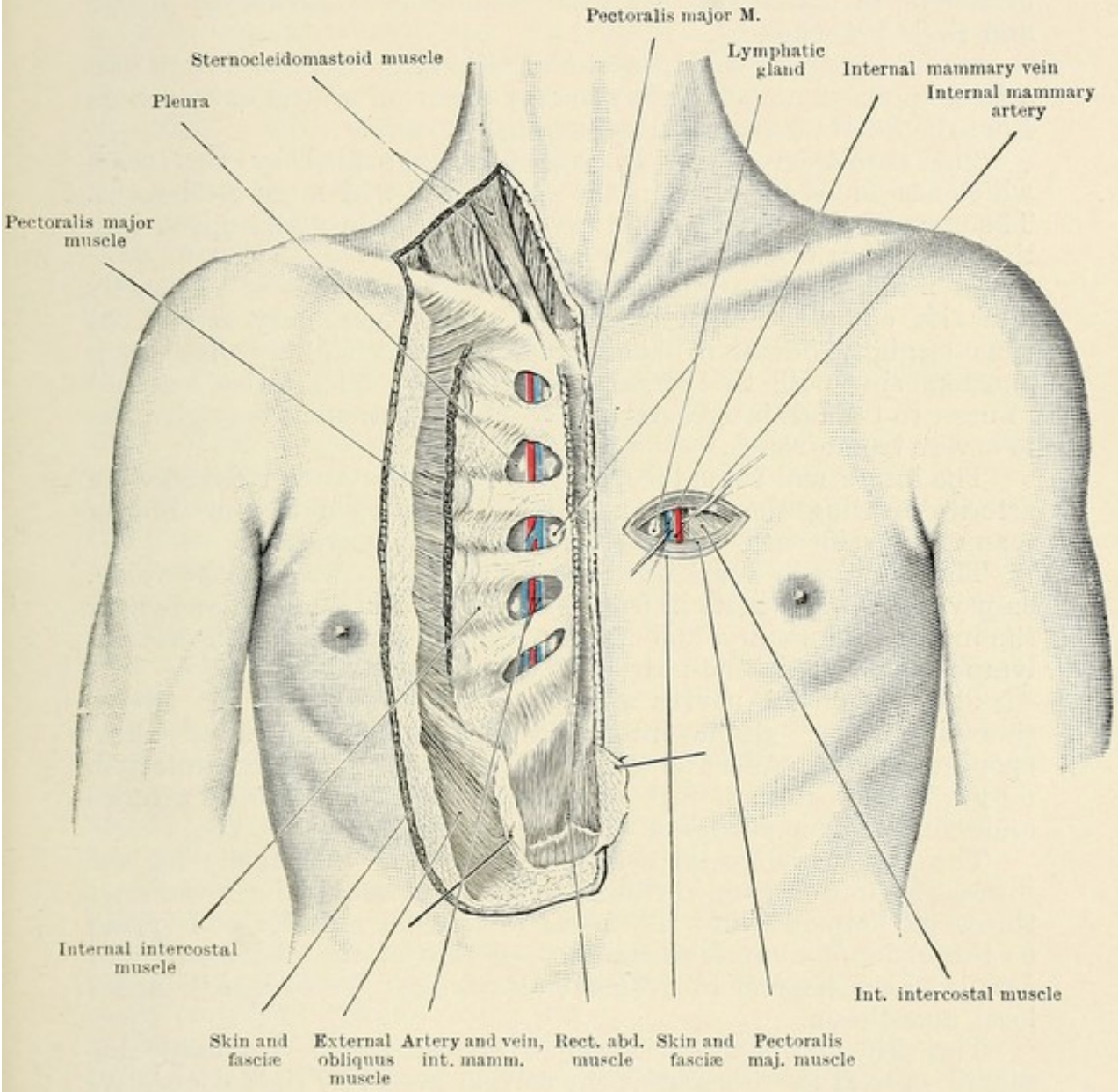

FIG. 2.—Internal mammary artery. (From JOESSEL'S "Topographical Surgical Anatomy," vol. i.)

Whereas in the first upper section the mammary artery is only covered by the pleura, from the 3rd intercostal space onwards it is covered by the triangularis sterni muscle, on which the pleura rests.

From the 7th rib cartilage onwards the mammary is divided into the musculophrenic artery, which is to be looked upon really as a continuation, and the superior epigastric artery. The musculo-

phrenic artery runs down the costal arch along the insertion of the diaphragm and the transversus abdominis muscle.

Both from the internal mammary artery proper and from the musculophrenic proceed, corresponding to each intercostal space, two intercostal arteries (anterior), one of which flows on the lower margin of the upper rib, the other on the upper margin of the lower rib, to unite with the intercostal arteries (posterior) proper and their branches.

It often happens that the two equally large anterior intercostal arteries proceed not separately but by means of a little azygos stem from the lateral margin of the mammary artery.

The mammary artery is usually accompanied by two veins which are joined together in the 4th to the 2nd intercostal space. The stem of the vein lies midway from the artery and opens into the subclavian vein.

In rare cases the internal mammary artery throws off shortly after its commencement a kind of lateral mammary artery. It runs straight down in about the anterior axillary line, and, anastomosing with the corresponding intercostal arteries, extends at most to the 6th intercostal space. In operations it may give rise to severe hæmorrhage.

The intercostal veins take, on the whole, the same course as the arteries bearing the same names. They flow into the inferior mammary veins and into the azygos or hemiazygos.

The lymphatic vessels behave in the same way as the veins, emptying their contents in front into the sternal lymph-glands near the internal mammary, and at the back into the little intercostal lymph-glands, which lie near the heads of the ribs.

The intercostal nerves are the front branches of the twelve thoracic nerves. Each intercostal nerve takes a course corresponding to the sulcus costæ inferior; they lie, least protected, on the lower section of each sulcus, whereas the intercostal arteries and veins lie deep down and are thus protected.

The upper intercostal nerves are intended exclusively for the intercostal muscles and the skin of the chest wall; the lower ones throw off branches into the lower intercostal muscles and spread to the abdominal muscles and to the skin of the abdomen. For details see Chapter IV., "General Surgical Technique," under local anæsthesia.

The skin of the thoracic wall is on the whole very easily displaced, only at the sternum is the corium bound by rigid connective tissue to the periosteum, and so less mobile on its substratum.

Regarding the incisibility of the skin of the chest, LANGER[1] states that the direction in which an incision will produce the smallest opening both in the lower and in the lateral thoracic regions, is a horizontal, or slightly descending, zone. In the upper thoracic region the lines converge from the shoulders to the median

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[1] "On the Anatomy and Physiology of the Skin: (I), on the Incisibility of the Skin." Reports of the Session at Vienna, April 15, 1861.

line in the form of a triangle with the base above, and the apex about as high as the nipple.

The thoracic cavity is bounded below by the diaphragm (figs. 3 and 4). It is a bilateral almost symmetrical muscular layer, which springs from the lower end of the sternum, the lower aperture of the thorax and the lumbar portion of the spine, and arches up into the thorax in the shape of a cupola. In the middle the arch is somewhat flattened (base of the heart). The diaphragm consists of a central sinewy section, the central tendon, and a muscular periphery, which is divided, according to the site of origin, into a pars vertebralis, costalis and sternalis. In the central tendon, on the boundary between the right and middle membrane, is the opening for the inferior vena cava. Between both partes vertebrales appears the aorta lying somewhat extra-median towards the left with the thoracic duct below to the right. Only a little farther on, higher up, forward and to the left, lies between the vertebral sections the œsophageal space, through which, beside the œsophagus, the vagi nerves run. The pars costalis of the diaphragm springs, as well as the transversus abdominis muscle with numerous processes, from the six lower ribs. The sternal part is inserted in the posterior surface of the ensiform process. "If you join the foundation of the diaphragm to the skeleton by a line, it takes substantially the form of an ascending zigzag from the lumbar vertebræ to the ensiform process." From its commencement to the fold of the pleura, to be described later, the diaphragm lies close to the thorax.

The arch of the dome of the diaphragm is higher on the right than on the left, and indeed the difference amounts to an intercostal space. On deep expiration, the highest point reached by the right summit of the diaphragm is the lower margin of the 5th rib, or up to the 4th intercostal space. On deep inspiration the top of the right pleura descends to the 6th rib in the nipple line (see figs. 3 and 4). On the left side the position of the diaphragm on expiration and inspiration is correspondingly lower.

In young people the position of the diaphragm is higher, in more advanced age lower. (See Chapter "Rigidity of the Thorax.")

The relation of the organs placed inside the thorax (the two lungs and the heart) and their investing membrane can be most easily pictured in the following way.

Imagine that the whole inner space of the thorax is divided into three parts by two almost sagittal partitions (mediastinal). In the middle division lies the heart, in the two lateral divisions are the lungs.

Each of these three organs is enveloped in a serous sac, so that each organ is in a twofold sac. The one closely envelops the organ in question, that is the visceral sac (membrane). The other outer sac loosely enfolds the organ, that is the parietal sac (membrane). The parietal sac lies alongside the inner wall of the thorax or the adjacent sac. So that in the medial space of the thorax corresponding parts of the parietal lung sacs, that is of the pleura, and of the parietal heart sac, that is of the pericardium, do not only touch, but also grow into one another, and there arise two partitions stretching from front to back, the mediastina.

Each lung is, as it were, from the middle of the thorax onwards, enveloped in its serous sac, and that so completely that the two resultant sacs, one inner and one outer, touch one another without interruption. The visceral sac covering the lungs is called pleura pulmonalis, the second enveloping parietal sac is called, according

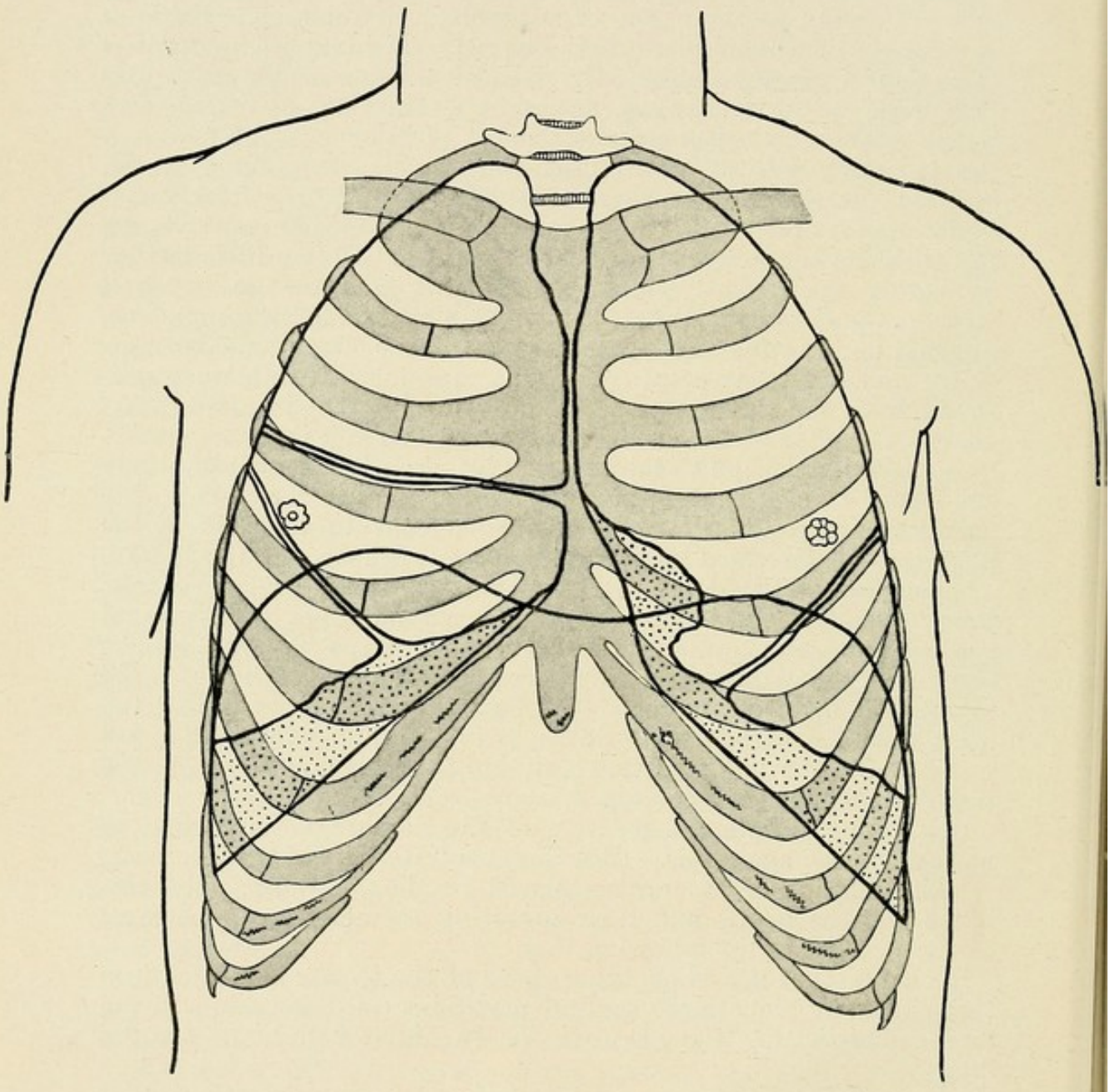


Fig. 3.—Front boundaries of the lobes of the lung and the pleura. Complementary spaces dotted. Position of diaphragm drawn in accordance with an X-ray picture.

to its position relative to the adjacent organs, costal pleura contiguous to the thorax, diaphragmatic pleura, which covers the diaphragm, and mediastinal pleura, which, having grown into the pericardium, forms the wall of partition (mediastinum).

The visceral pulmonary membrane covers the whole of the

upper surface of the lungs till the bronchus appears in the hilum of the lung; it penetrates between the two lobes of the lung, and is firmly adherent to the upper surface of the lung.

Both the visceral and parietal membranes consist of a strong fibrous substratum, which is covered with a thin endothelium.

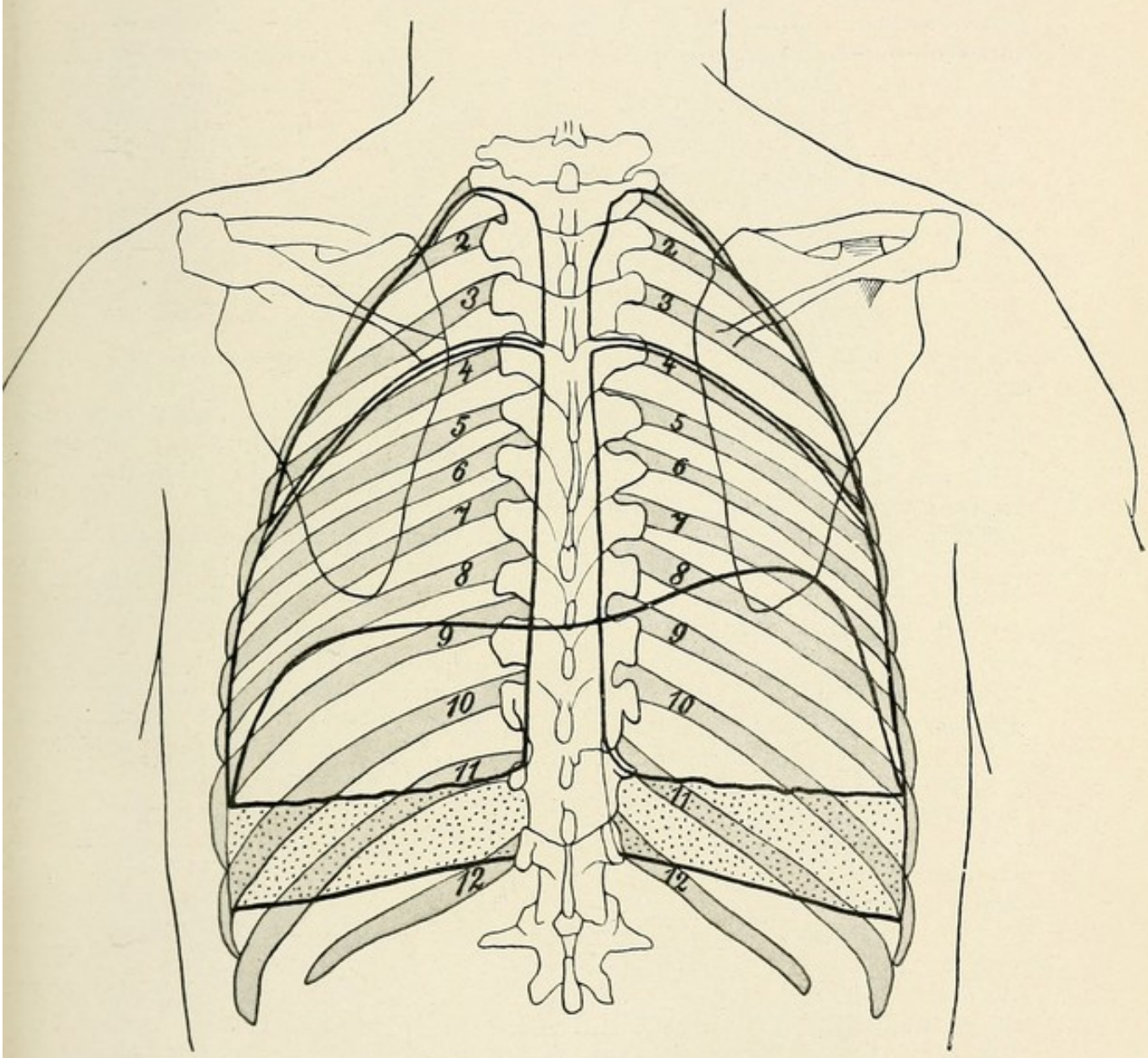


FIG. 4.—Front boundaries of the lung and pleura. Complementary spaces dotted. Position of diaphragm drawn from an X-ray picture.

Without giving any further details about the heart, the pericardium and their relation to the pleura, the following points must necessarily be mentioned.

The two lungs with their pleura, as well as the heart and the pericardium, do not completely fill up the thoracic cavity; there is behind, by the dorsal column between the two pleural sacs and

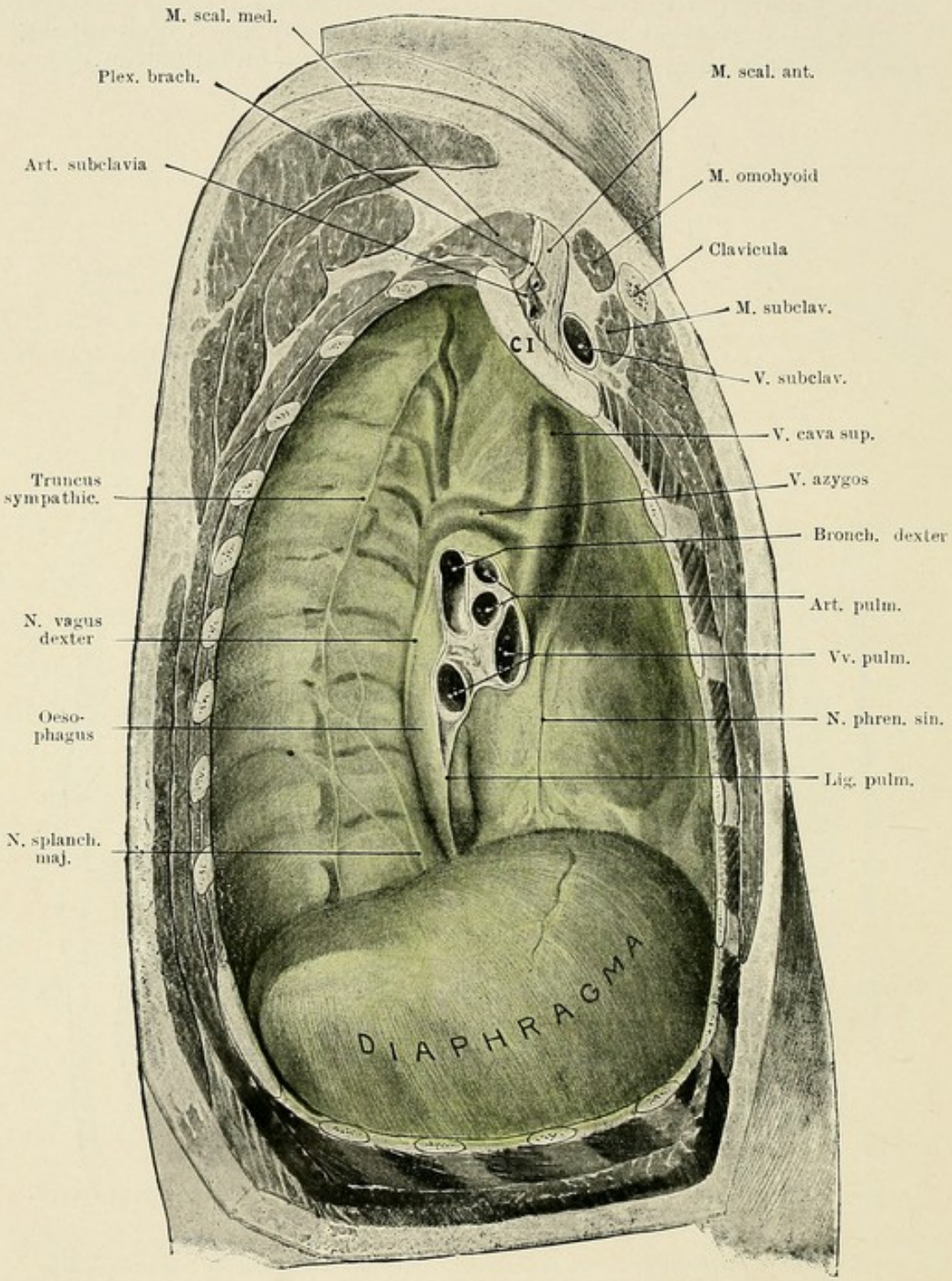


FIG. 5.—Thoracic cavity from the right after removal of the right lung (after MERKEL, out of CORNING'S "Text-book of Topographical Anatomy").

the pericardium, a free space, which is filled up by other organs. This space, which is erroneously called the mediastinum, and should more correctly be termed cavum mediastinorum (posterius), contains the œsophagus and the vagi nerves, the abdominal aorta, and the thoracic duct.

The sympathetic nerves, often mentioned here, are not in this space, but between the wall of the thorax and the pleura costalis. Finally, it must also be remembered that above also the heart and its covering (pericardium) do not fill up the whole space between the two lungs, as the large cardiac vessels and the trachea are situated here. It would not be inappropriate to describe this space as the cavum mediastinum superius.

The position of the lines which mark the merging of the sections of the pleura and form the limits of the pleural cavities on the anterior thoracic wall and in the lower periphery of the thorax, is of great practical importance, though the lines vary within certain limits (figs. 5 to 8).

The front folds of the pleura pass down on both sides from the upper margin of the first rib cartilage behind the manubrium sterni obliquely to a spot between the manubrium and the gladiolus, which lies a little to the left of the median line. Behind the body of the sternum the pleural folds pass further downwards at a little distance from one another. The pleuræ can touch each other here also. From the top of the insertion of the 4th rib the limits of the pleuræ diverge, the right passing straight down to below the insertion of the 6th rib to the sternum. The left passes more obliquely, close along the external margin of the sternum or even more laterally down behind the cartilage of the 4th to the 6th rib.

In the region of the lower half of the sternum or behind the 4th to the 6th rib cartilage, there remains therefore a triangular space free from pleural covering ; here the pericardium lies directly against the walls of the thorax.

The lower boundary of the right pleura is formed by a line which cuts the sternal line at the upper margin, the parasternal line in the middle, and the nipple line at the lower margin of the 7th rib cartilage. It meets the axillary line at the lower margin of the 9th rib, divides horizontally the 12th rib, and ends at the lower margin of the 12th dorsal vertebræ.

For the practical localization of the lower boundary of the pleura, you can proceed as follows : Draw a horizontal line through the lower angle of the 11th dorsal vertebral spinous process up to the point of intersection with the 10th rib. Then ascertain the central point of the sternum opposite the insertion of the 5th rib cartilage and join this point with the point of intersection on the 10th rib by a flattened curve, which cuts the 7th rib in the nipple line. As much as half the 12th rib may be above this line, a fact the non-observance of which in operations on the kidney may result in opening into the pleural cavity.

On the left side the lower limits of the pleura lie somewhat deeper, but, clinically speaking, this difference has scarcely any importance. Whilst the lower limits of the pleura in general vary

in their position at the most to the extent of a finger breadth, PANSCH noticed sometimes that the back parts extended to the lower margin of the process of the lumbar vertebræ. The folds are most continuous at the back, where the pleuræ pass from the ribs to the vertebræ and the organs of the medial space.

The extent of the costal pleura may, from what has been said above, be easily overlooked ; it is connected with the thoracic wall by the fascia endothoracica, and may be detached from its support in the region of the intercostal spaces. But on the inner surface of the ribs the pleura and the fasciæ are firmly grown together and these with the ribs. In the cleft between pleura and fascia a deep emphysema may arise from an opening in the pleura—caused by an injury or by the puncture needle (artificially produced pneumothorax) ; this emphysema may spread in front up the sternum and beneath it upwards to the collar-bone, and then make its appearance again in the neck. The diaphragmatic pleura is more closely ingrown with the diaphragm and covers it as far as the greater part of the central tendon, and an adjacent part of the pars musculosa on the left side, which are covered by the pericardium. In the proximity, too, of the fundamental processes, the diaphragm is not covered by pleura, but here, as already mentioned, is for a space directly contiguous to the ribs.

The anatomical relations are most complicated in the mediastinal pleura ; here they may prove of practical importance, as in the excision of a portion of the lung, in consequence of the ingrowth of the visceral and parietal membrane of the pleura, the adjacent organs of the medial space, and even the pleura on the other side, may be injured. In order to avoid such injuries, one must keep as close as possible to the lung side of the adherent pleura, in order not to endanger the life of the patient by hæmorrhage, which cannot be arrested, or by pneumothorax.

The mediastinal pleural membranes pass from the back of the sternum backwards to both sides of the vertebral column, and enclose between them the organs of the cavum mediastinorum. Whereas over a third of their upper course they run without interruption from the sternum to the vertebral column, in their lower section, which is larger, they are interrupted by the hilum of the lung and the ligamentum pulmonale. The latter is a membrane resembling the mesentery, which, in close connection with the pleural duplicature passing over the hilum of the lung, stretches from the mediastinum to the posterior margin of the lung, and terminates freely close above the diaphragm.

Behind the gladiolus the two pleural membranes above the 4th rib lie at first close to one another, and are only separated by a layer of connective tissue varying in strength. After a short space they separate one from the other, and pass over both the lateral surfaces of the pericardium, with which they are united by strong connective tissue. Below the 4th rib both mediastina diverge immediately behind the sternum, as here the pericardium, as already mentioned above, is in direct proximity to the sternum. Between the pleura and the pericardium, on both sides, run the phrenic nerves.

The upper surface of the mediastinal pleura is somewhat complicated owing to the vaulting of the organs of the cavum mediastinorum surrounding it, and which gives an essentially different appearance to the right and left sides. These conditions are of great importance in all operations in the vicinity of the mediastinum, and a detailed knowledge of the relief of the mediastinal pleura will, on penetrating into the cavum mediastinorum, after opening up a pleural cavity, render a rapid survey much easier, and enable one to avoid dangerous complications through the injury of larger vessels.

On the right side above the hilum of the lung the eminence of the superior vena cava projects farthest into the pleural space; the pleura lies immediately on the wall. In front of this ridge, more medially, is a second, less pronounced eminence, in which, usually separated from the pleura by quantities of adipose tissue, lies the ascending aorta. Between the pleura and aorta also appears the uppermost part of the pericardium, peak-shaped, up to the beginning of the innominate artery. Between the two protuberances, that is at the front boundary of the superior vena cava, immediately below the pleura, the right phrenic nerve runs downwards. It, as well as the vena cava, lies in front of the hilum of the lung. On the hilum of the lung lies the azygos vein, bow-shaped, running forward from behind, and also easily found by a distinct protuberance.

From the beginning of the hilum of the lung downwards can be distinguished two mediastinal pleural membranes, which cover the hilum of the lung, from before and behind, and below it come together in a frontal pleural reflection, the ligamentum pulmonale. The anterior, much broader membrane obtains its relief by the arching of the two auricles. The posterior is also slightly arched, and in this arch immediately below the pleura lies the œsophagus.

On the left side the most striking arch is that of the arch of the aorta, situated immediately above the hilum of the lung. Further above and lying close below the sternum is a flat protuberance caused by the left innominate vein, and passing upwards about the middle of the arch of the aorta a further protuberance caused by the left subclavian artery. Between innominate vein and subclavian artery passes the left vagus nerve in front of the aortic arch downwards and beside it, somewhat more lateral—the left phrenic nerve accompanied by the arteria and vena pericardiacophrenica.

At the hilum of the lung they divide, the vagus passing behind, the phrenic in front of the hilum. The phrenic here crosses the pulmonary artery lying on the pericardium. At this point it runs the risk in the operation of TRENDELENBURG of being cut through at the moment when the pericardium is opened (see Chapter on "Trendelenburg's Operation"). This is avoided by keeping as much as possible to a middle course and below on the pulmonary artery. All three vessels lie immediately below the pleura. In front of the hilum of the lung the pulmonary artery forms a flattened arch running down from the front up to the back and passing over into

the upper margin of the hilum. In front of the hilum also the two ventricles project far into the pleural cavity; behind the hilum, or its continuation below, the ligamentum pulmonale, lies the noticeable protuberance of the descending aorta.

The azygos is easily injured and not only gives rise to hæmorrhage but to embolism caused by the entrance of air.

According to JONNESCO injury may very easily be done to the pleural cavity between the œsophagus and the aorta in front of the 7th to the 9th dorsal vertebræ and in front in the cavity of the third intercostal space.

As the lungs do not completely fill up the pleural cavities in every direction, slit-like spaces arise (sinus pleuræ or complementary spaces) in which the parietal pleural membranes meet. The largest of these is the space at the point of transition of the costal pleura into the diaphragmatic pleura, the sinus phrenico-costalis. It is bounded below by the turning-point of the pleura already described, and above by the lower margin of the lung. According to LUSCHKA, when the breathing is regular, it attains in the right sternal, para-sternal and nipple line a height of 2 cm., in the axillary line 6 cm., and near the vertebral column 2·5 cm. Of practical importance also is the sinus mediastino-costalis, which by the passing of the sternocostal pleura to the posterior surface of the sternum is formed into the mediastinum. Whereas here, the right lung, when an inspiration is taken, almost completely fills up the pleural cavity, on the left, corresponding to the incisura cardiaca of the left lung (see below) at the level of the 4th and 5th rib cartilage, a portion of the pericardium covered by pleura remains uncovered by the lung. This spot corresponds to the absolute cardiac dulness (compare figs. 3 to 7).

Finally, the domes of the pleural cavities, which are completely filled by the apices of the lung, require special consideration; at the back they extend as far as the upper aperture of the thorax; in front, however (with reference to the vertical axis of the body), in consequence of the downward direction of the 1st rib, they project 5 cm. beyond it; the level of the 1st rib is only exceeded by the apex of the lung sometimes when emphysema is present. In the ordinary upright position the apex of the lung projects beyond the clavicle 1 to 3 cm., whereas when lying on the back, when a deep inspiration is taken, owing to the altered position of the clavicle, this is not the case. In their lateral section the apices of the pleuræ are connected with the inner surface of the lower insertion of the scalene muscles. Right across the pleural domes, on both sides, run the subclavian arteries, arching the pleura forwards. Of the branches of the subclavian artery the internal mammary lies close to the anterior half of the pleural domes, the vertebral arteries close to the posterior half. Moreover, down from the pleura run the vagus nerve, after it has passed the anterior surface of the subclavian artery, and the laterally placed phrenic, which comes from the anterior surface of the scalenus anticus muscle. Lastly, the innominate veins, divided into the subclavian vein and jugular, come into contact with the domes of the pleura.

FIG. 6.—Mammillary longitudinal section of the right side with the lung *in situ*.
(Topographical Atlas by Dr. R. DOYEN, J. P. BOUCHON, E. DOYEN.)

FIG. 7.—Left side mammillary longitudinal section with pulmonary parts in position.

(Topographical Atlas by Dr. R. DOYEN, J. P. BOUCHON, E. DOYEN.)

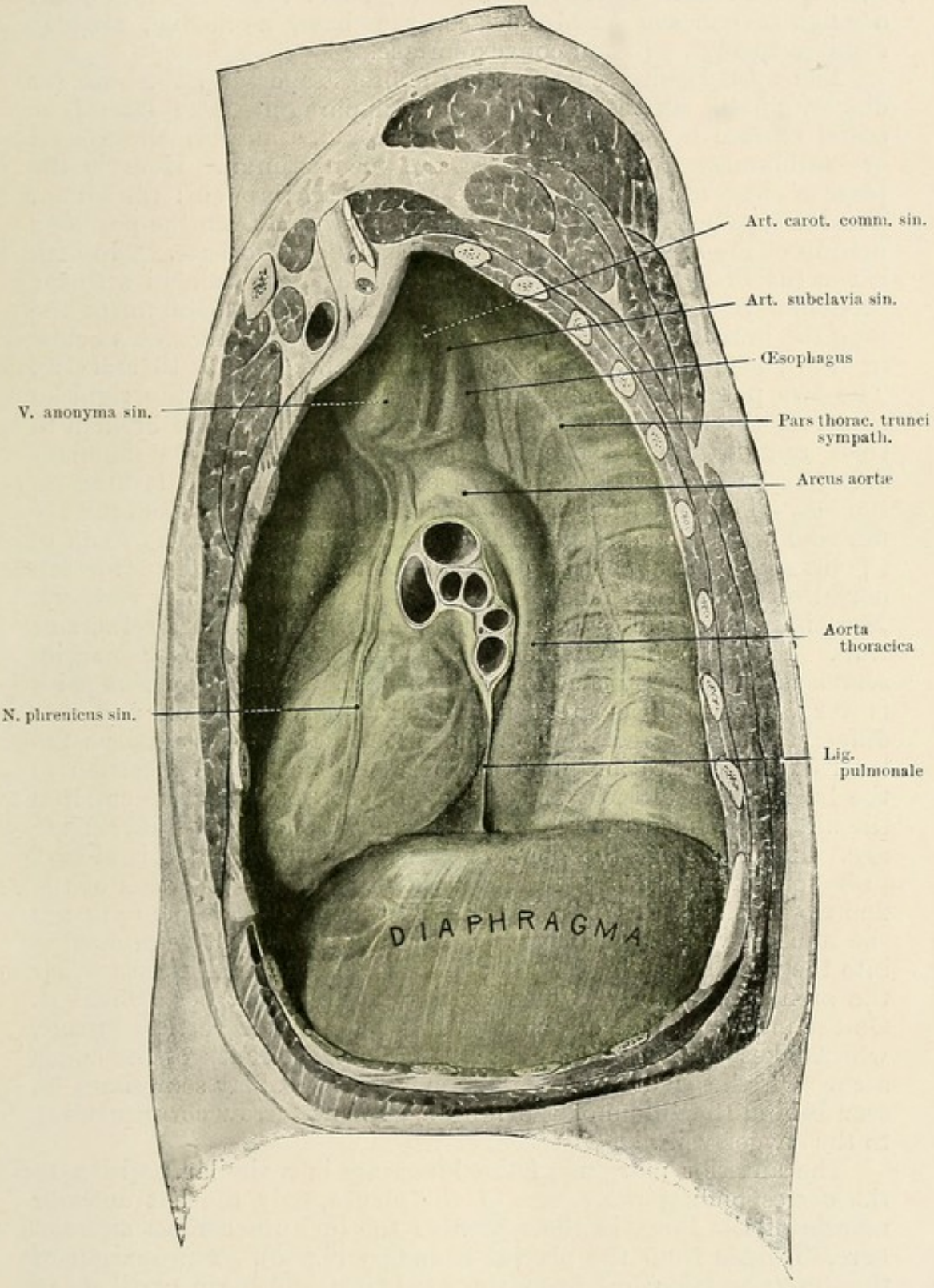


FIG. 8.—Left side of the thoracic cavity after removal of the lung. (According to MERKEL from CORNING's "Text-book of Topographical Anatomy.")

Each lung has the shape of a longitudinally divided cone, that is, of a half cone. There can be distinguished : The summit, apex, a slightly concave basal surface, the base, a medial, slightly concave surface, a lateral convex surface.

The apex is directed towards the breast aperture, the base (or diaphragmatic surface) rests on the diaphragm. The lateral or costal surface lies contiguous to the thorax, the ribs, the medial or cardio-mediastinal surface to the mediastinum. Here is the place of entry of the large blood-vessels and the bronchi: the hilum. The latter is marked by an oval depression which from the posterior margin of the lung lies midway between apex and base. Through it run the branches of the pulmonary artery, the bronchi with the bronchial vessels and the pulmonary veins. In the hilum of the lung the branches of the arteries lie above in front, the veins below in front, behind the vessels lie the bronchi (figs. 9, 10 and 12). The two pulmonary arteries appear in the hilum on the right in three, on the left in two, branches, and accompany the bronchi in their ramification. Above the branch of the right pulmonary artery is an eparterial bronchus (see below), which is lacking on the left. The structures passing through the hilum of the lung are united by loose connective tissue and bring together the roots of the lung. Their upper margin corresponds to the level of the 5th dorsal vertebra or to the spinous process of the 4th dorsal vertebra. More important still is their projection on to the anterior thoracic wall. The bifurcation, which corresponds to their upper margin, serves as a starting-place for this purpose. Opinion on this point is very uncertain, as great individual differences exist, and also differences due to age. According to BRÜNING'S investigations the level of the bifurcation may vary between the sternal insertion of the 1st and the 3rd rib. It is generally accepted that in children the bifurcation is at the highest level and gets lower with increasing age. In middle age the point of division of the trachea is always to be sought in practice at a level with the sternal insertion of the 2nd rib cartilage. In front of the right-hand root of the lung lies the superior vena cava, above it the arch of the azygos vein, flowing into the vena cava (fig. 9). The left root of the lung passes under the arch of the aorta, which as descending aorta lies behind it. On the medial surface of the left lung this makes a vertical furrow, which takes the form of an arch at the top, the mark of the aortic arch. On the right medial pulmonary surface may sometimes be seen behind the hilum of the lung a shallow furrow corresponding to the azygos vein.

The anterior margins of the lungs are in a similar position to the corresponding reflections of the pleura, only the left anterior margin of the lung, in the region of the incisura cardica situated here, diverges from the pleural boundary (fig. 5). The margin of the lung branches off from the level of the 4th rib cartilage in arches convex on the outside behind the 5th rib cartilage, which it intersects in the parasternal line, or somewhat farther to the left. From this point it continues again medially to the sternal end of the 6th cartilage, where it becomes a tongue-shaped process (lingula), the lower margin of the lung.

The inferior margins of the lung (figs. 5 to 8) are sharp, and there is no essential difference in the level on either side. In the living subjects in the parasternal line they correspond to the inferior margin of the 5th rib cartilage, in the nipple line to the superior margin, in the axillary line to the inferior margin of the 7th rib.

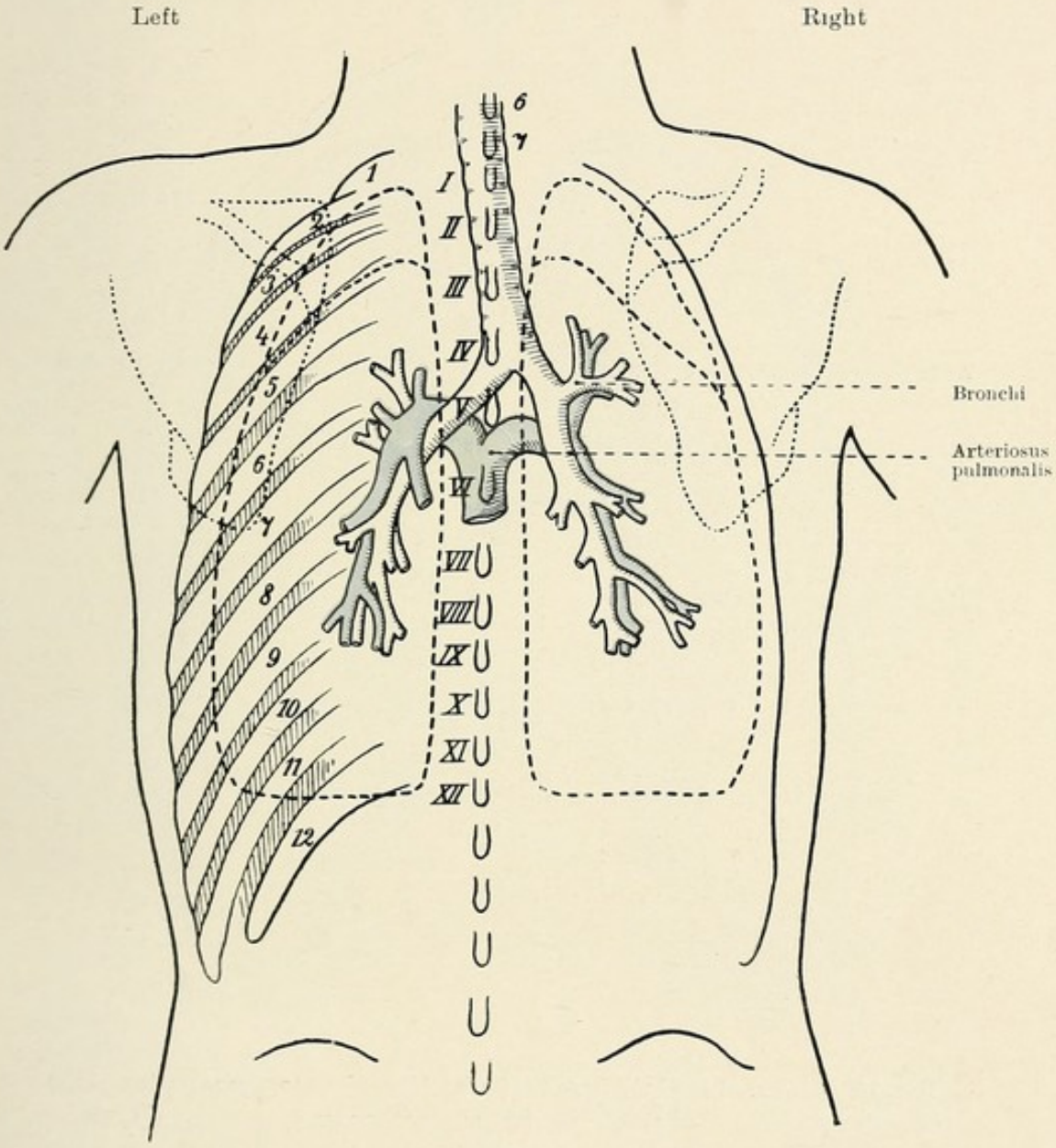


FIG. 9.—Position of the trachea relative to the vertebræ and of the bronchi to the lungs.

In the scapular line they are situated at the inferior margin of the 9th rib, and near the vertebral column they reach the 11th rib. In the right lung the inferior border can also be determined near the sternum; here it is at the superior margin of the 6th rib cartilage.

According to LUSCHKA a narrow ledge close behind the root of the lung is to be claimed as the posterior margin of the lung. This

corresponds to the border line between the anterior and lateral circumference of the vertebral bodies, and at the back, on the left bounds the furrow for the aorta, on the right that for the azygos vein.

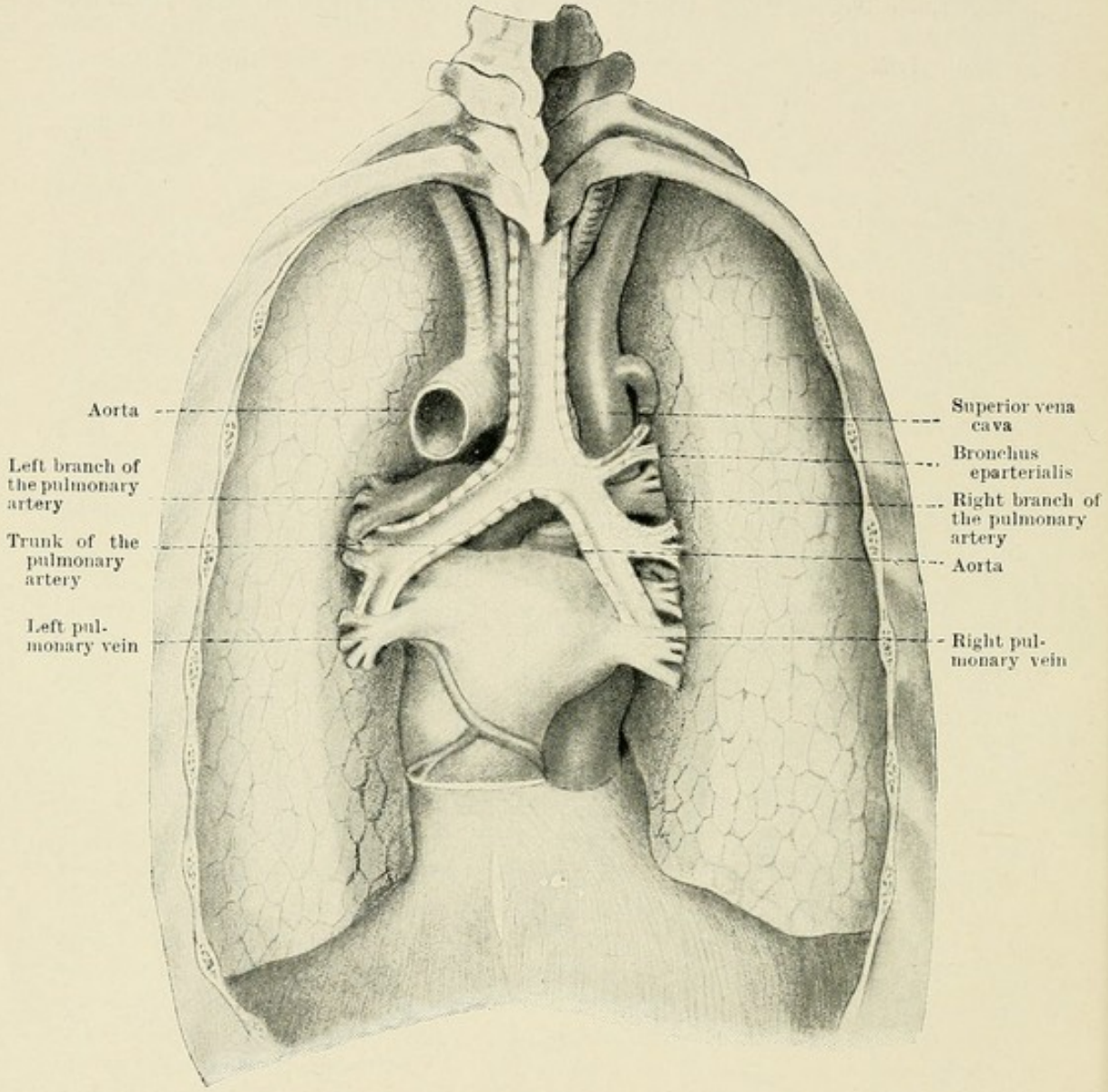


FIG. 10.—Hilum of the lung from the back. (According to a preparation of the Königsberg Anatomical Institute.)

The lungs are divided by fissures into lobes, the left into two, the right into three (figs. 5 to 8). The line of projection of the left incisura interlobularis in the thorax begins at the level of the third spinous process of the dorsal vertebræ (fig. 8), and passes down obliquely to the lateral end of the 6th rib cartilage; so that we have on the posterior surface of the left half of the thorax above the level of the spinous process of the dorsal vertebræ, the left upper lobe, below it the lower lobe, on the left lateral surface the line of partition lies between both lobes at the 4th rib, in front lies almost exclusively the left upper lobe. On the right the cavity projected to the thoracic wall begins also at the level of the third dorsal

vertebra, but in the posterior axillary line on a level with the 4th intercostal space; it is divided into two peduncles: the upper (between the middle and upper lobes) runs horizontally forwards to the sternum, which it reaches at the level of the 4th rib, the lower (between the middle and lower lobes) intersects the lower margin of the lung in the nipple line.

So the position of the lobes is the same in the right hand posterior half of the thorax as in the left; laterally above the 4th rib we have the right upper lobe, from the 4th to the 6th rib the middle lobe and below the latter the lower lobe. On the right anterior side of the thorax above the 4th rib is the right upper lobe, beneath it the lower lobe.

The visceral pleura sinks deep into the fissures. The fissures may be obliterated by adhesive pleuritic processes, or serous and purulent discharge in them may simulate cysts and abscesses of the lung.

Among varieties of the interlobular commissures may be mentioned a division of the right lung into four, of the left lung into three, lobes. Incomplete fissures have also been noticed.

As modern surgery has included the pulmonary artery within the domain of the operator, the topography of the hilum of the lung becomes specially important. SCHUMACHER has made very minute investigations on this point of special interest to surgeons. The detailed description of his findings, and other topographical details regarding the hilum of the lung important to surgery, are given in Chapters X ("Trendelenburg's Operation") and VI ("Suppuration of the Lung"), in the discussion of ligature of the pulmonary artery in cases of bronchiectasis.

The trachea extends from the intervertebral disc between the 6th and 7th cervical vertebræ down to the 4th dorsal vertebra, and is about 12 cm. long. It consists of from sixteen to twenty cartilaginous rings, which project into the lumen of the windpipe. The rings are not completely closed, but interrupted in the posterior portion. There the membranous wall of the organ is strengthened by a layer of muscles superimposed on the inside, and on contraction projecting like a ledge into the lumen. Only the lower section of the trachea belongs to the thoracic cavity. It is embedded in loose connective tissue, and therefore very mobile. In its cervical portion it lies above superficially, covered only by skin, platysma, hyoid muscles, and the thyroid gland isthmus (in front of the second and third cartilaginous rings). Farther down its position is deeper; here an extensive venous plexus lies in front of the trachea. The œsophagus situated behind it also accompanies the windpipe in its mediastinal section. Here immediately in proximity to the windpipe lie the innominate artery and farther to the front the innominate vein running forwards up from the left down to the right, with the ima vein which flows into it. Farther down follow the arch of the aorta and the pulmonary artery, behind which the division into the two bronchi takes place. The site of partition corresponds to the level of the 5th dorsal vertebra, and the sternal insertion of the 2nd rib cartilage. The shorter right bronchus takes a steeper course and has a some-

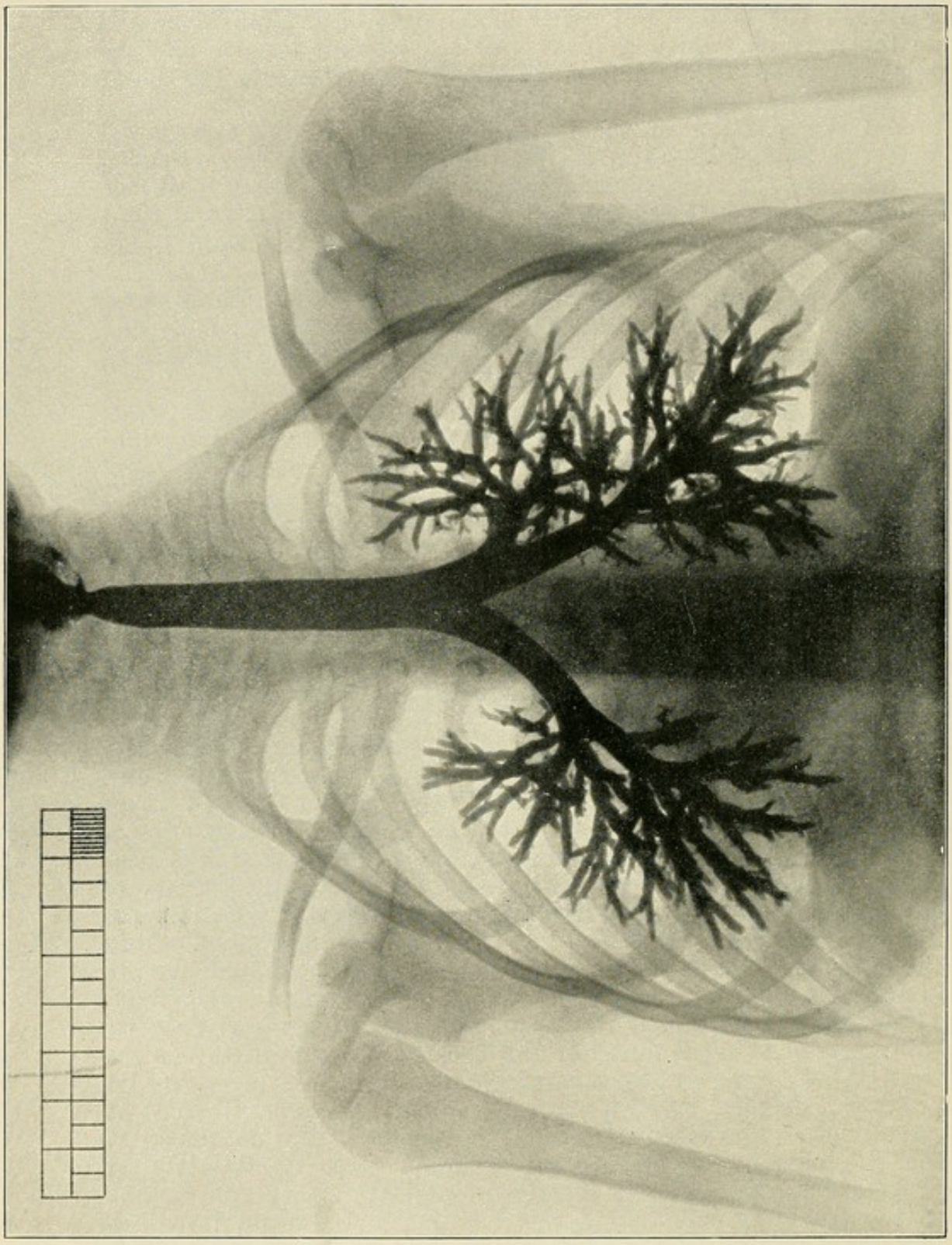


FIG. 11.—Orthographical distance photograph of the normal bronchial tree with scale in centimetres (girl 12 years old). (BRÜNING).

what larger lumen than the left one. Therefore foreign bodies are more easily inhaled into the right bronchus. The ratio of the transverse section of the right and left bronchus is 100 : 78·4. Over the left bronchus passes the aortic arch directly after its commencement, over the right the azygos vein. Both bronchi have a slight convex curve a little to the side and at the back. In their structure the bronchi and the trachea are exactly alike; the right consists of six to eight, the left of nine to twelve cartilaginous rings.

They are covered with a thin, easily torn mucous membrane.

From the bronchial trunk, which traverses the lung on each side throughout its whole length and ends at its lowest point between the diaphragm and the vertebral column, lateral bronchi branch off in a downward direction. The latter are divided into the ventral bronchi, which run in a forward and lateral direction, and the dorsal bronchi, which run behind, and are, on the whole, weaker. The left bronchial trunk, after a space of about 4 to 5 cm., throws off four ventral and four dorsal lateral bronchi. Of these, only the first ventral lateral bronchus passes into the left upper lobe; the others provide for the lower lobe. The lateral bronchi of the left side all pass below the pulmonary artery into the lung, and are therefore described as hyparterial.[1] On the right, directly from the bronchial trunk, which is from 2½ to 3 cm. in length, a strong lateral bronchus runs down above the pulmonary artery. This eparterial bronchus enters the right upper lobe. Then in the same way as on the left four ventral and dorsal lateral bronchi are thrown off. The 1st hyparterial (ventral) lateral bronchus is destined for the right middle lobe, the others for the lower lobe.

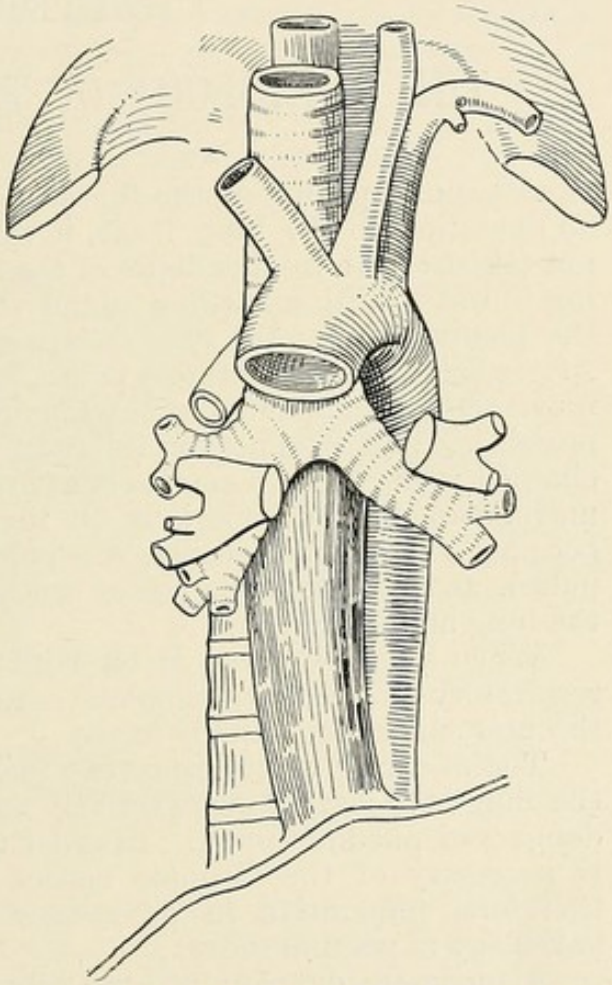


FIG. 12.—Position of the trachea with reference to the aorta and its branches, to the azygos vein and pulmonary artery.

[1] I have used here the terms eparterial and hyparterial first used by AEBY, because topographically they are very distinctive. But this does not imply my agreement with AEBY's view regarding the bronchial tree. As is well known, AEBY's views with regard to the bronchial tree are refuted by NARRATH's minute investigations.

CHAPTER II.

ON THE PATHOLOGY OF THE PNEUMOTHORAX.

A LARGE opening of the thoracic cavity, such as is necessary for an operation on the lung, leads, if special preventive measures are not taken, to the total collapse of the lung with symptoms endangering to life. With a rustling sound the atmospheric air rushes into the pleural cavity; the lung collapses and falls back on the hilum. After a short reflex respiratory pause, follow irregular jerky inspiratory movements accompanied by the maximal tension of all the accessory muscles. This dyspnœa is followed by cyanosis. The blood, surcharged with carbonic acid, acts as an irritant on the centres of the medulla oblongata, especially on the vagus centre; the breathing becomes slower and deeper, the pulse tense, full and slow (vagus pulse), and finally there comes the entire arrest of the action of the lung and heart.

When pneumothorax is on both sides, after rapid, convulsive respiratory movements, complete cessation of breathing and death through suffocation rapidly ensue.

The first and most important task, therefore, in the surgery of the lung is to learn how effectively and seasonably to deal with the dangers of pneumothorax. In order to do this a full understanding is necessary of the ultimate causes of these disturbances; it is, therefore, imperative to go somewhat more in detail into the pathology of pneumothorax.

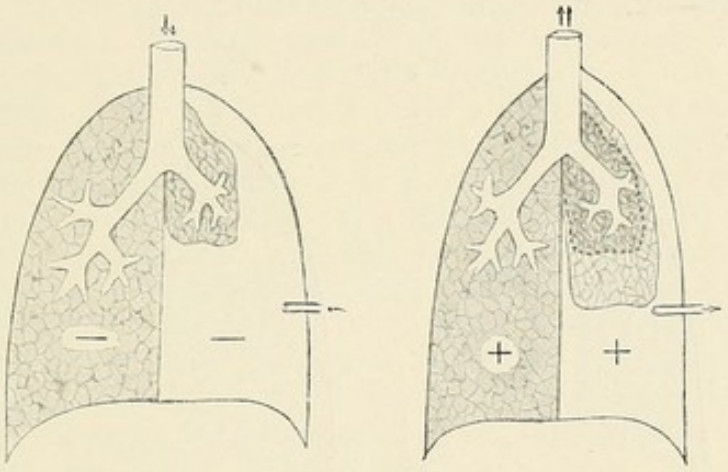
A moderate quantity of atmospheric air may be admitted into the pleural cavity without any reaction worth naming, provided that no pathogenic bacteria are taken in with it. If no more air follows, the signs of displacement of the lung soon disappear, if this has already taken place, for the oxygen is absorbed extraordinarily quickly, somewhat more slowly the nitrogen disappears, the lung expands again, leaving no, or very slight, signs of irritation on the pleural membrane.

The adhesion of the two pleural surfaces prevents total pneumothorax from taking place; provided no synechiæ extend over the whole lung, a number of points of adhesion are sufficient to prevent the total collapse of the lung; partial pneumothorax involves, however, essentially slight disturbances, and scarcely any danger.

If air enters when the pleura-surfaces are free, then the lung collapses, and disturbances in breathing of a more or less dangerous nature set in at once.

It can be experimentally proved that the size of the opening exercises a decisive influence upon the severity of the functional disturbances. If we make a slight opening in the thoracic cavity, for example, with a cannula and trochar, horizontally smaller than the trachea, then at each inspiration a certain quantity of air will flow into the pleura, and the lung will proportionally collapse, gradually at each fresh inspiration. However, it still shares in the breathing; even when it has quite collapsed, it is not functionally ruled out. For each inspiration, which is energetic or deep enough to reduce the atmospheric pressure by only a few millimetres of mercury, will expand the dilatable lung a little.

The position of the mediastinum is of importance in the functions of the other lung; this is dependent on the pressure which rests upon the mediastinum. Its position will not be altered when the pressure in both pleuræ is alike. In pneumothorax with a slight opening and small volume on inspiration there is always a negative pressure, which, however (7 mm. of mercury), does not reach the healthy side. A thin, pliable, mediastinal membrane, corresponding to the difference, must place itself convexly on the healthy side, and thus somewhat impede the inspiratory expansion of the sound lung. The reverse would take place on active expiration, when the result would also be determined by the slight difference between the positive pressure right and left. Besides air breathed out by the sound lung is driven into the collapsed one.



Inspiration. Active expiration.

FIG. 13.—Schema of breathing with pneumothorax with a small opening.

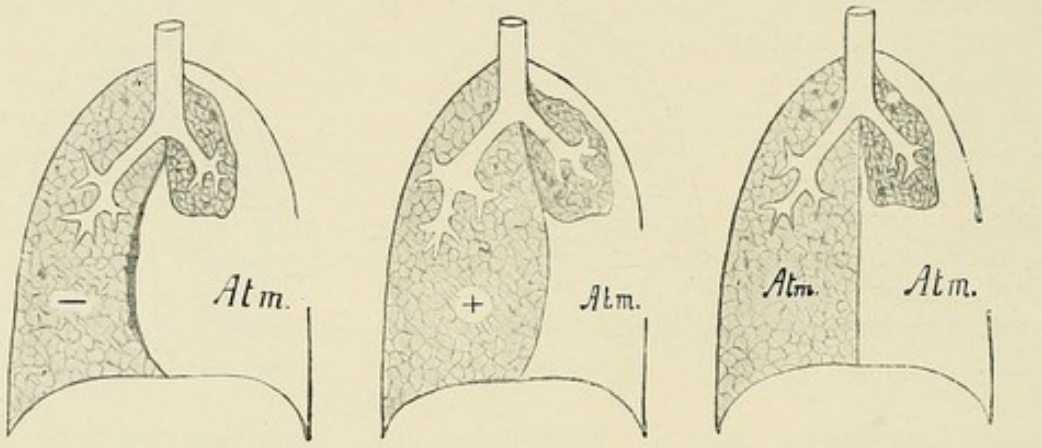
The functioning of the sound lung is, however, scarcely noticeably affected by the unimportant differences of pressure mentioned in the individual respiratory phases; the loss is so small that it is compensated for by the increased frequency and depth of the inspirations. The amount of breathing, that is the quantity of breath inspired in the unit of time, remains unaltered. Difficulty in breathing and cyanosis do not therefore occur.

The blood-pressure, too, only at first somewhat increased, remains almost unaltered, for the collapsed lung receives in the unit of time the same quantity of blood as the inflated one. So no disturbances of circulation occur.

As shown, the mechanism of respiration only takes place when,

as already remarked, the pleural opening is smaller than that of the trachea and glottis, for only then, on each inspiration, can a negative, and on each expiration a positive, pressure arise: but both are necessary for the other sound lung to function sufficiently.

The conditions are different when there is a large opening in the pleura. If such an opening is present, through which on inspiration and expiration the atmospheric air can flow unhindered in and out of the pneumothorax, then naturally the function of the lung on the side in question immediately ceases. On each inspiration now the pressure in the two pleural cavities differs; in the pneumothorax atmospheric pressure, on the healthy side a negative pressure (normal inspiratory variation in pressure = 7 mm. mercury). The consequence will be, that the partition wall of the pleuræ, the mediastinum, is drawn to the healthy side, forms a pouch in it and is arched forward. Under such conditions the healthy lung cannot expand sufficiently.



Inspiration. Normal expiration. Active expiration (pressure).

FIG. 14.—Schema of breathing with pneumothorax with large opening.

On each expiratory pressure, on coughing, groaning, reflex "forced inspiration" with contraction of the glottis (for instance, when pain is felt), a positive intrathoracic pressure of the healthy side will arch forward the mediastinum towards the open pneumothorax, and there results again an insufficient expiratory evacuation of the half of the lung still functioning.

By this oscillation of the diaphragm to and fro, the so-called "mediastinal fluttering," which is repeated on each inspiratory motion, function of the sound lung is extraordinarily affected; the inspiratory expansion and the expiratory evacuation are insufficient, the exchange of gas in the lung is inadequate and excess of carbonic acid gas and insufficiency of oxygen in the tissues are the immediate disastrous consequences.

The similar mechanical conditions in cases of empyema, with extensive excision of the thoracic wall, when such alarming disturbances of breathing are generally absent, cannot be adduced as counter-proof, for then the mediastinum has long since lost

its mobility owing to inflammatory infiltration and fibrous deposits, the lung is not affected in its expansion by the suction of the mediastinum.

Dyspnœa only rarely occurs after excision of the rib and evacuation of a large pleuritic exudate. And those are the cases in which the mediastinum has not been immobilized by indurations. In such a case DELAGENIÉRE immediately relieved the dyspnœa by filling the pyothorax with water.

MURPHY has proved conclusively that it is not the supposed displacement of the heart which causes the death of animals with wide-open pneumothorax, but the fluttering to and fro of the mediastinum and the resultant insufficiency of breath. For as soon as he fixed the mediastinum in some way or other and limited its fluctuations, either by holding it with forceps, or by pulling up the collapsed lung, the breathing and pulse improved immediately. Also in the case of men many operating surgeons have immediately relieved alarming conditions with collapse and dyspnœa in total pneumothorax by this simple method.

A valuable observation of more worth than a practical experiment, was made by W. MULLER,[1] on the occasion of the extirpation of an osteosarcoma of the ribs adherent to the lung. The pleura was rent and an opening was made in the thoracic wall quite as big as the palm of the hand. "At this moment the tumour released sank somewhat with the lung into the thoracic cavity, which was immediately followed by a condition of most critical collapse; the breathing ceased, the pulse was not perceptible, but the symptoms changed as soon as the tumour was again taken hold of and drawn forward. Now it was clear that it was inseparably adherent to the right lower lobe of the lung. When the lung, thereupon set free, suddenly collapsed, immediately a condition of serious collapse again occurred. The lung, quickly seized again and drawn up immediately, filled again on inspiration and the symptoms of collapse disappeared."

In a similar case BAYER,[2] as it would appear, was the first to take the right course to obviate the symptoms of collapse caused by pneumothorax resulting from an operation. After the operation, which had to be suspended three days earlier in consequence of the pleura being torn twice and the collapse of the patient, was resumed the pleura was again rent wide. "I saw the lung completely collapse and sink down, the patient again collapsed; then I quickly drew up the upper lobe of the lung with the vulsella forceps out of the thoracic cavity, through the wide pleural fissure, and made its lower margin fast to the periosteum by sutures about 3 cm. apart. Immediately the patient recovered and we saw the fixed upper half of the lung breathe regularly."

A simple and useful expedient to improve the impeded breathing when the pleura is open is to place the patient on the side operated

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[1] W. MULLER, *Deutsche Zeitschr. f. Chir.*, vol. 37.
[2] BAYER, *Centralblatt f. Chir.*, 1897, p. 37.

on in such a way that the aperture of the thorax is placed lowest. The weight of the heart and the collapsed lung expand the mediastinum, so that the healthy lung acquires more freedom of expansion.

It is also possible, according to MACEWEN, completely to avoid pneumothorax in this position. He recommends the thorax should be strongly compressed and the diaphragm, too, from the abdomen; then the pneumothorax air escapes, the lungs lean right on the parietal pleura. When this does not suffice an active inflammation of the lung by coughing, sneezing, or pressing will remove the last trace of the pneumothorax.

On turning over on the healthy side, of course air can again flow into the pleural cavity and the lung again collapses.

In order that this astonishingly simple manœuvre should succeed, a wide, free, opening in the thoracic wall is necessary so as to allow the air to pass out freely. The clinical observations, made by MACEWEN, are as striking and convincing as they possibly could be.

To remove a pneumothorax caused by the suture WITZEL has described a method which under certain circumstances, may be of use. He changes the pneumothorax by artificial methods by injection of a warm solution of boric acid into a hydrothorax and immediately removes this by aspiration. As the solution runs away the lung expands.

Although it is quite comprehensible how the displaced heart can stretch the diaphragm, it is not so far quite clear according to our physiological observations why the pneumothorax does not recur when the compression of the thorax ceases. This fact is quite incompatible with the widely spread opinion that the collapse of the lung is due to the pressure of the atmospheric air in the pleural cavity. Other (physical) forces must come into play which counteract the atmospheric pressure, and at the same time the retractile power of the heart when the thorax is open.

MACEWEN has gone into the question, and has shown by experiments, "that the full expansion of the lung is maintained by the molecular cohesion[1] of the two pleural surfaces, assisted by the capillary attraction exercised by a thin layer of serous fluid between the two serous surfaces."

Although, MACEWEN says, these molecular forces at any given point of the pleura are not powerful, yet it is probable that, in their totality, spread over the whole surface of the lung, they do possess considerable power, quite sufficient for their purpose. If the molecular cohesion ceases, then the lung collapses owing to the elasticity of its tissue; air flowing into the pleural sac is unquestionably calculated to destroy the cohesion. But the atmospheric pressure alone is not sufficient in any case to cause

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[1] The expression "molecular cohesion," as used in the original, is to be taken to mean that besides the adhesion, according to a purely physical definition, the inner (molecular) cohesion of the capillary interlayer (serum) plays a part as a cohesive force. This, by way of explanation, when we have occasion to speak of adhesion.

the total collapse of the lung and the degree of retraction in the lung is dependent on various circumstances and conditions.

Thus the power of cohesion depends on how moist and how smooth the surfaces in contact with one another are. Just as a cover-glass on a preparation slide is fixed so fast owing to the spreading of a tiny drop of fluid, by "molecular cohesion," that it can only be pushed away, but only with great difficulty lifted up, so also the presence of a thin layer of fluid is essential to the adhesion of the parietal and visceral pleura. A dried-up pleura loses its adhesive power; sterilized water, or water with glycerine, lubricates the serosa and makes them capable of adhesion again, normal serum has the greatest cohesive power.

The surface adhesion of the pleural surfaces is greatly lessened, or even destroyed, when fibrinous aggregations, or infiltration of the pulmonary tissue is present, which affects its power of expansion.

These physiological statements of MACEWEN are supported by his clinical experience quoted above, and after experimental verification I do not hesitate to adopt these opinions. They are calculated to bring more light to bear on the pathology of the pneumothorax and to effect an advance.

It is noteworthy that pneumothorax on the right side is more to be dreaded than on the left. As the right lung is larger, naturally on the collapse of the right lung the functional prolapse and the resultant disturbances are greater than on the collapse of the left lung.

In rabbits this is specially striking. Their left lung is smaller than the right by one-third and the amount of oxygen contained in the blood sinks to 58 per cent. when there is a pneumothorax on the right side and only to 76 per cent. when there is one on the left.

GERULANOS considers the danger of pneumothorax on the right side to lie, not only in the prolapse of the respiratory function, but also in the influence of the full atmospheric pressure on the vena cava and the thin wall of the auricle. It cannot be denied that the power of suction of the right ventricle of the heart on the venous blood is affected by this so that the heart's action is made more difficult; the feeble, scarcely perceptible and quickened, sometimes also irregular, pulse would thus be explained. Other causes too play their part as regards the severity of the illness, such as the strength of the heart, the general condition, loss of blood, narcosis, &c.

Moreover we must take into consideration anatomical differences in the mediastinum, and the shape of the thorax; when the mediastinum is thin, when the thorax is badly formed, the healthy lung runs more risk.

This is also clear in animals. Thus dogs, for example, which have a thin, easily torn mediastinum, die from pneumothorax more easily than rabbits.

To a certain extent the contraction of the diaphragm may stretch the mediastinum and so lessen the oscillation to and fro.

So it is possible that, under certain circumstances, when, for example, pneumopexy cannot be performed, the fixing of the diaphragm to the thoracic wall, as it were the shortening of it, might remove threatening symptoms in cases of pneumothorax.

Clinical experience and, in agreement with it, experiments on animals, teach that a small opening in the pleura, through which air can be drawn in, is only dangerous when it forms a valvular plug, so that on inspiration air is drawn in, which on expiration cannot escape again. Soon the pressure in the pleural cavity becomes greater than the atmospheric pressure, so that the lung is compressed as when a large exudation occurs, and the heart is very much displaced.

When the excessive pressure does not arise, the lung remains collapsed and makes no respiratory movement, at least none that are at all normal. When, nevertheless, some observers maintain that the lung on the side of the pneumothorax does take part in the breathing, they are misled by the fact that on coughing, pressure, &c., the air from the sound lung is driven into the collapsed one; it is somewhat inflated in this way and on inspiration collapses again. This can be described as an inverted type of breathing, but the forcing of the pulmonary air saturated with carbonic acid gas into the collapsed lung may be functional without any real importance to the organism.

When the free pleural cavity must be opened, the sudden collapse of the lung, which is generally immediately followed by disagreeable consequences, should be avoided, whenever possible. According to MACEWEN, it is sufficient to place the patient on the injured side and according to the dilatation to cover the pleural opening with a thick, moist, gauze compress. It is more to be recommended, however, to make sure of the lung by using a forceps or a strong thread, placed deep into the parenchyma (not only holding the pleura). When the conditions make it desirable, the lung should be fixed to the margin of the pleural wound.

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CHAPTER III.

METHODS OF MAINTAINING A DIFFERENCE OF PRESSURE.

The dread of the dangers of pneumothorax has very much hindered progress in the surgery of the lung. We remember that, a short time ago, many surgeons would only operate when the pleural surfaces were adherent, and if this were not the case, they brought it about by artificial means and operated twice. Certainly here another factor also had weight, the prevention of the infection of the pleural cavity by suppurating processes.

Fortunately, in the meantime, clinical observations have shown that the dangers of pneumothorax, as a complication, have been very much over-estimated. In the recognition of this fact lay the first germ of progress in the surgery of the lung.

Meanwhile, for sixteen years surgeons have continually sought for means to prevent the collapse of the lung when the thorax is opened. Thus, in the year 1896, Quénu and Longuet wrote: "We have realized that the essential condition of success in a pulmonary or intrapleural operation, granted the supposed absence of pleural adhesions, is to maintain a difference of pressure between the intra-alveolar air and the surrounding air, the effect of pneumothorax being to make the intrathoracic and extra-thoracic pressure uniform, the pulmonary tension remaining the same, or to increase the intrathoracic pressure."

These words already lead the way to the method of maintaining difference of pressure: the method of reducing pressure, where the difference is produced by rarefying the air over the upper surface of the lung (the method was later perfected by Sauerbruch) and the method of increasing the pressure, by which the pressure of the air in the trachea and bronchi is raised from 7 to 10 mm. mercury. "We have stopped at this last limit," say the writers. They worked experimentally with an improvised apparatus, which must be considered the precursor of the increased pressure apparatus with constant pressure: in an air-tight bag which was put over the head and neck of the animal, they maintained the respiratory air at a constant pressure of 10 to 12 mm. mercury.

Tuffier and Hallion went into the question in greater detail (1895). They proved that when the pleura was opened pneumothorax does not occur when the pressure of the air in the trachea and bronchi is raised by 10 cm. of a column of water. An apparatus,

which they constructed, and which was also of use to TUFFIER in an operation on the lung, consisted of a laryngeal tube in connection with a pair of bellows with a water valve in between to regulate the pressure.

Finally, DOYEN (1897) recommended another kind of bellows, which allowed alternately of insufflation and respiration.

Whereas, in Europe, not much was expected from such apparatus for the surgery of the lung, and in any case they were not perfected for practical application in America, the idea was more favourably received among the ranks of American surgeons. NORTHRUP replaced, in 1896, an apparatus used by FELL in a case of opium poisoning by the improved O'DWYER [1] tube; in this way the whole apparatus became certainly very manageable, but still not practically useful in the primitive state.

R. MATAS, in 1902, replaced the bellows by a forcing-pump worked by a cylinder, which drives out the air breathed and draws it in again. The adjustment of the cock for inspiration and expiration works automatically. Further essential improvements are the addition of an air filter, a mercury manometer and a device for the introduction of ether and chloroform to produce anæsthesia.

In spite of the certainly important aid afforded by these instruments, no use worth mentioning has been made of them in the practical surgery of the lung.

SAUERBRUCH was the first to succeed in making the method of maintaining a difference of pressure available in a practical form, physiologically without exception, by the construction of a pneumatic cabinet. Incited thereto by MIKULICZ, in the year 1904 he entered upon the study of the method of maintaining difference of pressure; as is well known, he abandoned the method of increasing the pressure, as it proved less reliable in experiments. He then improved the method of reducing the pressure in the surgery of the thorax applied to human beings with such genius that he paved the way to the greatest progress in the domain of the surgery of the thorax which has been known of late years. His thorough and purposeful studies were the starting point and inspiration of a large number of very cleverly thought-out apparatus for operations in the free pleural cavity by the application of the principle both of increased and diminished pressure. These apparatus have become useful, nay, indispensable, not only for operations on the pleura and lung, but also for the surgery of the heart and the great intrathoracic vessels, and, above all, in the surgery of the œsophagus.

The Cabinet for Reducing the Pressure.

SAUERBRUCH started with the following idea: To produce, by means of a large pneumatic cabinet over the body of the patient, a negative pressure of about 7 mm. mercury, and to maintain this throughout the duration of the operation, whilst the head outside

[1] Illustrations of the apparatus of FELL and O'DWYER and of MATAS are given in the first edition of this book.

the cabinet is under the pressure of the atmospheric air. The difference of 7 mm. mercury between the atmospheric pressure in the bronchial tree and the pressure on the open pleura is sufficient to keep the lung distended; this corresponds to the physiological difference.

The floor and ceiling of the original cabinet were made of strong sheet-iron; the side-wall and head-wall were provided with large glass windows. The front wall had an oval aperture at the height of a table, in which an india-rubber collar was inserted. Opposite

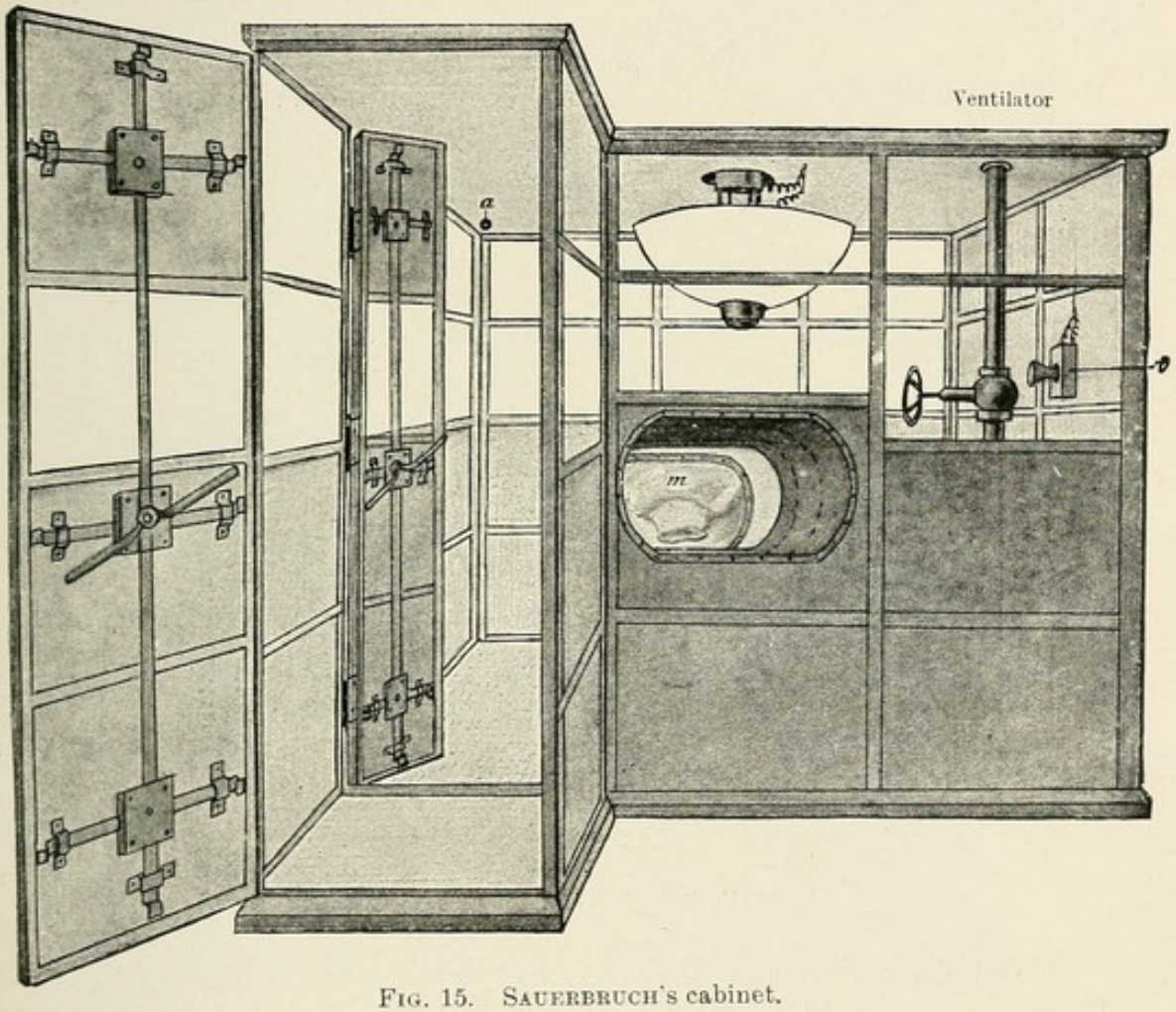


FIG. 15. SAUERBRUCH'S cabinet.

the head-wall a double door was placed (air sluice), which allowed you to go in and out of the cabinet during the operation, without prejudice to the constancy of pressure. The necessary reduction of pressure was effected by an electrically driven suction-pump, there was also a water valve to regulate the pressure inside the cabinet. Communication with the anæsthetist was only possible by telephone. Indirect lighting from the ceiling by means of an arc light (see figs. 15 and 16).

The drawbacks, such as difficulty of transport, overheating of the air in the cabinet, necessity to use the telephone to com-

municate with the outer world, and, above all, the costliness (10 to 14,000 marks) led the inventor soon to make alterations in his original Breslau model.

To a transportable, quickly mounted, metal framework plates of cane-fibre are screwed to make it air-tight. Instead of a floor the bottom of the walls are fitted with wide rubber flanges, which immediately adhere to any floor with the rarefaction of the air. By curving the front wall into two recesses ⌣—⌣ the necessary elbow-room is provided for the operator and assistant. The central portion is fitted with an induction coil with a ring for the head, easily moved up and down; the neck ring is omitted. A window of balloon material allows direct communication by word of mouth with those outside, and especially with the anæsthetist. The ventilators are improved, so that there is no overheating of the cabinet.

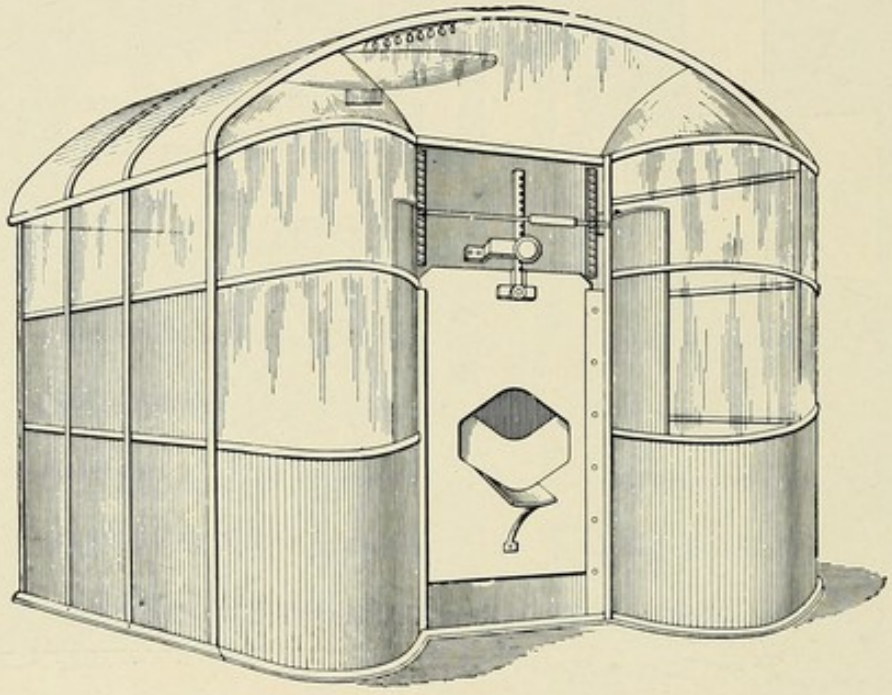


FIG. 16.—SAUERBRUCH'S cabinet. New model.

The lighting is much improved by dividing the source of light. In this way the most serious drawbacks to the old cabinet are removed, the troublesome bulging of the (neck) collar is obviated, it is much easier for the operator to get at the upper portion of the thorax, and any change of position in the course of the operation can now easily be made. The cabinet can be taken to pieces; it can be put up in any place whatever which has an even floor.

Finally, any room in a hospital can, at small expense, be converted into a pneumatic cabinet. MICULICZ and ANSCHÜTZ, and recently FRIEDRICH also, have busied themselves with this question. The windows and door frame of the room are made air-tight with strips of india-rubber or asbestos, the walls with three coats of enamel; a powerful ventilator sucks up the air.

A water valve provides for as constant a pressure as possible. The room is used at other times for other purposes; when required it can be arranged as a cabinet for reducing the pressure.

On SAUERBRUCH'S idea is also based WILLY MEYER'S (New York), model, 1909. He has succeeded splendidly in solving the cabinet problem. It was found possible to apply both increase and

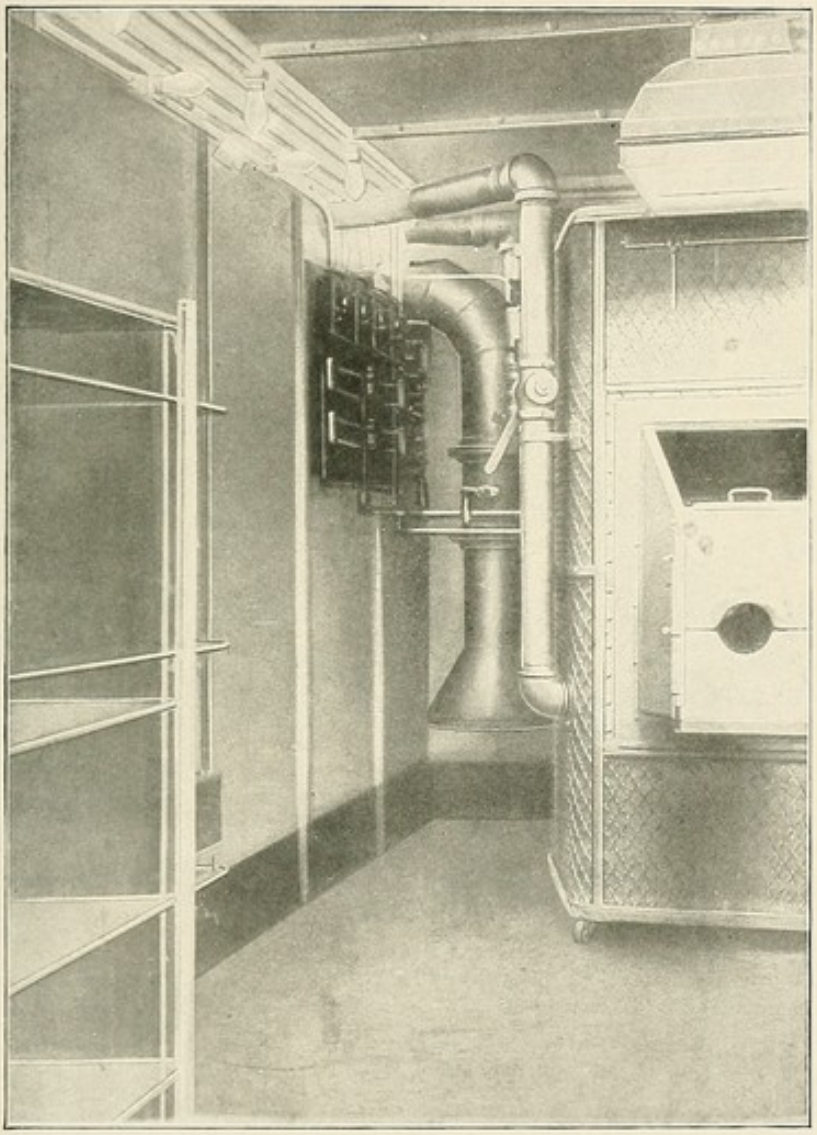


FIG. 17.—Universal differential cabinet by W. MEYER.

decrease of pressure in the course of one and the same operation by combining two cabinets in one apparatus which functions as a whole. He calls it the universal differential cabinet. The cabinets are constructed of a frame of iron wire and a portion like an air-balloon, the latter of which makes the cabinets air-tight, the former offers resistance to the atmospheric pressure.

