

EMPHYEMA THORACIS

by

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IX. Tuberculous empyema

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X. Chronic empyema

I. Definition

Empyema of the chest is a pleurisy with purulent effusion. This implies a collection of purulent fluid in the pleural cavity or interlobar spaces.

II. Etiology

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According to Boyd, infection may reach the pleural cavity in three ways:

1. By spread from neighboring organs
2. By introduction from without
3. By the blood stream

1. By Spread from Neighboring Organs. Most of the empyemas are due to spread of the infection from a pneumonic lung. The pneumonia may be a lobar pneumonia, in which case the infection of the pleura follows the pneumonia, and is due to the pneumococcus. This type is frequently referred to as the "metapneumonic" type. The "synpneumonic" type of empyema is that type of empyema which accompanies the streptococcal pneumonias which are so frequently associated with influenza, and less commonly with measles and other exanthemata. In the streptococcal empyemas it was repeatedly found that the primary lesion was a subpleural abscess. The same is true of some cases of pneumococcal empyemas, but whether this holds for the majority of cases it is difficult to say.

Although the lung is the major neighboring organ from which infection may spread, there may be other primary sources of infection. An abscess in the mediastinum, an infective process in the chest wall, a subphrenic abscess, a liver abscess, suppuration in the gall bladder, and

even inflammation in more distant organs may be followed by empyema.

A small percentage of empyemas are tuberculous and associated with a tuberculous lung underneath. Abscess of the lung is also a primary disease which gives rise to empyemas, in addition to the usual lobar or bronchial pneumonias. Empyema occurs in about six per cent of the cases of pneumonia, and the pneumococcus causes from fifty to sixty per cent of all cases of empyema.

2. By Introduction From Without. A perforating wound of the chest is likely to be followed by an empyema. This cause is rare in civil practice.

3. By the Blood Stream. In exceptional instances empyema may apparently begin as a primary condition. These cases are due to spread by the blood stream from a focus elsewhere. This may occur following tonsillitis, appendicitis, acute otitis media, or puerperal sepsis. It may develop in the course of one of the infectious diseases, but probably in these cases pneumonia is an intermediate factor. An empyema may develop in the course of a bacteremia, but in this case it acts as a fixation abscess, and the prognosis becomes distinctly more favorable.

III. BACTERIOLOGY

The usual organism is a pneumococcus (Type I, II, or IV), streptococcus, or a staphylococcus. Occasionally there is a mixed infection. The bacteriological findings vary in different seasons and in different years. Often, during the fall and winter months, the pneumococcus may be the chief organism found, and will run a straight series of Type I variety. A year later during the same season the prevailing type may be Type IV. In the spring seasons the prevailing organisms most often are either a streptococcus or a hemolytic staphylococcus aureus.⁴

The influenza, typhoid or colon bacillus may be the infecting agents in exceptional cases. The tubercle bacillus, usually with mixed infection, is occasionally met. Actinomycosis of the lung may be accompanied by an empyema, and anaerobic streptococci are encountered on rare occasions.^{5,6}

The types of empyema complicating pneumonia, given in the order of frequency are:

Massive or general
Interlobar
Sacculated
Bilateral, and
Necessitatis.

IV. MORBID ANATOMY

An empyema is usually preceded by a slight exudation of serous fluid, which later becomes purulent. Abundant inflammatory exudate is deposited on the parietal pleura and lung, and pus accumulates between the two. Allen has recently offered the suggestion that blood in the pleural cavity causes the onset of the empyema, the blood arising from the granulation tissue. This purulent exudate may be large enough to cause a tremendous loss of nitrogen in the body. The usual site of a subpleural abscess is the convex surface of the lung, in which case a diffuse empyema results. The abscess may be located in a fissure, in which case an interlobar empyema will result, or it may occur on the medial aspect of the lung, where one or more pockets of pus will form retrosternally between the lung and mediastinal pleura. The pus pocket may accumulate between the diaphragm and the lung and extend either out into the costophrenic angle or upwards as a partly median collection.

The inflammatory exudate consists of fibrin, serum and polymorphonuclear leukocytes. In the course of time fibroblasts invade and lay down connective tissue, so that the affected portion of the lung may be covered by a thick layer of dense fibrous tissue, which may attain a thickness of one inch. A similar deposit is also laid down on the parietal pleura. This thick inflammatory exudate plays an important part in preventing the proper expansion of the lung following the removal of pus; to insure lung expansion, Dakin's solution is used because of its decorticating action, which results in the bringing away of the deposit in fragments.

The pus varies somewhat with the infecting organisms. In pneumococcal cases it is thick, creamy and yellowish or greenish in color, while in streptococcal cases it is usually thinner and more watery and contains flakes of fibrin. Tuberculous pus is also thin and contains masses of caseous material. If the pus has a fecal smell, infection with the colon bacillus may be suspected. Anaerobic organisms give rise to a putrid empyema.

The effect on the lung of the purulent exudate is of great importance. The lung is lifted up on the fluid, and becomes more and more collapsed, until it may form a small compressed mass at the hilum. Moreover a purulent fluid exerts a much more deleterious effect on the lung substance than does a serous collection. There may be necrosis and destruction of the lung tissue at the site of pressure, together with an interstitial inflammation which results in fibrosis and contraction, and this also interferes with lung expansion.

Unless the purulent material is removed soon after it has accumulated the lower portion of the lung in contact with the fluid becomes firmly adherent to the chest wall and mediastinum. The lung becomes firmly anchored by the rapid organization of the adhesions which prevent the lung from re-expanding even when the fluid is removed. The longer the purulent material is allowed to remain the more certain it becomes that the lung will not be able to reexpand. If the empyema has existed for several months the parietal pleura forming the sac becomes greatly thickened and in places may become eroded. In moderate sized effusions after the lung has become adherent the fluid is then completely walled

off and really constitutes an abscess. The effusion may remain indefinitely, the patient eventually succumbing as the result of septic absorption, amyloid disease, brain abscess (from the lung abscess), or the empyema may rupture externally or into a neighboring cavity, such as the esophagus, a bronchus, or the peritoneal cavity. In many cases the purulent material is gradually absorbed. Following absorption of the pus calcium salts in the form of plates are frequently deposited at the base of the cavity.

Prolonged compression of the lung by a purulent effusion is one of the commonest causes of unilateral fibrosis of the lung. Empyema also has a crippling effect on the diaphragm. The diaphragm becomes swollen, thickened and stiff. As the result of inflammatory changes it loses its elasticity and becomes rigid; later it becomes atrophied, the tissues undergoing fibroid changes and becoming hardened. If the effusion is large the weight of the fluid may flatten the diaphragm or cause it to become concave in shape and at times produce a tumor below the costal margin.

V. PHYSIOLOGY OF OPEN PNEUMOTHORAX

Experimentally, Graham has shown that the mediastinum of man offers only a slight resistance when the pressure in one pleural cavity is made equal to that of a column of water ten centimeters high. Hence, in the normal individual when an open pneumothorax is created on one side, both lungs are compressed, since there is practically an equilibrium of pressure throughout the thorax, and respiration is maintained by both lungs. Of course, factors which tend to immobilize the mediastinum, as adhesions and post-inflammatory thickening, change these relationships by making a more rigid partition.

In order to show the effect that an open pneumothorax would have on an empyema arising in pneumonias of pneumococcal or streptococcal origin, it would seem advisable to discuss the pathology of the two types of pneumonias. This will bring out the reason for the careful avoidance of an open pneumothorax in the acute stage.