The apparatus consists of a positive and a negative cabinet, the inner, small one (positive) is the room for anæsthetic purposes, and the other large one (negative) the operating room.

W. Meyer writes: "This arrangement is to be preferred, first because it is the nearest approach to operating in the open air: secondly, because the room for anæsthetic purposes can also be used independently of the large cabinet as an apparatus for increasing pressure; thirdly, because this arrangement offers the fewest constructional difficulties and can also easily be adapted to any conditions rendered necessary by changes in the position of the cabinets; for example, the small (anæsthetic) cabinet can be placed

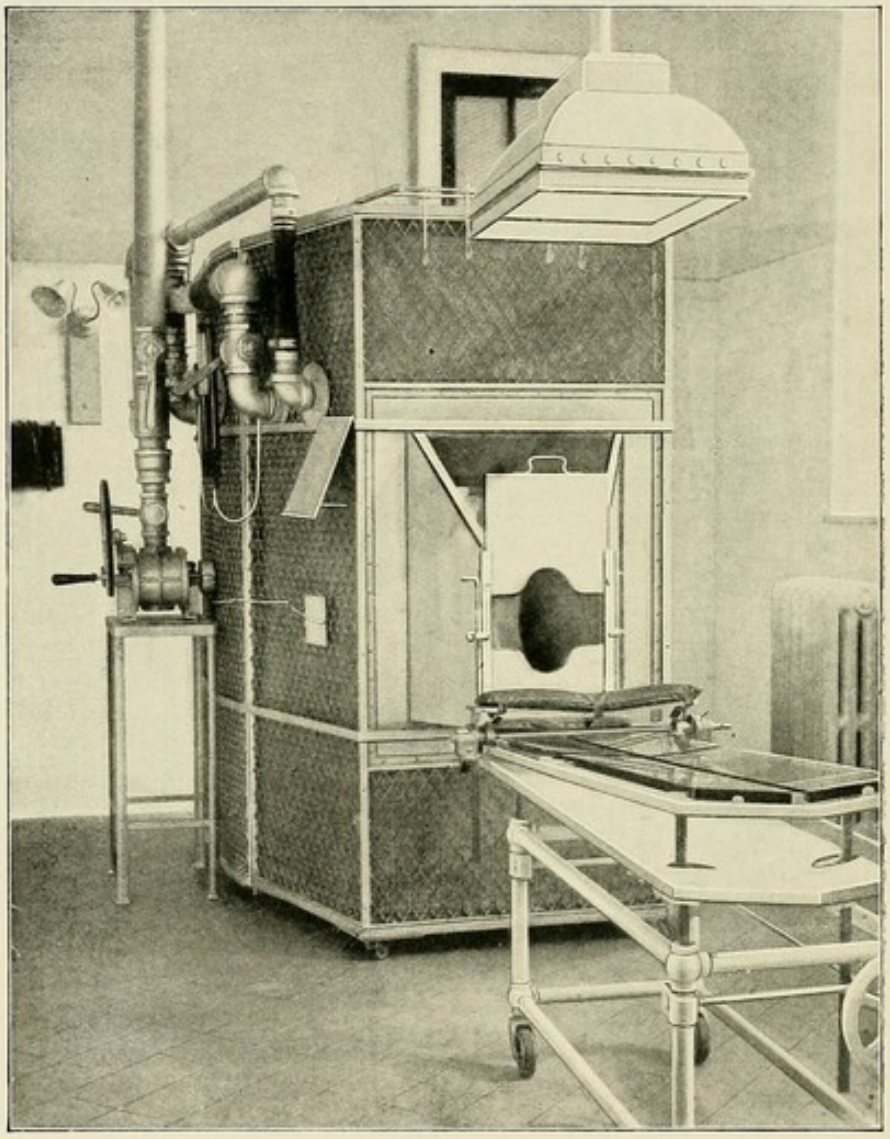


Fig. 18.—Universal differential cabinet by W. Meyer.

in the large (operation) cabinet. Both cabinets have their own independent system of ventilation with valves and manometers. You can go in and out of the outer negative cabinet without any sluice device, because for the moment when the door is opened the difference of pressure between the two cabinets can be correspondingly modified. The inner positive cabinet has a sluice. Among other advantages, on which the inventor justly prides

himself, may be mentioned: Sufficient 'elbow-room' for the operators and assistants; unimpeded communication between operator and anæsthetist during the operation (the balloon stuff allows sound to pass through); sufficient ventilation; possibility of rapid change of pressure; removable head section, no protruding (neck) collar."

The universal differential cabinet has been in use since 1910, in the department of thoracic surgery in the German Hospital in New York; according to WILLY MEYER it has fulfilled every requirement. But the expense involved must be very considerable.

No legitimate objections have been made to the application of the method of reducing pressure in operations on the lung. The method has held its ground against the criticisms of physiologists and pathologists; it is sufficiently based on experiments, and has finally proved most successful in practice. We shall see later that it affects the normal conditions of circulation in the lung and the large thoracic vessels very slightly. If, nevertheless, the method of increasing the pressure has since, as rivals, produced a large number of apparatus and won more and more recognition in practice, the reason is not to be sought at all in the disadvantages and deficiencies which are freely acknowledged and easily recognizable—what system is without them?—but only in the unwieldiness and costliness of the whole apparatus.

So the idea of QUÉNU and LONGUET "to increase the intra-thoracic pressure" was taken up again and apparatus for increasing the pressure were constructed, avoiding the American apparatus on account of the disadvantages connected with its discontinuous pressure.

The Apparatus for Increasing Pressure.

An increased constant pressure in the lung can be maintained (1), with the aid of a box-like apparatus, in which the head is placed, or (2) with a mask which is put over mouth and nose so as to be air-tight, or (3) with a tube, which is introduced into the larynx, or the trachea. But these three groups cannot be kept strictly apart, as the new mask apparatus can for the most part also be used for intubation.

THE CABINET APPARATUS.

A cleverly constructed apparatus by L. BRAUER, 1905, the advantages of which are its transportability, its simplicity and its cheapness, soon found recognition owing to successful operations on human beings having been performed with the aid of the apparatus; the model was quickly introduced into practice.

It is an apparatus for raising the pressure. Instead of rarefying the air over the opened thorax in order to prevent the lung from collapsing, he placed the head of the patient in a cabinet in which an atmospheric pressure of + 7 mm. mercury is maintained; the increased pressure actively inflates the lung.

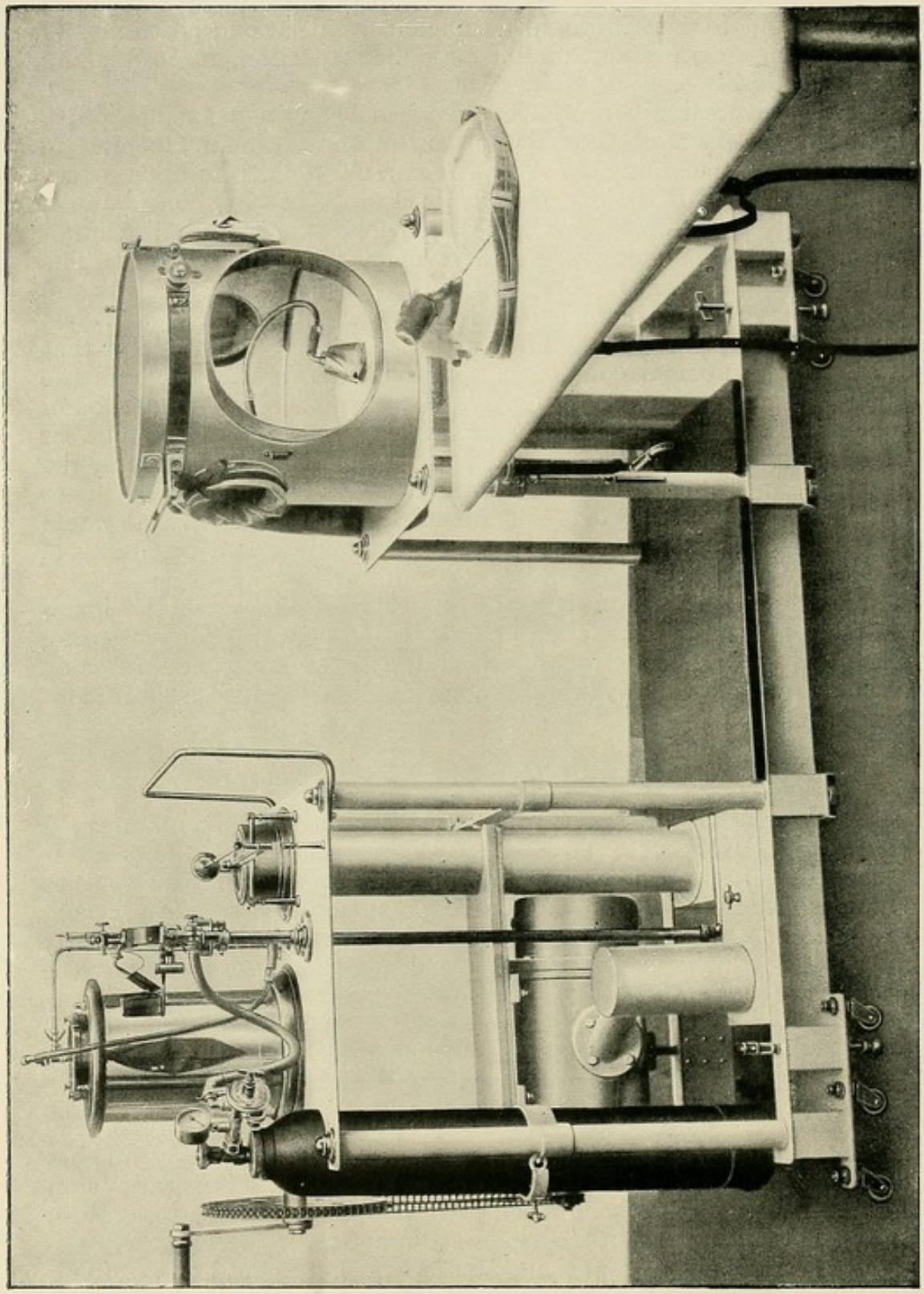


FIG. 19.—BRAUER'S cabinet apparatus for increasing pressure.

According to the inventor's description the apparatus consists of :—

(1) The devices for obtaining, maintaining, and regulating the compressed air.

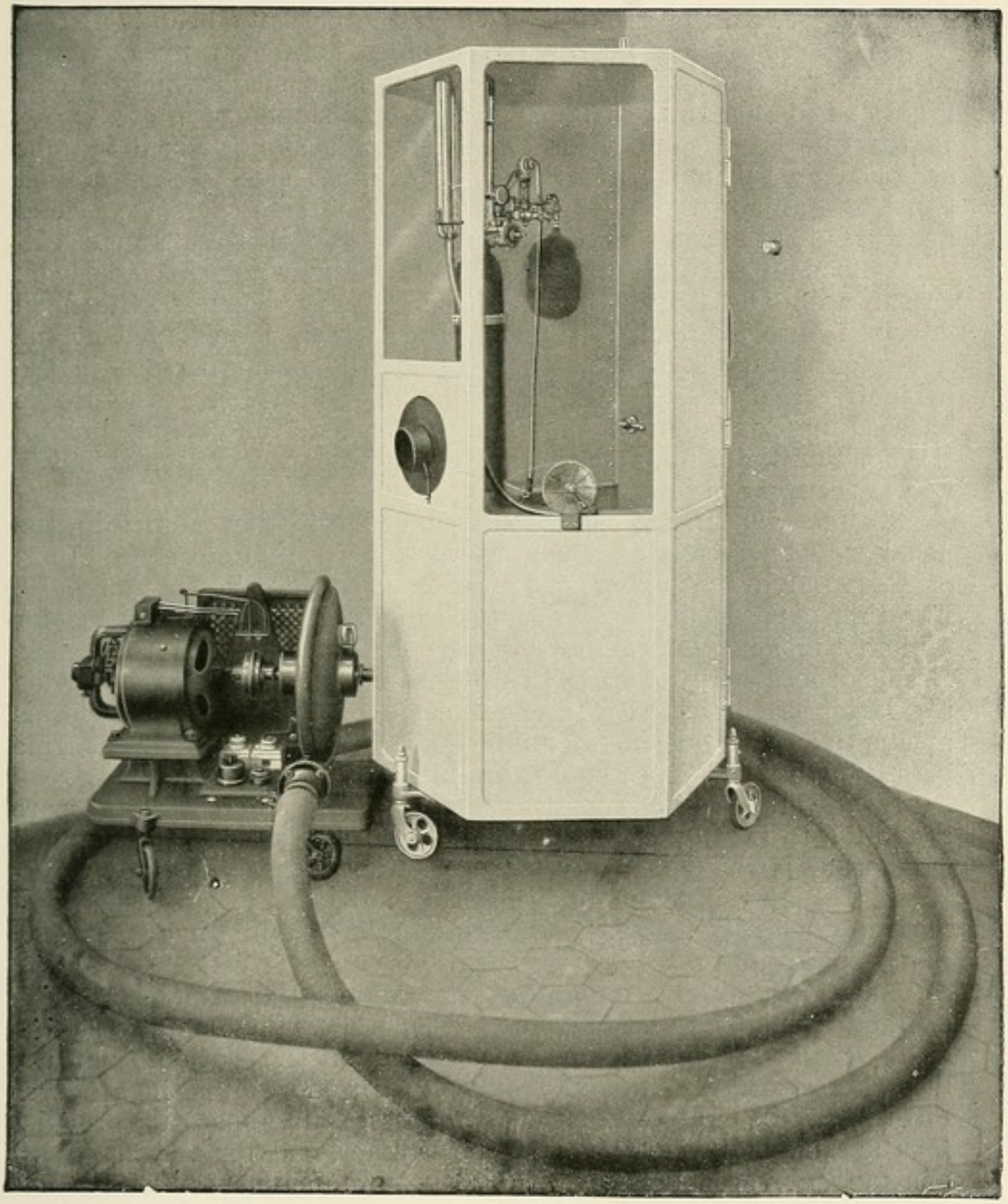


FIG. 20.—ENGELKEN'S apparatus for increasing the pressure.

(2) The head-cabinet and the devices for preventing the outer air having access to the head of the patient and the hands of the anæsthetist in this cabinet.

(3) The connection of ROTH-DRÄGER'S apparatus for administering oxygen and anæsthetics.

(1) The compressed air is conveyed by a Root's blower (worked by electricity, or by hand) : 600 to 800 litres of compressed air per minute can easily be conveyed. A metal tube conveys the air from a distance of about 6 cm. to a pair of bellows, the upper movable cover-plate of which comes in contact with spiral springs.

Out of these very large bellows the air passes to a manometer and then on into the cabinet, in which the patient's head is placed. The pressure of the air in the cabinet is shown by a water-manometer. The air leaves the cabinet by a shaft which can be regulated to offer the resistance desired by a sliding weight.

(2) The large cabinet for the head holds 150 litres ; it is to be strapped on the operating table. The upper side of the cabinet consists of an adjustable glass cover. On the side there are several apertures for the arms of the anæsthetist or another assistant.

A hood of air-tight material envelops the whole head, as well as the chin, and leaves the face free. Below the neck the hood develops into a broad, fairly long bag, which is fastened at the lower extremity to a projecting part of the head-aperture in the cabinet. The arms of the anæsthetist and of his assistant are encased in gloves or mittens. The pressure in the cabinet presses the hood on the head, and the gloves on the arms, and in this way makes them air-proof.

(3) The anæsthetic can be introduced into the cabinet in the usual way by means of a simple mask with chloroform or ether, or ROTH-DRÄGER'S apparatus may be used—as shown in fig. 19. For this purpose are used the tube of oxygen, the apparatus for mixing the gas, the conduit-pipe belonging to it and the mask. Besides there is also a spare bag which stands under a glass shade ; the latter is connected with the inside of the cabinet. By this means the spare bag inside and outside is always under the same pressure (that is the pressure prevailing in the head-cabinet).

KAREWSKI, in 1909, constructed a cabinet for increasing pressure according to BRAUER'S system, the dimensions of which are much smaller, and which is ready for use at any time and easily transportable. The supply of air by electro-motor, or by a quick-working treadle device (velocipede), amounts to a maximum of 10 cubic metres per minute.

ENGELKEN, in his apparatus, also adopts the principle of the cabinet. A light, transportable sheet-metal cabinet is made sufficiently large to admit not only the head of the patient, but the anæsthetist and a cylinder of oxygen. In one wall is the aperture for the head. A motor-driven compressed-air apparatus provides for the sufficient ventilation of the cabinet, and for the necessary constant increased pressure of 7 to 10 mm. mercury. The cabinet is drawn up to the head of the operating table. The arrangement can be easily understood from the illustration (fig. 20).

A further simplification and improvement we owe to GREEN and JANEWAY. It is a simple cabinet set up on a table in which, following BRAUER'S idea, the head of the patient and the arms of the anæsthetist are placed. By a valve trap of original construction the respiratory rhythm with the rising and falling pressure in the

system is regulated to the artificial respiration (*Annals of Surgery*, vol. 52, 1910).

THE MASK APPARATUS.

A notable simplification is obtained by the introduction of an air-proof mask for the mouth and nose, instead of the cabinet for the head, such as is used by TIEGEL-HENLE, BRAT and SCHMIEDEN, LOTSCH, ROBINSON, MORRISTON DAVIES and others.

TIEGEL'S apparatus, of the year 1908, consists mainly of a modified WANTSCHER mask fitting closely to the face, into which is conveyed by the insertion of a pipe a continuous stream of air or

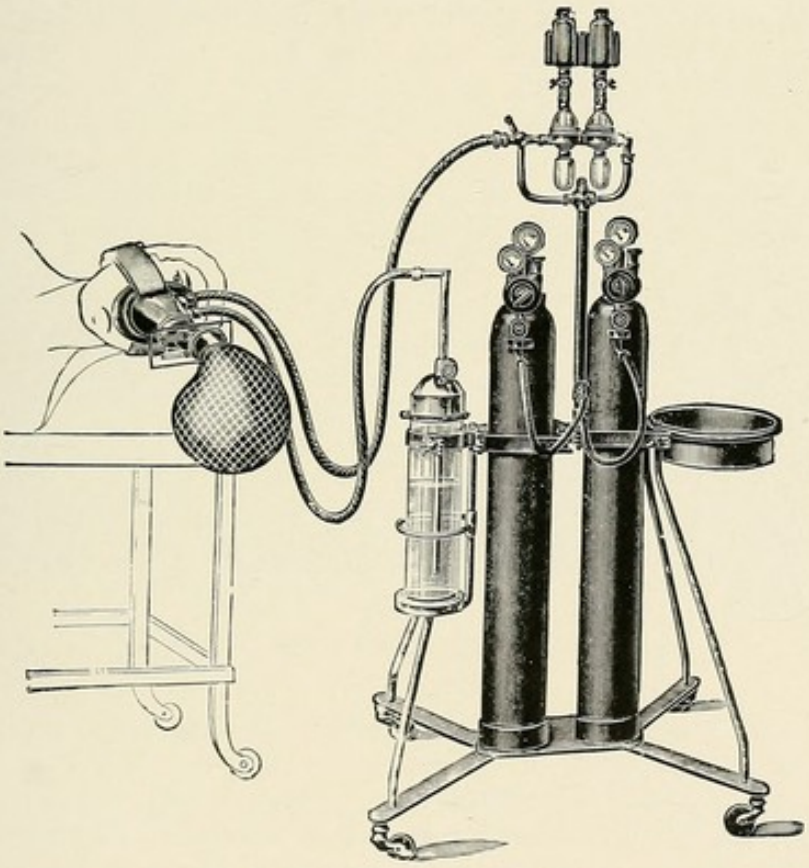


FIG. 21.—TIEGEL'S simplified mask apparatus.

oxygen. A second pipe fitted to the mask takes off the current of air through a water-valve, which produces and maintains a certain pressure in the air. In the intermediate pipe small chambers are inserted, in which by means of a dripping apparatus, which can be regulated, the anæsthetic can be added to the air breathed.

Thus TIEGEL briefly sketches the principle of his apparatus (*cf.* fig. 21).

The pressure is derived mainly from a cylinder of oxygen, which is fitted on a movable stand. The pressure of the outgoing gas can be reduced as desired by a valve, at the most ½ atmosphere.

A second source of pressure can be added to the conduit-pipe by a bifurcated piece with stopcocks; the two sources of pressure can be used simultaneously or alternatively. For this purpose a water-jet blower, or a little air-compressor worked either by electricity or by the hand, is used.

The air-bellows work continuously during the whole operation: the supply of oxygen is regulated, as required, by the anæsthetist.

The large rubber balloon placed in front of the mask lessens the variation of pressure on inspiration and expiration, which would otherwise be considerable and disturbing; it makes breathing easier.

The pressure in the whole system is regulated by a water gauge pipe which, according to the depth to which it descends in the water, allows the establishment of differences of pressure which can be measured and regulated (10 cm. for the normal inflation of the lung).

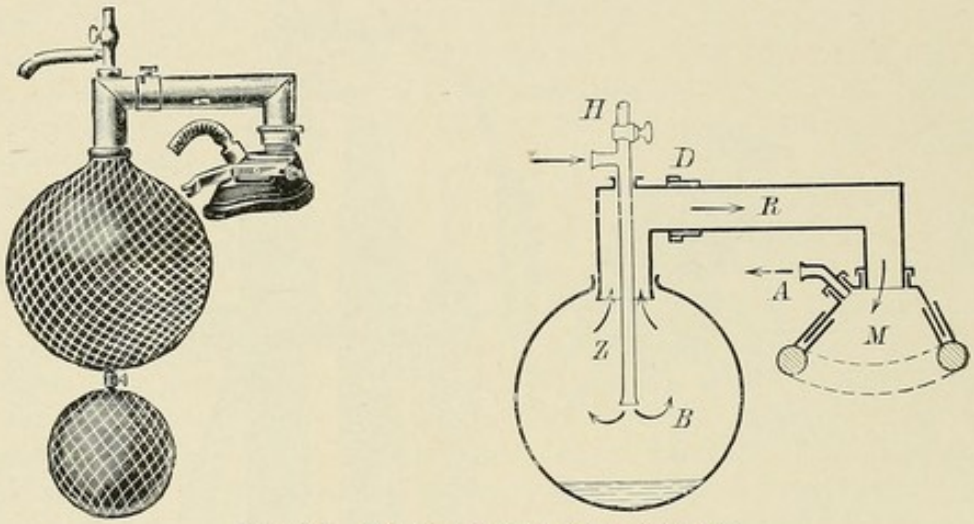


FIG. 22.—TIEGEL'S mask with extra bag.

Criticism was directed to the danger arising from incidents due to the administration of anæsthetics, above all from vomiting. TIEGEL then added a second exchangeable bag balloon mounted on a slide, which, however, he does not appear to use himself. He gives as his reason, that in his operations there is no need of it, as the mask is first steeped in a powerful narcotic, in which case vomiting is rare. When the open pleura is well covered with wet compresses, or the mediastinum is fixed to the lung which is set free, the process of increased pressure can be continued for a time until all is in order again without any harm to the patient. This can be done without any hesitation when the blood has been arterialized before by a quantity of oxygen.

The apparatus has been found to answer in practice. This is proved by a series of very noteworthy intrathoracic operations performed by HENLE in Dortmund, in which TIEGEL'S apparatus worked splendidly. Its chief advantages besides the simplicity of its construction and handling are its handiness; it allows of the

patient being placed in any position, and in the absence of the troublesome collar enables the operation to be aseptic in a way to which no objection can be taken. It can be quickly and easily used whenever necessary, and at any moment while the operation is going on just as quickly and easily can the mouth of the patient be set free. No special knowledge or practice is required before using it.

In spite of the hesitation just explained, the idea of the mask apparatus has not been abandoned; on the contrary, to-day efforts

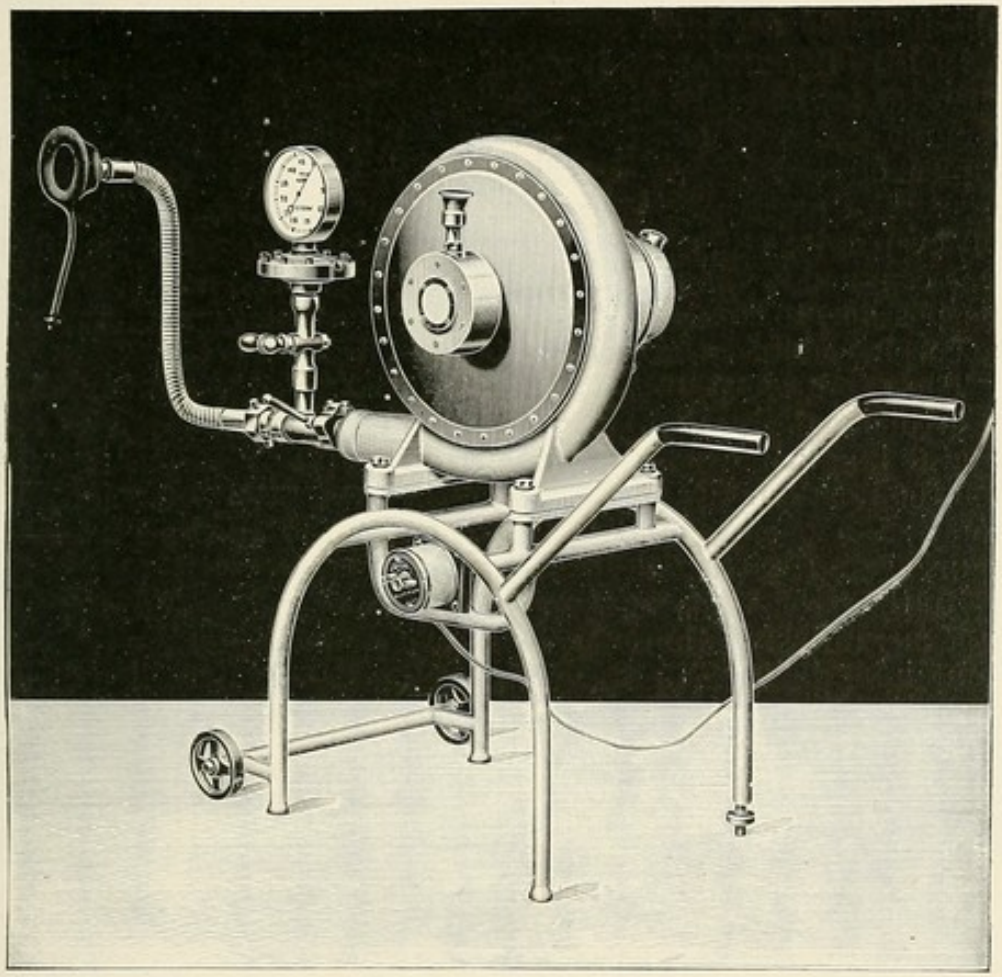


FIG. 23.—SCHOEMAKER'S apparatus.

are still being made to perfect it, starting from ROTH-DRÄGER'S handy apparatus for administering anæsthetics.

Thus the apparatus recommended by BRAT and SCHMIEDEN is based on this principle. Two bags serve as reservoir and air-buffer, a screw valve regulates the influx of oxygen, which passes into the mask covering mouth and nose.

At the instigation of DEPAGE, MAYER and DANIS constructed in 1907 an apparatus for increasing pressure which would seem to be very practical. The patient receives the air for breathing from a cylinder of oxygen with a receptacle for chloroform interposed;

the air is introduced through an intrabuccal mask, which consists of metal plates which can be screwed together, one of which is placed between the teeth and lips, the other on the lips. A tube in three parts is connected with the plates: for inspiration, for expiration, and for the control bag (at the same time to be used as a receptacle in case of vomiting). The pressure can be easily regulated by the water gauge. So the patient breathes against a resistance which can easily be varied, by means of which the inflation of the lung can be regulated as desired. A rubber bag modifies the variations of pressure. This "appareil à baronarcose" is very handy and portable. The intrabuccal mask cannot be unhesitatingly accepted.

In 1910 SCHOEMAKER, it would appear, solved the question of an apparatus for administering anæsthetics with increased pressure, in a simple and very appropriate way. A powerful electro-motor is coupled directly with a ventilator, both placed in air-tight metal cases. The anæsthetic is dropped in front of the ventilator, sucked in it evaporates and mixes with the air. By a cock the compressed air is confined in the pipe and thus in the simplest way (manometer) it is possible to regulate it exactly. The air flows into the mask, the surplus escapes through an aperture in the mask.

The same apparatus, it would appear, also works excellently for artificial respiration. By opening the cock wide air is forced into the lung; if when the lung is inflated the stop-cock is closed, then the lung empties itself by means of the elastic tension of the thorax; the opening fills the lung again, and so the performance begins again and can be regulated at will.

In the year 1911, an apparatus was placed at the disposal of surgeons, in which the anæsthetic oxygen mixture, the method of maintaining increased pressure and automatically regulated artificial respiration are combined: DRÄGER'S combined apparatus. By one single manipulation it can be turned on from one function to the other; for example, from an anæsthetic to increased pressure (with or without anæsthetic) and *vice versa*, or from an anæsthetic to artificial respiration.

DRÄGER'S apparatus for artificial respiration — called "pulmotors" — have proved very useful as apparatus for restoring animation in cases of poisoning with gas, smoke, &c. Automatically adjusted, if desired, to the rate of breathing, also with long or short expiration, oxygen is conveyed through a mask to the lung and the harmful gases drawn off by aspiration.

Unquestionably such mechanical artificial breathing may be of use in incidents occurring during the administration of an anæsthetic, especially when it can be set going by merely turning a cock.

The combined apparatus (see fig. 24) is compactly mounted on a movable table. The supply of air with the aid of a blow-pipe is so ample that the necessary fresh air can be raised in a standard minute from 20 to 120 litres. The current of oxygen sucks in fresh air through the pipe, and in this way the patient receives air rich in oxygen, which is to be preferred to inhaling pure oxygen. The used air breathed out is carried off from the mask through a separate pipe.

On the suggestion of WILMS the apparatus has lately been improved, so that with a very slightly increased pressure (2 to 3 cm. water) it can be used in accordance with VOLHARD'S method and also permits of the application of KUHN'S tubage and MELTZER'S insufflation.

Fig. 24 represents the whole of the upper part of the apparatus. Compressed oxygen is used in working it. O is a cylinder of oxygen of the usual trade size containing 1,000 litres. It is connected with the apparatus by the spiral pipe B. After the opening of the cylinder trap valve, the oxygen passes through B into the reducing valve. The content of the cylinder can then be read on the scale F. The high pressure is reduced by the

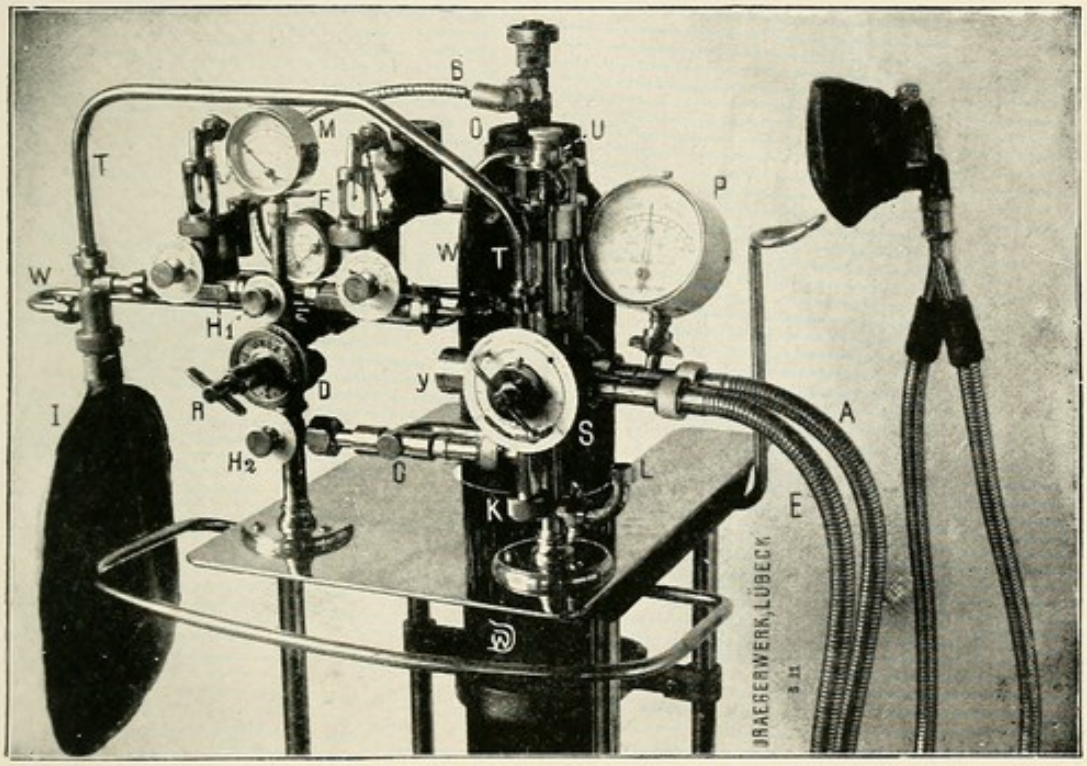


FIG. 24.—DRÄGER'S combined apparatus.

reducing valve to the working pressure of 8 atmospheres. By screwing down the regulating screw R this pressure is suspended by watching the manometer and turning the screw until the pointer stands on the red mark. (Before use and whilst the apparatus is not being used, screw R must be screwed right back and the pointer must be at O.)

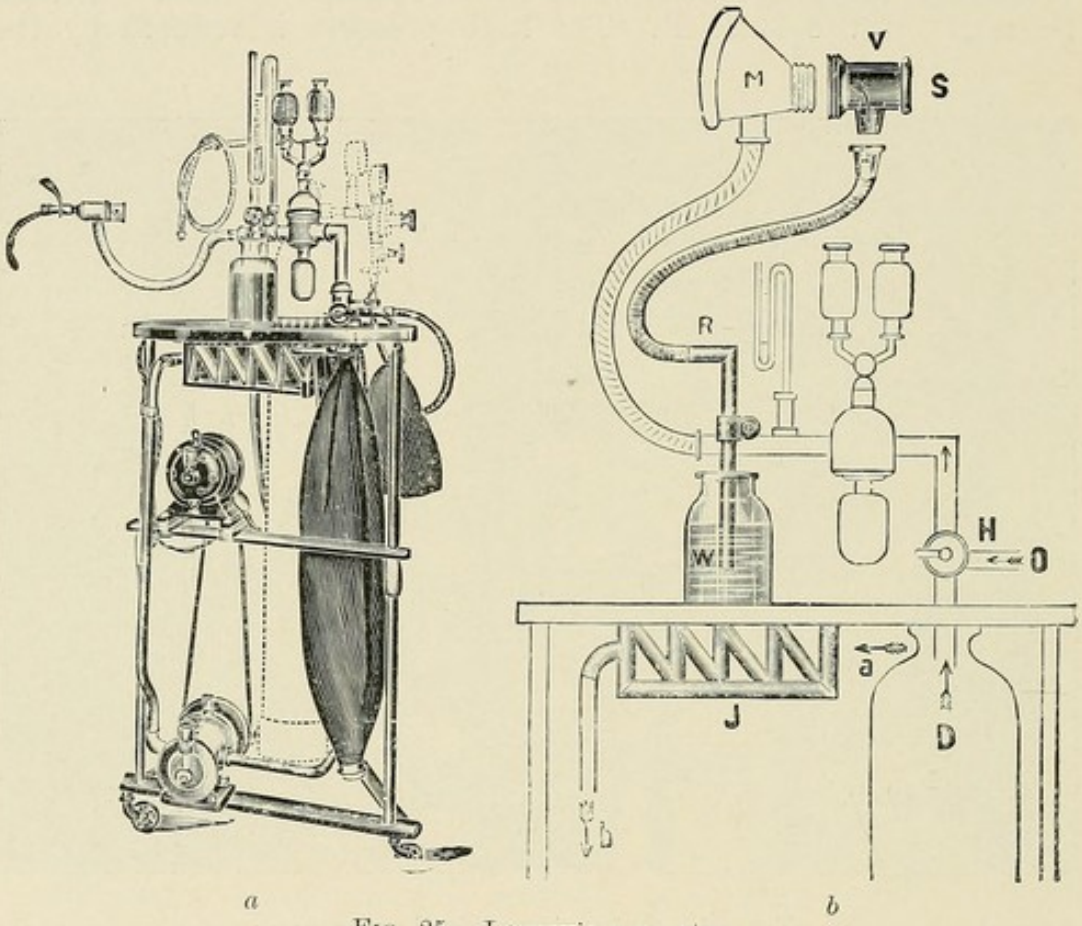
By the regulator tap H_1 the working pressure is transferred to "Dr. ROTH-DRÄGER'S" well-known apparatus for administering an anæsthetic, by H_2 to the suction and pressure pipe, which is used to create a vacuum or high pressure in the respiratory mask.

Reversing cock, S, is easily drawn forward and turned till it is adjusted in accordance with directions showing the nature of the

work. These are: (1) Ordinary anæsthetic mixture; (2) high pressure with and without anæsthetic; (3) re-animation, inspiration; (4) re-animation, expiration.

Directly cock S is at work, the apparatus ceases to perform its previous functions and begins its new functions.

Lotsch has recently (1911) constructed a very practical high-pressure apparatus for compressed air and for oxygen, easily adapted for insufflation. It has rotatory bellows driven by an electromotor which can be connected with a mask or with the intubation.



a *b*

Fig. 25.—Lotsch's apparatus.

Fig. 25, *a*, shows the construction of Lotsch's compact apparatus with motor and ventilator. The schematic fig. 25, *b*, illustrates the course of the current of air or oxygen.

The air sucked in by the ventilator flows in the direction of the arrow through the glass receptacle S, the bottom of which down to the mask is filled with warm water. The surfaces of the material are soaked with water; the air flowing through becomes moist, free from dust and slightly warm.

The moist dust-free and slightly warmer air is driven down by the rotary bellows into the bag D. It passes on into the rigid pipe bent at right angles which carries the three-way cock H, the anæsthetic spray apparatus and the manometer, and further on

through the flexible metal pipe to the mask (or to the tube) M, which bears the valve V. Through the side branches of the valve the air leaves the apparatus in the direction of the arrow. By turning the disc S the opening of the outlet can be narrowed at will and in this way the pressure in the pipes regulated.

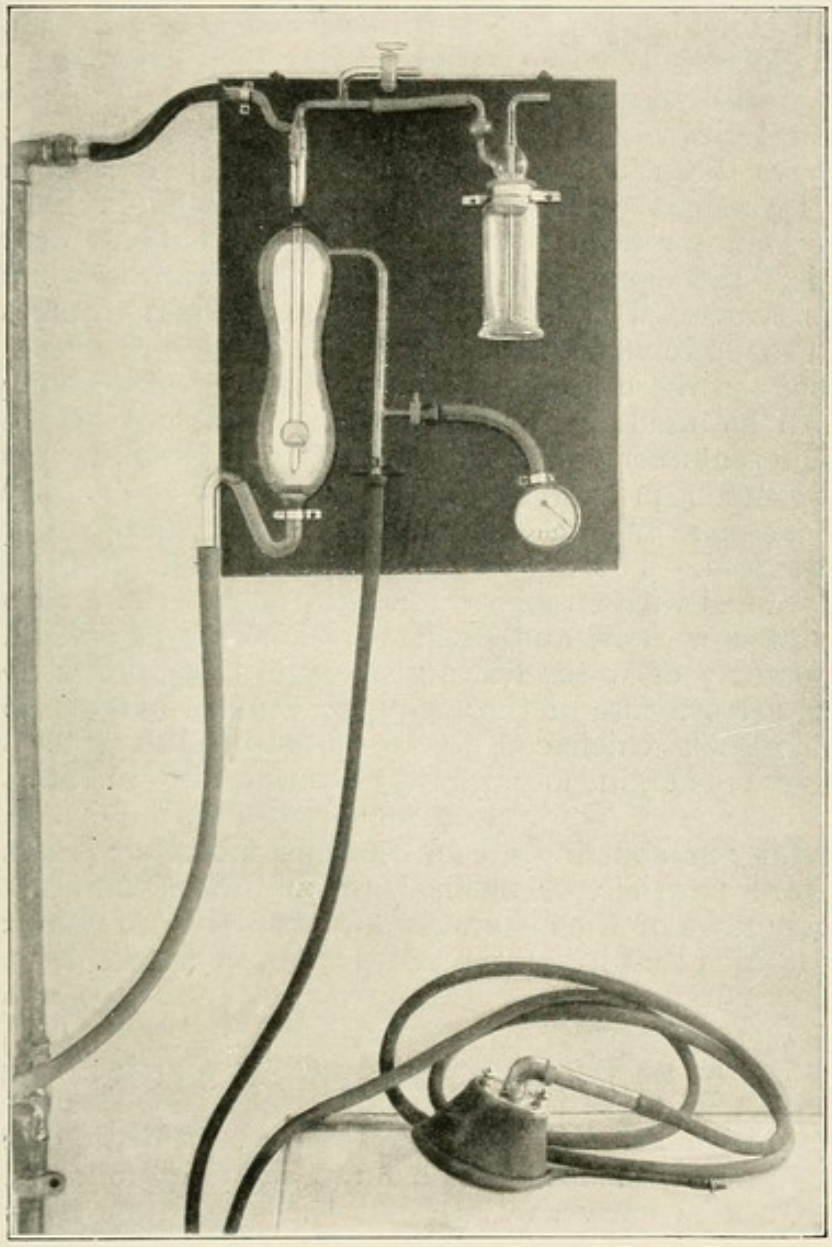


FIG. 26.—Simple apparatus for increasing pressure by means of hydraulic bellows, constructed by STEINMANN.

When the apparatus is to be used for oxygen the three-way cock H is inverted, so that the motor and air current cease perforce and communication is opened with a smaller regulating bag. The oxygen passes through the side pipe O from the steel cylinder into the conduit pipe. Then the course is the same as for the compressed air.

In order to use the oxygen economically, you open the valve V fully and insert a water valve W, fastening the flexible metal pipe K by simple bayonet joint to the exhaust and connecting branch of valve V. When you want to change to compressed air, you take away the spiral pipe E, invert the three-way cock and regulate the high pressure by turning the disc S.

STEINMANN shows us how simply by means of a hydraulic blower a useful high-pressure apparatus can be constructed. He has kindly placed the illustration at my disposal and gives the following short description of the construction.

In laboratories where water at high pressure is laid on hydraulic bellows have been used for a long time, which are, generally speaking, inversions of Bunsen's hydraulic air-pump. The water enters an aspirator from above and takes air bubbles with it, the lower end of the aspirator opens into a large drum in which water and air are separated and pass away through different pipes. The principle has led to various constructions.

In hospitals where there is a high-pressure water supply, these bellows can be used to produce increased pressure in the lungs. Fig. 26 represents bellows installed for this purpose, in which the so-called Munich principle of construction is applied. With a hydraulic pressure of two atmospheres a sufficient quantity of air can be produced. The dry bottle, placed in front of the suction aperture, is filled with an anæsthetic and causes the air sucked in to be saturated with it, and thus make anæsthesia possible.

The quantity of water flowing through the bellows gives the measure of the pressure in the air-pipe; a manometer in this pipe and a good cock which can be regulated in the water conduit enable you to obtain any pressure you desire in the current of air.

By opening or shutting a cock the current of air is composed, as desired, of pure air, or of air with anæsthetic fumes.

The advantage of the apparatus constructed by Messrs. Schärer and Co., Bern, is that it is three or four times cheaper.

THE INTUBATION APPARATUS.

The primitive FELL-O'DWYER method of intubation and inflation of the lung by means of the bellows was very much improved upon by KUHN as early as 1904. At the same time by so doing he was the first to solve adequately, and in a manner to which no objection could be taken on physiological grounds, the problem of administering anæsthetics with increased pressure.

KUHN has combined his tube constructed for oral intubation with an apparatus for increasing pressure which has been modified many times. He uses for this purpose the ROTH-DRÄGER apparatus for administering anæsthetics with a cylinder of oxygen; instead of using an electrically-driven ventilator he increases the current of air by means of bellows. Two bags inserted in the conduit of pipes—one for oxygen, the other for chloroform—with safety

escape valve, serve as regulators of the pressure and as reservoirs. These pipes can be opened or shut by means of cocks. A return valve in front of the tube prevents the back flow of the air expired into the feed pipe, and a mouth valve with a mechanical escape valve provides for the outflow of the used respiratory air. By the adjustment of this escape valve to the mouth, KUHN, as early as 1904 to 1905, put into practice the principle of the apparatus for maintaining an increased pressure.

DURRANCE (1911) wishes to continue the tubage with a flexible tube down into the subglottal cavity, and there make it air-proof with a rubber bag like the Trendelenburg tubes.

Scruples on account of the danger if vomiting should occur, which certainly deserve consideration when the masks are used, need not be much considered in the intubation methods, for vomiting, also the severe, very disturbing pressure in narcosis, is impossible with an open glottis. This is a distinct advantage; on the other hand, the accurate and certain insertion of the tube is often impossible.

KUHN, however, in 1908, in a very simple way—similar to that recommended later by MELTZER and AUER for artificial respiration—maintained the pressure in the lung after intubation, as he says, constant and capable of regulation, by sending into the tubage pipe from a sufficiently strong source of high pressure, with the aid of a thin, small pipe attached, not air-proof, a stream of oxygen or air under $\frac{1}{2}$ to $\frac{3}{4}$ atmospheres, while the patient is under the influence of a deep anæsthetic. All the parts (tube and small pipe) are pervious to the air, therefore the current of atmospheric pressure is free, the ventilation always good. The supply of pressure is obtained either from a cylinder of oxygen or compressed air, or from a compressed-air machine.

Among high-pressure apparatus, a special position is held by the method of insufflation, which has been much used of late in practice in America. All apparatus hitherto constructed aim at avoiding pneumothorax by inflating the lung. As a matter of fact, however, open pneumothorax on one side involves in itself no danger. One lung is quite sufficient for the necessary supply of oxygen to the blood. Only when the other lung, owing to the fluttering of the mediastinum, no longer makes it possible for the blood to obtain a sufficient interchange of gas, and the oscillation of the air quickly increases the poisoning with carbonic acid gas, do the disturbances begin.

There is no need, then, to trouble about pneumothorax, if only (1) a sufficient quantity of oxygen is transmitted to the blood, and (2) if the exhalations of carbonic acid gas are removed. VOLHARD demonstrated, in 1907, that this also is possible without respiratory movements. He succeeded in keeping animals alive for hours, when breathing had completely ceased under the influence of curare, by irrigating the trachea with a small quantity of oxygen without special pressure; the CO_2, which is given off, escapes alongside the thin intubation pipe.

With a water gauge and a cylinder immersed in mercury (Hg.),

Volhard constructed a wonderfully simple apparatus for artificial breathing, in which the variations in the inertia of the mercury direct the rhythm of the respiration. With the same improvised apparatus in the case of a patient suffering from arrest of breathing during an operation on the brain, he maintained the breathing automatically in regular rhythm for nine hours, during which, on the passive inflation of 8 cm. hydraulic high pressure, a negative phase of −3 to 4 followed in which the air expired was removed by suction. The patient underwent tracheotomy.

Also, as TIEGEL has shown, in open surgical pneumothorax with oxygen a pressure of 3 cm. is sufficient. The lung on the open side of thorax is only slightly inflated, which is not without its advantages for the operation. Only on the conclusion of the suture of the thorax is the lung fully inflated with increased pressure (over 10 cm. Hg.).

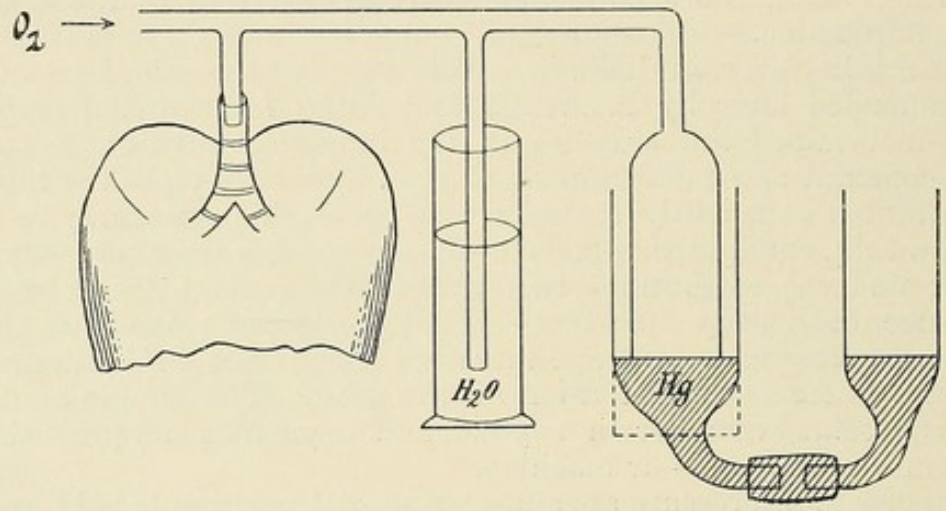


FIG. 27.—VOLHARD'S improvised apparatus.

The Americans, MELTZER and AUER, helped on the introduction of this method into the surgery of the lung by proving that the lung can be also quite sufficiently ventilated with air (even in cases of double pneumothorax), when the respiratory air is brought in a powerful current, 20 mm., by a small thin pipe as far as the proximity of the bifurcation of the trachea (intratracheal insufflation).[1]

Dr. ELSBERG (New York) has lately gone thoroughly into the question of the MELTZER method of insufflation. He also constructed a very practical and easily transportable apparatus for operations on human beings (*Annals of Surgery*, February, 1911), which is to be still further simplified and improved.

The apparatus consists of a blower driven by an electro-motor

[1] It appears that KUHN experimented in the same way in the year 1908. But the application of the experiment to human beings seemed to him too risky, for the intensive and direct renewal of the air, and the consequent reduction of temperature, made him fear serious catarrh and pneumonia.

of $\frac{1}{6}$ H.P. (In reserve are bellows worked by the feet.) The air passes through a vessel with warm water, where it is warmed and saturated with moisture; in another it absorbs the anæsthetic (ether). On the far side of the reservoir a pipe conveying oxygen from a cylinder opens into the air-pipe; this can be made use of, or not, as desired. A mercury manometer. A rubber tube leads to the cannula.

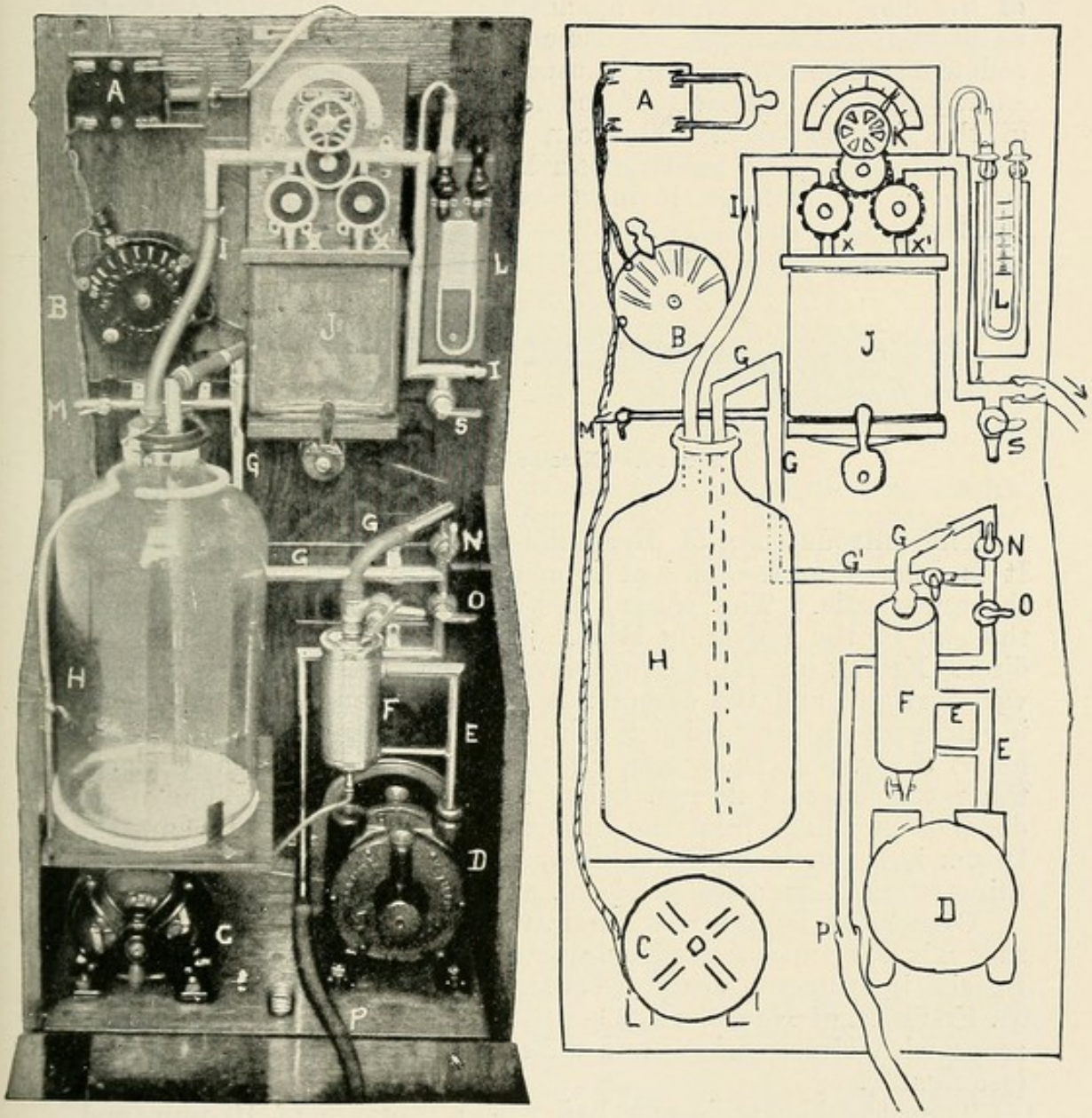


FIG. 28.—Dr. ELSBERG'S apparatus for intratracheal insufflation (in an easily transportable wooden cabinet).

Dr. ELSBERG uses a woven silk catheter, about 30 cm. long, corresponding to No. 24 charrière, which is pushed through the glottis till it nearly reaches the bifurcation of the trachea, and is then inflated from a blower with air at a pressure of 20 mm. Hg.

By this powerful current of air a sufficient quantity of oxygen to arterialize the blood reaches the alveoli, but there immediately arises, just as powerful, a counter-current, which streams outwards along the walls of the trachea. With it the exhalations of carbonic acid gas are carried away; it also at the same time hinders the influx of blood or secretions into the larynx and trachea; it drives all the secretions out of the wound.

The accompanying illustrations may give the reader an idea of the construction of the apparatus made by ELSBERG. As far as details of technique are concerned, ELSBERG points out the following: The catheter to be used as the tracheal tube must not exceed half the diameter of the trachea, or close more than half of the rima glottidis. This can be estimated by means of the laryngoscope. For adults charrière No. 22 or 24 is generally suitable; for children it must be correspondingly smaller and shorter.

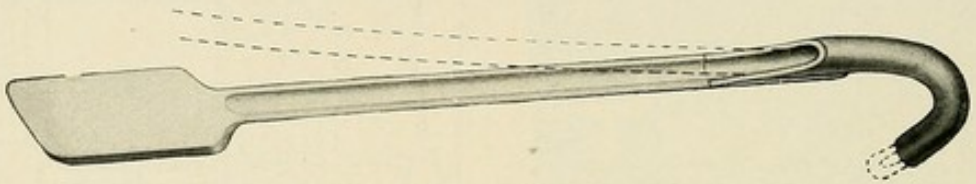


FIG. 29.—Director by FISCHER.

The introduction of the tube may present some difficulty. It is done after the patient is completely under the influence of the anæsthetic. The patient is placed with head reclining over the end of the operating table. The glottis is focused with the direct KILIAN or KIRSTEIN laryngoscope, the epiglottis pressed well forward, and the catheter is pushed through the glottis till it comes into contact with the bifurcation; then it is drawn back about 3 cm. and fixed between the teeth. When rightly placed the point is about 26 cm. below the upper incisors. The mean distance in adults from the incisors to the glottis is 14 cm., the larynx is 5 cm. long, the trachea, 12 cm. to 13 cm. It is a good thing to mark the tube at 14 cm. and at 26 cm.

Care must be taken when introducing the sterilized catheter that it is not contaminated by mucus from the mouth or pharynx. Special instruments are also constructed for this purpose: one by H. FISCHER, of New York, a bent tube, fixed on a HAYES laryngoscope with direct vision,[1] and a director by COTTON and BOOTHBY (see fig. 29).

Then the blower is attached with a pressure of 10 mm. and, after a few minutes, with a pressure of 20 mm. Hg. The mouth remains open. Every two or three minutes the current of air is interrupted for an instant. To avoid extreme fluctuations of

[1] To be had from Wappler, Electric Controller Co., 173, East 87th Street, New York City. My Assistant, Dr. FRÜND, has constructed such an instrument as renders possible an aseptic introduction of the tracheal tube.

pressure through pressing, the operation should only begin when the patient is completely anæsthetized.

If the air is to be replaced by oxygen through the second pipe, a pressure of 3 mm. mercury is sufficient, as remarked above, for the exchange of gas in the alveoli. This would be advisable, for example, when, for some reason or another, the lung is to be only slightly inflated during the operation. Combined in this way, VOLHARD'S and MELTZER'S method are the most useful in the surgery of the lung.

The consumption of ether is minimal. The formation of foam in the pharynx ceases at once on insufflation. The breathing is regular and light, the pulse full and strong, the face congested.

If the air pressure rises above 20 mm. the breathing becomes superficial, without cyanosis; with a pressure of 30 and 40 mm. mercury apnœa occurs.

Irritation, exciting cough when the insufflation is begun, point to the fact that the tube is too low down; when lightly placed breath sounds can be heard over both lungs.

Cyanosis may be the result of insufficient air pressure or of too narrow a tube. In the latter case a slight compression of the trachea from outside improves the breathing. No injury caused by the tube has been observed; neither pains in the neck, nor hoarseness; no tracheitis, or pneumonia.

ELSBERG has used his insufflation apparatus more than twelve times in experimental thoracotomy and in treating pulmonary abscesses in human beings. According to his experience, it performs what is necessary in the surgery of the thorax.

The method of insufflation has also, as he writes to me, "proved satisfactory as a method of administering ordinary anæsthetics. We have used it for this purpose more than a hundred times, and have good and astonishing results. Especially in operations for goitre, operations on the brain and in the face and oral cavity, it is very valuable, for no blood or secretion can pass into the larynx or deeper down; the current of air drives all out of the mouth."

These practical results, confirmed too by others, are indeed very encouraging, especially in consideration of the instrument, which, by the absence of cabinet and mask, is very much simplified and has therefore gained in practical usefulness.

Quite a number of experimental works[1] are available to help us in forming an opinion of the effect of the method of maintaining difference of pressure on the lung, its ventilation, the oxygenation of the blood, the effect on the heart (especially the right ventricle) and the whole vascular system. By the inflation of the lung the mediastinum is no longer forced out of place when the pleural cavity is open, the "fluttering" of the mediastinum ceases, the respiratory air is no longer driven to and fro between the two bronchial trunks, and the diaphragm and muscle of the thorax are

[1] I may mention the work of SAUERBRUCH, BRAUER, TIEGEL, DREYER, SEIDEL, FRIEDRICH, MAYER, VON SPEE, O. BRUNS, and others.

again brought into play for the purposes of expiration and inspiration. When the lung is amply supplied with blood, the blood is sufficiently arterialized, dyspnœa disappears, the function of the heart and the circulation of the blood become almost normal.

The method, unquestionably, does all that was expected; it does away with the direct and indirect consequences of pneumothorax.

The experimental works, to which I alluded above, have gone fully into the question of whether the method of maintaining increased pressure is to be preferred, on the physical and physiological grounds, to that of maintaining decreased pressure, or *vice versa*.

Recent investigations, especially those of TIEGEL, prove that the method of maintaining increased pressure involves a greater deviation from the physiological normal.

By the positive pressure an increase of pressure takes place in the endothoracic veins, and especially in the artery of the lung. This resistance of the blood is not without importance to the heart; the right ventricle is overburdened doubly, because at the same time the normal suction of the blood by the negative pressure of the thorax ceases.

Owing to the great adaptability of the muscles of the heart in practice disturbing or threatening complications do not appear at first. Only if the over-pressure on the lung continues for a long time, or if the heart is weak, do disagreeable symptoms appear as the result of the overburdening of the right ventricle. Add to this that, according to CLOËTTA, the lung under increased pressure is very poorly supplied with blood.

For this reason I have strongly urged that increased pressure should not be maintained for long, and that too high a pressure should not be used.

In SAUERBRUCH'S cabinet, on the other hand, as a result of the negative external pressure, the indrawing of the venous blood is increased and the resistance of the blood-vessels decreased in the peripheral pulmonary capillaries.

So, in this case, complications of the heart are not to be feared—it is not functionally overburdened.

And yet, even in the SAUERBRUCH cabinet, breathing is not physiological. The negative pressure on the thorax causes a more or less permanent position (of the vocal cords) during inspiration—strong expiration is absent; this produces a strong influx of blood (CLOËTTA). It is true that 7 to 10 mm. mercury minus pressure is no hindrance to conscious expiration. You must remember, however, that you are treating an anæsthetized patient.

The consequence, if the over-pressure is maintained for long, will be an impoverishment of oxygen in the tissue. So none of the methods is free from objection from a physiological point of view, and when we give the preference to the apparatus for maintaining an increased pressure for purely practical reasons, we must not forget the overburdening of the right ventricle of the heart.

Our conclusion, then, as to the application of the apparatus in the surgery of the lung—and that is the point we are considering

here—will be, that in the physiological effect there is certainly a difference between increased pressure and decreased pressure, but when the apparatus are carefully and thoughtfully used it is without importance in practice. The two methods can reasonably be held to be of equal value.

That the methods are of equal value does not, of course, imply that the apparatus are of equal value. Here the advantages and disadvantages must be weighed one against the other (I do not know of any apparatus which has no disadvantages) and here personal considerations, such as habit and practice, experience and taste, play an important part. Finally the question of cost decides! I may well abstain here from a critical comparison of individual apparatus and a consideration of their practical utility. As far as objective criticism seems desirable, I have already given it in short remarks when describing the apparatus. I refer specially to the criticism of the method of insufflation.

Disadvantages and Dangers of the Method of Maintaining Difference of Pressure.

The Maintenance of the Aseptic Condition.—The rubber collar, which makes the neck air-proof in the cabinets, is easily brought over the upper section of the thorax. In this way not only is the work of operating in the upper sections of the thorax made much more difficult, which, in any case, is more or less cramped in every cabinet, but, above all the asepsis of the operation is endangered. Improvements have been made (notched tappet rod), but this point is still worthy of attention.

With the mask apparatus and with the intubation methods this danger does not exist.

Vomiting in Anæsthesia.—This is to be feared when masks are used. If the mask is removed, then the difference of pressure is destroyed. The sudden alteration involves risk when the thorax is open. The operator must at least find time to pad the pleura well. This undesirable interruption *may* coincide with a critical moment in the operation.

This has been remedied by adding to the mask receptacles for vomited matter, which are exchangeable (Tiegel, Mayer and Davis). Tiegel and Henle, who have certainly had the most experience with masks, do not fear aspiration when vomiting occurs even when a simple mask is used.

With the intubation method, vomiting is impossible, as the glottis cannot be closed. Moreover it is permissible to plug the entrance to the œsophagus (Kuhn). In insufflation the pharynx remains freely accessible.

Interruption of the Difference of Pressure.—Every apparatus, however carefully it is constructed, may fail just at the most important moment—through the fault of the attendant or for some other reason. A careful operator will, therefore, always have the necessary requirements for plugging (two or three large wet gauze

compresses are the best) at hand, to meet the risk of the total collapse of the lung; this is preferable to seizing and pulling the lung forward, on account of the risk of infection.

When the lung partially collapses pus or blood from the periphery of the lung or from the pleural cavity may be drawn in by retrograde aspiration. The aspiration is preceded by an inspiratory movement. The complete (gradual) collapse of the lung would then be the surest preventive measure, as long as the difference of pressure has not been re-established.

The collapse of the lung is quickly followed by impoverishment of the oxygen of the blood; when the interruption of the difference of pressure is a lengthy one, this must be met by a timely insufflation of oxygen.

Hæmorrhage, too, from the lung tissue may become more profuse on the collapse of the lung (plugging, compression, temporary suture).[1]

Acute Dilation of the Stomach.—Acute distension of the stomach has often been noted as a result of the difference of pressure, which in one case of KÜTTNER's led to death from ileus of the stomach. In experiments, for instance, SAUERBRUCH has observed how the stomach, distended to the maximum extent, forced up the diaphragm and the animals became short of breath.

This condition arises when the head and neck are under different pressures, that is, when the (neck) collar is placed immediately below the chin. For as soon as the counterpressure is removed from the neck, which compresses the œsophagus—whether you are working with increased or decreased pressure—the (relatively) increased pressure of the air overcomes the pharyngeal sphincter the œsophagus is inflated and, by reflex action, the cardia opens to admit the inflowing air.

Acute distension of the stomach may, as already mentioned above, prove fatal. In any case it must be considered as a serious complication in operations in which a difference of pressure is maintained. The high degree of meteorism prevents the movement of the diaphragm, affects the working of the heart and forms a source of secondary affections of the lung.

The risk can be avoided by placing the collar in the cabinet apparatus on the lowest section of the neck, the masks with increased pressure seem to cause distension of the stomach more frequently. Perhaps it might be avoided by merely bandaging the neck.

The Use of too high Pressure and lengthy Operations while maintaining a Difference of Pressure.—With the inflation of the lung, that is in proportion to the amount of pressure used, the capillaries of the lung are compressed; which is equivalent to a

[1] Here I should like to draw attention to a disturbing symptom in operations on the infiltrated lung. Through the increased pressure in the bronchioles the air rushes out of the surface of the wound and mixes with the blood to form foam, which often obscures the field of operation in a very disturbing way.

difficulty in the circulation of the blood in the lung. Such an increase of pressure in the pulmonary region very soon overburdens the right ventricle of the heart. SAUERBRUCH, therefore, recommends, in cases of weak or diseased hearts, that the difference of pressure should be kept as low as possible, and especially with patients suffering from emphysema with the heart already overburdened, not raised above 4 to 5 mm. Hg.

Differences of pressure, which exceed 10 to 12 mm. Hg., are in any case to be avoided with cabinet and mask apparatus. Only in insufflation is a pressure of 20 mm. mercury to be used without hesitation, the current of air must be interrupted for a short time all the more frequently. To me there seems no doubt that also the long duration of operations, where difference of pressure is maintained during anæsthesia, involves risks, to which we have hitherto hardly paid any attention. Many operators must have seen their patients, after a prolonged operation, performed under difference of pressure, pass away towards the end of the operation, or immediately after it, and that accompanied by symptoms not to be accounted for either by the anæsthesia, or by a hæmorrhage, or by aspiration. Then not finding any pathological anatomical cause, it has been described in the non-committal words "Death from shock."

When we remember that in none of the methods of maintaining difference of pressure is the exchange of gas in the lung normal, that the lungs are breathing in the position for inspiration, and that strong expiration is lacking, it is unavoidable that the quantity of residual air impoverished of oxygen must be disproportionately high. The blood is more and more overburdened with carbonic acid gas, until finally the retroaction makes itself felt at the respiratory centre and the vaginal centre. The pulse at first becomes slower (vagus pulse) and is characterized by sudden depressions, then as the pressure of the blood slowly decreases it changes to a proportionately rapid pulse-beat. Breathing may go on regularly undisturbed. That conceals the magnitude of the danger. Experiments on the "inner" breathing and the impoverishment of the tissue in oxygen have explained these things to us.

From the above remarks we must deduce, that for our lengthy operations when difference of pressure is maintained, we must not only have oxygen ready to hand for insufflation, but, above all, must prevent the stagnation of carbonic acid in the residual air and in the blood. That is achieved best by frequently allowing the lung to return to the position for expiration.

If I add a word about my personal experiences, I must say that I have performed the greater number of my operations on the lung without any respiratory apparatus. The dangers of pneumothorax are not so great that they cannot be controlled by the simplest measures, such as compressing and pulling forward the lung; the frequent pulmonary operations for gangrene, abscesses and bronchiectasis (provided you only want to locate the focus) can be performed without apparatus.

Later on I operated with SAUERBRUCH and with BRAUER'S apparatus, and have learnt to appreciate their value in serious plastic operations on the thorax and injuries of the lung.

In some of our pulmonary operations—and, of course, œsophageal—and in the surgery of the heart, the apparatus, during the short time in which they have been used, have become indispensable aids, which—and this is unquestionable—have simplified the operations and lessened the risks.

Still our wishes in this respect are not yet fully satisfied, we must—and this must be our immediate task—strive after the greatest possible simplification of the apparatus.

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CHAPTER IV.

GENERAL SURGICAL TECHNIQUE.

Local anæsthesia, especially in that form due to loss of nerve conduction or infiltration, with ½ per cent. novocain, is to be preferred to general anæsthesia with patients seriously ill and those cases in which, owing to profuse secretion into the bronchi and the unfavourable position of the focus of pus or gangrene communicating with the bronchi, an aspiration of suppurating or putrid matter is to be feared. With the perfected technique of to-day this is possible even in cases of most extensive resections of the rib and when it is necessary to penetrate deep into the pulmonary tissue. Its use is, however, limited as soon as it is a question of much manipulation in the pleural cavity. The pleura is painful when touched and pressed, and even under the effects of morphia reflex spasmodic expirations are caused through each trauma and when the glottis is contracted, so-called compressed breathing. This not only restricts the surgical process and renders it more difficult, but does the patient more harm than general anæsthesia. The sudden reflex decrease of the blood-pressure through irritation of the inflamed pleura is not without danger.[1]

In local anæsthesia of the thorax for major operations it must be remembered that the region to be rendered anæsthetic is unusually large. We must, therefore, try to produce an anæsthesia due to loss of nerve conduction, so as to reduce the quantity of the anæsthetic to a minimum. The position of the intercostal nerves which are concerned is favourable for this, as the region in which the nerve is to be sought is narrowly limited by the ribs. The position of the nerve trunk, too, in loosely constructed connective tissue between the tense muscular plates of the external and internal intercostal muscles, favours a deposit of the anæsthetic in the immediate proximity of the nerves (see "Anatomical Part," fig. 1, Thoracic Wall, transverse section). Here it must be remembered that each intercostal nerve in the posterior third of the circumference of the thorax consists of a trunk, which lies in the middle of the intercostal space. In front the nerve divides into two branches, the stronger of which follows the course of the next rib above, close to its inferior margin and partially embedded in a

[1] Capps and Lewis, *Amer. Journ. of Med. Sci.*, December, 1907.

sulcus; the weaker branch runs along the superior margin of the next rib below, sometimes along its inferior surface. The further you go behind, then, about to the angulus scapulæ, the surer you will be to have to reckon with only one nerve trunk.

The arrangement of the cutaneous branches, too, is such as to make an anæsthesia due to loss of nerve conduction possible. At three points the branches of the intercostal nerves, intended for the skin, break through the muscular stratum. Close to the spinous processes one to two sensory branches pass through the erector spinæ and curve laterally below the skin. The second point at which they break through lies on a line drawn perpendicularly down from the anterior axillary fold. Here the cutaneous nerves pass with one to two branches through the processes of the serratus anterior and spread in front and behind. The third point lies about 2 cm. laterally from the sternal margin.

Taking these anatomical conditions into consideration it is possible to perform even extensive plastic operations on the thorax without pain (HIRSCHEL). According to HIRSCHEL's[1] directions, the following is the procedure: First, the posterior, inferior and anterior border of the region intended to be operated upon is surrounded by a border of subcutaneous infiltration. The intracutaneous pomphus for the next puncture is fixed from inside, and so the painfulness of numerous punctures is avoided. In this infiltrated border line the intercostal spaces are sought out and a puncture is made in the middle of them and with the point of the needle you proceed to the upper, then to the lower rib. Then you probe round the upper and lower margins of the rib and place here a deposit of the anæsthetic. This is done all over the zone of infiltration, both posteriorly and anteriorly. The nerves mentioned in the second place are the most important. It is easy to locate them, in patients who are not too fat, by constructing the line given above, and determining their points of intersection with the easily recognizable sulcus between the individual serratus processes.

The only danger in this method is the possibility of injuring the pleura, and injecting a not quite negligible quantity of fluid into the pleural cavity. But this danger can be easily avoided by taking care that after probing the lower and upper margins of the ribs the cannula is only pushed forward, when at the same time infiltration takes place. In this way when the fluid injected precedes the point of the needle, the pleura recedes before it. Moreover, according to what we have already said above, it is only necessary to penetrate the stratum of the external intercostal muscle, as the nerves lie in the space between the two muscular strata.

We have often attained a sufficient anæsthesia for resection of the rib in a somewhat simpler way, by ½ per cent. injection of novocain with adrenalin. The nerve trunk is sprayed in the region of the costal angle in the middle of the intercostal space, and then in the axillary line, the branches near the lower and upper margin

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[1] HIRSCHEL, *Münch. med. Wochenschr.*, No. 10, 1911.

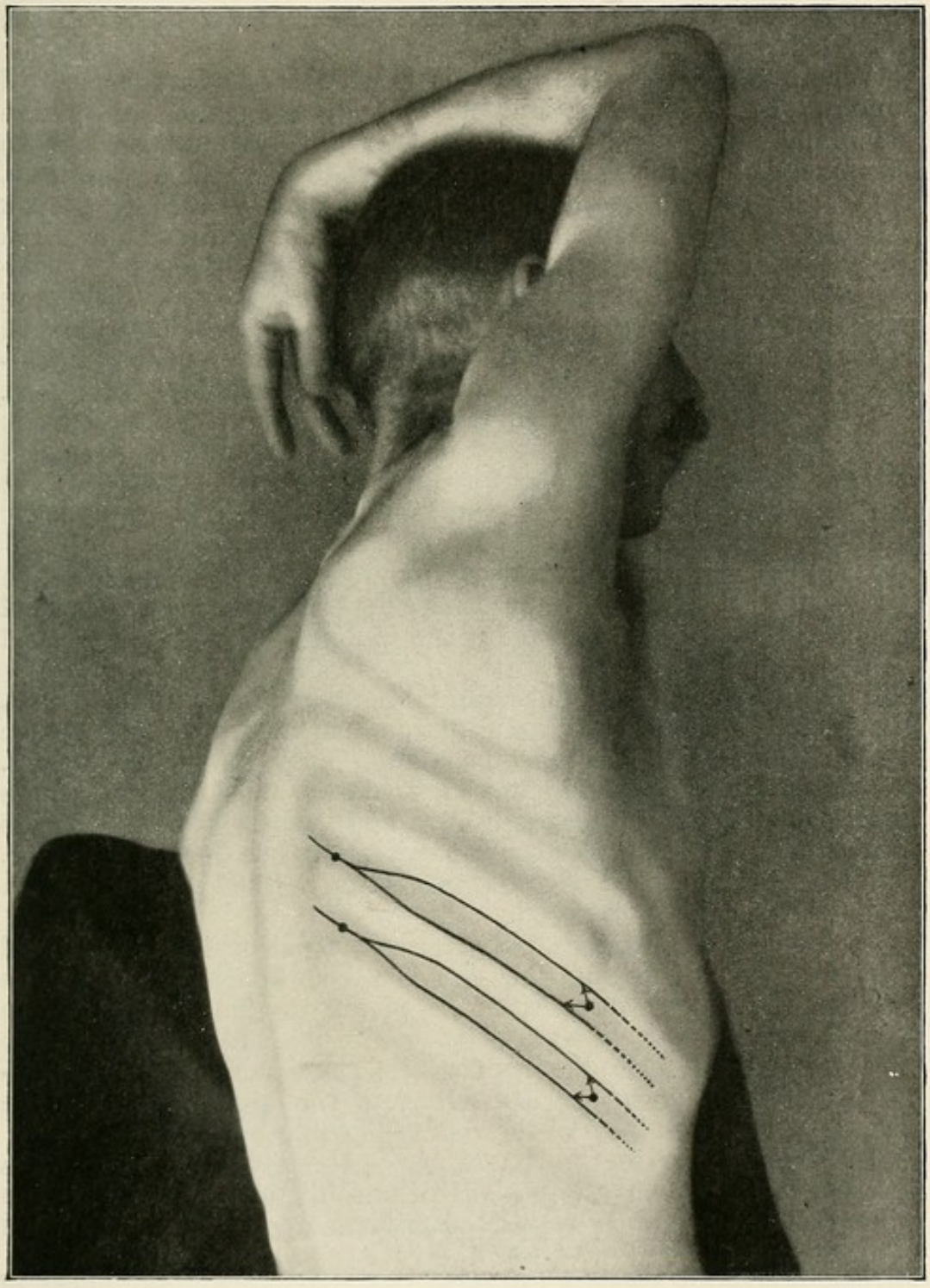


FIG. 30.—Ramification and position of two intercostal nerves projected on the skin. Points of puncture for the injection.

of the rib are sought out with the needle as shown[1] in fig. 30. For the resection of one rib two intercostal spaces, and for several ribs a correspondingly increased number must be anæsthetized. Finally, the soft parts bordering the region of the operation are infiltrated.

When a general anæsthesia is applicable, as in the case of tumours, hydatids, operations for fistula, extractions of foreign bodies and injuries, chloroform or the BILLROTH mixture is to be recommended in the first instance, although I would not hesitate, in the case of patients suffering from cardiac defects or a weak heart, to use ether as an anæsthetic with due precaution; and when apparatus for maintaining increased pressure are used, and especially in the case of insufflation, ether is generally used. We have good results by giving patients half an hour before the operation an injection of morphia (0·01 to 0·015). Scopolamin or scopolamin-morphia should not be used, on account of obstructed expectoration.

General is undoubtedly to be preferred to local anæsthesia in cases of exploratory thoracotomy, when the lung must be examined and the danger of reflex shock from the pleura is very great. It also makes it easier to fix the lung and to adjust the pulmonary suture, because there is no compressed breathing.

For the accurate localization of the diseased focus and when an operation is planned to be performed at two different times, local anæsthesia is to be preferred; the pulmonary tissue is almost without feeling.

When apparatus for maintaining difference of pressure are used, the apparatus should be carefully examined in every detail before use, and the anæsthetist must be thoroughly familiar with its use. The pulse must be watched, special attention must be paid to the appearance of the "vagus-pulse." The pleura should not be opened before a state of absolute toleration has been arrived at. Vomiting rarely occurs; with the intubation method it is impossible as the glottis cannot be closed.

In the case of abscesses and gangrenous foci, which have spread into the bronchi, during the narcosis and operation, as far as possible, the patient should not be placed on the sound side, to avoid the risk of secretion passing into the healthy bronchi and the infection of the healthy lung. The best position for this is a half-inclined sitting posture. DEPAGE lets the patient lie on the abdomen, mainly in view of the risk of pneumothorax.

In thoracotomy in the dorsal parts, the operation is made a little easier by placing the patient in an oblique position with the injured shoulder slightly supported and the operating table placed as high as possible.

The following may be remarked on the general technique of thoracotomy and intrathoracal operations:—

Thoracotomy.—The localization of the pulmonary focus and its

[1] The method practised in the Zurich Clinic, in principle corresponding to this procedure, has recently been described by SCHUMACHER, in the *Centralbl. f. Chir.*, No. 8, 1912.

diffusion, the tumour, the hydatids or the foreign body, the injury, &c., is the condition which decides the site of operation—the site cannot be chosen.

An ample incision should be made in the soft parts, so as to allow for the resection of two or more ribs, either parallel to the ribs, or in the shape of a flattened curve, or as flap amputation.

The simple intercostal incision (fig. 31) is sufficient for many operations or for exploratory thoracotomy, but it must be very long. The ribs can be forced apart with a tenaculum or rib-retractor (MIKULICZ-SAUERBRUCH model given in fig. 55, or the

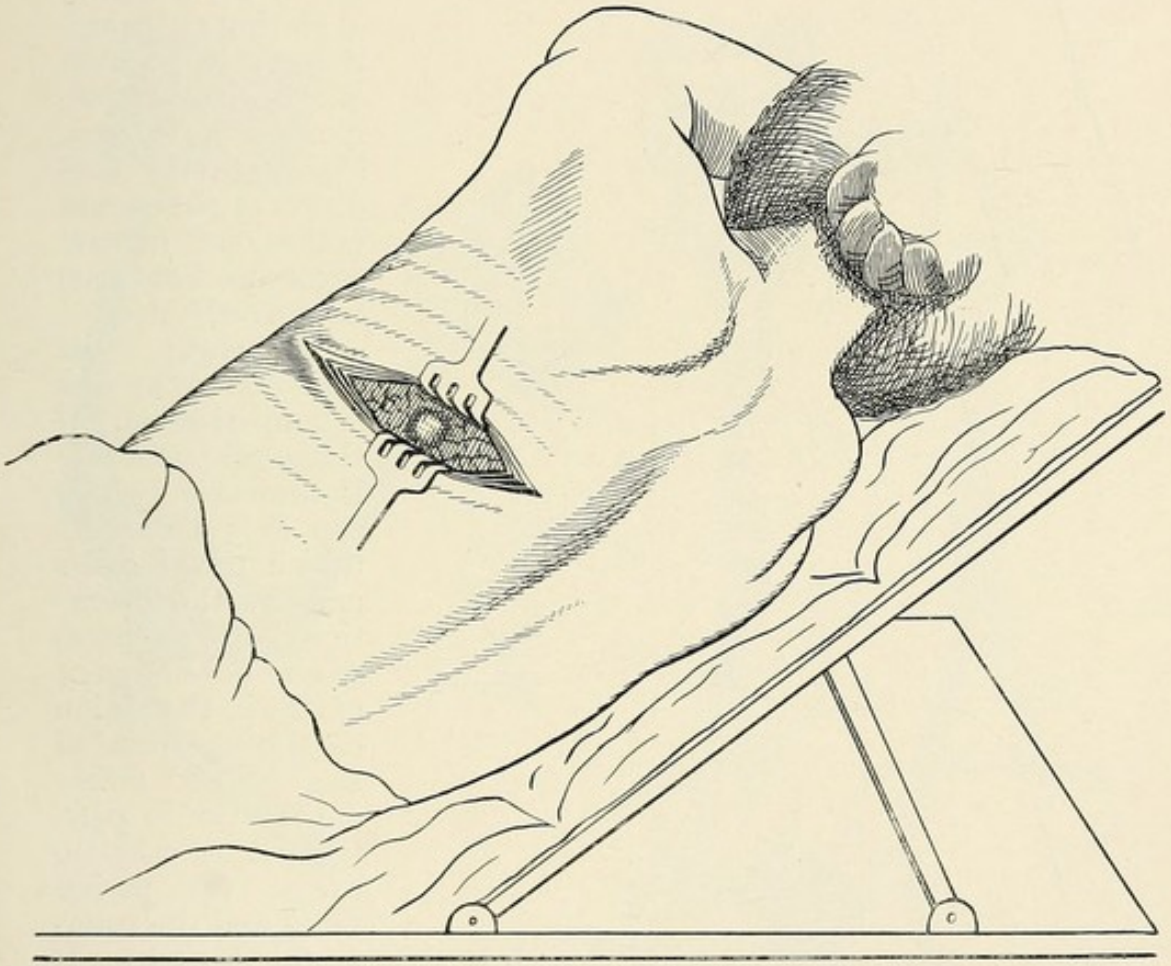


FIG. 31.—Intercostal incision for the denudation of a pulmonary focus.

DE QUERVAIN'S improved instrument, fig. 33). In France the flap-incision with the ribs folded back seems to be preferred, as described by DELORME in his decortication of the lung (*cf.* figs. 32 and 36).

For a focus in the upper lobe and the apex of the lung, the removal of the 2nd, or the 2nd and 3rd ribs, gives plenty of room in front; the lower and middle lobe can be easily approached by removing from two to three finger-lengths of the lateral or posterior parts of the ribs, best of the 8th, 7th, and 6th rib.

I consider it better not to resect at once a large portion of the ribs, but only sufficient for the examination of the pleura and lung.

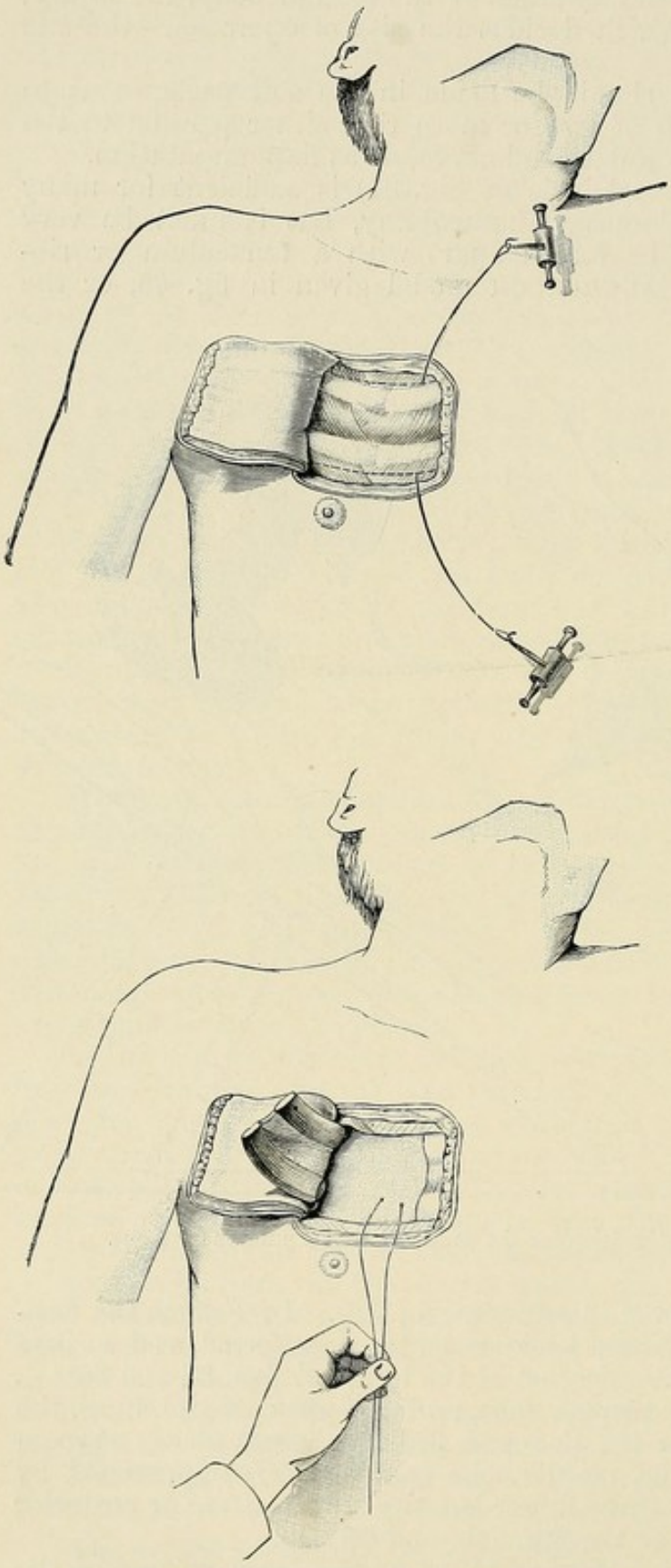


FIG. 32.—Temporary resection of the thoracic wall according to DELORME with the lung fixed.

The further resection of the thorax which is almost always necessary is determined as to its extent entirely by the nature of the focus; it can therefore only be performed, when, by probing, exploring or inspection, the position of the diseased pulmonary parts, and, above all, the condition of the pleura (adhesions, indurations, perforations) is perfectly clear.

Generally the resection of the ribs is subperiosteal. If the conditions make it desirable (which can only be ascertained towards the end of the operation) to suppress the re-development of ribs in the region of the aperture of the thorax either entirely or in part, then it is easy to excise the periosteum and the intercostal muscles, if necessary, in addition.

Starting from an incision parallel to the ribs by pushing up the soft parts and lengthening the incision in proportion, one can easily resect four and more ribs. Vertical incisions are also used with

advantage, especially in cases in which the lowest point of the necessary resection cannot be fixed beforehand. Each of the incisions mentioned can, if necessary, be developed into an L, a T, or an H incision, which is, however, only required in the rarest cases.

There are difficulties in the removal of the three uppermost ribs. It is possible to approach from the front; but in the case of the first rib special caution must be exercised; after lifting up the periosteum, you pull up the costal cartilage and bone cautiously, bit by bit, with LUER's gouge forceps. From behind the approach is much more difficult, owing to the shoulder blade and the strong

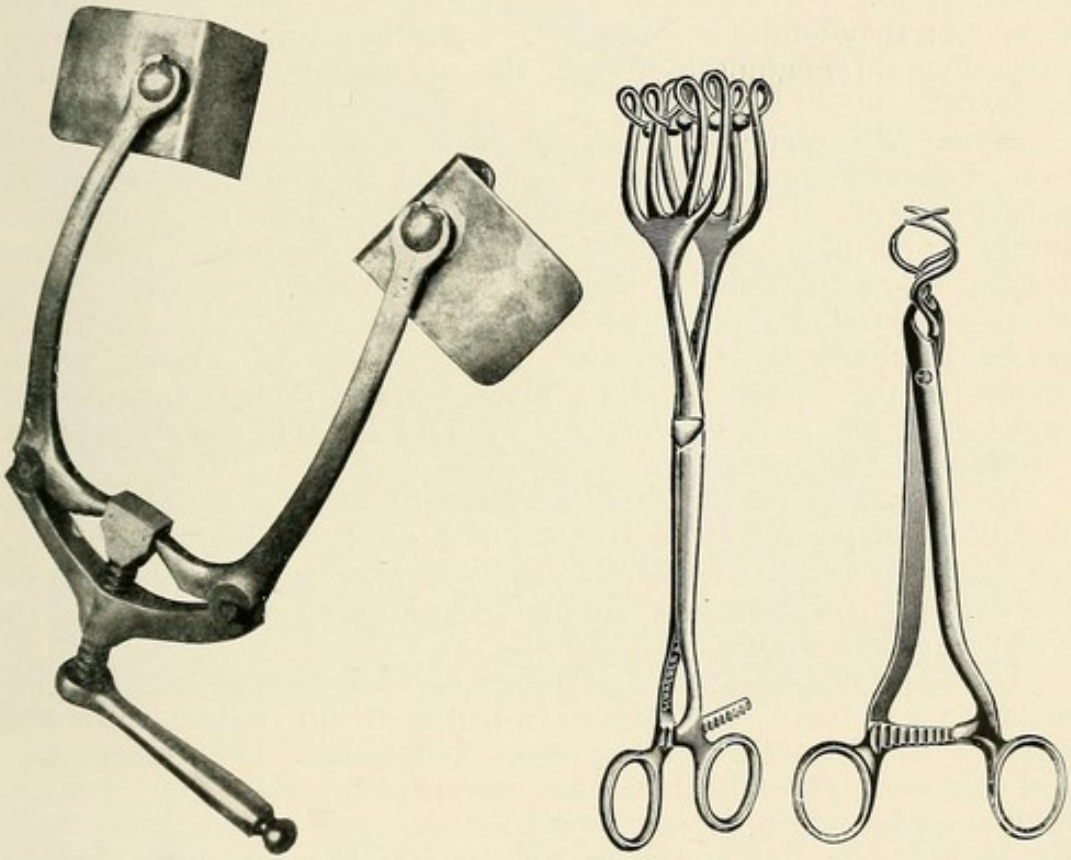


FIG. 33. FIG. 34. FIG. 35.

Fig. 33.—Rib retractor (according to DE QUERVAIN).
Fig. 34.—Lung fixation forceps (according to FREIDRICH).
Fig. 35.—Forceps for the hilum (according to FREIDRICH).

muscular apparatus. The incision is made parallel to the muscular fibres of the trapezius, and entails the blunt severance of the low-lying muscles.

The removal of the ribs and rib cartilage in the heart region should, if possible, be avoided, because by the adhesion of the heart to the thoracic wall painful throbbing scars, and not infrequently cardiac disturbances, are caused.

A temporary resection of the thoracic wall with an H-shaped flap with external base is only indicated in cases of hydatids, tumours, injuries, and foreign bodies in the lung: whereas in all

cases of inflammatory processes the solid thoracic wall must be removed.

After resection of the ribs, the freely moving parts of the lung can generally be recognized. When there is any doubt—open the pleura by a puncture with a narrow scalpel (an aperture 3 mm. wide is sufficient), and probe in the different directions.

When it is a question of intrapulmonary, suppurating, infectious processes (abscess, gangrene, bronchiectasis, suppurating hydatids), then the main consideration in the technique adopted must be the protection of the open pleura from infection; for suppurating pleurisy, or even saneous empyema, is a very serious complication. Firm pleural adhesions are the best protection of a wound; they admit at once of penetration into the pulmonary parenchyma (pneumotomy), and the opening up of the inflamed focus.

When the pleura is free, or when the pleurotomy extends beyond the bounds of the adhesions, the rest of the pleural cavity must be protected in any case. This is best done by continuous suture, or by plugging combined with suture. In cases which are not urgent, and when the fixation suture is not used, the closing of the pleural membranes by adhesion may be achieved by artificial means (zinc chloride, iodine, nitrate of silver), which permits of the operation taking place without danger four to ten days later. This will be discussed in more detail in the chapter on "Pulmonary Suppuration."

In operations on the lung we have to reckon almost without exception on partial or total pneumothorax; we must, therefore, ask ourselves how best we can deal with it. (See "Discussion of the Pathology of Pneumothorax and the Method of Maintaining a Difference of Pressure.").

Under all circumstances a sudden opening of the pleural cavity must be avoided. The sudden collapse of the lung is followed directly by threatening symptoms of dyspnœa, heart weakness, and collapse. Should this happen unexpectedly, then the retracted lung must be seized at once with forceps, and pulled firmly into the wound. By this means, as I showed at the beginning, by the fixation of the mediastinum, a sufficient ventilation of the lung is rendered possible—the dyspnœa at once disappears, the pulse becomes stronger and slower. Or else turn the patient at once on to the side operated on, and firmly compress the thorax, so as to reduce the pneumothorax (Macewen).

When operating without an apparatus for maintaining difference of pressure, the opening of the pleural cavity must be performed slowly and cautiously, then the lung is made secure by a strong suture, which takes up 1 to 2 cm. of the pulmonary parenchyma, and fixes it to the corresponding place on the chest-wall.

If difference of pressure is maintained, this is only introduced before the pleura is opened, and then only, as Sauerbruch recommends, under half pressure (5 mm. mercury). After the incision in the pleura, some air penetrates, but only sufficient for

the lung to retract slightly. This makes the pleurotomy, or the possibly necessary resection of the ribs easier without disquieting disturbances of the breathing. At the same time the lung can be more easily examined when slightly retracted.

In intercostal incisions broad, blunt tenaculi, or rib retractors, are inserted, and the ribs are pressed as far apart as possible, so as to obtain a sufficient survey of the field of operation—at least far enough to allow of the hand being admitted to the pleural cavity. The intrapulmonary pressure is now raised to 7 to 9 mm. mercury, as, according to SAUERBRUCH, in this inflated condition of the

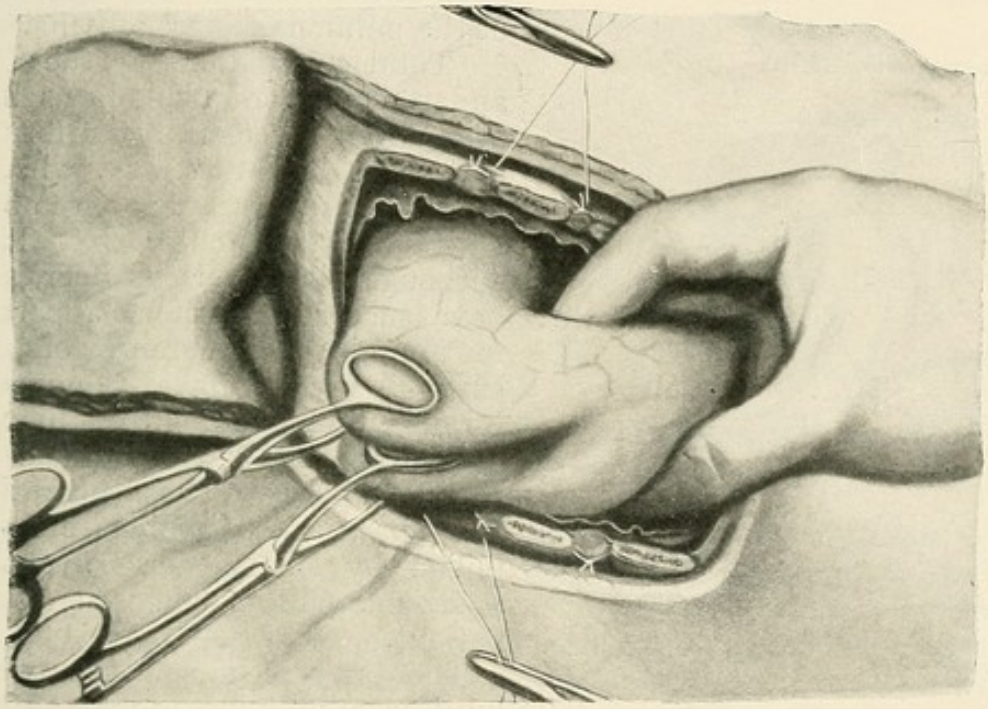


FIG. 36.—Fixation of the lung and investigation thereof (PICOT)

lung, the best and most rapid investigation as to the localization of the morbid changes is possible. In this way the lung can easily be examined, and the focus of disease sought out in the thoracic cavity itself, or at the costal aperture.

Here we must also remember the decortication of the lung according to DELORME—a method of operation recommended in chronic empyema, but which can also be advantageously used, under certain conditions, in operations on the lung, in order to lay bare the actual site of operation. If the pulmonary affection, which indicates the necessity for an operation, is complicated with chronic empyema, and if the lung is wholly or partially encased with a solid cortex of connective tissue, then you will cautiously attempt a "decortication," not so much, as DELORME says, to bring about the development of the lung as to make it easier to locate the pulmonary foci. An incision is carefully made in the thickened visceral pleura till the smooth surface of the lung appears; then

the necessary stripping is made from here with the probe, the scissors, or the finger. Decortication is not always possible, nor can it be performed, from every point.

In operations for the occlusion of pulmonary fistulæ (see Chapter VII) the pleural indurations after partial stripping may be advantageously used as plastic covering of the defect.

Now follows the operation on the lung itself, which naturally varies according to the disease, its extent and localization. These special points will be dealt with in separate chapters. Here I will only deal with the extirpation and resection of the lung with maintenance of the bronchi and the suture of the pulmonary parenchyma.

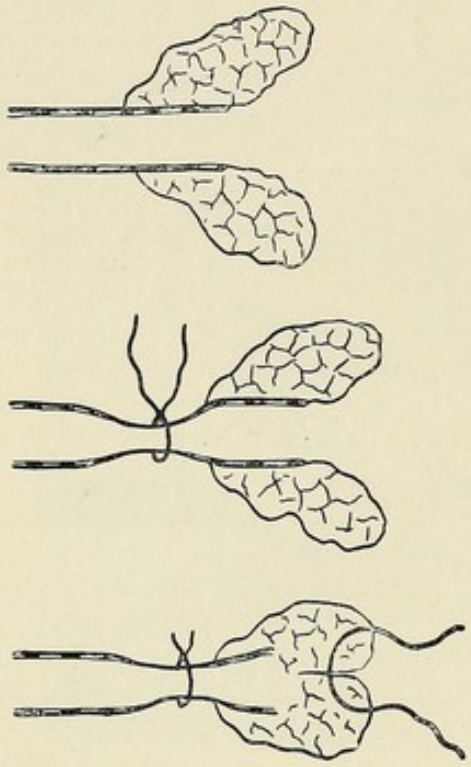


FIG. 37.—Bronchial suture. Closure of the bronchi (according to TIEGEL).

Total extirpations of the lung and resections of whole lobes have often been successfully performed, above all by MACEWEN, who, as long as sixteen years ago, removed entirely a tubercular left lung. Although these serious operations have succeeded without apparatus for maintaining differences of pressure—I myself have removed a lower pulmonary lobe in this way—it would be narrowminded not to recognize that these operations have been in many respects simplified by this modern invention, and rendered less dangerous to the patient.

The extirpation of the whole lung or of individual lobes, as may be necessary in the case of tumours, bronchiectasis, tuberculosis, takes place from the hilum. The lobe is set free from its surroundings, and its adhesions, and indurations, if such exist, must be carefully stripped off, and by pulling and drawing forward it must be provided with a pedicle. Then the hilum blood-vessels must be tied up and separated, and finally the bronchus, too, must be isolated, so that it may be possible to fasten the suture securely.

On the occasion of the extirpation of a lung on account of carcinoma, KÜMMELL convinced himself that the lung in a state of imperfect expansion was easy to separate from the hilum. He therefore proposes to maintain artificial pneumothorax for a little time before the operation. SAUERBRUCH also hopes to attain the same end by the ligature of the pulmonary artery, for in a short time the pulmonary lobe in question shrinks quite perceptibly.

The greatest importance must be attached to the closure of the bronchus. If air gets out tension pneumothorax occurs as a disagreeable complication, and the secondary infection threatens to

become dangerous. I have successfully secured the bronchus freshened up from within, and then closed with a suture by sewing over the pulmonary tissue. A constricting ligature added proximally protects the suture from the intruding current of air (TIEGEL, FRIEDRICH). The thread must not be fastened directly or very tightly on the bronchus on account of the risk of necrosis of the cartilage.

WILLY MEYER recommends another method, which has now been proved satisfactory by experiment. After separation of the ligatured blood-vessels he compresses several centimetres of the bronchus with a broad clamp, binds up the tube, which is now quite pliable, and separates it. Now the stump can be easily invaginated, and the bronchus united over it by suture.

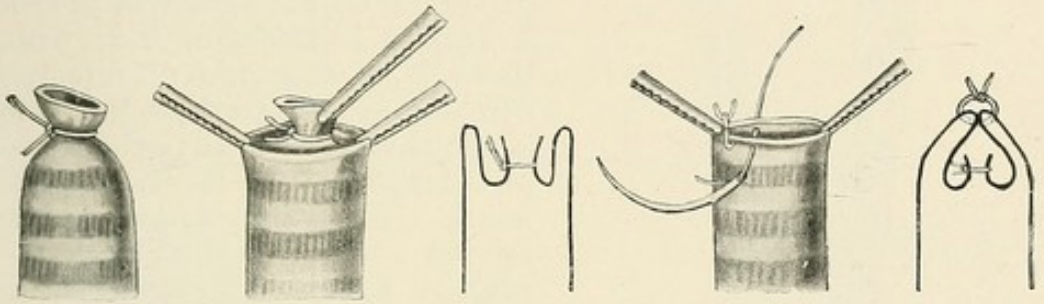


FIG. 38.—W. MEYER'S suture of the bronchus (according to a drawing by SCHUMACHER).

Great care, as already remarked, must be taken of the principal bronchus. It has often happened that, not being closed so as to be air-proof, it has slipped back into the mediastinum and has caused fatal mediastinal emphysema. Peribronchial progressive emphysema has even been observed on the other side. When the mediastinal pleura is thickened by inflammatory deposits the risk of emphysema is sensibly diminished.

The best protection is to suture over it pulmonary tissue, which, for plastic purposes, is left *in situ*. GUNDERMANN[1] has described portions of the adjacent lobes of the lung healed according to this principle as "counter-healing."

The resection of a large portion of the lung can generally be performed bloodlessly. The blood-vessels of the hilum can be temporarily compressed (forceps, fig. 35), or, if it is a question of the marginal parts, the lung can be compressed (fig. 39) with wide, soft-springed clamps (fig. 39). Then all vessels and the fine bronchi in the incision made with the scissors are tied up with the finest silk. Then follows the suture, for which I prefer fine silk. Experiments have shown me that the pulmonary tissue pressed together between the sutures remains imperfectly expanded (TALKE); therefore it is advisable to make the stitches not too far from the margin of the wound and to push the needle as far as

[1] *Beitr. z. klin. Chir.*, vol. lxxiii.

possible to the bottom of the wound (fig. 40). The sutures must not be drawn too tightly. They generally heal up without reaction. A superficial pleural suture may be added with advantage. The invagination of the pleura has proved useful, as well as TIEGEL'S suture, with supporting threads lengthwise to the wound (see fig. 41).

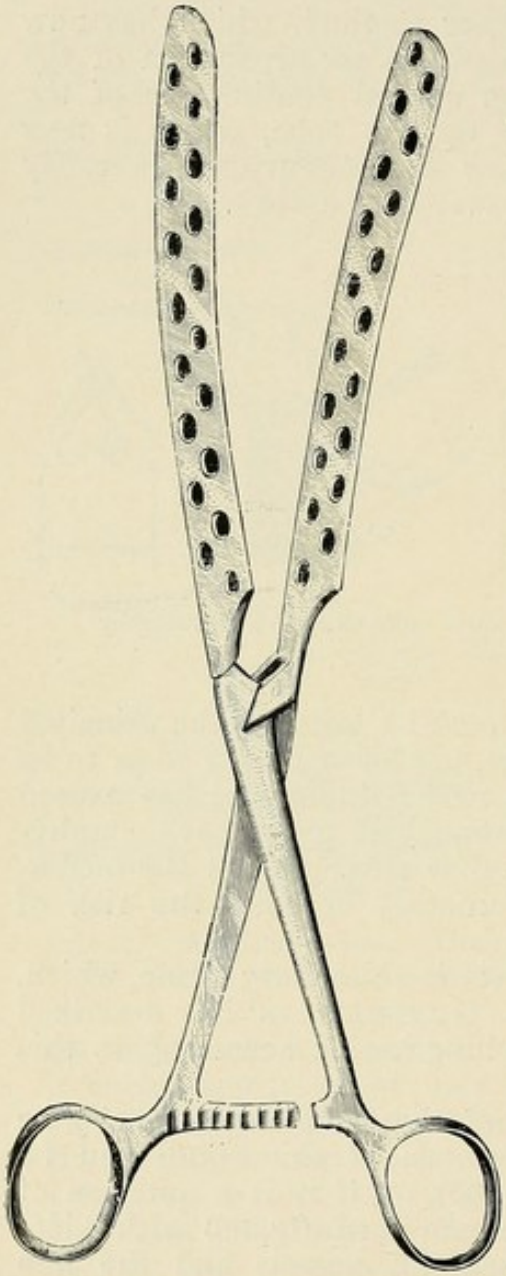


FIG. 39.— Forceps for compression of the lung (according to SCHUMACHER).

After aseptic operations of short duration the thoracic cavity, after the pneumothorax has been removed, is completely closed. It is true that almost always a secondary pleuritic exudation takes place, but this is generally reabsorbed in a short time. Drainage of the pleural cavity is imperative in cases known to be infected, or in which there is a suspicion of infection. Also, when the arrest of the blood is incomplete it is advisable to put in a drainage-tube for twenty-four hours. When the pleura has been injured traumatically during a lengthy operation and by the influence of the atmospheric air, then it reacts with a profuse discharge.

Then a primary drain must be very cautiously inserted, because, under such circumstances, a very slight accidental infection may develop into empyema. If, on the contrary, the pleura is kept dry, it very quickly coalesces; if the worst comes to the worst, then you have only to deal with an encysted suppurating focus.

The drainage-tube must be fitted with a valve so that the fluid may pass out, but no air flow in. This can be done (fig. 42) by Perthe's suction drainage, or, according to THIERSCH, by an open thin rubber finger-stall fastened to the mouth of the rubber drain.

TIEGEL, on the suggestion of HENLE, put together a pliable metal drainage-tube which could be screwed up, and which was closed by a rubber membrane (see fig. 43). A thin rubber membrane is fastened to the plate with four screws; it is raised on expiration, and lets the exudate and air escape, but is sucked in on inspiration on to the aperture. A wire net placed over it prevents the dressing from adhering.

Also in the case of pneumothorax with tension, which does not yield to a puncture, and of progressive cutaneous emphysema (starting from the lung), valvular drainage may be of use.

WILLY MEYER drains like DELANGIÈRE in the 9th or 10th intercostal space in the line of the scapula and completely closes the original wound in the case of thoracotomy. He prefers as drain the cigarette drain with a central rubber drain and beside it two drains with longitudinal bifurcation. He leaves his patients

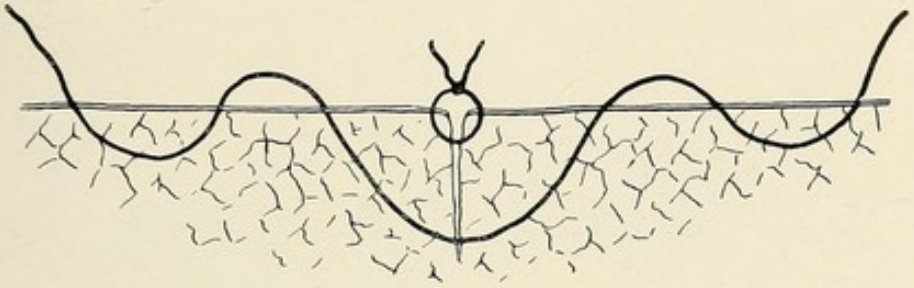


FIG. 40.—Pulmonary suture according to GARRÈ and TALKE.

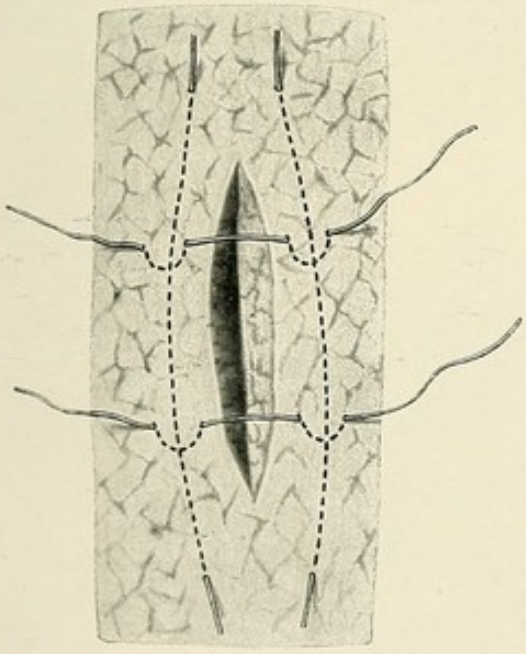


FIG. 41.

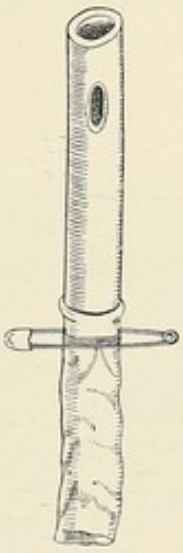
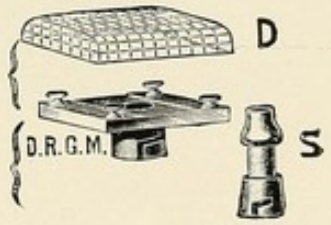


FIG. 42.



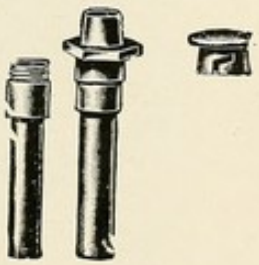


FIG. 43.

Fig. 41.—TIEGEL's pulmonary suture with supporting thread of magnesium wire.
Fig. 42.—Drainage tube with valve (according to THIERSCH).
Fig. 43.—Drainage tube with valve by TIEGEL.

twelve to fifteen hours after the operation in the increased pressure cabinet and for half an hour administers artificial respiration. After this period the surrounding pleura must be made to adhere.

It is also possible to make an air-proof drainage of the pleura by inserting a tampon which traverses the chest-wall in an oblique channel (KÜTTNER). Retention, however, may easily take place. SAUERBRUCH expresses himself as satisfied with the tamponade. He adjusts the dressing under difference of pressure so that it is

air-proof, paints the proximity of the wound with zinc paste, covers the wound itself with a little sterilized gauze and places over the whole a large piece of rubber and fastens it with ligatures. The dressing is changed under the maintenance of difference of pressure.

The closing of the wound caused by thoracotomy is done by careful sutures one above the other. You may have made a costo-

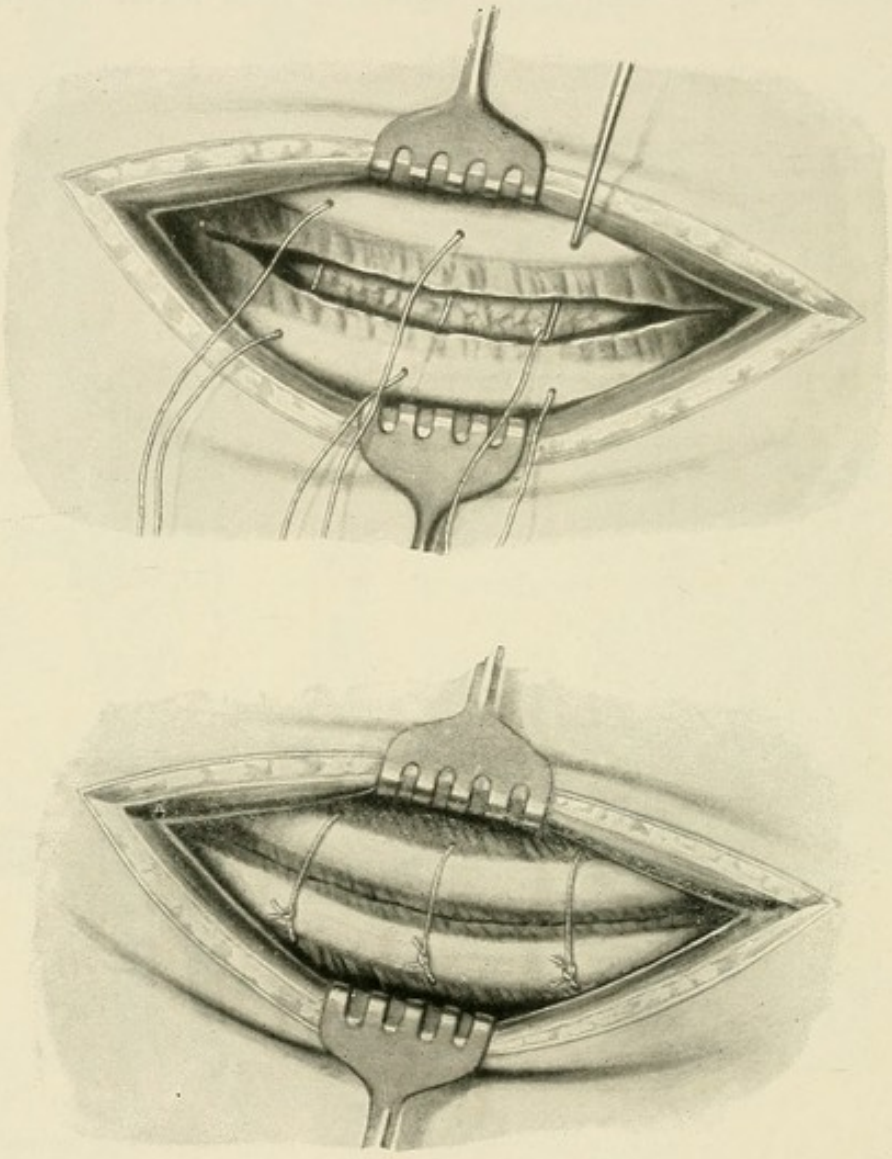


FIG. 44.—Percostal and pericostal suture (from SAUERBRUCH and SHUMACHER's "Technique of the Surgery of the Thorax").

muscular flap, or resected ribs still, when the wound in the lung has not itself to be plugged, closing up the pleura with the divided intercostal muscles by themselves and therefore specially carefully, the skin is always joined together by the suture.

When an intercostal incision is made, the parted ribs are easily and quickly united by pericostal or percostal sutures (see fig. 44.)

Before closing the last suture of the pleura we must be careful

that there is absolutely no pneumothorax, by distending the lung powerfully with the apparatus or get rid of the air according to MACEWEN by compression and turning the patient over, or, as I recommended before, fasten the last thread at the moment of a forced expiration. If pneumothorax is present it increases the risk of infection, therefore its removal is important.

In the case of a patient under anæsthesia, the lung should be slightly distended with the aid of an oxygen cylinder before the closing of the suture, as ROCKEY has done. The tube with the oxygen, to which a rubber bag was adjusted for the regulation of the pressure, was placed directly in the nostril and the other nostril was closed with the finger.

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CHAPTER V.

INJURIES OF THE LUNG.

We must distinguish between subcutaneous and penetrating injuries of the lung.

Subcutaneous injuries of the lung generally follow on oblique fractures of the ribs or splintered fractures, when a sharp fragment pierces the visceral pleura, which is most likely to happen in cases of pleural synechia. As any considerable hæmorrhage seldom occurs here and emphysema in the subpleural or subcutaneous cellular tissue never attains any great size, spontaneous healing generally takes place.

In the case of ruptures of the lung the conditions are different, these are generally caused by a heavy weight suddenly coming into contact with the thorax, as when anyone is run over, by compression and by a fall from a considerable height and similar accidents. The suddenness of the blow with reflex closure of the glottis, or also with simultaneous compression of the trachea, or the impact of the blow simultaneously with deep inspiration causes a rupture of the lung. The way this happens is easily understood and has, moreover, been explained experimentally.

In young people, with elastic thorax, large ruptures of the lung may occur without the fracture of a single rib, as in the case of a boy of 11, in whom I saw a rupture 7 cm. in length across the whole upper lobe, after he had been run over by a waggon, without any injury of the ribs (Diss. Richter). The rupture of the lung is not necessarily on the site of the impact, it may take place at any point whatever.

The visceral pleura is generally injured, also the pulmonary tissue more or less deep down. The rents are 4 to 10 cm. long, the latter traversing whole lobes. Under certain circumstances there is only a central rupture of the parenchyma, then a cavity is formed filled with blood, which may later give rise to the formation of gangrene and cavities. Such central ruptures are also caused by a sudden fall. Rössle has described such ruptures in a lung with pneumonic infiltration and in a sound lung (inferior lobe).

Smaller rents in the substance of the lung, bursting of single pulmonary cells or smaller blood-vessels are not infrequently the consequence of mere contusion of the thorax, violent exertion, vomiting, coughing, &c. They cause dyspnœa, hæmoptysis, sub-

cutaneous or subpleural emphysema, &c., and in one single case (WEIKARD) made a surgical operation urgently necessary.

The symptoms of a rupture of the lung—essentially the same as the signs of hæmothorax, pneumothorax and hæmoptysis, &c., are practically covered by those of open injuries to the lung; so I do not need to describe them in detail. The treatment, too, does not need to be described separately.

Concussion and compression of the thorax, caused by something blunt, may (under certain conditions) prove fatal without any tangible cause of death being discovered at the autopsy. It is the "commotio thoracica," when the victim falls down with a deep inspiration; the pulse is feeble, scarcely perceptible, becomes slower and intermittent, the skin pale and cool, the injured man is unconscious and lies in a state of the most severe shock. Many soon recover, the physician searches in vain for any trace of the injury. Many die, without having recovered consciousness. The disease is explained by a direct irritation of the vagus and in the depressor effect on the region of the sympathicus (deep depression of the pressure of the blood, anæmia of the brain).[1]

It should be treated by placing the patient in a horizontal position, with the head low down and the administration of a good dose of morphia.

The lung may be penetrated by cutting or piercing instruments of all kinds (knives, awls, foils, bayonets, &c.), and also by bullets. In working with machinery far-reaching traumæ of the thorax are caused by the explosion of steam boilers, the breaking-off of fragments of iron, &c.; finally, injuries caused by being impaled must be mentioned (being impaled on iron railings, branches, &c.).

CROUSE, for instance, treated an engineer, whose chest had been completely pierced by a pale, two inches thick, entering from the front it projected from the back. The patient recovered, except for a pulmonary fistula.

If the stab or shot traverses the whole lung and the opposite wall of the thorax, it is called a perforation of the lung. The injuries caused by a shot are generally of better prognosis than those caused by a stab, especially when the latter dealt with great force penetrates deep into the lung.

Injuries due to shots in time of peace, generally produced by revolvers or pistols, count among the less dangerous wounds owing to the small calibre of the projectile (7 to 9 mm.) and the relatively slight percussion. The bullet generally remains in the lung or in the opposite wall of the thorax, you then get a wound where the shot entered and where it left the surface of the lung or several such wounds if two lobes are injured. Both lungs are rarely shot through. The wound caused by the shot piercing the lung is characterized by a livid, bloodshot spot about the size of a nail, in the middle of which is a roundish, bleeding wound, or one covered with coagulum, with irregular margins.

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[1] *Cf.* the experimental work of CAPPS and LEWIS, *Amer. Journ. of Med. Sciences*, 1907.

The bullet may carry along with it splinters of bone, fragments of cloth and other foreign bodies; then the point of entry is larger and often becomes an irregular gaping rent. Infiltrated pulmonary parts or parts with pleural adhesions are sometimes torn to pieces and shreds by a shot.

Shots through the lung are most frequent occurrences in war; penetration of the lung by stabbing is much less frequent. Thus in the Franco-German War, 2,156 wounds in the chest from shots were treated and only 11 from stabs. The rate of mortality was 53·4 per cent., not including the numerous complications arising from simultaneous injuries of the large blood-vessels, for instance. With the introduction of the small calibre coated cartridge, the prognosis of shots in the lung has very much improved, as the experience of modern army surgeons proves.

The course of the bullet is straight, generally perforating the thorax; with a round wound where it enters and a slit-like aperture where it passes out. It seldom remains in the lung and seldom carries along with it foreign bodies such as buttons, bits of cloth and splinters of bone. In this way the secondary risks of empyema and suppuration of the lung are diminished. The rent made by the shot closes up extraordinarily easily, favoured by the surrounding pulmonary tissue being saturated by blood.

KÜTTNER,[1] whose experience I am following here, says that lung-shots can only result in death on the battlefield when the shot comes into contact with large blood-vessels, or when extensive disturbances of the pulmonary tissue are caused by bruising and by dislodged splinters of bone, perhaps also by shots through the large bronchi. About a quarter of all cases of penetration of the lung die at once from shock, or hæmorrhage. A relatively small number succumb later as the result of infection.

Coated cartridges produce narrow, smooth shot-wounds, if they do not come in contact with any bone. The pulmonary tissue closes up at once, the hæmorrhage is often slight, and there is not even any pneumothorax, unless the air is violently drawn out of the wound by coughing. Many wounded men do not fall, they may even be able to take part in the battle for a long time, or walk many kilometres. But when larger blood vessels are injured, dyspnœa and cyanosis are almost always present, caused by extensive hæmothorax or hæmorrhagic infiltration of the lung. This happens in a third of the cases. The hæmoptysis, noticed in half the cases, begins immediately after the injury and may last as long as fourteen days.

The hæmothorax generally ceases in the first few days and is then slowly re-absorbed. Prolonged and difficult transport of the wounded man may lead to renewed intrathoracic hæmorrhage: KÜTTNER has even seen secondary hæmorrhage set in with fatal results thirty-two days after the wound was made, therefore the greatest care is needed in cases of lung-shots for four to five weeks.

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[1] KÜTTNER, *Beitr. z. klin. Chir.* Vol. xxvii, 1900; cf., also SENN. *Jour. of the Amer. Med. Assoc.*, July, 1898; MACCORMAC, *Lancet*, 1900.

The worst are those cases in which hæmorrhage goes on for days and weeks, in spite of absolute rest, ice packing and the application of the usual internal remedies. Up to the present these cases have almost all proved fatal, because at first one hesitated to use energetic surgical measures to arrest the hæmorrhage and later the patient was in too exhausted a condition to permit of such an operation.

Empyema rarely occurs in lung-shots with the small calibre coated cartridges.

Experienced army surgeons, such as MacCormac, Senn, Küttner and others, also recommend for these an absolutely conservative treatment of such shot wounds in the lung.

Injuries of the lung caused by artillery shots are quite different. According to Schjerning shrapnel shots make wounds big enough to hold one or two fingers. Fragments of shells make larger irregular wounds, generally with extensive injuries to the ribs and chest wall. Many of such wounded men succumb to shock, but some have been reported as cured. In contradistinction to the shot-wounds with hand guns of small calibre, wounds due to artillery shot often lead to empyema and pulmonary suppurations, lasting for a long time and generally deadly, caused by large splinters or other foreign bodies.

When the question of the extraction of a bullet is under consideration, attention may here be drawn to a very cleverly constructed extractor by Peugniez (Amiens), which constructed for projectiles in the brain may very well be used for bullets in the lung. The probe in connection with a fixation forceps in three parts is put in connection with a telephone with dry cell (Manufacturer: Gentile, Paris; Description, see French Surgical Congress, 1910, p. 1126).

SYMPTOMS AND COMPLICATIONS.

The main features of a severe injury of the lung are collapse of the lung, loss of blood and possibly emphysema and secondary suppuration. First a condition of shock, lasting one to four hours, followed, according to the amount of blood lost, by repeated faints, pallor, rapid superficial breathing, dyspnœa, irritating cough, and under certain circumstances immediate hæmoptysis, increased heart beat, weak pulse, complaints of acute pains in the chest and back, frequently also in the epigastrium (diaphragm); this last symptom must not lead you to the conclusion that there is necessarily a simultaneous injury to the diaphragm.

The lung is compressed more or less by traumatic hæmothorax or a hæmo-pneumothorax. Blood and air generally flow through the injured lung into the pleural cavity, seldom through suction from without. But in any case it must not be forgotten that when there is an isolated injury of the pleura, air may be aspired through an oblique wound, which cannot escape again on expiration (valve closure) and that also a hæmothorax endangering life may be the result of an injury of the internal mammary artery, or of an intercostal artery. The question, whether the blood or the air flows

from the lung, or whether the wound in the chest-wall is the cause of the hæmorrhage or inrush of air, is important from a therapeutic point of view. The site of the injury (proximity of the internal mammary, intercostal) is an important indication. Extravasation of frothy blood indicates a probable injury of the lung. Where doubt exists the opening up of the wound by an incision will disclose the origin of the hæmorrhage, which may of course be from without. Highly developed pneumothorax and its increase after the pleural opening has been closed, points to a lesion of the lung as its cause. For the diagnosis of injuries penetrating the lung, moreover, the nature of the instrument as well as its direction and the force with which it penetrated, are of importance. The position of the wounded person too, the way the arms were held, is to be taken into consideration in deciding the course taken by the object driven in. In many cases the right diagnosis was indicated by the evidence of elastic fibres, fragments of cloth, coloured leucocytes in the sputum.

A penetrating isolated pleural injury need not always cause air to flow into the pleural space. When there are pleural adhesions pneumothorax is not present, also when the perforations of the thoracic wall are oblique and narrow. The opening in the thoracic wall may after the inrush of a certain quantity of air, disappear or remain, so that the patient comes to be treated with still open pneumothorax. The symptoms vary in intensity according to the size of the perforation. The suppressed conditions have already been discussed in dealing with the pathology of pneumothorax.

In ruptures of the lung, as in the case of penetrating traumæ, the pneumothorax may by its intensity and violent tension become dangerous to life. By irritative coughing more air is continually driven out of the injured bronchial branches or aspired through a valvular closure on the pleural wound, the tension in the pleural cavity increases more and more, the mediastinum and the heart are forced over to the other side. Respiration increases in frequency, the dyspnœa and cyanosis increase and the pulse becomes feeble and irregular. This alarming aspect of the so-called tension pneumothorax must be instantly removed by puncture and aspiration, or better still by valvular drainage, in order to avert the further danger of emphysema.

The most reliable symptom of an injury to the lung is hæmoptysis; it may, indeed, be absent in the case of small injuries, but is easily overlooked when it is unimportant. The blood-stained sputum may continue as long as fourteen days. More abundant hæmorrhage leads to an irritation, exciting cough.

Emphysema, a common accompanying symptom of injuries to the thorax and lung, occurs specially when the air cannot escape outwards. As subcutaneous emphysema it spreads first of all to the axilla and may spread to the trunk and extremities. Even in a severe form it is rarely dangerous, as long as it does not spread from the neck to the mediastinum.

Mediastinal emphysema is dangerous, it generally accompanies ruptures of the lung and medial injuries to the lung from stabbing

or shooting, or injuries of the trachea and bronchi. Besides the usual symptom of severe dyspnœa, this condition is characterized by a feeble, rapid and irregular pulse, cyanosis of the face and great swelling of the veins of the neck consequent on impeded discharge in the region of the superior vena cava (compression and reduced respiratory suction of the venous blood). It often develops alarmingly quickly after the injury. It soon spreads up to the neck as crepitating cutaneous emphysema and spreads over the whole of the body.

A prolapse of the pulmonary tissue occasionally complicates larger wounds of the thorax caused by stabbing or shooting. A cough drives them into the wound, where they are incarcerated. Apart from the risk of secondary infection it is not a serious complication, for it prevents the complete collapse of the lung and tension-pneumothorax. Portions of one pulmonary margin always prolapse, the inferior lobe is, on account of its greater mobility, more often involved. The prolapsed portion of the lung, when recent, is easily recognizable by its appearance: characteristic is the change in magnitude on respiration, the result of palpitation. In perforations in the lower sections of the pleura, especially on the left side, if the prolapse is not quite recent, protrusion of omentum may be observed. The prolapse of the lung may gradually recede, or, on severe constriction at the base of the necrosis, disappear. In the latter case a fistula is formed.

The infection of the pulmonary wound is certainly the complication most to be dreaded. In subcutaneous injuries, owing to the surface infiltration of the bronchial mucous membrane, it occurs less frequently than in penetrating injuries, when germs are easily introduced into the thoracic cavity by the instrument which causes the injury or by foreign bodies carried along by it. Gashed, gaping wounds are much more unfavourable in this respect than a smooth narrow wound. On the other hand, wounds made with a knife are much more frequently infected than wounds from bullets. Astonishingly favourable is the course of lung shots with the small calibre coated cartridge of the modern infantry weapon. The narrow wounds are usually free from bacteria; they adhere *per primam*. During recent wars a large majority of men suffering from shots in the lung were fit for service after a few weeks and rejoined their company.

The pleural cavity filled with blood is the best medium possible for the culture of every kind of pathogenic organism; the signs of inflammation are often super-acute, the empyema becomes ichorous, the pulmonary wound is complicated with gangrene, the suppuration spreads over the mediastinum or the pericardium. Thus some of the patients die in a very short space of time with septic symptoms. Secondary suppuration also occurs after shot wounds (GRÄTZER).

Frequently the diaphragm is also injured in the case of penetrating wounds of the thorax—which must always be looked upon as a serious complication. In injuries from shots, more frequently than in those from stabs, the abdominal viscera are also affected; in this case death generally ensues rapidly. When the right side of

the diaphragm is injured the liver is almost without exception also involved, whereas, on the left, stomach and spleen may very well escape injury.

Small wounds in the diaphragm may very soon close up by adhesion of the neighbouring serous surfaces; that is specially the case in the complementary space of the pleura; then no symptoms appear. Through larger wounds the abdominal viscera (omentum, stomach, intestine) at once thrust themselves, and symptoms of constriction of the intestine may be associated with the signs of compression of the lung. By the abdominal pressure more of the intestine is forced continually into the pleural cavity, and the wound in the diaphragm becomes larger and larger. Tympanitic percussion-note, rippling sounds, violent vomiting, dyspnœa, intense pain, radiating from the region of the diaphragm to the shoulder, which increases on deep respiration, are clear signs of a wound in the diaphragm.

Under these circumstances a wound in the lung, complicated with injury to the diaphragm urgently demands an operation, and imperatively, when the contents of the intestine or stomach have penetrated the pleural cavity. The wound in the diaphragm must be sought out, and closed by the suture. Sometimes a long intercostal incision, low down, is sufficient—otherwise a bone flap in the soft parts must be made and bent back, so as to give further access.

If the heart or the large blood-vessels are also injured these, of course, take the first place in the treatment. The injury to the lung takes the second place.

TREATMENT.

The treatment of subcutaneous injuries to the lung (ruptures and piercing by fractured ribs) is, at first, in the main, expectant. By the application of ice and subcutaneous injection of morphia, the cough which causes the hæmorrhage, and the unrest caused by dyspnœa and anæmia are favourably affected. When dyspnœa is more severe owing to hæmothorax or pneumothorax an attempt at least should be made to relieve the pleural cavity by puncture. It must, however, be remembered when so doing that by the re-expansion of the lung a hæmorrhage, arrested by the pressure of the contents of the pleura, may burst forth again, therefore no more discharge should be allowed than the state at the moment demands. If pneumothorax rapidly supervenes again, pleurotomy with valvular drainage is indicated. This may also arrest a rapidly spreading cutaneous emphysema, if it does not succeed in recognizing the point in the pleura where the air enters by a fractured rib, and in closing it.

Thus Fritz König, in a case of severe traumatic emphysema, the presence of which was indicated by projecting subcutaneous air-tumours at the site of fracture, drew off air and blood, pulled down the lung and made a suture, and thus worked a cure.

If, after a subcutaneous injury of the lung, the symptoms of anæmia and suffocation still maintain their threatening character,

in spite of the more or less palliative measures taken, then the question of a more radical operation must be considered: the opening of the pleural cavity and the treatment of the pulmonary wound itself. Here also it is terribly difficult to decide whether and when to do this, as under similar circumstances, when it is a question of acute hæmorrhage, of more or less enfeebled patients and of a serious operation, when we can neither localize with certainty the source of the hæmorrhage, nor know whether by our technique we can master it, when finally even under the most unfavourable circumstances we have seen expectant treatment result in a cure.

Certainly the prospects of a cure in the case of ruptures of the lung are so unfavourable that we can take heart from this fact, and cease the expectant treatment in time and arrest the hæmorrhage by a suture of the lung. Out of thirty-seven ruptures of the lung twenty-three proved mortal (RICHTER). Out of six operations recently performed it is true that only two resulted in a cure, but in two cases the operation had nothing to do with the death.

Penetrating injuries of the lung are in the majority of cases capable of being cured by a conservative treatment; but there still remains a high percentage of cases which prove fatal during the "expectant" period under the hands of the surgeon in the first few days.

The classical treatment, as LENORMANT terms it, whose most ardent advocates are, in France, LUCAS-CHAMPIONNIÈRE, in Germany, KÖNIG and BRUNS, consists briefly of the following procedure :—

The wound and its vicinity are at once carefully cleansed and disinfected, painting on the skin with iodine. Under certain conditions an attempt may be made to close the wound by a suture. In no case is it allowable to probe the wound.

The injured man must then be kept absolutely still. Transport must be avoided, whenever possible. The thorax is immobilized by being firmly bandaged. Talking and movement is forbidden. Morphia for pain or cough. Strict diet, slight aperient. The rest treatment must be continued for two, and in severe cases for six, weeks. Hæmorrhage from the chest wall (from the intercostal or mammary artery) must be arrested by ligatures. The hæmothorax is relieved by a puncture as soon as signs of increasing dyspnœa and displacement of the heart appear. So as not to loosen the fresh thrombi on the torn blood-vessels, and guided by the opinion that the compression of the lung helps to end the hæmorrhage, it is recommended only to make the puncture when the case is one of extreme necessity, if possible, only on the second or third day (KÖNIG). We are not speaking here of the secondary puncture when resorption of the hæmothorax is delayed.

In the same way pneumothorax with tension can be removed by puncture. In progressive cutaneous emphysema in the first place the cutaneous wound on aspiration must be attended to and then either entirely opened or closed more securely.

That complicating wound infections require immediate recourse

to such measures as excision of the wound, drainage of the pleural cavity, resection of the ribs, &c., is already clear.

Such are, briefly, the principles of the "classical treatment," as described by LENORMANT. According to his statistics, out of 1,056 cases the rate of mortality is only 10 per cent. In order to appreciate these figures correctly, it must be mentioned that they deal only with patients in civil practice, and that cases complicated by injury of the vessels of the hilum are excluded. The rate of mortality is considerably higher if all cases of injuries to the lung are included, that is, if injuries in war are included. Proceeding on these lines, in the year 1905, out of 700 cases, I reckoned the rate of mortality as nearly 40 per cent. (38 per cent. for injuries from stabbing, and 30 per cent. for shot wounds).

More important than these absolute figures appears to me the fact that with expectant treatment 5 to 6 per cent. of the injured die from internal hæmorrhage (or from pneumothorax with tension) after several days, and all of these patients who, demonstrably, came into the hands of the physicians in a condition fit to be operated upon.[1] This was ascertained from a careful review of about 150 reports on patients with *post-mortem* records. From this fact the demand for a more active and indeed surgical treatment must be conceded without further question, and it seems to me justified since we can with certainty control the arrest of hæmorrhage in pulmonary wounds with the help of the suture, and since anxiety because of the risk of surgical pneumothorax no longer paralyses the surgeon.

In cases of ruptures of the lung and in injuries caused by stabbing and shooting, thoracotomy and suture of the lung are indicated, when it is a question of severe intrathoracic hæmorrhage, which, in spite of palliative measures and absolute rest, betrays its progressive character by breathing and pulse becoming worse, increasing cyanosis and anæmia. The same holds good in those cases in which hæmorrhage, arrested at first, begins again and becomes threatening to life, also in the case of progressive mediastinal emphysema. A conscientious decision as to the necessity and urgency of an operation can only be arrived at when the patient is under the most careful hourly observation, and in this way the fact that the general symptoms (pulse, breathing) are

[1] The conflict of opinion as to the necessity for operation has not yet subsided and presumably will not soon subside. This is owing to the difficulty of objective criticism, and the relatively small material for observation which falls to the share of individual surgeons. The question was discussed in detail in the Paris Surgical Society in 1907 and 1909, and finally in 1911, a lively discussion of the "Abstentionists," and the "Interventionists," took place at the International Surgical Congress. The excellent report drawn up by LENORMANT for this Congress, gives the best and most detailed information on the subject. Even LENORMANT, in spite of his favourable criticism of the expectant treatment (10 per cent. mortality), is obliged frankly to admit that of the 10 per cent. one-third succumbed to infection and two-thirds (that is about 6 per cent.) to hæmorrhage. This agrees in a most striking way with the 5 to 6 per cent. of cases fit for operation in a study made by me of the year 1905, for precisely in the cases of hæmorrhage is any waiting imperatively forbidden.

becoming worse and the hæmothorax is continuing, can be ascertained. This watching and control is necessary in every serious case. One must not allow one's self to be misled by the nervous collapse immediately following the injury (pallor, anxiety, shivering, cold perspiration, dyspnœa) and be persuaded to over-hasty measures.

When there is any doubt as to the urgency of the case, relieve the hæmothorax first by aspiration of 2 to 300 c.c.; if the improvement does not continue, then hesitate no longer but proceed to thoracotomy and treat the pulmonary wound by suture or plugging.

An apparatus for maintaining difference of pressure is not absolutely necessary for these operations, but it undoubtedly makes the operation on the lung easier, and makes it possible to proceed more quickly, and to close the pleura when the lung is fully inflated.

The site of the thoracotomy when there are penetrating wounds is determined by them; in subcutaneous lesions of the lung it is best to proceed from the side; whether you resect 6 to 10 cm. of one or several ribs and pull the wound well apart or with an H-shaped incision make a flap of cutaneous tissue, muscle and bone, is in itself irrelevant; the chief thing is to get sufficient room to be able to pass the whole hand into the pleura, pull forward the lung, and examine it.

Broad, jagged, superficial wounds are unsuited for the suture, and if a sphenoidal resection with secondary suture is not practicable, they should be brought to the surface and sewn into the pleural wound.

After the wound has been attended to and the pleura dressed, the lung is fixed either to the opening of the thorax and, if necessary, a loose plug is added, or—and according to latest experience, Rehn, Küttner, &c., this is to be done whenever possible—the wound in the thorax is first closed so as to be air-proof, even though it may be necessary to open it again later on. Here the method of maintaining difference of pressure is of great assistance, for on the one hand by the inflation of the collapsed lung the hæmothorax can be quickly evacuated and small wounds, especially shot wounds, can be quietly searched for and relatively speaking easily found on the slightly inflated lung; on the other hand there is the inestimable advantage of being able, after the suture of the lung is finished, to close the chest wall, avoiding or immediately removing any pneumothorax exactly over the distended lung.

If the resorption of a hæmothorax is slow, after a time the absorption of the exudation can be hastened by a puncture, repeated if necessary; if even then no improvement takes place and if the effusion of blood is extensive, then thoracotomy with inflation of the lung by maintaining increased pressure, removal of blood and immediate closure of the wound in the lung and thorax by suture is urgently to be recommended, but drainage of the pleura, as was formerly the custom, is very inadvisable, or should to limited to primarily infected cases. Compare the chapter on "General Technique."

The coagula of blood are to be removed from the pleural cavity, the lung to be cleansed, and the surface to be carefully examined for injuries, rents, shots or stabs.

Small, smooth wounds can be closed with a few button-hole sutures; contused and very dirty wounds, however, must be cleansed by cutting off the jagged edges or be joined by a suture after a wedge-shaped excision. Fine silk or catgut is the best for this purpose; do not make the stitches too far from the margin, but down to the base of the wound, and do not pull too hard. In this way even large wounds can be closed so as to be completely air and blood proof, especially if some fine superficial pleural sutures are added; in any case, when care is exercised, TIEGEL'S absorbable magnesium needles may be dispensed with, which in order to avoid tearing the suture are inserted close below the pleura parallel to the margin of the wound.

If the wound is near the hilum it may be sufficient to plug it; plugging will be more effectual in stopping hæmorrhage here than in other places, for the pressure of the blood in the small vessels is only a third of that in the large vessels.

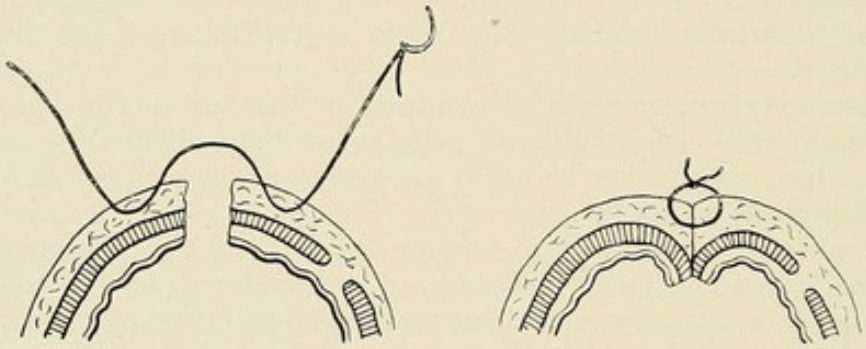

FIG. 45.—Suture of a bronchial wound (according to TIEGEL). Position of suture to be secured by sewing over with pulmonary parenchyma.

Progressive mediastinal emphysema too, which often rapidly develops into a complication involving danger to life, demands energetic treatment. That is to close the source from which the air escapes, generally a wound in the lung or trachea, therefore treatment of the pulmonary wound by suture or tamponade. SAUERBRUCH has, moreover, with the aid of the reduced pressure apparatus drawn the air from the pleura (pneumothorax with tension was present) and from the cushion-like inflated mediastinum after wide thoracotomy.

This procedure is indicated and may prove the means of saving life when it is a question primarily of wounds in the lung and at the same time pneumothorax is present. For emphysema produced in other ways, by fractured ribs, &c., TIEGEL has shown us how to obtain good results with simple remedies. In a case of very severe progressive mediastinal emphysema, he made an incision in the base of the neck, and applied BIER'S suction apparatus; under negative pressure of 30 cm., later 60 cm. water, the air

bubbled out of the wound and the threatening condition of the patient improved perceptibly.

Pneumothorax with tension can be easily and quickly removed by a simple puncture. If the pleura quickly fills up again with air, this shows—granted there is no valvular aspiration through the wound in the thorax—that one of the larger bronchial branches is injured. Here, also, thoracotomy is indicated, but, as I must admit, only quite exceptionally for the purpose of making the pulmonary suture; the insertion of a drainage pipe covered with rubber-tissue (BRAMANN'S or THIERSCH'S valve) will suffice to bring about healing. In one case by suture of a bronchus the cause of the pneumothorax was removed.

When both sides of the lung have been injured with double hæmothorax, or hæmopneumothorax, life can be preserved in spite of the partial collapse of both lungs. If, during the first twenty-four hours the patient has even the smallest amount of breathing surface at his disposal, this becomes gradually larger as the air and blood are absorbed, which generally takes place rapidly. FRANKE and BECK (German Surgical Congress, 1903) have reported cases which have turned out so fortunately. Moreover, the dangers of insufficiency of breath with closed pneumothorax can be quickly removed by aspiration with an ordinary suction syringe.

Of course, this is only applicable when the pneumothorax is really closed, that is when neither from outside through the wound in the thorax, nor from inside through a wound in the lung, do fresh quantities of air or fresh effusions of blood enter.

In cases of open pneumothorax on both sides, whether with or without injury, it may well only be possible to save the life of the patient by a rapid fixation of the lung in the wound in the thorax, or by artificial respiration with an intubation or mask apparatus (preferably with oxygen). In such cases the necessity for an operation will force itself upon the notice of every one.

The above discussion of the indications for an operation was exclusively concerned with the nature and extent of the pulmonary wound and the pleural complications. As, however, a matter of fact, only a third of all injuries to the thorax are exclusively pulmonary wounds and two-thirds are combined with injuries of other organs of the thorax, LAWROW[1] very rightly draws attention to the fact that in practice this important modification must be taken into consideration. In other words, in the case of a pulmonary wound, which by itself alone might be healed by the

[1] Most interesting are the statistics given by LAWROW of the cases under observation in ZEIDLER'S Clinic in Petersburg. According to them, out of 257 cases of penetrating injuries of the thorax due to stabbing, 102 were treated by the conservative method, and 155 by operation. Of these latter 78 per cent. were complicated with injuries of internal organs; of these 35·4 per cent. (55 cases) affected the diaphragm, 9 per cent. (14 cases) the heart and the pericardium, 27·7 per cent. (43 cases) the lung and 6·4 per cent. (10 cases) the vessels of the chest wall. I cannot unconditionally agree to LAWROW'S far-reaching demand that all injuries from stabbing should be exposed when not more than twelve hours old.

conservative method, but which by suspicious symptoms point to the injury of other organs of the thorax, the pulmonary wound must be straightway enlarged to make the condition of affairs clear. Here, we have to take into consideration lesions of the diaphragm, heart and pericardium and hæmorrhage from an intercostal or mammary artery. Of course, you will not then confine yourself to the removal of the complication, but, whenever possible, close the pulmonary wound, too, with the suture.

What can be done, in spite of many and most serious complications by determined surgery, is shown by PIQUINE (1911). A woman with twenty-three wounds, five of which had penetrated the thorax, was brought in four hours after the injury and operated upon at once. On the left side thoracotomy with plugging of a pulmonary wound and suture of a cardiac wound, on the right side suture of a wound in the liver and of two wounds in the diaphragm, search for the wounds in the right lung, which were no longer bleeding, pleural suture. The patient was cured.

Even injuries to the vessels of the hilum are not given up as hopeless. V. EISELSBERG successfully closed by suture an hour after the injury to the left pulmonary vein a stab ¾ cm. in length. The patient succumbed fifty-four days later to a complication.

Up to the present the results of operations have a high rate of mortality; there are about 300 cases with nearly 25 to 30 per cent. mortality. Considering the serious nature of the cases one could hardly expect anything else, particularly as these statistics are not confined by any means to isolated pulmonary wounds, but include complications of the most serious nature, such as concurrent injuries to the heart, the diaphragm and the abdominal organs, &c.

Naturally it is the serious and most serious cases which are operated upon, whereas some serious, but in the great majority of cases slight ones are not operated upon. LAWROW reckons that out of five or six patients belonging to the first group one patient falls into the second group. So no parallel can be drawn between the results.

In my opinion it is not right to judge this very difficult question from a one-sided standpoint (whether conservative or radical). This does not help matters. It will be the task of active therapy in the future, by careful judicious diagnosis, to reduce to the unavoidable minimum the number of deaths, so serious up to the present—namely, those due to hæmorrhage, tension-pneumothorax, mediastinal emphysema, as well as those due to the simultaneous injury of other organs of the thorax.

Regarding the methods of healing stabs and cuts in the lung without complications, according to HADLICH a rapid adhesion of the margins of the wound takes place, which resists even a hæmatoma developing low down. Already after three hours, apart from the effusion of blood which varies in severity, swelling and desquamation of the alveolar epithelia may be seen, and an infiltration, slight certainly, of the adjacent pulmonary parts with round cells. After a few hours there is a great increase of the epithelia, which fill up whole alveoli; the round cells too are very much

more numerous and permeate the alveolar margins as well as the perivascular and peribronchial connective tissue. In the next few days the desquamation of the alveolar epithelia, which often contain nuclei, increases still more, or remains at its height; at the same time abundant interstitial infiltration of round cells takes place. In the smallest arteries an endarteritis obliterans is developed. A divided bronchus with free uncollapsed lumen passes into the extravasation of blood. On the visceral pleura is seen the foundation of connective tissue infiltrated with round cells, the endothelium is very much swollen. When the wounds are not too large, on the third or fourth day spindle cells appear which finally, in unbroken lines, cover the wound, so that a cicatrix is formed with cells in close layers, which is continued without any sharp delimitation into the adjacent alveolar septa. After the process of desquamation is over the alveolar walls are provided with fresh epithelial covering. In larger cicatrices there is frequently a system of cavities, some of which are, individually, ten times the size of an alveolus. These cavities are often connected with the divided bronchus, and near the point of connection are covered with epithelium. A reactive traumatic pneumonia, as described above, spreads far over the surrounding pulmonary tissue, without, however, becoming progressive in character. HADLICH did not observe any adhesions of the parietal and visceral pleura, only on a few occasions pseudo-membranous cords.

TALKE, at my instigation tried to verify these processes by a number of experiments on animals, specially directing his attention to the healing up of ligatures and sutures. He found that the silk threads almost always healed up without reaction, the alveolar epithelium perishing through pressure, and only the framework of connective tissue remaining. The threads were thus surrounded by a capsule of connective tissue, which, however, did not consist of newly-formed tissue, but of remains of the old connective tissue. Interrupted sutures are, therefore, in so far unsuitable as they destroy a relatively large part of the pulmonary tissue. Even by using catgut this could not be avoided.

The healing of loss of substance of the visceral pleura, studied in my clinic by CRESCENZI, is so conducted that, though no regeneration of the pleura ensues, the scar formed at the expense of the adjacent perishing pulmonary parenchyma, enveloped in pleural epithelium, fully compensates for the loss, and shows no inclination to form morbid adhesions with the parietal membrane.

LITERATURE.

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CHAPTER VI.

PULMONARY SUPPURATIONS.

General Pathology and Therapy of Pulmonary Suppurations.

The most frequent of the processes in the lung, accompanied by suppuration, are the suppurations of the mucous membrane. They are not often subjected to operation because they are generally diffuse, and because the bronchial tree makes a wonderfully complete evacuation of the purulent secretion possible through the larynx by means of the expiratory movements, provided both the lung itself and the thorax are perfectly mobile and elastic, and the expulsive powers of the muscles are intact. These conditions are generally most perfectly fulfilled in youth.

In case of emphysema, induration of the connective tissue, either diffuse or circumscribed, pleural adhesions, rigidity or anomalous forms of the thorax in congenital atelectatic foci, these conditions are generally lacking, either in the whole or in a part of the lung. In these cases by the pressure of the collected pus (with the concurrence of other circumstances) dilatations of the bronchi may take place, which sometimes, cylindrical in form, affect a larger number, sometimes form bottle-shaped cavities, which, generally situated in the lower lobe, often extend almost to the pleura. These bronchiectatic cavities then anatomically and clinically resemble old abscess cavities.

Less common than the suppurations of the mucous membrane, but much more important for us, are the parenchymatous suppurations in the lung, which are caused by inflammations, probably often combined with the presence of foreign bodies. Often, too, we find fully developed abscesses, without succeeding in determining by anamnesis that they have been preceded by pneumonia or bronchopneumonia.

At first the pulmonary tissue only appears brittle and purulently infiltrated, then a cavity is formed filled with pus and bits of tissue with villous walls, which only after some length of time becomes clearly differentiated from its surroundings, and finally appears enveloped in a pyogenous membrane.

According to their origin from broncho-pneumonic or lobar foci, these purulent foci vary from the size of a pea to that of an apple, or even larger; there may be a number of them, especially of the small ones, and several of them may coalesce and form one large

one. Superficial foci may affect sympathetically the pleura in the form of purulent pleurisy, or, when the infection is slight and the progress slow, in the form of adhesive pleurisy.

These abscesses sometimes are in communication with the bronchi from the beginning, or when they develop in an inflamed infiltrated lobe they may later on break in the direction of a bronchus. Here the pus produces bronchitis, the secretion of which mingles with the pus, and may, in certain circumstances, exceed it in magnitude. By the aspiration of this fluid broncho-pneumonic foci, followed by fresh abscesses, may arise in the healthy parts of the lung. Bronchitis caused by an abscess which has become chronic may lead to bronchiectases.

After evacuation of the purulent softened pulmonary tissue an abscess cavity in the lung, as in other organs, may become cicatrized; it may, however, with the formation of smooth walls, continue permanently as a so-called cavern; the necessary conditions will be discussed later.

As the pulmonary abscesses are formed with more or less free admission of air, the suppuration is often from the first, or by secondary infection, mixed or putrid.

When the healthy lung becomes putrid, the tissue may break down and decay under the influence of microbes without (any or any immediate) noticeable inflammatory reaction: pulmonary gangrene. These foci are discoloured, greyish-green, soft, sometimes the size of a pea, sometimes taking in nearly a whole lobe. When vomited matter from the stomach is aspired. the tissue may be chemically affected by digestive ferments, and thus become a favourable culture medium for putrefactive organisms The disintegration of the decayed tissue gives rise to a villous circumscribed cavity, which later on may be differentiated by inflammatory infiltration of the walls, and cleansed by the evacuation of its contents.

There are all sorts of intermediate grades between simple abscess formation, putrid suppuration, and primary gangrene, which leads later to secondary differentiating inflammation.

Foci due to aspiration from putrid and gangrenous foci and attacks of pleurisy bear the character of these.

ETIOLOGY AND PATHOGENESIS.

Pulmonary abscesses are very frequently formed round foreign bodies taken in by aspiration, partly owing to the mechanical irritation, but more often under the influence of the chemical and bacterial irritation.

Here we have to consider, not so much those foreign bodies generally treated by surgeons, but other soft, often small, particles, less striking, often only recognizable with the aid of the microscope; particles of dust which, suspended in the air, may be breathed in with it, then also moist particles adhering to the pharyngeal mucous membrane; particles of food, vomited matter

from the stomach, mucous flakes and epithelial shreds from the oral and pharyngeal cavity. These may, in narcosis or in stupor (*e.g.*, in the case of epileptics), in intoxication, in deep sleep, after vomiting, even when awake on sudden unregulated inspiratory or swallowing movements (laughing, hurried eating, &c.), pass the larynx, favoured partly by gravity, partly by the inspiratory current.

Disturbances of the pharyngeal and laryngeal movements and reflex actions in case of central and peripheral paralysis and anæsthesia, *i.e.*, after diphtheria, have the same effect, and finally, general weakness, when the automatic and reflex movements are unregulated and lacking in energy.

In accordance with the conditions of their origin the foci due to aspiration are generally manifold, often multifarious. The particles pass all the more easily into the minor bronchi, when, owing to disease of the mucous membrane, the healthy ciliary movement is in any way interfered with or weakened. They act probably exclusively as hosts of bacteria. The inflammatory focus produced by the latter may at first be very small, and only make itself clinically noticeable after days, perhaps even after weeks have gone by.

As is easily understood, the inflammatory foci arising in this way are often not merely purulent, but also putrid, and precisely in the putrid character of many a quite isolated focus of disease, "arisen spontaneously," lies the proof of its origin being due to something swallowed.

I would also mention as possible sources of putrid infection of the air-passages, chewed tobacco, stomatitis, and carious teeth, disintegration of tissue, and suppurations in the larynx, in the pharynx, and the nasal cavities.

Also after a fall into water, and on diving for a long time, if the water is impure (in harbours), aspiration abscesses may arise owing to involuntary respiratory movements under water.

Sometimes the matter which causes suppuration passes directly into the bronchial cavity out of small bronchiectatic cavities, broken down bronchial glands, perforating cancer of the œsophagus. By the chemical irritation of gases or corroding fluids taken in in aspiration superficial or circumscribed purulent inflammation may arise, which are then probably always secondarily infected from outside.

Healthy lungs probably overcome the aspiration of these things by the ciliary movement and the vital energy of its tissue. If the body is weakened (by acute or tedious disease, by drunkenness, diabetes), or if these particles pass into regions of the lung which are already inflamed, the exciting causes of suppuration and putrefaction find the conditions more favourable to development, but even then, all foci due to aspiration do not become purulent.

Clinical observations show that the majority of pulmonary abscesses develop from lobar pneumonia or bronchopneumonia, especially pneumonia after influenza, sometimes from bronchitis, then probably with the aid of bronchopneumonia, or a bronchiectasis which has remained latent. When abscesses appear to have developed "spontaneously," they are probably due to the earlier formation of such inflammatory foci.

The pneumococcus, which generally only produces a fibrous exudation in the lung, may certainly lead to the formation of suppurations in the lung and also on the pleura, meninges, and in other places, especially to the little "initial" abscesses; it is very often a question of a mixed infection by staphylococci, streptococci, and other cocci, which found their way through the air-passages, often with the help of minute foreign bodies mentioned above. In the case of pneumonia after influenza there is always a mixed infection at work besides the influenza bacillus.

In the putrid foci, according to their genesis, there are usually the bacteria of the flora of the mouth (*e.g.*, *Bacillus fusiformis* and *spirillæ*). According to KISSLING the real exciting cause of the gangrene of the lung is the *Streptococcus putridus* (KRONIG, SCHOTTMÜLLER); it forms chains, is positive to Gram, grows aerobic on grape sugar agar.

From the simple suppurations the specific diseases, even with more or less formation of suppurations—actinomycosis, streptothrix-mycosis, tuberculosis—are rightly differentiated, but clinically, especially in the initial stages, they are very similar.

(2) The second way, in which the exciting causes of suppuration may pass into the lung, is the blood-vessel; whereas simple emboli lead to hæmorrhagic infarcts (rarely to simple anæmic necrosis), infected emboli result in simple or putrid suppuration in the obstructed vascular region. Since the introduction of asepsis these embolic abscesses have become rarer; they also seldom give rise to operations, because they are generally far more numerous than the aspiration abscesses, and because frequently a purulent pleurisy caused by them or the serious general condition very quickly leads to death.

Among the more frequent starting-points of embolic pulmonary abscesses, I would like to mention otitis media, puerperal condition of the uterus, phlebitis of the lower extremities. The emboli proceeding from the last two sources are often somewhat larger, more solid, and only slightly infectious, so that they sometimes lead to solitary pulmonary abscesses which can be operated on.

In sterile infarcts, in very rare cases, simple necrosis and demarcating suppuration may occur, but these foci are very soon infected with microbes from the air passages.

The same may happen with the putrid anæmic necroses, which sometimes develop out of croupous pneumonia; generally small and superficial, furthered by emphysema and disease of the pulmonary arteries.[1]

(3) Finally, a suppuration attacks the lung from the vicinity by means of the lymphatic vessels, or directly, for example, from the liver.

Very striking are the geographical differences in the frequency

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[1] CAGNETTO (Padua): "Necrosi anemica nelle Pneumonite Pathologica, Rivista quindicinale," vol. iii, 1911, pp. 532-547; quoted ROSENTHAL, Diss., Berlin, 1907. KÜHN: *Arch. f. Kinderheilk.*, 1903, p. 273. BRINKMANN, Diss., Kiel, 1897.

of the occurrence of pulmonary abscesses. Comparatively rare in South and Central Germany, abscesses (generally putrid) are much more frequently observed in the north, on the coast, in Hamburg. The occurrence of bronchitis and broncho-pneumonia favoured by the climate may be the reason of this; more important, to my mind, are the customs of the inhabitants: alcoholism and the chewing of tobacco; among the longshoremen the irregularity and, at times, increased intensity of the heavy physical work may lead to conditions of exhaustion and too hurried meals; these circumstances, and sleep made unnaturally profound by alcohol, are favourable to the inhalation of foreign bodies; when the constitution is enfeebled by alcohol, gangrene, and suppuration occur more easily.

SYMPTOMS.

Suspicion is generally roused of the existence of a purulent cavity by the quantity and other characteristics of the sputum. If, as is done in hospital, each patient's sputum is collected and measured every twenty-four hours, modifications in character and quantity are soon noticeable; this is not always the case in private practice, and on this account the existence of purulent cavities may be ignored for a long time, or even altogether; therefore, when finally the cavity is recognized, its age is often doubtful. Most striking is the quantity of the sputum, which may amount to over 500 c.cm.

Besides measuring the sputum every twenty-four hours, it may, under certain circumstances, be important from a diagnostic point of view to know how it was divided up throughout the day by measuring the sputum in definite periods of time—for example, during the night and in the early hours of the morning—and to compare the result with the condition revealed by auscultation, percussion, and the use of the X-rays.

The sputum naturally does not only proceed from the one or more purulent cavities, but also from the bronchial mucous membrane, which is more or less also diseased, and by the passage of the contents of the cavities is stimulated to more or less abundant secretion. Although in general cavities with larger wall surfaces secrete more pus, still, it is not permissible in the individual case to judge the size of the cavity by the quantity of sputum, especially when there is putrescence.

The sputum is sometimes simply purulent, of corresponding colour, with more or less admixture of mucus; sometimes watery, dirty green or brownish owing to the admixture of blood.

When left standing in the glass three layers are often formed, the undermost of which consists of more or less confluent pus, the uppermost of a layer of viscous foam with purulent globules and threads, the middle layer being like cloudy water. The last layer may also be found when no water had been placed in the glass before; it consists of oral and bronchial secretion, which is secreted in larger quantities owing to the irritation of the contents of the cavities.

This sputum in three layers is also known to be found in cases of pleural empyemæ (or other extra-pulmonary purulent cavities), also in that form of bronchiectasis which is accompanied by numerous slight cylindrical dilatations of the bronchi (about as thick as a lead pencil); and also in simple chronic purulent cases of catarrh in which, indeed, there may be a slight dilatation of the whole bronchial tree, but without preponderating participation of its terminal branches. It is most unsafe to recognize these different sources of the three-layered sputum from its character. Generally speaking, the pus from the pleura or from non-tubercular pulmonary cavities is more confluent in the undermost layer than in the case of purulent bronchial catarrh and cavernous phthisis; but pleural pus, when the perforation is sieve-like, often forms, especially in the upper, but also in the lower layer, fine threads and flakes which remain isolated from one another. This is due, it seems, to a layer of mucus originating in the bronchial mucous membrane. Generally, the quantity and the place of secretion of the secreted bronchial mucus seems to determine the appearance of the sputum in the glass. It depends, of course, on varying conditions. The layer of foam on the surface is specially found when there are painful fits of coughing and cavities with putrid contents.

As a practical rule, it may be laid down that such cases are generally unsuited for operation, when the lumps of sputa, though abundant, show little tendency to coalesce in the glass, as the nummular lumps of this kind are generally due to bronchial blenorrhœa; the spherical ones generally originate from tubercular caverns.

Small quantities of blood are often mingled with the sputum and give it the dirty-brown colour; in larger quantities the blood is recognizable as such. It occurs specially in the case of acute destructive processes; sometimes also, when there are old cavities, it is due to slight aneurisms.

Sometimes, in the sputum, there are little shreds of the lung; when charcoal is present, they are specially noticeable.

In one of ARNOLD'S cases little stones from 5 to 7 mm. in diameter were evacuated with the sputum (6 to 7 per day); they were fragments of a lung, affected with the stone-cutter's disease, set free by necrosis.[1]

The microscopic examination of the sputum is important. The pus corpuscles are often in a more or less imperfect condition, destroyed or changed into detritus. Fat crystals generally denote that the cavity has been in existence for some length of time; they are usually found mixed with detritus and bacteria specially abundant in DITTRICH'S emboli, small particles from 1 to 3 mm. in diameter—also in sputum not actually fœtid. Sometimes, especially in more recently formed abscesses, we find abundant hæmatoidin crystals or amorphous blood pigment. Specially important is the discovery of elastic fibres (boiling of the sputum with 2 per cent.

[1] *Münch. med. Wochenschr.*, 1897, No. 47.

liquor potassæ; or, better, shaking with antiformin, then centrifuging). In form they look like alveoli, often a group of alveoli; they denote with certainty a cavity in course of formation or growth. Their absence does not of course exclude the possibility of a cavity being present; it may be stationary, or the elastic fibres may already have been given off in the putrid secretion.

Partial softening of the elastic fibres induces evacuation both in the case of simple and of tubercular abscesses; more abundant solution takes place in pulmonary gangrene and in putrid secretion. According to ROSENFELD[1] in the latter case the carbon pigment of the lung is retained in alveolar form; on the contrary, in phthisical sputum, both in initial and in chronic pulmonary abscess, the smaller microscopic shreds of elastic tissue are free, he says, from carbon pigment. ROSENFELD explains this as follows: whenever the evacuation of the necrotic shreds takes place slowly, the carbon migrates before the sloughing occurs, whereas when the evacuation of the gangrene or the large abscess-embolus takes place rapidly there is no time for this.

The bacterial flora in suppuration in the region of the air-passages are generally very mixed, the most so in chronic and putrid cases. Under certain circumstances it may be very important for differential diagnosis, when only one kind (streptococci, pneumococci or staphylococci) is found, that points with greater probability to burst pulmonary abscesses. Even in the case of freshly burst pulmonary abscesses the sputum shows at once mixed bacteria. In putrid sputum spirilla and *Bacillus fusiformis* are found.

In specific suppurations the characteristic microbes are found: tubercle bacilli, actinomycotic granules (staining according to GIEMSA); these sometimes on small ramified bronchial effusions: streptothrix threads, interwoven like tufts of hair.[2]

In cases of simple abscess the sputum has the stale smell of pus or of catarrhal sputum: from this we find all the intermediate grades to evil smells and the unbearable stench of the gangrene. It is true, that in individual cases of chronic bronchitis with uniform dilatation without the formation of cavities, the sputum may have an evil smell, but it preponderates in the case of cavity formation both of abscesses and of the final stages of bronchiectases of various calibres; in fresh abscesses only when there is gangrene of the wall and the cavity increases in size; old stationary cavities may also produce it, when the wall, being intact, the content is putrefying; also in sinuous abscesses elsewhere putrid suppuration is not always accompanied by progressive disintegration of the tissue.

In fresh extensive gangrene the smell is different, "like carious teeth," in old bronchiectatic cavities often dominated more by volatile fatty acids; from the diagnostic point of view, however, these differences are of little value, at most subjectively.

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[1] ROSENFELD, "The Initial Pulmonary Abscess," *German med. Press*, 1902, No. 2.

[2] LICK, "Beiträge zur Kenntnis der Streptothrixmykose der Lunge," *Mittei. aus den Grenzgebieten*, vol. xxiii, 1911, p. 531.

When left standing in the glass the evil smell of the sputum sometimes diminishes or disappears (because of the access of the air?). Sometimes only the breath smells on expiration, but always to the same extent, sometimes (probably generally when the putrid cavity is of small size) putrid and odourless sputum is brought up separately at different times. The patient distinguishes between the two himself by taste and smell, and, if attentive, can sometimes by the feeling indicate the side or the region of the thorax from which the putrid sputum comes.

Generally on the formation of a cavity, especially in the inferior lobe, the expectoration takes place periodically. This alternation of long periods free from coughing with periods of an hour or more of abundant expectoration also occurs, it is true, in cases of chronic bronchitis, and especially of numerous small terminal bronchiectases, but in the case of cavities it is specially pronounced and the quantity of sputum produced in a few minutes is specially striking ; moreover the expectoration is sometimes favoured in such a way by certain conditions or positions of the body—by lying on the side or local pressure—that one is able to conclude with certainty the position of the cavity.

Deep breathing, voluntary or occasioned by speaking, movement of the body, cold air, generally gives rise to coughing, and, when the cavity is full, to expectoration also ; superficial breathing (quietude, sleep), causes both to stop for the time.

Lying on the healthy side produces coughing and expectoration when there is a cavity on one side ; they are absent when the patient is lying on the affected side often for many hours, only reappearing after the cavity has been refilled in the meantime, and then becoming specially abundant on change of position. When with a cavity on one side the influence of position is felt, either indistinctly or not at all, either the passage to the bronchi is obstructed or the sputum comes from other sources, cavities in other parts, or a diffuse affection of the mucous membrane.

When there are cavities in the upper lobe the position of the body has generally little noticeable influence on the expectoration.

When the cavities are in the lower lobe there may be absolutely no sputum for hours when the patient remains in an upright position, but on assuming a horizontal position it becomes abundant ; if the cavity is once completely emptied, for a time the patient will be able to lie flat without any irritation causing coughing.

The increase of expectoration in the early morning hours, noticed in cases of chronic bronchitis, is still more pronounced when there are cavities in the lower lobe ; by lying flat on the back with the trunk inclined in the opposite direction (with raised pelvis), it is generally increased and concentrated in a shorter time. This may, under certain circumtances, be of use therapeutically and also in diagnosis, so as to examine the cavity in different conditions of fulness. The patient, by observing for himself the conditions which determine the expectoration and also the periods of rest, may often be of great assistance in the local diagnosis of the cavity.

Many patients with bronchiectatic cavities in the lower lobes expectorate more easily and freely when the trunk is bent right forward (standing or sideways out of bed), others when they raise their arms and hold on to a horizontal bar, still others when, in the (abdominal) position recommended by GERHARDT, they press the lower anterior half of the thorax on expiration against a cushion placed crosswise and at the same time plant their feet against the end of the bed.

The state of the temperature is of great importance in pulmonary suppurations. Here, as elsewhere, fever, especially remittent fever, may be a sign of the beginning of the formation of a cavity or of the retention of pus; very often, however, the temperature is just as much determined by the processes of disease going on in contiguous or remote portions of the lung apart from the formation of the abscess, and is important just because it draws attention to them.

In cases of chronic suppuration the temperature may be little or not at all changed, either because the patient has grown accustomed to the substances exciting fever or that these are not absorbed. Even a chronic putrid suppuration is sometimes borne remarkably well, when it occurs in old cavities with smooth walls, whereas acute putrid processes or the progress of chronic ones affect the temperature, it is true, but slightly, but seriously affect the general condition, strength and circulation.

The circulation should be carefully observed, less for the diagnosis of the abscess as such, than for the determination of the general condition, and therefore of the question whether there shall be an operation, and if so when. If the frequency of the pulse increases or the fulness of the arteries decreases it will be decided to hasten the operation, especially if there is putrescence; signs of great cardiac weakness make the prospect of a cure less favourable and will, under certain circumstances, prevent the operation from being performed. If the putrid secretion is successfully removed, the action of the heart often improves perceptibly.

The number of leucocytes in the blood is generally increased by the preliminary inflammatory processes, so that an increase as a symptom of the formation of suppuration could only be of diagnostic value if they were counted again in the case of an abscess still closed.

In determining the position of the cavity most would naturally be expected from auscultation and percussion; but, unfortunately, only a limited value can be attributed to these methods of examination; the extent of the indurated and otherwise pathologically modified pulmonary tissue in which the cavities occur, can certainly be approximately determined, but the position of the cavity therein only very imperfectly.

The classic symptoms of cavities (change of sound, amphoric breathing, metallic tinkling rhonchus) hold good mainly or exclusively of the cavities in the upper lobes, which, kept open and full of air by their position, are preferably described as caverns. Owing to their origin being usually tubercular, they rarely come

into consideration for surgical treatment, but in their case also the observation of the symptoms of cavities, especially of the various kinds of change of sound, certainly disclose the presence of a cavity, but their absence does not exclude it.

The cavities of the lower lobe rarely represent larger air spaces; as the ribs and adjacent organs yield, they form as a rule flaccid

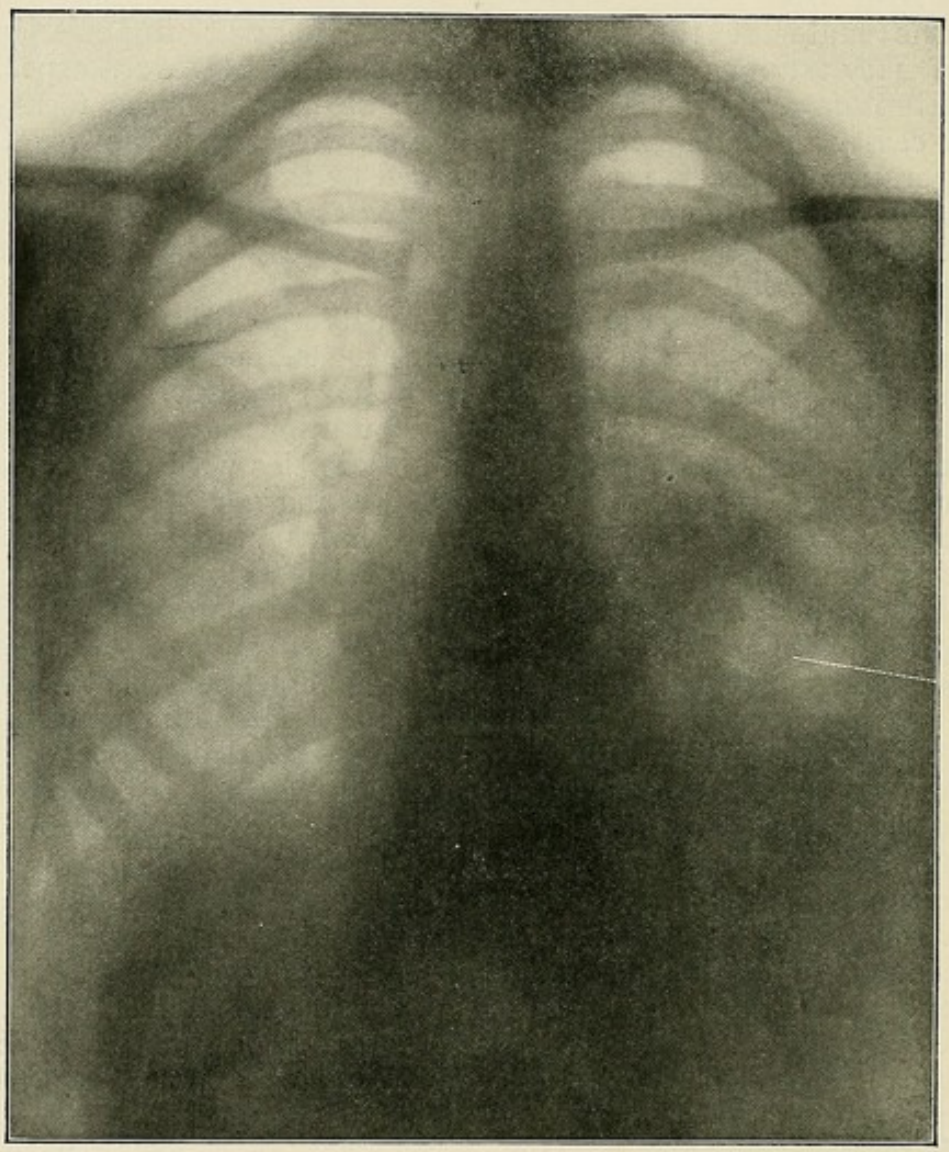

FIG. 46.[1]—Metapneumonic abscess on the left in a man of 19, cured by operation. The cavity "h" lies in indurated pulmonary tissue. Dorsoventral.

sacs, often only in the form of a fissure, which are for the most part filled with secretion. According to the nature of the surrounding tissue, therefore, they give a dull percussion note, with a more or less tympanitic accessory ring. The effect of the

[1] I owe the photographs for figs. 46, 47 and 48, to Prof. HOCKHAUS, of Cologne; that for fig. 49 to Prof. PAUL KRAUSE, of Bonn.

collapsed cavity or the cavity full of pus, on the breath sound, like that of an encysted pleural extravasation or a flaccid induration, is generally only deadening. On expectoration these symptoms are not generally changed, as with yielding surroundings the walls of the cavity approach each other; only when the cavity is surrounded by rigid tissue it may become full of air and then

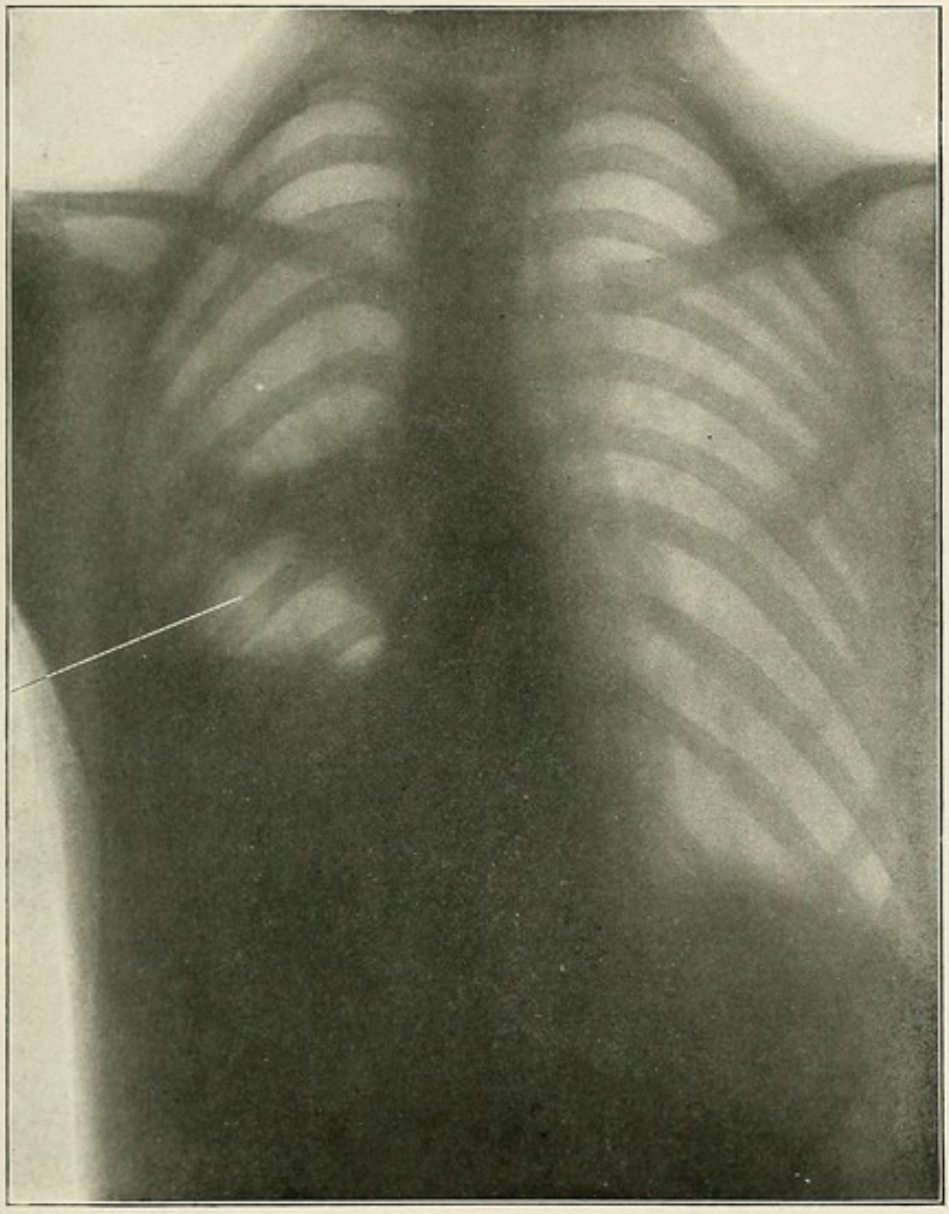

FIG. 47.—The same case as fig. 46. Ventrodorsal.

present the symptoms of the cavities of the upper lobe. This is possible in the case of large, quickly formed metapneumonic abscesses and bronchiectatic cavities, which are formed after pleurisy and when the pulmonary tissue is atrophied. But even then the typical symptoms of cavities occur, as a matter of fact, rarely and often pass away again rapidly. Much more important

is the variability of the acoustic symptoms owing to the expectoration. When the cavity is full complete dulness and absence of breath sound, after expectoration dull tympanitic note and bronchial breathing of various degrees, possibly accompanied by ringing rhonchi.