There is considerable difference in the pathology and clinical course in the two types. Pneumococcus empyema is almost always a complication of lobar pneumonia and it is usually not recognized until after the acute stage of pneumonia has passed, and at a time when much of the exudate in the lung has disappeared, so that the vital capacity is greater than it was during the acute stage. However, in the hemolytic streptococcus infections, a massive pleural effusion occurs early in the disease. The pathology of the hemolytic streptococcus infection can be described as follows: There is extreme dyspnoea during inspiration, resulting in cyanosis. Many of the patients lose their voices completely. There are

two main types of lesions that have been described, although these are frequently combined. The first type, called interstitial broncho pneumonia, is characterized by a great change in the walls of the bronchioles and in the adjacent pulmonary tissue. This results in a collapse of the lung to which the obstructed bronchi lead, together with the formation of firm nodules of consolidation about the terminal portions of the bronchi. There is also extreme vascular engorgement and hemorrhage about the nodules of consolidation. The bronchial walls become infiltrated with monocytes and thickened. The formation of new blood vessels and the connective tissue proliferation add to the thickening and deformity of the wall. In addition, the adjacent alveoli become infiltrated with mononuclear cells, the capillaries are distended, and epithelium is proliferated and desquamated into the alveolar cavity. This results in a plugging of the alveoli adjacent to the bronchi with blood, epithelial cells, and mononuclear cells. The pleural exudate begins as a thin greenish-brown fluid containing streptococci, disintegrated leukocytes, and fibrin shreds, but it soon becomes more purulent. The inflammatory exudate is rapidly organized, and as a result of connective tissue growth, the alveolar walls, the bronchial walls and interlobular septa become thickened. The rapid organization of the thick layer of fibrin covering the pleura results in the formation of thick red granulation tissue on the pleural surface, and adhesions between surfaces in contact with each other become permanent in a very short time. Large portions of the inflamed lung may become necrotic. The second type of lesion described in these streptococcal infections, called lobular pneumonia, although giving the same clinical symptoms is different on section. No firm peribronchial nodules are

present. Instead there are patches of consolidation in which the alveoli are filled with blood and leukocytes and large numbers of organisms. Widespread necrosis occurs with final destruction of areas of lung substance. Hemorrhage occurs about these areas and there is pleural effusion, but with no organization of the exudate. This lobular pneumonia may occur independently of the interstitial broncho pneumonia or together with it. They are different expressions of reaction to the same infection.⁷

The important points brought out in the pathology, which should be remembered in treatment are the extent of involvement of lung tissue in the streptococcus cases, the involvement of the bronchioles with sufficient exclusion of air to produce cyanosis and dyspnoea, and the tendency to rapid organization of the pleural exudate. In contradistinction, there is less disturbance in the air intake with less cyanosis and dyspnoea in pneumococcus cases, and there is also much less rapid organization of the pleural exudate.

An open pneumothorax in an acute case of streptococcus empyema is clearly contraindicated, since it would result in an additional element of difficulty of respiration in a patient already so dyspnoeic that he is cyanotic and suffering from air hunger.

Graham estimates that a thoracic opening of 5x10 cms. is the largest for which compensation can be theoretically established in the average human adult even for short periods if the mediastinum has normal mobility. This is based on the average vital capacity of 3700 c.c. and hence would obviously be greater in an individual having a larger vital

capacity. It should also be remembered that what appear to be very large openings in the chest wall are actually much smaller because of the presence in the incision of a lung which has been delivered out, gauze sponges, and fingers of the operator, all of which tend by their plugging to reduce the size of the opening and consequently the amount of air which is sucked in during an inspiration.

The size of the opening compatible with life would be diminished in individuals with a small vital capacity, or where there is a greater demand for oxygen. This occurs where there is obstruction to the passage of air to the lungs (tracheal or bronchial stenosis), where the available breathing space of the lungs is reduced (pneumonia and pleural effusions) where there is interference with the normal aeration of the blood and tissues (heart disease with acidosis), where there is interference with the normal action of the respiratory muscles (fatigue and prolonged surgical anesthesia), and where the level of metabolism is raised.

In a closed pneumothorax it is only necessary to increase the respiratory effort sufficiently to create enough negative pressure to take in the desired amount of air for proper aeration of the blood, which is the tidal air, or 500 c.c. at rest. In an open pneumothorax, air enters both through the thoracic opening and the glottis, and if the opening is considerably larger than the glottis enough air may enter into the pleural cavity to prevent the acquisition of the tidal air, and death from asphyxia will occur. When an open pneumothorax is converted into a closed pneumothorax, particularly if this be done at the end of expiration, the amount of air enclosed in the pleural cavity is very much less than the

amount required to prevent the inspiration of the necessary amount of tidal air, and there is, therefore, very little dyspnoea. This is brought out clinically, since an adult can have as much as 2000 c.c. of fluid in his chest without producing severe dyspnoea, as long as he remains at rest.

An open pneumothorax also results in heat loss, danger of infection and disturbances of circulation. Graham quotes Sauerbruch as having shown in the dog, unanesthetized, a fall in body temperature of two degrees after one-half hour following a pleural opening, and rise again 1.6 degrees within an hour after closing the opening. Obviously, repeated aspiration of large quantities of air with each inspiration over long periods will carry innumerable bacteria into the pleural cavity. The disturbances of circulation are probably due to the changed pressure relationships which interfere with the normal return of the venous blood to the heart.

Graham showed the danger of early open drainage by experiments on dogs. In a series of dogs that had been subjected to early open drainage, the dogs had a higher mortality and were more sick than their controls that had empyema but were left alone. Presumably, the harm is produced by the open pneumothorax, the effects of which have been discussed.

If, however, the acute stage of the disease has passed and frank pus is present in the pleural cavity, there is little danger from an open operation for the purpose of securing free drainage, for the following reasons, as stated by Graham.

1. "There is less danger of creating an open pneumothorax

because there is likely to be a circumscribed abscess shut off by adhesions from any communication with the free pleural cavity so that during the operation the pleural cavity, properly speaking, is not entered.

2. Even if an open pneumothorax is created the patient is in much better condition to withstand its harmful effects, because (a) the subsidence of the active pneumonia has the effect of making the area of the air-inlet to the lungs much larger than when many of the bronchioles and much of the lung parenchyma are blocked by the pneumonic process, so that the pleural opening is incapable of producing the same amount of harm, (b) the presence of adhesions and the inflammatory thickening and induration of the mediastinum tend to make it less mobile, (c) the patient's need of oxygen is less because of a more nearly normal metabolism, (d) the respiratory compensation is more efficient since, owing to a diminished toxemia, the respiratory muscles will not become so easily fatigued.
3. The patient is in better condition to withstand whatever shock there is connected with even so slight an operation as pleural drainage.
4. There is probably less risk of creating a septicemia from absorption of organisms from the fresh operation wound."

If in some particular case it is decided to institute early open drainage, in spite of the dangers of an open pneumothorax, it is obvious that only a small opening should be made during the active stage of pneumonia. This is especially true in a streptococcic pneumonia, since there is obstruction to the air passages and the vital capacity is greatly reduced by the plugging of the bronchioles, the exudate limiting the expansion of the lung, and the exhausted condition of the respiratory muscles. There is also an increased demand for air due to the increased general metabolism. Because of all these factors, the ability of the patient to compensate for a thoracic opening, even if very small, may be so poor that he will succumb to an opening of any appreciable size.

By applying this principle of avoiding an open pneumothorax in the acute stage of the disease, the Empyema Commission was able to reduce the mortality to 4.3% from 48% at Camp Lee, Virginia, during the war.

VI. DIAGNOSIS OF EMPYEMA

A. History (Symptomatology). The onset of a purulent effusion may be abrupt as in the case of a serous fluid. When empyema occurs as a complication of one of the acute infections, notably pneumonia, the exudation of the purulent fluid may be very rapid, and a considerable amount may accumulate as early as the fourth or fifth day of the disease. Rarely, it has an insidious onset and is not suspected, either because it develops during the course of other diseases or supervenes upon a pre-existing serous effusion.

However, in every case of pneumonia, empyema should be suspected if symptoms develop after the crisis or after the time the crisis is expected. Delayed resolution is rare, and should not be considered until empyema is ruled out. Certain complications in children simulate empyema because of septic symptoms. Otitis media, pericarditis and endocarditis are the chief ones. In the severe streptococcus pneumonia a massive pleural effusion may develop within the first few hours after the initial symptoms of cough and pleural pain, and the physical signs resemble an extensive lobar pneumonia. The diagnosis must be made on the history, the probabilities, the septic symptoms, the physical signs, aspiration by a needle and the roentgen ray.

The septic symptoms are very important as an aid in the diagnosis of empyema. Following the subsidence of the pneumonia recovery is not complete, but malaise and asthenia persist and it is noted that slight fever occurs, particularly at night. The patient gradually becomes more septic with higher fever and marked leukocytosis. A pulse rate

which does not drop following crisis should make one suspicious of empyema. Sweating at night is common. In children, clubbing of fingers occurs early and there is rapid weight loss. In the aged fever may be slight or absent. In the streptococcus group the symptoms are more intense and even delirium comes on rapidly. Convulsions may occur in children. There is anemia, pallor, exhaustion and rapid emaciation. Pain in the affected side of the chest, dyspnoea and cough and expectoration are some of the symptoms which are not always marked.