The change in the auscultatory symptoms may be caused either by secretion or by a pulmonary sequestrum lying loose in the cavity which may for a time obstruct the opening of the inosculating bronchus (KISSLING).

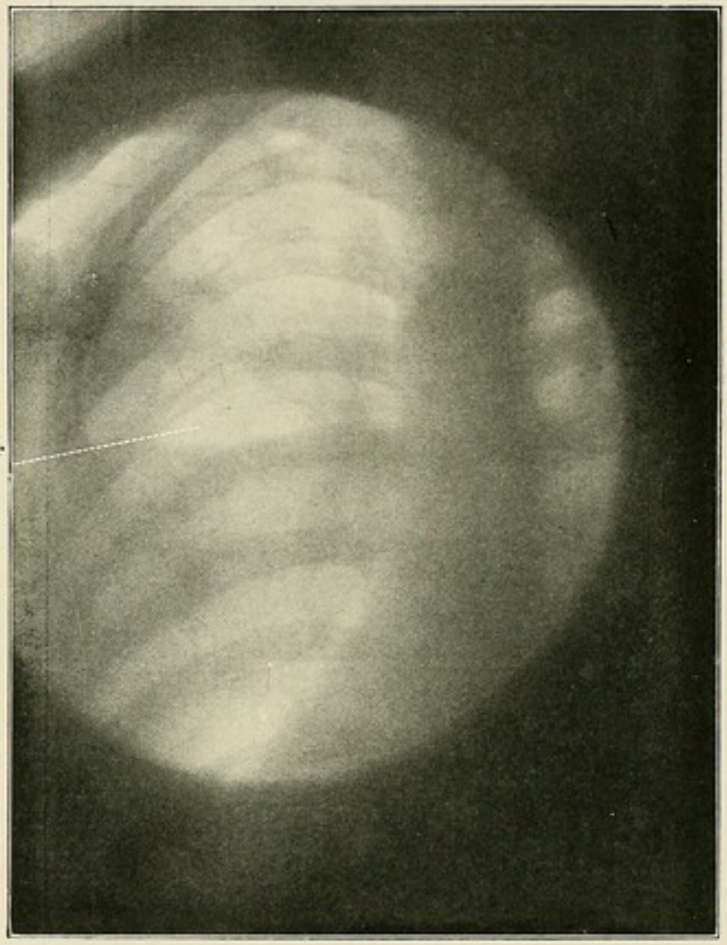

FIG. 48.—Metapneumonic abscess situated in almost normal pulmonary tissue, and therefore only recognizable by the use of X-rays. The horizontal level of the fluid (f) clearly recognizable; operated upon, died of after-hæmorrhage into the cavernus. Ventrodorsal.

The amphoric breathing, which also may be heard over the smallest caverns and cylindrical terminal bronchiectases, is very deceptive.

Of the greatest value for the local diagnosis of the cavity, but especially for the determination of the condition of the lung, is the use of the X-rays, as they enable us to perceive both superficial and deep-seated foci, and also smaller foci than we can discover by percussion. By using the X-rays, too, in different diameters we can determine more exactly the size and position, and obtain by photographs a reliable comparison of the condition at different stages; by examination with the screen, moreover, we can determine the mobility of the diaphragm and the pulmonary margins, and by this means reliable conclusions as to the presence of pleural adhesions, at least on the lower pulmonary lobe.

When the general condition is serious, one must content oneself with taking plates. By shortening the time of the exposure we obtain to-day not only much clearer pictures than before, but

can also recognize small circumscribed foci, which formerly only appeared on the plate at most as diffuse shadows.

When we obtain from the shadow a picture of the extent and intensity of the induration of the lung in general, it is of value in forming our opinion of the whole diseased condition, the abscess or abscesses will always only correspond to a part of the foci of induration.

The abscess cavity may, when it contains air, stand out from the indurated surroundings as a centre of light (figs. 46, 47, 49), when partially filled with secretion this may be shown by sharp horizontal demarcation of the shadow thus caused towards the top (fig. 48).

As a matter of fact, however, even by the use of the X-rays, the cavity rarely comes into sight, as it is often insufficiently filled with air, or quite devoid of it, a circumstance which so often also renders the acoustic evidence worthless.

Foreign bodies are the most easily discovered in the normal lung, and when they are of metal or bone, with more difficulty, when they are already surrounded by inflammatory indurated tissue.

If the induration is limited to one lobe, then its demarcation is shown in the X-ray picture as a sharp line.

The demonstration of multiple foci is often only possible by means of the X-ray picture; they are considered under certain circumstances, when situated on the other side, as hopeless for operation. If after the opening up of an abscess indurations also are discovered, they may indicate other foci still in existence—in the vicinity or far away—and lead to a search being made for them.

We must confess the local diagnosis of the purulent foci is still very uncertain and deceptive. It can rarely be made directly. As the dulness and the shadows may be caused by old or new thickenings of the most diverse kind and by indurations, we have to consider also changes in the form and mobility of individual sections of the thorax, as well as of the diaphragm (LITTEN'S "Phenomena of the Diaphragm"), local sensitiveness to pressure, subjective observations of the patients as to coughing and expectoration, the way in which the disease develops and the course of the fever. All these things give us valuable indications, which we have to combine with the result of the acoustic and optic examination, as well as with the nature of the expectoration (see p. 94).

It must be emphasized that in diagnosing we must not only consider the locality and size of one focus on which we wish to operate, but that it is just as important for the whole proceeding whether there are other foci and where they are.

The idea often occurs to make certain of the place where an abscess is suspected by an exploratory puncture; this must not be done! An exploratory puncture of a pulmonary abscess with the thorax closed must be absolutely avoided; because by so doing the pleural cavity may be infected. Even when pleural adhesions have been diagnosed, no puncture must be made, for this diagnosis is uncertain. If the content of the cavity is putrid, then even if

there were adhesions their tissue is often spongy, and the whole channel of the puncture would be infected and might become the starting-point of a septic cellulitis. Besides carrying the infection into the pleura and as cellulitis into the thoracic wall, emphysema, spreading into the mediastinum and severe hæmorrhage are to be feared. Out of thirty-seven punctures in cases of purulent pulmonary foci, six were followed by similar serious complications, which in three cases ended in death (Picot). The exploratory puncture of the denuded lung is of value during the operation.

For various reasons it is important to ascertain as certainly as possible whether, and if so, to what extent, the pleural layers have adhered. Local adhesion, not too loose, over the purulent focus is

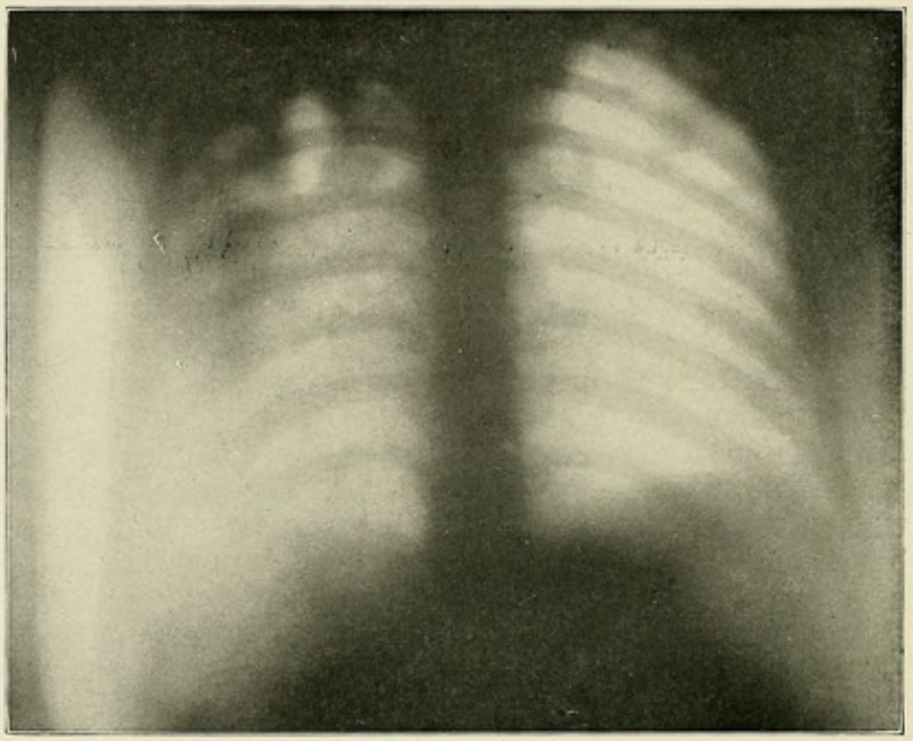

Fig. 49.—Cavity in upper lobe thickened by tuberculosis.

least desirable, when it is intended to open it up. On the other hand, treatment with collapse by means of pneumothorax is only possible when the pleural sac is fixed at least for the greater part. The decision in the one direction or the other is rather difficult to make; easier, of course, when denser adhesions of the pleura have narrowed the intercostal spaces and have fixed the ribs or led to a reduction of their mobility, or even to their contraction; these things may be ascertained by feeling with the finger or inspection with suitable illumination, such as examination with the X-rays. In the last case the intercostal spaces appear somewhat darker, also narrower, the contours of the ribs dim.

These modifications, when occurring on one side or locally

limited, can be recognized by comparison with the other side, or the adjacent intercostal spaces, most easily in the lower half of the thorax; here the injury to the mobility of the ribs of the pulmonary margins and of the diaphragm (by percussion, by the X-rays, LITTEN'S "Phenomena of the Diaphragm") are specially noticeable; sometimes intercostal spaces or costal margin are even drawn in on inspiration; when sufficiently solid adhesions run from them directly or indirectly to the diaphragm.

Mistakes may occur here also. Rigidity of the ribs, induration and infiltration of the lung, circumscribed cords of adhesion may stimulate more extensive adhesions; on the other hand, even in the case of surface adhesions, when these and the pulmonary tissue are in themselves elastic and movable, the change in the volume of the lung on inspiration may be very considerable. For this reason even the respiratory lifting of a needle inserted in the pulmonary tissue (FENGER) cannot decide.

Owing to the reduced change of volume the breath sound is weaker over adherent parts, and when the adhesions are more dense the percussion note is also less distinct. But these symptoms too can only be interpreted in one way. Not infrequently from the mention of earlier pains and from the rest of the anamnesis one is led to conclude that at an earlier date pleurisy has been present; the nature of the earlier illness too gives a certain amount of assistance. According to experience hitherto, adhesions appear to be of more frequent occurrence in the acute abscesses, perhaps because they are generally the result of pleuropneumonia. Of course they are also present in the cases of bronchiectases resulting from contracting pleurisy; on the other hand, they are often absent in bronchiectases resulting from chronic bronchitis, and also in the cavities developing slowly from within, for example abscesses caused by foreign bodies. In general, more frequent adhesions are not to be expected in diseased processes of longer duration than after acute ones.

It is necessary to emphasize the fact that even with well-founded positive diagnosis of adhesion, disappointments are not infrequent on operation. One must be prepared for these, and be prepared to meet the consequences, because the success of the operation and the life of the patient may depend upon this. When the content of a purulent focus finds its way into the recently opened normal pleural cavity, the most serious symptoms always ensue, which are to be attributed partly to the accompanying rapid collapse of the lung, partly to the septic poisoning.

The promotion of artificial pneumothorax for the purpose of obtaining a therapeutic collapse of the lung is, of course, impossible when the pulmonary adhesions are extensive, but even circumscribed cords of adhesion, which scarcely affect the respiratory mobility, may prove a considerable hindrance. We shall refer to this again later on.

DIAGNOSIS.

Let us sum up once more the most important points for the diagnosis of pulmonary suppuration; they are: the quantity of the

sputum (the quantity to be measured regularly every twenty-four hours), the kind (usually periodic) of expectoration, the microscopic condition of the sputum (very often elastic fibres), the change in the acoustic and optic condition and its relation to the expectoration. That a cavernous suppuration exists is generally much easier to discover than its locality. Extent and number of the cavities: for this several days, sometimes weeks, are required. The decision whether there are several foci is very important.

We must also consider the differential diagnosis for suppurating pleurisy, which with perforation in the direction of the lung may lead to similar large quantities of sputum in three layers, as in the case of suppuration of the lung. Soon after the eruption (which does not generally take place suddenly, so that the quantity of sputum only becomes greater gradually after a few days) the condition under auscultation and percussion and the signs of displacement are certainly usually unambiguous and certain. But this is not the case when the perforation remains ignored, when the patient only comes to be examined after weeks, or perhaps months, and the effusion of pus is practically over. The region of dulness is then irregular in shape; both imperfect dilation of the lung and empyema are present, the auscultatory symptoms are less characteristic, signs of cavities are lacking, the thorax already shows signs of shrinking.

Among students as well as physicians you often come across the opinion that in suppurating pleurisy, which breaks out in the direction of the lung, pneumothorax may be expected. As a matter of fact, such a thing practically never happens, because the eruption does not occur into the pulmonary parts containing air, but into those imperfectly expanded.

The difficulties in diagnosis described above are intensified when suppurating pleurisy is developed where there are old adhesions; the encysted exudates may simulate invaginated thickenings.

In the sputum the thread-like character of the pus is very noticeable. If the pleurisy was not putrid from the first, the sputum remains, even when the illness has been going on for months, free from putrefaction. whereas this may easily occur in the case of a cavernous suppuration. Under the microscope the sputum reveals almost exclusively *one* kind of microbe, in pulmonary suppuration very various kinds.

At first the perforating pleural suppuration is accompanied by a continuous irritative cough, by means of which small quantities of sputum are thrown off; the opening of the perforation is rarely large enough for larger quantities to be thrown off at the same time as in the case of an abscess; the periodicity of the discharge is, therefore, less pronounced in the case of perforated pleurisy, irregular, less dependent on the position of the body. For days at a time, too, there may be no sputum at all, then there is often a feeling of pressure and fever.

As a matter of fact, the decision whether it is a case of suppuration of the lung or perforated empyema, is often only made during the operation, and not always at once even then.

Many pulmonary abscesses burst very early in the direction of

the pleura; very small, superficial foci may then very quickly lead to circumscribed and also to massive empyema, especially when they are putrid. These cases then appear clinically at first as primary pleuritic foci; even after the operation the connection is often only clear when accidentally a pulmonary slough is found in the suppuration. If the pleurisy is putrid when opened, you can, with more probability, conclude that there is a primary pulmonary focus; it may not be larger than a pea.

In the case of such a pulmonary abscess, breaking through at first only in the direction of the pleura, under certain circumstances the empyema produced by it (total or encysted) may later burst in the direction of the air-passages. This connection is probable when the expectoration from the pleural suppuration is from the first putrid.

That subphrenic abscesses, too, abscesses of the liver, of the mediastinum, &c., like empyema, may burst in the direction of the lung, can only be mentioned here, but not further discussed.

When suppuration develops inside a consolidated pneumonic pulmonary lobe, a closed abscess-cavity may arise, without any connection with the bronchi. This may be conjectured from the continuance and the intermittent character of the fever, the persistence of the dulness and the increase of the so-called consonance symptoms. In very rare cases this stage may last so long that, even without any purulent discharge, an abscess may be diagnosed and an operation be performed; generally an eruption in the direction of the bronchi will have taken place.

COURSE AND CONDITIONS OF HEALING.

Suppurating softening of the pulmonary tissue may, when the suppuration is discharged on the bronchial passage, heal spontaneously; the more easily, of course, the smaller the focus or foci.

Rosenfeld[1] describes such cases with "initial formation of abscess," which were only recognizable by the appearance of elastic fibres in the form of alveoli, and in hæmatoidin crystals; the quantity of sputum was not necessarily increased, nor the temperature curve raised.

The total duration and the condition on auscultation offered nothing abnormal; in four to six weeks the patients had quite recovered. It may well be that such small abscess formations, otherwise without symptoms, are present more frequently, and only escape observation because in all cases of pneumonia the sputum is not examined minutely enough.

But larger, even putrid, abscesses, too, which present the symptoms above described, and when cavities can be demonstrated, may, according to the information of various observers, heal spontaneously in four to eight weeks. This is due here, as

[1] *German med. Press*, 1902, No. 8.

everywhere, to the walls of the abscesses coming in contact with one another, adhering and forming cicatricial tissue.[1]

In other cases, however, the abscess does not heal up, or it increases and fresh foci of suppuration arise through aspiration of secretion to sound portions of the lung; owing to the exhausting suppuration and the hectic fever the patient succumbs. Or, even if the suppuration does not spread, but the abscess is enveloped in a pyogenous membrane, still no healing takes place, and the suppurating discharge continues. The patient may become so accustomed to the regular expectoration from the suppuration, that sometimes he does not know of its existence, or looks upon it as the result of an unimportant bronchial catarrh. This tolerance, or indifference, is one of the main reasons why so many abscess cavities only come to the knowledge of the physician at a later stage.

When the expectoration is of a putrid nature this tolerance is not so great, because the cough is more troublesome and the general health is more upset. The patient himself suffers from the disagreeable smell, those who associate with him suffer generally still more; often it is not so much his own discomfort which brings him to the doctor as the way in which people avoid his company when at home, or at work.

The reason abscess cavities in the lung do not heal more easily is due to the special anatomical conditions of the organ, which make the conditions of healing quite peculiar and require special discussion.

Here, as in every other case, the cicatrization of an abscess takes place by the walls coming in contact with one another, adhering and forming cicatricial tissue. This is not so simple in the lung, on account of its special anatomical conditions and on account of its position in the thorax, as in most of the other organs. The tissue and organs in the vicinity of the abscess must either, when they have been displaced, return to their former position, or, after the cicatrization they are more or less displaced, according to the amount of the fusion of the tissue produced by the abscess. Whereas in other organs only the natural elasticity of the tissue counteracts this tension produced by the scar, in the lung the elastic tension is added, which is exerted in a centrifugal direction by the tension of the organ in the rigid walls of the thoracic cavity. If the abscess is formed in an otherwise normal lung, and if it is not too large, here, too, the adjacent pulmonary tissue (often to an extent which is surprising) may follow the tension produced by the scar, and so compensate for the malformation. In the lower lobe of the lung the mobility of the soft adjoining organs (diaphragm and abdominal viscera) and the mobility of the ribs are favourable to cicatrization.

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[1] K. Wasmer describes six cases observed by me in "On the Spontaneous Healing of Pulmonary Abscesses and Pulmonary Gangrene," Diss., Kiel, 1903. See also a case examined anatomically by Quincke, *Mitteil. aus den Grenzgeb. d. Med. u. Chir.*, vol. i., 1896, p. 1.

In the upper lobe this is not the case; here the firmly closed ring of ribs offers considerable resistance to the shrinking. Even here we do see a moderate loss of pulmonary substance compensated for by the formation of a cicatrix. We find this to be the case in sections without the volume of the lung, during life, appearing noticeably smaller, or the costal arch being altered. When the shrinkage is considerable, the adjacent parts of the lung become emphysematous, the inferior lobe and the diaphragm may even be drawn up, the arch of the upper ribs subsides. This is intensified in cases of pulmonary phthisis with induration of the connective tissues. The more quickly a cavity is formed in the upper lobe, the larger it is, the less can the tension produced by the scar succeed in attracting the neighbouring tissue and the ribs. The cavity remains tense, the more so as its inner surface by communication with the bronchi is under higher pressure than the surrounding pulmonary tissue. Frequently a direct centrifugal tension is added when the lung adheres to the thoracic wall. These powers, hostile to the cicatricial retraction, are least effective in children, in young people with weak muscles, soft bones and flat thorax; they come into play much more in the case of strongly-built individuals with well-developed bones and muscles, and with well-formed thorax, still more in the case of older people with rigid, often emphysematous, thorax.

The cicatrization of purulent cavities is also rendered difficult when the adjoining tissue is not, as it normally is, soft and pliable, but has become harder by abnormal modifications. The longer the illness lasts the more usual this is, as in the case of chronic abscesses, bronchiectasis, and tuberculosis.

The conditions for the discharge of pus from the upper and lower lobes are just the reverse of those in the case of cicatrization. In the upper lobe the direction of the bronchi makes a constant discharge in the direction of the principal bronchus easy, so that an accumulation of secretion rarely occurs. In the lower lobe gravity checks the discharge. Still, as long as it is only a question of the evacuation of the bronchi, the greater mobility of the inferior walls of the thorax, and the strength of the expiratory muscles compensates for this to such an extent that on violent coughing the smaller bronchi are squeezed like a sponge, and this possibility of a more considerable change of volume, namely of a more considerable expiratory minimum volume, puts the lower lobes to a certain extent in a more favourable position than the upper lobes. The predilection of the latter for tubercular disease may, perhaps, be due to the fact that they do not contract to such an extent and so cannot free themselves so completely from the inhaled tubercle bacilli.[1] On the contrary, it is even possible that during violent coughing part of the contents of the lower lobes (air, dust and

[1] The help given by the respiratory movements to the blood and lymph-stream is not so efficacious in the upper lobes; perhaps for this reason the tubercle bacilli deposited in the tissue are not dispatched so successfully here as from the upper lobes to the bronchial glands.

secretion) may be driven into the upper lobes. That this does actually happen we see occasionally by the formation of secondary putrid abscesses in the upper lobes.

But the secretion is only driven out more successfully from the lower lobes so long as the ribs are pliable and yielding, the muscular power good and the pulmonary tissue itself normal. If any of these conditions are lacking a certain amount of secretion remains behind, and that most plentifully just in the diseased (inflamed or chronically indurated) part of the lung. This residue, as in the case of abscesses with incomplete discharge, acts as a permanent inflammatory irritant, and this all the more when the bronchial branches in question are already dilated, or when an abscess cavity is already in existence.

If we compare, then, the conditions of healing in the upper and lower lobes, the chief hindrance in the former is the rigidity of the ribs, in the latter the congestion of the secretion. Therefore the opening of the cavity is less essential in the upper lobe, the main thing is to render the surroundings mobile by extensive resection of the ribs. In the case of cavities in the lower lobe, on the other hand, the all-important thing is to open up the cavity and to draw off the secretion. It will only be necessary to make the walls of the cavities yielding when they are very extensive or of long duration. The following table gives a summary of these conditions :—

	Upper lobe	Lower lobe
Discharge of pus	Easy	Difficult.
Compression on coughing	Slight	Abundant.
Cicatrization	More difficult	Easier.

TREATMENT.

If the pulmonary abscess has burst in the direction of the air-passages, expectoration must be made easier to the patient by placing him in as comfortable and convenient a position as possible ; the position suitable for expectoration must, for the recovery of the patient, be alternated with one as free from coughing as possible. Remedies for arresting the cough must only be used with caution ; on the other hand, stimulants (also liq. ammonii anisatus) are sometimes used.

In the case of cavities in the lower lobe expectoration is furthered most effectually by lying flat, or with the shoulders at a lower level (several times a day for one to three hours—the morning hours are the best from 5 to 8 or 6 to 9, and in the evening from 5 to 7) ; in other cases tests must be made to find the most suitable position.[1]

Luce,[2] in a case of acute pneumonia of the lower lobe, which

[1] S. H. Quincke "On the Treatment of Bronchitis," *Berl. Clin. Weekly*, 1898, No. 24. P. Schaefer "On the Treatment of Bronchial Diseases by Placing in a Slanting Position." *Arch. f. Clin. Med.*, 1909, vol. xcv, p. 276.

[2] *Münch. med. Wochenschr.*, 1911, p. 2585.

was becoming gangrenous, used successfully, as well as the sloping position, a circular bandage compressing the lower parts of the thorax in the position of maximal expiration, in order to procure relative atelectasis and compression of the inferior lobe.

Most important is pure air, free from dust—if possible day and night in the open; full and sufficient respiratory movements which are so important are best furthered in this way.

If spontaneous healing does not take place, surgical help must be called in. Two methods may be employed:—

(1) Opening of the abscess to allow of the discharge of the pus.

(2) Furthering the shrinkage of the lung by making the thorax yielding by removing the ribs; or by producing artificial pneumothorax, allowing the lung to retract and collapse.

The first method is generally selected (especially in acute cases, when the discharge is copious, especially when it is putrid); the opening of the abscess by incision after resection of 6 to 7 c.m. from two or three ribs. By placing the patient in a suitable position for hours, or days, the cavity is emptied as much as possible before the operation, local anæsthesia and morphia to be preferred to general anæsthesia. During the operation the patient lies as far as possible in the position proved to be most free from cough. In this position, then, the cavity fills, which makes it easier to find and open, the longer the time that must elapse between the operation on the thorax and pneumotomy proper. If the discharge is sufficient, after two days often sputum and fever cease; the putrescence of the secretion disappears more slowly, often only after the shedding of sloughs: the inflammatory induration in the vicinity of the abscess cavity demonstrably decreases, the wound shrinks and closes in from three to four weeks, often, certainly, only after a much longer time, namely, when the local diagnosis was not quite correct, or when the partial continuance of the symptoms leads to the supposition that there are other cavities and therefore necessitates an enlargement of the aperture in the ribs and of the incision, perhaps also a second operation at another place.

When the discharge of secretion through the wound is insufficient, this condition is sometimes improved by the suction, for a short time several times a day, of air and secretion by means of PERTHES' apparatus, *i.e.*, an air-pump worked by a jet of water, with a suitable glass funnel or BIER'S suction apparatus adjusted to the skin over the opening of the wound.

Respiration in the apparatus for maintaining increased pressure has the same effect. When an opened abscess was a long time in healing, VAN STOCKUM often saw this successfully applied (twice daily for one hour), the pulmonary tissue surrounding the cavity is made more pliable or more capable of holding air by this means.

As a rule the incision must be made at the point where the abscess cavity is the nearest to the upper surface of the lung, taking into consideration the discharge of pus if possible on the posterior, or it may be, the lateral wall of the thorax, quite exceptionally on the anterior wall. This consideration may even lead

one so far as not to choose the spot nearest to the upper surface, but to prefer to cut through a thicker pulmonary layer.

When the general symptoms point to the existence of one or of several cavities, and to the necessity for an operation, but when the site is uncertain, the following may be remembered: cavities which have been a long time in existence in the majority of cases are situated low down, especially low down at the back, particularly is this true of secondary bronchiectases; the incision should therefore most frequently be made at the back below the angle of the scapula. When on general grounds a cavity is suspected and there is a dulness below at the back without clear local signs of a cavity, then this spot will be chosen because it offers the greatest probability and at the same time the possibility of reaching from this point a cavity in the immediate neighbourhood (medial or lateral, above or below).

Besides the discharge of the pus there is another point to be considered for the healing of the cavity, namely, the mobility of its walls. This must, if necessary, be procured by resection of the ribs. This is particularly necessary in the case of the upper lobes and also in the lower lobes as well when the mobility and powers of retraction of the pulmonary tissue have been affected (see p. 105) by indurations and interstitial thickenings. When this is from the first certain, or probable, as in the case of cavities which have been long in existence, or bronchiectases, a large aperture in the ribs should be made straightaway, otherwise it is only after exposure of the cavity that one can see in what direction and to what extent the chest-wall must be made to yield—whether temporary removal of the bones is sufficient, or whether the reforming of the bones must be avoided by the removal of the periosteum, whether finally the soft parts of the chest-wall and thick pleural indurations must also be removed. Sometimes by their removal the lung which has been compressed can be made capable of expansion and yielding again.

When there is no large cavity, but several smaller dilated bronchi traverse a lower lobe, an opening may be avoided and the chest-wall may be rendered mobile straightaway (extra pleural plastic operation on the thorax).

The second method of using the shrinkage of the lung to heal the purulent cavities is the artificial collapse of the lung by pneumothorax produced by operation. This method has hitherto been preferred in cases of pulmonary tuberculosis and will be discussed more fully when these are dealt with. For its application it is necessary that at least the greater part of the pleural cavity should be free from adhesions. Only in a few cases of pulmonary suppurations is this the case.

Forlanini (*Münch. med. Wochenschr.*, 1910, No. 3), healed a putrid abscess of the left lower lobe, which had been in existence for six years, by continuous treatment with pneumothorax for two years (gradual separation of numerous, tenacious adhesions) with mobility of the lower margin of the lung, controlled after three years.

A third very effectual way of causing the lung to shrink was adopted by SAUERBRUCH and BRUNS[1] by ligature of major pulmonary arterial branches. After the practicability and efficacy of the method had been proved, SAUERBRUCH twice treated putrid bronchitis in human beings in this way, with palliative results.

TIEGEL[2] also caused shrinkage in animals by ligature of the pulmonary veins.

There are cases, however, in which it is impossible even after repeated operations to heal the purulent cavities by opening and by shrinkage of the lung. In these cases it only remains to extirpate the diseased pulmonary lobe, or a part of it (together with indurations and chest-wall appertaining thereto).

Individual Forms of Suppuration of the Lung.

In the present work it is not possible to group the processes with accompanying suppuration strictly according to pathological and anatomical principles, for in individual cases most diverse modifications occur simultaneously or in the course of time, and because in life the different anatomical conditions often cannot be distinguished from one another. It is advisable, then, from the clinical standpoint, to divide suppurating processes according to the following table:—

(1) Acute abscesses.
  (*a*) Acute, simple abscesses.
  (*b*) Acute putrid abscesses and pulmonary gangrene.
(2) Chronic abscesses (and bronchiectases).
  (*a*) Chronic simple abscesses.
  (*b*) Chronic putrid abscesses.
(3) Abscesses caused by foreign bodies.

Pulmonary tuberculosis, as well as actinomycosis and streptothrix-mycosis of the lung, both of which also bring about the formation of abscesses and cavities, will be discussed in special chapters.

In order to complete the general remarks made above, we will now discuss simple points dealing with the pathology and diagnosis of each of the three groups mentioned above.

(1) (*a*) ACUTE, SIMPLE ABSCESSES.

These occur most frequently in croupous pneumonia, owing to the specially destructive influence of the pneumococci, when, through the air-passages, or more rarely, through the blood-ducts, the inciting causes of suppuration enter the focus of inflammation. Certainly these simple abscesses are rare, but not to the extent

[1] BRUNS and SAUERBRUCH, "The Artificial Production of Shrinkage of the Lung by Ligature of Branches and Pulmonary Arteries," *Mitteilnz. aus den Grenzgebieten*, vol. xxiii, 1911, p. 343.

[2] Reports of the Surgical Congress, 1911.

assumed by TUFFIER, who, in the majority of cases, supposes a confusion with encysted, interlobar pleurisy; even if this may happen, it is impossible in cases in which a quantity of elastic fibres are found in the sputum. It is true that it has been observed with certainty that such abscesses can also heal spontaneously, therefore only those require an operation in which the shrinkage of the cavity and cessation of the secretion of pus and of the fever, signs that the healing process is going on, are lacking.

From three to ten weeks are necessary for such healing. During this space of time, therefore, taking all the other circumstances into consideration, it will have to be decided whether an operation shall be performed. Such considerations are also necessary in the case of suppurations in other parts, for example, in cases of empyemæ which have burst in the direction of the air-passages.

The results of pneumotomy are most favourable in the case of these acute abscesses, partly because in most cases the pleural layers are already adherent, but, above all, because as a rule the lung is otherwise healthy, and its tissue can yield to the tension produced by the cicatrization.

(1) (*b*) ACUTE PUTRID ABSCESSES AND PULMONARY GANGRENE.

Putrescence may occur in purulent cavities, or wherever there is an insufficient drainage, in such a way that putrefactive organisms may penetrate into a cavity already in existence and proliferate in its contents; they very rarely, however, penetrate into the tissue of the abscess wall. When exciters of sepsis invade the healthy or inflamed lung before the suppuration is formed, gangrene may occur in the portion of the tissue first met with even before the inflammation begins or immediately it does begin. So that within an extensive zone of suppuration, softening inflammation often only isolated spots develop gangrene, or gangrene may so predominate that, at first, there is hardly any inflammation beside it. These primary gangrenous sites must then first be thrown off further by suppuration. When the enlargement of the focus is extensive (diffuse gangrene), the patients often succumb, even before this takes place, from septic poisoning or from the primary disease.

Even very small gangrenous foci may give the contents of a pulmonary abscess a putrid appearance. Pulmonary shreds and elastic alveolar fibres in the sputum denote progressive decay of the pulmonary tissue; their absence does not prove the contrary, as in the gangrenous sputum ferments are present which dissolve them. It must also be noted that the contents of the gangrenous focus irritate the mucous membrane of the bronchi, and cause it to secrete freely, and therefore the quantity of the putrid sputum makes it more difficult to form a decision as to the size of the focus.

From the above remarks it may be seen that the bad smell of

the pus has a very varied significance as regards the character and prognosis of the diseased process. Small gangrenous foci may be quickly cast off and eliminated through the air-passages or through an opening made by an operation; the putrescence may thus disappear and the abscess become a simple one. This is what happens in many acute aspiration abscesses. Large diffuse gangrenous foci may make the breath smell disagreeably, but putrid discharge only does so when it is accompanied with inflammation. Putrescence is a complication, which need not essentially modify the course of events, although it makes the prognosis worse; for precisely the putrid aspiration foci are frequently at the same time manifold, and then the one focus often leads to other secondary ones. Whether this is present, or is impending, cannot be decided at once on the first appearance of fœtid breath or putrid expectoration, but only on examination of the lung.

Moreover, it must not be forgotten that small putrid abscesses may also heal spontaneously without operation.

Cases of pure pulmonary gangrene are hardly ever seen except on the dissecting table. When we diagnose pulmonary gangrene, and when we get it for treatment, it is almost always accompanied by suppuration; it is a case of abscess and gangrene. It is generally impossible to decide whether the one was there before the other, and what is the percentage of each; often, too, it is impossible to say whether the putrescence may not be secondary. There is the same uncertainty often with putrid suppurations of the connective tissue after serious injuries, but we do not call the process gangrene, but cellulitis, septic cellulitis, cellulitis with gangrene. The same holds good with abscesses of the liver and brain, which may also contain fragments of organic tissue. For this reason I do not consider it right to describe, as LENHARTZ does, the cases operated upon by him as "gangrene of the lung" (pars pro toto!), but prefer for these cases the more comprehensive term, which prejudices nothing, of putrid abscesses.

The question, therefore, whether with putrid acute abscess of the lung an operation shall be performed or not, will be answered according to the same principles and considerations as with acute simple abscess. If the focus has been diagnosed, then the indication becomes certainly much more urgent, just because of the greater danger of secondary foci and of septic poisonings. As a matter of fact, the results in the case of really acute, circumscribed putrid abscesses are not so bad, even if, as it seems, they are less favourable than in the case of simple ones.

Moreover, the following circumstances are worthy of notice: There are, in the first place, small, quite circumscribed bronchiectases, which remain quite unobserved. The pus from them does not attract attention in the expectoration, even when it is somewhat malodorous. But such a small focus may some time or other infect its surroundings when they are perhaps infiltrated with blood owing to trauma, or are attacked by acute, croupous inflammation, perhaps even without this. Clinically, such a case appears as acute, simple, or putrid abscess, whereas the whole

thing proceeds from an old, though often very small, focus. In the second place, extensive bronchiectases, seen anatomically to be old, may exist without any perceptible symptoms ; they are only infected on the occurrence of bronchitis or some other incident, and then give rise secondarily to an acute abscess or simulate one.

It remains to answer the question: Should a fresh focus of gangrene, not yet delimited, be operated on? I should answer the question in the affirmative, not, of course, in the sense of extirpation, but of exposure and incision in order to obtain an outlet and lessen the danger of secondary foci. But only very rarely will it be possible to diagnose the locality of such fresh gangrenous foci (perhaps in the case of foreign bodies or a gangrene proceeding from the immediate surroundings) ; as a matter of fact, up to the present, they have only been opened when the operation was really being performed on a purulent focus already in existence.

Here must be mentioned the cases of circumscribed subpleural gangrene, which only make themselves perceptible, or only first make themselves perceptible, clinically through the pleurisy resulting from them. They do not really belong to our subject, for when the empyema is opened the gangrene focus is also indirectly drained, from which often later sloughs are spontaneously cast off, and which only very exceptionally necessitates an operation on the lung itself (*cf.* p. 103.)

(2) (*a*) CHRONIC SIMPLE ABSCESSES AND BRONCHIECTASES.

These arise from acute abscesses not healed up ; they are always surrounded by more or less dense, unyielding, pulmonary tissue, in this, therefore, congestion of secretion in individual bronchi, and, consequently, the formation of terminal cylindrical bronchiectases very often results, all the more easily as the abscess pus, through aspiration, infects here or there the bronchi, hitherto healthy, and the adjacent ramifications are naturally most exposed to this danger. The aspiration of pus may also give rise to actual secondary abscesses through fusion.

Primary bronchiectases arise through lack of mobility and congestion of secretion from chronic bronchitis of long continuance, therefore preponderatingly in the lower lobes, also in circumscribed fœtal imperfectly expanded foci, and, finally, where by cicatricial contraction, consequent on prolonged pleurisy on the one hand, one part of the lung has become insufficiently expanded, and on the other hand, by the tension produced by the scar and the ribs moved by respiration, an eccentric tension has been exercised on the bronchial walls. In the first case the bronchiectases are generally more cylindrical and bottle-shaped, in the latter they are more pouch like. Sometimes with these processes stenoses are formed at different places in the bronchial tube ; these naturally favour congestion and formation of pus. Often a whole upper lobe is trans-

formed into a series of bronchiectatic cavities with connective tissue between them.

Just as the chronic pulmonary abscess very often leads to secondary bronchiectases, so on the other hand, from the primary cylindrical, and still more from the pouch-like bronchiectases, abscesses may arise, when the mucous membrane is ulcerated and the suppuration encroaches on the pulmonary tissue. So, almost without exception, we get chronic abscesses and bronchiectases together and very often more than one; even the anatomist often cannot decide whether a cavity has been primarily caused by an abscess or by a bronchiectasis. Therefore, clinically, chronic abscesses and bronchiectases can only very rarely be separated from one another, and only sometimes, by a knowledge of what has gone before, be distinguished from one another with a certain amount of probability. But for the treatment this does not need to be taken much into account; the question as regards the treatment is rather: Is there a large cavity or are there several small ones? Where is it located? Are they stationary, or are they increasing? Only rarely are all these questions to be answered with some certainty. Here we are conscious of the difficulties of diagnosing the focus discussed above, and that not so much that a cavity is not recognized, but that, in addition, cavities which are in existence, either in the vicinity, or what is much more serious, in far distant parts, remain undiscovered. Here, the knowledge that a preponderating number of these cavities are situated in the lower lobe is of some assistance.

In all chronic cases the process of shrinking and the collapse of the cavities in the diseased portion of the lung must, above all, be made possible and promoted. Therefore pneumotomy must be combined with an ample resection of the ribs; this makes both the discovery and opening up of any possible secondary cavities easier. Often in these cases, according to the condition and results many subsequent operations are required, so that the treatment may extend over several months. Often by removal of compressing pleural indurations the atelectasis can be removed from one part of the lung, more frequently numerous bronchiectatic tubes and sacs are placed in such dense indurated tissue that shrinkage is impossible; then a permanent fistula may at least bring relief, the secretion of the cæcal pouches passing circuitously through a major bronchus to the fistula.

When, from the first a major cavity is to be excluded, and only several cylindrical bronchiectases to be allowed for, the evacuation of the pus seems impossible and pneumotomy purposeless. Here the simple extensive removal of the ribs is indicated (extra pleural plastic operation on the thorax). Often, certainly, in the course of the operation, it will happen that pleural indurations have also to be removed if the thoracic wall is to be able to yield sufficiently to the tension of the shrinking lung. When this is not sufficient, the whole of the pulmonary portion traversed with cavities can be extirpated. Instead of this SAUERBRUCH has brought about the obliteration of the whole lobe by ligature of the pulmonary arterial ramifications.

The demeanour of the pleura when chronic abscesses and bronchiectases are present is very varied. Whereas some of the latter owe their formation to pleurisy which has given rise to indurations, others are due to chronic bronchitis through the congestion of secretion; these latter cases just the same as central chronic abscesses may run their course without the pleura being involved at all.

In these cases, as in the case of tuberculosis, an attempt may be made to produce the retraction and shrinkage of the lung by artificial pneumothorax. As compared with the extra pleural plastic operation on the thorax, this operation is less dangerous and less far-reaching, but on account of the necessity of repeated compression, it requires more time and more patience on the part of the invalid. Certainly the decision whether the pleural cavity is maintained or not, is made more difficult because, in these cases, the lung is also considerably affected in its elasticity and respiratory mobility. One can then only be certain of the condition of the pleural cavity on the initial incision for the induction of pneumothorax. The results attained by AD. SCHMIDT with this method in cases of bronchiectasis are certainly not very encouraging.

(2) (*b*) PUTRID CHRONIC ABSCESSES AND BRONCHIECTASES.

The same difficulties of diagnosis as in the case of simple hold good in the case of putrid chronic abscesses and bronchiectases, with the added difficulty that in this case secondary foci often in quite distant and unusual places are more frequent, and that acute gangrene and inflammation supervene more frequently. When the patients are brought to the doctor for these, he is often, owing to faulty anamnesis, ignorant of the existence of the old trouble, and thinks he has before him only an acute illness.

Moreover, there are cases in which by the smell and nature of the sputum one may be in doubt whether they are to be reckoned as simple or as putrid. Often the nature of the sputum on different occasions varies according to whether it has originated in a very putrid or a less putrid cavity.

The resorption of the contents of the cavities varies according to the nature of the wall of the cavity and the condition of the bronchial mucous membrane; this is of importance for the general health. Deterioration of the general condition is often a more certain indication of the progress of the disease than the local condition. This is not only due to the fact that through aspiration of secretion fresh foci of inflammation and gangrene spring up, but also because the wall, often thin, of an old bronchiectatic cavity is destroyed by ulcers and the contiguous pulmonary tissue becomes directly gangrenous. Elastic fibres in the sputum are more frequently absent in these chronic putrid cases than in the acute ones.

It is very difficult in diagnosis to distinguish putrid cavities in

the lower lobe from simple putrid bronchitis, which are localized in a lower lobe and by peribronchitic infiltration may cast a shadow in the X-ray photograph; the discharge of sputum may also in this case occur periodically and slight bronchial breathing be heard. This condition may easily lead to the supposition of a local purulent focus.

The indications for an operation are the same in the putrid cases as in the simple chronic ones, only strengthened by the greater danger of the disease. The treatment by collapse of the lung seems here less rational than the more radical treatment by pneumotomy and pneumectomy. Certainly the patients, usually very enfeebled, offer very little power of resistance after these operations.

The results are much less favourable in all chronic, and especially in putrid, cases than in the acute ones.

In individual cases the prospect of success is specially doubtful owing to the uncertainty of the diagnosis as to the extent of the process; after extensive operation it may happen that there are still cavities which cannot be operated upon.

KÖRTE in 21 cases of bronchiectasis had only 4 cures, 11 deaths. In the Kiel Clinic, from 1901 to 1908, in 7 operations for bronchiectasis, I only had two cases of improved condition and 5 deaths; moreover, the reason for the bad result, or incomplete success of operations for abscess, was the presence of numerous concurrent bronchiectases. SAUERBRUCH found in 123 cases collected by him, 33 per cent. cured, 6 per cent. improved, 27 per cent. not cured, 35 per cent. died.

Specially unfavourable is the prospect when extensive bronchiectatic foci must be expected on both sides; KÖRTE and others consider these cases as unsuited for operation. On the other hand, the prospect of a cure without an operation in these chronic cases is absolutely nil, and the condition is almost as unbearable for those round the patient as it is for himself. The circumstances and character of the patient, as well as of the doctor, will therefore be decisive in settling whether the operation shall be risked or the invalid left to his fate; sometimes, too, the site of the cavities and the result is better than was anticipated. Certainly the statistics will not be improved by operation on such cases.

(3) ABSCESSES CAUSED BY FOREIGN BODIES.

As we saw, foreign bodies, often of very small dimensions, which only act as conveyers of bacteria, help in the formation of many abscesses, especially putrid ones. Those abscesses only are described as "Foreign Body Abscesses," in which a foreign body in the surgical sense (therefore, with a diameter of some millimetres, generally larger) is present.

For the general diagnosis and treatment of foreign bodies I must refer you to Chapter IX; here only the abscesses caused by them will be discussed.

First of all the foreign body, wherever it remains stationary, makes an ulcer caused by pressure in the bronchial mucous membrane, which, according to the size and hardness of the body, may encroach on the adjacent pulmonary tissue and change into an abscess cavity. This takes place quickly or slowly, in days or weeks, according to the magnitude of the mechanical—above all, however, of the bacterial—irritation produced by it. Often months pass before an abscess is formed.

The presence and nature of the foreign body cannot always be ascertained. The illness is often only considered to be an obstinate case of bronchitis, when the aspiration of the foreign body is either not noticed on account of accompanying circumstances (*e.g.*, intoxication) or, if suspected at first, completely forgotten later on. In many a slowly developed suppuration of the lung of uncertain origin, finally a foreign body is discovered.

Most of these abscesses when they come under observation are no longer clean, but are putrid, and therefore belong to the cases in Group (2) (*b*) (p. 114); they, too, easily lead to secondary aspiration cavities and to bronchiectases. Often these purulent cavities are larger than the abscess cavity round the foreign body itself, which, however, is generally too large to get near to the upper surface of the lung, so that it maintains permanently a central position. Perhaps the frequent absence of pleural adhesions in abscesses caused by foreign bodies (TUFFIER) is connected with this position.

In the case of an obstinate bronchitis limited from the beginning to one pulmonary lobe with very purulent or even putrid secretion one must always think of a foreign body even if the X-rays do not bring it to light; the supposition becomes more probable when the right lower lobe is attacked. In the majority of cases the foreign body gets there owing to the form of the ramification of the bronchial trunk.

If, in the case of a putrid abscess, one is in doubt whether to operate or not, the indication for an operation will be much strengthened or even become obligatory when a foreign body is suspected, or known to be present. Certainly, hitherto, its immediate removal during the operation has rarely been achieved, in most cases only later, if at all, did it become loosened and ejected, or coughed up.

The change of volume of the bronchi owing to the respiratory movements, perhaps also to active movements of the bronchial muscular system, seems to be favourable to a movement along the line of least resistance toward the major bronchi; the following observation favours this point of view: In the case of an old putrid abscess in the lung on the right below at the back with bronchiectases, pneumotomy was performed and the pus from four fistula mouths was fairly successfully evacuated; ten weeks after the operation a bit of a chicken bone which had been in the lung for three years was thrown up during a fit of coughing. Into the largest of the fistulæ, which had a tendency to shrink, a Nélaton catheter was inserted by way of drainage, fastened with thread and

adhesive plaster and changed daily. On the third day, during a violent fit of coughing, the catheter (4 cm. in length, 5 mm. in width), which must have been insecurely fastened, was thrown up *per os*, with the threads hanging on it. The patient had had no inconvenience from the presence of the foreign body in the bronchi, except for the last violent coughing, and was surprised by its appearance in his mouth. Its smoothness and cylindrical shape had, of course, greatly favoured the movement of this foreign body.

If there is such an abscess caused by the presence of a foreign body with a quantity of putrid secretion, then, even without a very definite local diagnosis of the cavity, a bronchial fistula under the angle of the right scapula is to be recommended, for even if the primary abscess is not found, one can at least hope, by drawing off the putrid secretion from one bronchus, to prevent the formation of secondary foci.

Results and Indications of the Surgical Treatment of Pulmonary Suppuration.

If we now glance back at the surgical treatment of pulmonary suppurations just discussed, the results are very remarkable (*cf.* p. 132);[1] a large number of the patients are cured or very much improved, whereas, otherwise they would either have succumbed fairly quickly to the suppuration, or, avoided by all around them, slowly pined away. The most favourable are the acute abscesses; in these cases healing may be so complete that only the cutaneous scar remains visible, the state of the lung and thorax being quite normal. But even when the region of the scar reveals under auscultation and percussion slight abnormalities, when the mobility of the lung or even the shape of the ribs has suffered somewhat, still the respiratory functions and ability to work can fulfil all claims made upon them.

Often some cough and sputum still persist, caused by the diffusely diseased bronchial mucous membrane, sometimes also to some extent by the remains of the cavities which have not been completely destroyed. But often these can be removed by a second operation.

The results are much less favourable in the case of chronic suppurations, whether abscesses or bronchiectases, or, as frequently happens, both combined. Here the surrounding pulmonary tissue has lost its elasticity, the connective tissue of the cavities is modified. The special diagnosis being more difficult and uncertain, these cases generally offer less prospect of success the older they are.

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[1] Out of forty-one cases of pulmonary abscess, which came under my treatment from 1901 to 1908 in the clinic in Kiel, seventeen (mostly for extraneous reasons) were not operated upon. Of the twenty-four who were operated upon, fourteen were cured, three considerably improved (small fistulæ, hardly any sputum), seven died.

Accompanying putrescence makes the acute, as well as the chronic, cases more difficult, the operation, therefore, all the more necessary, because spontaneous healing is still less likely.

There are not a few cases, moreover, among these chronic ones, in which the number and position of the cavities do not allow of any considerable and lasting diminution, or in which the patients refuse to allow really necessary operations to be performed. In some of these cases the opening made by the operation remains as a permanent bronchial fistula, and must indeed be preserved in such cases when by this means a considerable quantity of secretion from the bronchi and cavity, often of a putrid nature, can be thrown out. Even if such a fistula is disagreeable and necessitates continual care of the patients, still the cough and sputum, as well as the risk of secondary pulmonary foci, is so much lessened, that even in such cases the patients have derived considerable benefit from the operation ; in one case which came under my observation the fistula was endured for twenty-eight years, during which the patient was able, though with some difficulty, to go on with his work. Such a bronchial fistula differs from other fistular parenchymous suppurations, in that the purulent cavities are being constantly compressed and flushed with air and the resorption of the wound is trifling.

To sum up I lay down the following **principles for operating on pulmonary suppurations.**

(1) Pulmonary suppurations are to be treated surgically on principle, above all acute ones, so that they may not become chronic.

Acute suppurations may, it is true, with special treatment heal up without an operation, and may therefore be observed from three to eight weeks before being operated upon. But if there is profuse secretion fever, decrease of strength, increase of the focus of disease (many elastic fibres in the sputum !), risk of secondary foci, pneumotomy must be performed as soon as the diagnosis has been made.

(2) Putrescence and accompanying gangrene make the operation imperative.

Only in the case of small septic foci, otherwise healthy lung, slight secretion and good general condition can one wait ; they may heal spontaneously.

(3) In cases of acute, diffuse gangrene an attempt may be made, if a local diagnosis is successful, to make an incision in the focus and to drain it ; result very doubtful.

(4) Also in the case of chronic abscesses and bronchiectases an operation is to be recommended on principle ; here extensive resection of the thorax is as important as the opening of the abscess.

(5) When the secretion is slight (not putrid) success has been achieved also by mere collapse of the lung (extra-pleural thoracotomy or artificial pneumothorax). On this point, especially as to the selection of suitable cases, the results of experience must still be collected.

(6) Pulmonary lobes transformed by bronchiectasis should be resected.

(7) When there are several cavities each case must be decided on its own merits; in acute cases, adjacent cavities, it may be also such adjacent lobes, should be, if possible, opened up at the same time, if not the operation must be repeated; this, too, when both sides are attacked.

(8) In chronic cases with several cavities in one lobe, extensive fissure or resection of the lobe.

If two lobes on one side or even both lower lobes are affected, this is generally taken as a contra-indication of any operation—certainly not quite rightly; it depends on the extent to which each lobe is diseased and the size of the cavities. I would refer to the considerations given p. 116.

(9) Even incomplete healing of a pneumotomy with permanent bronchial fistula may be of considerable benefit to the patient.

(10) Pleural adhesions, it is true, make pneumotomy easier, but are not a necessary preliminary condition.

(11) Profuse hæmoptysis demands, when the local diagnosis of the source is possible, opening and plugging of the cavity (when collapse of the lung by artificial pneumothorax is otherwise indicated and possible, this may also assist in arresting the hæmorrhage). *Cf.* chapter on tuberculosis.

Surgical Technique of Suppurations of the Lung.

With reference to the surgical treatment of the purulent cavities of the lung two important points of view must be borne in mind. First, the prophylaxis of the infection of the pleura. Empyema is a serious complication, generally fatal; to avoid it is one of the most urgent necessities.

Second, the principle that chronic abscesses and disintegrating cavities of the lung must be treated in general according to the principles which dominate operations on purulent cavities with rigid walls—that is, by rendering the walls mobile.

An acute pulmonary abscess, fairly recent, may perhaps be healed by mere incision and drainage, just as an abscess cavity may close spontaneously after perforation of the bronchi. In these cases the pulmonary tissue has retained sufficient elasticity to make the shrinkage of the cavity possible.

In all cases of subacute and chronic focal disease, and when an acute affection is of long standing, the surrounding pulmonary tissue has become indurated, the adjacent pleura is very much thickened; to this must be added the rigidity of the thoracic walls. If the two pleural layers are adherent, then, as QUINCKE describes it, the pulmonary cavity between the thoracic walls is kept in a state of tension. In all these cases—and they are in the majority by far—the only possible successful treatment is the combination of pneumotomy and extensive costal resection.

Until recently, insufficient consideration has been given to this

point of view. Many failures, especially cases of incomplete healing, are to be explained by the inadequacy of the surgical treatment.

For the preparations for the operation, and the question of anæsthesia, and local anæsthesia, &c., I must refer to the chapter on "General Surgical Technique."

The kind of incision selected for the thoracotomy (flap-incision, longitudinal or vertical) is not of very great importance. The only important thing is a sufficient resection of the ribs over the diseased lobe to render the chest wall mobile, for then only do we get the necessary preliminary condition for the cicatrization of the pulmonary parenchyma. One begins with the resection of an opening in the thorax of about 10·6 cm., which serves for purposes of investigation; and the enlargement of this opening depends entirely on the position and extent of the pulmonary focus. Here, too, I would add emphatically, rather one rib too many than one too few!

As regards the prophylaxis of the infection of the pleura, this is best secured by synechia of the pleural layers, or by adhesions within the range of the field of operation.

Many surgeons, therefore, hold fast to the standpoint only to operate in the case of gangrene and abscess when the lung is adherent. This considerably limits the field of operation. Although, according to present statistics, in 87 per cent. of the cases adhesions were present, it must not be forgotten that—just because it was customary to wait until these formed—there were many late operations among them. If you follow modern indications, according to KÖRTE, you can only count on sufficiently protective adhesions in half the cases. Side by side with the great disadvantages of a delayed operation, when there is progressive inflammation, the final obliteration of the pleural cavity has certainly some advantages which are not to be despised. More important than all are firm superficial pleural adhesions. Slack distensible adhesions may prevent pneumothorax, but do not always act as a barrier to infection.

Unfortunately, the presence of pleural adhesions cannot always be demonstrated with the certainty desirable before the operation. Even when undoubted symptoms of adhesive pleurisy have been noticed beforehand, really superficial adhesions may be absent. Inspiratory inhalations in the intercostal spaces, the needle test, the interpretation of the diascopic condition—even the results of auscultation and percussion—everything may mislead.

The practical importance of these methods is not great, for if in other respects pneumotomy is indicated, the demonstrated absence of pleural obliteration is no counter-indication, all the less, as we possess means to lessen the risk of infection of the open pleural sac.

Whoever esteems the value of adhesions so highly that he will only venture on pneumotomy under their protection has artificial means at his command to produce such adhesions. Certainly none of them seem to be quite certain in their effect.

QUINCKE has frequently applied chloride of zinc paste, later a plug soaked in a solution of chloride of zinc, to the bared intercostal muscles, but in individual cases, in spite of repeated applications in the course of two to three weeks, he did not obtain adhesions sufficiently solid and extensive.

Others have put in needles and left them there several days (DE CÉRNVILLE), or injected tinctures of iodine, hydrarg. nitr., &c., or applied cauterization or electrolysis. Others have sutured the lung perpleurally, but here, also, the result was incomplete.

If a twofold operation is decided upon, which naturally is only possible in cases which are not urgent, then it is best, after resection of some of the ribs, to apply a tampon of iodoform gauze (NEUBER) for about ten days to the pleura. Then adhesions are formed in the vicinity, but too much must not be expected from such artificially produced fresh adhesions. If they are limited in extent not much is gained, for the fresh and still loose adhesions are easily set free. Firm adhesions capable of resistance are always the result of inflammation.

Apart from the inadequacy and uncertainty of artificially produced pleural adhesion, in all cases of acute suppurations and gangrene, especially where there is danger in delay, the twofold operation is prohibited. We must, therefore, find a way of drawing off purulent foci with the pleural cavity free—that is, not closed by adhesions.

The precautions against contagion of the pleura consist in careful closure by suture and plugging. You make a circular suture round the site of the pneumotomy or the recognizable focus of inflammation on the upper surface of the lung; C. ROUSE recommends the uninterrupted suture with back stitches. In order to avoid the rending of the suture, pulmonary tissue, as well as intercostal muscles, must be included — so a costo-pulmonary suture—for with pneumothorax the retractory force of the lung must be reckoned with.

KÖRTE prefers a simple "U" suture, into which he ties a tampon. When the sutures are cut through or rent, one must manage with a simple plugging; it is, then, important to leave the tampon lying quietly for eight days. So VAN STOCKUM once opened up a bronchiectatic cavity from the base of the lung. He fixed the pulmonary margin to the wound in the thorax, and placed compresses between the diaphragm and lung, leaving between them a narrow passage for the opening and drainage of the focus. The pleura escaped all infection (*cf.* chapter on "General Technique," fig. 36).

We now come to the most important part of the operation--to pneumotomy, the finding and opening up of the focus.

If indurated dense pulmonary tissue with thickened pleura is present over a focus near the upper surface, then it is best to use a knife; in a case of soft pulmonary parenchyma, rich in blood, I prefer the Paquelin cautery.

Severe hæmorrhage is not to be feared so long as the operation is performed in the peripheral parts of the lung—the nearer to the

hilum, the sooner one must be prepared for arterial, or venous, hæmorrhage. It is, therefore, a mistake, which may often be fatal to the patient, for a channel 6 to 8 cm. in length to be cauterized, in the pulmonary tissue, when the focus lies low down. The field of operation must remain visible and accessible, in order that a larger blood-vessel may be held with a long clamp, if necessary, ligatured, or acupressure applied.

It is difficult, often very difficult, to find the focus correctly diagnosed, when it lies low down in the lung towards the hilum or the base of the lung. A good aspiration spray with thick cannula, with a lateral opening near the point does excellent service in this case; repeated punctures in the opened lung are not attended with the same risks as is the puncture, so beloved for diagnostic purposes, in the closed pleura, which has often led to a sudden death.

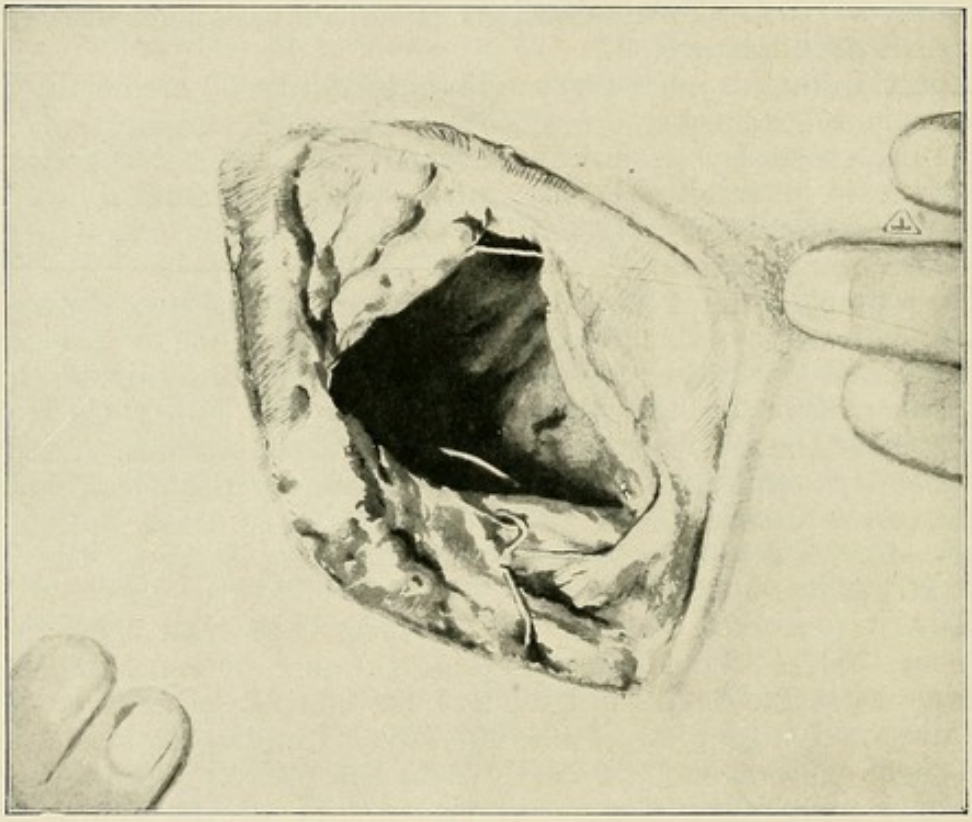

FIG. 50.—Wide opened, low-lying gangrenous cavity.

If pus is taken in by aspiration, then let the hollow needle lie and proceed alongside of it low down, with careful arrest of hæmorrhage, by acupressure by the application of clamps. The forcible drawing of a dressing forceps in the direction of the cavity is not without danger; it is better to enlarge the channel of the wound in the shape of a funnel down to the cavity. Then the cavity is opened wide, emptied and carefully cleansed with tampons. Necrotic fragments of the lung are, of course, removed, gangrenous parts, which have not yet freed themselves, are left, so as to

avoid unnecessary hæmorrhage ; the same holds good with cords and transverse ridges which are generally found in gangrenous cavities ; they contain major blood-vessels. It is a good thing to ligature them, for they generally have aneurismal dilatations, which easily rupture ; not infrequently there are aneurisms in the wall of the cavity.

A danger not to be underestimated is embolism, caused by the entrance of air. The infiltration of the parenchyma, the lung fixed by adhesions favours its formation on deep inspiration. The application of the method of maintaining difference of pressure (especially of decreased pressure) averts this generally fatal complication.

A careful investigation of the cavity is strongly to be recommended. KÖRTE applies cocaine to the wall of the cavity and searches it with the help of a frontal mirror or cystoscope, for secondary cavities and pouches which must be laid open into the main cavity with dressing forceps. We must urgently warn against the douching of the cavity—with anything whatsoever—even if it does not give rise to coughing, infectious matter can easily be carried into the bronchi and foci of bronchitis formed, twice as easily in complete anæsthesia. Many times patients on the operating table have been suffocated in consequence of the douching.

The cleansed cavity is then, if the hæmorrhage is not quite arrested, plugged with iodoform gauze ; in doing this care must be taken that no gauze is put into a bronchus, as the irritation excites cough. Or else a drainage pipe is inserted, swathed in gauze, and fixed.

Most surgeons consider—as I have seen by a perusal of reports of operations—that the operation is now complete, and I also think that this procedure has attained its end in the case of recent acute abscesses, and prepared the way for an uninterrupted cure. But for this to be the case, not only must the thoracic wall be yielding and offer no resistance to the cicatrization of the cavity, but the pulmonary tissue must not have become rigid and unyielding through reactive inflammation.

When these conditions are lacking—as in the case of all chronically inflamed processes—then the healing, if possible at all, will only take place in a hesitating manner and often only after many complications. These are the cases in which, after a pleasing improvement at first, there is a pause, during which the wound remains open for many months, when chronic bronchitis persists and finally bronchiectases are formed.

I have already pointed out that such pulmonary cavities must be treated as rigid-walled purulent cavities. The pulmonary tissue is freely opened, the anterior wall of the cavity removed as far as possible, pleural indurations anywhere in the proximity resected, and, if necessary, another secondary resection of the ribs is added. It is better to resect one rib too many than one too few. The larger the cavity and the more rigid the wall, the more drastically must the surrounding pulmonary parenchyma be removed.

No one will expect by this procedure to further the immediate results of the operation ; perhaps the contrary is rather to be

feared, if sufficient consideration is not paid to the state of the patient's strength; but I am convinced that the permanent results will be improved in all chronic cases. QUINCKE, who has had a wide experience in this respect, pointed out years ago the uselessness of the mere opening of chronic abscesses, because the pus is not under pressure, but the cavity in the thorax is tense. I, therefore, also agree with GROSS,[1] who says: "the pneumotomy must be enlarged—the greater number of the many failures may be explained by the inadequacy of the operation hitherto usually performed."

In accordance with this, PERTHES has recently proposed "first to open up and drain" the chronic pulmonary abscess, and "to perform the operation for the removal of the abscess cavity later on when the patient's general condition is better. The pneumotomy for the opening of a chronic pulmonary abscess is appropriately performed at two different times. The first part, the resection of the ribs and the pleural suture, takes place under anæsthesia with the abscess evacuated; the second part, which follows a few days later, consists of the exploratory puncture of the abscess, which is kept full, from the wound and in its opening without general anæsthesia."

Some time later, and after extensive secondary resection of the ribs, PERTHES completely cured the rigid-walled cavity, as big as a fist, which was left behind, which gave off muco-purulent secretion and which, from the bronchial openings onwards, was made partially epithelial by extirpation of the whole indurated wall of the cavity. For the closing of such cavities with bronchial fistulæ practically the same methods are used, as those fully discussed in the chapter "Bronchial Fistulæ."

TUFFIER'S attempt to induce compression and cicatrization of an abscess cavity by the implantation of a lipoma or a piece of omentum, &c., may be mentioned here (*Bull. et Mém. Soc. chir.*, Paris, January 25, 1911). In this way he hopes to avoid pneumotomy and its risks. But in cases in which such an implantation succeeds, a simple plastic operation on the thorax would also attain the end. I can unhesitatingly pronounce the method to be irrational.

The immediate success of the opening and evacuation of the purulent cavity is shown by the rapid diminution or complete cessation of the sputum; in putrid suppuration the putrescence ceases on the following day. The patients feel in consequence fresh vigour, in spite of the pain of the wound, for the penetrating odour of the sputum had completely taken away their appetites—now the appetite returns, and they improve perceptibly.

If the sputum still remains copious and retains its putrid smell, this may be due to insufficient incision in the cavity, or insufficient drainage (retention of secretion), or unopened purulent foci are still left behind in the lung. A renewal of putrescence in the sputum points to retention of secretion or the formation of fresh gangrenous

[1] GROSS (KRAUSE), *Beiträge zur klin. Chirurgie*, vol. xxiv, 1899.

foci through aspiration. If a revision of the wound cavity does not clear the matter up, it is advisable to examine the lung in front of the Röntgen screen or with plates.

The temperature does not go down as rapidly as the quantity of sputum decreases. It is true that after the evacuation of an isolated abscess, which has not perforated the bronchi, the temperature quickly goes down to normal. But this is not the case with gangrene and acute bronchiectasis. For in these cases the fever is not only maintained by the retention of pus and sputum, but also by complications, such as pneumonic infiltrations of greater or less extent, pleuritic exudates, &c. These, however, yield only slowly; the reduction of temperature, therefore, often only takes place after two to four weeks.

In the after-treatment, the cavity is best packed with damp gauze. Peroxide of hydrogen or aluminium acetate are to be recommended; the iodoform gauze tampon or gauze impregnated with balsam of Peru (KÖRTE) also does good service. The first tampon is left about four days; if the secretion is copious, a drain, wrapped in gauze, is inserted.

It should be remembered that a good closure of the pulmonary wound makes expectoration much easier; this is specially important when bronchitis is present. When major ramifications of the bronchi open into the cavity, this, in conjunction with the pain from the wound, may bring about very threatening conditions (dyspnœa, cyanosis, irregular pulse). VAN STOCKUM brought about an immediate improvement in such a case, by covering the wound with a gutta-percha tissue. Still the tampon must not be inserted too tightly on account of damming back secretion. If the change of dressing is followed by an irritating cough, which lasts for some time, the reason generally is that a tiny end of gauze is projecting into a bronchus; cough irritation occurring later is generally the consequence of retention of secretion or difficulty of expectoration.

For the cicatrization of the wound in the lung, too, the method of plugging is important. From the third week onwards the wound in the thorax generally closes quickly, the wound in the lung cannot generally keep pace with it, and so it happens, if no attempt is made to regulate this inequality in the process of cicatrization at the right time, that a fistula is formed in the thorax owing to the discharge of secretion being hindered. The difficulty of gaining access to the cavity makes a careful plugging impossible; a drain does not perform the same service. It is advisable, by means of loose plugging within to keep the thoracotomy wound forcibly open from the beginning with gauze. By so doing, the pulmonary wound closes well, which makes expectoration easy to the patient.

A slight elastic compression of the side operated on is said to hasten the cicatrization of the wound cavity. It would be perhaps more expedient to let the patient once or twice a day for ten minutes breathe air under increased pressure; that not only helps to get rid of the secretion, but also expands the surrounding insufficiently dilated pulmonary tissue. When the parenchyma of

the lung is not indurated and the chest wall is sufficiently yielding, as in the case of young people, the healing of even major cavities takes place so extraordinarily quickly, that is, in about eight to ten weeks. Smaller cavities heal up in about a month.

In acute processes it is really astounding how quickly the cavity shrinks. This is specially striking in gangrenous cavities; the surrounding pulmonary tissue is little modified, so after the sloughing of the necrotic tissue the freely removable elastic parenchyma follows, and there is a smooth cicatrization. The cicatrice, at first slight, and a finger wide, may, in the course of a few years, so completely disappear, that at the autopsy, the place where there was a gangrenous cavity as big as a fist, can hardly be found.

Chronic abscesses, like tubercular cavities, heal up with a dense radiated scar. The healing takes much longer than with gangrenous foci, and this because the surrounding tissue for some distance has become indurated.

If the shrinking of the pulmonary cavity is delayed, the pulmonary wound from the bronchi and bronchioles onwards becomes epithelial, which then generally gives rise to the formation of a pulmonary fistula. Such a wound, having become epithelial, looks very like a pulmonary wound covered with delicate flat granulations. A microscopic examination explains the process.

Large bronchial lumina opening into a pulmonary cavity, probably on account of their rigid walls, and perhaps also in consequence of the sustained bronchitis, may also delay the healing. Generally with chronic abscesses troublesome bronchial fistulæ are left behind, which necessitate another operation.

In the course of the after-treatment one must be prepared for secondary hæmorrhage. This may occur spontaneously through erosion of larger blood-vessels on the demarcation of necrotic parts, or through pressure produced by the drainage-pipe. If the bleeding vessel cannot be seized by a clamp, one must be content with a firm iodoform gauze plug, left for some days; but a return of the hæmorrhage is then to be feared. Little is to be hoped from injections of gelatin.

Among other complications after operations on the lung must be mentioned septic pneumonic processes. They generally have their origin in the purulent infiltration surrounding a pulmonary focus, or in little disseminated broncho-pneumonic spots. Infection is also possible from the surface of an incision in healthy pulmonary tissue with putrid bronchial secretion, easily comprehensible with the great lymphatic system of the lung. Unfortunately many patients succumb to this septic pneumonia after two or three weeks, who could at first have successfully borne a severe pneumotomy, and could have been expected to make a complete recovery. A very carefully and skilfully perforated plugging of the wound cavity, which, when frequently changed, absorbs the secretion from the wound and so prevents any stagnation, would be the only remedy of prophylactic importance.

Pleurisy and empyema must also be mentioned as complications. These may originate in various ways: either directly from the

wound owing to insufficient pleural adhesions or inadequate suture, or from other subpleural purulent foci, or as metastatic suppuration (pyæmia). Encysted empyemæ, especially the interlobar and epidiaphragmatic empyemæ, are generally very difficult to diagnose.

I have observed severe nephritis with hæmorrhage as a complication in the case of bronchiectasis. Cellulitis of the chest-wall is relatively rare.

The same principles hold good in operating for bronchiectasis as for other local diseases. From the site of pneumotomy several adjacent cavities are opened and drained. Unfortunately such a procedure has often proved completely inadequate, because generally

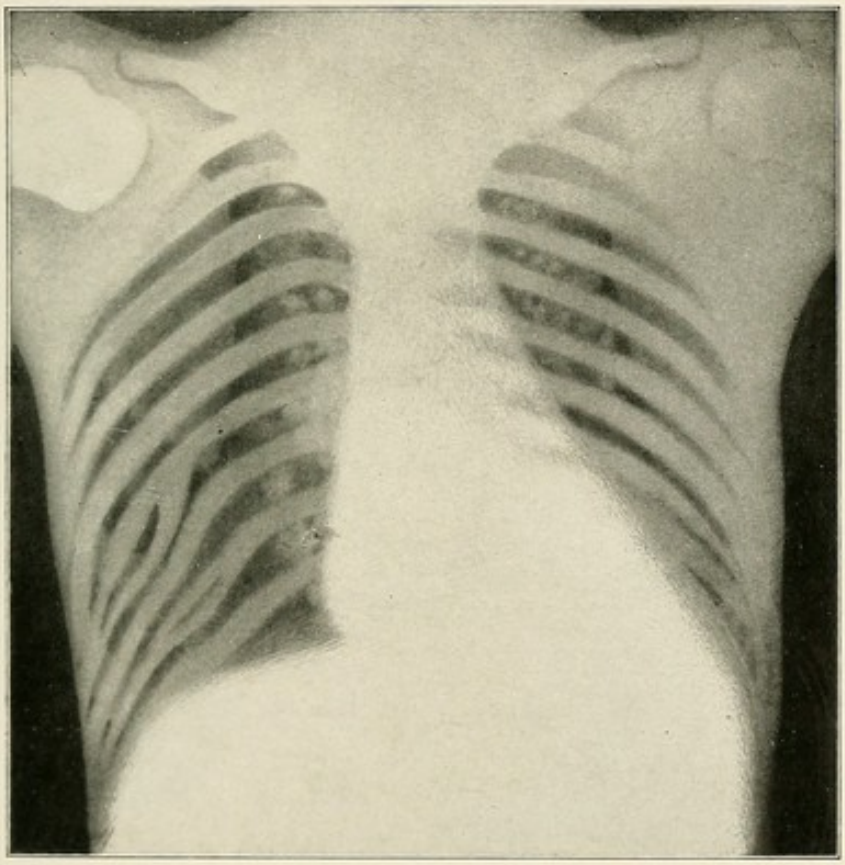

FIG. 51.—X-ray picture (re-touched), two years after extirpation of the left lower lobe (GARRÈ).

a large part or the whole pulmonary lobe is traversed with bronchiectatic cavities. Even the combination of pneumotomy with an extensive mobilization of the chest-wall by costal resection only sufficed in cases of bronchiectasis freshly formed in connection with an acute empyema. So further measures were taken, and the pulmonary sections affected with bronchiectasis, even whole pulmonary lobes, generally the lower lobes, extirpated. The operation is a difficult one, and has only been performed a few times (KÖRTE, GLUCK, FRIEDRICH, KÜMMELL, MÜLLER). Once I resected the

left lower lobe *in toto*, the patient retained a troublesome bronchial fistula, and still suffered from bronchiectasis on the other side. The accompanying X-ray photograph (fig. 51) shows how heart and diaphragm have moved into the vacant place. The deficiency of the ribs on the right side is due to an exploratory thoracotomy; the right lower lobe seemed to contain no major cavities, the pleura was quite free. For the technique *cf.* p. 66 and onwards.

In a second similar case I tried to promote atelectasis of the left lower lobe by thoracoplastic, combined with displacement and invagination of the lung.

After resection of nearly the whole of three ribs, I removed the adhesions from the left lower lobe, fixed the margin of the lung with a series of sutures to the upper margin of the opening in the thorax.

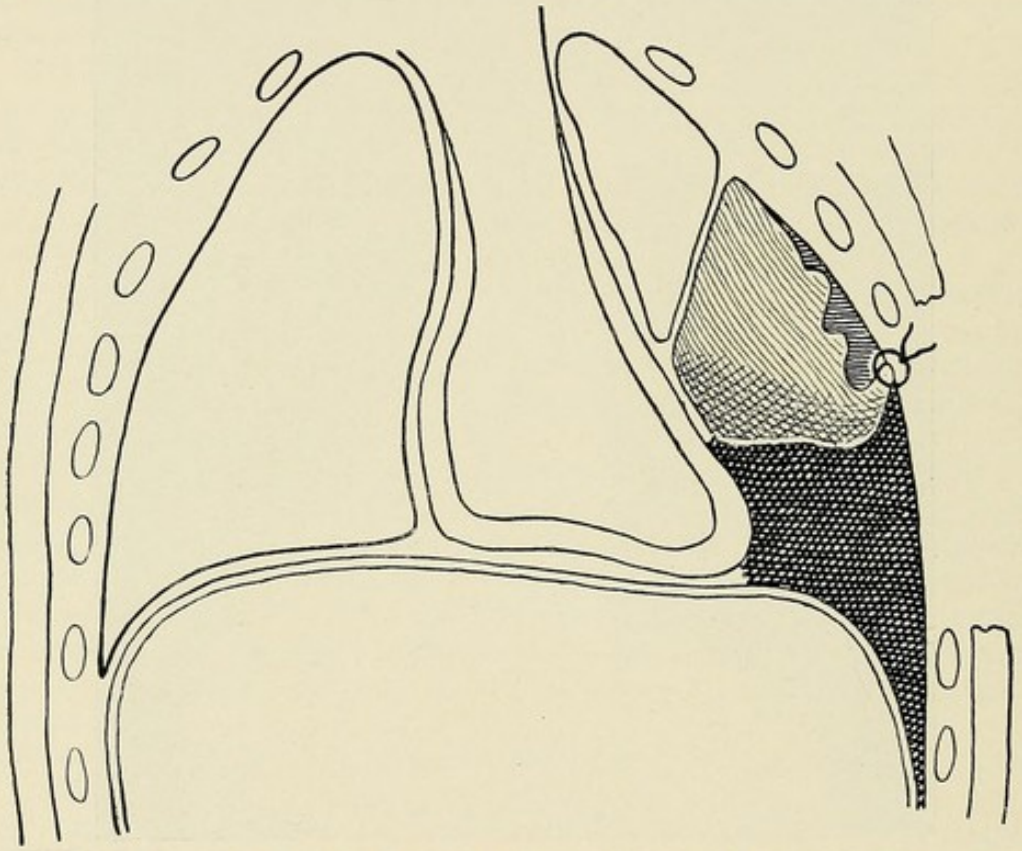

FIG. 52.—Protrusion of the inferior lobe by displacement and folding (GARRÈ).

The large cavity formed between the base of the lung and the diaphragm, and between the heart and the vertebral column, was plugged with a tampon, and in the course of weeks was obliterated. The lower lobe remained, as the X-ray picture showed, atelectatic (*cf.* fig. 52).

Here, too, the success was marred by the disease of the other lower lobe.

SAUERBRUCH tried to attain the same end, namely, atelectasis of a pulmonary lobe traversed by bronchiectases, by ligature of the arteries. Experiments which he carried out in conjunction with

BRUNS, showed that in connection with the ligature of the several pulmonary arterial ramifications, a peculiar induration process was developed. "From the interstices, especially those in the vicinity of the bronchi, profuse proliferation of connective tissue takes place. Finally the whole pulmonary lobe down to below the pleura is traversed by connective tissue. The alveoli are surrounded and compressed. Then the granulation tissue begins to shrink. At the same time, between the upper surface of the lung and the parietal pleura, broad indurated adhesions are formed, which are strictly limited to the region of the ligatured artery. The retraction and shrinking of the lung and the surrounding indurations are so great that in young animals with flexible ribs whole sections of the chest wall are drawn in in boat shape. Thus is attained in full measure that which the collapse therapy aims at: a shrinking of the connective tissue of the lung" (SAUERBRUCH).

FIG. 53.—Ramification of the right pulmonary artery (according to SCHUMACHER).

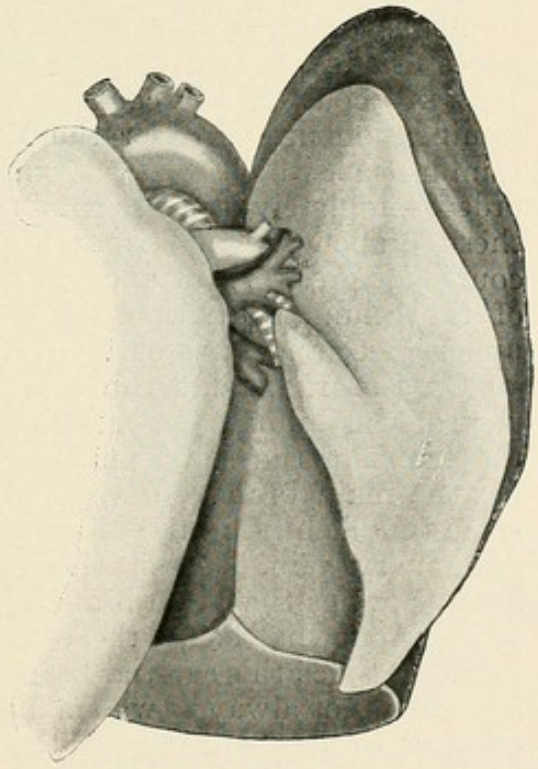

FIG. 54.—Ramification of the left pulmonary artery (according to SCHUMACHER).

The method was introduced by SAUERBRUCH into surgical therapy, after SCHUMACHER had provided the necessary data by careful anatomical studies on the ramification of the pulmonary artery in the several lobes, and on the possibility of performing the operation on human beings.

We give here briefly the topography of the hilum of the lung with the sketches made by Dr. SCHUMACHER for his book.

On the left side we find the arrangement of the vessels when they leave the mediastinum to be as follows: Highest up, that is,

in the uppermost margin of the hilum, lies the left pulmonary artery, first in front of, then above the left bronchial trunk. Immediately below it, and somewhat to the front, lies the upper main branch of the *vena pulmonalis* between both, and behind it the bronchial trunk. Immediately on its lower surface we find the inferior main branch of the pulmonary vein.

The pulmonary artery crosses the left bronchial trunk before it gives off the first lateral bronchus. From this point onwards, it lies always above and a little to the back of the bronchial trunk. According to SCHUMACHER'S investigations, the distribution of ramifications in the individual lobes does not correspond to that of the bronchial system. Whereas, for the left upper lobe, only one lateral bronchus branches off from the bronchial trunk, the left pulmonary ramification throws off several lateral ramifications for the upper lobe. Of these the two first can be reached from the front, the others can only be seen by forcing the two pulmonary lobes apart from the side, as they lie behind the bronchus of the upper lobe. In order to reach them then it is necessary to proceed from the side. SCHUMACHER also points out that in about 20 per cent. of the cases examined by him from a ramification intended for the lower lobe, there is also a secondary ramification which passes from beneath into the upper lobe. In order completely to extirpate the upper lobe, the ligature of all these branches, which may amount to from three to six, is, of course, of great importance. In the veins, right at the beginning of the hilum, a division takes place into a main branch for the upper lobe, and one for the lower lobe.

On the right side the right bronchus occupies the uppermost part of the hilum. In front of it, and somewhat lower down, lies the trunk of the right pulmonary artery, in front and below this lies the main branch of the pulmonary vein. Lowest, and at the same time behind in the hilum, lies the lower main branch of the pulmonary vein. From the upper periphery of the pulmonary artery springs the main branch for the upper lobe; it lies in front of and somewhat below the eparterial right bronchus of the upper lobe. Besides this arterial branch, by far the most important, there are often, not always, two smaller branches, one of which is thrown off close to the main branch, the other farther off and somewhat in the direction of the posterior margin of the pulmonary artery. In order to reach it it is necessary to force the upper and middle lobes apart. A third branch will be mentioned in the discussion of the arteries of the middle lobe.

The second branch, springing from the anterior margin of the pulmonary artery, is intended for the middle lobe and, according to SCHUMACHER, in nearly half the cases another smaller vessel close beside it. In the same lateral space in the posterior periphery rises a branch for the upper lobe, sometimes very powerful, which enters it from behind and below. The other branches require no special description, as both on the right and on the left they provide for one and the same part, the lower lobe.

In several cases of extensive diffuse bronchiectases SAUERBRUCH

ligatured the branch of the pulmonary artery to the left lower lobe. He recommends the following technique: Lying on the right side the trunk is bent down over a pillow. Thoracotomy is performed in the 5th intercostal space. Lower and upper lobes

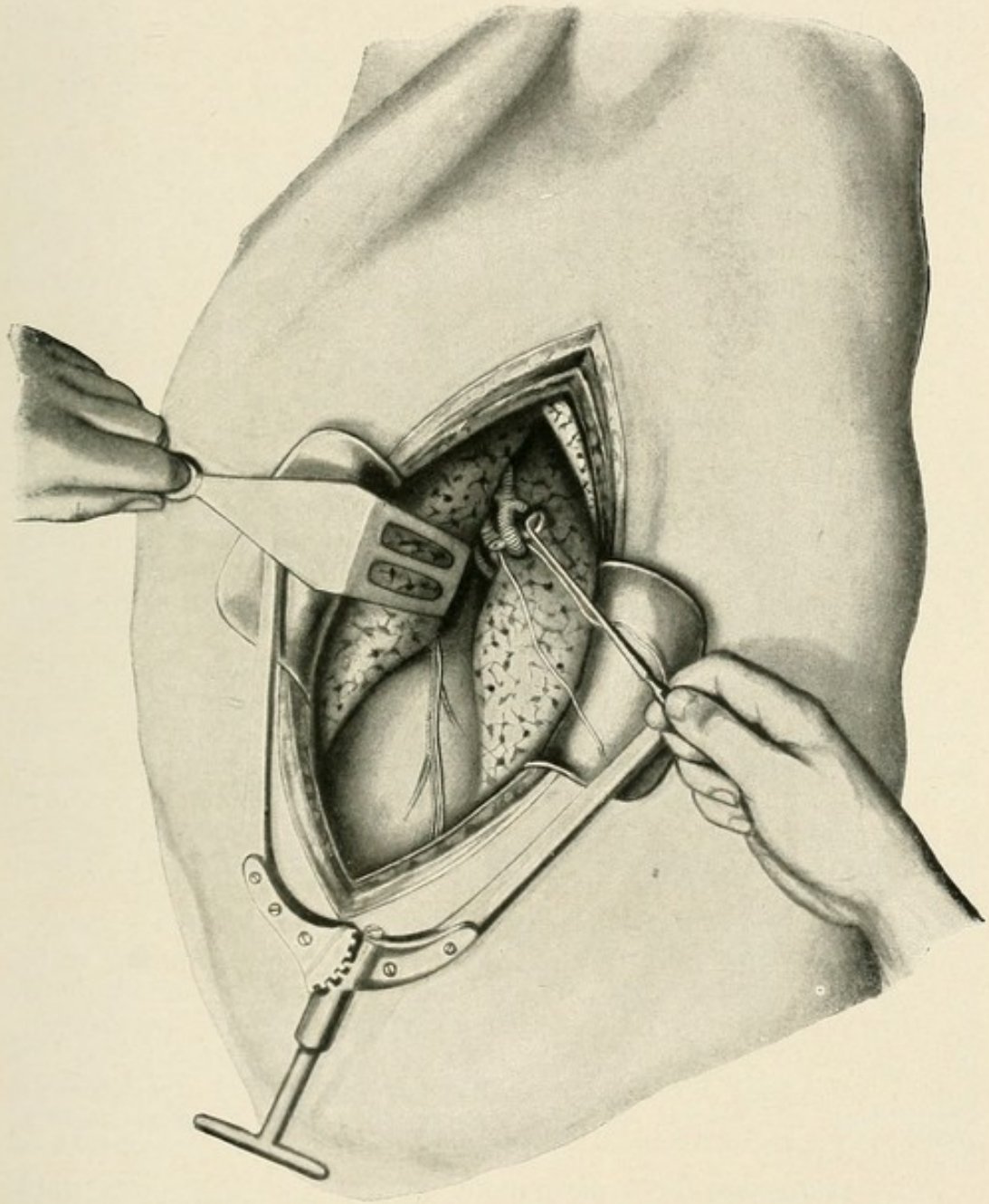

FIG. 55.—Site of operation with ligature of the ramifications of the pulmonary artery for the left lower lobe according to SAUERBRUCH and SCHUMACHER.

are carefully forced apart in the interlobar commissure. When adhesions are present be careful not to injure the lung! The pedicle is exposed; here artery, bronchus and vein lie so close to one another, that the artery lies above, the bronchus in the middle (*cf.* fig. 55).

The isolation of the artery is rather difficult; when the separation is high up the branches must be ligatured separately. They are drawn up with strabismus-hooks and the ligature thread bound round them with DECHAMPS' needle. The operation takes place with slight inflation of the lung (5 mm. mercury); the lung is only fully inflated again when the pleura is closed. The patients were out of bed in three or five days. In a second operation SAUERBRUCH added also the plastic operation on the thorax, to make the result of the collapse of the lung as complete as possible.

Considerable improvement was always achieved, but no cure—which is not to be wondered at—in cases of diffuse bronchietases. So DE QUERVAIN was constrained to a supplementary extirpation of the pulmonary lobe. A decisive verdict cannot be given. Under certain circumstances the ligature may be a suitable preparation for the extirpation of the lung.

RESULTS OF OPERATION.

When we proceed to the criticism of the results of operation, we must leave bronchiectases out of consideration. The peculiar nature of the disease, its multiplicity, prevents the application of the same standard as regards the prognosis of operation, although, on the other hand, they cannot be unhesitatingly separated from the other suppurations of the lung.

Can a permanent cure be wrought by operation on a pulmonary suppuration (abscess and gangrene)? This question has hardly been touched upon in the literature, usually it is concerned only with recording the immediate results. According to our experience, in all acute forms (gangrene and acute abscesses) one can count on a permanent cure. Cases in which, within a year, there is a reopening of the cicatrix and the formation of a fistula or a fresh abscess are rare.

Patients, who have lost a whole pulmonary lobe through gangrene, are not only quite capable of following a calling which necessitates severe physical exertion, but remain permanently cured. We have not noticed either that such patients are specially predisposed to bronchitis or pleuritic irritations, although TUFFIER points out that after pneumotomy coughing and dyspnœa are often left behind as a consequence of fibrous cicatrices, or bronchiectases.

The conditions for a permanent cure are much less favourable in all chronic suppurations. This is also comprehensible, when one remembers that in the vicinity of purulent cavities the surrounding tissue is extensively diseased and indurated, partly even infiltrated with pus—that the chronic bronchiectatic cavities rarely occur in isolated cases, and broncho-pneumonic foci often traverse the pulmonary lobe in question. A large, if not the largest, number of relapses of continuous bronchial purulent secretion, of suppurating fistulæ, &c., are due undoubtedly, as we have described in detail elsewhere,

to the insufficient mobilization of the chest-wall and the inadequacy of the pneumotomy usual up to the present time. The more thoroughly everything diseased is removed by resection of the lung, the better will be the lasting results in chronic cases also.

I have continued my earlier collection of statistics (*cf.* first edition, p. 59), according to which 400 cases of pneumotomy gave a mortality of 25 per cent. I found that out of 182 more cases of abscesses there resulted 148 cures and 34 deaths, that is 17·5 per cent. of mortality.[1]

The operation results of individual operating surgeons with wider statistics, including gangrene and abscesses, gave a higher rate of mortality. Out of 95 operations LENHARTZ had 69 complete cures (mortality 26·3 per cent.), KÖRTE 25 cures and 12 deaths out of 37 cases (one-third mortality).

The failures are due partly to the severity of the disease and the long delay before resorting to operation, which may certainly be justified by the difficulty and uncertainty of the diagnosis. Strikingly seldom was the unfavourable result produced by a purulent pleurisy as a result of the abscess incision, although generally there was only one operation. In four-fifths of the cases more or less protective adhesions of the pleura were present.

The prognosis of gangrene is less favourable. Out of 281 cases of gangrene 197 were cured and 84 (= 29·3 per cent.) died. We surgeons, however, must nevertheless be satisfied with this mortality of 30 per cent., when VILLIÈRE reckons with the internal treatment of this affection a mortality of 75 per cent.

On a closer examination of the history of the patients we see, moreover, that a good number of the deaths cannot be attributed to the operation, as, for example, cases of multiple gangrenous foci in one lung, or even in both lungs, progressive gangrene and complications of meningitis, abscess in the brain, embolism, &c.

The different prognosis of individual gangrenous forms, when they are grouped etiologically (TUFFIER), must also not be ignored. Thus, for example, embolic gangrene and gangrene with bronchiectasis offer in themselves alone very little prospect of a cure—naturally the results of operation are directly influenced by this.

The cure of bronchiecasis is the most difficult of all. The very fact that new methods of surgical treatment are continually being sought after, shows clearly enough how unsatisfactory the results have been up to the present. "Cures," we must admit, are rare occurrences; with improvement and considerable improvement

[1] I should not like too much importance to be attached to these statistics—I, myself, cannot recognize the individual observation collected with great trouble from the whole literature as the absolutely correct standard of the heights attained by the surgery of the lung to-day. The methods applied are not sufficiently uniform, the individual cases themselves too various and the reports sometimes too imperfect—it is difficult from so varied a mosaic to obtain a clear picture of the whole. Moreover, the limits between "good" and "bad" are so wide, that every one must feel the need of giving sharper contours to the picture by definite numerical proportions—even at the risk of making some mistakes.

we have to be satisfied. They can be estimated at 60 per cent.; the mortality amounts to 40 per cent.

The reasons for these poor results are the extent of the disease over large portions of the lung (not infrequently on both sides), partly its etiology (congenital, diffuse modifications of the parenchyma) and principally the chronic irremediable affections, which have attacked the bronchial tree.

In these chronic protracted cases, when the surgical operation is generally looked upon as the last resource, in which a whole lobe of the lung is indurated and traversed by the bronchiectases, it has often, unfortunately, been considered sufficient to drain the nearest accessible cavity. By so doing, of course, nothing is gained; afterwards, just as before, the patient is exposed to the dangers of the decomposition of the putrid secretion and the consequent gangrene of the lung.

Very frequently brain abscesses follow. KING[1] found in seventy-two cases of bronchiectasis eight times abscesses of the brain and four times they resulted from surgical operations.

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[1] *Münch. med. Wochenschr.*, 1904, p. 1485.

CHAPTER VII.

PULMONARY TUBERCULOSIS.

WHEREAS in cases of simple pulmonary suppurations the main consideration for the surgeon is to draw off the pus from within, and other mechanical considerations take a second place, with pulmonary tuberculosis it is otherwise, because here the pathological procedure is much slower, more varied in form and generally more diffuse.

The first efforts of surgeons were, certainly, directed against the so-called tubercular abscess cavities, opening up as with other abscesses; these were soon abandoned, because not very successful. Two principal reasons for the failure may be given: the distension of the lung in the thoracic cavity, and the tubercular disease of the cavity wall and of the adjacent pulmonary tissue to a greater or less extent.

In parenchymatous organs with yielding surroundings, for example, lymphatic glands, tuberculosis generally leads to the formation of indurations with infiltrated caseous foci and sinuous abscesses, the lumens of which may, when the pus is evacuated, collapse owing to the congestion and displacement of the surrounding yielding tissue. The residuum may, as well as the caseous foci, be partly absorbed and partly encapsuled and destroyed by the gradual formation of progressive indurations. In the same slow way numerous grey tubercles may also be rendered harmless and "heal up."

The same processes in the lung may lead to "healing," as long as the region infected with tuberculosis is of small extent, so that there is sufficient yielding and movable tissue in the vicinity. In dissecting we often find such smaller foci healed up, which in life gave rise to no symptoms, or only to transitory ones. In the region specially liable to tuberculosis, however, the apices of the lung, the tubercular foci are very often, from the first, so numerous that there is hardly any yielding pulmonary tissue left between them. When the tissue breaks down, therefore, the cavity is kept open in the rigid surroundings; when atrophy and collapse set in the further surroundings of the adjacent pulmonary lobe and the thoracic wall are drawn in. Up to a certain extent (varying individually) the bony zone of the upper ribs may yield and become malformed, especially in young people. But the tension of

the cicatrix acts not only centripetally on the chest wall, but also centrifugally on the walls of small abscess cavities which may be present, preventing the adhesion of the wall or directly increasing the cavity. This centrifugal tension of the chest wall, increased by inspiration, is not only exercised in the case of pleural adhesions, but just as well without them, when the lung is kept fixed to the costal pleura by capillary adhesion. When the cavities communicate with the bronchi, they are filled with air, and although in a different degree, take part in the respiratory alternation of air, the cavern is made, it becomes, as well as the diseased bronchial mucous membrane, unfailingly, secondarily infected with pyogenous and other cocci.

The pus formed in the cavern is evacuated in the direction of the bronchi, generally easily from caverns on the apex, assisted by gravity, although the bronchus does not always open into the lowest point, but more frequently laterally. The opening up of a cavern of the apex of the lung to the outside, therefore, does not usually improve to any great extent the conditions for the evacuation of the pus, but gives an opportunity for tubercular infection of the wound surface. In the few cases in which the operation was of use this was due less to the opening than to the accompanying resection of the ribs; in the case of tubercular chronic pulmonary abscesses the mobilization of the chest wall is just as much, nay more, indicated as in cases of simple chronic abscesses, in order to bring about shrinkage for cicatrization.

Purulent breaking down is, however, only one, and certainly the most destructive, of the results of tubercular pulmonary foci. A very important part, quantitatively, is played by the formation of connective tissue, to which every, even the smallest, tubercular focus gives rise in its surroundings, though certainly to a very varied extent. This alone is able to bring even fresh tubercles to a state of atrophy, it enables caseous and necrotic tissue to become encapsulated, when they remain unchanged or undergo slow, harmless absorption or calcification. This formation of indurations is specially important because it places hindrances in the way of the further dissemination of the tubercle bacilli through the clefts in the tissue and lymph channels.

Experience has long shown that these shrinking processes are considerably aided and furthered when the lung, in accordance with its natural elasticity, retracts or has become atelectatic by slight pressure, with simple serous pleurisy or simple (not complicated by inflammation of the pleura) pneumothorax.[1]

These facts gave FORLANINI in Pavia (1882, 1892), and MURPHY in Chicago (1887), the idea of exercising a therapeutic influence on the disease of the lung by artificially produced pneumothorax. This idea was at first only very slowly and cautiously adopted, because the technique was naturally only gradually evolved, but above all because spontaneous pneumothorax in phthisis of the

[1] See for example B. L. SPLENGLER, "Zur Chirurgie des Pneumothorax." In BRUNS' *Beitr. z. klin. Chirurgie*, vol. xlix, 1906.

lung had, in a very great majority of the cases, impressed itself upon the minds of the doctors as an extremely serious form of disease. The seriousness is certainly determined by a number of secondary circumstances : by the infection of the pleura with all kinds of microbes exciting inflammation which is generally coterminous, by the usually advanced disease of the lung, by mechanical disturbances due to the great tension of the air in the thorax, which again causes the formation of valves at the site of the fissure of the pulmonary pleura.

How harmless simple aseptic pneumothorax is in itself, its extent and tension being under control, has only been proved by the ever increasing number of cases in which it has been used therapeutically.

Artificial Pneumothorax.

If into the closed pleural cavity, for example the right, of rabbits, or men, sufficient air is introduced until the lung retracts till it becomes devoid of air and atelectatic (with men a pressure of the pleural air of + 2 to 6 mm. mercury = 3 to 8 cm. water is sufficient), then the heart and the other organs situated in the mediastinum move from their medial position of equilibrium towards the left, following the elastic tension of the left lung, which at the same time contracts a little. The contraction of the respiratory surface results at once in lack of air, then to adjust this an increase of respiratory movements ensues. On inspiration only the left lung is filled with more air, in the right pleural cavity the air pressure, and therefore the external pressure on the left lung, is on inspiration reduced by 4 to 6 mm. mercury, but air hardly enters this lung, it is only moved somewhat to the right together with the heart and mediastinum, to swerve again to the left on expiration.

Meanwhile the right side of the thorax is somewhat nearer the position during inspiration, the right half of the diaphragm lower. All these conditions can be followed in detail by the use of the X-rays.

If now, when one side of the lung is diseased, pneumothorax is so applied by compression with nitrogen into the pleural cavity of the diseased side that the lung retracts until it is void of air, then the dyspnœa about to set in is compensated for, the sputum is lessened or ceases altogether, because the respiratory movements of the diseased lung no longer aid, and also because less secretion is exuded in the lung now at rest. The secretion already present and the toxins produced in the tissue, which, hitherto, have been thrown out, must now be absorbed ; this is surely the reason of the rise in temperature, which generally begins on the day after the operation and lasts some days ; but then the fever, which perhaps was present before, also disappears, and gives place to a steady normal temperature, because in the lung at rest the diseased processes come to a standstill, and then to retrogressive metamorphosis. With the cessation of the respiratory change of volume the opportunity for

the formation of fresh foci of disease is also removed. This condition will, of course, only continue while the same amount of pneumothorax is maintained; as nitrogen is constantly absorbed by the pleura it must be added to now and then, the pneumothorax must be maintained at least several months, often one or two years, and then only under very careful control be left very gradually to self absorption, when the diseased parts are atrophied and become encapsuled. The normal pulmonary parts, which have only been

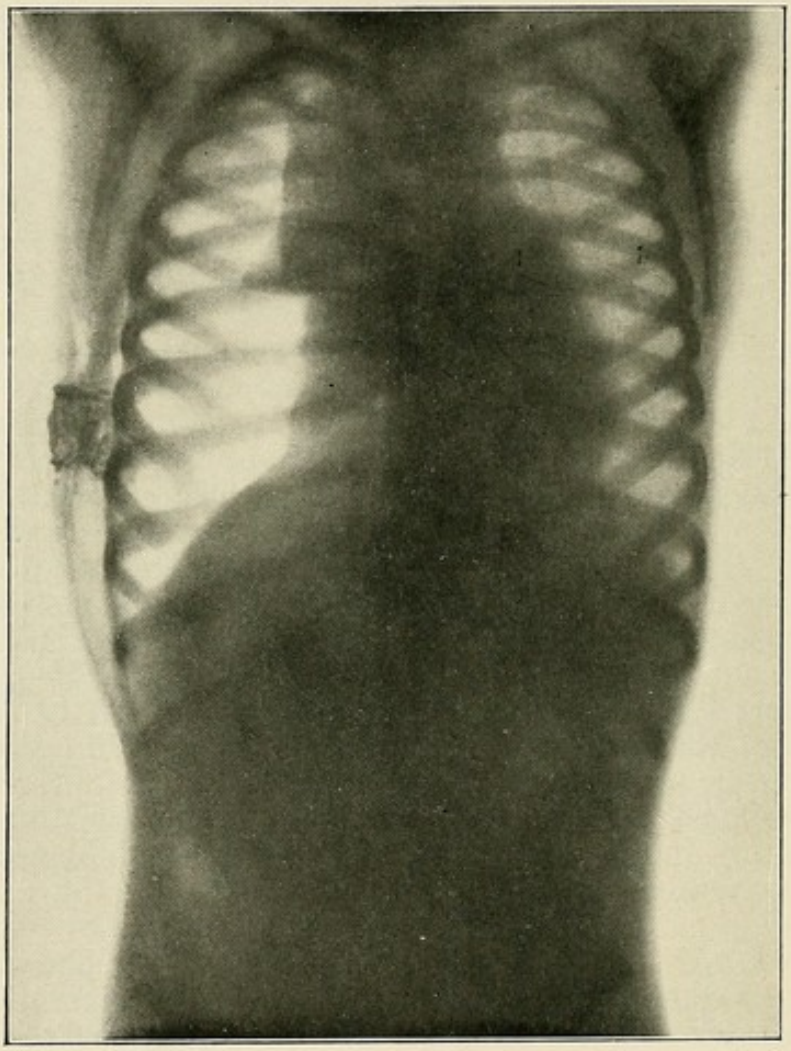

FIG. 56.—Child, aged 6. Pneumothorax of the right side 1,100 c.c. Diaphragm very low. The three lobes of the lung distinguishable, the upper, owing to infiltration, least retracted.

atelectatic, become filled with air again and capable of performing their functions—so completely that FORLANINI, in the case of two patients after the pneumothorax had continued for two and seven years, was able later to cut out the other lung by pneumothorax; the lung which had been compressed so long was able alone to do the work of respiration.

In the lung retracted to a state of atelectasis the anatomical

conditions and all conditions of life are modified extensively; only in the extremities is a similar degree of immobility attainable; in no other organ of the body is so prolonged a suspension of function possible without permanent injury.

The smaller amount of blood contained in the lung collapsed until it is in a state of atelectasis, and the smaller amount of blood flowing through the lung, has been long known. Of importance is, perhaps, the changed metabolism in the collapsed lung caused by the lack of oxygen, as the whole of the blood of the main current remains venous and arterial blood is only brought by the bronchial arteries.

The conditions of such lungs have been examined experimentally in animals by BRUNS and SHINGU, tubercular lungs in human beings by GRAETZ.

The rabbit, among the animals generally used for experimental purposes, like human beings, has a relatively solid mediastinum, so that pneumothorax of one side with atelectasis of the lung may be maintained for weeks and months; in dogs and goats, on the other hand, the flexible mediastinum gives way so much, that with pneumothorax of one side the lung on the healthy side is also considerably contracted, and if breath and life are to be maintained, one can only arrive at a slight retraction and at most a few small atelectatic foci in the pneumothorax side of the lung. In rabbits BRUNS found the blood-contents of the atelectatic lung compared with those of the sound lung reduced (quite at the beginning by two-thirds, if continued longer by half). The quantity of blood flowing through is considerably decreased, the large arteries and veins are distended, but the capillaries are small, partially empty. Meantime the epithelium of the alveolar walls in contact with one another remain perfectly intact, they do not adhere. The connective tissue of the tunica adventitia of the arteries, of the bronchi and septa, is somewhat increased. The lymphatic vessels, especially of the pleura, are full and enlarged.

To which volume of the lung corresponds the largest stream of blood, whether to that on inspiration or expiration, seems to me, even from the latest experiments of CLOETTA,[1] who accepts the latter, still undecided, probably the optimum lies in a medial position. A small amount of blood and a reduced stream of blood should, however, be characteristic of the completely atelectatic lung.

According to SHINGU'S[2] investigations the atelectatic lung eliminates the soot previously inspired more slowly than the breathing lung. Whereas, in the latter, the particles of soot, mostly intracellular, lie in the bronchi and alveoli, in the atelectatic lung the soot-cells are more abundant in the connective tissue and in the pulmonary and bronchial lymphatic glands. This condition may well be attributable to the retardation of the lymph-stream, which seems probable, too, for other reasons.

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[1] *Archiv für exper. Pathol. u. Pharmakol.*, 1911, vol. lxvi, pp. 409-464.

[2] BRAUER'S *Beiträge zur Klinik der Tuberkulose*, vol. xi, 1908.

GRAETZ found in tubercular lungs, in which artificial pneumothorax had been maintained for two to seven months, encapsulation of caseous foci and organization of pneumonic processes by connective tissue; the connective tissue was produced the more abundantly the more completely the pulmonary part in question had been compressed. The tubercular foci contained very few tubercle bacilli. The fresh tubercles were sparse, rich in giant cells, free from caseation. GRAETZ did not find any increase of the tubercular processes in the bronchial lymphatic glands (which might well have been expected according to SHINGU'S investigations); fresh tubercles were almost entirely absent.

Pneumothorax demands greater functional capacity of the other lung, its respiratory movements are more numerous. Might this excite in the tubercular foci of this lung an activity of the diseased process? As a matter of fact, during the first few days after the application of pneumothorax signs of increased activity do appear in the existing foci; they are interpreted—probably correctly—as a tuberculin reaction, caused by the absorption of the toxins from the collapsed lung. This reaction, however, generally dies down and a continuance of the disease only takes place when there are more extensive and active processes on the breathing side; but such cases are unsuited for treatment by pneumothorax and should be from the first excluded. But smaller, especially apical and not acute, processes are not usually stimulated by pneumothorax of the other side; on the contrary they sometimes become retrogressive, granted, of course, that the breathing lung is not hindered in its power of dilatation by pleural adhesions or too great pressure in the pneumothorax displacing the mediastinum.

The heart is not only displaced by the pneumothorax, but the external pressure under which it works is changed, the suction of the blood to the thorax is interfered with, and thus the supply of the right ventricle of the heart is lessened: this must be more marked in pneumothorax of the right side than in that of the left, but varies very much according to the solidity of the mediastinal pleura. The conditions are the same as in spontaneous pneumothorax and pleural effusions. The healthy heart seems to be able rapidly to adapt itself to these changes.

The channel for the whole blood-stream of the lungs is probably considerably reduced in area by the collapse of the one lung (according to BRUNS probably by more than a half); by this possibly the heart was made more resistant. BRUNS, therefore, after continuing the treatment for several months, examined the heart, and parts of the hearts in rabbits and dogs, according to W. MÜLLER. He found no enlargement of the left, but a relative enlargement of the right, ventricle. Proportion of the right ventricle to the total weight of the heart:—

	Normal	In pneumothorax
In rabbits	18 to 19 per cent. ..	21·4 per cent
In dogs	21·5 ,, ..	24·4 ,,

It is certainly questionable whether these slight differences in the figures are of importance. Moreover, it made no difference

whether the dogs were kept quiet or ran about in the exercise area every day for several hours.

Patients, when pneumothorax is rightly applied, adapt themselves to this condition, so that as far as respiration and the capacity for movement are concerned their condition does not differ from their usual one; as the general condition is improved they are even better off. Some of the patients can follow their calling with the pneumothorax, some were able (contrary to medical advice) to take part in sports, without injury.

For producing pneumothorax filtered atmospheric air can be used; nitrogen is better, as the rapid absorption of the proportion of one-fifth necessitates early replenishment.

When there is any doubt about individual anatomical conditions, so that gas embolism or interstitial emphysema might be feared, oxygen should be used for the first compression; it is quickly absorbed out of the cellular tissue, and out of the lumen of the vessels; the dangers would be thus considerably lessened. When the oxygen has duly reached the pleural cavity, during the next few hours an examination must be made by percussion, still better with the X-rays, and nitrogen must be injected forthwith.

The site of injection usually chosen is the fifth to the seventh intercostal space in front to the side. The direct puncture with the hollow needle, according to FORLANINI seems not without objection because of the uncertainty as to space and the consequent risks; the proceeding of MURPHY, BRAUER, and L. SPENGLER (cutaneous incision, pressing forward as far as the pleura, penetrating the latter with the blunt cannula of SALOMON) should be the rule.

Not a few doctors, however, make use of the direct puncture, without hesitation and without ill results. Perhaps it is more suited to the hand of those doctors who by more frequent use of the method of incision are already adept in the minutiæ of the proceeding.

DENEKE, on the first application of an artificial pneumothorax, always injected first 10 to 20, then 50 to 100 c.c. of oxygen. After a small incision in the skin with a spring lancet he pierces the soft parts and the costal pleura with a needle 1 mm. thick and a slit of 5 mm. above the cutting point, after cannula and manometer have been filled with oxygen. When fluctuations in the manometer show that the pleural cavity is free, then DENEKE injects nitrogen. Several hundred punctures have been made by him without incident in this manner.

For the first pneumothorax $\frac{1}{2}$ to 1 litre of nitrogen is sufficient, according to the state of the patient and the pressure to be observed by the manometer; this should fluctuate about 0. If the pressure is higher the mediastinum may be pushed aside too violently and too suddenly, sputum may be taken in by aspiration from the collapsed lung to the other side.

When you have convinced yourself by auscultation, percussion and, when possible, by the use of X-rays, that there is sufficient air space to ensure against injury of the pulmonary pleura (sufficient thickness of the stratum of air between lung and chest wall), the

second injection of gas may be given by simple puncture with the hollow needle. The first secondary injection takes place after one to two days, the following injections at intervals of at first a few days, later, three to four weeks and longer, as the absorbent capacity of the pleura for nitrogen decreases. On the average the injection has to be made sixteen to twenty times. The secondary injection is regulated by the size of the lung, which can be controlled by hearing and by sight, but, above all, by the pressure in the pleural cavity, which is measured before making the puncture; according to BRAUER and L. SPENGLER it ought to be maintained, generally

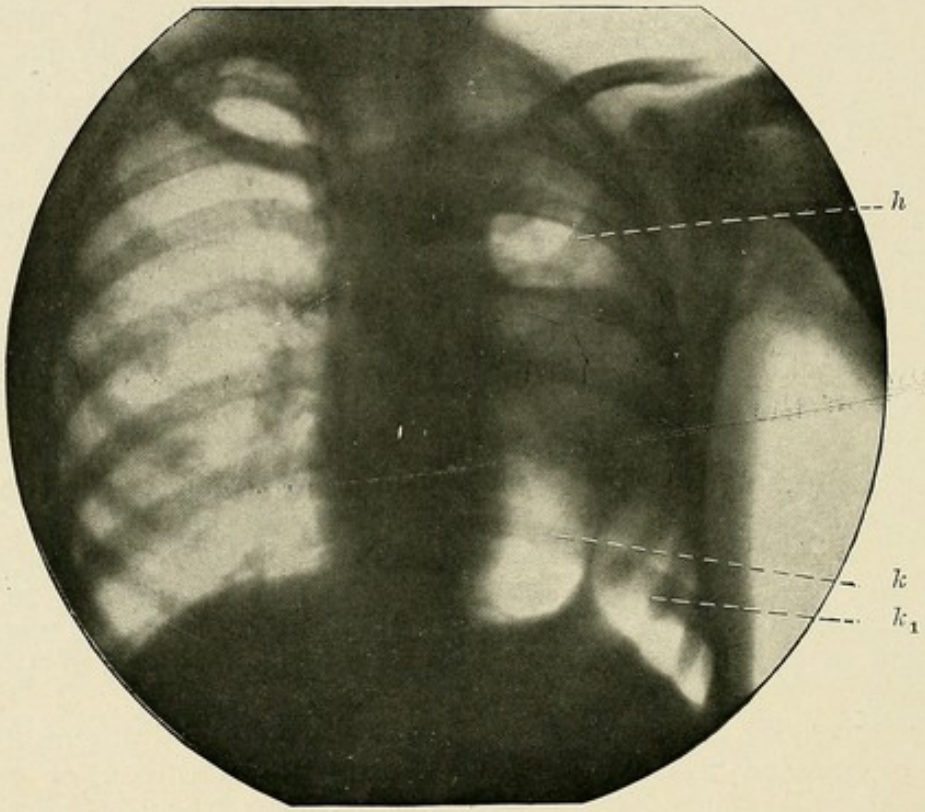

FIG. 57.—Partial pneumothorax (left), divided above the diaphragm into two chambers $k\ k_1$ by adhesive tract. In the indurated and extensively adherent upper lobe cavity with horizontal fluid level h.

speaking, on inspiration at $\pm$ 0, on expiration at 3 to 6 mm. mercury (4 to 8 cm. water). JESSEN gives 12 to 13 mm. mercury (= 16 cm. water), but will only rise to 6 to 8 mm. mercury, when the other lung is considerably diseased and thus limited in its respiratory power. The quantity of gas for the secondary injection varied from 300 to 1,000 c.c. according to the amount of absorption and the capacity of the pleural cavity; this depends on the extensibility of its walls (especially of the mediastinum) and on the presence of adhesions. Decrease of sputum and fever which have reappeared may be observed after the later injections as after the first.

Hitherto we have referred to cases without pleural adhesions; in cases where these are present retraction of the lung is prevented only as regards those parts which, by infiltration, have lost their elasticity.

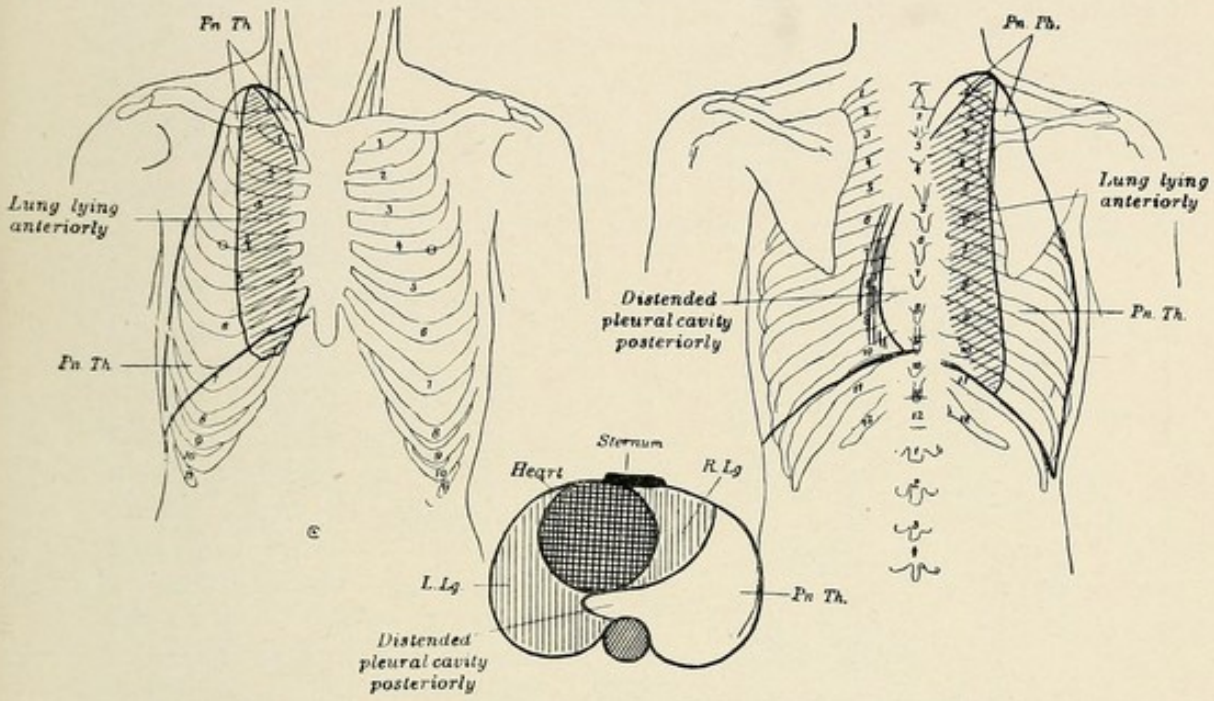

FIG. 58.—Pneumothorax on the right. Diaphragm low down. Lung medially retracted, adherent in front and at the apex. The mediastinum at the back in its medial and inferior part projected into the left side of the thorax.

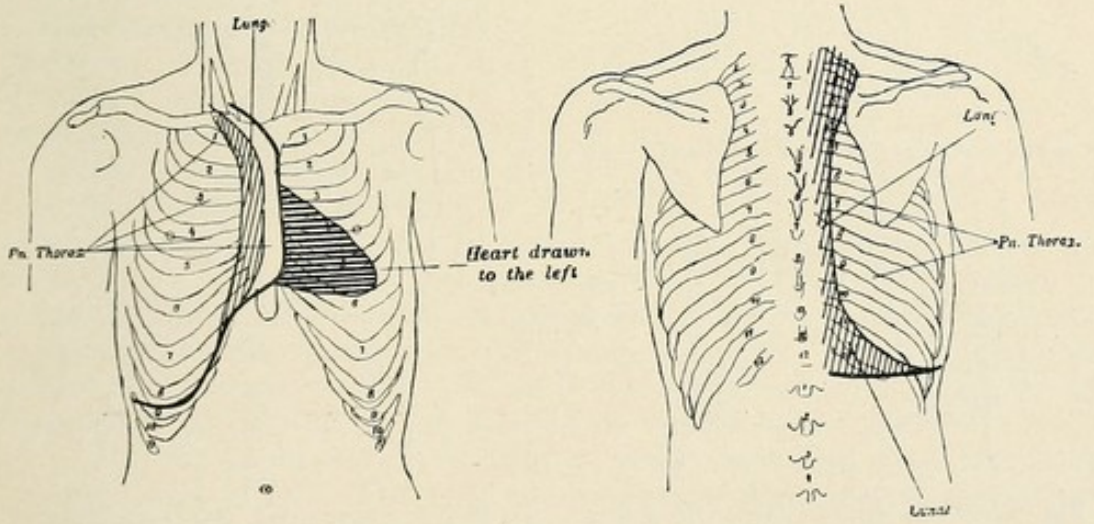

FIG. 59.—Pneumothorax was at first only partially obtainable owing to extensive adhesions of the upper lobe and adhesions to the diaphragm. During six months by twenty-two secondary compressions (each 200 to 400 c.c. + 5 mm. mercury pressure) the adhesions gradually gave way; now complete pneumothorax; adhesions only at apex and diaphragm.

In the majority of cases, however, the lung is to a certain extent adherent to the chest wall, especially at the diseased parts. In these cases, then, the use of pneumothorax to obtain a state of rest is

circumscribed less when the adhesions are in the form of cords, much more in surface adhesions; retraction here can only be brought about by removal of the lung tissue itself from the parts which have become atelectatic. As is well known, the adhesions occur most frequently in the upper lobe, but also in an

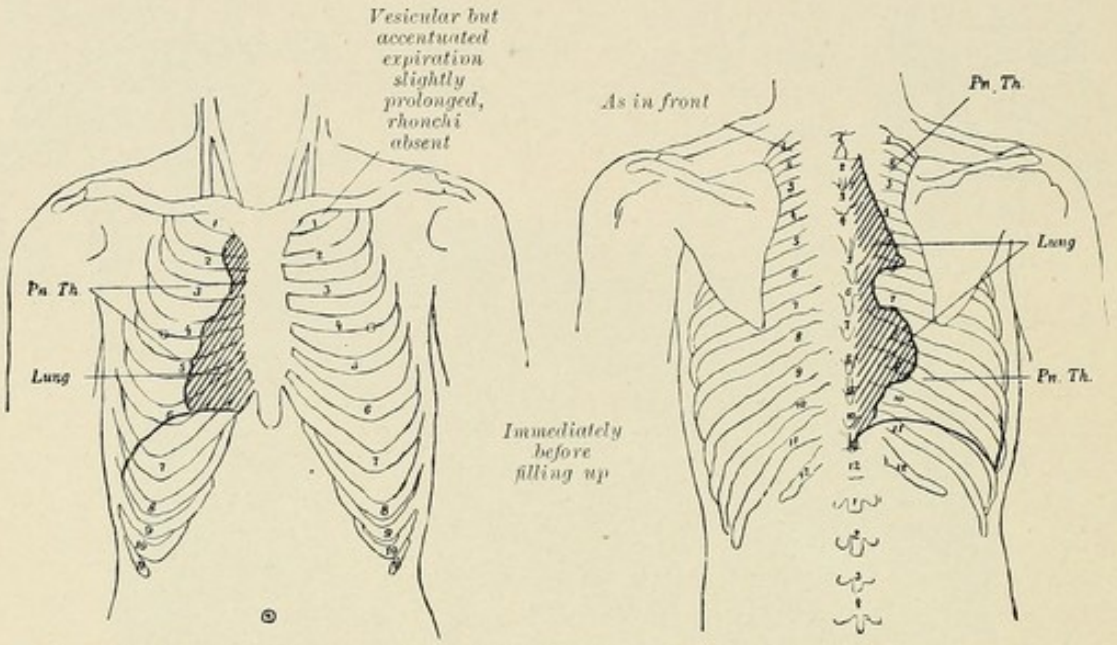

FIG. 60.—Pneumothorax on the right, 1,000 c.c. pressure, 4½ mm. mercury, lung (incompletely) retracted, medially.

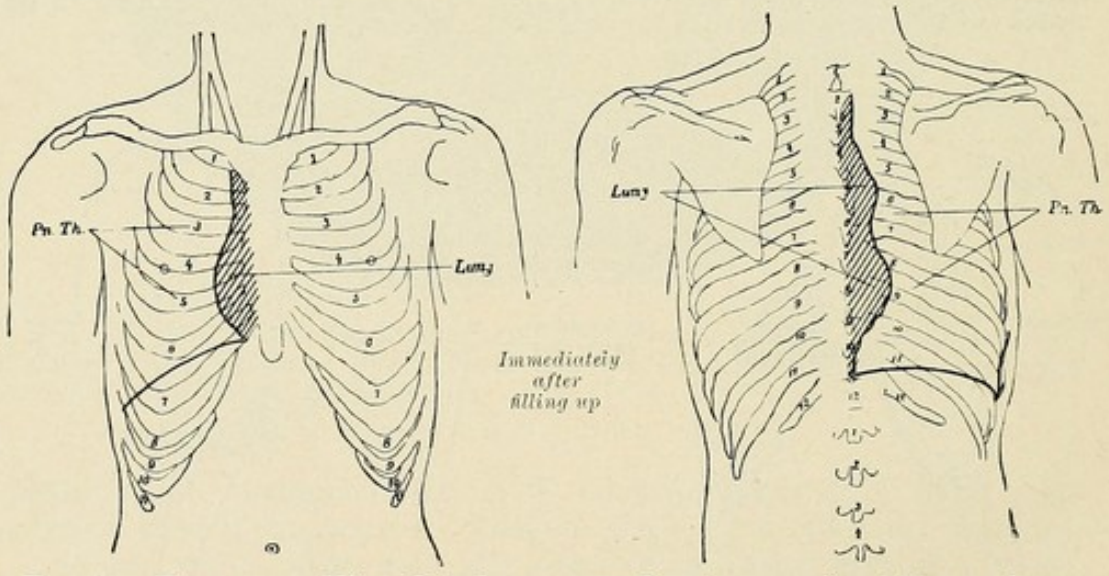

FIG. 61.—The same. Nine days later, secondary compression 800 c.c., lung much better retracted, only fixed by adhesion in the direction of the diaphragm.

unaccountable way at other places, where they may be obstructive even to the application of the pneumothorax or lead to complications. With regard to the diagnosis of pleural adhesions I would refer to p. 101.

FORLANINI attaches special importance for the absence of pleural

adhesions to the evidence by percussion of the mobility of the lower margin of the lung; this part is generally the freest from adhesions. If adhesive places were successfully avoided, still the resultant pneumothorax was encysted or multilocular or irregular. Under these circumstances, sometimes, by cautious, gradual increase of pressure in the secondary compressions (up to 20, 30, even 45 mm. mercury, 30 to 60 cm. water) the adhesions have been partially stretched and set free, and an extensive collapse of the lung has been achieved. The loosening of the adhesions is always accompanied by more or less pain.

FORLANINI in such cases occasionally injected daily 60 to 70 c.c. of nitrogen.

The foregoing are some schematic drawings (according to BRAUER and L. SPENGLER) which reproduce various forms of artificial pneumothorax.

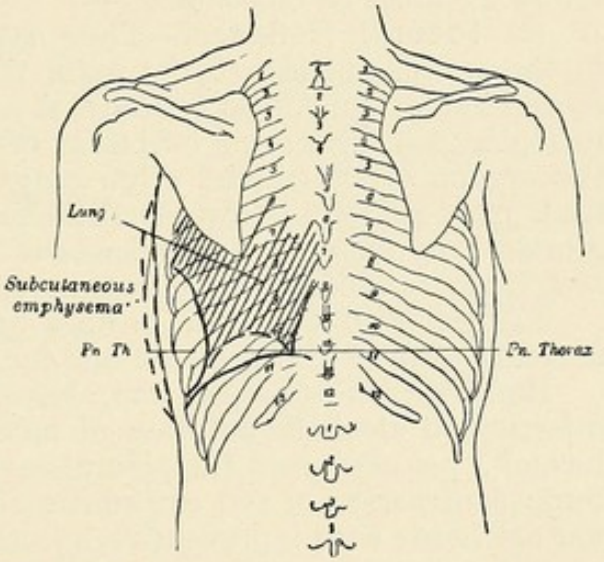

FIG. 62.—Double-chambered pneumothorax on the right.

At first FORLANINI wanted to maintain the pneumothorax continuously. Now all writers are agreed that it should only be maintained until the diseased foci of the lung are arrested and have become encapsuled by connective tissue. How soon this can be achieved depends on the extent and nature of the processes in the lung which vary so much in individual cases; it must be decided rather by the general condition and the earlier and actual course than by the local condition which is difficult to control. SAUGMANN prefers to maintain the pneumothorax rather too long than too short a time, for frequently after the development the pleural surfaces adhere to one another and then it is impossible to reproduce the pneumothorax. Up to the present the pneumothorax has been allowed to continue from a few months to several years (FORLANINI once seven years).

As the mean duration BRAUER and SPENGLER give one to one and a half years. The treatment appears then at first glance very wearisome and troublesome; in reality this reproach loses much of its force when you remember that, owing to the nature of the disease, any treatment which might be used would last as long—if the patient does not die before, or cease the treatment from lack of patience. As a matter of fact, this has often been done because of the feeling of subjective well-being.

Moreover, with a certain number of the patients already after a few months such an improvement and condition of equilibrium had been attained, that they were able to follow their calling and

had only to present themselves from time to time to the doctor to be examined and receive a secondary injection. So that the initial treatment in an institution can be continued by the family doctor (with secondary injections).

If the pleural surfaces have come into contact with one another again, the respiratory exchange of volume, recognizable by the mobility of the margins of the lung, is already somewhat abnormally restricted, because part of the pulmonary tissue is atrophied. Often adhesion of the pleural surfaces contributes to this, but it does not always happen, and the adhesions can be extended or separated during their formation by methodical breathing exercises.

Accidents and Complications.

Of accidents and complications in artificial pneumothorax the following must be mentioned :—

(1) **Pleural Reflexes.**—They are only, or generally, caused in the normal pleura (or its parts which have remained normal), by mechanical, chemical or thermal irritation (for example, too cold nitrogen gas), by tearing off bands of adhesion (the displacement of the organs of the thorax often plays a part in these symptoms) : local pain, radiating towards the shoulder, dyspnœa, spasm of the glottis, reduction of the pulse-beat to 40 to 50 (L. SPENGLER), temporary collapse, general vasomotor disturbances.

SAUERBRUCH observed in dogs quick, forced respiration, with decrease of the blood-pressure and increase of the pulse.

ROCH and FORLANINI too, have observed in rabbits by the injection of alcoholic solution of iodine, silver nitrate 2 per cent., formol 1 per cent. into the pleural cavity, besides pain and dyspnœa tonic contraction of the extremities, of the head and trunk, which did not occur with a preventive injection of stovaine.

Whether more serious conditions, such as eclamptic attacks, may be caused in a purely reflex manner by the pleura, seems very doubtful ; in agreement with BRAUER I also should like to take up the position that in the cases so described (as pleural shock) other processes, air embolisms, or the spreading of thrombosis from the pulmonary veins are also involved.

(2) **Emphysema of the Cellular Tissue.**—If the cannula is not rightly adjusted during the injection of nitrogen, for example, if it is still outside the costal pleura, with a feeling of pain, air is driven into the subpleural cellular tissue and may, rising below the inner fascia of the thorax, become palpable above the clavicles. If the point of the needle lay in the midst of loose pleural adhesions then the air injected spreads within them, just as in loose cellular tissue, to different distances according to their solidity, sometimes as far as the base of the lung and on the median side of the lung ; this induration-emphysema is really a small and multilocular (although therapeutically useless) form of pneumothorax. Finally, if the point of the needle has penetrated into the pulmonary tissue itself, the air injected may pass away into the air-passages or (completely or partially) reach the root of the lung along the peri-

bronchial and perivascular connective tissue and lead to mediastinal emphysema. Finally, if the aperture of the cannula lay outside the intercostal muscular system, then intermuscular and subcutaneous emphysema is caused.

All these mishaps are much less likely to occur, if, in producing pneumothorax, you make an incision as far as into the intercostal system of muscles and observe the following precautions: in piercing the pleura the cannula should simply be connected with the manometer, only when distinct fluctuations are apparent should it be connected with the gas-receptacle; in the latter, the pressure at first should be only $\pm$ 0, so that the gas at first is only drawn in, not driven in; the pressure of the inflowing stream must also be compared with the quantity of the inflowing gas. A decrease of the pressure in the tube of the manometer on inspiration is also

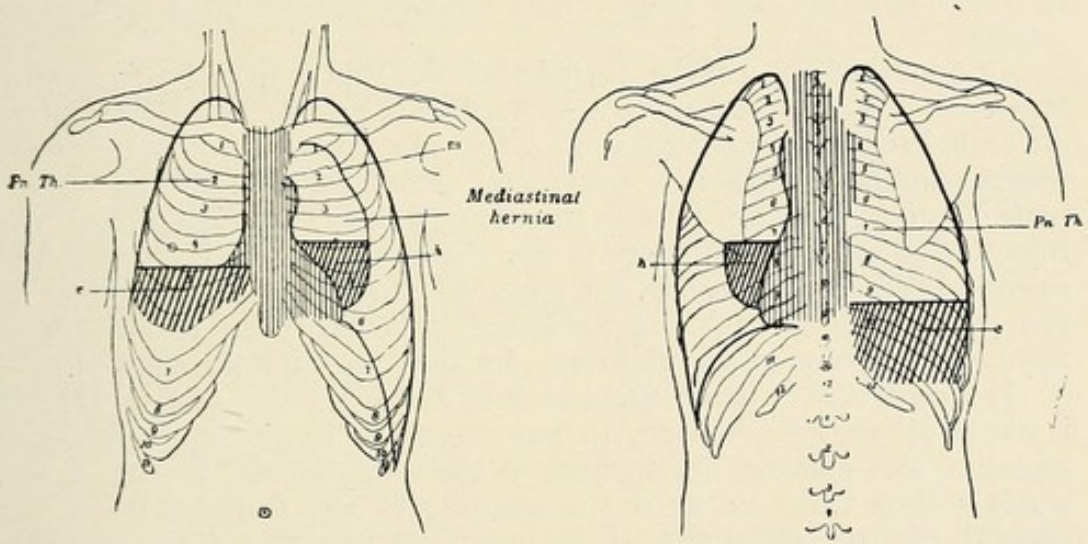

FIG. 63.—Seropneumothorax on the right (formed eleven months after the first production of pneumothorax, with fever) with secondary exudate *h* in a large hernia extending to the left of the front mediastinum, the limits of which are indicated by the lines *m*.

apparent when the needle-aperture lies in the pulmonary tissue or in loose pleural adhesions or even in sub-pleural connective tissue; the air, however, flows more slowly into the connective tissue and only under higher pressure than into the free pleural cavity; if there is communication with the air-passages it passes easily away; in order to make sure of this BRAUER gave a slight odour to the air injected by the addition of perfume.

It is well to place the patient in such a position that the site of the puncture is the highest point, so that the air-bubble may not change its place immediately and make its presence noticed on the manometer (KORNMANN).

If the lung was injured, the size of the interstitial emphysema does not depend alone upon the quantity of air injected, but can be considerably increased by inspiratory movements and by coughing.

Of all these kinds of emphysema only the mediastinal may

become dangerous by compression of the blood-vessels (BRAUER, according to SAUGMANN not so serious), &c. In individual cases (in a manner certainly not quite comprehensible) even circumscribed, dangerous emphysema of the laryngeal mucous membrane and of the face and lower extremities has occurred.

Moreover, even when pneumothorax is rightly produced, the pneumothorax air may be pressed from the site of puncture by coughing into the intermuscular or subcutaneous connective tissue and spread away farther. This can be avoided by initial compression of the site of puncture, and when an incision has been made by suture of the intercostal muscle.

(3) If the needle has penetrated the lung it may injure a pulmonary vein, part of the injected air may reach the latter and lead to air embolism in the larger blood-vessels. This may happen very easily in certain parts of the lung where the veins are kept open by infiltration of the tissue, and so can exercise the power of suction.

Of four sudden deaths, mentioned by BRAUER and SPENGLER, two certainly, and two more very probably, are to be attributed to air embolism. Such occurrences act as incentives to make us prefer the method of incision in producing pneumothorax to the simple method of puncture. The precaution, too, of noticing before the injection of air whether there is any extravasation of blood from the cannula, gives no certainty, for with the low pressure prevailing in the pulmonary veins blood need not necessarily be extravasated, nay, even at the given moment, air may be directly aspired.

If a puncture is made without denudation of the pleura, then it is above all things necessary to pay attention to the appearance of negative and positive fluctuations of the manometer ($\pm$ 5 to 6 cm. water); they must occur if the opening of the cannula is in the pleural fissure, especially if in order to counteract the possible (physical) effect of adhesion, you inject according to DENEKE cautiously, 10 to 20 c.c. of oxygen. If these fluctuations are not clear, it is better to abandon the injection of gas at this place and to try another.

(4) In some cases (about 50 per cent., BRAUER; 8 per cent., SAUGMANN), during the pneumothorax treatment, a discharge of liquid takes place into the pleural cavity, varying in quantity, generally serous. An intercurrent disease, angina, or the like, often an infection from the collapsed lung, generally starts its formation; it is furthered by mechanical detachment of pleural adhesions. The formation of the exudation is often accompanied by fever, especially when it is somewhat purulent or tubercular.

The mechanical effect of the pneumothorax on the diseased lung is assisted by the discharge of liquid; often the discharge acts as a sort of equivalent for absorbed nitrogen.

If of moderate size it gives no trouble, and it, as well as the residuum of gas, is spontaneously absorbed. At other times dyspnœa and displacement of organs takes place, because the pressure in the pleural cavity increases too much; then by puncture of the exudate the pressure must be correspondingly decreased.

If there is lasting fever, or if the discharge proves on exploratory puncture to be purulent, then, even if there is no considerable increase of pressure, as far as possible the liquid must be removed by puncture, and at the same time by injection of air through a second puncture, the normal pneumothorax pressure (see above, p. 142), and with it the collapse of the lung, must be maintained.

If the exudation does neither mechanical nor toxic harm, it is best left alone; only if it continues too long it can be replaced by means of puncture and injection of nitrogen by gas (as in the treatment of simple pleural exudations according to HOLMGREN).

(5) The expansibility of the mediastinum under equal pressure is very varied, both individually and after previous diseases of the pleura.

According to the investigations of NITSCH, the mediastinum has two weak spots, which bulge out when there is increased pleural pressure on one side:—

(1) Below the upper sternum, corresponding to the remains of the thymus at the level of the 2nd to the 4th rib.

(2) At the back below in front of the vertebral column between the aorta and the œsophagus. The solidity of both places varies individually; often when the pleural sac is filled with air or liquid regular recesses are formed, which extend beyond the median line. The right pleural space more frequently projects beyond the middle than the left. The upper recessus extends tongue-shaped 3 to 4 cm. below the upper part of the sternum, the lower may somewhat depress the sound lung, without, however, coming in contact with the vertebral column and posterior chest-wall (*cf.* figs. 59 and 64).

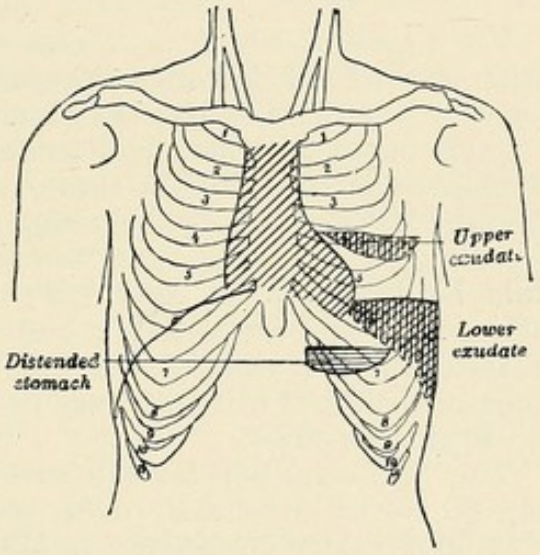

FIG. 64.—Pneumothorax on the left with about ten secondary injections in five months; then a pleural exudation is formed, accompanied by fever, in two tiers one below the other.

In cases of fresh acute pleurisy the resisting powers of the mediastinum decrease; in chronic cases, owing to inspissation of the pleura, they increase.

There is more frequently occasion to increase pneumothorax by repeated secondary puncture than to decrease it by suction, because the displacement of the organs has proved too extensive.

(6) As mentioned (p. 140), after the production of pneumothorax, not only does the resorption of the toxins from the collapsed lung cause temporary fever, but often the tuberculin takes effect upon the other lung also and causes swelling and increased activity of the diseased foci here (with increase of the physical sign). If the

foci are older, more torpid, less extensive, this occurrence may even favour their retrogressive metamorphosis; if they are more extensive and recently pneumonic their progress can be stimulated, and disintegration hastened. In cases of the latter kind, if they can be diagnosed, the production of the pneumothorax will either be abandoned or only produced tentatively, and increased very cautiously, or may be diminished by drawing off gas.

Very often, certainly, it is not possible to arrest the process, which, perhaps, would have gone on without the pneumothorax.

INDICATIONS.

For a method which is so new and requires so lengthy an application as artificial pneumothorax, sure indications cannot yet be laid down. Up to the present it has been used preferably in severe cases, in which other treatment had not been successful, and offered little prospect of success; among these, some of which had been despaired of, many improved in so surprising a way, and became even capable of earning their living, that from the layman's point of view they could be looked upon as cured; in many cases no success was obtained, or only a temporary one. It is evident that in cases not so serious more will be able to be done, and all medical men acquainted with the method are in favour of extending its application in this direction.

The first condition for artificial pneumothorax is that the other lung should be in a condition to answer the increased claims upon it without injury to itself. It is probably never quite free from tubercular foci even when clinically nothing can be proved. In practice it may be considered as free when there is only a slight catarrh of the apex. But even this requirement does not seem, according to present experience, to need to be so strictly insisted on as was thought at first. JESSEN has even described disease of a third of the upper lobe of the other lung as the extreme limit for the application of pneumothorax.

Still more than on the extent does it depend upon the nature of the disease of the "other" lung: older chronic foci are the most favourable; in fresh, inflammatory and infiltrated processes, the danger of exacerbation by the operation is the greatest.

In the case of the collapsed lung itself, the chronic and subacute foci offered the best prospects of obliteration, but we have not sufficient experience as yet to prove this; on the other hand, the state of rest may be considered as specially important and desirable for the acute foci. Too extensive disease will offer mechanical resistance to the collapse, quite apart from pleural adhesions. This has been discussed earlier.

Some feeling of uncertainty about the expediency of pneumothorax will always remain, because we have to pronounce not only upon the extent but upon the nature of the diseased foci (age and

condition, and nature and extent of the pleural adhesions). We cannot conceal from the patient, or those round him, the risk involved in this unavoidable uncertainty as to the final success, and that is a much greater risk than that involved in the dangers of the operation itself.

Based on the work of JESSEN we may, in the present state of experience, say somewhat as follows:

Certain Indication.—Severe disease on one side; other side free or almost free. Adhesions on the diseased side absent or slight.

Possible Indication.—Severe disease on one side of slow formation with many adhesions. Other lung free or almost free.

Gradual detachment of the adhesions by secondary compressions. Fever and sputum only disappearing when the diseased parts are successfully compressed.

Protracted severe hæmorrhage with severe disease of one side without adhesions.

The adhesions are obstructive, because only immediate rapid collapse of the lung can be successful.

Severe affection of one side with less severe affection of the other side (at the most one-third, and, if possible, without disintegration).

It is more hopeful when the upper lobe of the less diseased lung is affected than when the lower lobe is.

Contra-indications.—Extensive disease of the healthier side, especially when there is a tendency to disintegration.

Extensive solid pleural adhesions on the side to be operated on.

Serious disease, tubercular and otherwise, of the organs.

Statistics on the results of treatment with pneumothorax are of little value, because the condition of the patients on the application of the pneumothorax was (and always will be) too diverse. As in every case of pulmonary tuberculosis which is not very slight, a cure can never be attained in the actual meaning of the word, but in its practical sense, only really a prolongation of life; the question comes to be, how long would the patient have lived without the operation? Here each individual case must be judged on its merits.

With this restriction the following figures may be given: BRAUER and L. SPENGLER report (1911) on 102, SAUGMANN (1911) on 83 cases of artificially-produced pneumothorax; in 26 or 31 cases the induction was attempted, but was rendered impossible by extensive adhesions.

BRAUER describes (1910, out of 40 cases) the result in 45 per cent. as very good, in 17 per cent. as good, 15 per cent. satisfactory, 15 per cent. unsatisfactory, 7 per cent. died.

Excluding cases operated upon with very severe phthisis or with serious additional organic disease, SAUGMANN analyses 35 to some extent pure, though serious, cases of pulmonary tuberculosis; of these 18 completely lost the bacilli from their sputa, 5 were completely cured (for from four months up to three and a half years) 13 were free from symptoms but still under treatment, 10 much improved; 4 died.

Retraction of the Lung by Resection of the Ribs.

In cases of total artificial pneumothorax the whole lung ceases to work, the healthy as well as the diseased parts; as the latter have lost some of their elasticity, it may happen that many of the diseased parts retract less than the healthy tissue. Still more is the collapse hindered by adhesions, which are more frequently found on the diseased parts, sometimes the whole lung being prevented from collapsing.

It is not, however, necessary that a pulmonary part affected by tuberculosis should completely collapse, in order to be healed; the possibility even of a slight retraction favours the formation of connective tissue, the reparation of a disintegrating centre by a cicatrix, and thus the "healing." It is above all important to assist this retraction at places, and in cases when rigidity of the ribs offers resistance to the retraction of the pulmonary tissue; in the upper half of the thorax, and especially when the thorax is rigid; these conditions have already been discussed in the case of simple pulmonary suppurations (p. 103).

In pulmonary phthisis the contraction often to be observed of the yielding ribs, especially over the apices of the lung in young people, points to this cicatricial contraction; attempts have been made to relieve this, as in the case of simple chronic abscesses, by removal of the ribs. At first this was only done at circumscribed parts of the upper lobes, above in front (Quincke-Bier) or at the back in the interscapular space (C. Spengler). Then Turban and also Landerer made more extensive resections of the ribs in the lower half of the thorax; thereupon first the lower lobe retracted, and indirectly, but only imperfectly, the upper lobe too. C. Spengler resected above at the back. A total length of 30 to 50 cm. of rib was removed. Then as the more frequent attempts to apply artificial pneumothorax showed how often this was frustrated by extensive or even complete pleural adhesions, Brauer, L. Spengler and Friedrich sought to obtain total collapse of the lung by extensive mobilization of the thoracic wall (extirpation of bones, "extrapleural thoraco-plastic") by removing a total length of rib up to 200 cm. Apart from the fact that by this procedure so complete a collapse of the lung can never be attained, and especially never such immobility, as by artificial pneumothorax, in many cases serious disturbances of the respiration and the cardiac action occur owing to the mediastinal fluttering (see below); Friedrich, therefore, limits the extent of the resection of the ribs, removing the 2nd to the 10th rib, no longer for the greater part, but only in their axillary part, so that both before and behind large pieces are left. Sauerbruch did not perform extensive resections, but on both sides, first removing below three or four ribs, and after healing with partial depression of the thorax he removed the upper ones.[1] Finally, Wilms-Kolb removed in the neighbourhood of the angle of

[1] Not in reversed order, as otherwise foci due to aspiration may easily develop in the lower lobe.

the ribs 3 to 4 cm. out of each rib from the 1st to the 8th or 9th rib, after this the whole half of the thorax could sink and turn so far round the costal cartilages as axis that the surfaces of the sections of the ribs met behind; if the costal cartilages were not sufficiently yielding then later all the costal cartilages of this side not far from the sternum were severed, or partially resected.

Every part of the chest-wall which (without injury of the pleura) is made yielding by the removal of a piece of rib, follows the respiratory fluctuations of the contents of the thorax; it is drawn in on inspiration, on expiration, especially on coughing, arched out, particularly when the lung is normal and elastic; this may also be noted in openings of the ribs over abscesses, but not, as a rule, to any very great extent, as the pulmonary tissue in the immediate vicinity is more or less inflamed and thickened.

The larger the aperture in the ribs, the more extensive is the section fluctuating to and fro. Expectoration may be considerably impeded by this, because the quantity of air escaping into the pulmonary hernia is lost to the cough, and because the latter is not so violent on account of the pain caused. By application of the hand, by a suitable bandage this lack of solidity in the chest wall may be more or less compensated for.

If the deficiency of the ribs is very great, then the abnormal movements of the pleura are transmitted not only to the pulmonary layers on the upper surface, but also to the lower ones, even to the root of the lung. If, as often happened in FRIEDRICH'S plastic operations on the thorax, half or two-thirds of the bony wall of the thorax were removed, the mediastinum might also, if its normal expansibility were retained, flutter to and fro in a similar way, though not to so great an extent, as in the case of wide open pneumothorax; it would be moved on inspiration towards the intact side, on expiration towards the side operated on, the exchange of air, especially the inflation of the other lung on inspiration, would be affected by this, also part of the respiratory air hovers to and fro between the intact and the half collapsed lung operated on. Expectoration out of the intact lung is only very slight. By all these circumstances severe dyspnœa is caused, the diaphragm overstrained and exhausted, and perhaps also the heart is injured by the fluttering of the mediastinum.

Some of the cases in which thoracotomy has been so performed to such a large extent seem to have succumbed to the results of the operation. The latter do not occur, or only to a less degree, when the mediastinal pleura (on the one side or the other) has been thickened and become denser by previous inflammation. If this is not the case, the evil consequences can be averted to a certain extent, according to FRIEDRICH, by leaving larger portions of the ribs before and behind, by only making one long axillary aperture in the ribs, at the most 10 to 14 cm. broad, and by bringing the anterior and posterior costal margins as near as possible to each other, pulling them forcibly together and suturing the soft parts. In order to assist this, BRAUER proposed to make a kink in the stumps of the ribs at the point of insertion before and behind, and

farther on in their course. FRIEDRICH did this, but has given it up again.

The lung and mediastinum were still better assisted by WILMS's procedure, in which the axillary part of thorax is retained, and only at the angles of the 1st to the 9th rib are 3 to 4 cm. (possibly also in front a small strip from the costal cartilages) along the sternum removed from each of the ribs in question.

When the disease is confined to the apex of the lung, in order only to affect it, BRAUER and HARRAS have proposed to resect only the 1st and 2nd ribs, together with the clavicle.

The general condition of the patient, the site of the disease, the extent and solidity of the pleural adhesions, will determine which of the various methods of costal resection and plastic operation on the thorax is to be followed.

The resections of the ribs presuppose a much better condition of strength and nutrition than compression by artificial pneumothorax, the more so, the more extensive they are to be. Operations of a limited extent only will be performed on rather weakly individuals. The action of the heart must be taken specially into consideration. In cases of circumscribed disease it is sufficient to render possible the retraction of only this part of the lung; very extensive extirpation of the bones would in such a case permanently reduce the functional power of an unnecessarily large part of the pulmonary tissue.

Both after artificial pneumothorax, and the plastic operation on the thorax, the collapse of the diseased portion of the lung is generally followed by decrease of the sputum and of the fever.

The wound takes, according to circumstances, several weeks to heal, and months till the solidity of the part operated on is restored by the formation of cicatrices or fresh bones. During this time, and often still longer, a bandage must be worn to support the weak spot in the chest wall.

Scoliosis, through cicatricial contraction, does not occur in extensive (!) plastic operation on the thorax; on the contrary there is often a slight flexion with concavity towards the healthy side.

Of the 27 costal resections, mostly very extensive, performed by FRIEDRICH, during the first three weeks 8 of the patients died, of the others 3 were distinctly, 16 very considerably, better. As to doubts of the value of statistics the same holds good as was said with regard to artificial pneumothorax.

Artificial pneumothorax and the retraction of the lung by costal resection are the methods which have to be considered to-day in the surgical treatment of pulmonary phthisis.

As already explained at the outset the most accurate diagnosis possible of the extent and nature of the anatomical disease is essential. For this, next to the acoustic methods, the use of the X-rays is rendering more and more assistance every day, especially in the discovery of deep-seated foci.

The diagnosis of the pleural adhesions is discussed on p. 101. Even when they are very extensive, small circumscribed portions of the pleural cavity are often still maintained.

For the nature of the lesion, the course (anamnesis, fever), the sputum and the general condition must be taken into consideration.

If the lesions, still inflammatory and tending to break down, seem unfavourable for treatment by artificial pneumothorax, they are much less suited for plastic operation on the thorax, especially of any large extent; for this only those cases are suitable which are tending to contract, even when there are already considerable caverns.

Resection from the back, including the 1st rib, seems specially suitable for contracting and cavernous processes of the apex. FRIEDRICH and others have sometimes also shortened the clavicle by excision.

If the ribs are resected with retention of the periosteum, the thorax later gets more support on the side operated on; in any case the contraction is generally less considerable; the decision must be made according to the conditions of each individual case.

The treatment with artificial pneumothorax requires in typical cases only a short stay in a sanatorium, at the most a few weeks, then only attendance as an out-patient and occasional re-injection for a period of one or two years, whereas resections of the ribs, according to their extent, require first a period in hospital of several weeks or months, but then, under favourable circumstances, the patients can be discharged.

A considerable difference exists between the two methods after the treatment is over; in the case of artificial pneumothorax, as the thorax was left intact, after the conclusion of the treatment the part of the lung which was not affected by the disease expands again and recovers all its functional power; after resections of the ribs the thorax is mutilated according to the extent of the operation, and, owing to this, the whole of the lung on that side, even in those portions which are healthy, is permanently affected in its mobility and change of volume. Such contraction is, as cases of simple pleuritic thickening have taught us, not unimportant for the course of secondary intercurrent diseases, catarrhs and inflammations. The lung in such a condition has also less power of resistance to fresh local infections with tuberculosis.

I have tried to bring out the most important points in the two methods in the table on next page.

There are still a few other operations for the treatment of pulmonary tuberculosis which must be mentioned.

(1) Attempts have also been made to produce contraction of the lung by surgical operations on the pulmonary vessels.

SAUERBRUCH aud BRUNS[1] made experiments on dogs, sheep and goats, by ligaturing the branches of the pulmonary arteries. The section of the lung becomes anæmic at first, but is filled with

[1] BRUNS and SAUERBRUCH, "Artificial Contraction of the Lung by Ligaturing Branches of the Pulmonal Arteries," *Mitteil. aus den Grenzgeb. Med. u. Chir.*, vol. xxiii, 1911, p. 343.

blood by anastomoses, so that there is no formation of infarct (KÜTTNER). After eight days it is dark red, devoid of air, adherent to its surroundings, then from the surroundings of the bronchi there is a proliferation of connective tissue up to the pleura; after two to three months the lobe is contracted and adherent to the thoracic wall, with indurations. Up to the present SAUERBRUCH'S operation has only been performed on human beings in the case of bronchiectases; it can be performed from one of the intercostal spaces, especially favourable for both lower lobes and the right upper lobe. After a few weeks the sections of the ribs lying above the contracted lobe must be resected, so that the thoracic wall can follow the traction of the contracting lung.

	Artificial pneumothorax	Resection of ribs and thoracoplastic
Condition of the pleural surfaces	Pleural surfaces free	Pleural surfaces adherent.
The general condition of the patient	Can be employed even in cases of bodily weakness	State of nutrition and strength must be fairly good.
Severity of the operation	Slight	Not inconsiderable.
Length of treatment ..	At first at the most a few weeks in the sanatorium, then 1 to 2 years' out-patient treatment	A few weeks or months in hospital.
Immediate effect upon the lung	Total collapse, immobilization	Only slight retraction; respiratory movements only less free.
Secondary effect on the lung	After cessation of the pneumothorax the healthy parts of the lung become expanded again and can perform their functions	The reduction attained in the volume of the lung remains permanent.
Effect on the diseased portions of the lung when there are partial adhesions	Uncertain and limited ..	The effect can often be satisfactorily localized.

TIEGEL[1] compressed the pulmonary veins of rabbits and dogs with silver wire. The section of the lung in question became first a bluish-red, increased in volume, and after weeks or months became smaller, paler and more dense. The alveolar septa and the pleura were fibrously thickened, more so in the dog than in the rabbit. After total ligature of the veins the contraction was greater.

When TIEGEL performed the operation on rabbits, which he had infected intravenously a short time before with tubercle bacilli, after two or three months the tubercular foci on the congested side were less numerous, smaller, more clearly defined, less inclined to caseation. The more severely congested lobes suffered the least.

[1] M. TIEGEL, "Surgical Congestion of the Lung and its Influence on Tuberculosis," *Arch. for Clin. Surgery*, vol. xcv, 1911.

In the dog only once was extensive pulmonary tuberculosis attained. In this case the differences were still more striking.

From these two series of experiments will result perhaps the possibility of successful surgical treatment of monolobular pulmonary tuberculosis.

(2) The extirpation of a diseased pulmonary lobe. Although, owing to the ramification of the lymph tracks, as far as these come into consideration, the spread of tuberculosis generally takes place first within a lobe of the lung, still the disease rarely remains so circumscribed that even from the anatomical point of view, the extirpation of one lobe seems to offer much hope of success. The experiment has, however, been made in a few isolated cases, seven times with fatal results. TUFFIER, LAWSON and DOYEN were successful some time ago, and recently MACEWEN, whose patient was still cured after ten years. SAUERBRUCH believes that a preparatory ligature of the pulmonal arterial branch in question would make the extirpation of a lobe easier.

(3) Whether the opening up of caverns, considered insufficient justification for an operation on them alone, may be useful as a supplementary operation in individual cases of contraction by plastic operation on the thorax, when the cavities are very large and peripherally placed, can only be decided by experiment.

Even now such cavities, which have become secondarily putrid, are opened up—though this is a very rare event; they must be operated upon like other chronic abscesses on account of their putrescence, in spite of their tubercular origin, and this complication is also generally averted. Still more important is it here than in the case of simple purulent cavities to strive after contraction and obliteration as quickly as possible, in order that a tubercular fistula, difficult to heal, may not be produced.

In a tubercular lung simple abscesses may also develop; they must be opened up as in the case of other patients,[1] but a fistula is very easily left behind in their case.

Caverns which, lying on the surface, have attacked the thoracic wall itself, have sometimes been cured by extirpation of the outer wall and curetting (TUFFIER, NAENTGEN, KAREWSKI).

(4) STUART TIDAY[2] tried to secure immobilization of the lung, in case of disease on one side, by constricting the lower half of one side of the thorax with strips of plaster. He carries several strips of plaster from the lower end of the sternum in the expiratory position backwards to above the vertebral column. This is done for several months. The patient has to move a little and to take deep breaths.

The tendency of the proceeding is the same as that of artificial pneumothorax, but the immobilization is certainly very limited. Bandages would have a similar effect (and perhaps as a support of

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[1] *Cf.* QUINCKE, *Mitteil. aus den Grenzgeb.*, vol. i, 1896, p. 17, Case 3, four cases with KISSLING.

[2] STUART TIDAY, "On Mechanical Support of the Lung in Phthisis," *Brit. Med. Journ.*, 1896, vol. i, p. 721.

the plaster) as V. CRIEGERN[1] has suggested for the treatment of contractions of the thorax on one side and SAUERBRUCH[2] for the secondary treatment after plastic operation on the thorax; they are supported on the hip of the healthy side, and the shoulder of the diseased or the healthy side.

(5) In consequence of the favourable results of injections of iodoform in cases of tuberculosis of a joint, GESSNER[3] made injections of 10 per cent. iodoform glycerine into initial tubercular foci of the lung (5 c.c. puncture at the back through the 1st intercostal space two to three fingers' breath laterally from the spinous process, inclined 45° downwards. By drawing back the piston one makes sure that a blood-vessel has not been punctured; repetition after ten to fourteen days. Pain ensues only in the first two or three days, probably through the glycerine; cough and sputum are reduced.)

KÜLBS, in the medical clinic at Kiel, then under my control, made such injections according to GESSNER in seven cases of disease in the apex on one side, apparently successfully; after the injection severe irritation exciting cough, but no other disagreeable effects. In three cases, after six months to a year, considerable improvement could still be demonstrated objectively. One case came up for dissection a year later; on the site of injection there was a considerable development of connective tissue—the possibility that some iodoform might get into a pulmonary vein and lead to embolism in the larger vessels seems to me to leave this procedure open to some objection.

(6) FREUND'S preventive division of the costal cartilages. In 1858, W. A. FREUND pointed out in the paralytic thorax of many sufferers from phthisis an abnormal shortness of the 1st rib, in cured cases often abnormal articulation in the cartilage. He therefore proposed a division of the 1st costal cartilage with a view to prophylaxis of the tuberculosis of the apex. He, HART and others, have taken up and pursued these investigations again during the last few years. Whereas the normal length of the rib is on the average,

	In the man.	In the woman.
According to FREUND	3·8 cm.	3·1 cm.
According to HART	3·6 ,,	3·02 ,,

in the phthisical subject it is often as low as 3, or 2.2 cm. This causes a contraction of the upper opening of the thorax, which assumes, instead of the normal horizontally oval heart shape, a longitudinally oval shape. By this means the level of the 1st rib is inclined much more forward than is normal, and in this way the antero-posterior diameter of the upper aperture of the thorax is reduced, the inner space of the upper thorax very considerably con-

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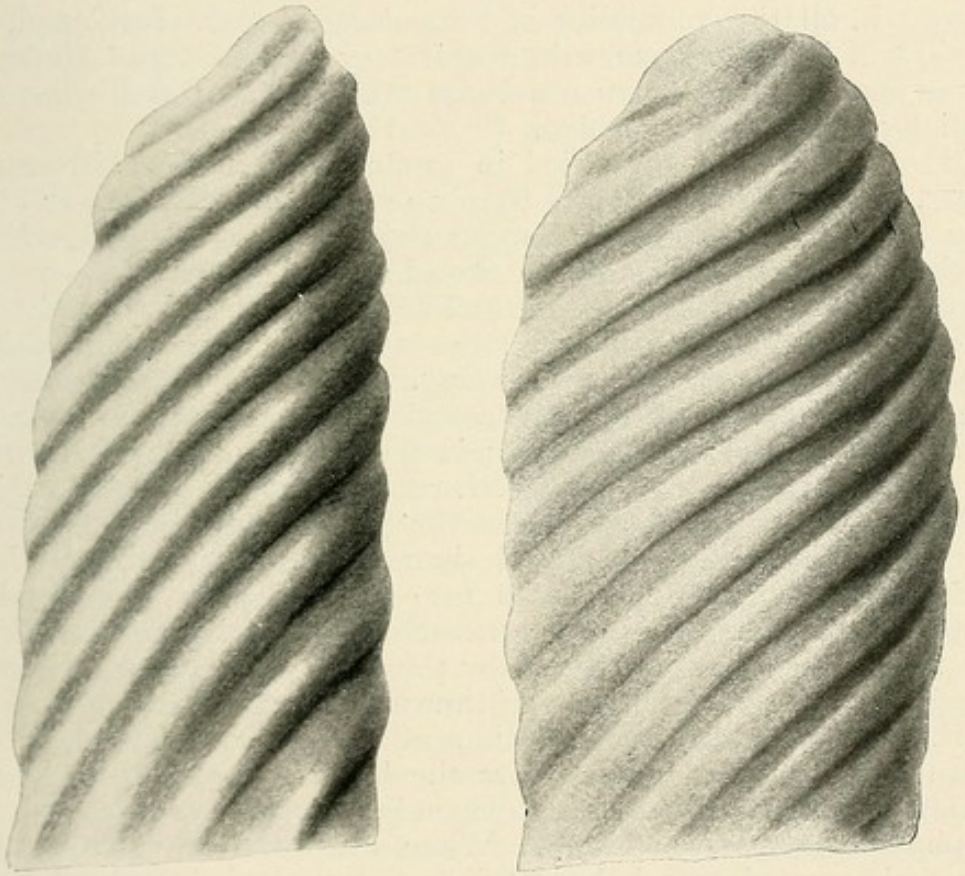
[1] V. CRIEGERN, *Berl. klin. Wochenschr.*, 1904, No. 29.

[2] SAUERBRUCH and SCHUMACHER, "Technique of the Surgery of the Thorax," p. 53.

[3] W. GESSNER (Olvenstedt), "Treatment of Pulmonary Tuberculosis with Injections of Iodoform Glycerine," *Centralbl. f. Chir.*, 1904, No. 16.

tracted. Often, too, the 1st rib cartilage is found rigid and completely ossified, which is attributed to the more severe mechanical strain of the inspiratory movements (hindered by it). All these modifications are more frequently on both sides than only on one; they may generally be considered as disturbances of growth, but also often as the result of a scoliosis of the uppermost thoracic and cervical vertebræ; they are not exclusively, but much more frequently, found in cases of tuberculosis of the apices of the lung. Generally the second costal cartilages, and to a less extent the immediately succeeding cartilages also, share in the arrest of growth.



A B

FIG. 65.—A, paralytic; B, normal thorax. (From plaster casts by D. VON HAUSEMANN.)

HART very often found (24 per cent. of all cases dissected) the formation of articulation in the 1st costal cartilage; they occur more frequently on both sides than on one side only, and specially in those cases in which the tuberculosis of the apices was healed, or very nearly so. The apices of the lung, in a thorax of this shape, are less developed, more slender, and are not so well aerated on respiration as is normally the case, and are, therefore, more liable to disease.

As a sign of the way in which the space is affected, SCHMORL found, in such thoraces on the upper surface of the lung, the subapical furrow due to pressure proceeding from the first rib,

described by him, and which occurs normally in children, still present in adults, and BIRCH-HIRSCHFELD found very frequently in diseases of the apices, the sub-apical bronchus contracted or bent.

In all these conditions, which represent some of the anatomical peculiarities of the paralytic thorax, we find the anatomical basis, the local predisposition for the disease of the pulmonary apex.

Whether the defective growth of the 1st rib is really causally the prime agent or not may be left undecided; perhaps defective growth of the lung and other parts go on at the same time, perhaps insufficient intensity of the respiratory movements causes the ribs, and with them the lung, not to develop normally. If, in the course of growth, all the anomalies of form described are developed, the 1st rib will indeed obstruct the respiratory movements of the apex, just as is the case when an otherwise normally shaped rib loses its elasticity and becomes ossified.

BACMEISTER has succeeded in producing in animals, by experiments, such anomalies of the thorax and investigating their effect upon the lung. Round the upper thorax of not fully developed rabbits about six months old he placed a wire, crossed the vertebral column behind between the 1st and 2nd dorsal vertebræ, and went close beneath the 1st rib round the sternum. The rabbit had to complete its growth in the wire ring. After four to six weeks the transverse diameter of the 1st costal ring appeared reduced, the 1st rib sloping more downwards; in the upper surface of the lung a groove due to pressure, subapical, paravertebral. In this region, besides a small atelectatic focus the alveoli and broncheoli are reduced in size, the whole apical tissue is pressed together. Now if cinnabar emulsion is injected into the blood of an animal so treated, the apex remains for the first few minutes unstained, because the cinnabar is diverted by the level of pressure as it were by a filter; after a longer space of time and after repeated injections, on the contrary, an accumulation of cinnabar is found in the obstructed part of the apex above the level of pressure, and more abundant cinnabar in the corresponding lymph tracks and the lymphatic tissue of the hilum. When BACMEISTER caused rabbits previously treated to inhale soot for some length of time, the soot accumulated in specks in the obstructed part of the apex, and also abundantly in the lymphatic apparatus, and in the perivascular part of the atelectasis. Therefore the stream of blood and lymph, as well as the exchange of air, are obstructed and made slower in the mechanically modified part of the apex.

BACMEISTER succeeded in producing in rabbits previously treated tuberculosis of the apex, whereas in normal quadrupeds there is no predisposition to disease of the apex. BACMEISTER achieved this by injection of very much diluted cultures of tubercle bacilli into the blood, and also by subcutaneous inoculation over the inguinal region; in the last case the bacilli also settled on the blood ducts, but the foci arose not only perivascularly, but also peribronchially. The tubercular foci had developed preferably in the region of the groove due to pressure. BACMEISTER also succeeded in producing

a few tubercular pulmonary foci aerogenously, but not tuberculosis of the apex, both with dry and with moist spraying of the substance inhaled.

From these experiments it follows that when there is occasion for infection mechanical obstruction of the apex of the lung produces therein a local predisposition to the development of tuberculosis. Such obstruction may be afforded by a hereditary deficiency in growth power in the first and immediately succeeding ribs; this may be aided by insufficient respiratory movements caused by habit or occupation, sometimes perhaps this is sufficient by itself; in growing individuals, therefore, systematic exercise in this direction will often equalize matters and should be tried first of all.

If, however, when this period of growth is over, the abnormal shortness and inclination of the 1st rib has become settled, a compensatory mobilization of the upper parts of the thorax can only be attained by division of the 1st (and perhaps also of the succeeding) costal cartilage.

But also in the case of normally shaped upper ribs, loss of elasticity and ossification of the cartilages sometimes arise very early, increase the predisposition to tuberculosis of the apex by hindering the respiratory mobility, and thus indicate the necessity of surgical mobilization.

Now should the division of the cartilage only be performed when the foci and signs of tuberculosis of the apex are apparent, or before, say when there is a general predisposition to tuberculosis? Up to the present it has not been decided to take the last step. At all events the operation might be performed by way of prophylaxis to prevent the establishment or the further dissemination of the tuberculosis in the apex.

To mobilize the apex of the lung seems, in the presence of the already existing foci, to be in contradiction to the principles of the treatment by pneumothorax; but this is only apparent, for the immobilization by artificial collapse of the lung should only be resorted to in cases of more severe and extensive disease, whereas the improvement of the respiration of the apex should only be applied in the very first commencement of tuberculosis of the apex. Do we not see, too, in other organs that a moderate and regulated demand made on the function so strengthens the conditions of nutrition of that organ that the healing up of circumscribed foci of disease is furthered?[1] Also in the treatment by pneumothorax, tubercular foci of small size in the lung on the other side, which must breathe more energetically, are often favourably affected.

As a matter of fact, the division of the first costal cartilage in the case of tuberculosis of the apex is only rarely performed by KAUSCH and by SIEDEL on adults, apparently at first with beneficial effects on the course of the disease.

More definite indications can only be gathered from wide experience; at present the matter stands as follows:—

[1] See HARRAS, *Grenzgebiete*, vol. xxi, 1910.

The operation is not to be performed purely prophylactically, that is, before disease of the apex has been proved to be present.

A preliminary condition is initial and exclusive disease of the apex of the lung, which does not extend beyond the 2nd rib. The shortening of the cartilage due to anomalous formation is to be influenced in individuals still growing by breathing and other exercises; only when growth is complete should surgical treatment be taken into consideration. In normally formed ribs, too, when they become prematurely rigid and the cartilages calcify, the division of the 1st (perhaps the 2nd and 3rd) costal cartilage is justified as a therapeutic experiment.

For the diagnosis of these cases, besides the other methods of examination, the use of the X-rays and of acupuncture of the costal cartilages come into consideration.

Surgical Technique.

(1) DIVISION OF THE FIRST COSTAL RING IN CASES OF A NARROW APERTURE IN THE THORAX.

In connection with the opening up of the 1st costal ring in cases of a paralytic thorax, I will say a few words on the technique of linear chrondrotomy.

SEIDEL makes a semicircular incision from the upper margin of the sternum, to the 2nd rib convexly towards the right sternal margin, entering between sternal and clavicular heads of the pectoralis major; amputation of the anterior perichondrium of the 1st costal cartilage, diagonal division from below outside up inside with chisel or LUER'S forceps, and, later, interposition of a small flap of muscle.

KAUSCH, from an incision a finger long, running parallel to the clavicle, resects the cartilage and bone freely (up to 2 cm.) with the arm held up high.

Owing to the paravertebral reduction in space for the apices of the lung, which leads to the formation of SCHMORL'S furrow, HENSCHEN considers it more rational to resect the 1st costal ring in its paravertebral portion. He gives the following directions as to technique :—

Cutaneous incision at the spine of the sixth or seventh cervical vertebra, behind and parallel to the level of the shoulder, outwards to the acromial end of the sternum, then a vertical complementary incision. The arm of the patient, lying half in the abdominal position, is lifted forcibly forwards. The parts of the trapezius, rhomboides and serratus posticus superior muscles occurring in the incision are severed longitudinally, the levator anguli scapulæ transversely. If the shoulder blade is drawn sharply back with tenaculi, one can probe to the tubercle of the 1st rib, and prepare the semicircular segment subperiosteally for resection.

HENSCHEN still considers FREUND'S chondrotomy indicated for the premature ossification of the 1st costal cartilage (HART'S

"Anomaly in the Aperture in Older People"), whereas he considers the "paravertebral decompressive resection," as he calls his operation, indicated for cases with primary arrest of development in the costal cartilage or the rib itself, as well as the stenoses of the aperture attendant on malformation of the vertebræ. This operation has not, as yet, been performed.

(2) OPERATIONS ON THE LUNG ITSELF.

The surgical treatment of a circumscribed tubercular focus in the lung—by extirpation or denudation of the focus—has been repeatedly attempted. The results obtained, however, have not encouraged any surgeon to continue in this direction; on the contrary, it seems to me almost as if all surgical experiments in this direction have fallen into disrepute. Although some few good results were obtained in this way, the total results are not encouraging. According to MURPHY, out of forty-seven cases operated upon, twenty-six cures, that is, temporary cures or considerable improvement, with arrest of the tubercular process from two to five years, are to be reported, with nineteen deaths.

The material made use of for these statistics is too dissimilar, and the attitude of the individual surgeons as regards indications too diverse up to the present time, for us to be able to draw any definite conclusions from these figures. Moreover, the results of various methods of operation have been included.

TUFFIER and LAWSON proceeded in the most radical fashion. They have successfully extirpated fresh circumscribed tubercular foci of the lung, which, like isolated tubercles on the brain, resembled anatomically a tumour. After them others did the same, but with less success. The general adoption of this procedure, which must always be a very dangerous operation, will always be checked, first, by the uncertainty of the diagnosis of a really circumscribed single focus, and, secondly, by the consideration of the possibility of spontaneous healing.

The tubercular abscesses of the lung, the cavities, on account of their frequency alone, would seem to call much more urgently for surgical aid; they do at least as much harm as other pulmonary abscesses, especially in so far as by their secretion, by way of aspiration, fresh tubercular foci are developed. But clinical experience of about thirty cases has shown that by the mere opening up of the cavities, generally situated in the upper lobe, nothing is achieved as regards the complete cure of the fundamental disease. The discharge of the secretion still takes place essentially through the bronchi; we only get in addition the formation of a tubercular fistula.

A considerably better result was, on the other hand, attained by opening up and drainage in all those cases, which, in consequence of pyogenous mixed infection of the stagnating content of the cavity, suffered from symptoms of septic fever. Cough and sputum were diminished, the fever disappeared, and the general

condition improved. Undoubtedly, in these not very frequent cases surgical treatment is indicated, although the tubercular process itself was not demonstrably affected. Whereas in the suppurations hitherto discussed in the majority of cases, the restoration of these mechanical conditions is sufficient to provoke in the diseased tissue of the wall of the abscess the expulsion of the pathogenic microbes—and in this way so to induce regeneration of the tissue—this is not the case with the walls of cavities which are permeated with tubercles, as experience with other organs (for example, tubercular suppurations of the bones and articulation) shows. To operate on the walls themselves, perhaps by curetting, is prohibited by the danger of hæmorrhage; here, therefore, only elimination and encapsulation by the activity of the living tissue itself can occur.

When, in 1890, by the introduction of tuberculin into the therapy, hopes were raised of bringing about the breaking down and elimination of tubercular tissues, SONNENBURG, at ROBERT KOCH'S suggestion, combined the surgical denudation of an apical cavity with tuberculin treatment. After two months, the cavity, which, at first, by the breaking down and disintegration of its caseously infiltrated walls had increased in size, was completely cicatrized, and the patient appeared to be cured. However, in the following four years, now and again tubercle bacilli appeared in the sputum and the patient succumbed in the fifth year after the operation to recent tuberculosis of both lungs.

Only a few surgeons have ventured on the radical extirpation of whole lobes of the lung or of the whole lung. All the more remarkable is the brilliant success, which W. MACEWEN has achieved in a few cases with total or almost total extirpation of the lung. Thus a patient whose surgical experience we will briefly sketch, is now, sixteen years after the operation, healthy and fit for work.