Every case of empyema must be individualized and carefully and patiently studied. Each will show some variation, such as character and virulence of the infection, condition of the patient, or associated complications, such as bronchial fistula, pneumothorax or pulmonary abscess. Age is an important factor.

Cases are reported of two or more encysted purulent effusions within one pleural sac. ⁸ In one case, the purulent effusion occurred in the right chest, one in the right posterior sub-apical region, the other between the right side of the pericardium and the pericardial aspect of the right lung. In another case, there were three loculi in the right chest, namely at the apex, in the axillary region, and at the base, together with an empyema necessitatis pointing between the vertebral column and the vertebral border of the right scapula. The three separate cavities and the subcutaneous collections were all drained through separate incisions. Both of the above patients recovered.

To further complicate the diagnosis, cases of bilateral empyema

occur, both sides becoming involved at or about the same time.⁹ Most authors agree that empyema is bilateral in less than five per cent of the non-fatal sporadic cases. In 603 cases of autopsies of empyema cases, Dunham found that 43%, an unusually high figure, were bilateral. Hellen states that 7.7% of all empyema cases are bilateral. Tod that 2.0% and Tholt 3.0%. The majority of these cases occur, according to Curtis and Bowman, during the early decades of life, and males are affected in 65 per cent. Graves reports that it is frequent in children under ten and in adults beyond middle life. In Keyes' series of 44 cases, the death rate was 19.5%. He pointed out that it is most frequently met with in association with broncho-pneumonia, for example, during the influenzal epidemics of 1917-1919.
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B. Physical Examination.

1. Inspection. An individual having empyema is apt to reveal the evidences of a chronic suppurative process, such as fever, sweating, loss of vigor, some emaciation and anemia. Acute cases will not show these signs. Clubbing of the fingers is marked in chronic empyema, and some of the most extreme grades of this condition are encountered. The clubbing of the fingers may develop very rapidly and instances have been recorded in which the condition was apparent within two or three weeks. It has been noted also that the clubbing disappears with the removal of the pus from the pleural cavity.

On inspection the affected side bulges and the intercostal spaces are widened. The side moves less freely with respiration. Tenderness on pressure is commonly present. Displacement of the apex beat is apt

to be marked. If the empyema has existed for some time, the small subcutaneous veins on the affected side may be very noticeable. Edema of the chest wall is frequently met with. In some cases pulsation of the chest wall is noted over the area overlying the empyema. For the most part, pulsating empyemas are left-sided. Although pulsation is synchronous with the cardiac systole no satisfactory explanation is given to show how the cardiac impulse is transmitted through the effusion. There is an absence of Litten's diaphragm phenomenon, which is not of great significance.

Less frequently a localized tumor is seen on the chest wall caused by the burrowing of the pus through the thoracic parietes. This is the so-called "empyema necessitatis". A fistula may be formed by the complete perforation of the chest wall. An empyema necessitatis is often pulsating in character. When an empyema necessitatis develops it almost invariably appears on the anterior or lateral chest wall, somewhere between the third and sixth interspaces.

In children, the heart is more markedly displaced to the opposite side, especially in right-sided effusions. When the effusion is small the ribs are approximated owing to the lack of expansion of the affected side, but when the effusion is massive the ribs of the affected side are separated.

2. Palpation. There is increased resistance, edema of the intercostal spaces, which one may not suspect until he applies pressure with his finger-tips, and local tenderness on deep pressure in chronic cases.

Tactile fremitus is reduced or absent, and the liver and spleen are depressed.

3. Percussion. There is flatness from fluid and compressed lung, beginning at the base posteriorly. This may extend to the clavicle and to or beyond the midline, merging on the right side with the liver dullness, and on the left side with Traube's semilunar area, which is only obliterated by large effusions. Movable dullness is rather rare, and suggests pneumothorax.

In some cases one can demonstrate "Ellis' S shaped line". In moderate effusions with the patient sitting erect, the upper limit of dullness rises from the spine to the axilla and then falls to the sternum. When reclining the line slopes continually from the spine downward, and is due to the position of the root of the lung. It may also be possible to demonstrate "Grocco's paravertebral angle of dullness." A triangle of relative dullness with the apex upward along the spine on the opposite side of the effusion, the space being two to eight centimeters in width. It is distributed to bulging of the mediastinum or collapse of the lung, and is absent in pneumonia.

The liver dullness extends much farther below the margin of the ribs than in cases of serous effusions. This is due to the greater weight of the fluid which not only flattens the convexity of the upper surface of the diaphragm but may even cause it to become concave.

Skodaic resonance may be elicited above the level of the fluid, this is important in differentiating from pneumonia.

4. Auscultation. The same variations in the character of the breath sounds occur in empyema as in serous effusions. The breath sounds may be faintly heard or entirely absent. Above the fluid the vocal resonance is increased if the lung is condensed. Occasionally, and especially in children with large effusions, the breathing may be loud and bronchial in character.

The transmission of the whispered voice through a serous effusion and the absence of such transmission in case pus is present (Bacelli's sign) is of no great value.

Sacculated effusions give irregular physical signs which vary with the position of the fluid. In cases of pyopneumothorax, tympanitic resonance will be found above the fluid level. Succussion splash is an important finding and amphoric respiration and the coin test should be elicited.

In children the diagnosis is more difficult because of the greater resiliency of the chest wall, the greater mobility of the heart, and the greater ease with which the vocal and respiratory sounds are transmitted. As in adults the history suggests an empyema. The characteristic sounds are bronchial breathing and exaggerated vocal resonance over the apex or upper part of the chest and absence or diminution of the vocal and respiratory sounds over the lower part with dulness to percussion. Care must be taken to compare the two sides, because in the child, loud sounds may be heard at the base of the affected side, but they are always louder and clearer on the unaffected side. Light percussion will elicit the dulness in the child when heavy percussion gives a resonant note.

In large purulent effusions the physical signs are adequate, but in encysted or interlobar types where the diagnosis is in doubt, repeated x-rays should be made, supplemented by exploratory thoracentesis, for without these aids a positive diagnosis may be impossible.

C. Laboratory Examination.

1. Exploratory puncture. In a patient with the physical signs of a pleural effusion and in whom there are septic symptoms, it is highly probable that an empyema is present. The use of an exploratory needle and bacteriological examination is the only way to distinguish absolutely between pleurisy with effusion and empyema, and to determine the character of the causative organism. This exploratory puncture should be done carefully and aseptically. The sixth or seventh interspace is the posterior axillary line is used. A wheal is raised with one per cent novocaine solution, and five cubic centimeters of the solution is slowly injected with the syringe into the muscles and beneath the rib. After waiting a minute or two a large needle with a ten cubic centimeter Luer syringe can be introduced painlessly and a few cubic centimeters of pus withdrawn. The pus is put into a sterile tube for culture, and the puncture wound is sealed with collodion.

A negative aspiration does not rule out the presence of pus. Repeated aspirations may be required at different points. A roentgen examination is of great value when skillfully interpreted.

2. Roentgen ray examination. The x-ray affords a means of diagnosis, and reveals the extent of the collection, the displacement of the

heart and trachea and the condition of the opposite lung. Lateral as well as anterior-posterior films are taken and both erect and horizontal positions assumed. Fixation of the diaphragm, obliteration of the costophrenic angle, obliteration of the cardiophrenic angle, disappearance of the diaphragm and disappearance of the usual lung shadow occur. Unless there is air in the pleural cavity the upper margin of the fluid level is not horizontal. It reaches its highest point at the posterior axillary line and then curves downwards to reach the liver or cardiac shadows. (Ellis' S shaped line on percussion). The x-ray is particularly useful in the diagnosis of small loculated collections or an interlobar empyema. The most important appearance of the more uncommon types are:

Diaphragmatic collections. An elevated and fixed diaphragm, with a lung lesion above, or a history of one. (Differentiate from subdiaphragmatic abscess). The diaphragm and the collection have the same shadow density. If the collection is complete, its shadow extends completely across as a band from mediastinum to chest wall. If it is incomplete, a portion of fixed diaphragm will be observed in addition, and the diagnosis is not so difficult. This type is rather uncommon.

Central or mediastinal collections. The shadow is always a continuation outward of the normal mediastinal shadow (Heart and vessels). The apex is above, and the base below at the diaphragm. If on the right side, it resembles a pericardial effusion. On the left side the greater part of the effusion is likely to be overshadowed by the heart and only the upper portion may be seen. It may resemble a dilated descending thoracic aorta.