Severe pulmonary tuberculosis on the left side for three years with extensive formation of cavities and secondary pyæmic infection, large quantities of sputum with enormous quantities of tubercle bacilli. Fever. Patient very emaciated and wretched.

April 24, 1895. Extensive opening up and evacuation of the gigantic cavity after resection of an opening in the ribs in the posterior axillary line; four weeks later plastic operation on the thorax, 4th to 8th rib entirely resected. There are only a few bits of the wall of the left lung remaining; they are extirpated after removal by ligature of the vessels of the hilum. Only the apex of the lung is so firmly adherent that its amputation has to be abandoned owing to the risk of injuring the subclavian vein. A subsequent secondary resection of some ribs leads to the closing up of the cavity.

In the first few weeks after the operation the patient could only lie on the healthy side, as soon as he turned on the other side threatening symptoms of angina pectoris set in, which are undoubtedly to be attributed to the displacement of the heart. They disappeared as soon as the pericardium was fixed by adhesions.

The patient, as Sir W. MACEWEN told us in September 1911, is still perfectly well, without a sign of fresh tuberculosis. The following photographs, which I owe to the kindness of the operator, show the enormous gap in the thorax.

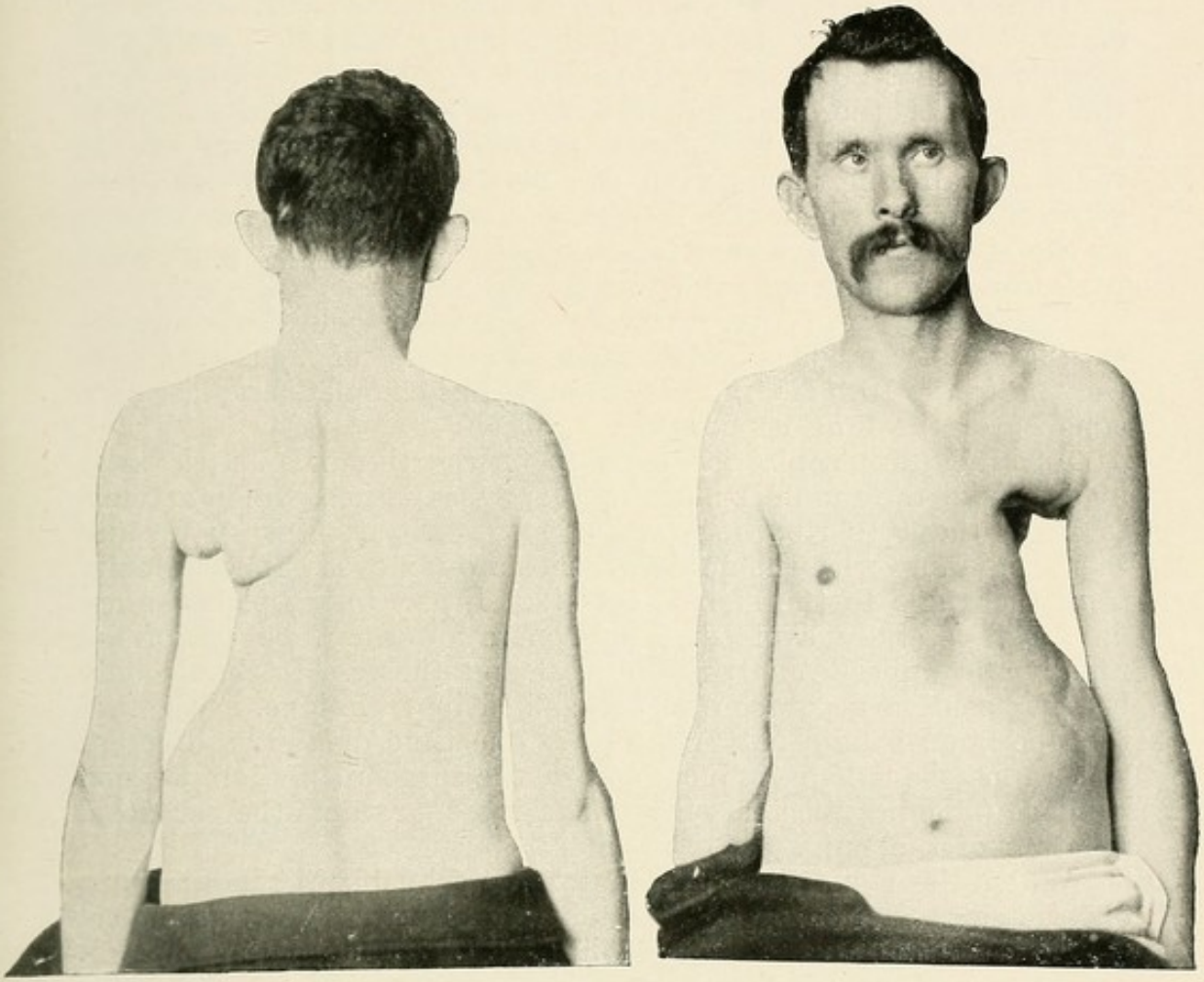


FIG. 66.—Extirpation of the whole of the left lung (MACEWEN). The patient has been cured for sixteen years.

(3) THE THORACOPLASTIC METHODS.

In spite of this brilliant success, in general, in the chronic infiltrating form of tuberculosis and in the case of tubercular caverns, more is to be hoped from a mobilization of the chest-wall, according to the opinion first expressed by QUINCKE, than from resection. The diminution or cicatrization of these cavities is made easier by the removal of the rigid thoracic ring, in so far as the diseased tissue can collapse and cicatrization can take place and the continual tension due to the respiratory movements is avoided. Therefore, not infrequently after plastic operation on the thorax profuse and repeated cavernous hæmorrhage occurs (*cf.* on this point, p. 179 and after).

The mobilization of the chest-wall by resection of ribs will also

have a relaxing and (relatively) immobilizing effect upon such diseased tubercular pulmonary parts more deeply seated, which are not yet permeated with cavities. The effect of the plastic operation on the thorax can be considerably increased by opening the pleura and removing the surface adhesions.

In any case the resection must be sufficiently extensive for the diseased pulmonary part to be sufficiently relaxed; SPENGLER considered that 20 to 25 cm. at least should be removed from the length of the rib and always resected behind right up to the vertebral column; TURBAN removes from the side of the thoracic wall long pieces from five to six ribs; he expects to be successful even when the resection does not take place exactly at the site of the diseased focus, because the healthy pulmonary parts can move towards the retracting ones.

FRIEDRICH went the furthest. He undertook the complete extirpation of the bones on the whole of one side of the thorax from the 2nd to the 10th rib, in order to obtain as complete and lasting a collapse of the lung as possible.

As in SCHEDE'S plastic operation on the thorax an incision is made round the shoulder-blade in a large semicircle, which extends to about the 10th rib, the whole flap of soft parts turned up and then, beginning with the 2nd, eight ribs are removed subperiosteally from the angle to the sternal margin. Injury to the pleura must be most carefully avoided. The operation must be performed rapidly and unhesitatingly under local anæsthesia. It should only be entrusted to a surgeon highly skilled in technique. Whether the operation should be performed at one time or at two different times must be left to the judgment of the surgeon. A compression bandage (sticking plaster with rubber inset) prevents the paradoxal inflation of the lung.

When the rigidity of the thorax, or solid pleural indurations, obstruct a retraction of the lung due to cicatrization, this radical plastic operation on the thorax will certainly produce the physical conditions necessary for the complete cure of a lung permeated with caverns. As a matter of fact, FRIEDRICH is able to report some splendid clinical successes.

On the other hand, this extirpation of bones has led to rapid death, not to be attributed entirely to the severity of the operation or to the feebleness of the phthisical patients, but must be looked upon as an immediate result of the collapse of the lung with displacement of the mediastinum (for detail see p. 24). This has caused FRIEDRICH recently to make the operation dependent on the presence of a rigid, that is to say slightly movable, mediastium. But this is rarely to be ascertained with the necessary certainty. Then he decides only to perform this operation on such patients as are not younger than 15—not older than 35, and also to exclude very anæmic patients and those with fresh metastases on other organs; in this way the indications are so restricted that the operation would only have to be considered in quite exceptional cases.

FRIEDRICH, himself, it would seem from his latest publications,

has turned his attention more to partial plastic operation on the thorax, which he performs in various ways, usually from an axillary longitudinal incision, but, generally speaking, makes the localization and extent of the costal resection dependent on the nature of the existing transformations of the lung. However, in spite of this restriction, the rate of mortality is still very high (28 per cent.). We must not forget that it is a question of advancing cases of phthisis with cavities, which, in spite of the usual treatment, were getting steadily worse, and must also emphasize the fact that in the case of fourteen patients FRIEDRICH reports a distinct, to some extent pronounced, improvement.

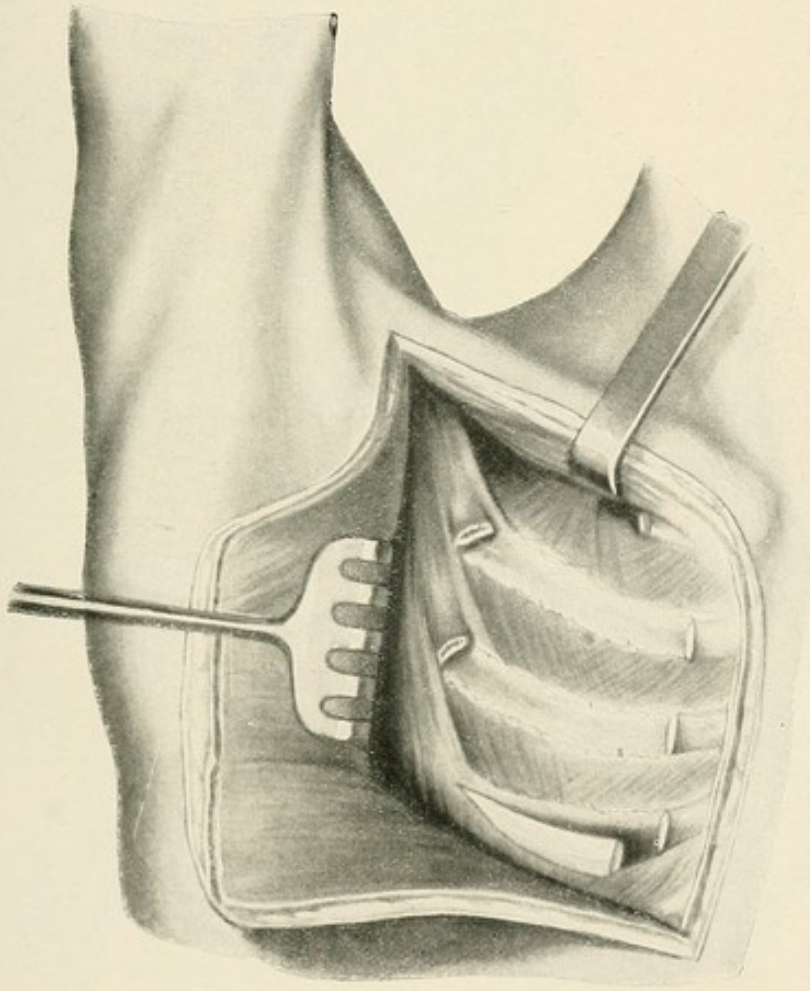


FIG. 67.—Plastic operation on the thorax over the upper lobe, according to SAUERBRUCH. (Out of SAUERBRUCH and SCHUMACHER'S "Surgery of the Thorax.")

The dangers of an extensive plastic operation on the thorax are considerably lessened when the operation is performed in two independent parts, as SAUERBRUCH suggests, and has successfully performed. First resection of the 4th to the 8th rib; then after some weeks or months resection of the 1st to the 4th rib. In case of more severe disease of the upper lobe (especially when there are cavities), the lower lobe must first be compressed, as

otherwise there is a risk of the secretion of the collapsed parts of the apex producing in the lower lobe pneumonia due to aspiration.

Under local anæsthesia the 4th or 5th to the 8th rib are resected in the first session. In order thoroughly to compress the lower lobe, BRAUER and SAUERBRUCH made their patients wear an

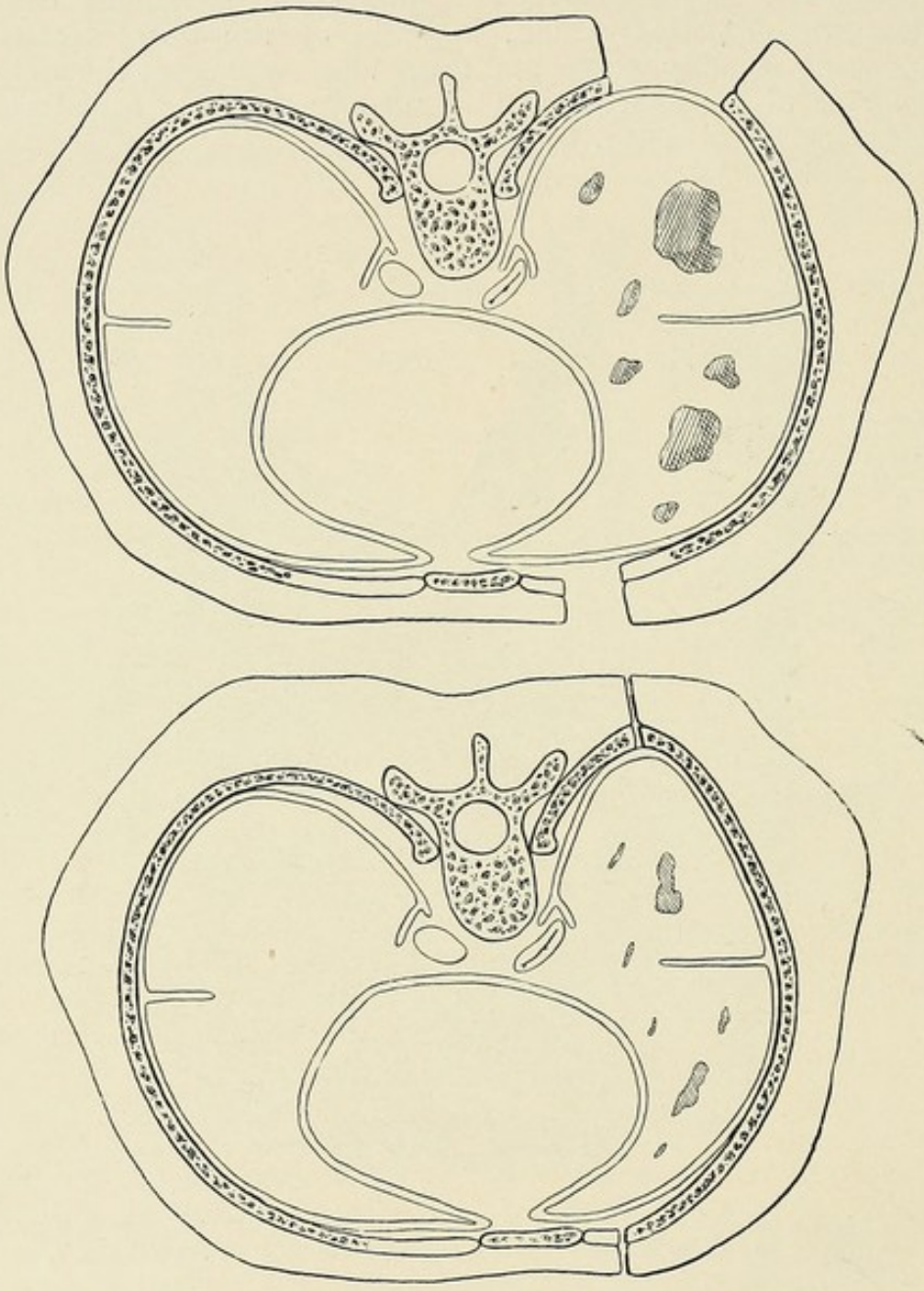


FIG. 68.—Diagram of the contraction of the thorax by WILMS.

elastic bandage for a time. In the second session from a ⅂ incision after removal of the pectoralis major (*cf.* fig. 66), the 2nd rib is removed periosteally as far as possible, and then with the greatest care the 1st rib, which is now easily accessible, is resected bit by bit with LUER'S bone forceps. Then if 8 to 10 cm. of the 3rd

and 4th ribs are removed, the chest-wall can be depressed over the upper lobe. (The result could be increased by a resection of part of the clavicle—but this is not necessary.)

SAUERBRUCH performed partial twofold thoracoplasty on twenty-four phthisical patients in various ways corresponding to the local and general condition of the patient. He had one death

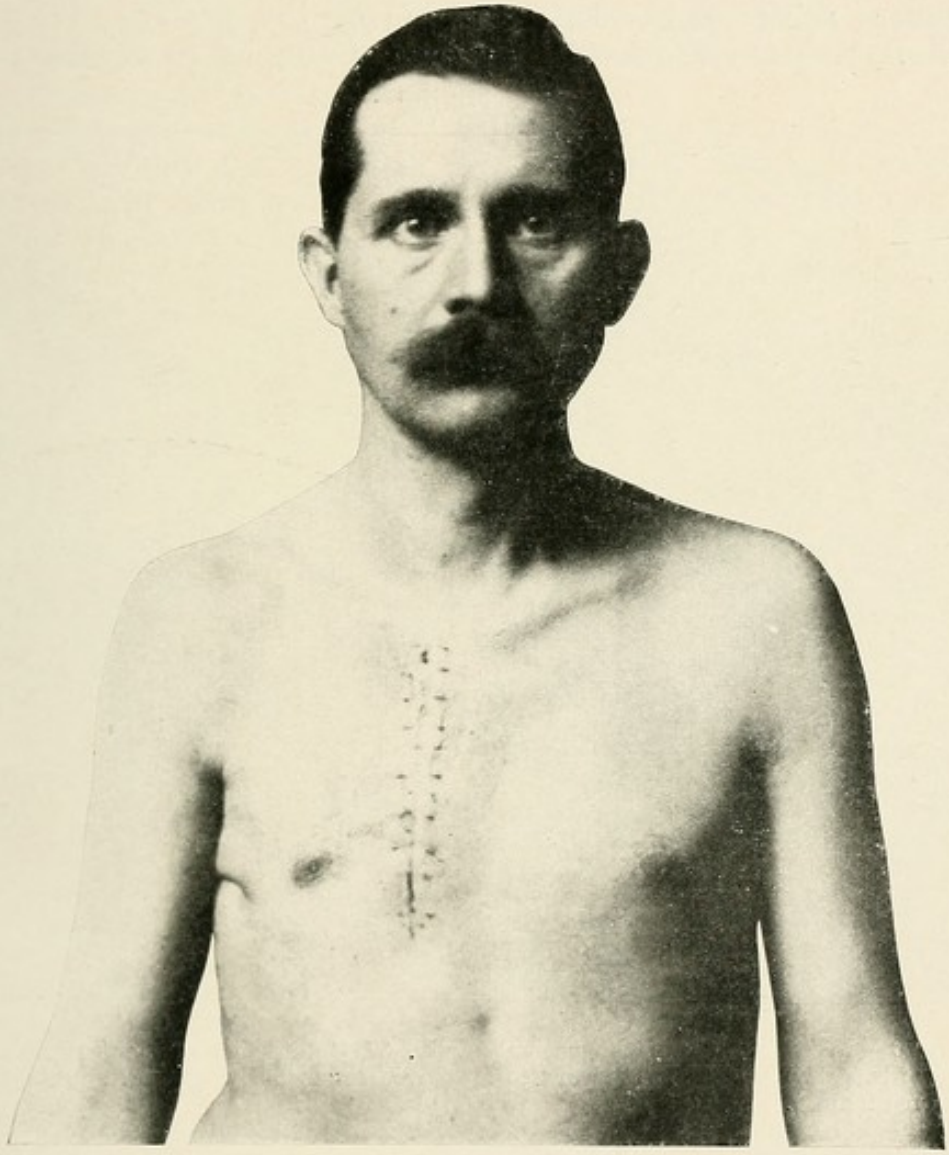


FIG. 69.—Collapse of the right half of the thorax, five weeks after the operation. (Patient of WILMS.)

in consequence of the operation and two secondary deaths (caseous pneumonia) after nine months. He reports: two cures, two cases of improvement almost amounting to cures, four considerably improved, seven somewhat improved, and two cases not affected; four patients are still under treatment (1912).

SAUERBRUCH rightly emphasizes the fact that in the case of pulmonary tuberculosis there can be no question of *one* thoraco-

plastic method as the typical method for all cases; the nature of the disease, its localization and diffusion are too varied for this. Here also there must be the most careful individualization—"the decision as to which form of operation shall be used, and to what extent is the main difficulty in the surgical treatment of tuberculosis."

Wilms has recently (1911) applied a new and, as it seems to me, successful method of contracting the thorax in the case of pulmonary tuberculosis. In the region of the posterior angle of the rib he resected 3 to 4 cm. from each of the 1st to the 8th ribs;

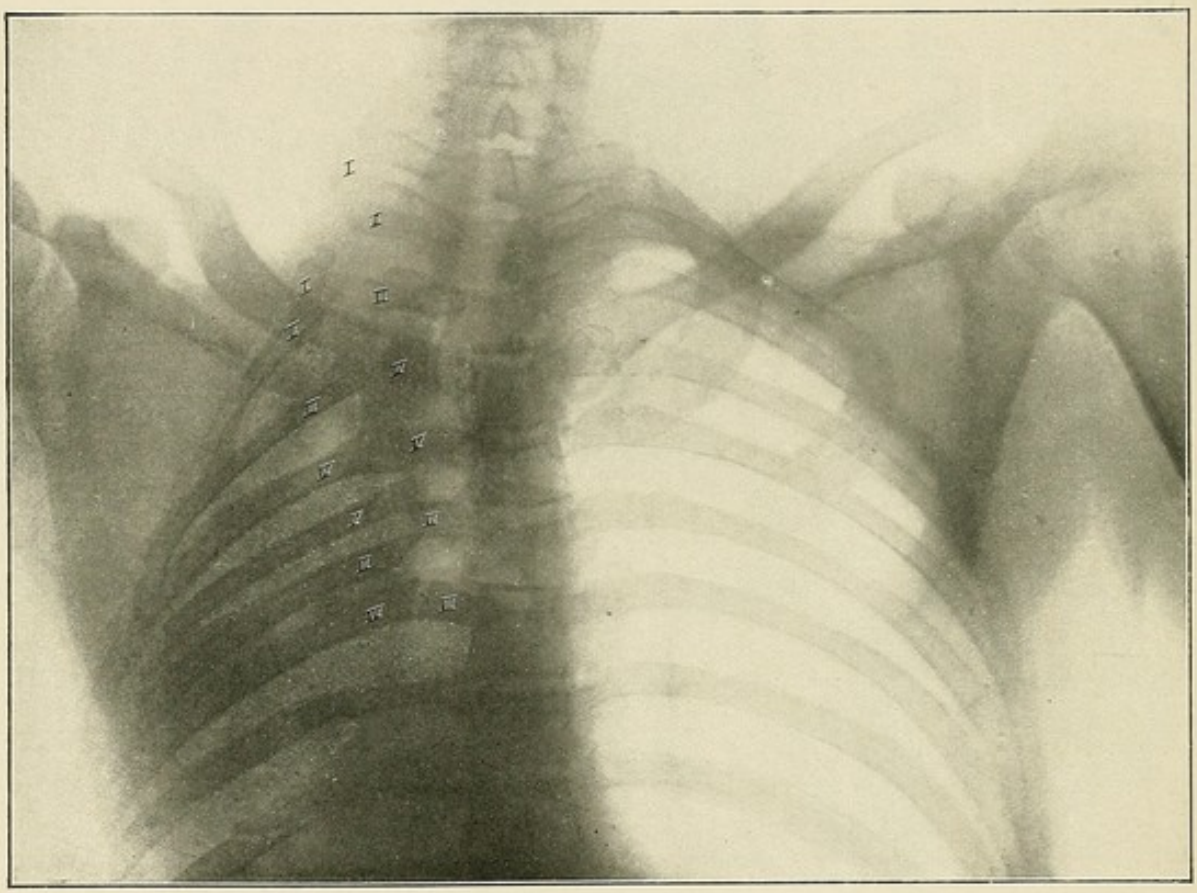


Fig. 70.—X-ray picture of the patient of fig. 67 (1st to 6th rib bent right down and inwards. Cavity between the 3rd and 4th rib reduced by one-half, pronounced retraction of lung).

in a second session, three weeks later, the costal cartilages were divided at the sternum, in order, then, to press the now movable chest-wall considerably into the thorax. He operated in this way on eight cases. The ends of the resected ribs had not only approached one another, but fallen into the expiratory position, which considerably increased the pulmonary collapse. The two photographs which the writer most kindly gave me show most clearly the effect of the operation.

The operation is performed under local anæsthesia. After longitudinal cutaneous incision the muscles of the back, especially

the trapezius and the rhomboids, are bluntly severed in the direction of their fibres (longitudinally or diagonally). When the severed muscles are drawn forward with tenaculi, from one opening in the muscles several ribs can be divided. Three transverse incisions are sufficient—the first at the level of the 2nd rib; the second on the 5th, and the third on the 7th rib. WILMS lays especial emphasis on the accessibility of the 1st and 2nd ribs, the resection of which is important for the collapse of the apex of the lung.

For this reason he considers his method applicable also when the apices are affected on both sides if only the three uppermost ribs on each side are mobilized.

Undoubtedly the dangers of the plastic operation on the thorax are considerably diminished by this mode of procedure. The operation, with the same result in the reduction of the volume of the thorax, is considerably easier and less dangerous as compared with the partial resections of the wall or the removal of the bones of the wall of the thorax.

Here, too, in the after treatment, a forcible compression of the side of the thorax operated on, and placing the invalid on the injured side are necessary. Breathing is painful, expectoration difficult; therefore broncho-pneumonia is still to be feared. The results seem to very satisfactory.

(4) ARTIFICIAL PNEUMOTHORAX, APPARATUS AND TECHNIQUE.

The aim of artificial pneumothorax, as of thoracoplasty in all its different methods, is the spontaneous cicatrization of the tubercular foci with the lung fixed in a position of rest, that is not functioning.[1] In the clinical part of this section the indications, the mode of application, the complication and dangers, &c., are discussed in detail. According to these, the method is indicated in cases of not too advanced tuberculosis on one side, and may also be applied in cases affected on both sides, when the second is only slightly affected, Just recently FORLANINI has expressed a wish to see the method applied as early as possible, and to limit the duration of the pneumothorax to the shortest period possible. Acute cases of tuberculosis, and those which are complicated with myocarditis, or severe intestinal or laryngeal tuberculosis, must be excluded from this treatment. Post-mortem examinations have shown the lung transformed into a dense cicatricial tissue, including encapsulated thickened caseous foci.

The technique requires the greatest care with some practice. The dangers lie in the production of an interstitial emphysema, in the formation of a pleuritic exudate, and in death from air embolism.

[1] Artificial pneumothorax may also be recommended as an excellent palliative in the case of painful pleurisy. I have twice in the case of very painful carcinomatous pleurisy promptly arrested the pain by the insufflation of air into the pleura.

For the compression nitrogen gas is chosen; it lasts the longest. Oxygen and the oxygen from the air are very quickly absorbed, and therefore require more frequent secondary compressions. The apparatus is simple. FORLANINI, SAUGMANN, and BRAUER have constructed such apparatus. They are, in principle, communicating bottles or tubes, of which one contains sublimate solution, the other the nitrogen to be injected. By hydraulic or air pressure (RICHARDSON'S rubber inflated bag), the gas is pumped into the pleural cavity by a puncture needle, which is connected with the apparatus by a tube.

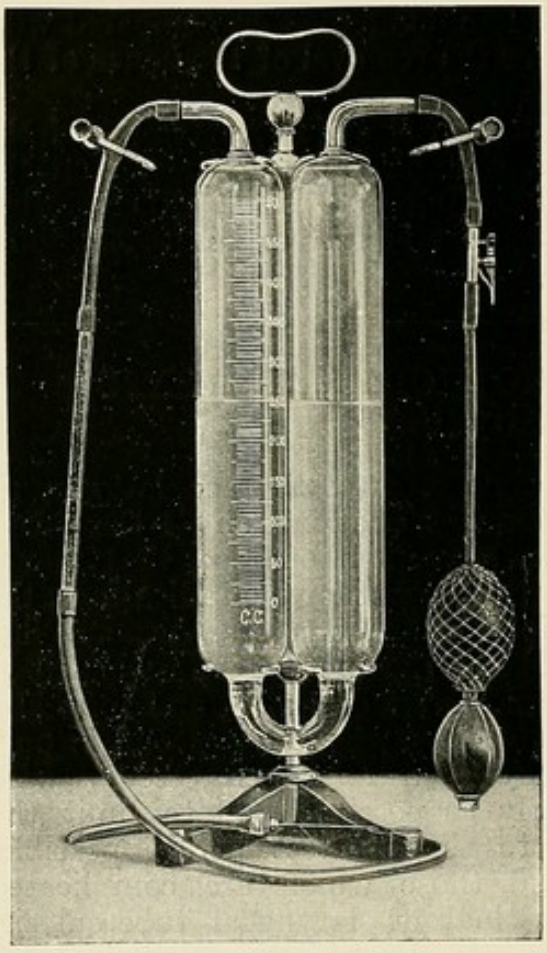


FIG. 71.—Nitrogen apparatus by FORLANINI.

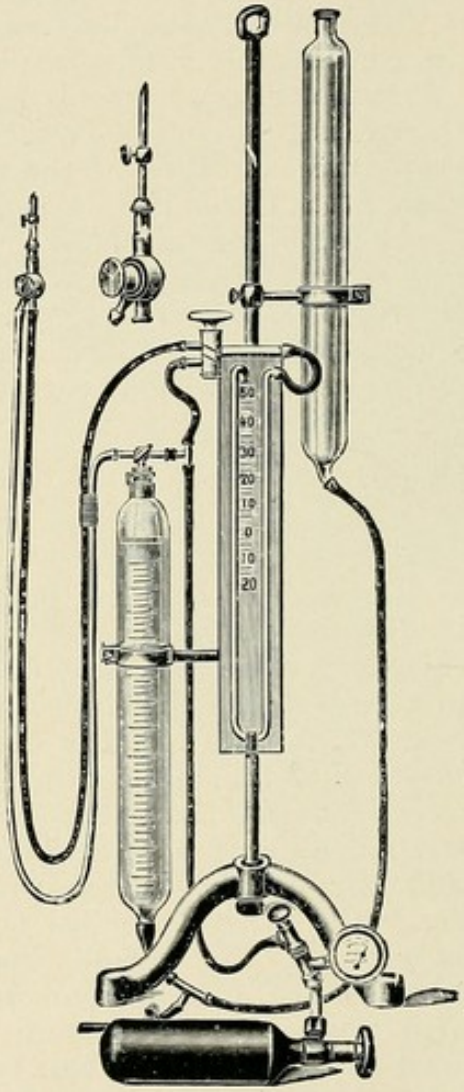


FIG. 72.—Nitrogen apparatus (Breslau model).

It is advisable previously, by use of the X-rays or otherwise, to ascertain that the pleura is mobile. Solid pleural adhesions make pneumothorax impossible. One must therefore seek with the needle for the free pleura guided by the manometer reading.

In conclusion, by way of supplement to what is said on p. 141 about the application of artificial pneumothorax, I must deal briefly

with the technique and the apparatus used. MURPHY'S original nitrogen apparatus (*cf.* first edition of this book, p. 67) has been modified in various ways and improved. FORLANINI, BRAUER, O. FRANK, SAUGMANN, DENEKE, and HÄRTEL, instrument maker in Breslau, have constructed very useful apparatus (*cf.* figs. 71-75).

The apparatus consists of two glass receptacles (cylinders or bottles), in which the nitrogen gas can be placed under pressure of a column of fluid; they are connected with each other and with a manometer as well as with the puncture needle by means of rubber tubing. The only essential difference between them is the way in which the pressure is obtained under which the nitrogen is injected. FORLANINI and SAUGMANN obtain the required increased pressure by means of a hand-blower; BRAUER, whose apparatus consists of two bottles of which the one contains water, the other

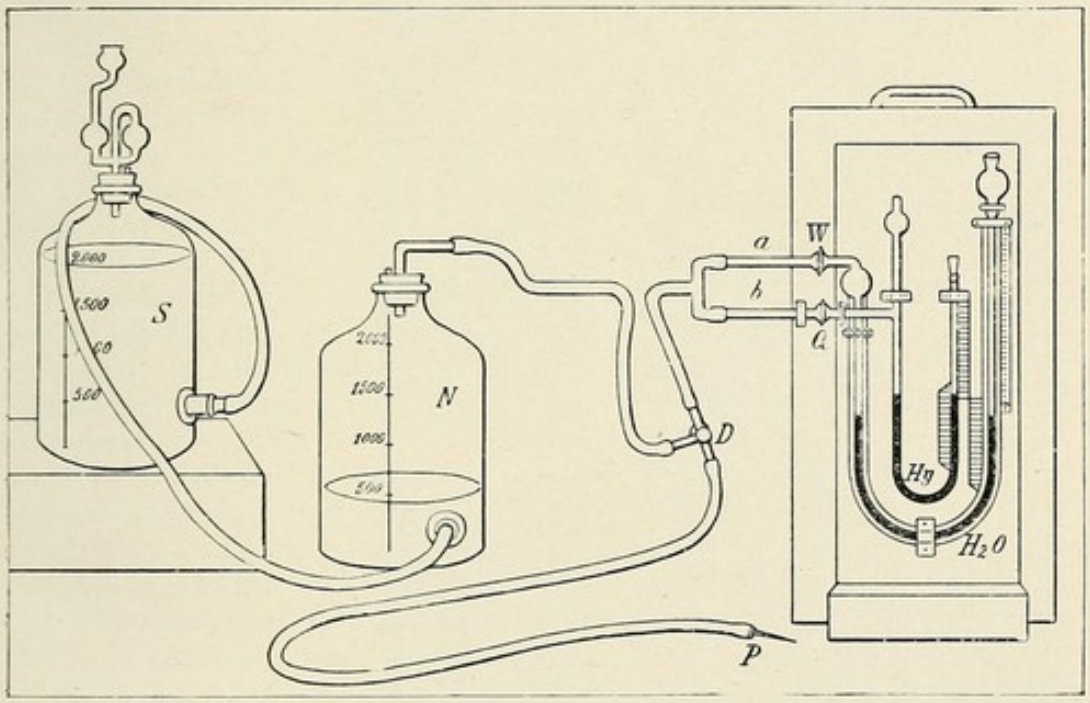


FIG. 73.—BRAUER'S nitrogen apparatus.

gas, places the water receptacle higher in accordance with the desired pressure. The apparatus of DENEKE and the Breslau model are handier. In them the receptacle for the liquid is fastened to a slide bar which enables the receptacle to be pushed up higher, and at the same time the pressure thus obtained to be read. DENEKE'S apparatus (fig. 73) is a double one. On one side is a receptacle for nitrogen, on the other side a similar arrangement for the reception of oxygen. DENEKE uses the oxygen for experimental inflations on the first application of pneumothorax, by which he hopes to avoid the risks of an embolism caused by nitrogen gas.

SAUGMANN'S apparatus, which we use in my clinic, is prepared for use as follows: First both cylinders are half filled with a solu-

tion of sublimate. In order to charge it with nitrogen you remove on the one side the cotton wadding filter, whilst to the other the blower is adjusted. By the blower now the fluid of the right cylinder is driven over into the left, which is intended for the reception of the nitrogen. Here it is retained by compression of the tube. Then the compressed tube of the left cylinder is connected with a cylinder of nitrogen, and by very careful opening of this cylinder and removal of the compression stop-cock, gas is allowed to flow slowly in, until the solution of sublimate of the left side has been all passed over to the right side. The cylinder is closed and the tube released again. Now the right side is again armed with the blower, the left with the filter and the connected system of pipes with the puncture needle; now the apparatus is ready for use. The cotton-wadding filter and the puncture needle must be sterilized by the dry process; liquid in the needle easily hinders the functioning of the manometer when the pleural fissure is being investigated. The connecting tube is cleansed by boiling.

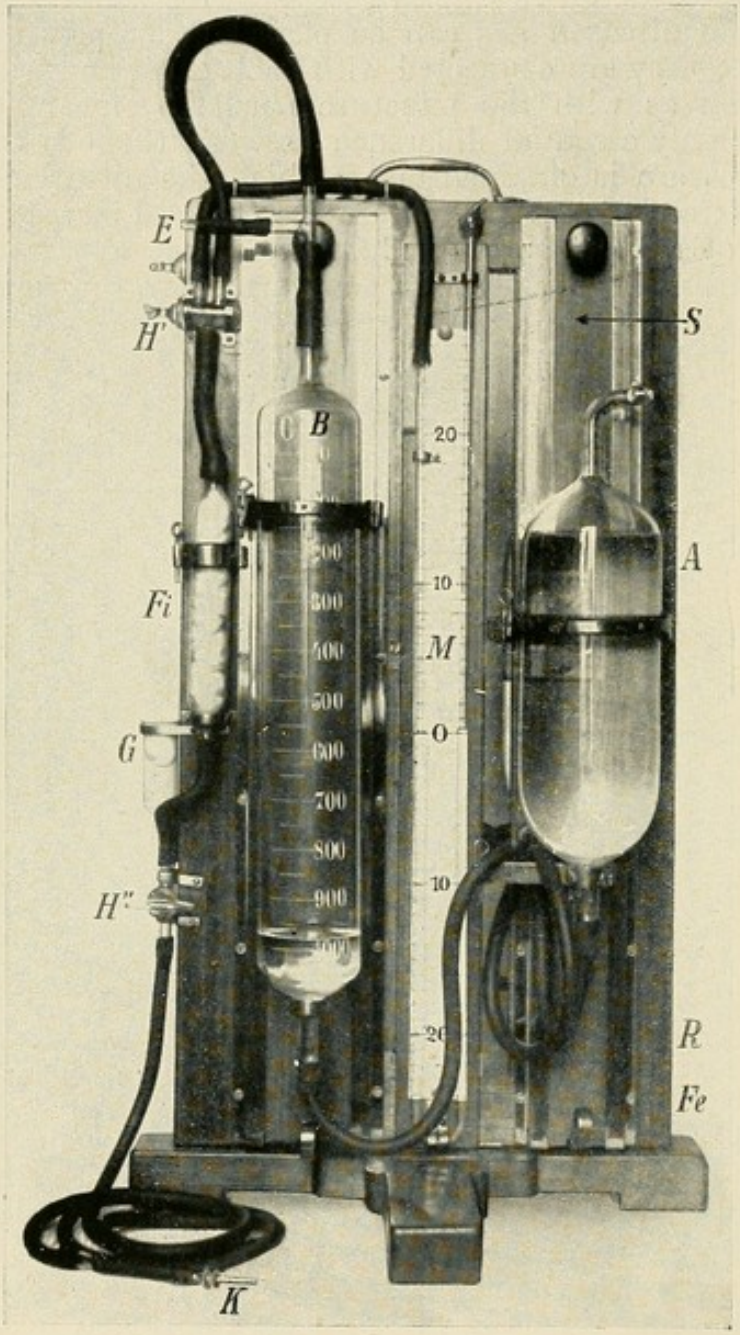


FIG. 74.—DENEKE'S APPARATUS.

For the puncture it is well, especially with nervous patients, to apply a local anæsthesia or morphia in sufficient quantity. For the local anæsthesia an intracutaneous pomphus and an infiltration of

the subpleural tissue is sufficient. Local anæsthesia is specially necessary in cases when one is not sure of finding parts free from adhesions, and, in consequence is obliged when moving the needle to and fro to pass the pleura several times.

The puncture needle to be used must be very thin and have as short a point as possible, so that on passing through the visceral pleura the lung may not also be pierced. A very practical needle has been designed by SAUGMANN in the shape of a Potain trocar. If it gets obstructed it can be cleaned *in loco* by a stilette and can, in doubtful cases, be connected with an aspiration spray.

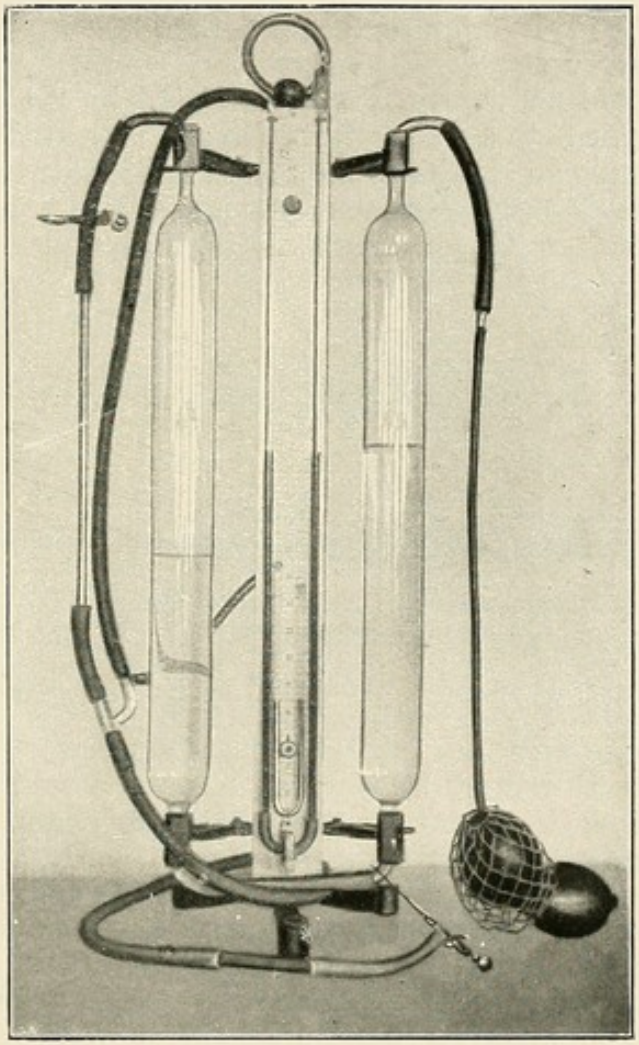


FIG. 75.—SAUGMANN'S nitrogen apparatus.

The needle invented by DENEKE (fig. 76) has a short cutting, not piercing, point, and is closed at the end, while just above the point there is an opening 5 mm. long. By the end being closed the needle is prevented from being obstructed by skin or portions of adipose tissue. The absence of a sharp point is intended to lessen the danger of injury to the lung, whereas the lateral cleft as in the KJER - PETERSEN model makes it easier for the gas to flow into the opening in the pleura. Owing to the blunt end of his needle DENEKE first cuts through the skin with a FRANK spring lancet, such as is used in examinations of the blood.

It has been sought to avoid the difficulty of seeking out the pleural opening by denudation of the pleura. For this purpose a short cutaneous incision in one of the intercostal spaces is sufficient, which can be performed with local anæsthesia (BRAUER). The pleura is laid bare for about 1 sq. cm. and then pierced with a thin, blunt metal catheter. The advantages of this method are, that the condition of the pleura can be ascertained, whether adhesions are to be expected, and that it is known exactly when the point of the puncturing instrument will reach the opening in the pleura. The disadvantages of the method are, that on the withdrawal of

the puncture needle part of the gas easily escapes. Therefore when this method is used a deep emphysema often appears. Another drawback is that if the place chosen proves unsuitable, a repetition of the operation at other points is undoubtedly more trying to the patient than the ordinary puncture.

Generally speaking, it does not matter which part of the chest wall is chosen for the puncture, as long as the neighbourhood of the heart is avoided. A place will naturally be selected where physical examination has led us to expect that there are no adhesions.

Here we are greatly assisted by the use of the X-rays. With their help a site will be chosen where the lung appears to be free from foci; the immediate proximity of the heart and of the diaphragm is to be avoided. If auscultation at this spot also denotes the absence of focal symptoms (rhonchus, heightened

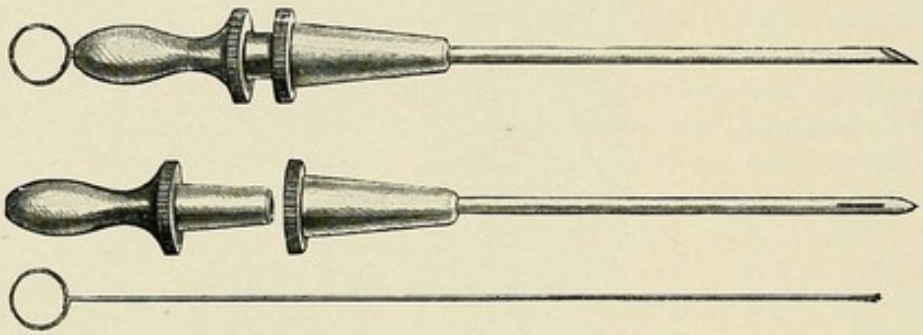


FIG. 76.—DENEKE'S puncture needle.

breath sound) then we have found a suitable place for the puncture. Then the patient will be placed in such a position that this place becomes the highest point of the thorax. The object of this is that the first air vesicle produced in the opening in the thorax may remain in contact with the point of the needle and not move to a higher point.

SAUGMANN regulates the position of the needle by water manometer on his apparatus. With some practice and exact obedience to the directions of SAUGMANN, the method of puncture is also reliable and free from danger.

Before the puncture the stilette is removed from the needle and the opening closed by the cock. In the apparatus the gas receptacle is closed by a compression stop-cock, the tubing leading to the water manometer is opened and thus the manometer is brought into connection with the needle. If the puncture is now made, the manometer will vary according to the position of the point of the needle. If the needle discharges freely in the pleural opening, then, if there are no adhesions, a small air vesicle will be formed at this place, and immediately the negative pressure of the respiratory movement can make itself felt. The water manometer then shows distinct fluctuations, which are very characteristic, the differences of level are from 6 to 11 and more centimetres, and their

lowest point, round which they hover, is higher on the side of the manometer which is in connection with the needle than on the other side.

If the point of the needle comes into contact with adhesions, the respiratory fluctuations cease or are only quite minimal. If the needle has already penetrated as far as the lung, then fluctuations also occur, but they attain at most to 2 to 3 cm. and have also this characteristic, that their lowest point is the same as that of the manometer when at rest, so that there is no negative pressure.

If there are no negative fluctuations there is still the possibility that a major vessel may be punctured. The manometer rises slowly. Then this is regulated by suction aspiration by means of a syringe. If the needle is in the lung, frothy blood is drawn out; if it is in a blood-vessel then blood is obtained, and if there are adhesions the piston of the syringe springs back.

Now it happens fairly often that the point of the needle lies between the pleural layers and yet no fluctuations occur. In such a case one must work with a slightly increased pressure, then immediately a slight pneumothorax sets in and with it the characteristic fluctuations of the manometer.

When the point of the needle has reached the free pleura, then the tube leading to the gas receptacle is opened; then on each inspiration gas flows in for a time, later the pressure is increased by means of the blower or by raising the other cylinder.

In order to avert the risk of embolism caused by gas, DENEKE generally lets in first 10 to 20 c.cm. of oxygen slowly and with observation of the fluctuations of the manometer; if any occur he adds immediately 50 to 100 c.cm. of oxygen. Only then does he inject nitrogen; in the first application 400 to 500 c.cm. are sufficient.

Later applications are then very simple. The gas receptacle is filled completely with gas, and placed at the same time under the pressure of the column of water of the other cylinder, puncture with the gas receptacle shut off, and the water manometer opened at a place which has been previously ascertained to be in the region of the pneumothorax already formed. When the pleura is reached the desired negative fluctuations in the water manometer will at once appear. Now the water manometer is closed and the gas receptacle opened. Then the gas flows in automatically till the columns of fluid in both cylinders are at the same level, and if it is desired to inject more gas, the necessary increased pressure can be obtained by means of the blower.

When the needle is removed, especially when the pneumothorax is under a certain amount of pressure, it often happens that air flows out through the opening made by the puncture, and under certain circumstances an extensive deep emphysema is produced. In order to avoid this, it is advisable, when removing the needle, to compress the opening of the puncture and to exert a continuous pressure for about twenty-four hours by the adjustment of a glycerine pad.

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HÆMORRHAGE OF THE LUNG.

SUPPLEMENT TO THE CHAPTERS—PULMONARY SUPPURATION AND PULMONARY TUBERCULOSIS.

Naturally, surgical treatment is out of the question for slight hæmorrhages of the lung, and those due to passive hyperæmia in the case of cardiac defects, after embolic infarcts, in hæmorrhagic diathesis, in neoplasms; finally, those due to perforating aneurisms of the aorta and pulmonary artery.

Hæmorrhages caused by traumæ have been discussed.

Acute profuse hæmorrhages demand surgical treatment, and also slight but frequently recurring ones. Both endanger the patients owing to the loss of blood, and also by the possible formation of foci, due to aspiration, in healthy parts of the lung. These hæmorrhages proceed from the surfaces of ulcers of the lung, especially from tubercular cavities, and also from simple chronic abscesses and bronchiectases. By callous thickening of the tissue contraction and retraction of the eroded vessels is made difficult. Acute abscesses and gangrene rarely lead to profuse hæmorrhages. The hæmorrhages from cavities of long standing often occur repeatedly and become specially dangerous, even the

first of them, when as often happens, aneurisms of the small pulmonary arterial branches have been formed. Hæmorrhage seems rarely to occur from the pulmonary veins, probably because of the slight internal pressure.

It is well known how important bodily rest, and especially quiet breathing, is for the arrest of hæmorrhage. Quietude of the lung is best attained by collapse by means of artificial pneumothorax, which at the same time reduces the current of the blood. For it to take full effect there must be no pleural adhesions. It has been applied successfully by FORTANINI, BRAUER[1] and others. FRIEDRICH reports a case with extensive adhesions, in which repeated hæmoptyses endangering to life, were permanently removed after plastic operation on the thorax.

SCHLANGE[2] once treated cavities directly; he resected 6 to 8 cm. from the 3rd rib, by removal of the adhesions, mobilized the apex of the lung as much as possible and pressed downwards and padded the cavity thus formed with iodoform gauze; by this means the cavities collapsed.

In a similar way bronchiectatic cavities could be compressed from without.

Aneurisms may also be formed and lead to hæmorrhages in simple chronic abscesses of non-tubercular origin; fresh abscesses cause hæmorrhage more readily when there is gangrene at the same time. In these cases, which—when locally diagnosed—generally in themselves call for pneumotomy, hæmorrhage is an urgent indication to open up the cavity and to plug it, and perhaps, if possible, to ligature the blood-vessel directly (KÖRTE).

When hæmorrhage occurs from cavities, which have already been opened up from outside, the tamponade will take place directly from the opening, perhaps after having previously enlarged the fistula by thermo-cautery; but it must be remembered that by so doing fresh blood-vessels may be injured, which in the indurated tissue have little inclination to retract, and may perhaps, if they are veins, lead to an embolism.[3]

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[1] *Cf.* BRAUER and SPENGLER, *Beiträge zur Klinik der Tuberkulose*, 1911, vol. xix, Case 73, p. 254; Case 81, p. 273; Case 102, p. 331. Once, however (Case 77, p. 265), by way of exception, immediately after the application of pneumothorax, and then on the second application, hæmorrhages occurred, so that no further application was tried.

[2] SCHLANGE, "Verhandlungen des Chirurgenkongresses," 1907, p. 80.

[3] *Cf.* QUINCKE, *Mitteil aus den Grenzgebieten* vol. i, p. 37, Case 11.

CHAPTER VIII.

ACTINOMYCOSIS OF THE LUNG.

The ray-fungus can get into the lung in two ways, either directly by aspiration, when prickles of corn, ears of barley, or pieces of carious teeth serve as hosts, or secondarily, by the inflammation spreading from the œsophagus along the vertebral column and the thoracic wall to the lung. In accordance with this, Poncet distinguishes between a broncho-pulmonary and a pleuro-pulmonary form of pulmonary actinomycosis. But actinomycosis may attack the lung from other adjacent organs, for example, from the liver, or may, in exceptional cases, occur by way of embolism through the blood channel. According to the statistics obtainable at present more than one hundred cases have come under observation.

The anatomical modifications caused by the disease of the lung by the ray-fungus consist of peribronchitic and pneumonic foci of granulation with disintegration and formation of cavities, as well as induration and contraction in the vicinity, which can be recognized from without on the thorax. The induration may affect large portions of the lung, in which the pulmonary tissue is changed into a fleshy mass devoid of air or finally completely atrophied through fibrosis.

When the disease spreads to the pleura, the formation of adhesions and indurations ensues, and also at the same time pleuritic exudations may be formed of sero-fibrinous turbid or purely purulent nature. From the pleura the process continues relentlessly to the thoracic wall, spreading in the shape of infiltrations and indurations. The proliferations of granulation rarely spread to the diaphragm, pericardium and mediastinum. The infiltrations of the thoracic wall may finally soften and give rise to the formation of fistulæ, from which only a little grayish-yellow watery pus, with the characteristic granules, is evacuated. By the coalescence of several fistulæ, atonic ulcers, covered with flaccid reddish-yellow granulations, may be formed.

The local clinical symptoms can be easily deduced from the anatomical changes. On the lung we find symptoms of the catarrh, the infiltration with contraction and formation of cavities, and in more advanced cases the changes described in the thoracic wall. Its course is almost always chronic; the duration of the disease varies from several months to several years. The symptoms due

to the disease of the lung and pleura, for example, cough, shooting pains, shortness of breath, are associated with increasing pallor and emaciation, fever and night-sweats. The sputum is mucoid and purulent, or sanious and mucoid like raspberry jelly, and rich in cells which have undergone fatty degeneration. It may also be putrid, as in the case of gangrene. Sometimes there is such an abundance of actinomycosis granules in the sputum that it crunches in the mouth like sand. Finally, in the form of a chronic septic pyæmia metastases occur in other organs or the patient dies from amyloid disease.

The diagnosis of pulmonary actinomycosis can only be made in the initial stages, when, attention having been roused by the constant absence of tubercle bacilli, on the examination of the sputum the well-known fungus glands are noticed. The fact that the process rarely makes itself seen in the apex (Moosbrugger, Lindt, Shiota), but generally below the clavicle and laterally behind, is to be noted, and a doubtful focus of infiltration persisting for a long time at the base of the lung must always arouse suspicion of actinomycosis. On the propagation of the process to the thoracic wall, swellings therein, combined with contraction, suggest the diagnosis. A softened swelling on the thoracic wall may suggest an empyema necessitatis, without the puncture confirming this supposition. Sometimes, even before the bursting of the fistulæ, it is possible to obtain some fluid from suspected places by exploratory puncture, and from it to make a certain diagnosis by the evidence of the characteristic granules.

An X-ray photograph may, under certain circumstances, start the diagnosis on the right track. A diffuse shadow, broken by darker spots in sharp contrast to the other lung well filled with light, is, as the accompanying photo shows, characteristic to a certain extent.

Hamm has also pointed out that with the bacterioscopic examination of the sputum it is possible to make the diagnosis even when there are no granules present, because Gram's process of staining allows the fungous threads to be clearly recognized, the nature of which can easily be demonstrated by anaerobic culture and the inoculation of animals.

Illich and Finkh draw attention to another, but not constant symptom, namely, the appearance of sputum similar to that of bronchitis fibrinosa. But the X-rays are the most indispensable aid to diagnosis, for the actinomycotic foci and the indurative processes surrounding them give fairly distinct shadows, so that it may be possible to recognize even small initial stages.

Besides pulmonary tuberculosis it is possible, when the disease has spread to the thoracic wall with extensive dense infiltration, to confuse it with a sarcoma—osteosarcoma of the ribs, of the sternum or shoulder-blade; the bursting of the fistulæ removes all doubt. Pulmonary carcinoma also comes into question, and, when the process spreads along the vertebral column with neuralgic pains and kyphotic bearing, spondylitis. Finally, a mycotic infection of the lung with similar symptoms, streptothrixmycosis, is described.

The prognosis is a very melancholy one, although with the often unusual chronicity of its course (up to ten and twenty years) one might, *a priori*, expect success from an early energetic treatment. The conditions are, however, as in actinomycosis of the intestines, in so far unfavourable, that it is difficult, indeed impossible, to recognize the initial stages,[5] which admit of radical surgical treatment. However, if it is possible to make an early diagnosis and to operate at a time when the disease can be still locally circumscribed, and no further metastasis has taken place, then in a case of really primary pulmonary actinomycosis a complete cure may be achieved, as, up to the present, eight cases described in the literature show.

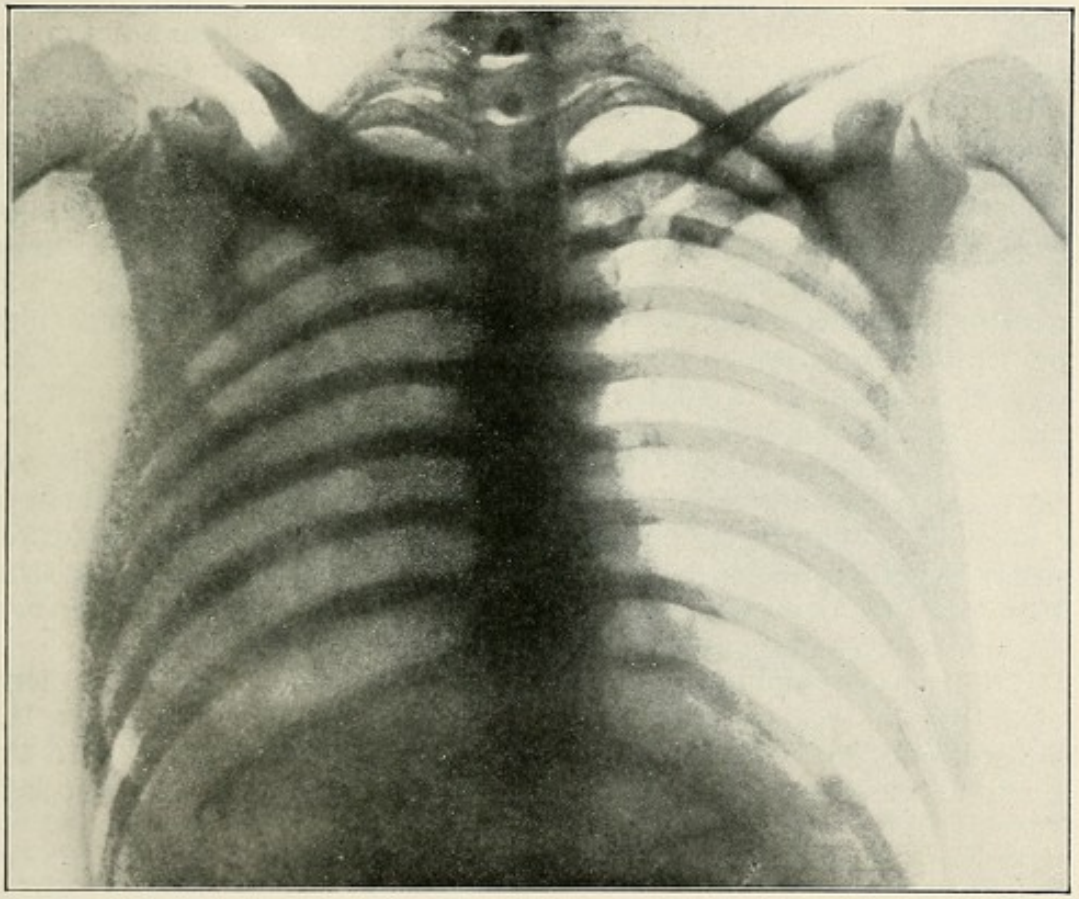

FIG. 77.—Actinomycosis pulmonis dextr. (CRANWELL).

Thus, for example, in the case of a patient of KAREWSKI, a severe and extensive disease has remained completely cured for seven years. And this fact alone justifies and demands, considering the otherwise absolutely deleterious course of the terrible disease, an operation in every case at all suitable. OPOKIN mentions seven more cures.

The indications for the operation and the nature of the same do not require any detailed discussion. Fistulæ which are present and superficial abscesses must be opened wide; the indurated tissue must be extirpated. Allowance must be made by ample costal resection for access to the pulmonary focus and for the possibility

of the cicatrization of the injured pulmonary parenchyma. Purulent cavities in the lung must not be drained, but, in accordance with the rules which hold good in the treatment of all chronic abscesses, the surrounding tissue, in fact, everything diseased, must be ruthlessly excised. Very advanced cases will not call for operations; in their case any surgical measures which may be necessary will have more of a symptomatic importance.

If the patient comes into the hands of the surgeon, which will only rarely happen, before the thoracic wall is affected, then the foci must be laid bare by costal resection, and, as far as possible, resected from the surrounding pulmonary parts. ILLICH recommends injections of sublimate (three to five injections of a 25 per cent. solution), especially into the infiltrated surroundings of the focus of disease. RYDGIER made successfully parenchymatous injections of 1 per cent. solution of iodide of potassium (two to four injections every eight days); ZURAKOWSKI, injections of 1 per cent. solution of copper sulphate, combined with the internal administration of this remedy in 1 per cent. solution; BARACZ, intravenous injections of colloidal of silver; and WYNN has even treated one case, it is stated, with positive results, according to WRIGHT'S opsonic theory. Much more important, however, both as a prophylactic and also as an internal remedy after an operation, is iodide of potassium or iodide of sodium, which, given in large doses (2 to 6 gr. per day and more) is undoubtedly most helpful here as the case of actinomycosis of other organs.

That prevertebral and periœsophageal foci of actinomycosis will be able to be surgically treated, is certainly within the bounds of possibility. The X-ray photograph helps in the diagnosis. Access must be gained to the field of operation by resection of the processus transversi of the vertebræ with the articulated ends of some ribs (costo-transversectomy according to MÉNARD).

A disease of the lung akin to actinomycosis, but far less frequent, streptothrixmycosis, has, up to the present, only once been the subject of a successful operation, and LIEK has recently reported the opening up of a streptothrix-abscess in the right lower lobe, with successful results.

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CHAPTER IX.

PULMONARY FISTULÆ.

Pulmonary fistulæ are formed less frequently after injuries, more frequently after an operation or the spontaneous bursting of purulent foci of the lung or empyemæ communicating with the lung. The mucous membrane of the open bronchus may either pass directly into the outer skin, or be connected with the outer epidermis by a more or less extended surface of epitheliaiized pulmonary parenchyma. The epithelium covering the defect in the lung then starts from the bronchial mucous membrane, and is for the most part transformed by metaplasia into pavement epithelium. In both cases it is a question of lip fistulæ. In other cases the mucous membrane of the bronchus is separated from the skin by a granulating channel or a granulating cavity, giving off little secretion, which shows no tendency to cicatrization.

In the case of these pulmonary fistulæ, we may suppose that the original process is completely cured. In contradistinction to these are the fistulæ, in the case of which the original process is only partially healed. The latter are of less interest to us, as their treatment coincides with that of the original trouble, and has been already sufficiently discussed elsewhere.

To the pulmonary diseases which may lead to the formation of fistulæ belong tuberculosis, actinomycosis, hydatids, abscess, gangrene, and bronchiectasis. To these must be added empyemæ perforated in the direction of the lung and outwards, also chronic inflammatory processes of the vertebral column or of the mediastinal lymphatic glands which have penetrated into the lung and also outwards (tuberculosis).

Sometimes the external openings of the fistula are far away from the pulmonary focus. Ten cases of gastric pulmonary fistulæ have also been described; as a rarity, a gall-bladder fistula of the bronchus.

If the fistula is long, narrow, sinuous, then the secretion is at once remarked; it cannot, however, be recognized at once as a pulmonary fistula. If it is, on the other hand, easy of access, more or less straight, if the outer opening is near the cavity communicating with the bronchus, then the characteristic signs of the pulmonary fistula are clearly to be seen: the entrance of air on inspiration, and the exit of the same on expiration, on coughing, especially on somewhat prolonged compression. In fits of coughing

the most varied sounds may be produced by the outgoing air. Many patients are more or less aphonic, like those on whom tracheotomy has been performed; the cough, too, may be toneless and feeble. Probing of the fistula sometimes produces irritation causing coughing, and even violent attacks of suffocation. The attempt to prove the existence of a fistula by injection of liquid, which is then expectorated, should be considered as hazardous.

When pleural and pulmonary fistulæ exist simultaneously, the diagnosis of the latter can easily be made in the following way. The patient must make as deep an expiratory breath as possible; upon this the external fistula is closed so as to be air-proof, with the moist hand; let the patient take deep inspiratory and expiratory breaths, and towards the end of the expiration remove the hand. Then there escapes from the fistula, when the hand is removed, a distinctly perceptible strong current of air.

A rational treatment of the pulmonary fistula cannot be imagined without consideration of its origin. The knowledge of the conditions which lead to the formation of fistulæ is also decisive for a suitable prophylaxis.

The origin of the pulmonary fistula is to be sought in the excessive distension of the defect in the lung which is beginning to form a cicatrix. It is also due to the fixation of the pulmonary pleura to the insufficiently yielding thoracic wall, or to an induration in the surroundings of the pulmonary cavity. It is also favoured by the lack of mobility of the other fixed organs in the vicinity, as well as by insufficient expansibility of the rest of the lung—either because it is cramped by thick pleural indurations, or its expansion is hindered by an abnormal adhesion to the thoracic wall. This distension of the pulmonary cavity in which cicatrization has begun, this tension on all sides towards the periphery, also makes its influence felt in the mechanical expansion of the adjacent bronchi and those opening into the cavity. So that the width of the bronchial lumina must not be considered straight away as an indication of the magnitude of the perished pulmonary substance.

There is no doubt that a pulmonary fistula presents some disadvantages for the patient and that the endeavour to remove it is justified. This is quite clear in those cases in which a large suppurating hollow space has been left; in this case the secretion from the fistula is in itself a great evil, quite apart from the fact that the secretion may be evacuated *per vias naturales*. Such cases should be operated on, if a complete cure is possible. In cases in which, owing to the nature and extent of the primary process this appears impossible (tuberculosis, extensive bronchiectasis, multiple abscesses), the fistula should not be touched; in this case it is a welcome outlet for the secretion from the opened cavities or neighbouring cavities, which otherwise would stagnate in them, and then easily give rise to the dissemination of germs of infection into other branches of the bronchial tree.

In the case of the primary affections which can be operated on, when spontaneous bursting, insufficient operation or induration of the lung after the operation have delayed the cure, the same rules of procedure hold good as in the case of chronic abscesses.

Ample resection of the ribs, extirpations of the indurations near at hand, detachment of pleural adhesions are all indicated. When the purulent secretion is not very abundant it might even be advisable, so far as freshened healthy pulmonary tissue is available, to reduce the defect in the lung to some extent by suture. In any case, if the plugging is necessary, drainage should be abandoned as soon as possible.

We come now to those cases in which there has been a complete cure of the primary process. In these cases the secretion is generally moderate in amount; the fistula is, however, harmful to the patient, in so far as cold air proceeding from it may give rise to a condition of irritation in the bronchi; on the other hand, patients suffering from pulmonary fistula, like those on whom tracheotomy has been performed, are less capable of earning their living because they cannot sufficiently compress the contents of the thorax, and the abdominal pressure also can only be used to a limited extent.

The principles of treatment founded on the origin of the pulmonary fistulæ and already frequently alluded to, also hold good in essentials here. The pulmonary parts which are covered with granulations must be freshened up. In all cases, when severe bronchitis is not present—and such periods will be chosen for the operation—the freshened and sufficiently mobilized pulmonary tissue should be unhesitatingly sutured over the open bronchus which is to be closed. The suture is securely closed when no air-bubbles are forced through it, the pulmonary suture can also be made secure by a union of the indurated thickened pulmonary pleura and by drawing up the diaphragm to the thoracic wall.

I should like strongly to recommend that the indurated thickened pleura in the immediate neighbourhood of the fistulæ should not be sacrificed straightaway, not even when it is possible by DELORME'S process of decortication[1] to mobilize the lung enveloped by indurations. In such a case I retained round the fistula a piece of the thickened pleura, two fingers thick and spindle-shaped, then cut round the fistula and closed the wound by a strong suture, which was well supported by the thickened pleura. In another case the soft parts of the thoracic wall cut round in this way offered, together with the costal periosteum, splendid security for the pulmonary suture.

Subpleural gangrenous foci of the lung, abscesses and caverns which burst into the pleura and have given rise to general empyema, often lead to operations for fistulæ. If it is desired to cause the lung to dilate, even if only partially, the fistula must first of all be closed. In this case my method mentioned above is exactly the right thing; it can be followed immediately (in favourable cases at least) by the decortications.

However, as I have already urged elsewhere, I do not consider it right to resect more ribs than is absolutely necessary—especially not in the case of young people. Not only because of the fear of severe scoliosis, but much rather because of the risk of permanent

[1] DELORME, *Rev. de Chir.*, 1901 (see chapter, "Technique," p. 62).

atelectasis and contraction of a whole lung. This is best avoided by the surgical closure of the pulmonary fistula early in the proceedings.

Such an operation is of course a big undertaking; therefore it is justifiable to try simpler methods first with the smaller fistulæ, such as cauterization, the freshening up of the soft parts over the fistula and suture, and plastic covering by means of skin flaps. ABRASHANOW, in a case of pulmonary abscess after injury by stabbing, in which, after plastic operation on the thorax a fistula was left behind, enlarged the fistulous channel and implanted therein a flap, taken from the latissimus dorsi. In the course of three weeks he achieved a cure, a strong scar being left behind.

But such palliative measures are not suitable in the case of ectatic bronchi; the possibility of retraction must be obtained in their case by costal resection, &c.

When a main bronchus is in communication with the fistula, an attempt must be made to suture the bronchus after its denudation. (For technique, see p. 67.)

In exceptional cases it may be necessary to sacrifice a large part of a pulmonary lobe (F. KRAUSE). The patient had a fistula so large that retrogressive respiration was possible.

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CHAPTER X.

TRENDELENBURG'S OPERATION ON EMBOLISM OF THE PULMONARY ARTERIES.

Embolisms in the pulmonary arteries are very various, according to the calibre of the obstructed vessels and the nature of the obstruction.

Only a very small number of the pulmonary embolisms can be operated upon. All embolisms in any way infectious in character are excluded from the first, as they might involve more than purely mechanical disturbances of the blood-stream; all embolisms, too, which are on the further side of one of the two main branches of the pulmonary arteries.

Only in the case of an embolism in the trunk or its main branches does surgical removal, Trendelenburg's operation, come into the realms of possibility. In these cases the material forming the embolism originates in the veins of the lower extremities; the thrombi represent effusions from a major vein and the ramifications opening into it; it is very doubtful whether they have ever completely obstructed the lumen of the vessel at their point of origin; the thrombi of the branches may often have fixed the thrombus of the principal trunk like roots for a long time, although it was washed by the blood-stream, so that it may have attained a certain fixity, until at last, by active or passive movements of the lower extremity, the lateral thrombi were loosened or torn away and the tree-shaped entire thrombus may be carried away by the stream of blood.

Among the "marantic" thrombi under consideration those due to general chronic wasting in cases of phthisis, nephritis, carcinoma, relatively seldom lead to the larger pulmonary embolisms; this is more frequently the case in puerperium, in cases of anæmia, large abdominal and pelvic tumours, and after fractures of bones. Disturbances of the circulation and œdema in one or both of the lower extremities may sometimes be produced, even without venous thrombosis, by the other determining conditions: on the other hand, the œdema may be very slight, in spite of thrombosis, probably just because the obstruction is not complete. Precisely in such cases large embolisms are easily formed, because movement is not so anxiously avoided and because the partial obstruction of the stream of blood favours their formation; after the removal of

abdominal tumours the stream of blood has just become very plentiful.

Large pulmonary embolisms, originating in this way, are much more suited for operation than those in which valvular defects or chronic myocarditis have played their part in bringing about disturbance of the circulation, partly because the weakened heart more easily succumbs to the attack, and also because very frequently other material suitable for the formation of embolism is present in the periphery.

From the size and form of the protracted thrombosis depend the amount of obstruction in the current in the pulmonary region. A thick short thrombus from, say, the iliac vein may very quickly block a main branch of the pulmonary artery, or, at the point of bifurcation by obstructing the current in both main branches, may quickly lead to over-distension of the heart and death. On the other hand, tree-shaped thrombi 10 to 20 cm. long and only 5 mm. in diameter may often remain caught in the auricle and on the tricuspid valve, and only protrude with the free floating end into a branch of a pulmonary artery without reducing the lumen to any considerable extent. Then the first attack of cardiac trouble may be followed by a pause of relative ease of 10 to 20 minutes, and only when the further end of the thrombus has detached itself from the tendinous cords is it driven on by the stream of blood, and only in proportion as the thrombus is folded and coiled up does the obstruction become more complete. So the massive embolisms of the pulmonary arteries offer diversities in course and duration of the attack causing death, diversities which only now, when there is the possibility of surgical help, will gain greater importance and need to be studied in detail.[1]

Very sudden cases cannot, of course, be operated upon, but those which last from twenty to thirty minutes, when the patients are already in the hospital, may be, especially when, owing to the condition of the patient, one is prepared for the possibility of an embolism and pays the greatest attention to the first premonitory symptoms—after change of bed, renewal of bandages, &c. It must also be remembered that not every attack with cardiac symptoms is necessarily due to pulmonary embolism (see p. 195).

The symptoms are as follows: Sudden collapse, not infrequently accompanied by painful feelings in the cardiac region, sometimes with a loud cry; the colour of the face sallow, the lips white, somewhat cyanotic, the jugular veins and some subcutaneous veins abnormally full; cold sweat, rigor mortis; the extremities white and cold, the pulse feeble, irregular, sometimes absent, the breathing frequent and strained; the pupils become enlarged and fixed, stupor passes into unconsciousness; after a few gasps death ensues, partly from paralysis of the heart dilated with excess of blood, partly from an insufficient supply of blood and oxygen to the

[1] *Cf.* Karl Bunger, "On Embolism of the Pulmonary Artery," Inaug. Diss. "Analysis of Thirty-seven Cases," Kiel, 1895.

brain. The enlargement of the heart on the right can generally be ascertained by percussion; sounds are inconstant and not at all characteristic. The length of the attack varies, as already stated, from a few minutes to thirty even forty minutes and more.

At first TRENDELENBURG'S idea was to remove the thrombi from the pulmonary artery by a suction apparatus working from the right ventricle, but as this was unsuccessful he proceeded boldly to open up the pulmonary artery. Experimental research had already proved that it could be done.

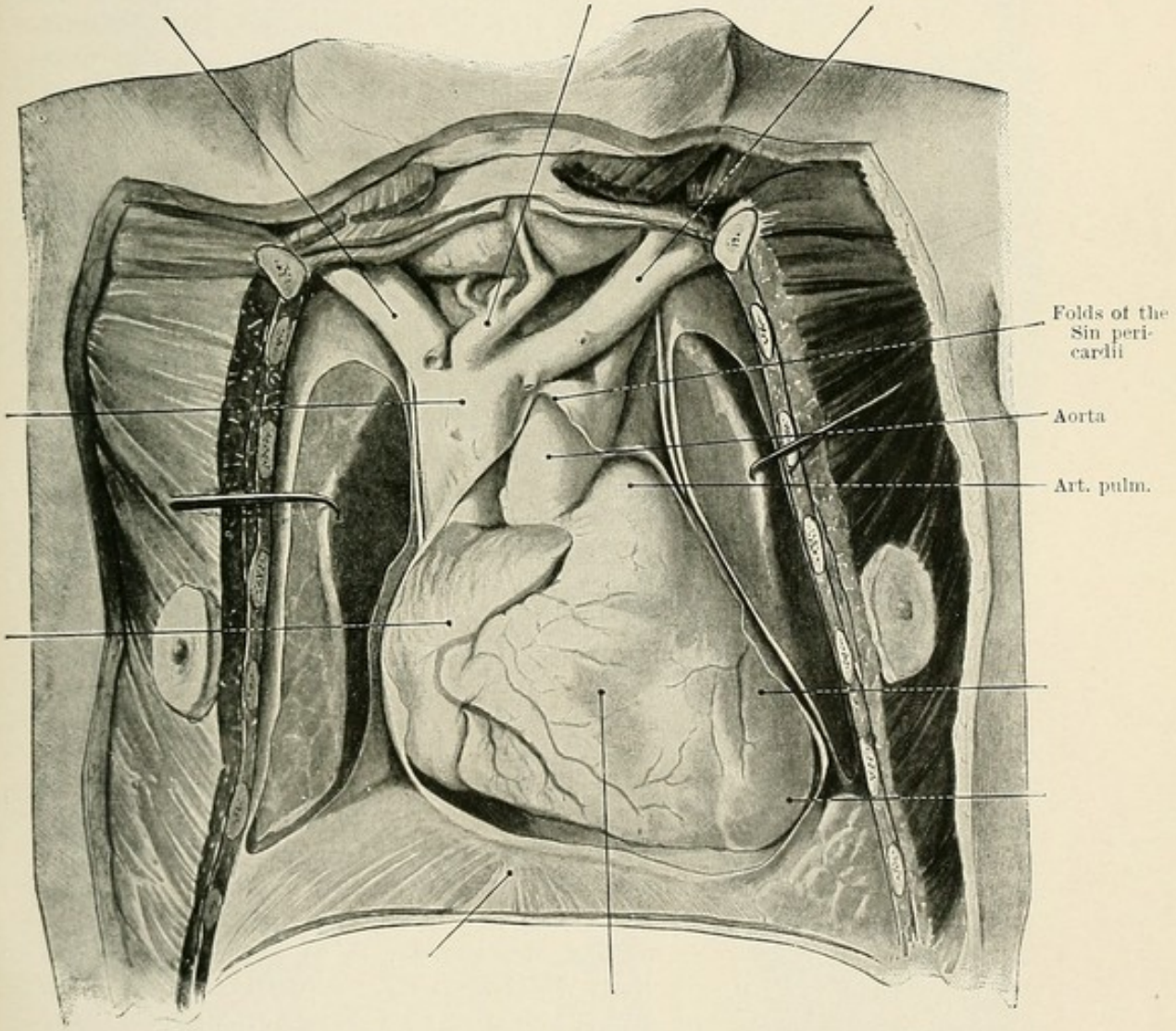

FIG. 78.—Front mediastinum laid bare (from CORNING'S Anat. Topogr. Atlas).

In order better to understand the operation some short topographical notes may be given first.

The pulmonary artery lies behind and laterally from the left sternal margin. The ostium pulmonale lies behind the sternal insertion of the 3rd rib, the bifurcation of the pulmonary artery on the upper margin of the second costal cartilage. The trunk of

the pulmonary artery thus lies in the space between the upper margin of the 3rd and lower margin of the 1st rib. If the left half of the thorax is opened by removal of the 2nd and 3rd ribs after the collapse of the lung the contour of the pulmonary artery is seen, enveloped in pleura and pericardium (often difficult to recognize owing to embedded fat, but still to be discovered by feeling). The pericardium here protrudes upwards, a point of the pericardium reaching up to the starting point of the left subclavian artery. On this part of the pericardium the left phrenic nerve passes down obliquely to the apex of the heart. If the pericardium is opened here the two large aortic and pulmonary vessels are seen, close together and firmly adherent to one another. Owing to the pericardium passing from the back of the great arterial vessels directly to the two auricles, there is formed behind the vessels a hollow space like a cleft, the sinus pericardii; this makes it possible to penetrate on the left side close to the pulmonary and without any resistance to come out again on the right near the aorta. This fissure is so wide that in the case of an adult one can easily put one finger through. Thus both arteries are encircled above their orifices.

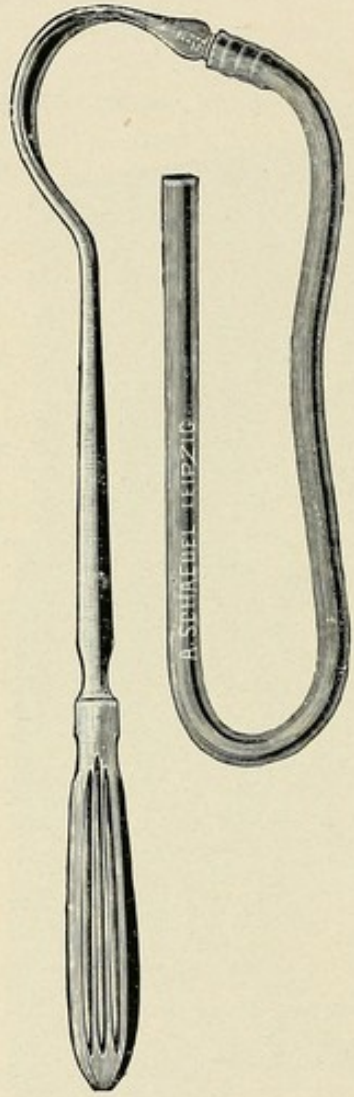

FIG. 79.—Pilot catheter with rubber tube.

TRENDELENBURG proceeds in the following way. He makes a transverse incision 12 cm. long on the 2nd rib and adds at the beginning of it a vertical incision, which extends from the 1st to the 3rd rib. The triangular flaps of cutaneous muscle thus formed are bent back and now the rib is resected from the sternum for a length of 10 to 12 cm. When the intercostal space is confined a relatively shorter piece may be resected from the 3rd rib. The pleura is opened up the whole extent of the incision and kept wide open with blunt tenaculi. The lung retracts and the pericardium now lies bare, the contour of the large vessels can be recognized. The pericardium is raised above them with two small forceps and an incision is made longitudinally. In doing this attention must be paid to the phrenic nerve. It can be avoided by keeping as far as possible in a medial position. The two margins of the incision in the pericardium are raised with clamps or supporting threads and kept apart.

Now the two great arteries are exposed and a specially constructed hook-shaped probe can be introduced from the left round

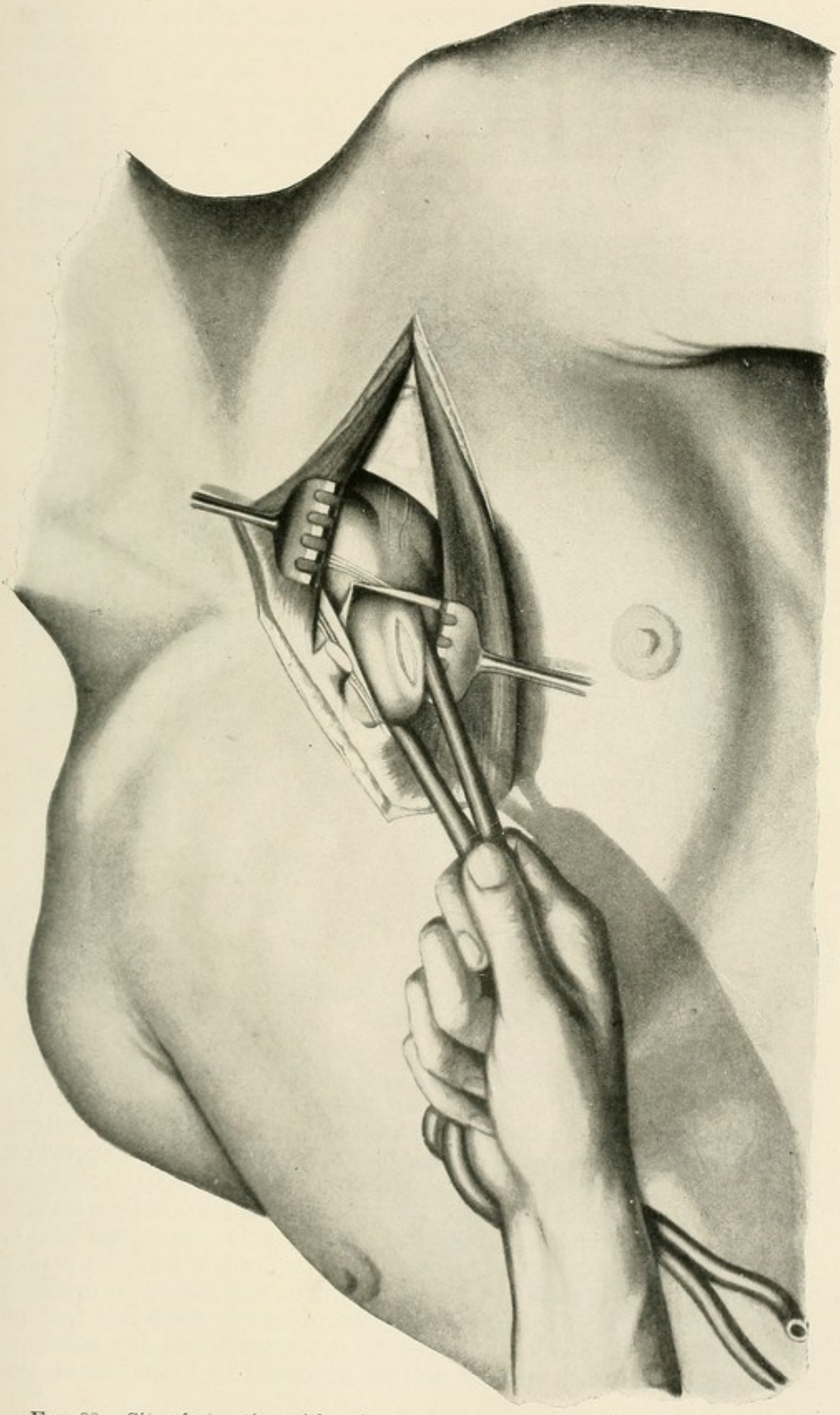

FIG. 80.—Site of operation with pulmonary artery opened up (from SAUERBRUCH and SCHUMACHER'S "Surgery of the Thorax").

the vessels. By twisting movements the head of the probe slips through the sinus pericardii and appears again on the right near the aorta. The manipulation of the probe is easiest if you keep as near as possible to the heart, as the sinus pericardii is the widest at that point.

Now a rubber tube is fixed to the head of the probe and drawn round the vessels by pulling the probe back. By means of it the vessels can be compressed without injury, and at any moment released so as to give free passage to the current of blood. The compression takes place about the level of the valve.

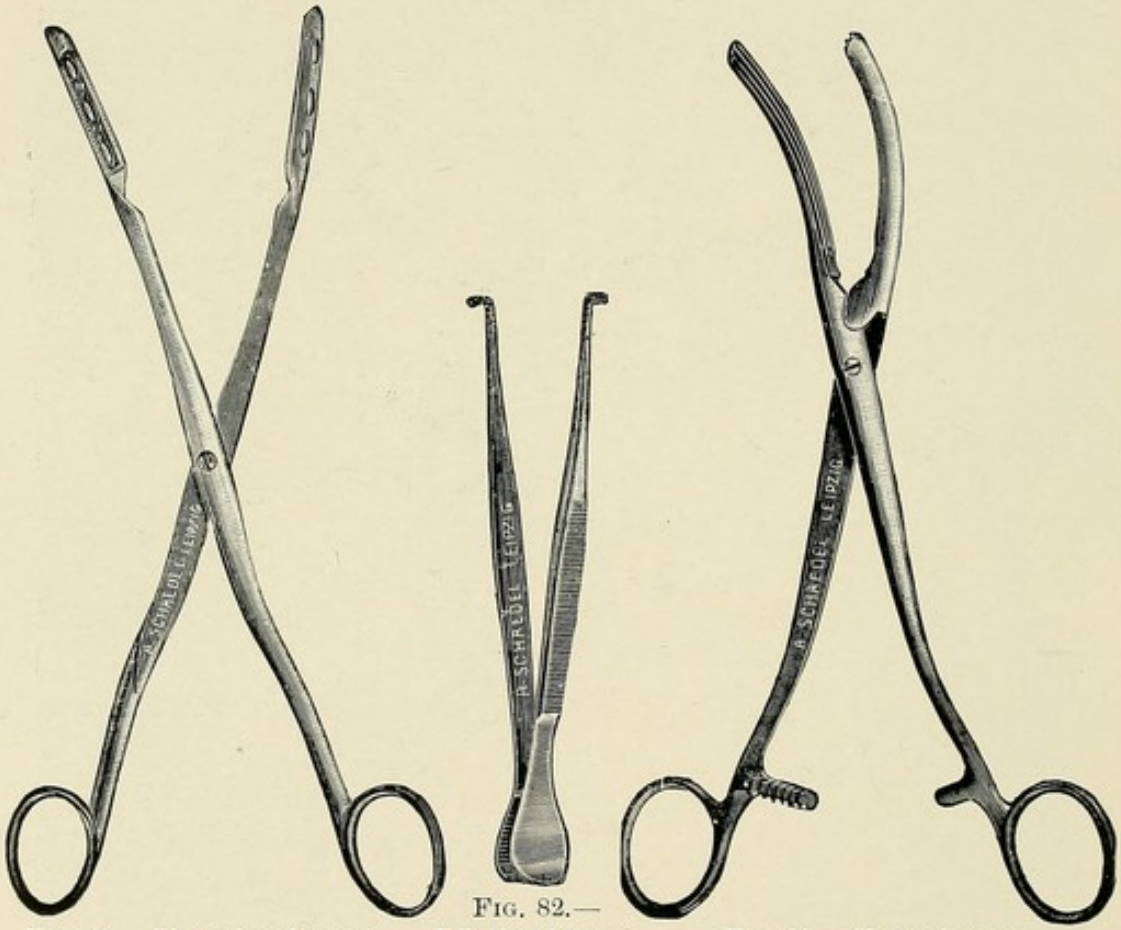

FIG. 81.—Thrombus forceps. FIG. 82.—Dilating forceps. FIG. 83.—Clamp forceps.