Interlobar collections. The lateral view is the one safe and sure means of diagnosis and localization and the appearance in the well-known interlobar region is not easily mistaken.

Large areas of atelectasis frequently occur in chronic lung disease, producing physical and roentgen signs which are distinguishable from those given by pleural effusions. During febrile exacerbations, empyema and lung abscess are often suspected, and the differential diagnosis may not be settled by exploring the chest wall with a needle, or even exploratory thoracotomy. For the diagnosis two procedures are sug-

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gested by Korol. In apical conditions roentgenograms are made in inspiration and in deep expiration. If the abnormal shadow is cast by an accumulation of fluid, it remains unchanged in the two phases of respiration; if cast by atelectatic lung, the shadow enlarges and "brightens up" by taking in air during forced expiration. (Kreutzfuch's phenomenon). If the shadow is located at the base of the lung, a film is made with the subject lying on the better side, for comparison with the film made in the erect posture. Areas of atelectasis are generally inflated in the upper lung.

3. Blood count. In empyema, a leukocytosis of variable degree is always present; sometimes it is very high (15,000 to 50,000 white blood cells). There is a relative polymorphonuclear increase.

D. Differential Diagnosis.

Empyema must be differentiated from an unresolved pneumonia. In empyema the percussion note is flat and tactile fremitus is absent. As mentioned previously, unresolved pneumonia is rare, and it is a good rule

to consider every case of unresolved or relapsing pneumonia to be an empyema until the presence of pus is absolutely disproven. Subphrenic abscess and pericardial effusion are characterized by the peculiar area of dulness. Neoplasms of the lungs and great thickening of the pleura must also be ruled out from the history, physical findings and laboratory findings present in empyema.

VII. PROGNOSIS

A. Complications and Sequelae.

The prognosis in empyema will depend upon the intensity of the infection, particularly if the streptococcus is present, the occurrence of complications such as meningitis, pericarditis, endocarditis, peritonitis, synovitis and empyema of the other side, the estimate of the correct time for the drainage, the age and general condition of the patient, and the nature and gravity of the primary infection of which it is almost always a complication.

When an empyema is untreated there are a number of possibilities as to the outcome. Absorption is rare, but occasionally occurs in children. Inspissation and chronic abscess is unusual except from tuberculosis. The pus may give rise to an empyema necessitatis, rupturing through the chest wall anteriorly or laterally at about the sixth interspace, and having a high mortality. The pus may perforate into the adjacent organs or cavities, especially the lung, and this may result in fatal asphyxia. Bronchial fistulas occur chiefly in children, and may be followed by evacuation of the pus by mouth with recovery (rare), suffocation, chronic empyema, or pressure pneumothorax and apnea. On rare occasions the pus on perforating invades the pericardium, stomach, esophagus, peritoneum and iliopsoas sheath. The mortality is higher in children with the streptococcic type, than in adults with the pneumococic form.

B. Morbidity and Mortality.

In a discussion of the mortality, I shall attempt to quote statis-

tics from authors employing the various methods of treatment, not for the purpose at this point of comparing the methods, but to point out the factors which govern the morbidity and mortality, irrespective of the type of treatment used. Such factors are age, race, type of infection, seasonal variation, and epidemiology.

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Steinke reports a series of 310 cases of empyema at the Children's Hospital in Akron during 1930-1932 from a little over 7,000 surgical admissions, an incidence of approximately four per cent. In his series there was a general mortality of 22.6 per cent, and an operative mortality of 15.8 per cent. Rib resection was the operation of choice, being performed either alone or preceded by aspiration in 256 (82.6%) of the 310 cases, with thirty-two deaths, a mortality of 12.5 per cent. His series demonstrates the high mortality of empyema in the first year of life. Of the 310 cases practically eighty per cent occurred in the first seven years of life. Of these having empyema during the first year of life, 71 per cent died, in the second year 45.5 per cent, and in the third year 30 per cent. The mortality rate drops to 7.7 per cent for the fourth year, 6.1 per cent during the fifth year, and 3.2 per cent for the sixth year. The rate was higher again for children seven years of age, being 16.1 per cent, and 23.3 per cent during the eighth year. The mortalities for pneumonia and empyema varied considerably in this series by years, but were practically the same over a ten year period. There were 186 males and 124 females. Pneumonia was the predisposing cause in 91 per cent of the cases where the cause was given and 72 per cent of all cases. Pure pneumococcus was grown from 69.5 per cent and mixed in

four per cent of cultured cases.

In a series of 341 cases of empyema treated on the children's surgical service, Bellevue Hospital, in children up to the age of twelve, there was a general mortality of fifteen per cent. ¹⁴ Again, in this series, the mortality rate was highest for the first two years, varying from 9 to 40 per cent for one year or under, and 9 to 28 per cent for two years, for the different years over which the series extended.

4

Harloe reports a series of 351 cases in which he used the closed negative pressure method. Below is a table showing the incidence and mortality.

| Age of children | Number | Deaths | Per Cent |
|---------------------|--------|--------|----------|
| One year or under | 20 | 6 | 30.0 |
| One to two years | 50 | 6 | 12.0 |
| Two to four years | 69 | 7 | 10.14 |
| Four to six years | 53 | 2 | 3.77 |
| Six to eight years | 26 | 1 | 3.85 |
| Eight to ten years | 7 | 0 | 0.0, |
| Ten to twelve years | 8 | 0 | 0.0 |
| Total | 233 | 22 | 9.87 |

| Age of adults | Number | Deaths | Per Cent |
|----------------|--------|--------|----------|
| 12 to 14 years | 5 | 0 | 0.0 |
| 14 to 20 years | 27 | 2 | 7.4 |
| 20 to 30 years | 34 | 1 | 2.94 |
| 30 to 40 years | 24 | 4 | 16.6 |
| 40 to 50 years | 19 | 2 | 10.05 |
| 50 to 60 years | 4 | 1 | 25.0 |
| 60 to 70 years | 4 | 1 | 25.0 |
| 70 to 80 years | 1 | 0 | 0.0 |
| Total | 118 | 11 | 9.32 |

In this series it can again be seen that there is a high mortality in the first few years of life, and also after the age of forty. Harloe recommends early operation in the care of infants. He also points out that most empyema deaths are caused by meningitis or septicemia, which may be secondary to lateral sinus thrombosis, multiple abscesses of the lung, associated simple putrid lung abscess, suppurative pericarditis and peritonitis, and diffuse cellulitis of the chest wall from infections by anaerobic organisms.

15

Tanner, in his report of 207 cases with a mortality of ten per cent, applies the most ordinary surgical procedures, and he is not so much concerned with the operation as with the carrying out of certain principles. He safeguards the patient's strength; he does not interfere in the presence of an active pneumonia, he uses local anesthesia, does the least possible at the initial operation, keeps up nutritional

care, and considers every case of empyema individually for the treatment to be employed.

Staphylococcic empyema is more serious and carries with it a higher mortality than pneumococcic empyema. In one series, the incidence of staphylococcus empyema in adults was 5.7 per cent (eleven cases), and in children under thirteen years of age 17 per cent (thirty one cases). Much more striking, however, was the fact that fifteen of the twenty-one cases of empyema in infants under one year of age were due to the staphylococcus (71 per cent). An additional fact is that half of the cases in this series occurred in the first year of life. There was a mortality of 42 per cent (thirteen deaths). Rib resection was performed in these cases.

16

Connors, in a recent report, had a mortality of 6.6 per cent (five deaths) in a series of 74 cases of empyema. He employed the method of open thoracotomy and packing of the pleural cavity. Although the operation is more radical than the usual measure used, Connors stresses the fact that he has a low mortality, which should be the most important factor in the treatment.

The colored race has a higher mortality rate from empyema than the white race, as can be seen by statistics taken from southern hospitals. In an analysis of 124 cases of acute empyema thoracis admitted to the Charity Hospital of New Orleans, it was found that 64.4 per cent of the cases were in the white race and 35.4 per cent in the colored. The greatest number of cases occurred between the ages of eleven and twenty years;

78.9 per cent occurred in the second to fourth decades. The mortality rate was highest above fifty years of age. An interesting fact in this series is that tuberculosis was the underlying lesion in 19.7 per cent of the colored patients and in only 8.7 per cent of the white patients. This may account for the high mortality rate in the colored race, which was 25 per cent, as compared to 10 per cent for the white race. Right sided and left sided empyemas occurred with equal frequency. In the colored race the mortality rate was higher in left sided (33.3 per cent) than in right sided processes (5 per cent), whereas in the white race the mortality in the right and left sided lesions was 13.16 per cent and 3.19 per cent, respectively. Empyema was of the metapneumonic variety in 60.3 per cent, of the synpneumonic type in 21.6 per cent, tuberculous in 12.6 per cent, and staphylococcic in 5.4 per cent. Improvement and recovery occurred in 92.24 per cent of the metapneumonic cases, in 75 per cent of the synpneumonic cases, and in all the staphylococcic cases. Improvement occurred in 71 per cent of the tuberculous cases. The pleural fluid was purulent in 79.03 per cent of the cases (mortality rate 7.3 per cent), serous in 3.98 per cent (mortality rate 20 per cent), and hemorrhagic in 4.83 per cent (mortality rate 100 per cent).

The above statistical report was of further interest in that the various methods of treatment of empyema were used by the surgeons. Aspiration alone was used in 8.8 per cent of the cases, aspiration plus air injection in 21.5 per cent, intercostal drainage in 30.3 per cent, and rib resection in 39.2 per cent. Aspiration alone resulted in improvement or recovery in 41.7 per cent of the cases in which it was employed.

Aspiration of the pleural exudate combined with air injection gave improvement or recovery in 79.2 per cent of the cases in which it was used. There was a mortality rate of 10.3 per cent. Intercostal drainage resulted in improvement in 80.5 per cent, recovery in 7.3 per cent, and death in 12.2 per cent. Rib resection gave the following results: 79.2 per cent were improved, 5.2 per cent recovered, and 13.2 per cent died. The lowest mortality, 10.3 per cent, was obtained by aspiration of the pleural contents combined with air injection.

Open drainage was employed in 45.2 per cent of the above cases, of which number 14.5 per cent died and 83.2 per cent were improved or recovered. The mortality rate in the colored patients following open drainage was 26.3 per cent, whereas that in the white patients was 6.9 per cent. Closed drainage was used in 54.2 per cent, of which number 12.2 per cent died and 87.7 per cent were improved or recovered. Complications developed in 5.8 per cent of the cases. Of the complications, 62.5 per cent occurred in the white race. Acute nephritis, representing 21.8 per cent of the complications, was the most frequent complication encountered. Of the complications, bronchial fistula and abscess of the chest wall represented 15.6 per cent and 9.3 per cent respectively. There was a mortality rate in the entire group of 15.3 per cent, and as previously mentioned, the mortality rate of the white patients was 10 per cent as compared to 25 per cent in the colored patients. Of the entire group 82.2 per cent were either improved or recovered.

Empirically there is in general a lower mortality rate after some form of closed drainage is used in the treatment of empyema. This me-

thod has been used as early as 1884, and the most recent version of this method has been aspiration with air replacement. Yet in spite of the long period of time over which this method has been used and the mortality rate obtained at the present time, the method has not been universally accepted.

The recent enthusiasm as regards this method of treatment, that is, treatment of empyema by repeated aspirations or by continued closed drainage, is probably to be explained by the fact that in recent years the mortality rate from pneumonia and, therefore, from empyema, has been comparatively low. A suggestion is made by Graham and Berck that the periodic adoption of such methods with an intervening lapse of years in which they are not advocated was due to the fact that the methods seem satisfactory during the years when the mortality figures are low, but that when the mortality figures become high again the methods are advocated with less enthusiasm or completely forgotten.

Patients rarely, if ever, die from empyema itself. They die because of the pneumonia and severe complications, or because they had an open drainage created at a time when it produced a fatal asphyxia. If care is taken to present an open pneumothorax during the formative period of an empyema, there is very little difference in the mortality whether the case is treated by some method of closed drainage or open drainage after a true empyema (abscess) is present.

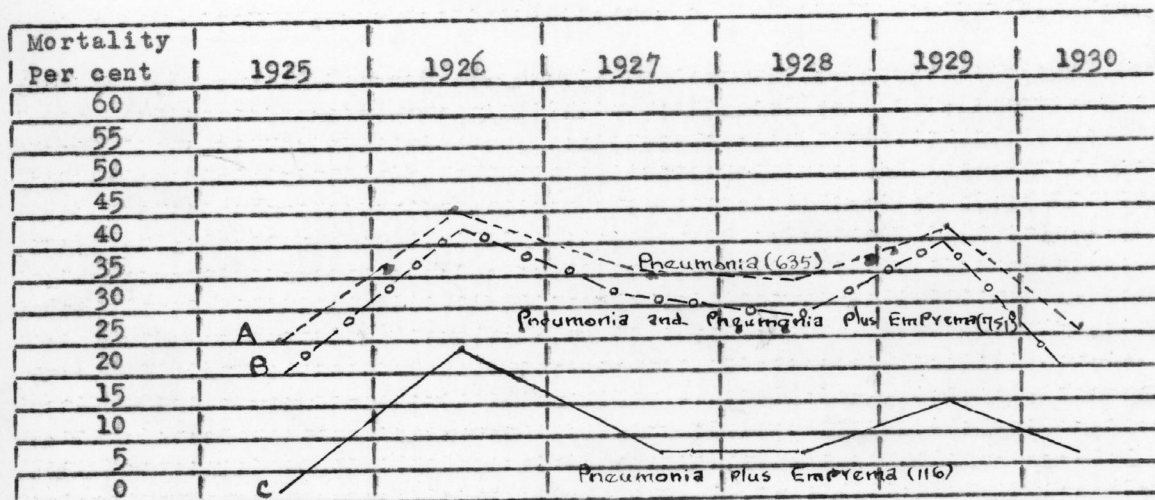
20

Heuer also called attention to the fact that the mortality rate of acute empyema is governed almost entirely by the severity of the viru-

lence of the epidemic, provided that there is no injudicious creation of an open pneumothorax.

The following charts show the parallelism of pneumonia and empyema mortalities.

COMPARISON OF PNEUMONIA AND EMPYEMA MORTALITY 1925-30 ST. LOUIS CHILDREN'S HOSPITAL



A is the mortality curve in 635 cases of pneumonia without empyema

B is the mortality curve of these 635 cases of pneumonia without empyema combined with the mortality of the 116 cases of pneumonia with empyema (A plus C).

C is the mortality curve of the 116 cases of pneumonia complicated by empyema.

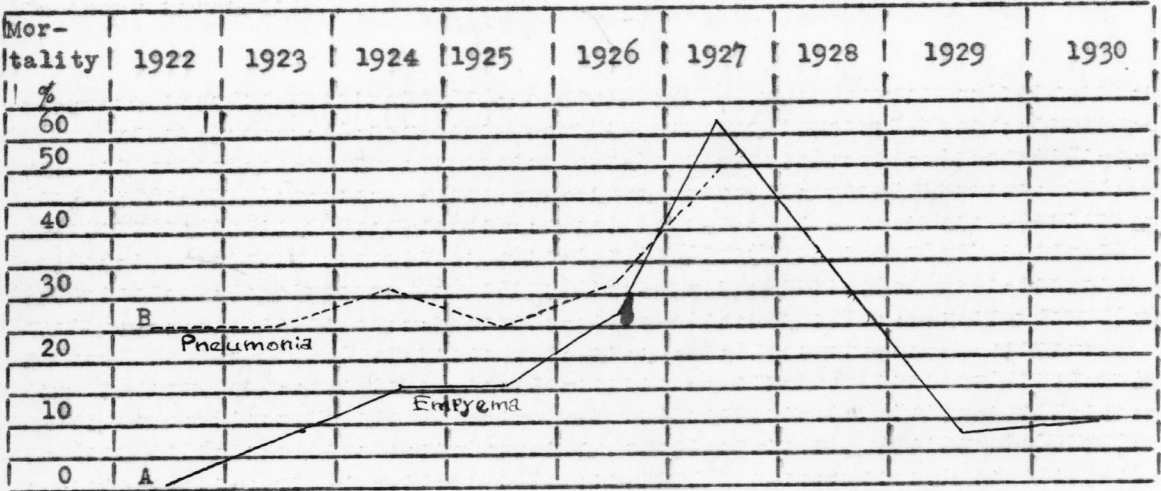
As this chart shows, the mortality curve of cases of pneumonia without empyema and that of pneumonia with empyema over a period of six years has shown a remarkable parallelism. The determining factor in common in these two conditions, which largely determines the death rate, is probably the virulence of the micro-organism. The above chart was taken

method.