Before the pulmonary artery is opened, TRENDELENBURG advises that the wall should be freed from the visceral membrane of the pericardium, so that it is not in the way later on when the suture of the wall of the vessel takes place. "Now the compression takes place, the operating surgeon makes an incision in the artery, dilates in the longitudinal direction of the vessel, quickly inserts a curved polypus forceps, searches for the embolus in the trunk, and, if necessary, 6 to 8 cm. down in the branches of the artery and draws out the embolus. The wound in the artery is, without delay, so compressed by a curved clamp forceps that the forceps is in a marginal position relative to the artery, and the margins of the wound in the artery project beyond the branches of the

forceps some millimetres." The adjustment of this clamp forceps is made easier by a small weak-springed forceps, the branches of which are provided at the top with small hooks projecting outwards. If this is introduced into the wound, closed and then opened so that the little hooks hold the ends of the aperture, by this means the margins of the wound are brought together and may at the same time be slightly raised. After this temporary closure of the incision, the tube is at once released and now the blood flows into the lung again, past the compressed wound. This ends that part of the operation, which must be performed as rapidly as possible, and the margins of the wall of the pulmonary artery projecting above the clamp can be quietly sutured with fine silk. Then the clamp is removed, any part of the suture which may not be air-tight made secure by button-sutures, the pericardium closed by a few sutures, and flaps of the thoracic wall turned back and sutured. The instruments used by TRENDELENBURG are reproduced here.

That it is possible to perform the operation without these instruments has been shown by KRÜGER, who, with an ordinary bulb-headed probe, introduced a tube through the sinus pericardii. Instead of the clamp forceps, he inserted two KÖCHER's clamps in the wall of the lung about 3 mm. apart, in a longitudinal direction corresponding to the ends of the incision to be made. Broad clamp forceps with sliding catch served for the provisional compression of the margins of the incision. But the hæmorrhage from the pulmonary artery seems to have been very considerable, and the suture of the wound in the vessel very difficult.

According to experience up to the present time there are two considerable difficulties which make the success of the operation doubtful.

The first is that it is only possible to interrupt the current of blood in the large vessels for a short time without danger to life. LAEWEN and SIEVERS have proved by experiments on animals that rabbits at least only bear the compression of the vessels for forty-five seconds to two minutes. How long human beings supported it, in the operations performed up to the present, cannot be stated. The consequence is that the removal of the thrombus will always be more or less incomplete. The cases operated on up to the present have shown this: in the post-mortem examination a number of medium-sized and major branches of the pulmonary artery were always found obstructed by smaller thrombi. Such peripheral thrombi, however, as we know, are not directly threatening to life.

The second difficulty lies in maintaining absolute asepsis. The greatest possible rapidity in undertaking and finishing the operation will always be essential to its success. Under these conditions, however cautious and calm the operating surgeon may be, as experience shows, mistakes in this respect are almost unavoidable; the consequences are mediastinitis or pleurisy, both favoured by the unavoidable accumulation of blood in the field of operation.

From the beginning, too, the symptoms may be difficult to read. There is no time for prolonged examination and exhaustive con-

sideration. Very often an embolism occurs in the case of patients in whom nothing previously indicated the existence of a thrombosis. In such cases it cannot be expected that the right diagnosis should occur at once to the mind. On the other hand, there are cases in which the clinical diagnosis was undoubtedly embolism, and in which, on post-mortem examination, no embolus was found. Busch[1] has collected ten cases clinically diagnosed as embolism of the lung, in which there was a possibility of an operation being performed; four of these proved on autopsy to be cases of mistaken diagnosis. He also reports two cases of absolutely certain embolism of the lung from the clinical point of view, in which life was preserved by the use of internal remedies. Such cases are known to all experienced surgeons. They warn us to be cautious!

The figures as to the mortality from embolism of the lung vary very much. Lotheissen found 52 deaths out of 61 cases of embolism = 83¼ per cent., Albanus 10 out of 23 = 43·5 per cent., Gebele 11 deaths out of 14 cases of embolism = 79 per cent. and Wyder 8 out of 12 = 66 per cent. These great differences are probably partly due to the one having included cases quite slight and not coming under consideration here, whilst the other only made the diagnosis when the symptoms were pronounced and severe. In any case, about 17 per cent. at the least, are not mortal, a clear warning not to operate too quickly.

Attempts have been made to clear up and avoid these various difficulties to which all patients hitherto operated upon have been sacrificed. Attention must be specially directed here to the experiments of Laewen and Sievers, the object of which was, on the one hand, to explain the cause of death occurring some time, more or less long, after successful operation, and, on the other hand, to find some means of making it possible to compress the major vessels for a longer time.

Theoretically, two important centres of life come into consideration, through the injury of which the deleterious effect of the interruption of the circulation may be caused, the medulla oblongata and the heart. The paralysis of the centre of respiration was the first to be considered. Laewen and Sievers, however, were able to prove conclusively that the centre of respiration always recovered, as soon as the heart fully resumed its activity. Batelli's experiments are also to be construed in the same sense; he proved that anæmia can be supported by the central nervous system much longer than is ever necessary for the compression of the major vessels. Therefore injury to the heart must be considered as the decisive cause. It is due to various factors, partly chemical, partly mechanical in nature. Laewen and Sievers suppose that the cardiac cells are poisoned by carbonic acid, for the blood flowing into the heart after the compression is removed is saturated with the maximum amount of CO_2; they are also of opinion that products of decomposition from the parenchymatous cells are formed by the stagnation of the blood, which also becomes poisonous to the cardiac cells.

[1] Busch, *Centralbl. f. Chir.*, 1909.

The mechanical disturbances to be considered, according to LAEWEN and SIEVERS, are the cessation of the suction exercised by the thorax owing to the arrest of respiration; transverse sectional increase of the pulmonary circulation on the left side in consequence of pneumothorax and paralysis of the vasomotors. A more important cause is the overstrain of the cardiac muscle. At the moment of the compression of aorta and pulmonary artery the following condition occurs. Both ventricles are filled with blood from the auricles in the normal way. Now if the contraction of the ventricle takes place, it meets, provided the auriculo-ventricular valve is intact, with an insurmountable obstacle. As the ventricle cannot discharge its content in any direction, an enormous output of strength is demanded from it, considering the inelasticity of its content. On the next systole the auricle presses a fresh, if smaller, quantity of blood into the relaxed ventricle; a fresh strenuous, but futile, effort at contraction of the ventricle ensues. The cardiac muscle cannot stand the strain of this unwonted demand, it relaxes, its wall becomes overstrained and a relative insufficiency of the auriculo-ventricular valve is caused. This, in a certain sense, improves the condition of affairs, as the ventricle can now discharge its content to some extent into the auricle. But then this blood is driven continually to and fro between ventricle and auricle and to it is added a certain quantity of the blood flowing from the vena cava. The overstrain of the heart continues and is shown in a considerable increase of volume. The contractions become feebler, and finally become muscular scintillations. Undoubtedly this overstrain of the cardiac muscle must be looked upon as a serious injury to the heart.

The carbonic acid gas poisoning of the heart may be overcome by artificial respiration, or, better, by ventilation of the lung with oxygen by means of insufflation. Artificial respiration must be begun the moment spontaneous respiration ceases. By this means the blood in the lung is kept permanently arterial. Then, if, after compression of the arteries, a certain quantity of blood is driven to and fro between the left auricle and the lung, in this way arterial blood can reach it. In experiments on animals this can be recognized by the bright red colouring of the left auricle.

The artificial breathing must be continued until the spontaneous breaths have regained their perfectly normal rhythm and no terminal, gasping breaths occur any more. Often these measures do not suffice to bring about a powerful action of the heart, on which all the rest depends. In these cases good results have been attained by heart massage. This depends very much on the way in which the massage is applied. Removal of the content of the ventricle by massage at regular intervals has proved to be the best method. But what holds good for the little heart of a rabbit cannot be applied without more ado to the human heart, if only for mechanical reasons. PRUS[1] has suggested another method. He puts the fingers of the right hand into the thorax, grasps the heart with them, the thumb resting on the sternum, then by pressing the heart against the posterior wall of the sternum its content can be cautiously and

[1] PRUS, *Wiener klin. Wochenschr.*, 1900, Nos. 20, 21.

yet amply pressed out. ARABIAN[1] recommends yet another method. He takes the heart in both hands, after opening up the pericardium, pulling it slightly forward. Both thumbs are placed on the right, the fingers on the left ventricle and then rhythmically compressed. He has achieved very favourable results with this method, for he succeeded in bringing permanently back to life seven out of thirteen dogs, whose hearts had been stopped by the administration of chloroform.

Warming, by applying hot cloths, seems to have a good effect. The compression of the ventricle must be done very carefully and the coronary arteries must not be compressed. As soon as the first sportaneous contractions occur, the massage must be abandoned. Fibrillary twitchings in the arrested heart, on the other hand, denote irreparable disturbances, they are the forerunners of the rigor mortis, Whether the injection of 0·2 c.cm. of a 10 per cent. solution of adrenalin into the left ventricle of the heart, according to LAEWEN and SIEVERS, would be of any use must be left undecided.

The question how long the massage should be continued, before being abandoned as useless, is answered by the statistics collected of V. CACKOWIC, showing that in individual cases in human beings the first spontaneous contractions, which led to re-animation, occurred after five minutes. The longest period of perisystole, after which a human heart was successfully stimulated to lasting activity, is given as ten minutes. Within this space of time, in eight out of nineteen cases, permanent results were attained. After ten minutes, no lasting success has been reported.

The cases operated upon up to the present time, according to TRENDELENBURG'S directions, show that the fulfilment of his idea lies within the bounds of possibility. If no permanent result has been achieved as yet, still the progress made up to the present time is most encouraging. The first patient died during the operation (TRENDELENBURG). In the second case (SIEVERS') the patient (female) was kept alive fifteen hours, and in the third case (TRENDELENBURG) thirty-seven hours. The fourth case (KRÜGER) may in a certain sense be described as a permanent success of the method, for KRÜGER'S patient (female) stood the operation very well; unfortunately, she died five and a quarter days later from purulent pleurisy.

Armed with modern instruments (TRENDELENBURG'S pocket case of surgical instruments and insufflation apparatus) and acquainted with the experience gained from the experiments on animals, one will always be ready, when the symptoms are conclusive, to make the attempt to save the patient from an otherwise certain death.

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[1] ARABIAN, *Thèse de Genève*, 1903.

CHAPTER XI.

THE TUMOURS OF THE MEDIASTINUM, THE PLEURA AND THE LUNG.

MANY tumours, which have their origin in the mediastinum, and not less those originating in the pleura, cannot be straightaway distinguished from the tumours of the lung; they often in the course of their development spread to the lung, and also *vice versa*. Therefore it seems to me better to gather together all these kinds of tumour in one chapter and discuss them from the standpoint of the surgeon.

Dermoid cysts of the mediastinum—more correctly described as teratomata—come into closest connection with the lung in cases of progressive growth. They originate in the anterior mediastinum in front of the major vessels. In the course of their development they exceed the limits of the mediastinum and stretch up into the root of the neck or laterally far over the sternal margin. Then they not only displace the surrounding organs but they adhere to them, burst, especially when they become purulent, in the direction of the bronchi, or, if fistulous, outwards.

They are mostly single-chambered, rarely multilocular cystic formations with the usual contents of the simple dermoid cyst or of the complicated teratomata with their wonderful histological samples of organic rudiments of all kinds (fœtal inclusion—embryomata). They vary in size from that of an apple to that of a man's head. Although they are generally found as congenital formations in young people it is not unknown for them to attain to a size which makes them clinically noticeable for the first time at a later age.

The symptoms are not very characteristic. They are dull retrosternal pains spreading to the back and shoulders, stridorous or short breath with occasional worse attacks. The dermoids tend to become purulent, and then, of course, the pain becomes more intense and there is acute swelling. They may, under certain circumstances, be felt from the root of the neck. When they burst into the bronchi epidermoidal cells or hairs are found in the expectoration. There is also displacement of the heart and the intrathoracic trachea, compression of the lung, communicated pulsation, neuralgic troubles. The X-ray photograph is very important for the diagnosis. The statistics include about sixty cases, of which twenty-two were operated upon; sixteen survived the operation.

On account of the difficulties of access and the numerous adhesions in so dangerous a part, the surgeon was, for the most part, obliged to be satisfied with partial excision and drainage of the cysts. Therefore, in half the cases, fistulæ were left behind. Teratomata, being tumours, should, whenever possible, be totally extirpated, as has been done up to the present four times with the best result : once by BASTINELLI (1893), by v. EISELSBERG (1903), by MADELUNG (1904) and by MORESTIN (1910). When the tumour does not clearly indicate, by pronounced growth towards one side of the thorax, the manner of the operation, MADELUNG recommends that the necessary access to the tumour should be obtained by

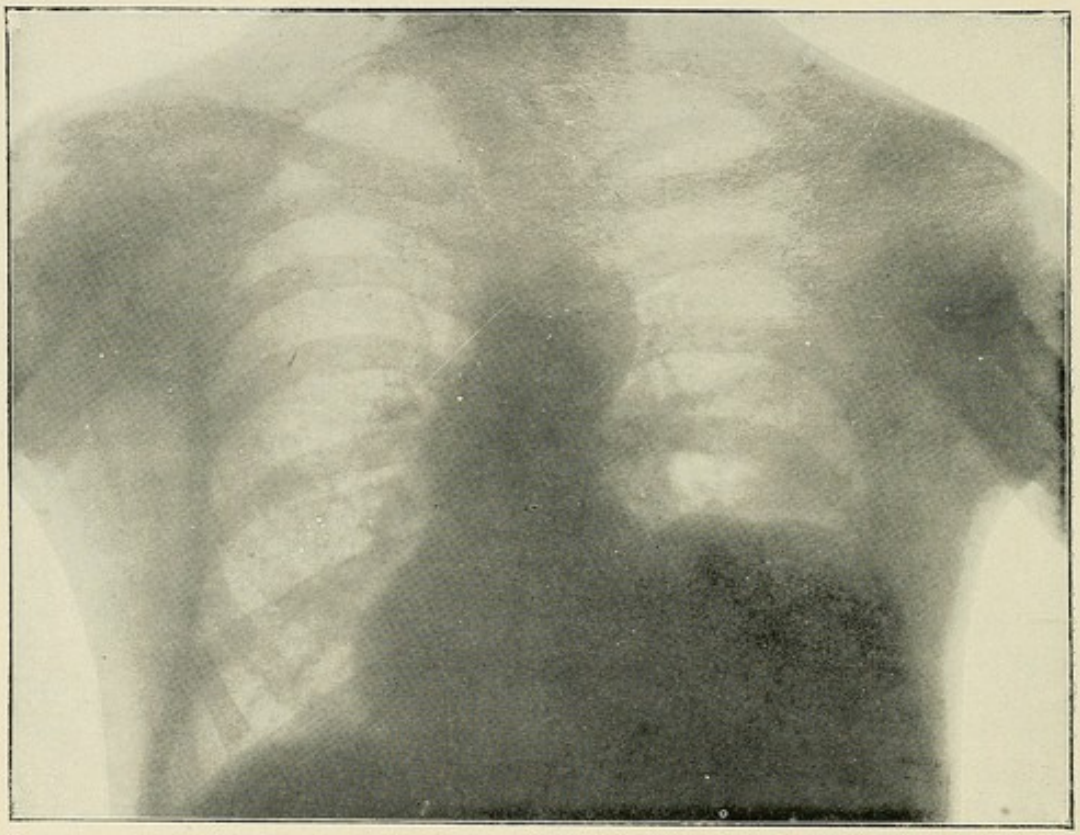

FIG. 84.—Primary sarcoma of the left pleura (GARRÈ).

severance of all the ribs on one side of the sternum, which should then be bent back.

Of non-malignant tumours of the mediastinum, on which it may be possible to operate, the following are described : Fibromata, congenital lipomata (KRÖNLEIN and AUVRAY), a one-chambered cyst (LASSAHN), also the thymus hyperplastica and the endothoracic gummata and the rare echinococcus. In the differential diagnosis aneurism of the aorta must always be taken into consideration.

The malignant tumours—carcinoma and sarcoma—in the mediastinum generally start from the larger bronchi or the bronchial glands on the hilum. The malignant HODGKIN'S lymphoma and the

primary sarcoma of the lymphatic glands are the most important, then come the metastatic tumours. The prospect of successful surgical treatment in these cases is very slight, for when they begin to give trouble they have already become unfit to operate upon.

Tumours, which start from the pleura, are not frequent; only about fifty cases are described. They are endotheliomata (twenty-nine cases) and diffuse sarcomata; in these cases an operation will hardly come into question; they are always of bad prognosis.

Lipomata of considerable size, which grew partly inwards and partly outwards, have been operated upon by GUSSENBAUER, CZERNY and others.

Then there are the tumours of the pleura, clinically mild—fibrosarcomata and myxosarcomata--which may grow to an enormous size, but which, nevertheless, thanks to their being very loosely connected with their surroundings, can be removed by operation. Such cases, seen on the dissecting table, are described by KAHLER and EPPINGER (1882), by BRAUN (1908), and first extirpated successfully by GARRÈ and RICARD.

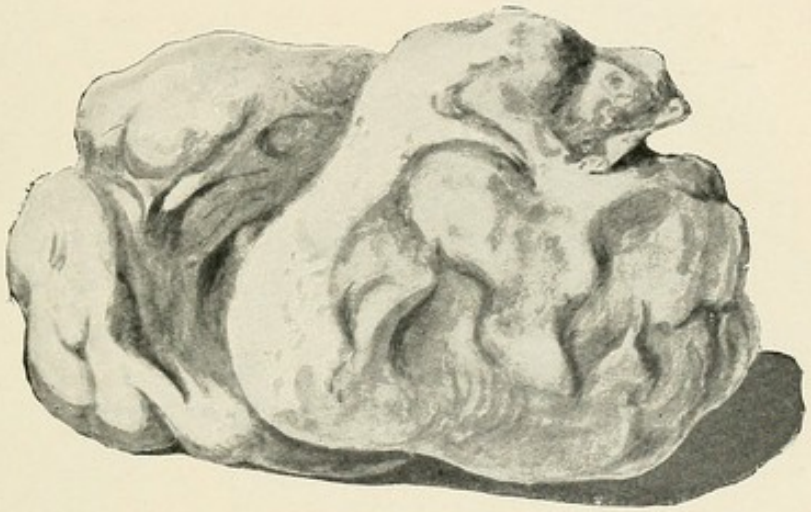

FIG. 85.—Extirpated tumours (*cf.* X-ray picture, fig. 84). (According to GARRÈ.)

They sometimes filled nearly the whole of the side of the thorax and weighed up to 6 kg.

Important for the diagnosis is the gradually increasing dulness, the ceasing of the respiratory sound, the absence of symptoms of a disease of the lung, the striking sensation of resistance on percussion by touch. In my case a pronounced hypertrophic pulmonary osteoarthropathy was present, the disease having lasted a year. Under certain circumstances the diagnosis can be made certain by the use of trocars; the X-ray picture is also valuable, one is reproduced here of my case, together with the extirpated tumour (figs. 84 and 85).

Histologically it was a spindle-cell sarcoma. According to BEUSE these large sarcomata of the pleura are according to their structure neuromata and neuro-fibromata, which have a tendency to become spindle-cell sarcomata or malignant fibrosarcomata.

Besides these, as we have said, relatively mild forms of sarcoma from a clinical point of view, the sarcoma appears in the pleura also as a thick, indurated mass of tumour, which soon causes metastasis in the glands, lung and liver. They are not suitable for operation.

An interesting tumour of independently proliferating plasma-cells, of malignant nature, a plasma-cystoma, is described by KLOSE; he gives notes on six similar cases.

Primary tumours of the lung are very rare and still more rarely occasion operations. Up to the present, an operation on account of a primary tumour of the pleura or lung has been performed fourteen times. SEYDEL, for example, among about 11,000 autopsies only found thirty-one cases of primary pulmonary tumours, against 135 metastatic ones.

In the literature preference is given to the description of such rarities, most of them are of no clinical importance whatsoever.

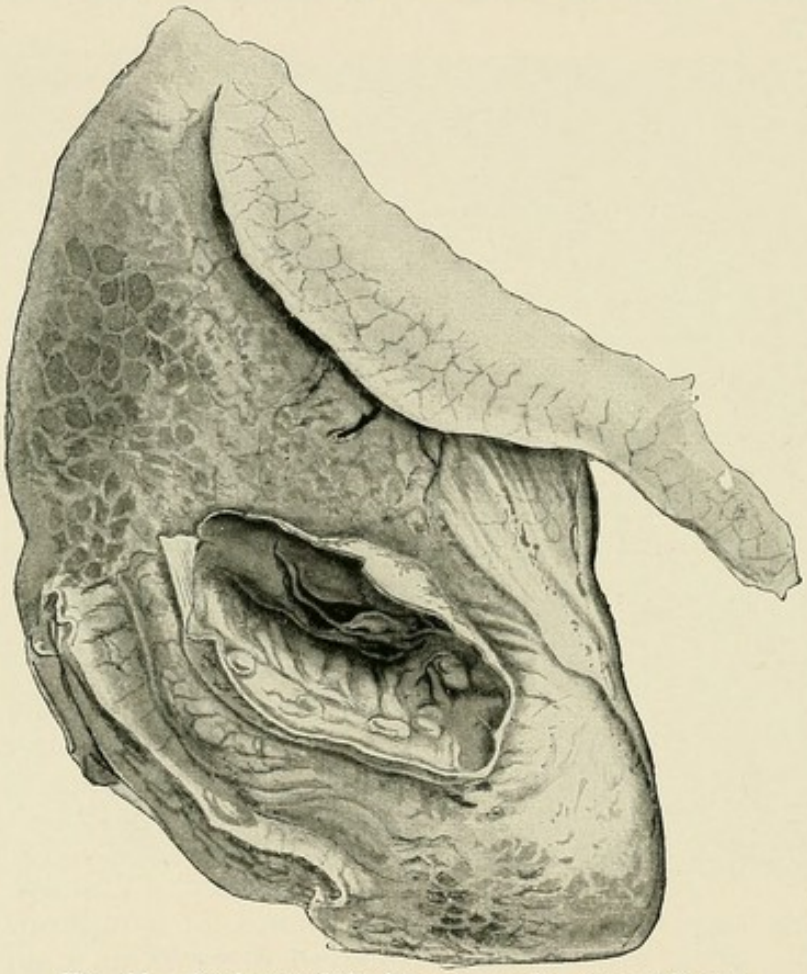

FIG. 86.—Angioma of the lung (opened). (According to HEDINGER.)

There are, for instance, fibromata multiple scattered over both lungs (RINDFLEISCH), chondromata, from the size of a hazel-nut to the size of a fist, osteomata as small scattered tumours, or diffusely disseminated or with ramifications, as a special rarity an osteoma as large as a fist (VIRCHOW)—more frequently the osteoma is combined with tuberculosis; angioma (TUFFIER, HEDINGER), finally dermoid cysts (eight cases?) are said to occur in the lung itself. An operation was performed by PÉAN on an enchondroma, by TUFFIER on the angioma; both were only incomplete extirpations.

BJÖRKSTEN described in 1904 a cystadenoma proliferum of the lung.

As polypous proliferations there are also in the bronchial tube non-malignant tumours, as, for example, a pedunculated lipoma, which occluded a larger bronchus (SCHRÖTTER). These seriously disturb the breathing and produce collapse of large sections of the lung; this is to be noted in regard to the symptoms of carcinoma of

the lung and the bronchoscopic diagnosis (see below). Thus SPIESS (1910) tells of a very interesting case of a high degree of dyspnœa, coughing and threatening attacks of suffocation in a woman of 74, when the diagnosis of carcinoma of the lung was in question. After unsuccessful tracheotomy, SPIESS found at last with the bronchoscope a polypus situated on the bifurcation, this closed up the right bronchus. With the aid of the bronchoscope it was extirpated, it was 4 cm. long and 1½ cm. thick, was placed on a thin pedicle, and proved to be a flaccid enchondroma covered with œdematous mucous membrane.

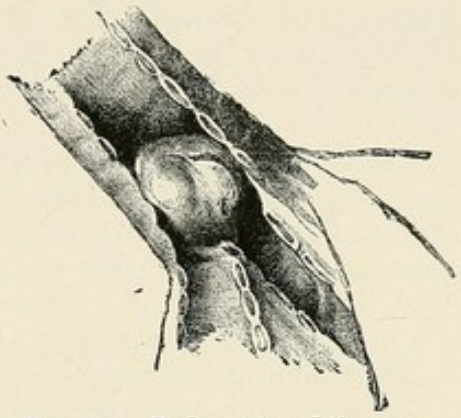

FIG. 87.—Pedunculated lipoma. (According to SCHRÖTTER.)

Finally, amyloid tumours are described in the trachea and bronchi (BALSEX), as well as gummata of the lung (SHINGU), which I must not omit to mention. Primary malignant tumours deserve more consideration on the part of the hospital surgeon.

The primary carcinoma of the lung is more frequent than has been supposed hitherto; I could only find some 130 cases in the literature. Nevertheless, hitherto it has been relatively seldom the object of an operation (nine cases; LENHARTZ, KÜTTNER, GARBET, KÜMMELL). As was only to be expected, the results were by no means good; only in one case, in which LENHARTZ removed a carcinoma of the upper lobe of a man of 31, was the patient after the lapse of a year free from relapse and fit for work.[1]

Primary cancer of the lung occurs three times as frequently in men as in women; the right lung is preferred in a striking manner. The combination with tubercular processes of the lung is specially noteworthy—a point which, moreover, is likely to obscure the diagnosis in many cases. One appears justified, as SEYDEL does, in assuming a causal connection between cancer and tuberculosis. Here I will only remind you of lupus carcinoma. Of ninety-two pulmonary tumours, combined with pulmonary tuberculosis, only four were sarcomal, all the other eighty-eight cases were carcinomata (Pathological Institute, Munich—SEYDEL).

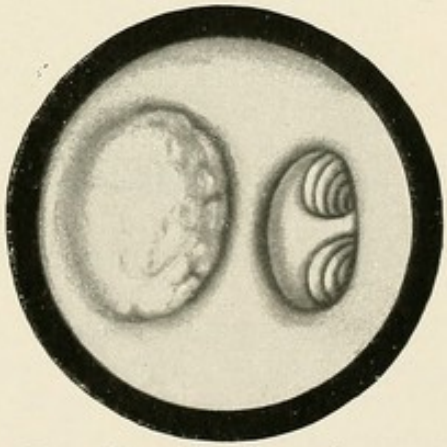

FIG. 88. — Bronchocarcinoma in the bronchoscopic picture. (According to GUISEZ.)

[1] HEIDENHAIN observed, when making an extensive resection of the lung on account of bronchiectasis, in the wall of a bronchiectatic cavity a carcinoma nodule of the size of a small hazel-nut, as a secondary condition.

Almost without exception—in 90 per cent. of the cases—the carcinoma starts from the bronchi, and at that point where the bronchus entering the lung divides into two and three branches. It appears as a nodulated circumscribed tumour and is easily recognizable in the bronchoscopic picture (fig. 88), or it infiltrates long stretches of the walls and grows diffusely into the pulmonary tissue. Histologically, it is generally an adenocarcinoma, proceeding from the glands of the submucosa—more rarely a pavement epithelium carcinoma.

Anatomically, various forms may be distinguished according to size and method of development. Sometimes there are more or less numerous tumours, from the size of a bean to the size of a hen's egg; starting from the bronchi, sometimes the tumour takes in a whole lobe, or even a larger portion. In other cases it surrounds the hilum, as big as a man's fist; less frequently it appears as dense infiltration similar to pneumonic hepatisation.

The tumours are sometimes cartilaginous and hard, sometimes soft and elastic and have a greyish-yellow surface of incision; in the centre there is often a softening, which leads to the formation of cavities.

The diagnosis presents no small difficulty. At first the pulmonary carcinoma causes only vague trouble, such as a feeling of oppression, pains in the back, slight irritant coughing, or, in the superficial forms, gives rise to pleuritic symptoms. The most important aids to diagnosis are the early appearance of lack of breath and a blood-stained serous pleural extravasation. Loss of strength and cachexia may soon arouse suspicion of a malignant process, but it must be emphasized as striking that in many cases, even when protracted in their course, not the slightest signs of cachexia are apparent.

By the surrounding or compression of a main bronchus a partial or complete atelectasis of a large pulmonary section is caused, which is betrayed by retraction of the chest-wall or inspiratory slurring, as well as by auscultatory phenomena. For a long time there are no bronchial sounds, only when bronchial ramifications are proliferated, or, above all, on the disintegration of the tumour, do there appear with bronchitis or bronchorrhœa also signs of the formation of cavities. The sputum may be very varied, its only characteristic is the admixture of polymorphous epithelial and large fatty granular cells. The repeated careful examination of the sputum is, therefore, very important. In consequence of the degenerative modification of the tumour, the sputum is often blood-stained. According to HAMPELN it contains non-pigmented epithelium in dense groups or separated, of peculiar polymorphous shape and various size, with distinct contour and distinct nucleolus. The evidence of glycogen in the epithelial cells may, under certain circumstances, be turned to good account in diagnosis. Greater importance is, according to the experience of LENHARTZ, to be attributed to the appearance of fatty granular cells which are distinguished by the brilliance of the inner cells and are present in large quantities (under certain circumstances also in the puncture

fluid). Large detached portions of the carcinoma have only twice been found in the sputum.

When the malignant growth attacks the pleura, in half the cases exudative pleurisy is the result; the extravasation may be serous or fibrous, but is generally hæmorrhagic in character. One often finds an obliteration of the pleural cavity. By the exploratory puncture of the exudation of the suspected pulmonary focus many minute particles of tissue, or the so-called granular cells, have often made the diagnosis certain.

As relatively frequent complications may be mentioned venous congestion in the neck, cyanosis, paralysis of recurrent laryngeal nerve, likewise remittent fever as a result of retention of secretion, or broncho-pneumonic infiltrations. As in the case of malignant

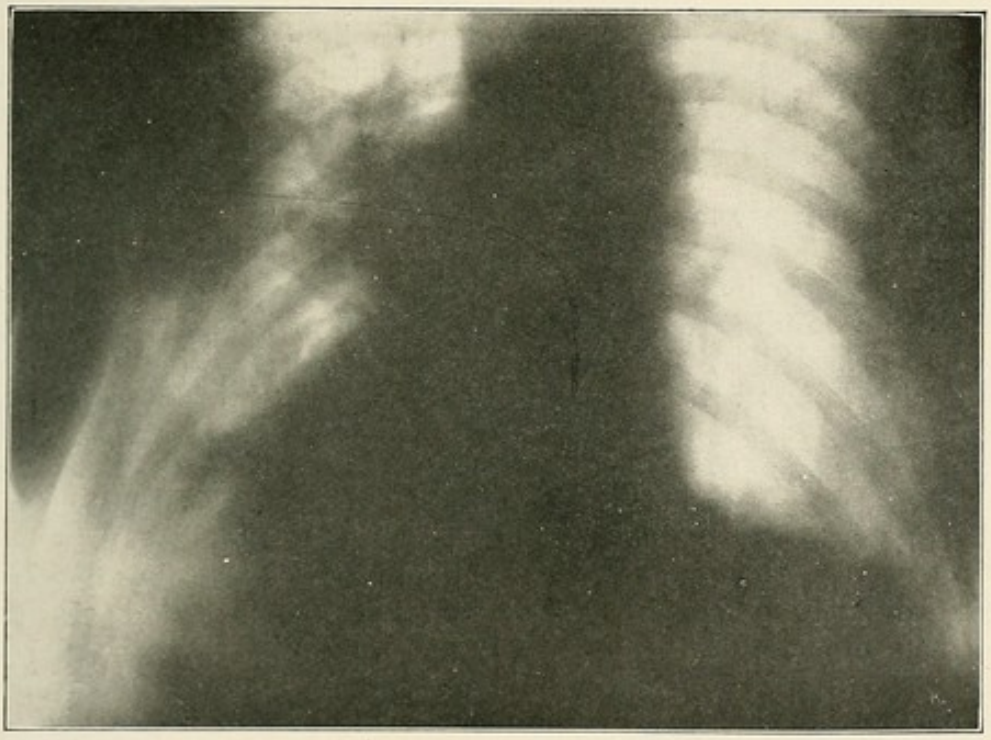

FIG. 89.—Carcinoma starting from the hilum of the lung. (According to P. KRAUSE.)

mediastinal tumours, here also a pronounced eosinophilia of the blood is observed (KAPPIS). Metastases appear relatively early; the disease may last from a few months up to two and a half years.

In recent times diagnosis has acquired in X-ray photography and in X-ray exposures valuable aid in ascertaining the position and extent of the focus. When the tumour has attained a certain size, the X-ray picture shows a lack of easily pervious tissue in consequence of the substitution or the compression of the parenchyma full of air. According to the extent of the tumour there arise, according to OTTEN, KRAUSE, ARNSPERGER, generally two main types of shadow pictures: a more bulky infiltration of a pulmonary lobe, most frequently of the upper lobe, or an infiltration of the primary bronchial carcinoma, starting from the hilum; a third

form, consisting of diffuse spot-like infiltration of both lungs in the course of the bronchial tree, is, according to OTTEN, very rare.

That, moreover, by careful clinical observation and the application of all physical methods of examination, especially careful examination of the sputum and the use of X-rays, it is possible to make a certain diagnosis, is proved by the fact that according to MÜSER in twenty-four observations out of LENHARTZ's division in all cases the diagnosis of primary pulmonary carcinoma was made with certainty during life.

Of the secondary pulmonary forms of cancer those due to metastasis have of course no surgical interest. Of those carcinomata due to propagation from the surrounding parts, the cancers of the mamma transmitted through the thoracic wall must be mentioned here, as they have been the object of surgical treatment. We will return to them later on.

Whether pulmonary carcinomata can be operated or not, is, as SEYDEL says, not at all certain. This is comprehensible, because 90 per cent. start from the root of the lung, because they undergo metastasis early, and because, in spite of all the progress that has been made, an early diagnosis can hardly be arrived at. Of fifty-five cases SEYDEL only finds four suited for operation.

LENHARTZ operated on five cases and was successful in one. In a desperate case he excised a diffusely infiltrating carcinoma bit by bit, without finding with certainty where the healthy part began; but he succeeded by systematic ray treatment into the open wound in healing it up; after a year the patient was still quite capable of earning his living and without any signs of a relapse. He died two and a half years after the operation.

All other operations—even a total extirpation of the lung by KÜMMEL—remained unsuccessful.

As regards the **sarcomata** of the lung, we must distinguish the extraordinarily rare primary sarcoma (there are thirty cases known) and the much more frequent lymphosarcoma. The latter has attracted special interest by having been observed to be endemic among the workers in the Schneeberg mines and is brought into causal connection with the inhalation of arsenic dust. The lymphosarcoma starts from the bronchial glands and the peribronchial tissue, proliferates further along the bronchi, and often forms several large tumour nodules. Among 600 to 700 miners, in nine years, there were 150 deaths from this form of pulmonary sarcoma.

The primary sarcoma, on the other hand, is generally formed of one nodule which takes in a lobe of the lung or a whole lung. The clinical symptoms of the pulmonary sarcoma are naturally somewhat similar to those of the carcinoma. Of diagnostic value is the stridor, exceptionally loud in the case of a lymphosarcoma, and which is to be attributed to swelling of the bronchial glands. It is often accompanied by enlargement of the veins in the mamma and signs of compression of the nerves. Pleurisy more often occurs with the sarcoma than with the carcinoma. In the pleuritic exudation, which is generally serous and hæmorrhagic, but which may be purely blood, diagnostic value should be attached to the

so-called giant vacuole cells. These cells are ten to twelve times as big as leucocytes, and contain several vacuoles (E. FRANKEL).

Not only the local condition, but also the more frequent process of metastasis, the rapid loss of strength and anæmia will make the possibility of a radical extirpation in the case of a sarcoma appear still less likely than in the case of a carcinoma.

Accordingly, a successful operation of primary sarcoma of the lung has not yet been published, but the large sarcomata which have been removed from the thoracic cavity in the last few years (by FERRÉ, GARRÈ, MARTIN, RICARD) all started from the pleura or mediastinum.

Whereas primary pulmonary tumours have up to the present only seldom and recently been operated upon, tumours which have spread from the thoracic wall to the lung have for a long time and frequently been successfully operated upon and removed. The method for maintaining difference of pressure has caused a considerable increase in the number of these operations in recent times. It is generally a question of chondromata or chondrosarcomata of the thoracic wall, of mixed tumours, such as fibro or chondromyxosarcomata, or also of metastases from carcinomata of the mamma, which from the thoracic wall have attacked the pleura and lung.

Thus, in the year 1883, KRÖNLEIN resected the thoracic wall and the lung for sarcoma in the case of a girl of eighteen. On that occasion a sarcoma nodule was excised with the scissors out of the lung collapsed by pneumothorax, and the pulmonary wound closed by some catgut sutures. After four years a fresh pulmonary sarcoma about as big as a fist with part of the lung, had again to be extirpated, also successfully.

Three years later the girl was perfectly healthy. This repeated successful resection of the lung is indeed unique, and at the same time an encouraging example of what is possible in the surgery of the lung.

HELFERICH went further. In the case of a sarcoma of the thoracic wall and the lung, after ligature of the hilum he extirpated the middle and lower lobe—thus performed a regular pneumectomy. After the detachment of the bronchus and the vessels for the upper lobe, partly with sharp, partly with blunt instruments, the large vessels and the bronchi for the middle and lower lobes were ligatured round a point and fixed with two large clamps and strong catgut. A residuum of pulmonary tissue which remained attached to the stump was sutured over the transverse section of the bronchi and vessels, so that the stump of the hilum received a serous covering. The ensuing gap was loosely plugged with sterilized gauze, as the soft parts did not suffice to cover it.

If in this case the severe operation was not subsequently justified by a favourable result, still this extirpation of the lung remained of importance to the technique of the surgery of the lung.

Recently, aided by the method of maintaining difference of pressure, extensive resections of the thoracic wall have been performed with the best results. Whereas formerly in fifty-one such

operations, there were seventeen deaths, SAUERBRUCH, KÜTTNER, HACKER, HOFFMANN, REISINGER and GARRÈ have cured cases without any accident (WERNER). The defect in the pleura is immediately plastically covered with a thick skin-flap, in which above all attention must be paid to an air-tight closing suture. A button suture close together and low down is made on the lower surface of the margin of the lobe without going through the cutis and the margin of the gap in the thorax; over this follows a closely adjusted suture of the cutaneous margin.

Therefore the prospects are favourable for curing the carcinomata and chondrosarcomata attacking the lung from the thoracic wall; as to whether the cure will be permanent or not we cannot say at the present time.

The operation on tumours of the mediastinum and the lung is considerably simplified by the method of maintaining difference of pressure. While able to survey freely the pleural cavity with the lung inflated as much as desired, it permits of a free examination of the extent of the tumour and unhindered manipulation. When it seems desirable, a preventive arrest of hæmorrhage can also be carried out; the vessels of the hilum are, according to SAUERBRUCH, to be temporarily compressed with a thin rubber ligature, or with FRIEDRICH'S hilum forceps.

The apparatus for maintaining difference of pressure is not absolutely necessary for the operation. Before its invention tumours of considerable size were successfully extirpated from the thoracic cavity, and I, myself, have had such cases. Only then the lung must never be allowed to retract completely, as long as the pleura is open. It is drawn up forcibly to the aperture in the thorax. The thoracic cavity is protected by warm wet compresses, while the field of operation is left free.

The nature of the operation on the lung is determined by the extent and locality of the tumour. As we have seen above, it may be a question of a total extirpation of a lung, in which the main difficulty is a reliable treatment for the hilum of the lung (*cf.* General Technique on this point).

If the greater part of a lobe is attacked, then this must be extirpated after previous ligature of the vessels; a possible residuum of parenchyma is utilized for sewing over the stump. Smaller tumours are best cut out of the parenchyma; this can be done almost bloodlessly with two DOYEN stomach clamps, or with the crushing forceps constructed by SCHUMACHER. The incisions are better made with straight strong scissors than with the knife. A deep pulmonary suture and a continuous fine pleural suture finish the operation (*c.f.* on this point "Healing of Pulmonary Wounds and Technique of the Pulmonary Suture," pp. 68 and 69).

When the operation has left a surface wound of the lung, this may be advantageously fixed in the field of operation of the thoracic wall with some sutures. When the pulmonary suture is smooth, and closed air-tight, there is nothing to prevent the simple closing of the thorax.

The question of the drainage of the pleural cavity after such

operations has been very fully discussed. My point of view is to abstain from drainage whenever possible. When one is certain of the asepsis, then an extravasation into the pleura need not trouble us. A single puncture on the third or fourth day removes it permanently. In a third of the cases a considerable sero-sanious extravasation, with fever, quickened pulse, and difficulty in breathing, occurred. This is due principally, no doubt, to slight infectious intra-operationii, and to antiseptics, secondary hæmorrhages, and mechanical and thermal irritations of the pleura, as is unavoidable in every operation.

When it is impossible to prevent infection, or when the mechanical conditions are unfavourable, it would be foolish to abstain from drainage on principle. Then the valve-drain of THIERSCH or of TIEGEL comes in useful (see fig. 42, p. 69). In all doubtful cases a small safety valve should be left open. Every endeavour will, however, be made not to leave a wide opening in the pleural cavity, either by closing a gap in the pleura, which it is impossible to suture, by a plastic operation on the lung (other organs, too, can be used for the purpose, diaphragm, pericardium), or, in the case of large gaps in the thoracic wall, by mobilization of the adjacent bony parts of the thorax, and the covering of the gap by a skin flap from the vicinity, so as to make the opening as small as possible. In extensive resections of the lung it must never be forgotten that the cavity formed must be able to shrink and disappear by the development of the remaining pulmonary tissue, approach of neighbouring organs, and, above all, by a sufficient mobilization of the rigid circle of ribs.

As in the case of injuries, so here, the possibility of a hæmothorax owing to secondary hæmorrhage, or a tension pneumothorax owing to insufficiency of the pulmonary suture, or of the bronchial closing, must never be lost sight of. Puncture and aspiration—repeated, if necessary—generally remove all threatening disturbances.

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CHAPTER XII.

PULMONARY ECHINOCOCCUS.

The echinococcus is found, next to the liver, most frequently in the lung, 7 to 12 per cent. of all cases. In Australia, according to Thomas, pulmonary echinococcus is very frequent. Its favourite site is the right inferior pulmonary lobe, in which it occurs as often again as in the left lung. It is usually isolated, and may develop in the loose pulmonary parenchyma in a relatively short time to considerable size. The fibrous capsule surrounding it, which consists of degenerated connective tissue and compressed pulmonory tissue, is very thin ; so it often happens that the parasite by perforating the bronchi discharges its crystal clear contents, together with its daughter-cysts, outwards. In this way, as we could constantly observe in Mecklenburg, where echinococci are so plentiful, spontaneous healing may take place, but there is, on the other hand, the great danger that, owing to this sudden flooding of the bronchial tree, the patient may suffocate. Such perforations are accompanied by very troublesome irritant coughing, which often lasts for weeks, even months ; after a hæmoptysis, large quantities ($\frac{1}{2}$ lb. to 1 lb.) of wine-coloured watery sputa are evacuated, in which are usually found whitish or vitreous membranes, which histologically present the characteristic stratified structure of the chitinous investing membrane of the cysticercus. Whole secondary cysts, as big as a cherry, may also be expectorated ; echinococcus tenaculi are very rarely absent from the sputum. After it has burst, signs of the formation of a cavity are rarely observed, because, owing to the absence of a rigid fibrous membrane, the pulmonary tissue quickly expands and the cavity collapses.

Bursting into the bronchi, however, does not always lead to the complete expectoration of the parasite. It is not impossible that the unilocular hydatid does not die out after the rupture, and, after cicatrization of the fissure, may fill up again ; if secondary cysts are present it is a lucky chance if all are coughed up ; one single one left behind will cause a relapse.

The bursting and evacuation fairly often occur into the free pleural sac. Violent pleuritic pains, exudation immediately demonstrable, perhaps symptoms of collapse, and, in consequence of the resorption of the echinococcus fluid, an extensive urticaria, are the classical symptoms. Fever is absent or only slight. The pleurisy slowly disappears, the pains continue for a long time, the exudation

is fibrous, if the cysticercus does not become purulent. The cysticercus may also develop primarily in the pleura (twenty-six cases) and there also perforate.

E. and M. VINCENT ascribe pleural echinococcus to the formation of specially thick indurations of the connective tissue (pachypleuritic échinococcique).

The bursting of the pulmonary echinococcus through the diaphragm is unusual, whereas, on the contrary, a hydatid of the top of the liver often perforates the right pleural cavity or even the lung after adhesion with the diaphragm. These conditions are difficult to diagnose, sometimes impossible, unless bile is mixed with the echinococcus fluid evacuated into the bronchi, or if already previously a tumour of the liver has been diagnosed.

The diagnosis is generally difficult, for the hydatid enclosed in the pulmonary parenchyma does not betray itself by any characteristic symptom. Small and centrally placed cysts generally remain without symptoms. In the case of large hydatids, the patients generally complain of a feeling of tension and of lack of breath. With the spasmodic fits of coughing and the bronchitis, slight, but irregular, increases of temperature occur, which are probably to be interpreted as the result of the congestion of secretion in the compressed bronchial branches. The sputum has sometimes a disagreeable smell, and is, like the bronchiectatic sputum, globulated.

According to the aspect of the symptoms DIEULAFOY has recently distinguished three stages of the disease: the initial stage of the usually still latent cysts, which with its irritant cough and sanious sputum, when the physical symptoms are indefinite, suggests to every investigator the diagnosis of initial tuberculosis, especially when there are also symptoms of pleurisy. In a country, however, where hydatids occur frequently, this possibility must always be seriously taken into consideration. SCHMEDEN considers the absence of night sweats in the case of pulmonary echinococcus as important for its differentiation from phthisis; this does not agree with my observations. On the other hand, the sudden appearance of the pleurisy is worthy of notice and, as SCHMEDEN insists, the fact that the patient can lie on the diseased side without discomfort.

The second stage of the advanced tumour is characterized by the appearance of a dulness, which, when the vesicle is situated in the lower lobe, appears as a curve convex above, but generally produces quite irregular areas of dulness with increased breath-sounds, among which normal breathing and full pulmonary sound or even intensified respiration may occur, whereas, if the cyst is situated on the surface, it also makes its presence known by pleuritic friction and less frequent fine râle. We must also mention those symptoms which are caused purely mechanically by the progressive, space-restricting growth of the cyst—the distension of the thoracic wall, the displacement of the heart, the diaphragn and the other organs.

In the third stage the symptoms of the bursting of the cyst or

the suppuration come into the foreground, and then the expectoration of the amber liquid with its scolices and chitinous investing membrane, nay, even whole daughter-cysts, which can be microscopically distinguished, as well as the urticaria which sets in on the bursting of the cyst, are characteristic points not to be mistaken in diagnosis.

The diagnosis is just as easy at this stage as it may be difficult in the initial stages, especially as an urgent warning must be uttered against having resort to a diagnostic exploratory puncture here as in echinococcus of the liver, on account of the danger of pleurisy and general poisoning.

Very welcome, therefore, is the progress made in several directions during the last few years in the diagnosis of echinococcus. As far as the increase of eosinophile cells in the blood is concerned, this has no great value for purposes of diagnosis, for, according to ROSELLO, this occurs as long as the parasite is alive, and also, according to SEELIGMANN, occurs in the same way in all other diseases due to worms in human beings. Quite apart from this, the ascertained presence of eosinophilia when pulmonary echinococcus is suspected offers no certain differentiation from several other complicating affections of the lung, such as asthma or simple bronchitis, which, as is well known, may cause a similar modification in the state of the blood.

Much more important appears to be the method of fixation of complement first discovered by CHEDINI, the efficacy of which has been confirmed by many writers (WEINBERG, ISRAEL, MEYER, KREUTER, &c.), according to which the serum of hosts of hydatids with hydatid fluid and the alcoholic extract from the hydatid cyst-wall reacts positively. The technique of the reaction is exactly the same as that described by WASSERMANN for the sero-diagnostic of syphilis. Some people deny this, but KREUTER, nevertheless, considers the reaction can be used in practice; his criticism runs as follows:—

"The echinococcus produces in the human organism specific antibodies, which with alcoholic extract give fixation of complement.

"The reaction cannot as yet be absolutely relied on, as it fails in individual cases when echinococcosis is certainly present, and as hosts of tape-worm sufferers from syphilis and leprosy react to echinococcus antigen.

"Still it is an exceptionally valuable adjunct to our diagnostic remedies. By improving the method, increased usefulness may be expected."

If the diagnosis of hydated disease is generally settled in this way, only the X-ray picture can, as a rule, decide the exact position and size of the cyst in the lung, and it is specially its rounded form and clear contours which strike the eye. According to whether the sac is full, or not, you see a sharply defined, rather dark uniform shadow, or a sharply defined dark ring, the inside of which is abnormally bright; the first picture corresponds to a cyst which is full, the last to an emptied sac, the wall of which, according to its

thickness, appears in varying degrees dark, the cavity, filled with air, appearing light. Sometimes by the use of X-rays the differentiation from an echinococcus of the liver, so difficult to diagnose, may be successful.

The prospects of spontaneous healing are not favourable. It may occur owing to the parasite which has perforated into the bronchi being coughed up, or after bursting into the pleura, if no secondary cysts are present, or finally, owing to the death of the cysticercus with inspiration of its contents, or calcification of its capsule. This is, however, unusual. Generally the sufferers die, either on the bursting of the cyst (suffocation pleurisy) or as a result of the suppuration of the cyst, or the accompanying complications; bronchopneumonia, fœtid bronchitis, pulmonary gangrene and empyema. It is, therefore, perhaps comprehensible that TERRIER and REYMOND do not consider the bursting into the bronchi as the preliminary to spontaneous healing, but consider an operation most urgent.

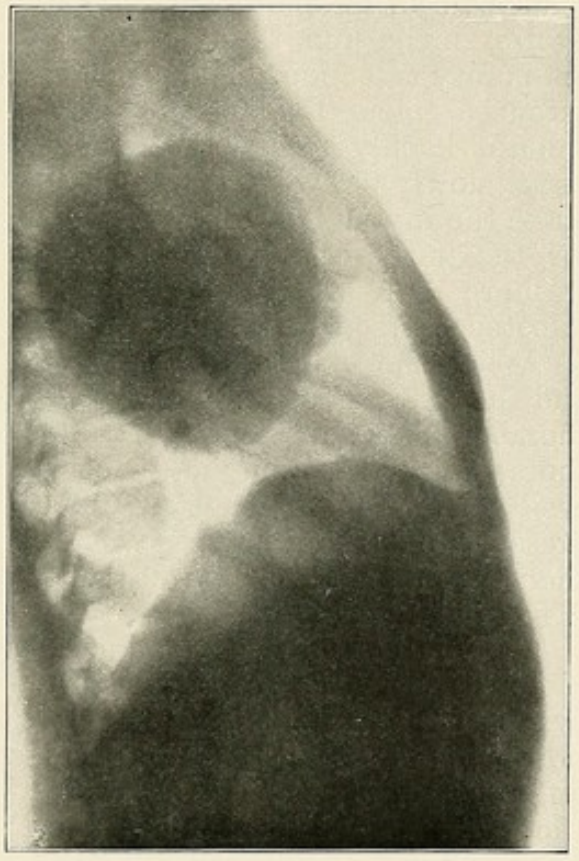

FIG. 90.—Pulmonary echinococcus (lateral exposure according to ALBERS-SCHÖNBERG).

Of internal treatment one cannot really speak—up to the present there has been no possibility of any causal therapy except by surgical measures. Statistics of the medicinal expectant therapy give a terrible rate of mortality, namely, HEARN gives out of 128 cases 64 per cent., THOMAS 61 per cent. out of 208, MADELUNG, 31·5 per cent., BECKER 25 per cent., VEGAS and CRANWELL 52 per cent.

Puncture, with or without subsequent injection of something which kills the hydatids, (such as sublimate 1 per cent. or formol 1 per cent.) is an extremely dangerous proceeding. Out of 36 such punctures PASQUIER counts, for example, five deaths immediately after the puncture, three a few hours after, and four during the next few days, and on the whole a mortality of 63·8 per cent.

MAYDL reported 11 deaths out of 16 cases treated with puncture; others also report sudden deaths following the puncture.

The same reasons which forbid the puncture of the cysticercus in the liver and other organs of the abdominal cavity are also valid in the case of pulmonary echinococcus. They are, apart from the

uselessness of the procedure when secondary cysts are present, the dangers of poisoning by resorption of the fluid, dispersion of the germs, pleurisy, secondary suppuration and hæmorrhage of the lung.

Surgical treatment has then, thanks to the much better results obtained during the last decade, gained more and more ground. Compare the following figures. In my collection of 99 cases, in which the hydatid was laid bare by incision, 78 recovered, that is about 80 per cent. GIUMBELLOT gives the latest statistics collected, 223 cases, of which 194 were cured and 29 died; that gives a mortality of 13 per cent., and 87 per cent. of cures after operation.

The operation is relatively simple, when it is possible to locate the cyst accurately and—this is most important—when it is not too deep down in the pulmonary tissue. An exploratory costal resection is first made and then enlarged as required. POSADAS makes a temporary resection. Then follows pneumotomy. The presence of extensive pleural adhesions may make this considerably easier. Then it is only necessary to cut through the pleura and pulmonary tissue slowly in layers to the wall of the cyst. They may, however, make the investigation more difficult, if the thoracotomy is intended for the purpose of exploring, when the localization is uncertain. In more than half the cases there were no adhesions; in the non-infected cysts as many as 72 per cent.

When the pleura is free the lung must be fixed for the incision and the parts around sutured, in order to avoid the infection of the thoracic cavity. Should the echinococcus not be found at once after thoracotomy, the lung must be examined with the hand. This is easily and quickly done by the method of maintaining difference of pressure, but requires care when operating without the apparatus; then the pneumothorax is produced slowly and the lung meanwhile is fixed at the opening of the thorax.

Only after the most careful closure by suture of the other free pleural sac by a back-stitch suture may the cyst be incised and evacuated; this holds good not only for the infected but also for the non-infected cases. I was obliged to perform the operation at two different times when there was an insecure, easily rent suture on the right upper lobe. One must be guided by circumstances: generally the opening up and the removal of the parasite can be performed at the same time.

Some surgeons inject 1 per cent. formol into the denuded sac, with uncovered pleura before the opening up to kill the germs.

The membrane of the hydatids is easily detached; the fibrous adventitious capsule can only in exceptional cases be peeled off the pulmonary parenchyma without risk, and as a matter of fact this is not necessary. The defect in the lung grows visibly smaller by the expansion of the contiguous collapsed pulmonary tissue, to which the thin fibrous capsule enveloping the cyst offers no resistance. Indeed, I am of opinion that under favourable circumstances, a primary adhesion of such a cavity is possible and therefore in a case of pulmonary echinococcus, without complications, I would venture the primary closure of the evacuated cavity with a suture. Thus, for example, WALTHER achieved a splendid and prompt

success by injecting into the sac emptied by puncture after thoracotomy 1 per cent. of formol according to DEVÉ, removing the cyst five minutes later, making sutures and closing the thoracic wall over them.

CRANWELL and VEGAS, out of their 23 cases of aseptic pulmonary hydatids, operated on 18 with drainage and five without drainage with primary closure; of the last, however, two patients succumbed to pneumonia. They, therefore, only advise primary suture, when dealing with a relatively small cyst with thin, not indurated or inflamed inspissated wall. GUIMBELLOT reports only one death out of 21 cases of primary suture.

GERULANOS succeeded four times, after laying bare the lung, in uniting the two pleural layers by suture. Then an incision was made in the lung, the cyst opened up, evacuated and most carefully cleansed. After inserting a drain, he sutured the pulmonary wound very carefully round it to the incision in the thorax. If the patient is told to cough and press and the secretion is removed daily from the cavity with a syringe, then the walls quickly close together; on the fifth or sixth day the drain can be removed.

It does not seem to me right to lay down any rules here. The operator decides best in each case on its own merits.

When for any reason an immediate suture does not seem advisable—primarily, of course, in all infected cases—the sac of the cyst is sutured into the wound in the thorax, a loose tampon inserted or drained. Healing often results in a short time, if no fistula is formed.

In hydatids placed centrally, the location of which in spite of the X-ray photograph cannot be diagnosed with any amount of certainty, the operation is rendered much more difficult. Hæmorrhage is especially to be feared when an incision is made.

DEVÉ, therefore, recently objects to any operation on these central cysts, but, from numerous statistics and investigations, comes to the conclusion that only the large cortical or parapleural hydatids, whether closed, open, or having perforated the pleura, should be handed over to the surgeon, and the small central parabronchial ones should be subjected to the expectant treatment, and the spontaneous bursting into the bronchial tree should be awaited, as an operation in these cases is risky and dangerous and generally quite useless. Washing out the hydatid cavities with anything whatsoever is not to be attempted; secondary pneumonia, risk of suffocation and immediate mortal embolism would be the consequence.

As in all cases of extensive pneumotomy, the operation involves some direct and indirect dangers. These are hæmorrhage, septic pleurisy, bronchopneumonia, secondary pneumothorax, and, in the case of large and dilated hydatids, the formation of a fistula (twelve cases), which necessitate a second operation.

I have already spoken of the results of operation, which absolutely justify strongly recommending surgical treatment for echinococcus of the lung as soon as it is recognized. Any delay involves great risk to the patient.

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CHAPTER XIII.

FOREIGN BODIES IN THE LUNG AND IN THE BRONCHI.

Foreign bodies reach the lung either through the chest-wall (bullets, knife wounds) or through the larynx or a wound resulting from tracheotomy (broken pieces of cannula). Only rarely do objects from the œsophagus perforate into the lung.

Bullets, and similar foreign bodies, penetrating into the lung, when they are more or less aseptic, become encapsulated and heal up permanently without reaction.

In this way foreign bodies may remain in the lung for decades, without any important symptoms.

Thus Manet reports the case of a patient who for fifteen years went about with an iron blade piercing the lung from top to bottom. The pulmonary tissue, enclosing the foreign body, was perfectly healthy and had provided it with a thin-walled sheath. In the same way Velpeau saw a man whose lung contained a long piece of a foil, which went straight through the thorax and one end of which stuck in the middle of a rib and the other in the body of a vertebra; the middle portion situated in the lung was covered with incrustations of lime.

But fairly often these foreign bodies give rise later to phenomena, the bacteria which penetrated with the foreign body, which at first took no effect, becoming virulent and having serious consequences. Sometimes the foreign bodies are coughed up; they may also, after having apparently healed up without reaction, endanger life by vascular erosion.

They are generally easily localized by the use of X-rays. This makes the operation, which may be necessary, easier. The latter is only indicated when the injury itself immediately leads to phenomena dangerous to life or when an infection (pulmonary abscess, gangrene, empyema) follows. Otherwise an expectant treatment is adopted. Subsequent operations are necessary when vascular erosion, already mentioned, or secondary infections occur.

Christowitsch succeeded in removing a revolver bullet from a patient aged 22. On the sixth day after the injury he had to be operated on for septic pleurisy. The bullet lay to the left in the 3rd intercostal space. After enlargement of the resection the surgeon could feel the bullet in the lung; he made an incision here

and applied a tampon to the wound cavity, after removing the bullet and the necrotic pulmonary tissue.

KORTEWEG extracted from the lung of a man of 23, wounded in South Africa, a splinter of a lyddite shell, on account of repeated hæmoptysis, about half a year after the injury. When the shell burst a few paces off the splinter pierced him on the right in front, between the 2nd and 3rd rib in a medial direction. Patient suffered from lack of breath during the first few hours, and a few days later coughed up maladorous blood ; otherwise, except for an uncomfortable feeling when he took a deep breath, he had no symptoms. About three months later, however, hæmoptysis occurred, which was repeated and occasioned the operation. KORTEWEG first resected the 2nd rib, and, in attempting to reach the pulmonary scar, opened up the free pleural cavity. He thereupon suspended the operation and fourteen days later removed with some difficulty the splinter and some bits of clothing. The patient recovered. The splinter was 4½ cm. long, 1½ cm. thick and weighed 42 g.

Bodies entering the bronchi in the natural way are very various. For practical reasons it is well to arrange this medley into different groups.

(1) Round or flat bodies (bullets, coins).
(2) Irregular, pointed, jagged bodies (bits of bone, &c.).
(3) Bodies that can swell (beans, &c.).
(4) Ears (of corn, spikes of grass, &c.).

Foreign bodies penetrate more frequently into the right bronchus than into the left, which is due to anatomical conditions (*cf.* fig. 91). The position of the patient, too, when the object is aspired, is important. According to their size and surface they penetrate more or less deep. Ears of corn, &c., owing to their shape, may move rapidly and pierce the pulmonary parenchyma. Jagged bodies will soon come to rest. Round bodies are more likely to injure a bronchus than those of irregular shape, especially when they subsequently swell. Apart from the position of the foreign body, the total or partial obstruction of the bronchus by it, the symptoms are influenced by the fact that the body is movable or immovable.

As regards the symptomatology of the foreign body in the bronchi, we must distinguish between the initial stages and the subsequent condition.

The immediate symptoms, apart from local pain, are : weakening or suppression of the breath sounds and the respiratory movement in the corresponding part of the lung. There may be no dulness ; if it is present it may be caused by atelectasis and also by an infiltration (which may very easily occur). The vocal fremitus and the respiratory expansion of the thorax is reduced. If there is any sputum it is sometimes partly sanious. Moreover, more severe hæmoptysis owing to vascular erosion is not at all rare. RIVINGTON reports forty-four cases. Purring and whistling or rattling sounds (shivering according to DUPUYTREN) in one half of the interscapular cavity are of special importance. Want of

breath must also be mentioned. Especially in the case of foreign bodies which can still move about, attacks of coughing and suffocation, choking movements and vomiting, twitchings, even attacks of unconsciousness, occur. In rare cases, when the bodies are very mobile, owing to dyspnœa which would otherwise set in, the patients adopt an unnatural position.

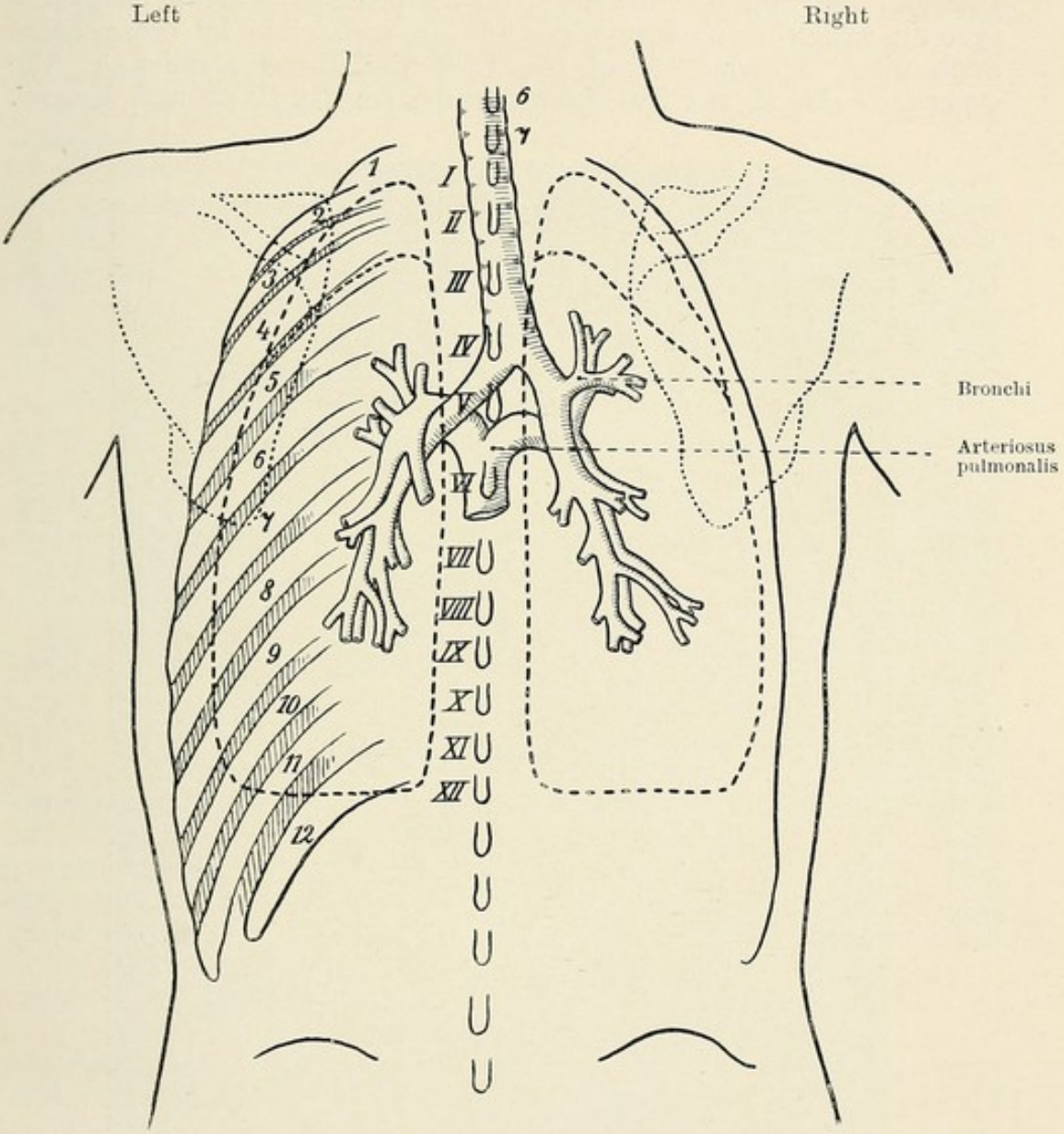

FIG. 91.—The air-passages and their ramifications projected to the posterior thoracic wall.

All these symptoms, except the first attack of coughing and suffocation, which can scarcely be absent during the passage of the foreign body through the glottis, may be either lacking altogether or very slight; in this way the diagnosis may be rendered very difficult if the anamnesis is insufficient, especially when, as not infrequently happens, the pain is in the gastric region.

In very many cases then the use of X-rays, which has become of

more and more importance during the last few years for the diagnosis of foreign bodies in the air-passages, may satisfactorily solve the difficulty. It is clear that in this way at least all metal foreign bodies due to aspiration, which are in the trachea or bronchus, can be demonstrated; more important than the demonstration of the foreign body is the determination of its shape, size and position, as well as its prospective position in the bronchial system, which is made more and more possible by more exact anatomical knowledge and the profound X-ray studies of the organs of the thorax by HOLZKNECHT, DE LA CAMP and KRAFT.

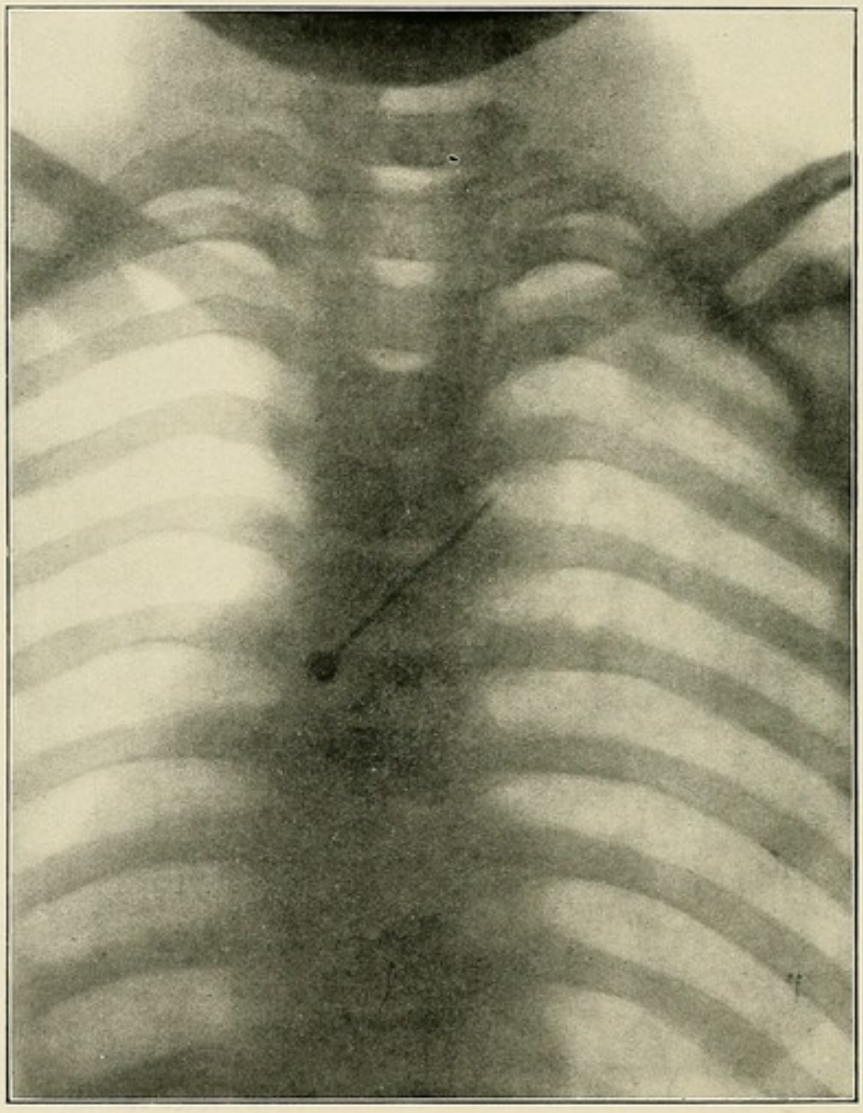

FIG. 92.—Pin in a bronchus. (According to GOTTSTEIN.)

If the so-called stereo-tubes are also used, we can, with the help of the Röntgen gauge of depth, read on a scale both the depth and also the lateral vertical distance of the body to be determined.

As regards non-metallic foreign bodies, the bone due to aspiration certainly casts a shadow, but generally not sufficiently large or intense to differentiate it from the other parts of the skeleton.

Nevertheless, in this case, as in that of other foreign bodies of this kind, the demonstration may be successful secondarily by the use of the X-rays. Thus, for example, a swelling pea may completely obstruct a bronchus, and so cause collapse or obstruction in the part of the lung in question, in which condition, on the one hand, modifications in the type of breathing, &c., on the other hand, the formation of shadows in front of the screen, may be observed. When the foreign body has been located there for some time, naturally the surrounding infiltration noticeable in the X-ray picture, the formation of cicatrices or abscess, give us the necessary information.

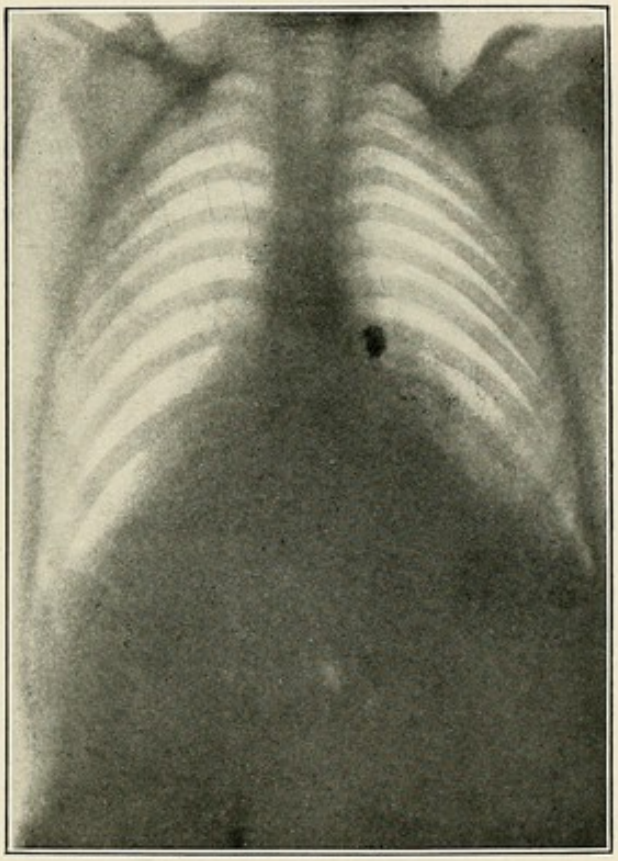

FIG. 93.—Foreign body in the lung.

Far more important, however, for the diagnosis of foreign bodies which have been aspired than the use of X-rays and the physical methods of examination mentioned before, as well as laryngoscopy, has bronchoscopy become so brilliantly developed by KILLIAN during the last decade. When discussing therapy we will enter more fully into this.

Whereas the foreign bodies which reach the lung through the chest wall have a tendency to become encapsulated and to heal up without reaction, those bodies which have passed in in the natural way generally lead, sooner or later, to serious results. Only one case (BLUMENTHAL) is known in which a piece of a tracheal cannula due to aspiration, and which after pulmonary symptoms had persisted for two months, healed up. In most cases, unless the foreign body is coughed up, or removed by operation betimes, purulent bronchitis, pneumonia, bronchiectasis, abscess, or gangrene, is the result. Pulmonary suppurations caused by foreign bodies are generally putrid in character (*cf.* Chapter VI., p. 115, "Abscesses caused by the Presence of Foreign Bodies"), and very often have the unfavourable prognosis of chronic abscesses. They are frequently multiple and spread over large portions of the lung. The gangrene may also be combined with bronchiectasis.

In the case of transformations of the lung not clearly to be accounted for, according to F. A. HOFFMANN, one must think of foreign bodies when one finds: "(1) Circumscribed bronchopneu-

monia and bronchiectasis in the right inferior lobe; (2) signs which denote the formation of an abscess without any cause being ascertainable; (3) in older people, especially when there is a peculiar condition of somnolence, as in the cases observed by HAMBURGER and HECKER, which appears inexplicable and when the respiration is curiously affected." In many cases the use of X-rays will clear up the difficulty.

It is well known that foreign bodies, after causing trouble at first, may often persist for years without causing any trouble—as in a case of STADELMANN'S, for six whole years, till gangrene or abscess with empyema suddenly appeared, or, as in the case reported by KILLIAN, when a needle which had been in the body for ten

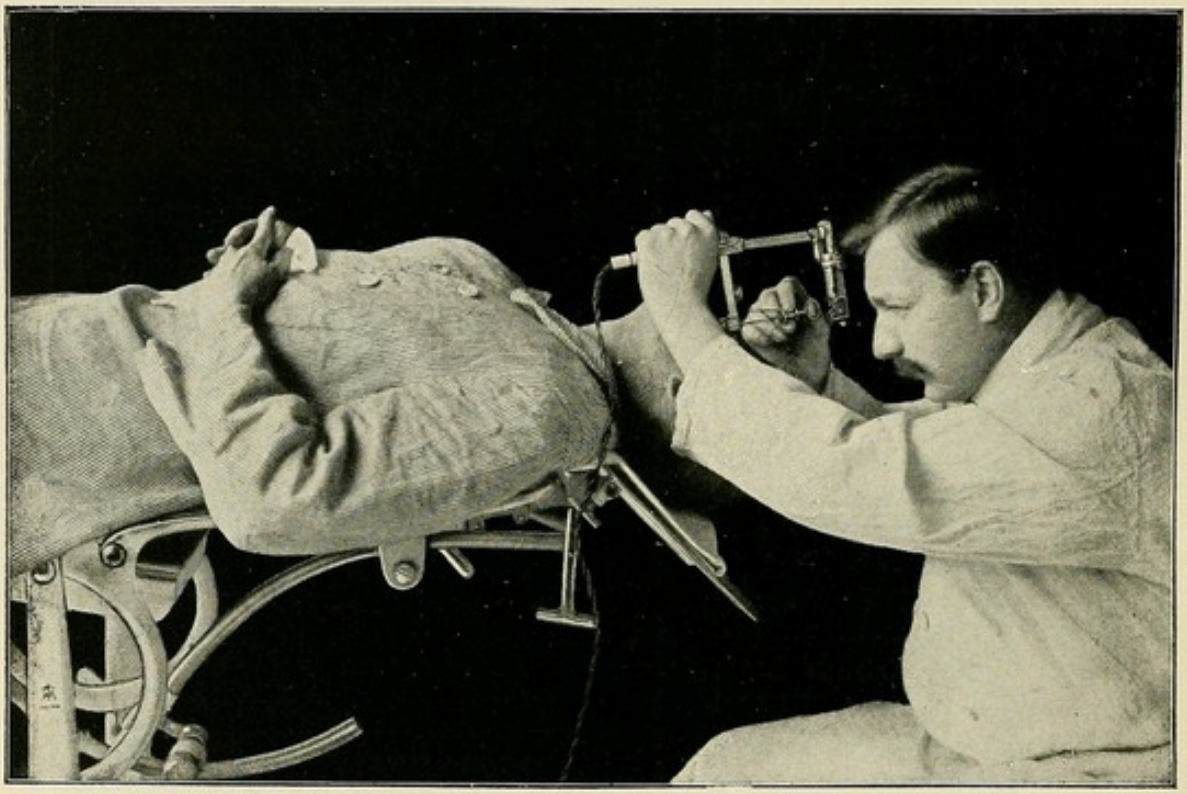

FIG. 94.—Bronchoscopy in a recumbent position. (According to BRÜNINGS.)

years suddenly gave rise to hæmoptysis and had to be extracted. A foreign body due to aspiration may also cause chronic bronchitis for years and thus rouse suspicion of the presence of a tubercular process.

HOFMEISTER mentions a case observed by MACKENZIE, who reports the spontaneous expectoration of a bit of bone which had been lying in the bronchi for sixty years. When ears of corn are aspired the abscess often breaks out through the wall of the thorax, when the foreign body is cast out. But as these bodies can comparatively easily slip through the lung, if there are either no or insufficient pleural adhesions, they may lead to pneumothorax (AST, ZUPPINGER). Pleurisy has also been observed after the aspiration of foreign bodies and may probably be attributed to previous bronchopneumonia. We have already mentioned elsewhere that

foreign bodies (beards of corn, carious teeth) may also act as host of the actinomyces penetrating into the lung. It is of interest to note that the actinomyces fungus reaching the lung through the instrumentality of a foreign body, as shown by SCHLECHTENDAHL'S case, does not necessarily develop specific characteristics.

FIG. 95.—BRÜNINGS' bronchoscopic operation (patient seated on a low stool).

A child, aged 3, after aspiration of an ear of corn, died of pulmonary gangrene. In the pus in the immediate vicinity of the ear actinomyces were discovered by the aid of the microscope, whereas they were absent from the more distant bronchi and cavities, and also, *intra vitam*, actinomyces were never observed.

Nevertheless, pulmonary actinomycosis had not developed, and the pyogenic micro-organisms, which had evidently entered simultaneously, had held the field against the less virulent actinomyces.

When we consider the not infrequent unfortunate consequences of foreign bodies which have not been removed (hæmoptyses), and the most unfavourable prognosis of operations on the secondary pulmonary suppurations caused by them, the necessity of an earlier active therapy needs no stronger argument.

The following therapeutic measures may be considered:—

(*a*) Bloodless.

(1) Alleviation of expectoration by position and external manipulation as well as by emetics (apomorphin).

(2) Extraction of the foreign body with the assistance of bronchoscopy.

(*b*) Surgical.

(1) Low tracheotomy.

(2) Interthoracic tracheotomy immediately above the bifurcation (MILTON).

(3) Bronchotomy from the posterior mediastinum.

(4) Pneumobronchotomy.

MURPHY recommends, according to the procedure of WEIST in recent cases, to hang up the patient by the feet and during expiration to press forcibly on the breast.

Adult patients can be placed right across a bed with the upper part of the trunk hanging down, the hands resting on the ground, and told to make violent expiratory movements, while the inspiration is cautious and gradual. Such attempts will be made as soon as possible after the aspiration, before the foreign body has become fixed. The application of cocaine to the larynx might make the passage of the foreign body easier. If the foreign bodies are very irregular in form, such experiments will not be made in the case of weakly people (especially old people), on account of the danger connected with the passage of the object through the glottis.

Then bronchoscopy plays its part. The method elaborated so admirably by KILLIAN and his pupil BRÜNINGS renders excellent service. In the last edition we had to say: "The method is too new for its indications and contra-indications to be determined," but now, by reason of the hundreds of brilliantly successful cures by the expert, we can hardly name a contra-indication. Out of 303 patients, from whom a foreign body was extracted with the aid of the bronchoscope, according to V. EICKEN, 233 were completely cured. The technique is not easy, and here, as in all these things, individuality will play a considerable part, and many failures will certainly not be published. Still the method need not remain solely in the hands of the specially trained laryngologist, but the instrument, brought to such high technical perfection by BRÜNINGS in the last few years, should now be in the hands of every surgeon. Bronchoscopy has also aided us in diagnosis in an unexpected way. I would remind you, apart from the discovery of "unsuspected" foreign bodies, of bronchial carcinoma, bronchial fistulæ, bronchiectases, parabronchial echinococcus, &c. Naturally, therapy has not remained uninfluenced by this.

BRÜNINGS' new broncho-electroscope consists mainly of three parts: (1) The tubular spatula, that is, a short, thick tube, sloped

off in front and somewhat broadened, through which (2) the perforated sliding tube can be pushed deep down into the bronchus of the inferior lobe to anything which requires removal. The sliding tubes are provided with a toothed spiral spring which works on the side of the tubular spatula, and by means of a toothed spring can be fixed in any position required. The tubes can be inserted at any depth required without the distance of the source of light or of the eye from the upper opening of the bronchoscope having to be altered in any way. Several of these tubes of various lengths, with a diameter of 5 to 12 cm. are sufficient in practice.

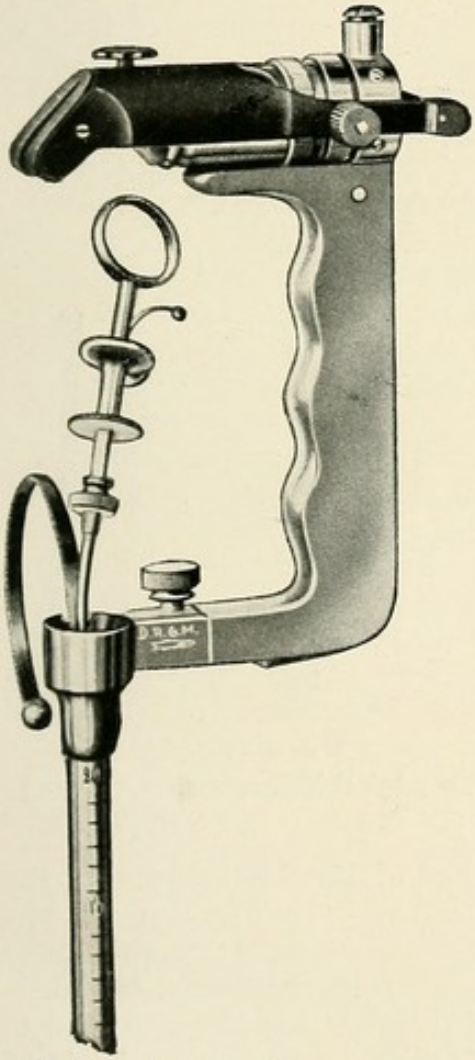

FIG. 96.—BRÜNINGS' bronchoscope.

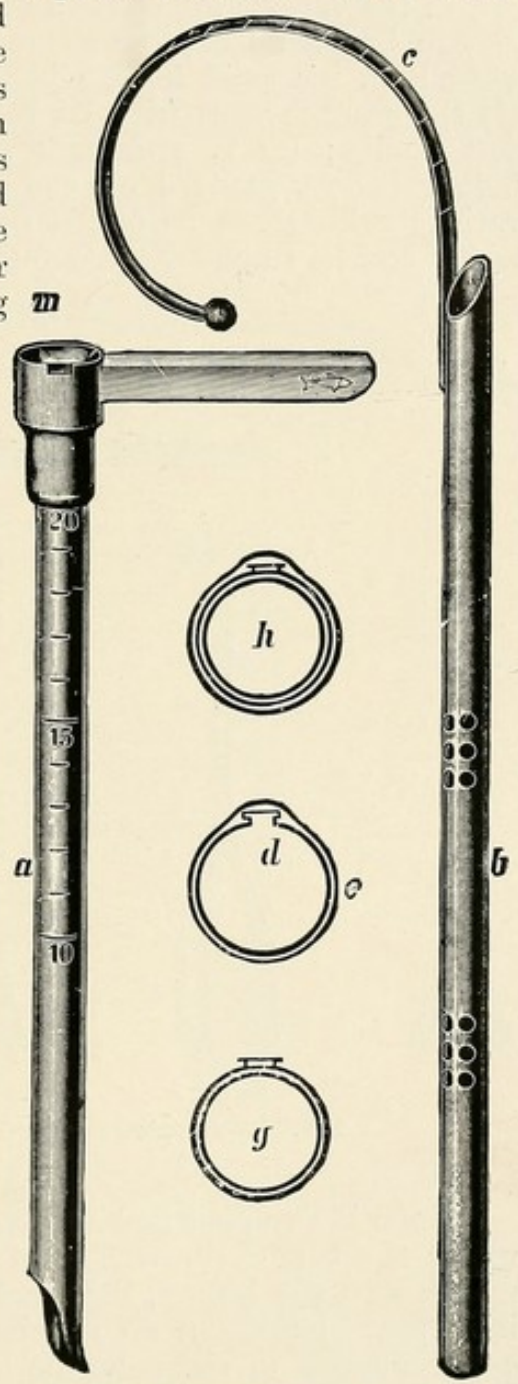

FIG. 97.—Tubular spatula (*a*) and sliding tube (*b*).

Instruments made by Fischer in Freiburg-i.-B.

As source of light BRÜNINGS uses, instead of KIRSTEIN'S frontal lamp formerly used, a hand-lamp, which, closely connected with the system of tubes, has a perforated adjustable reflector; through the perforation the instruments remain under the control of the eye.

The bronchoscopic surgical instruments are simplified in correspondence with BRÜNINGS' tubes of different lengths, and his method of adjustment, by the construction of an extensible forceps, to which the various forceps can be screwed. The chief types of these, as can be seen from the accompanying illustrations, are: (*a*) The vulsellum, for solid foreign bodies with irregular surface (bones); (*b*) the bean-forceps with its toothed branches with apertures for soft bodies; (*c*) V. EICKEN'S needle-forceps; (*d*) the forceps for hollow bodies, grooved on the outside, with which tubes of very various calibre can be seized from within by opening the forceps wide; and (*e*) the double scoop for exploratory excisions.

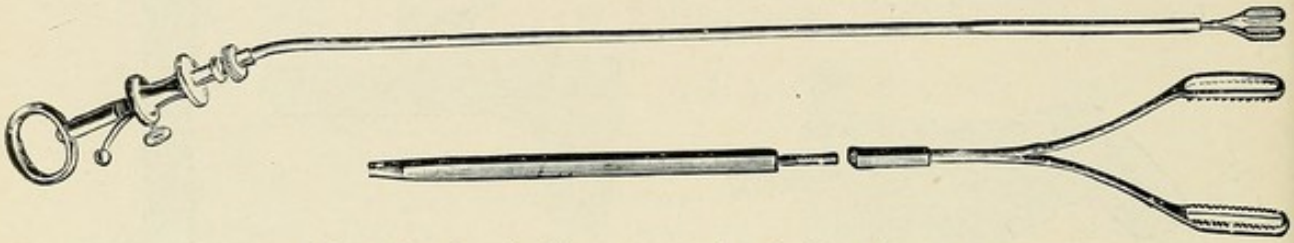

FIG. 98.—Surgical instruments for the bronchoscope.

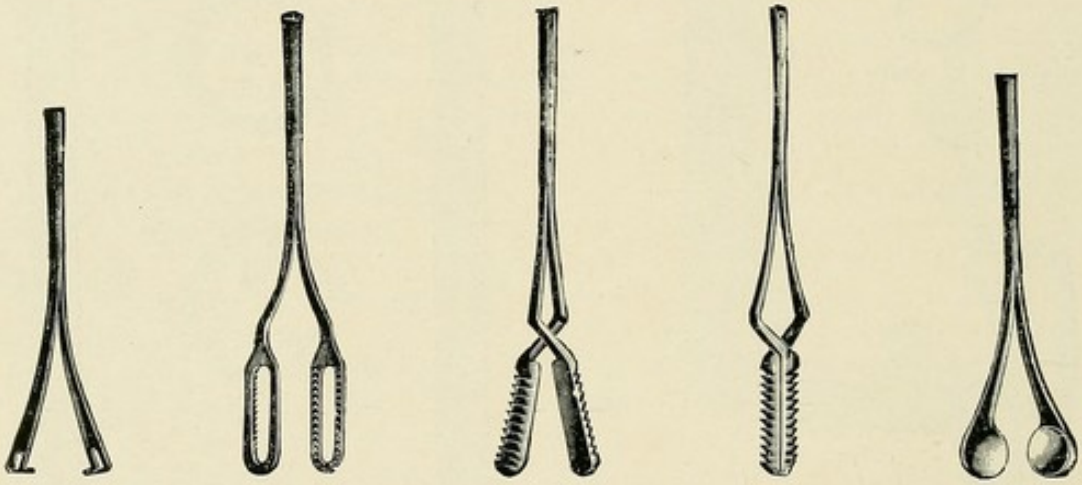

FIG. 99.—Supplementary parts of the surgical instrument.