20

Similar to the above chart is the one that Heuer has made in his series of cases:

THE MORTALITY CURVES OF EMPYEMA AND PNEUMONIA BY YEAR PERIODS



A is the mortality rate in empyema by year periods

B is the mortality rate in pneumonia by year periods

(Mortality rate in pneumonia was not determined for 1928, 1929, 1930).

The explanation of the fact that the death rate in patients who develop empyema is lower than that of pneumonia in general probably is that the development of an empyema (abscess) is an indication of a considerable amount of resistance against the infection.

Some of the important points to be stressed are that empyema has a higher mortality rate in the first two years of life and after the age of 45-50, that the colored race has a higher mortality rate (an important

factor being the high incidence of tuberculosis as the underlying pathology), that empyema occurred more often in males in Steinke's series, that staphylococcic and streptococcic empyemas are accompanied by a higher mortality rate than the pneumococcic empyema, that empirically there is a slightly lower mortality rate after some form of closed drainage has been used in the treatment of empyema, and that the mortality rate in empyema parallels the mortality rate of pneumonia for different years, indicating the relationship between the mortality rate of empyema with the virulence of the infection.

VIII. TREATMENT OF ACUTE EMPYEMA

A. Prophylaxis. As to the prevention of empyema, there is very little that can be done besides the immediate and careful treatment of the disease predisposing to this complication, and the prevention of these diseases, such as pneumonia, where the ordinary methods of prevention against any contagious disease should be stressed. Care must be taken whenever aspiration of a pleural effusion is done, not to introduce infection into the pleural cavity from without.

When an acute empyema does occur, care must be taken to prevent a recurrence by securing adequate drainage at the proper time, meticulous care to see that healing occurs from within outward, and hospitalization of patients until the empyema cavity has become obliterated.

B. Active Treatment.

1. Introductory remarks and preoperative treatment. In the treatment of empyema there are many factors to be considered, such as the age of the patient, the condition of the patient, and the type of operation to be performed. A streptococcus empyema is synpneumonic, and hence an open operation is contraindicated early, as was pointed out in the discussion on open pneumothorax. A staphylococcus empyema may at times appear early, but usually forms after the pneumonia has been in progress for several days. A pneumococcus empyema occurs when the pneumonia has almost subsided, and the patients are in a better condition for operation than those with a streptococcus infection.

If rib resection is contemplated, one should wait until the pneu-

monia has subsided sufficiently to withstand the shock of the operation and accompanying pneumothorax. Repeated aspirations should be resorted to if it is necessary to relieve cardiac or respiratory embarrassment. The mortality would be high were open operation to be performed upon an infant, an aged patient, or where the patient is in poor condition with an active pneumonia and profound toxemia.

As to the actual methods of treatment, there are two main types, the "open" and "closed" drainage, of which there are many variations. The closed drainage method is the better one physiologically, for it maintains the normal negative pressure within the pleural cavity, and in this way favors re-expansion of the lung, which results in its early return of function. From the results obtained by various authors, it seems to be the ideal method of treatment in those institutions where there is adequate help to keep the drainage system open and functioning. However, there is always the possibility of masses of fibrin clogging the system or not being properly removed. For this reason, rib resection (open drainage) is the better procedure in those cases where closed supervision is not possible, for it is more "fool proof".

In preparing the patient for operation, his general condition should be improved as much as possible. The patient should be given large quantities of water. Muller recommends a liter of saline intravenously every eight hours to sick adults and smaller quantities to children during the twenty-four hours preceding operation. Glucose (5%) is added if the patient is weak and thin or if the urinary output is low. Every case should be typed and provision made for transfusion, especially

in sick children. Food is given freely if the patient is not nauseated. Chilling should be prevented in removing the patient to the operating room, and the patient should be slightly inclined to the sound side for the operation.

2. Types of Operation.

1. Aspiration. A needle can be fitted with about twelve inches of rubber tubing attached to a large syringe and with a glass T tube in the middle of the rubber tube, with the outlet clipped the syringe aspirates the fluid and then by clipping the tube close to the needle and opening the outlet the fluid can be expressed and the process repeated without detaching the syringe. The needle should be inserted in an intercostal space, preferably the eighth, in the posterior axillary line and the fluid withdrawn slowly until no more can be obtained or untoward symptoms supervene. The surgeon should not puncture the lung and should watch the circulatory response, color of the patient, onset of dyspnea, blood pressure fall, etc. Local anesthesia of the skin, subcutaneous tissue, and parietal pleura is done with one per cent novocaine. If repeated aspiration is necessary, as in some streptococous cases, it will be found that this is indicated in from four to six days. After the second or third aspiration the pus thickens and tube drainage is indicated.

2. Closed Drainage. (a) Simple method of closed drainage with irrigation. (Kenyon's and Mozingo's methods). The simple method, known as Kenyon's method will be described first. One of the methods of introduction of the tube, which varies with different surgeons, is as follows: The patient should be made comfortable and placed in the position mention-

ed under "aspiration". The seventh or eighth interspace in the posterior axillary line is selected. The tissues are anesthetized with novocaine. The intercostal nerves are blocked, two above and two below the point of puncture. A small incision, about one-half inch long, is then made through the skin and an aspiration needle introduced to check for the presence of pus. The trocharcanula is pushed into the cavity. The tubes can be about nine inches long and marked for about six inches. The tube is pushed through the canula almost to the end but is withdrawn after removal of the canula until it is estimated that three inches project into the chest. Some of the pus may be evacuated at this time, but usually the tube is clamped after testing its working and the drainage is begun after the return to bed.

The wound is touched with antiseptic solution, (2% mercurochrome), dressed with a two inch square gauze pad saturated with vaseline and covered with a six inch square of new rubber dam which has a minute hole in the center through which the tube is drawn until the dam is snug on the chest. It is then "plastered down" with adhesive plaster, but this does not touch the tube because its adherence may result in the tube coming out when the dressing is changed. The tube is surrounded by a one inch wide piece of adhesive folded to make a small tab which is then pinned to the adhesive plaster dressing. It is not necessary under ordinary circumstances to dress the wound for a week. The tube only rarely comes out if care is taken to have a coil loose in the bed held by a safety pin attached to the mattress but not piercing the tube. When the patient returns to the bed the drainage tube is attached to a connection of sterile rubber

tubing in which is placed a glass T tube at a convenient situation for the purpose of delivering the Dakin solution. The drainage ends in a gallon sized bottle fastened to the frame of the bed and filled one quarter with a weak antiseptic solution such as a 1:40 carbolic acid. A full coil of the tubing should lie in the bottom of the bottle and clips should be placed below the T tube and on the tube leading to the Dakin's solution bottle.

Usually, drainage is practiced only during the first twenty four hours, after which the Dakin's solution is introduced every two hours day and night. About fifty cubic centimeters is used each time for children and one hundred cubic centimeters for adults, the drainage tube being clipped for fifteen minutes to obtain full action of the hypochlorite solution, after which it is released and drainage proceeds. The occurrence of coughing or the tasting of chlorine is a sign that a fistula exists and that irrigation must be abandoned.

In the Mozingo method (used in young, restless children) a smaller canula is used and the tube should be five millimeters in diameter, and have a number of fenestrae three millimeters in diameter and about one centimeter apart. It is inserted for a distance of six to eight inches in the chest. No drainage is attempted but the pus is removed with an aspirator or a syringe. Every three to five hours by day and once by night from fifty to two hundred cubic centimeters of Dakin's solution, depending on the size of the cavity, are injected by means of a bulb syringe, removed and repeated until the return is clear. After sterilization, which takes from four to ten days, a two per cent solution

of formalin in glycerin prepared twenty-four hours previously should be injected once daily in amounts varying from five to fifteen cubic centimeters, depending upon the reaction and after-irrigation. When the secretion obtained becomes a clear, sterile serosanguinous fluid, about five cubic centimeters of the formalin-glycerine solution should be injected, the tube removed and the sinus closed with adhesive plaster. The method requires the constant care of a skilled person.

(b) Tidal irrigation. Tidal irrigation is produced by a communication between the pleural cavity, through tube, with an outside reservoir, the fluid entering and leaving the chest under respiratory movement. This prevents obstruction of the tube by washing away obstructing particles when the flow is reversed. Fluid is drawn in by the expansion of the chest during inspiration. Hart reports thirty five cases using this method; ages varied from four weeks to forty eight years, twelve being two years of age or less. The average time of closure to a sinus holding five cubic centimeters was twenty one days. The sinus closed on an average five days following the removal of the tube. Twenty nine of the thirty five patients recovered. The six patients who died had overwhelming infections at the time of operation.

(c) Continuous suction drainage. Thomson describes an apparatus using the method of suction drainage, which is ingenious, and by means of which he cured a case of bilateral empyema in three and one-half weeks. Care is taken to have all the connections air-proof, and the most careful nursing is necessary. This method does avoid frequent and painful dressings, and while the results were excellent in Thomson's cases, the

apparatus is too complicated and cumbersome to be very practical. The difficulties which may be encountered in this method are blockage of the catheter, air leaks, non-air tight dressings at the chest wall, and restlessness of the patient.

23

(d) Closed drainage with air replacement. Danna uses the air replacement method with aspiration in the treatment of empyema. In favor of periodic evacuation and air replacement, he points out that this method can be used as a preliminary method without harm, that it can be used when other methods have failed, that it leaves no scar or deformity, that the patient is not bathed in pus and is up and about most of the time, that there is little danger of metastatic abscess, that the cost of many dressings is saved, that there is the least possibility of chronic empyema, that there is the least amount of trauma, that with proper precaution it should have the lowest mortality, and that it lends itself to rendering all operative procedures safer within the pleural cavity. Against this method he points out that it should not be used in sudden overwhelming infection of the pleura by ruptured abscess, that there is danger of tension pneumothorax, that chest wall infection is possible, and that during treatment a certain amount of pus is present, producing fever and malaise. This method also requires more frequent contact of the surgeon and the patient, and more frequent re-examination and roentgenograms. In all probability the normal process of healing takes place by this method, since the end result is a clean cavity filled with air.

24

Koster and his associates have a further variation of this method. In eight cases of unilateral empyema in children, the induction and main-

tenance of an artificial pneumothorax of the sound side, (Danna injects air on the affected side), was employed to favor drainage and cause earlier obliteration of the empyema cavity. In their cases there was a significant reduction in the duration of the morbidity, the cavity was emptied by closed intercostal drainage, and the drainage and obliteration of the cavity were hastened materially by artificial pneumothorax on the unaffected side.

3. Rib resection (Open drainage).

In this method the local anesthesia must be thorough. Usually the eighth rib in the posterior axillary line marks the incision of choice. The tissues and muscles are infiltrated before cutting. An incision is made on the bone above and below to separate the intercostal muscles and a periosteal separator gently introduced, separating the periosteum and intercostal tissues from the posterior aspect of the rib. The rib is then cut and a portion one and one-half inches removed.

If gas has to be used in nervous people and in children, the patient should be allowed to come out of the effects of the gas before opening the pleura. After the opening is prepared the pleura should be infiltrated with novocaine solution and a pair of pointed hemostats introduced through the pleura into the cavity and gently spread. Almost with the same motion a fairly large drainage tube is introduced into the cavity and the muscles rapidly sutured to either side with one or two catgut sutures. A laboratory clip keeps the end of the drainage tube from spilling pus. The skin is then neatly closed and dressings applied.

The patient's condition must be good, the pus well loculated and

thick in order to justify rib resection. Rib resection allows for drainage through a larger tube, and allows for cleansing of a cavity filled with coagulated pus. About one-half of the cases need rib resection either as a primary or secondary procedure.

10

Graham and Berck believe that the most important consideration in the treatment of empyema are to save the life of the patient and to prevent chronicity. They believe that the best way to promote adequate drainage and prevent chronicity is to create an open drainage by rib resection. By using this procedure they were able to discharge their patients on an average of five weeks and two days from the time the fluid was first recognized in the pleural cavity. They point out that the flaw in closed drainage is that frequently an acute empyema is converted into a chronic one by allowing the most favorable time for open drainage to slip by.

25

Eggers also prefers rib resection, and he treats empyema with this method as a basis. However, in streptococcus cases, where there is a large amount of pleural fluid, he aspirates the fluid until it is purulent and then does a rib resection, or where urgent treatment is demanded, he establishes closed drainage (either by means of the trochar catheter method or by the insertion of a tube through the intercostal incision), and continues this method until a cure results or only sufficiently long to bridge over the period of emergency and then he converts the drainage into an open one. He believes that the sterilization of the cavity and subsequent obliteration is best done by this method.

4. Open Thoracotomy with Packing.

One of the chief users of this method is Connors, who believes that the mortality in empyema has been lowered by the method of open thoracotomy and packing of the pleural cavity. This method seems to work uniformly, irrespective of the factors of age, bacteriology, etc. As to the advantage of this method, he points out that adequate exposure of the pleural cavity is obtained so that the pleural cavity can be cleaned under direct vision (opening two times two inches and the intercostal muscles, nerves, and vessels are removed en masse), that by removing the pyogenic membrane by gauze the lung will expand more easily, that no foreign bodies will be left in the pleural cavity, that no irrigating fluids are necessary, and that there is great economy of material and labor. However, it does not seem that the lowered mortality is sufficient (6.6%) to compensate for an operation where general anesthesia must be used, and where the effect of the open chest is always a danger.

3. Postoperative Treatment.

This is very important, and includes irrigation, respiratory exercises, diet, hygiene, and withdrawal of drainage.

Dakin's solution is prepared from bleaching powder, washing soda, and boric acid, and should be approximately neutral, because if too alkaline it irritates the tissues, and if too acid it deteriorates. The hypochlorite content should lie between 0.4 and 0.5 per cent. If below 0.4 per cent its efficiency as a germicide is reduced, and if above 0.5 per cent it is irritating. The solution must be freshly prepared, as it deteriorates in a few days.

Usually the irrigations consist of from fifty to one hundred fifty cubic centimeters every two hours, and after introduction the patient should move from side to side if possible to mix the fluid with the pus. In the event of a bronchial fistula opening up, a violent paroxysm of coughing and the tasting of the chlorine occur, and the solution must be discontinued. In some patients pain seems to follow the irrigation and in others a febrile reaction is induced.

After drainage is established, the cavity practically emptied, and the hypochlorite solution acting well, re-expansion of the lung must be considered. Of course, adequate drainage and sterilization of the cavity must first remove the exudate and allow for the expansion. Respiratory exercises should begin five or six days after the operation. These exercises consist of deep breathing exercises, blowing exercises, etc. Connors says that in doing open thoracotomy operations and then watching the effect of exercises, that there is not much benefit, but that the benefit (expansion) occurs in expiration; and, therefore, he advocates coughing as the means of expanding the lungs the most.

Fresh air, sunlight, and high caloric feeding should be given in abundance to improve the hygiene. Repeated blood transfusions should be given for persisting anemia.

The closed drainage with two hour irrigation should be used until the discharge materially lessens and fever disappears. It will be found practical to lengthen the intervals at night to four hours. After about a week the tube loosens and the cavity is open. A larger tube may be inserted if recovery is not yet attained. After about two weeks the

hypochlorite irrigations may be discontinued, the tube cut short and the cavity well washed out twice a day. The patient is allowed out of bed. Daily measurements of the size of the cavity should be made by estimating the amount of fluid it will contain. When this amount is thirty cubic centimeters, all drainage may be withdrawn and daily applications of an antiseptic applied to prevent staphylococcic infection. If a long sinus persists, or if a large cavity remains the case becomes one of chronic empyema, and requires special treatment. The duration of treatment during the acute phase will range from five to ten weeks, and after that the condition, if it does not get well, is spoken of as a chronic empyema.

IX. TUBERCULOUS EMPYEMA

A. Etiology, etc.

Empyema may develop from tuberculosis of the lung as a sole result of infection from the tubercle bacillus or from mixed infection. Tuberculosis of the ribs or bronchial glands may also act as a primary focus. Such empyemas are secondary, but it is also probable that rarely a primary pleurisy may develop, either as a dry, adhesive pleurisy or as an effusion. An effusion develops in at least five per cent of the cases of pulmonary tuberculosis, but these are mostly serous effusions, the typical empyema occurring much less frequently. An effusion frequently follows artificial pneumothorax but only rarely is it purulent. Only about one per cent of the cases of acute empyema are tuberculous. Wilensky reports two per cent in a series of 299 cases. In chronic empyema the incidence is higher, and Hedblom in a collection of nearly 2,000 reported cases found the incidence of tuberculous empyema to be ten per cent.²

Rupture of a caseous focus into the pleural cavity may result in an effusion containing tubercle bacilli, mixed organisms, or it may be sterile. Sometimes the organisms are found by direct examination, by digestion of the pus, or by animal inoculation, but usually the clinical evidence must be relied on. In those cases of draining empyema where tuberculosis is suspected as the reason for failure to heal, reliance must be placed on an examination of the tissues of the sinus or on the evidence of disease in the lung, glands, or bones.