There is an upper and a lower method of bronchoscopy. In the upper the tube is inserted in the natural way, that is, through the mouth into the larynx, the trachea and the bronchi; in the lower it is pushed through an incision made by tracheotomy, which is either already in existence or has been made for the purpose of bronchoscopy. In general the upper method will always be tried first and, with a little practice, will generally achieve its end. By tracheotomy the distance to be traversed is shortened by about 15 cm., a great advantage with regard to illumination and the use of instruments.

As regards the position of the patient during the examination, it is necessary to decide each case on its merits. In many cases a sitting position is uncomfortable because a good deal of saliva flows past the tube into the trachea and causes continuous coughing; in

other cases, however, especially with bronchiectases, it is desirable, indeed unavoidable. KILLIAN prefers a recumbent position, especially lying on the side, but the patient must lie in such a position that the place where the foreign body lies is highest and the head lowest.

General anæsthesia is only necessary with children; with adults, however, it is generally dispensed with, and absolutely in the lower method of bronchoscopy. Local anæsthesia is sufficient here and pharynx and larynx should be first painted with a 20 per cent. solution of cocaine and adrenalin, in a sitting position, controlled by means of a mirror, and later the bronchi, especially the seat of the foreign body, should be anæsthetized with the endoscopic cocaine spray.

If the attempts to remove the foreign body by superior bronchoscopy fail, or if one is not in possession of a bronchoscope, then low tracheotomy must be performed without delay.

Mobile foreign bodies, which otherwise, by striking the vocal cords, produce spasm of the glottis, coughing and suffocative attacks, which are very dangerous for weakly individuals, children and old people, are often expectorated immediately after the opening of the air passages, especially when, according to COLLET, both sides of the incision in the air passage are fastened by two sutures to the cutaneous incision, so that there is a wide opening which can be left without a tube, and through which foreign bodies, which otherwise come into contact with the tube, can easily be coughed up. Viscid mucus in the bronchi and in the vicinity of the foreign body, which hampers its movements, is wiped away with a feather brush or sucked up with a NÉLATON catheter. We may recall the original method of GARREL, who drew a nail in the right bronchus to the tracheotomy wound by means of a strong magnet. BURK succeeded in extracting a screw from the left main bronchus, which could not be located in spite of indirect bronchoscopy, by means of an electro magnet. In the case of foreign bodies which may swell, like beans, too much time must not be lost and tracheotomy must be performed as soon as possible, even foregoing the upper method of bronchoscopy (NEHRKORN).

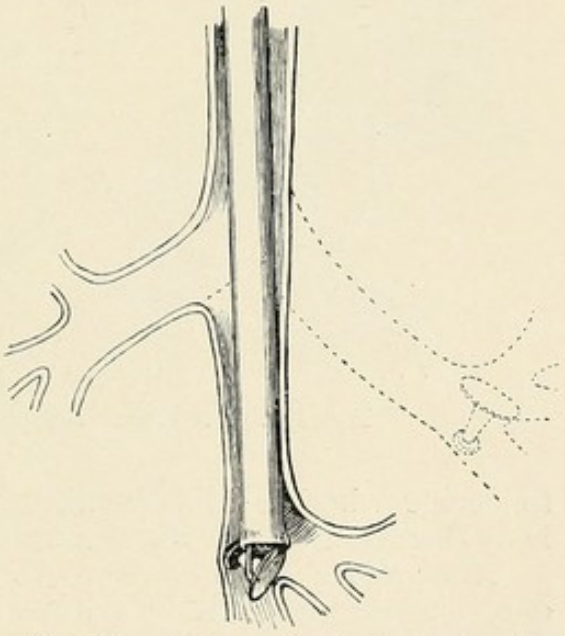

FIG. 100.—Seizure of a foreign body with the aid of the bronchoscope (extension of the left bronchus). (v. EICKEN.)

If, however, the foreign body is firmly lodged in the mucous membrane, and is not coughed up, an extraction with forceps or similar instruments, controlled by the eye alone, is permissible,

from the tracheotomy wound. The practitioner, especially if he has performed tracheotomy according to COLLET'S method, will probably be able to see as far as the bifurcation of the air passages with a simple funnel-shaped ear-speculum, whereas a short bronchoscope tube introduced through the wound will render the surgeon excellent service. The field of operation is nearer to the eye than with bronchoscopy, it is better lighted, the determination of the position and shape of the foreign body and the manipulation with the forceps are much easier. Whether in the case of irregular bodies which have penetrated deep down and got firmly wedged in, we should abstain altogether from tracheotomy, we will leave open. The prospects for the removal of these bodies are naturally not specially good ; still, considering the magnitude of the operations which would have otherwise to be considered, this relatively simple operation might well be tried first.

If by tracheotomy the foreign body cannot be extracted either at once or soon afterwards, and it is not expectorated, we have

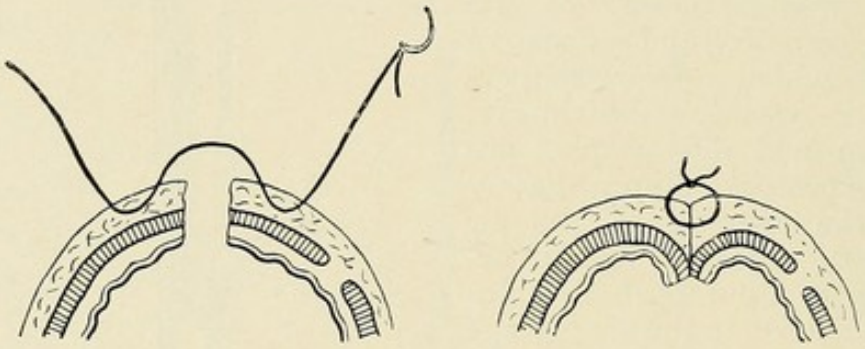

FIG. 101.—Peribronchial suture. (According to TIEGEL.)

to decide whether to leave nature alone or to attack the foreign body directly through the chest wall.

After using the bronchoscope in vain, the method carried out once successfully both by HUBER and by MORRIS, of feeling along the ramifications of the bronchus with long alligator forceps, working from deep tracheotomy under constant control with the X-ray screen and extracting the body, calls for little imitation.

With the expectant treatment, with luck, an inflammatory softening in the vicinity may make the foreign body mobile again, so that later it is expectorated, or we can again make attempts at extraction with more success. On the other hand, we shall by this means expose many patients to the danger of serious pulmonary lesions with their less favourable prognosis. Generally speaking, in the case of round smooth bodies, as long as no threatening symptoms arise, we may anticipate, with more probability than in the case of irregularly shaped ones, that they will scarcely be thrown up spontaneously.

In such cases, and also in urgent ones, attempts have sometimes been made to extract the foreign body by means of mediastinal bronchotomy. Attempts to open up the main bronchi, or the trachea immediately above the bifurcation, from the anterior or

posterior mediastinum, have not, as yet, given very favourable results.

MILTON, in the case of a patient on whom tracheotomy had been performed, and who had a piece of cannula in the right bronchus, after vain attempts at extraction, made an interthoracic tracheotomy on account of fever and fœtid sputum. After sawing through the sternum in the median line, he succeeded in extracting the foreign body, but the patient succumbed soon to mediastinitis, in consequence of insufficient tracheal suture.

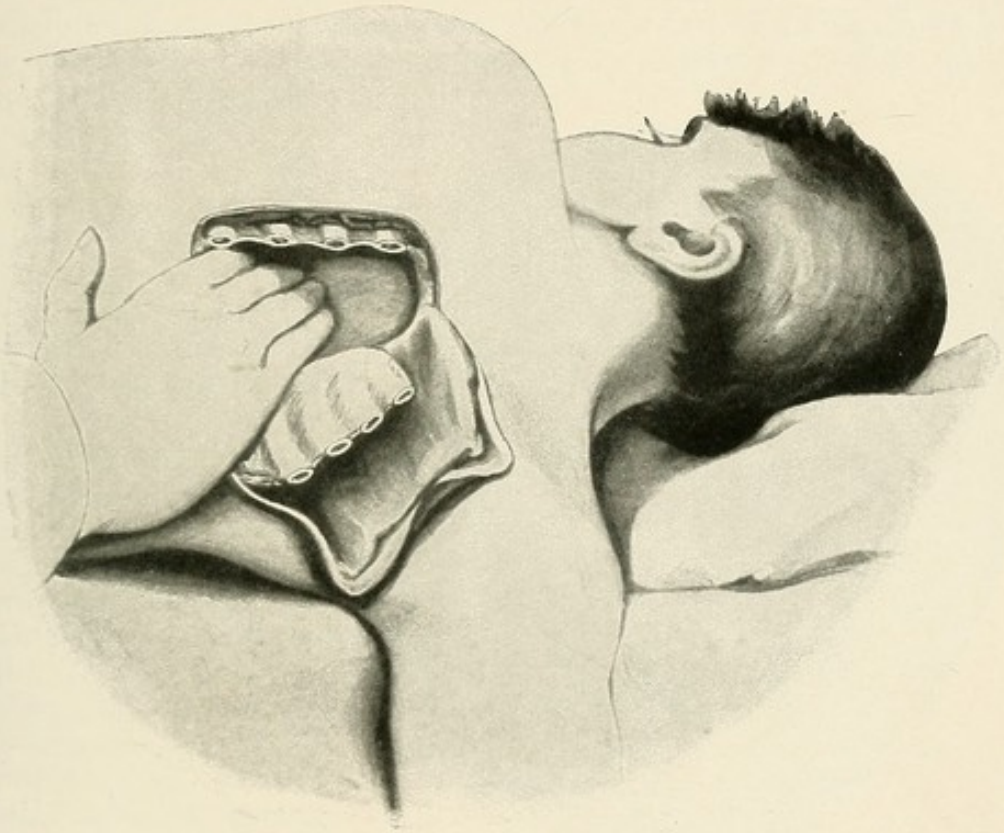

FIG. 102.—A. SCHWARTZ's method of performing bronchotomy from the posterior mediastinum.

In fact, everything depends on a secure, air-tight suture. We owe to TIEGEL an experimental study on the bronchial suture, according to which radical sutures on the bronchus or trachea do not answer to the demand put upon them. The peribronchial suture (fig. 101), made with the finest silk, proved efficacious and air proof. He tried to hasten fibrinous adhesion by painting with LUGOL's solution. The peribronchial suture becomes much more secure when covered with a small piece of pulmonary tissue.

Judging by the successes of KÖNIG one might strengthen and secure the bronchial suture by a fascia plastic.

For the examination of a bronchus TIEGEL says :—

"A good approach to the bronchus is obtained in human beings by an incision in the 2nd intercostal space, beginning from the parasternal line, and taken as far back as possible. After opening

up the pleural cavity (under the apparatus for maintaining increased pressure) the 3rd rib, after two-fold acupressure, is severed as far back as possible, and turned back. After forcing the ribs apart and insertion of the rib-retractor, the opening is sufficiently large, then the superior lobe, after detachment of any adhesions that may be present, is pressed into the inferior anterior portion of the pleural cavity, by means of which the bronchus, passing obliquely from upper median to lower lateral, expands, and the whole hilum revolves slightly. The bronchus lying behind the vessels is thus raised and is easily accessible from the wound in the thorax."

As far as I know the method has not yet been applied fully to a living person. Bronchotomy from the posterior mediastinum has, however, been introduced into practice according to a method developed as early as 1903 by A. SCHWARTZ at the suggestion of QUÉNU. DUNCAN and SCHIASSO have successfully operated in this way.

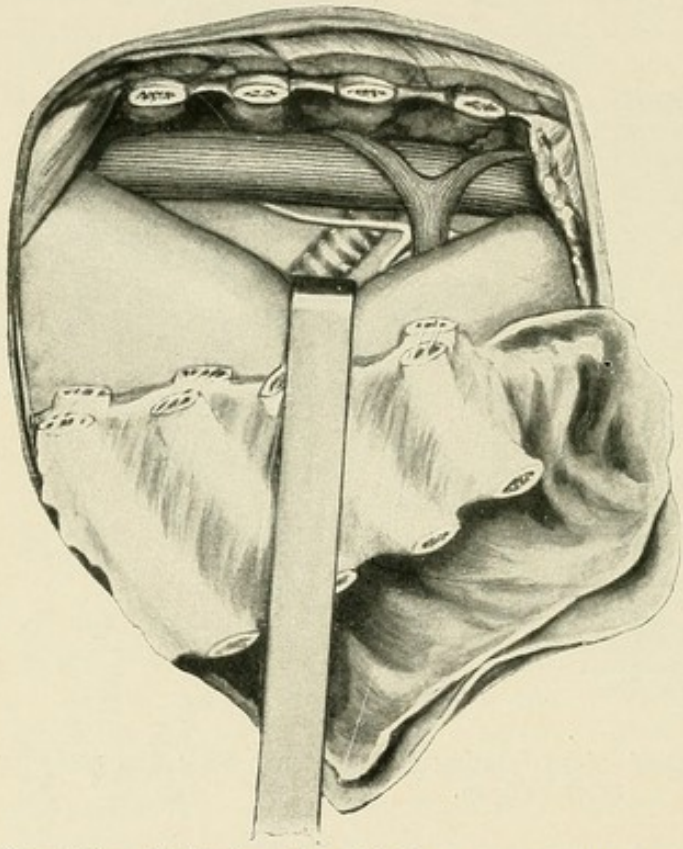

FIG. 103.—Right bronchus laid bare. (According to A. SCHWARTZ.)

ANSELME SCHWARTZ recommends the following technique: Bending back of an H flap with the base at the margin of the shoulder-blade, severing the 5th, 6th, 7th, and 8th ribs 4 cm. from the transverse process and bending back outwards. Blunt dissection of the parietal pleura towards the vertebral column (fig. 102). On the right and left the anatomical topographical conditions are different. On the right side you find beside the vertebral column the œsophagus, and above, crossing it, a branch of the azygos vein. At this point you cease removing the parietal pleura. The pleural sac, together with the lung, is drawn forward with a tenaculum. The vagus nerve can be seen for a certain distance and close to it in the angle of the azygos the right bronchus can be felt (fig. 103).

On the left side you very quickly reach the thoracic aorta. You push the mediastinal membrane away from it till you come into the vicinity of the aortic arch, push the vagus aside, force the lung forward with a blunt tenaculum. Here also the bronchus, which by its consistency is easily recognizable by touch, can be drawn

forward. As on the right, so here, the posterior membranous part presents itself in the incision (fig. 104).

Finally comes the question of pneumotomy. This is useful, above all, in cases in which the foreign body has penetrated far into the periphery of the lung, or when it is wedged in a branch of the third degree.

Thus BARDENHEUER succeeded in loosening and promoting the expectoration of a firmly wedged foreign body (set of teeth) in the lower bronchial tree from a pneumobronchotomy, before secondary symptoms had appeared.

GOELTZ succeeded in removing a trouser button located in the right principal bronchus by pneumobronchotomy, after vain attempts at extraction. He opened the thorax below the clavicle by bending back a semicircular flap of cutaneous muscle and bone. The lung was completely collapsed and the button could be plainly felt. A small incision was made in the lung, the foreign body removed, and the thoracic wall closed without suture of the pulmonary wound. The patient preserved his life.

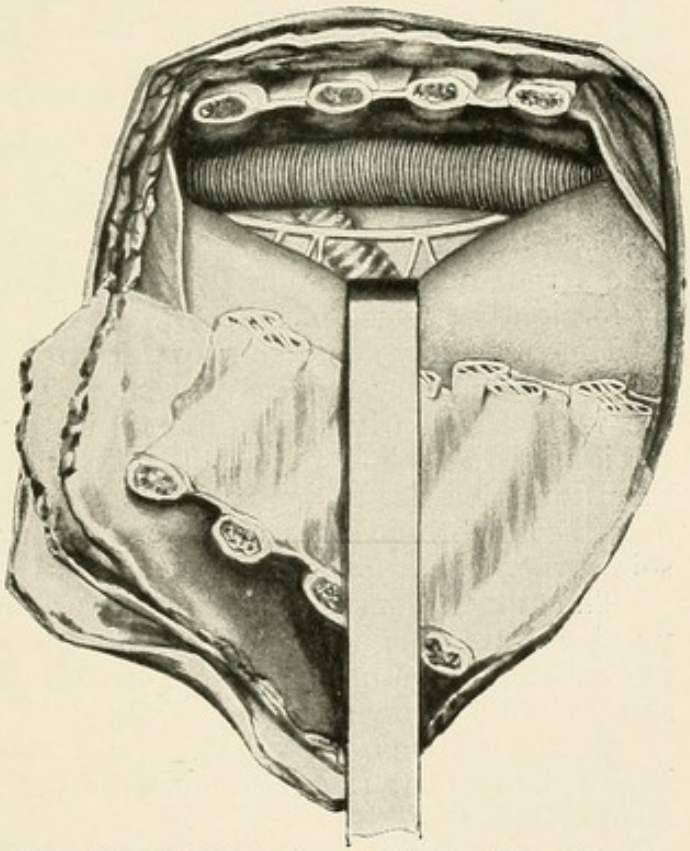

FIG. 104.—Left bronchus laid bare. (According to A. SCHWARTZ.)

HOFMEISTER, for the first time in 1904, made use of bronchoscopy as an aid in performing pneumotomy. A shirt button, inspired eight months previously, could be diagnosed by means of the bronchoscope, but on account of the large amount of suppuration and the risk of hæmorrhage it could not be removed. HOFMEISTER therefore proceeded, after denudation of the focus by pneumotomy, to prepare the way to the injured bronchus by the bronchoscope tube, pushed the tube into the incision made for pneumotomy and removed the foreign body through the incision in the thorax. The patient died subsequently from abcesses on the brain.

KILLIAN advises, in the case of foreign bodies which are inaccessible when pneumotomy has to be performed, to proceed as follows: to use the bronchoscope with 5 mm. tubes as far as possible, and after the bronchus in question has been recognized by the discharge

of purulent secretion, &c., to insert into this a catheter which can be manipulated from the opening in the thorax, so that pneumotomy should not be performed in vain and without result.

All these operations are, naturally, only indicated when bronchoscopy promises absolutely no more hope of success, and then an operation will only be performed when, by the X-ray picture or the bronchoscope, the site of the foreign body has been already accurately ascertained.

If patients are only brought to us when, after the inspiration of foreign bodies, the above-mentioned secondary conditions have arisen, then we can only hope to gain anything by the mere removal of the object if the secondary processes are not yet in so advanced a state that spontaneous healing would appear to be impossible. Otherwise the transformations of the lung—abscess, gangrene, bronchiectasis—must themselves be treated surgically. As abscesses caused by foreign bodies are frequently chronic in character the operation must be as radical as possible and performed according to the principles already explained. The *corpus delicti* will not always be found on opening up the purulent focus, it may be at some distance from it. TUFFIER collected eleven pertinent cases; four patients died, only two were considerably better, the others remained uncured. For the operation on abscesses caused by foreign bodies see p. 117.

Here we may add a short note on broncholithiasis. These so-called "pulmonary stones" are mostly concretions of lime, which are most frequently formed in cavities or bronchiectases. Besides foreign bodies, clots of blood, pulmonory sequestrum, indurated secretion, give rise to deposits of salt of calcium. In the few cases described a chronic tubercular pulmonary process was almost the sole cause.

The stones (concretions) singly, or sometimes occurring in large numbers, are coughed up, they are small, rarely as much as 1 cm. in diameter, sometimes pointed, so that not infrequently they occasion severe pulmonary hæmorrhage.

The symptoms are vague. They can be seen certainly in the X-ray picture, but are rarely interpreted aright until a particle has been coughed up.

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CHAPTER XIV.

HERNIA OF THE LUNG.

By herniæ of the lung are to be understood only those protrusions of the lung through a defect in the bony or muscular thoracic wall, which are covered by skin.

They may be classified as congenital, traumatic, and spontaneous herniæ of the lung.

In the first the hernia is not congenital, but only the gap in the thoracic wall. A few weeks or months *post partum* under the influence of the respiration, especially by screaming and coughing, the rupture is caused at the weak place and is covered only by membrane. Here we may mention a case of Polyas' in which, in consequence of a deficiency of the pectoral muscles, as well as of a piece 4 cm. long of the 4th rib and the abnormal shape of the 3rd rib, a pulmonary hernia developed spontaneously in manhood. Congenital protrusions of large portions of the lung, as in the case of very late formation of the sternum, are due to ectopiæ.

Traumatic pulmonary herniæ are due to the rending or destruction of the thoracic wall without solution of continuity of the skin. In this case the protrusion of part of the lung may take place immediately after the trauma and thus often give rise to a subcutaneous emphysema owing to a simultaneous rent of the lung; or the deep-seated injury heals up at first, and only later on, in the course of months, under the influence of violent expiratory movements, is the hernia (consecutive pulmonary hernia) formed at that part of the cicatrix which is least capable of resistance. The lesion may even only affect the intercostal muscular system. Fractures of the ribs with severe dislocation of the fractured ends and extensive rending of the intercostal muscles often give rise to the formation of herniæ. Detached rib fragments may then be so completely absorbed, that congenital defects of the ribs may be simulated. By the pressure of an intercostal hernia the neighbouring ribs may be worn away.

A penetrating injury of the thorax, and also an operation on the thoracic wall, may be followed by the formation of a pulmonary hernia (scar hernia). Even by repeated punctures of the pleura a gradually extending scar has been formed (Trevisano).

In the region of these traumatic or surgical ruptures the pleura is generally adherent; in men they are generally observed on the anterior thoracic wall.

Spontaneous pulmonary ruptures are generally due to pressure from within. In this case the muscles of the thorax are generally injured by a disease of the lung (arteriosclerosis, emphysema, and chronic bronchitis), inasmuch as they are stretched by the enlarged lung, by continual coughing, and difficult expiration. In this respect, those parts of the anterior chest wall which are only covered by one layer of intercostal muscles, namely, the 6th to the 9th intercostal space, are specially endangered. Moreover, spontaneous pulmonary herniæ often occur in the superior opening of the thorax down in the supraclavicular fossa between scalene muscles and sternocleidomastoid, where little resistance is offered to the protruding piece of the lung.

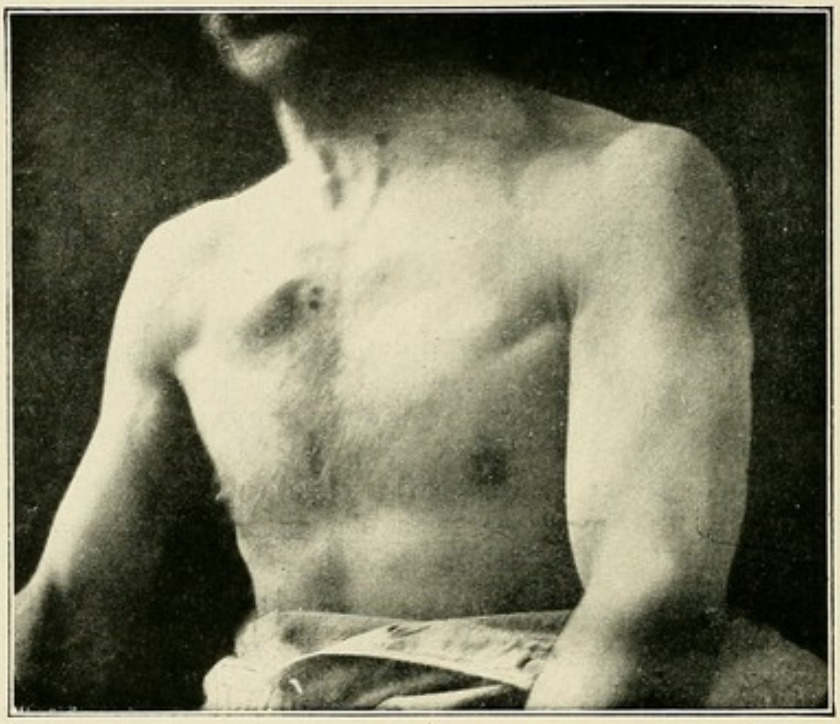

FIG. 105.—Traumatic pulmonary hernia. (According to VULPIUS.)

Also over-exertion on one or several occasions may cause a sudden rupture at the predisposed places in an otherwise sound lung and thoracic wall; for example, lifting something heavy in the cases of MENOTI, CLOQUET, and URBACH, or violent pressing in the case of a primipara (BOERHAVEN). There is nothing to prevent these forms being attributed to traumatic herniæ.

We must also reckon among spontaneous pulmonary herniæ those in which the defect in the thoracic wall is caused by purulent foci in the lung and pleura which have perforated outwards, or an inflamed superficial ulcer due to pressure in the case of a pulmonary abscess without direct propagation of the process to the rib (HOCHSINGER).

Spontaneous pulmonary herniæ have, at least at first, a slit-shaped aperture. Adhesions may often be lacking.

The symptomatology of pulmonary herniæ is generally pronounced, and makes the diagnosis easy. A more or less circumscribed tumour is seen of various size and round in shape, which is generally covered by intact skin, but also, as we have observed, may be covered by an external scar. It is immediately noticeable that the tumour changes in volume during respiration, and that it swells up on expiration. This is specially the case during violent coughing. During inspiration it is reduced in size, and during prolonged peaceful breathing may disappear, or even sink below the level of the thoracic wall. Only when the portion of the lung in the hernial sac is atelectatic or indurated are variations of volume absent during respiration. The skin over the tumour is movable; it is soft and elastic in consistency; it is compressible and except in a few cases (adhesions) reducible; it is often crackling to the touch. After the reduction the round or slit-shaped aperture of the hernia can generally be felt in the wall of the thorax. On expiration, especially during coughing, the lung presses against the finger. In some cases the muscular fissure through which the hernia had passed was no longer to be felt after the reduction. The percussion of the tumour gives rise to pulmonary sound, or, when the air is partly absorbed owing to a long period of quiet breathing, to a tympanitic sound. On auscultation sometimes, according to the amount of air in the hernia, vesicular breathing or crepitation can be heard. A pulmonary rupture may not be permanently present; many herniæ only appear rarely under the influence of violent coughing or great exertion (intermittent pulmonary herniæ). The pulmonary rupture may also be incarcerated. In the VOGLER case, VULPIUS noticed that by raising the arms manual replacement could be effected (*cf.* fig. 105).

The troubles caused by a pulmonary hernia consist in local pains on breathing and in fits of coughing. They are pronounced at first, especially when a rupture takes place suddenly. Later on they may disappear altogether. In cases of concurrent bronchitis repeated hæmoptyses have been observed. In any case a hernial rupture prohibits violent exertion, limits the earning power of the patient, and lessens his enjoyment of life.

The therapy of pulmonary herniæ has hitherto been mainly limited to bandages with pads. Undoubtedly they should be tried first. More suitable than devices of the nature of trusses for the retention of the rupture (fig. 106) would appear stuff corsets with spring pad. At the same time the cough which may be present should be combated by the treatment of the bronchial catarrh or lung trouble.

In a number of cases, mostly traumatic or congenital, the healing of the pulmonary ruptures has also been achieved in this way. Even in a case of hernia which could not be completely reduced a cure followed.

In other cases no cure was achieved. Sometimes the bandages slipped, or were not applied by the patient, because they inconvenienced him.

If unsuccessful then an operation must be attempted.

Vulpius was the first to attempt an osteoplastic closure of a large hernial aperture in the thorax.

After the dissection of a large flap in the soft parts and denuda-

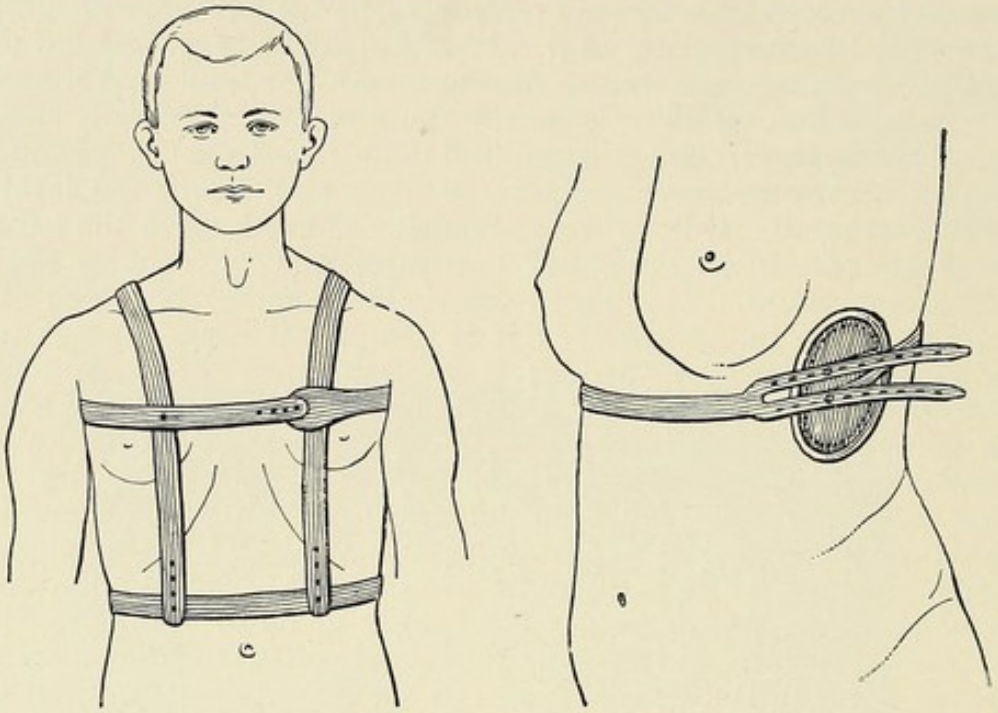

Fig. 106.—Bandage and truss in a case of pulmonary hernia.

tion of the very thin sac of the hernia, the rib which formed the upper margin of the aperture of the hernia was cleft longitudinally for some distance, placed obliquely over the defect, and sutured to the next rib stump. The analogous transplantation from the lower rib in order completely to enclose the defect in the thorax with a lattice, could not be performed on account of the overhanging perishable pleural sac of the hernia. So a complete cure was not achieved. Still, in similar cases it would be well to follow in the steps of Vulpius.

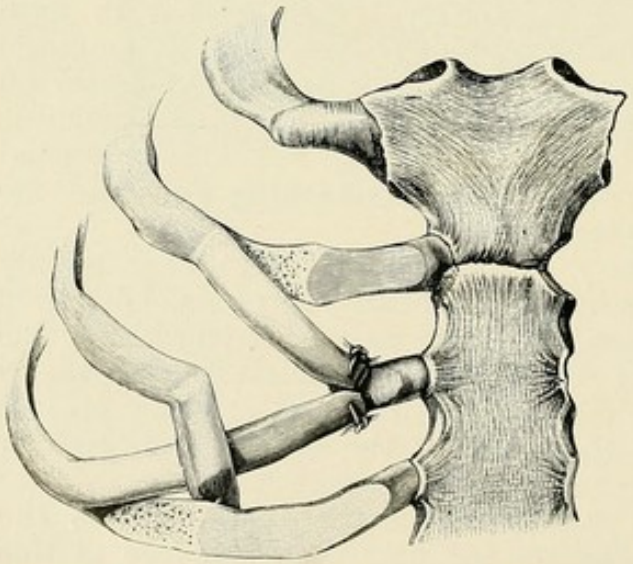

Fig. 107.—Plastic covering in a case of pulmonary hernia.

Hernial apertures in the neighbourhood of the sternum could easily be covered with a pedunculated periosteal bone flap. Also by implantation of free portions of periosteal bone, or by König's fascia-plastic, a gap in the thoracic wall could be closed.

Tuffier and Regnier in one case closed the hernial aperture by simple suture.

With the assistance of the apparatus for maintaining difference of pressure, radical herniotomy might be performed, when, after freshening the hernial aperture, the neighbouring ribs might be brought near to one another by the percostal or pericostal suture (see p. 70). The operation itself can be looked upon as without danger.

Quite peculiar conditions were noticeable in a case of WIGHTMANN'S, who, in the case of a trombone player, removed by operation a piece of collapsed lung below the trapezius, without finding a communication with the thoracic cavity.

There are not a large number of cases. AULER, up to 1892, collected altogether 51 cases which had been observed. About 40 more cases have been described since then, so that a total number of 90 cases are known.

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CHAPTER XV.

PULMONARY EMPHYSEMA.

SURGICAL TREATMENT OF RIGIDITY OF THE THORAX.

THE transformations of the costal cartilage in those suffering from emphysema, which were pointed out as early as 1858 by W. A. FREUND, have lately acquired increased consideration owing to the later works of this inquirer and of other writers. The proposal made at that time by FREUND to operate on the transformed cartilage, in order to alleviate the sufferings of the patients, has now in many cases been put into practice. In order rightly to appreciate the importance and applicability of this operation, it would seem advisable to make a few introductory general remarks on the subjects of emphysema.

Habitual difficulties of breathing, which often made it difficult for the persons concerned to get about and do their work, but which often did not interfere for a long time with the continuance of life, were still at the beginning of the last century described as asthma ; outside the medical profession this word is still used now and then for conditions of chronic lack of breath ; in medical phraseology, however, with increased knowledge of the processes of the disease, the mode of expression has been changed. The word asthma is now only applied to paroxysmal (even if habitual) want of breath, less frequently to the attacks due to heart trouble, principally to those connected with the respiratory system (bronchial spasm, angio-neuroses of the bronchial mucous membrane), and to attacks of somewhat obscure genesis (toxic, reflex or other origin).

For the majority of the cases of habitual lack of breath formerly described as asthma, which were caused by transformations of the respiratory system, the term pulmonary emphysema became usual after LAENNEC had demonstrated that in many of these cases there was a transformation of the lung which he termed (substantive) emphysema, and which was characterized by permanent increase in volume and loss of elasticity, here and there also was accompanied by atrophy of the pulmonary tissue. In correspondence with the trend of opinion of the day this pathological anatomical transformation of the lung was used as the name of the diseased condition, which was certainly often, but not always, accompanied by the

transformation named, of which, however, in the less common cases it was the sole or the principal cause. As in many other cases, this description of disease, based solely upon pathological anatomy, leads to much confusion, and has made it more difficult to understand the diseased conditions in question.

The clinical condition of these patients is clearly characterized, almost typical, and a common name was a practical necessity; so instead of asthmatic the term "emphysematic" is used, but every doctor knows that in the emphysematous patient a number of other disturbances and anatomic changes are present and important in the description of the disease—besides LEENNEC'S "emphysema on the lung."

The increase of volume in the lung, recognizable in life by the depth of the inferior pulmonary margins (compared with the normal average), is not in itself a sign of pulmonary emphysema, but often only the expression of an improved development of the lung though respiratory exercise, analogous to the hypertrophy of glands and muscles, the anatomic expression of the increased powers of the respiratory organs; it is often accompanied by a better development of the thorax and the respiratory muscular system.

A decrease in respiratory power is, however, characteristic of the emphysematic subject: he is short of breath when he exerts himself, in advanced cases even on slight movement, and only after some time recovers respiratory equilibrium; the breathing is more superficial, on the slightest provocation more rapid, the vital capacity is below the average, chiefly because he can only attain the normal maximal position for expiration with great muscular effort or even not at all. Certainly the increase in the volume of the lung and the decrease of its elasticity tends to produce these disturbances, but, as a matter of fact, we find connected with them a more or less pronounced decrease in the pliability and elasticity of the thorax, which, in advanced cases, increases to rigidity. Often, but not always, the form of this rigid thorax corresponds to an inspiratory position of the ribs which has also become permanent, especially of the upper ribs, and is, as FREUND has demonstrated, connected not only with structural change and calcification, but also with increase in the length of the 1st and 2nd costal cartilages. It is clear that these modifications in the pliability and elasticity of the thorax will act as a much greater mechanical hindrance to the respiratory changes in volume of the contents of the thorax than the loss of elasticity in the lung. Energetic action on the part of the respiratory muscles may at first compensate for slight modifications in the mobility of the thorax, but they can do nothing to counteract the higher degrees of rigidity, and perform their functions, therefore, less and less, and so in the end succumb to a certain degree of atrophy due to inactivity. The obstruction of the costal respiratory movements may be compensated to a certain extent by freer diaphragmatic breathing, but this also is increasingly obstructed as the rigidity attacks the lower half of the thorax. So by continuous over-exertion in many cases fatty degeneration may be caused in the diaphragmatic muscles, as has been observed by FREUND.

In many cases, as we know, the condition described above follows on frequent acute or chronic bronchial catarrh. Their intercurrent appearance increases the troublesome symptoms or makes them more noticeable. On the other hand, some emphysematous subjects have no catarrh whatever in their anamnesis, only later on do they develop catarrh and suffer therefrom.

Some emphysematous subjects, especially those with catarrh, have more or less extensive pleural adhesions, which may also impede the respiratory movements.

Loss of elasticity with more or less increase of volume develops also in the lung in consequence of venous hyperæmia in the case of valvular defects or myocarditis. This "pulmonary rigidity" (BASCH) is more or less concealed by the condition of the lung known as brown induration. It has the same effect then as LAENNEC'S emphysema and is not always clinically to be clearly distinguished from it.

After long illness emphysematous subjects very often suffer from an enlargement of the right heart, which at first compensated for by hypertrophy, leads later to the insufficiency of this part of the heart. As well as these cardiac symptoms others not infrequently make their appearance, which are certainly independent of the respiratory system, but are due to myocarditis and arteriosclerosis, develop gradually and are often not to be distinguished with certainty from the disturbances due to the respiratory system.

Thus we see in the emphysematous subject a whole series of concurrent disturbances, which are in part in more or less close causal relation with LAENNEC'S pulmonary emphysema and the rigidity of the thorax, in part only usually occur concurrently with them. In the individual case the part played by each one of these disturbances in the development of the diseased condition is very various and must be specially considered. To this is due the very varied opinions and theories as to the cause of "pulmonary emphysema"; it arises in very different ways.

The part which the modifications of the thorax play in the difficulty of breathing varies greatly in degree; having been for a long time underestimated, they have been recently overestimated in many quarters, or rather too much generalized. Without going into the question whether the modification of the thorax or the emphysema of the lung are primary, or whether both occur in co-ordination—whether the structural and longitudinal modifications of the cartilage are primary, or (according to LOESCHKE) secondarily conditioned by kyphosis of the vertebral column—whenever they occur the modifications of the ribs and cartilage certainly play a large part in the respiratory trouble. The experiment, demanded by FREUND, of alleviating these mechanical disturbances by division and excision of the cartilage, has been proved to be justified by many experiments on human beings. Owing to the variety of the pathogenesis and of the complications, the only question will be to ascertain in the individual case that the changes in the cartilage are present and that the other causes of the want of breath are really in the background.

In the case of the rigidly dilated thorax, by the division and excision the transition from the rigidity of the upper half of the thorax to a mean expiratory position and—by formation of artificial articulations—a lasting increase of mobility will be obtained.

As already mentioned above, however, the thorax may also become rigid in a medial position without dilatation; we see this often in older people, sometimes also in younger ones for unknown reasons, sometimes perhaps in consequence of extensive adhesive pleurisy. This condition develops slowly and only shows how pernicious are its effects when intercurrent catarrh supervenes. When the troubles are severe and permanent the experiment seems justified in such cases also, of rendering the rigid thorax mobile by simple division of the costal cartilage from about the 2nd to the 6th rib on one side or on both; not as in the first case to improve the expiration, but rather to make fuller inspirations possible.

RESPIRATORY MECHANISM.

Before we go more fully into FREUND'S theory of the rigidly dilated thorax and its foundation, it is necessary to make a few introductory remarks on the mechanism of the thorax.[1]

The ribs are connected with the vertebral column by articulations, which, as GEGENBAUR says, function as a physiological unity, in which the cervical portion of the rib turns on its longitudinal axis. As this physiologically uniform articulation has an oblique position, which increases according as the transverse processes of the dorsal vertebra tend in a downward direction, so on each levatory movement of the ribs revolving in that articulation a lateral movement of the ribs is also caused. This increases according to the measure of the obliquity of the costo-vertebral articulation. The arrangement therefore permits of a change in the circumference of the thorax.

The ribs themselves, owing to their cartilaginous ends, form very elastic clasps. The true ribs 1st to 6th fasten their cartilage direct to the sternum; the costo-chondro-sternal articulation forms a slightly flexible joint.

The 1st rib cartilage is more strongly connected with the sternum—here there is a synchondrosis—it is also broader and stronger in make, and is shorter than the others (on an average 3·8 cm. long in adults, in exceptional cases 2·2 cm.). By angular flexion the course of the cartilage deviates from that of the ribs, increasing again below. When the ribs are raised the cartilages must be twisted, and that in increasing measure corresponding to the more oblique direction of the costo-vertebral articulation.

The mechanism of respiration is as follows: The inspiratory muscles lift the ring of ribs out of the oblique position. The more

[1] The rest of the chapter is given in greater detail and provided with a complete bibliography in the 4th volume of "The Results of Surgery and Orthopædia." (GARRÈ).

the level of the ribs approaches the horizontal, the more is the costal cartilage turned on its axis.

We have then here latent elastic powers in the skeletal frame of the thorax which counteract both the inspiratory muscular activity (1st costal cartilage) and active expiration (2nd to 6th ribs), the other ribs 7th to 12th, are functionally rather connected with the diaphragmatic breathing.

The costal cartilage is hyaline, of yellowish colour and generally finely granulated opacities. Changes in the cartilages due to age, which effect this elasticity more or less, are sometimes seen in the 3rd decade, but regularly in the 4th and 5th. They consist of vascularization and the formation of medullary space. Senile degenerations of the cartilage are characterized by the appearance of asbestos-like macules and amber-coloured induration.

I need not say much about the muscular powers which are brought into action in respiration, because they do not take a prominent part in the question which interests us. Leaving aside the diaphragm as well as the auxiliary respiratory muscles (scaleni, sternocleidi, serrati muscles for inspiration, latissimus dorsi, triangularis sterni, and the abdominal muscles for forcible expiration), then for normal quiet inspiration the external intercostal muscles come into consideration, they raise the ribs; for normal expiration the internal intercostal muscles.

To go in detail into the part played by the diaphragm in respiration is impossible here. We could only remind you of the close connection of this muscle with the "false" ribs and of the transmission of the abdominal pressure by contraction of the abdominal muscular system to the diaphragm. On active inspiratory contraction of the diaphragm, the thorax is enlarged in its inferior aperture, the pleural cavity lengthened, the complementary cavity broadened. On expiration the diaphragm is pressed up according to the force with which the contracted abdominal muscles press on the abdominal organs—the pars verticalis rises straight up.

The costal and diaphragmatic respiratory mechanism work synchronously, and may, as regards intensity, combine in various ways and work for one another.

Not to be undervalued, especially pathologically, is the effect of suction which a powerful inspiration exercises upon the venous blood (specially in the cava, the auricles, and the right ventricle), and on the other hand the pressure of the diaphragm on expiration, on the powerful venous plexus of the abdomen. Indirectly by promoting and by hindering the venous circulation, the arterial circulation is also affected—the pressure of the aorta, for instance, increases on each deep inspiration.

The shape of the thorax changes with increasing age. The child's thorax is barrel-shaped with almost uniform transverse diameter, with almost horizontal upper aperture (1st rib), and large epigastric angle. In the course of time the transverse diameter increases more than the depth.

PATHOLOGY OF THE RIGIDLY DILATED THORAX.

We come now to the pathology of the rigidly dilated thorax. The respiratory mechanism makes clear the importance of the elasticity of the costal cartilages for the normal working of the thorax. As long as the cartilages retain their normal elasticity, respiration works well. If the cartilages become rigid by calcification, they can no longer follow the normal movements of the ribs—the consequence is the rigid thorax.

It would, however, be unpardonable, and a complete misunderstanding of the other important factors of the respiratory mechanism, if every rigid thorax were attributed to modifications of the cartilages. The stiffening of the costo-vertebral articulations, as has often been observed by V. SALIS in arthritis deformans, moreover the round back due to spondylarthritis deformans, according to LOESCHKE due to sinking of the ribs, causes rigidity of the thorax. Such senile and presenile forms need not be combined in any way with emphysema.

On the other hand, FREUND, as previously mentioned, has drawn attention to a peculiar form of the rigid thorax, which, in his opinion, is due entirely to transformations of the cartilages, namely, to a peculiar yellow fibrous degeneration. By the loss of elasticity of the costal cartilages and simultaneous lengthening of the same, the thorax is fixed in the position for inspiration, *i.e.*, the rigidly dilated thorax.

The permanent inspiratory position of the thorax causes acute dyspnœa, alveolar emphysema, with all its anatomical and clinical characteristics. W. A. FREUND summed up the important results of his anatomical investigation in the following words: "From about the sixteenth year up to advanced age the costal cartilages may become fibrous and of a dirty yellow colour, and by distension and the formation of cavities in every direction, become deformed and more voluminous, more dense, brittle, and unelastic.

"This degeneration may be local, usually at first in the 2nd and 3rd costal cartilage (most frequently on the right side) and spreads gradually from there over the whole thorax, but may remain confined for years to certain parts of the thorax, and give rise to peculiar malformations, sometimes scoliotic in appearance. This is most frequently observed in young people. Or all the costal cartilages are attacked at the same time, which is most frequently observed in older people. The costal cartilage which has increased in volume, placed between two movable bones, naturally presses these apart, whereupon the rib, owing to the well-known arrangement of its posterior articulations, is obliged to adopt the inspiratory movement. The sternum, according as the affection appears on one side or on both, is pushed up forwards either in a straight or oblique direction. When these movements and those of the sternum have attained a certain limit defined by the mechanical arrangements, the cartilage becoming larger will produce a condition of tension in the whole of the thoracic region, and finally over a smaller radius bend more outwards. This explains why after division of such a

degenerated costal cartilage, the rib, having become free, springs back into a position akin to the expiratory one."

FREUND has proved the enlargement of the yellow fibrous cartilage by a number of careful comparative measurements. The irregular distension and deformity is easily recognized, and the X-ray picture leaves us in no doubt on this point. The differences are clearly seen in the comparative pictures in figs. 108 and 109 of normal and degenerated cartilages. But there are ample proofs of the lengthening, too, in the works of FREUND, as early as 1859. We cannot go into details; according to the total results the average length of the normal cartilages is 4·3 cm., that of the yellow fibrous one 5·5 cm.

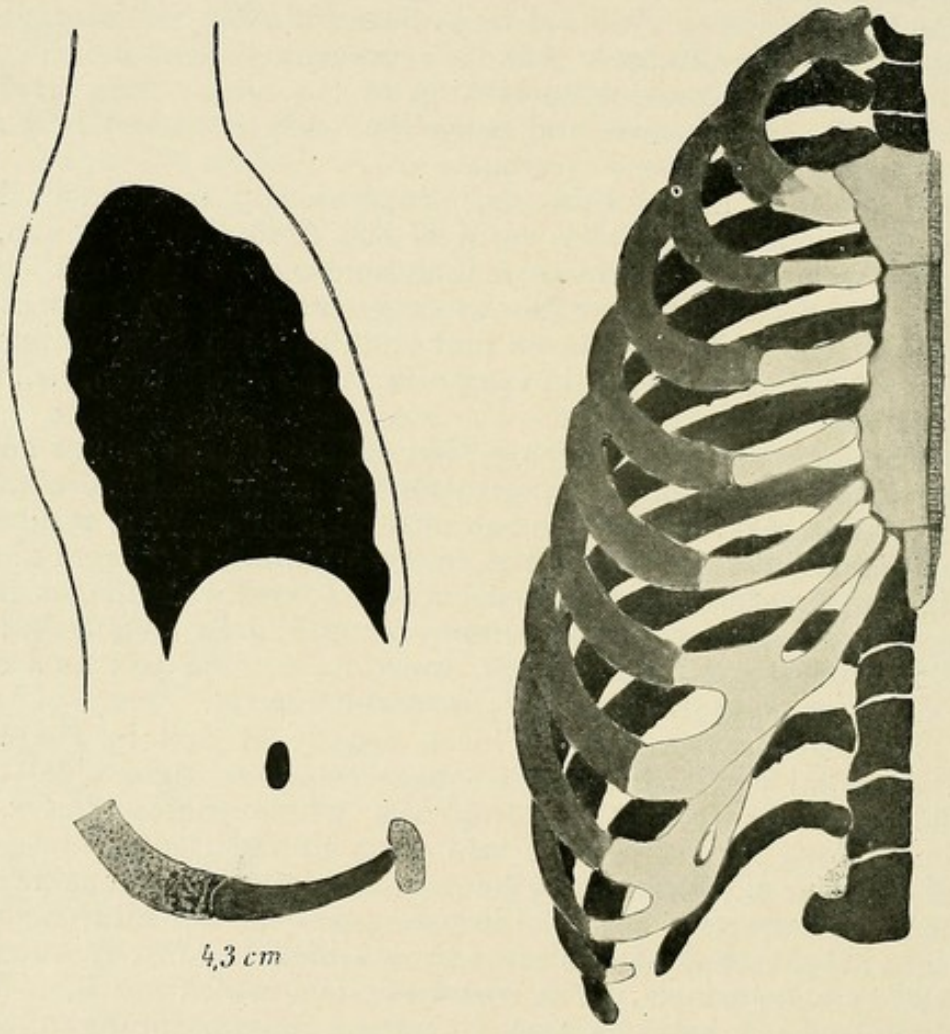


FIG. 108.—Normal thorax. Parasternal longitudinal section from a plaster cast. Transverse and longitudinal section of a normal costal cartilage of the average length of 4·3 cm. (According to W. A. FREUND.)

The lengthening of the cartilages is eminently calculated to force the ribs into the inspiratory position, and when the transformation of the cartilages is universal the breast-bone is pushed forwards and upwards. In this way the superior aperture of the thorax is enlarged—the angle of the ribs of the vertebral column increases from 30° to 40°. The inferior aperture of the thorax is also widened

in accordance with the inspiratory position, and the epigastric angle is increased from 90° to 140°. The thorax becomes barrel-shaped.

The next result is the modification of the shape and position of the diaphragm. It is flattened, for it has to bridge over a much wider space. Its costal parts are separated from the ribs, the muscular parts show fatty degeneration, and form an angle of 90° with the costal parts, the lowest position is taken up.

There has been no lack of critics who have cast doubts on the theory of the primary transformations of the thorax in cases of emphysema. Thus HOFBAUER, in a number of valuable works on the respiratory mechanism and the pathology of emphysema, occupies himself with the inflation of the lung. He falls back

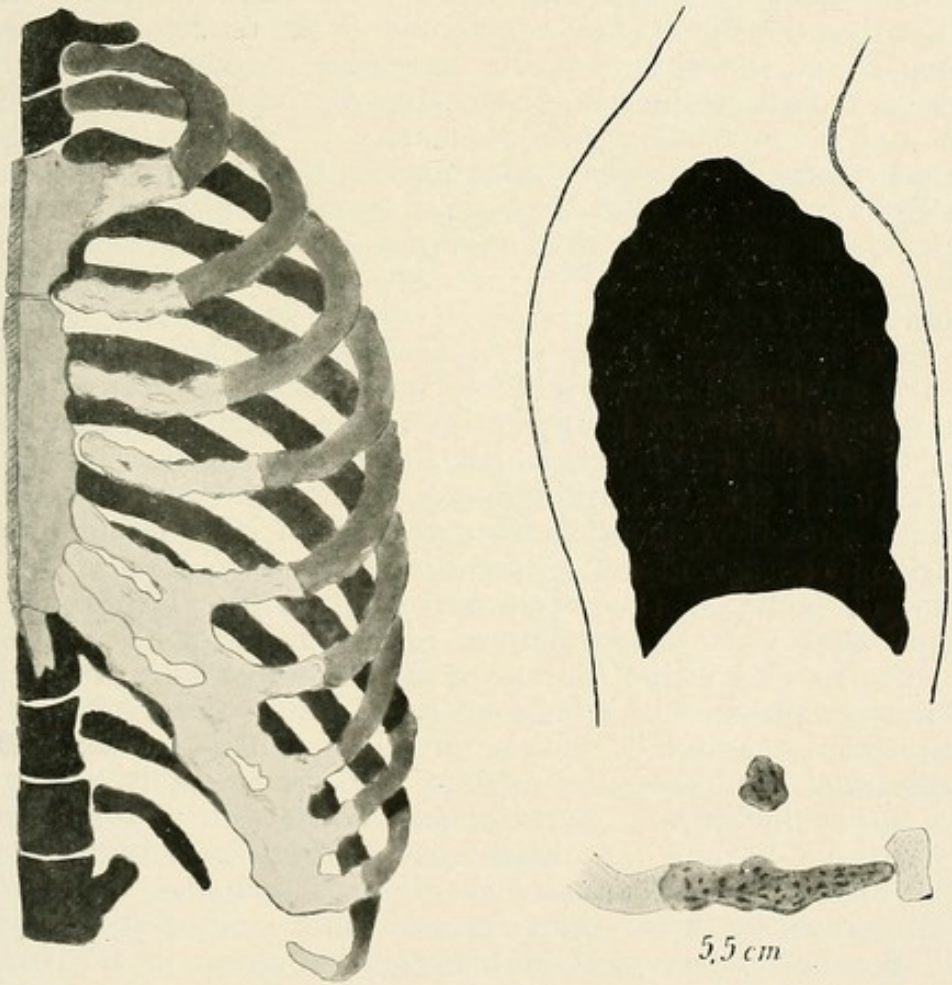


FIG. 109.—Rigidly dilated thorax. Parasternal longitudinal section with flattening of the diaphragm. Transverse and longitudinal section of a yellow fibrous cartilage, with irregular distension and perichondritic deposits (average length 5·5 cm.). (According to W. A. FREUND.)

upon LICHTHEIM'S classical works on atelectasis of the lung and the reasons of the incomplete "emptying" of the lung. He shows in a series of experiments with HOLZKNECHT how in most people "it is only in inspiration that deep breaths are taken, whereas expiration is by no means deep."

In a large number of people experimented upon, on the contrary, the expiratory rising of the diaphragm was much less on deep breathing than on quiet breathing. In other words, the lung and each of its alveoli contains more air at the end of the expiration on deep breathing than on quiet breathing.

In a whole series of people experimented upon this imperfect expiration was carried so far that the diaphragm, which on inspiration had sunk deep into the abdominal cavity, rose on expiration much less towards the centre of the thorax, consequently remained much farther from it, than is the case when quiet breathing prevails during inspiration. So in these cases at the end of the expiration, when the lung ought to be as relaxed as possible, there was more air in the lung than there was at the end of inspiration during calm breathing by the same person. HOFBAUER therefore insists that the therapeutic aim should be the reduction of the lung, distended by the pathologically increased residuum of air. This, he says, is best attained by the raising of the diaphragm, which is achieved more quickly and adequately by systematic exercise of the contraction of the abdominal muscles than by operation.

The function of the diaphragm certainly plays an important part in the pathology of the emphysema. FREUND has by no means neglected this cause; he has only looked upon it from another point of view.

In a new work from the Göttingen Pathological Institute SUMITA submits FREUND'S theory to searching criticism, based on a systematic series of investigations. He looks upon the transformations of the cartilages, which FREUND considers characteristic of the rigid thorax, as nothing but signs of disturbances of nutrition and of growth (anæmia, disturbances of the circulation and nutrition consequent on primary alveolar emphysema and as a result of faulty functional stimuli of growth). He disputes the theory that the transformations of the cartilages described can produce rigidity of the thorax; it is rather due to transformations of the condition of the lung or indirectly to the tonic muscular contractions caused by violent breathing when the conditions of respiration are changed. SUMITA here is probably referring to the theory laid down by BOHR and HOFBAUER of the dilatation of the lung beyond the measure of "mean capacity". He also looks upon the rigidly dilated thorax as a secondary symptom.

SUMITA'S representations certainly offer many points of attack; still the objective results of investigation given in the work are valuable and may incite others to clear up the question in dispute.

The unfavourable attitude of the medical men towards FREUND'S proposal to operate on the emphysematous thorax was no doubt mainly due to the variety of opinions as to the cause of emphysema. Generally speaking only secondary importance was attached to the modifications of the thorax, which SUMITA, too, has recently emphasized in his work. Therefore the resection of the costal cartilage was considered *a priori* as ineffectual.

Meanwhile, however, clinical observations have proved the better ventilation of the emphysematous lung after opening up

the rigid costal ring. The question of the etiology of the emphysema is not thereby affected, it is also not settled by surgical successes. The literature on this subject is endless, it would not be of any assistance to us to go into it in detail. We may be content to leave to future investigation the full discovery of the remote causes.

Moreover FREUND has never generalized his theory. He believed he had succeeded in proving that one out of the group of emphysemæ was due to primary inspiratory rigidity, and for this one alone he proposed surgical treatment.

WILMS supported the theory that the rigidity is due to the respiratory muscular system, with increased tonicity of the corresponding nerves. The investigations, conducted from this point of view, showed, according to D. SCHENKER, degeneration of the intercostal muscles with numerical increase of nuclei in cases of severe emphysema and rigidity of the thorax—in less severe cases muscular hypertrophy. These results do not controvert FREUND'S theories.

Recently LOESCHKE has brought forward for discussion another etiological cause for the thorax of emphysematics, that is the kyphotic flexion of the thoracic portion of the spine by deforming spondylarthritis.

According to his investigations the whole thorax is hardly ever in the inspiratory position, but some of the ribs actually in the position for maximal expiration.

He points out that a flexion in the thoracic portion of the spine would in itself alone be sufficient to lead mechanically to a rigid thorax. The upper half of the thorax bends forwards. The attachment of all the ribs to the sternum causes the ribs below the point of flexion also to be forced into the expiratory position. If the kyphosis continues increasing (perhaps solely as the result of the respiratory mechanism) the upper ribs are so raised in their vertebral articulations that they adopt the position for inspiration. Such a rigid thorax, with the upper ribs in the position for inspiration and the lower ones at the same time in the position for expiration, is known as characteristic of tubercular spondylitis. LOESCHKE believes these conditions to be also found in a similar way in the case of emphysematics with round backs.

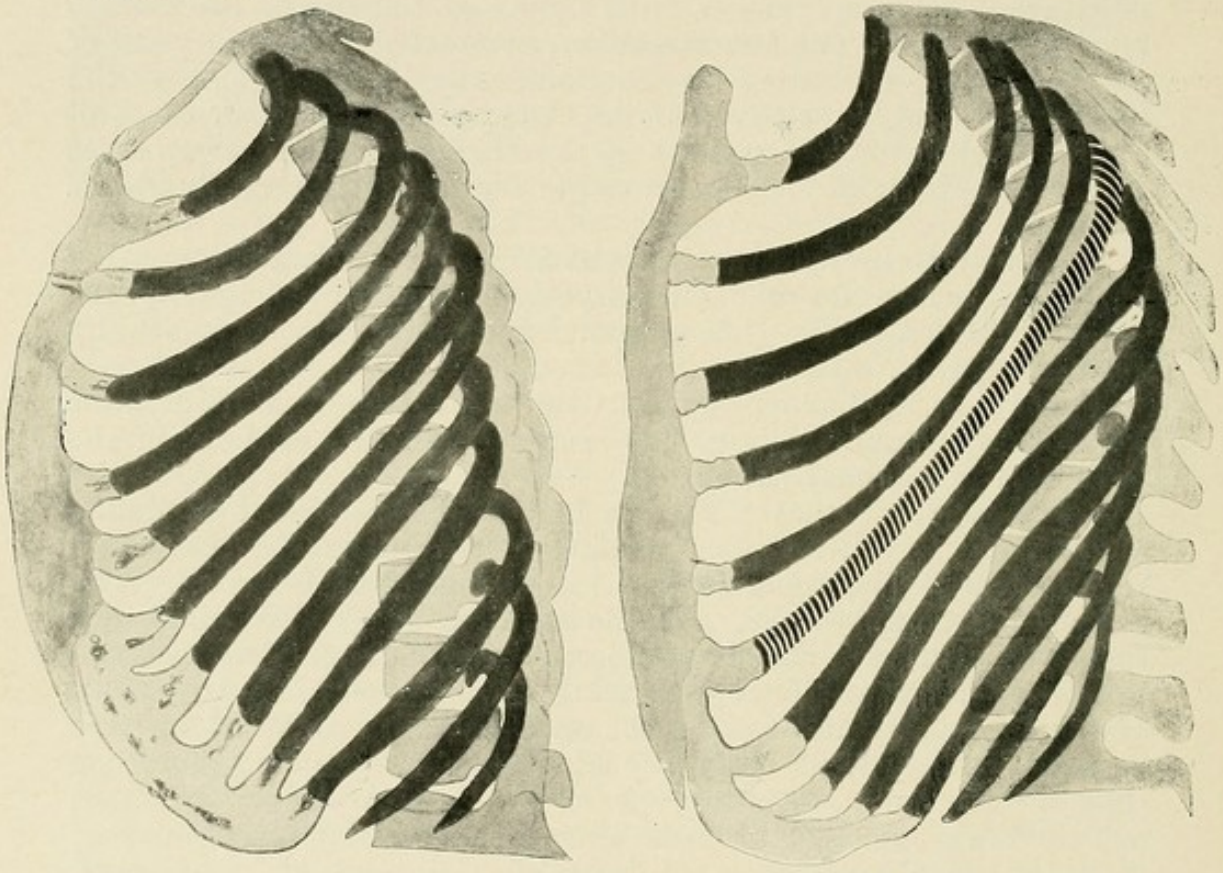
After fifty autopsies, he finds the most frequent cause of the round back to be a gradual disease of the vertebral column with atrophy of the intervertebral discs, shrinking and collapse of the vertebral bodies—the spondylarthritis deformans. It appears—this is true also of emphysema—as early as the 2nd or 3rd decade; with increasing age it becomes more frequent.

Another cause which contributes to the rigidity of the thorax is the not inconsiderable shortening of the vertebral column consequent on (the) rarefying ostitis.

The compensatory lordosis in the lumbar portion pulls up the thorax, turns it slightly outwards and so simulates—as LOESCHKE believes—the inspiratory position of the costal angle.

The position of the sternum, too, the curve of the costal arch

above its level and the formation of the infundibular thorax, LOESCHKE attributes to the same mechanical malformations, caused by spondylarthritis deformans. Whenever there was kyphosis of the vertebral column, the *post mortem* always revealed a rigid thorax and pulmonary emphysema (there are, however, vicarious and acute emphysemæ with no modification of the vertebral column and a mobile thorax). Undoubtedly LOESCHKE's investigations deserve the fullest consideration—FREUND acknowledges this too. But without being able to refute FREUND'S well-grounded theories, they show us other reasons for the appearance of the secondary emphysema.



a *b*

FIG. 110.—(*a*) Normal non-rigid thorax of a woman of 70. (*b*) Kyphotic thorax (spondylarthritis deformans). (According to LOESCHKE.)

Even in these "kyphogenous" forms of rigidity of the thorax, LOESCHKE does not consider the surgical mobilization of the vertebral column, according to FREUND, to be without hope, provided that all ribs fixed in the inspiratory position are divided in the cartilaginous part. In order not to make any mistake, he recommends the division of all ribs above the vertex of the kyphosis.

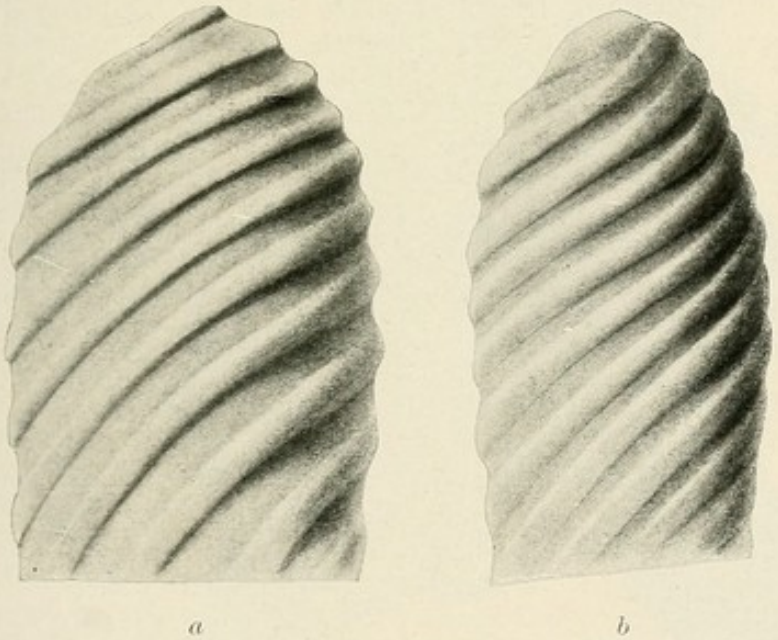
Certain other forms of emphysema are thus etiologically explained; the secondary emphysema with chondrogenously rigidly dilated thorax (FREUND) remains as a special type of disease. It is clearly delineated clinically and pathologically and anatomically corroborated.

DIAGNOSIS.

The diagnosis has been more clearly defined than before by VON DEN VELDEN, who had remarkable opportunities for observation; in the brief diagnostic notes I may be permitted to follow VON DEN VELDEN'S representations closely.

Among subjective symptoms must be mentioned slight inconvenience on violent inspiration, dyspnœa on exertion, constant irritation, exciting cough and chronic catarrh. Objectively, the first point to be noted is the barrel-shaped thorax in the position for inspiration. Ribs running almost horizontally, epigastric angle large (well above 90°, even up to 140°), hardly increased on respiration.

Stethography and spirometry can also be of great assistance in diagnosis. The respiratory curves of the rigidly dilated thorax have characteristic forms. Spirometry shows a considerable decrease in the vital capacity of the lungs. Whereas the normal figures are 3,500 to 4,000 c.c. (in a recumbent position 500 fewer), when the thorax is slightly rigid the volume is reduced to 2,400 c.c., and in the most severe forms to 1,500 c.c. and less (minimum 800 c.c.).



a *b*

FIG. 111.—(*a*) Rigidly dilated. (*b*) Normal thorax. (Drawing from plaster casts by HAUSEMANN.)

It is specially important to get a clear conception of the condition of the costal cartilage. The accentuated arching forwards and bending downwards of the degenerated cartilages, the thickening and irregularity of the same (perichondral deposits) may be determined by the touch.

Diagnosis by means of the flexible so-called Carlsbad needle may be of great assistance. Whereas the normal cartilage offers an elastic resistance to the needle, none is offered by the yellow fibrous cartilages; the needle remains fixed and comes across calcification or slips easily into the cartilages full of cavities. All the cartilages may be degenerate; the most frequently affected are the 2nd to 5th cartilages. The affection may be on one side only (right

side preferred), then the sternum is pushed to one side (asymmetry of the thorax).

An X-ray photograph of the five first cartilages gives valuable results (*cf.* fig. 112). First the irregular contour of the cartilage attracts attention (perichondral incision); then a broadening, and finally, more or less infiltrated turbid foci in the substance; costal cartilages projecting bent down in a short radius; veins of the neck and thorax congested; SAHLI'S marginal zone of capillary venous dilatation at the insertion of the diaphragm; cyanosis, lateral compression meets with no elastic resistance from the ribs, the thorax is unyielding.

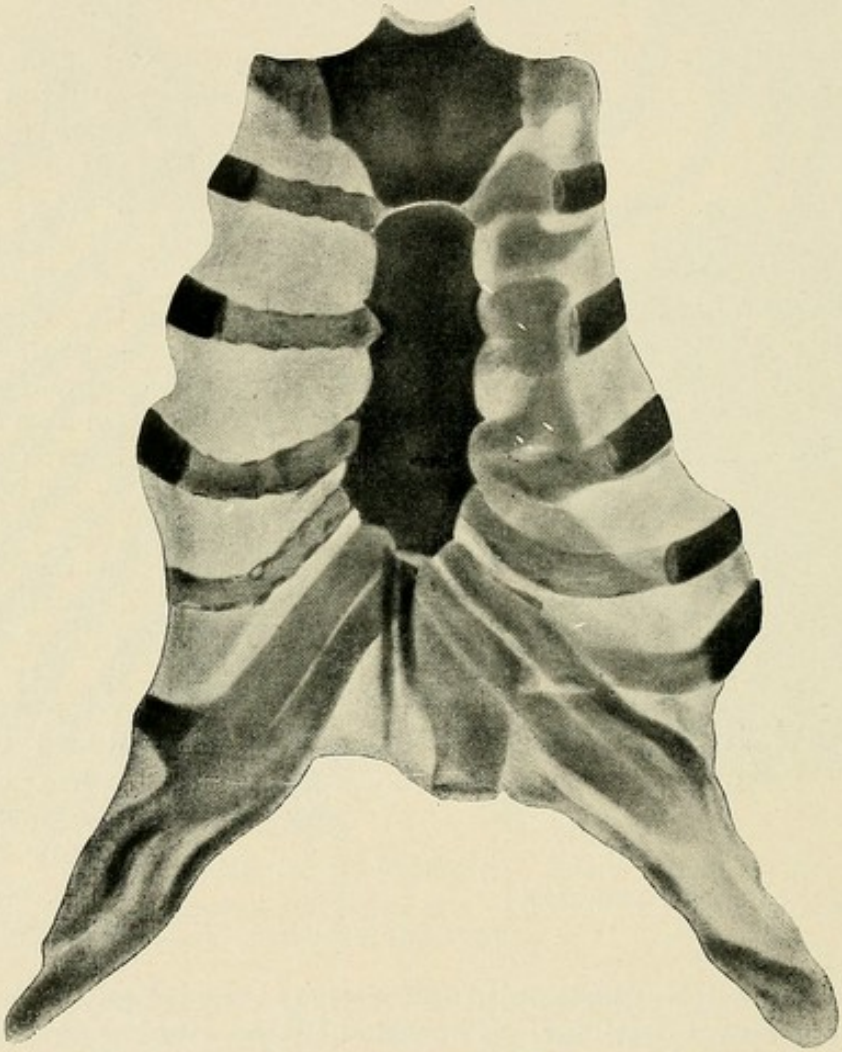


FIG. 112.—X-ray picture of a thorax 3½ weeks after the operation. Right side operated upon (pseudo-arthrosis). Left side not operated upon, with the characteristic modifications of the cartilage. (Combined picture according to VON DEN VELDEN.)

Respiration difficult, strained inspiration, with little movement without lumbar raising of the ribs, often with tension of all auxiliary muscles, raised shoulders and arms propped up; expiration prolonged, stridorous, with tension of the abdominal muscles; the epigastric angle and the lower aperture of the thorax scarcely lessened.

Cough, sometimes an irritant cough, or in paroxysms, generally with some (not characteristic) sputum. Percussion and auscultation reveal the characteristic signs of emphysema: hollow note, heart dulness diminished, the lower margins of the lung deep down (in front, 7th or 8th, at the back, 12th rib), indefinite breathing, generally drowned by bronchitic sounds.

Observation of the movement of the diaphragm on the X-ray screen shows clearly that it is flattened and its outward movements are reduced. The angle of the diaphragm may rise to 90°; the arching of the diaphragm on expiration is very much reduced. The examination of the mobility of the diaphragm is of the greatest importance.

Very instructive comparative figures showing the mobility of the ribs can be obtained by placing figures showing the difference between the circumference, depth, and transverse diameter at different levels of the thorax, side by side with the normal quotations, and compare the inclination of the upper aperture (normal, about 40°), the width of the epigastric angle on respiration (normal, 80° to 120-140°).

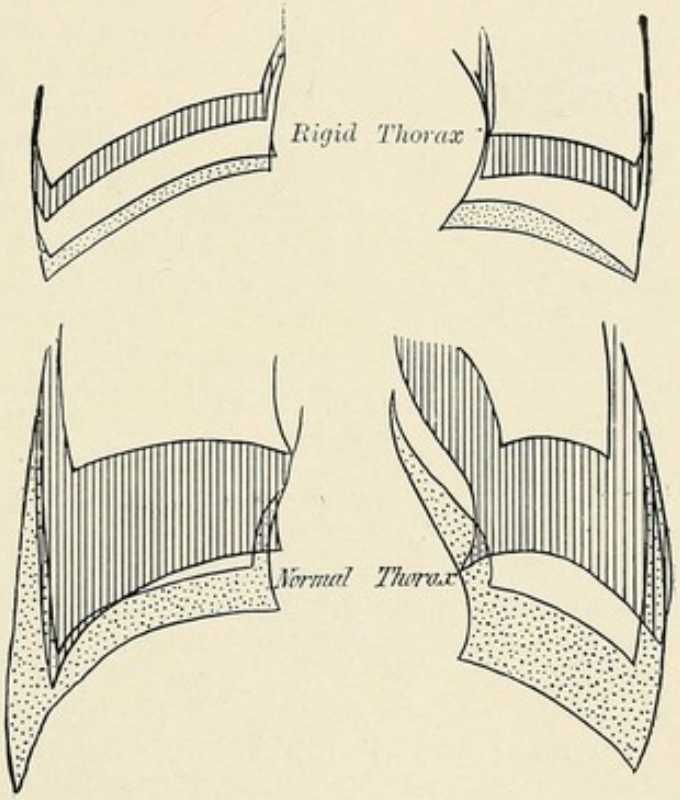


FIG. 113.—Mobility of the diaphragm with rigid and with normal thorax. Distance covered in a recumbent position ||||, in an upright position : ⁚ ⁚ ⁚. X-ray pictures by VON DEN VELDEN.

The rigidity of the whole thorax can be clearly felt by an attempt at compression with widely opened hands; the difference from the elastic spring of the normal thorax is unmistakable.

VON DEN VELDEN has given a detailed account of these conditions in his monograph. It also contains good X-ray pictures. I have combined these in fig. 112, so as to assist the reader in his criticism.

Symptoms of disease in the circulatory apparatus—I am only speaking of those caused by emphysema—are seldom lacking. The immediate effect of impeded movement of the thorax and insufficient diaphragmatic action on the circulation is soon shown in modification of the heart; the persistent chronic bronchitis and violent bodily work are calculated to produce this rapidly, or to increase it.

The right ventricle is overburdened. Its enlargement can, in the worst cases, be demonstrated by percussion, and generally by orthodiagraphy. The venous pulse in the neck, the epigastric pulsation, the cyanosis, the over-filled veins, &c., are all signs of disease with complications, which vary according to the severity and continuance of the rigidity of the thorax, with the unavoidable chronic bronchial catarrh.

In the above I have confined myself to the pronounced symptoms of the rigid thorax. It is not the place here to discuss the initial symptoms and the gradual development of the disease extending over years. The diagnosis then requires specially careful consideration of individual symptoms and a right appreciation of apparently unimportant things, such as can only be accomplished by modern methods of medicine. Anyone who wants information on the subject will find the most important directions in VON DEN VELDEN'S book. When we remember that the prospects of the success of an operation are most favourable just at that period when the emphysema is not fully developed, and degeneration of the diaphragm and dilatation of the heart are still lacking, the great importance of the early diagnosis is clear.

THE OPERATION (CHONDRECTOMY).

FREUND recommends the excision of wedge-shaped pieces from the degenerated cartilages in order to mobilize the rigidly dilated thorax.

Naturally, great care must be taken to avoid pneumothorax; the pleura is very thin and easily torn in the case of emphysematics. The operation is relatively simple. Often an operation on one side is sufficient. The cartilages of the 2nd to the 5th ribs are resected for a length of about 3 cm. It is only rarely necessary (on account of incomplete results) to mobilize the other side.

With an incision running parallel to the sternal margin and blunt dissection of the pectoral fibres the four costal cartilages are laid bare and removed with a sharp curette or LUER'S forceps. It must, however, be remembered that the posterior perichondrium must be removed, which is certainly difficult because of the proximity of the fragile pleural membrane and must be performed with the greatest care on account of the danger of pneumothorax.

When the perichondrium is retained, regeneration occurs in a relatively short time and with it a fresh production of ankylosis of the ribs. This has been several times anatomically determined.

KRÜGER makes the resection of the cartilages easier by making an incision, 2 mm. from the margin of the cartilage, in the intercostal muscles up to the pleura, and then from the opening in the muscle pushes the pleura away with the first finger and grasps the cartilage from behind up to the upper incision. The rib-scissors can then be easily adjusted from outside to avoid the mammary artery, and the cartilage with its whole investment removed.

In order to ensure the formation of a pseudoarthrosis, SEIDEL has recommended the implantation of a muscular flap from the

pectoralis, and MAX HOFFMANN covers the amputated stumps with the dissected posterior layers of the perichondrium. AXHAUSEN, on the other hand, destroys the layer of perichondrium capable of regeneration with the Paquelin cautery, which, experimentally at least, was successful. BIRCHER cauterizes the places with concentrated carbolic acid and KLAPP with fuming nitric acid.

Every operating surgeon is astonished, how, after the division of the 4th costal cartilage immediately the respiratory movement of the thorax, a rising and sinking, which was not present before, begins. At the same time the divided ends draw together. The thorax approaches an expiratory position, to which, hitherto, even with the help of auxiliary muscles, it has not attained.

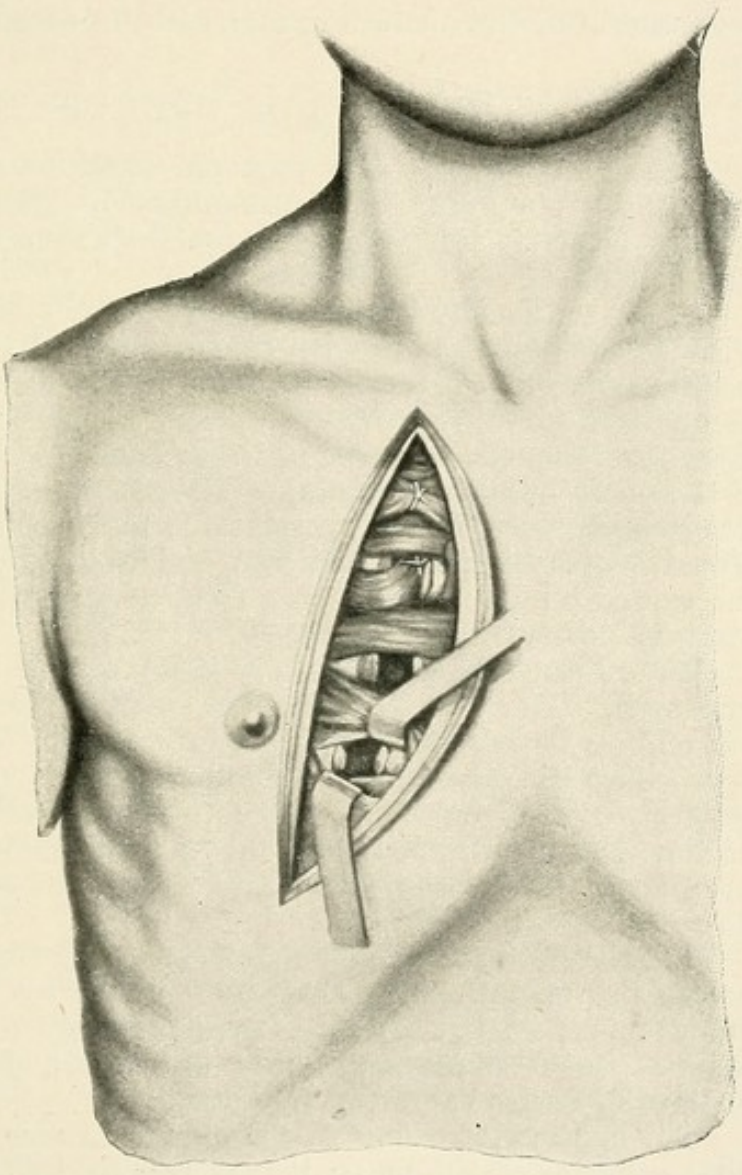


FIG. 114.—Chondrectomy with interposition of muscular flaps. (From SAUERBRUCH and SCHUMACHER'S "Surgery of the Thorax.")

Many surgeons, including SEIDEL, TUFFIER, GOTTSTEIN, STICH, have also resected the 1st costal cartilage. This is not necessary, nay, the mechanism of the thorax seems *a priori* unsuited to it, because it is just the costal ring which acts as the director of all the movement of the thorax. In practice, however, it has been proved that when the 1st cartilage is rigid it has no influence on the expiration either.

When one is desirous of enabling the overstrained, but still elastic, lung to retract, the thorax must be reduced by the removal of the larger cartilages and pieces of the ribs. MAX HOFFMANN resected 4 cm. from three ribs and considers this was not without

importance in the great success he achieved. BIRCHER removes the whole cartilage. Further experience is needed to decide this point.

By way of dressing, most surgeons are satisfied with simple sticking plaster. FRIEDRICH recommends the fixation of side of the thorax operated upon by strips of adhesive plaster and sheets of india-rubber.

Anæsthesia of those patients with the labile heart and the diseased lung is rightly dreaded. Whenever possible local anæsthesia must be tried. The danger lies in broncho-pneumonic processes after the operation, much less in complications due to the heart.

RESULTS OF OPERATIONS.

Out of fifty-seven cases operated upon, four succumbed to the operation : one man from pulmonary œdema (chloroform), one woman (Harras, six hours post. op. with unusual and inexplicable symptoms).

As the immediate result of the operation most surgeons report with astonishment how with the division of the last of the four costal cartilages the thorax at once becomes mobile and the side in question shows clearly respiratory rising and falling. At the same time the side operated upon sinks about 1 cm. below the level of the other side of the thorax. The thorax is certainly reduced in its circumference, but is considerably more mobile. Even the day after the operation most patients feel much freer, only the pain in the wound hinders them at first from making full use of their newly attained power of respiration.

But, objectively also, the ventilation of the lung is considerably improved. This can be clearly seen after the wound has healed, but only to its full extent after some weeks. The type of breathing approaches the normal, the individual breaths are deeper and fuller, they are not so frequent. The difference between the expansion of the thorax on expiration and on inspiration, which, before the opening of the thorax, was 2 and 1 cm. respectively, has risen to 5 and $3\frac{1}{2}$ cm. respectively.

The inferior pulmonary margins, which were almost immobile before the operation, have become mobile up to $2\frac{1}{4}$ cm. after the operation ; a sign, therefore, that the diaphragm contracts more easily. In severe cases certainly an increase of the muscular power of the diaphragm cannot be expected.

The spirometer shows in a striking manner the increase of the vital capacity of the lung ; it may rise to 100 per cent. and more ; indeed in one case it rose from a minimum of 400 c.c. to 2,000 c.c. (FRANGENHEIM). That was certainly a rare case of rigidity of the thorax in a young man of eighteen with well developed muscular power, and no degeneration of the diaphragm.

Expectoration is easier. Attacks of bronchitis, from which the patient suffered throughout the whole year, become much less frequent, are often much milder, and not nearly so painful. Asthmatic attacks become much rarer, or do not occur at all ;

the patients are refreshed by sleeping peacefully at night, which they could not do before. They become much more capable of work. Thus cases are reported of completely broken-down invalids, who afterwards could resume their work as stokers, porters, locksmiths, skippers. Observations, lasting in many cases over three years, have shown that the result is permanent—both subjectively and objectively. SEIDEL proved by measurements the spontaneous further increase of the expansions of the thorax in the course of two and a half years.

It cannot, of course, be expected that far-reaching transformations of the lung (atrophy of the tissue, initial bronchiectases, &c.) will improve or even retrograde.

Less perceptible, and not to be measured in absolute figures, is the influence of the improved condition of the thorax on the circulation, especially on the heart. The disappearance of the cyanosis, the decreased dilatation of the veins in the neck, the improved distribution of the blood, and, above all, the less frequent pulse, are the best proofs of the restoration of the functions of the thorax as regards aspiration and pressure.

Only a small proportion of those operated on received after-treatment. There is scarcely any doubt that by physical after-treatment, by appropriate breathing exercises under medical supervision, the results would be still better, and more certain to last. Therefore VON DEN VELDEN rightly demands this after-treatment for every patient operated upon, so that he may learn how to make use of and increase the power of costal respiration which has been restored.

This can easily be done by systematic regular breathing exercises at home (breathing through the nose without tight clothing, intemperate, pure air). Under certain circumstances the patient must be removed for some time from all influences harmful to the respiratory organs; if need be, he must change his occupation. On the medical side, besides the chronic bronchitis, the consequences of the venous congestion and disturbances of the circulation in the abdominal organs specially require therapeutic measures.

In individual cases a spontaneous improvement sets in later. Thus GOTTSTEIN discharged a patient three weeks after the operation very little better; after six months he saw her again, and was most surprised at the excellent result, which showed objectively also as regards function an increase of the vital capacity from 2,000 to 2,500, and a much greater mobility of the lower pulmonary margins.

Are the improvements lasting? If you can speak of a permanent result after a period of observation of three years, then it may be said the improvement was lasting in the case of a small number. In others, after months the thorax became rigid again. In these cases the reason was the renewed production of ankylosis of the ribs at the site of operation. The operation was therefore probably imperfectly performed. Everything depends upon performing the chondrectomy in such a way that a pseudoarthrosis is left at this place. As a matter of fact, many *post-mortem* results

have confirmed both the regrowth (KÖRTE) and the formation of good cicatrices of connective tissue, which allow, if not of the normal springy function of the thorax, still of a sufficient torsion of the ribs (VON DEN VELDEN).

The results of the operation will only be permanent when the perichondrium posterius of the cartilage is removed. If it is left, then an ossifying perichondritis develops, which proliferates round the intercalated cicatrix in the shape of a sheath, and holds the mobilized ends like a vice.

INDICATIONS FOR OPERATION.

We have already mentioned that there have been failures. It is not, however, difficult to show how in the said cases the condition of the patient, and, above all, the respiratory trouble were incorrectly diagnosed.

Among these, according to VON DEN VELDEN, are to be reckoned "failures in bronchial asthma and in conditions resulting in a dilated, but not a rigidly dilated, thorax; also cases in which, with complicated diseases, the rigid dilatation of the thorax only played a subordinate part in the whole diagnosis."

Certain important points must be considered as special contra-indications for an operation in the case of FREUND'S emphysema. Complications of the lung almost always occur in emphysematics, so that in spite of slight bronchial catarrh an operation may be performed. Only severe feverish bronchitis, or bronchorrhœa, or bronchopneumonia, as well as bronchiectases of considerable extent, are contra-indications. Bronchial asthma in itself is no contra-indication in so far as it is really concurrent with a rigidly dilated thorax. The cure of this neurosis is not, however, to be expected; considerable improvement has often been recorded.

It is of the greatest importance to form an opinion as to the circulatory system. In case of pronounced cardiac insufficiency the operation should be abandoned, when preparations of digitalis are unable to avert or lessen the compensatory disturbances. In cases of aneurism or severe arteriosclerosis the operation is better abandoned.

Age is no reason for abstaining from the mobilization considered necessary. The oldest patient operated on was seventy-two, the youngest eighteen.

The surgical mobilization of the thorax should—here all writers are in agreement—according to the advice of FREUND, not be delayed till cardiac complications arise, and, as we should like to add, should take place before the diaphragm's power of contraction has been seriously injured. LAMBERT points out as a further reason for an early operation the danger of ankylosis in the costo-vertebral joints, which with rigid cartilages would result in an "ankylose pantothoracique." An attempt has been made to make the indications more precise by means of the spirometric figures. But these are only relative. Age, too, gives no basis to go upon. The most important indication is the condition of the costal

cartilage; if it has really become inelastic through asbestos-like degeneration, so that it keeps the ribs in the horizontal (inspiratory) position, then the only way to avoid ankylosis of the ribs, and thus to improve the mechanism of the respiration, is to remove a portion of these cartilages.

Of the greatest importance is the right selection of the cases, that is to say, chondrectomy should be confined to those forms of emphysema in which the thorax is kept in the inspiratory position. It is a matter of indifference—this has been proved by experience—whether the calcification of the cartilages (yellow atrophy) is to be considered as primary and the emphysema as secondary or *vice versa*—a scientific question not yet settled.

It must not be forgotten that the operation is to remove the rigidity of the thorax. Whether and to what extent the peculiar transformations in the pulmonary parenchyma due to the emphysema are indirectly affected is beyond our discernment.

In spite of the precise and clearly formulated indications given by FREUND in his first publication, they were exceeded. This led to the first failures.

It seems to us, as a result of practical experience up to the present, that, in course of time, these indications may possibly be added to. First, QUINCKE wishes to extend chondrectomy to the thorax, which has become rigid in the medial position, with a view to improving the inspiration (see p. 241), and then LOESCHKE believes that improvement might be expected from chondrectomy in the cases of emphysema described by him which are due to a round back. This seems very likely in consideration of the mechanical conditions.

In one peculiar case pains in the ribs, especially in the cartilages, were the sole reason for BAYER performing chondrectomy. It was the case of a young girl with a symmetrical forward flexion of the uppermost costal cartilage, with unbearable pains on moving the arm, which increased during work. Emphysema was not present. The X-ray picture showed nothing abnormal. After resection of the 2nd to the 4th costal cartilages, the pains disappeared. The cartilages were softened centrally to liquefaction, cellular proliferation in the vicinity.

The fact that several cases have been known, in which easier respiration and better health continued, in spite of a renewed production of ankylosis of the cartilage, made FRIEDRICH wonder whether the reduction of the volume of the lung alone was not perhaps in itself responsible for part of the success. GOTTSTEIN also urges an extension of the indications to include all kinds of emphysema; especially cases which may be hereditary, in which the emphysema begins to develop in youth, appear to him suitable for an operation.

MOHR clearly formulates the contra-indications for chondrectomy, by saying; "No operation should be performed in cases of dilated and rigid thorax due to an abnormal tension of the inspiratory muscles (tonic rigidity), for example, in case of dyspnœa following bronchitis, in case of an attack of asthma, and in case of nervous and

cardiac asthma, by which the thorax is kept permanently in the inspiratory position. Moreover, no operation should be performed in cases of rigid thorax accompanied by a contraction of the thorax in the case of paralytic thorax and rigidity due to age. Both show symptoms of modifications of the cartilage."

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