B. Diagnosis.

An empyema is considered to be tuberculous if it develops primar-

ily without a preceding acute infection. History fails to show a previous pneumonia, influenza, or embolic possibility. The empyema has an insidious onset, and may have been preceded only by a pleurisy. Suggestive features as to the etiology are cough, night sweats, weight loss and ehmoptysis. Sputum examination and x-rays of the chest may reveal tuberculosis. Theleukocyte count is apt to be low. The fluid at aspiration is thin and usually sterile, but should be examined for tubercle bacilli.

C. Treatment.

Differentiation of a sterile tuberculous empyema from one of pyogenic origin is of the first importance to treatment, in that a sterile tuberculous empyema should not be subjected to an open drainage, for this would result in a secondary pyogenic infection, which endangers the patient's life and leads to chronicity. There are conservative and radical methods of treatment. The conservative measures frequently used are: Aspiration, aspiration and air replacement, and aspiration and irrigation with antiseptic solutions such as sodium chloride, gentian violet, acriflavine, and potassium permanganate. Hedblom believes that the best procedure is radical thoracoplasty when the tuberculous pleura is secondarily infected, since the pleura has little healing power under such conditions.

A sterile tuberculous empyema of idiopathic origin, and without clinical evidence of pulmonary tuberculosis, is treated on principles directly opposite to those governing treatment of a sterile tuberculous empyema with active pulmonary tuberculosis on the same side. In the first

instance an effort is made to obliterate the cavity by securing re-expansion of the lung. In the latter treatment is directed to keeping the tuberculous lung collapsed.

The treatment of a sterile tuberculous empyema of the idiopathic type is aspiration of the pus, filtered air being substituted in an amount to keep the intrapleural pressure about atmospheric. The procedure is repeated at intervals as the pus accumulates. If pus continues to accumulate after from six months to a year of such treatment, and the lung does not show very much expansion, a graded extrapleural thoracoplasty is indicated. If the pus is allowed to be absorbed indefinitely, permanent damage will be done to the heart, kidneys and extensive amyloidosis may occur.

Sterile tuberculous empyema with associated active pulmonary tuberculosis is treated similarly to the idiopathic type, except an attempt is made to keep the lung from expanding by keeping the pneumothorax pressure atmospheric or positive. Again, if pus accumulates indefinitely, thoracoplasty is indicated. The age, the condition of the patient, and the presence and the type of the pulmonary or other tuberculous process may constitute contraindications to thoracoplasty.

An undrained tuberculous empyema may be secondarily infected by a bronchial fistula or by the lymph or blood stream. If this occurs, but the bacteria are few in number and the clinical symptoms are mild, treatment should be the same as for the sterile tuberculous form. If the pyogenic infection is heavy, drainage must be instituted, but Dakin's solu-

tion or gentian violet must not be used if there is evidence of pulmonary tuberculosis.

A tuberculous empyema secondarily infected by injudicious drainage is treated as a chronic empyema initially, but its final treatment is as given for the tuberculous type. If there is evidence of pulmonary tuberculosis of the same side, a thoracoplasty is indicated; if there is no pulmonary tuberculosis, it is desirable to obtain re-expansion of the lung.

D. Prognosis.

Statistics are meager, but from the results that are published, there is a high mortality (average of fifty per cent) and hence the prognosis is poor. McKinnie aspirated eight cases of tuberculous empyema with mixed infection. One died and the others apparently recovered. He did open drainage in twenty cases with bronchial fistula, with nine deaths and only one considered as cured. Hedblom, in 1922, reported a series of seventy-four cases with twenty-five deaths (ten operative) and thirty-nine satisfactory results. There were three aspirations with one death and forty-six drainage operations with twenty-five deaths. Together, these two men reported on sixty-six patients, of which thirty-four died, a mortality of slightly over fifty per cent.

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Recently, Rosenblatt presented the end results in a series of twenty-one cases of toxic tuberculous empyema, treated conservatively and followed up for from three to eleven years. The treatment in his cases was by aspiration of as much of the pus as possible and replacement with air. The amount of air introduced was dependent upon the amount of fluid

aspirated and the intrapleural pressure. In large pleural effusions with a free pleural cavity, a slightly negative pressure was left at the end of treatment. If the pleural cavity became limited and further collapse of the lung was desired, enough air was introduced to produce a slightly positive pressure. This procedure was repeated periodically as long as pus accumulated. The successful cases remained under treatment for from eight months to four years. The average length of treatment was two years. Eleven patients were cured and ten died, again a mortality of about fifty per cent.

X. CHRONIC EMPYEMA

The causes of chronicity can be divided into groups - (a) cases in which chronic empyema could have been prevented, and (b) cases in which healing is very difficult owing to the primary cause or to unavoidable complication. The first group seems to be the larger. It includes empyemas either not recognized or not treated until the pleura has become a rigid membrane by organization changes; those in which drainage has been inefficient owing to the opening being too high or too small; those in which reinfection has occurred; those in which irrigation with Dakin's solution has not been done and was necessary to remove the deposited lymph in order to prevent organization or to arrest persistent infection. Finally, in this group of preventable cases are those in which the chronic cavity is maintained by the presence of a foreign body, such as drainage tube, or fragments of rib, or on account of the divided rib.

The second group, in which the chronic empyema is due to unavoidable complications, includes those cases with bronchial fistula, with associated fibrosis of the lung, or in which the primary cause was tuberculosis or actinomycosis.

Treatment is directed, whenever possible, to correct the original fault. Efficient and dependent drainage must be instituted by enlarging and extending the original opening, and if that is not practicable, a new opening must be made. Foreign bodies should be looked for and removed. Frequent irrigation with Dakin's solution will help to sterilize the cavity and may even effect a decortication of the pleural surface, separating off the organized lymph. Dakin's solution, of course, is contra-

indicated in tuberculosis, or if there is a bronchial fistula.

It is only after giving the above measures full trial that the major operative procedures are considered. The object of these is mobilize the chest wall by removing the ribs over the affected area, and at the same time to mobilize the lung by decortication. When dealing with a cavity of any size, mobilization of the chest wall alone or of the lung alone is rarely adequate. The operations must be performed in a series of stages, and it is most important that approximation should begin at the apex and that apposition should be secured over the upper area before an attempt is made to obliterate the lower segment. In cases of very large empyemas it may be necessary to dissect away the whole of the parietal pleura, together with the periosteum of the ribs and the intercostal muscles.

Bronchial fistulae may clear up spontaneously after free drainage has been instituted. If not, the opening should be cauterized. To obliterate a large chronic fistula the bronchus must be freed, the end cauterized and closed by sutures, and the lung mobilized so as to bring it into apposition with the chest wall.

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29
Hedblom reported a series of 310 cases of chronic empyema treated at the Mayo Clinic. The causative factors contributing to chronicity were late drainage in 105 cases (33.8 per cent), insufficient drainage in at least fifty per cent, and persistent infection in the pleurae in an uncertain proportion of the ninety recurrent cases, and probably in some others. Bronchial fistulae were present in twenty-eight per cent; More than a third were found in the cases of recurrent empyeam. Tubercu-

lous pleurisy was a cause of chronicity in thirty-seven proved cases, and in an uncertain number of forty-four cases in which there was tuberculosis elsewhere, or in which empyema had developed on an idiopathic pleural effusion. Foreign bodies were present in thirty-five cases. Massive collapse of the lung and fibrosis of the lung were at least contributory causes in many cases.

Various methods of treatment were used in the above series; drainage in ninety-one cases, decortication in thirty-six, and plastics in eighty four. Of this series 226 patients were completely cured or so markedly improved that they could work. A late report was not received concerning fifty-six, and eleven were too recent to classify. One patient not operated on died from brain abscess. The operative mortality was five deaths, or 1.6 per cent.

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