THE TREATMENT OF GUNSHOT WOUNDS OF THE LUNG AND PLEURA.

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The conclusions upon which this paper is based were obtained from the study of forty-three consecutive cases of injury to lung and chest wall treated in hospital from September 1, 1915, to November 30, 1915.

These injuries were caused by rifle bullet, shrapnel ball and fragments of casing of shell and bombs; the cases arrived from seven to twelve days after the infliction of the wound.

In none of these cases had any surgical treatment, such as aspiration, been attempted on the P. or on the hospital ship.

The clinical signs presented by these cases were those of fluid or air and fluid in the pleural cavity, and for purposes of classification and essential treatment can be described under the headings hæmothorax, pneumohæmothorax, and pneumothorax.

HÆMOTHORAX.

There are three clinical varieties of this condition. First a massive hæmothorax with collapse of lung, the level of fluid rising to the clavicle. Second, an effusion of fluid with lung floating on top of the fluid level and compressed against the unyielding chest wall. Third, a minor degree of effusion, varying from a thin layer at the base to an amount that rises to the angle of the scapula; in this variety there is still presence of tactile vocal fremitus and vocal resonance in a degree varying with the amount of effusion.

In the variety with massive effusion up to the level of the clavicle there is complete absence of breath sounds and of tactile vocal fremitus. In the second variety there is usually loss of breath sounds and of tactile vocal fremitus up to the level of the fourth rib, while, above, there is "skodaic" resonance and increased harshness of breath sounds.

At the time the cases reached the hospital each variety of hæmothorax seems to have been definitely established, for in no case did either variety merge or become transformed into the other. By the seventh day from the infliction of the wound the amount of the effusion seemed to have been definitely determined.
Even in the cases of re-accumulation of fluid after aspiration the level of the fluid never rose above its original height. This appears to afford clinical justification for the established practice of waiting for some days, except in urgent cases of cardiac embarrassment, before aspiration is attempted.

There is a marked immobility of the chest corresponding in degree to the amount of effusion. The heart is dislocated to the other side in all cases of gross effusion of fluid, but the amount of embarrassment depends more upon the rapidity with which the effusion is poured out and the presence of coexisting pneumothorax than upon the actual amount of fluid. The development of the chest has an important bearing on the degree of cardiac embarrassment; the more capacious the chest the more room for the contralateral lung to expand.

There is also more cardiac embarrassment in cases of left-sided hæmothorax; the heart appears to tolerate dislocation to the left of the sternum more readily than to the right. In empyemias, where the fluid is under greater pressure in view of the protective attempts of pleural adhesions to wall in the effusion, and where the fluid is excreted more slowly, there is often very great cardiac dislocation with little embarrassment of cardiac action and dyspnœa.

The slight effusions of fluid invariably show tendency to rapid absorption, particularly after aspiration, even though only slight amounts of fluid are removed. Aspiration in these cases seems to upset the balance between excretion and absorption in favour of the latter process. These slight effusions often present the clinical paradox of a thin layer of fluid with a coincident coarse pleural rub, especially in expiration. This is due to the separation of pleural surfaces covered with clot of butter-like consistency. This is the only type of hæmothorax which shows a tendency to natural recovery and absorption, without aspiration, in a reasonable time.

**Hæmopneumothorax.**

In the majority of these cases the pneumothorax is apical, but there are cases, clinically very difficult to diagnose, in which there is a patchy pneumothorax even at the base of the lung. Here the air is imprisoned by adhesions and, masking the clinical signs, increases the difficulties of diagnosis. These localized collections of air do not appear, as a rule, to be under any very great pressure and present a natural tendency to absorption. In none of our
cases of pneumothorax was there any evidence of the presence of gas from gas-forming bacilli.

The condition of hæmorrhax with apical pneumothorax presents an immobile barrel-shaped chest on the affected side, often with very marked bulging and dyspnoea, especially in the recumbent position. There is great displacement of the heart, greater and accompanied with more embarrassment than in gross hæmorrhax or pneumothorax. The fatal cases in particular are of this type, death occurring from cardiac syncope. In left-sided apical pneumothorax the heart is so dislocated as to give the impression of torsion, as if there was acute kinking of the great vessels at the base of the heart by the degree and suddenness of the dislocation. The displacement of the heart varies with the pressure under which the air exists, and the embarrassment of that organ with the rapidity with which the air and fluid collect. The heart exhibits remarkable power of accommodating itself to varying degrees of pressure of air, and may show a diminishing degree of embarrassment as time goes on without a corresponding diminution in the amount of dislocation.

The clinical signs in these cases are those of fluid below the level of the fourth rib, as a rule, and the "box" note of pneumothorax above, with complete absence of breath sounds and tactile vocal fremitus. These signs transgress the middle line, and often show the distended pleura as far as two inches beyond the edge of the sternum.

Pneumothorax, pure and unaccompanied by hæmorrhax, is very rare as a rule; a slight effusion is always present. So much air is absorbed during the first few days and during the subsequent period of observation that the physical signs may rapidly alter. The clinical signs presented in these cases are those of absence of breath sounds and vocal fremitus in a rigid, immobile, barrel-shaped chest. There is little doubt that these cases, arriving at M. after a considerable lapse of time, do not nearly represent the condition at the time of the original wound. In the field a number of cases are seen where the initial wound of the chest, more marked where the exit wound is in the front of the chest, are accompanied by ingress and egress of air; these wounds are either packed or closed up superficially. But on arrival in M. there is very little of the pneumothorax, which must have existed at the commencement of the voyage, to be discerned, so rapidly is air absorbed.

Clinical Value of Temperature.—As a guide to treatment the
study of temperature is valuable. All effusions of blood into the pleural cavity, with the possible exceptions of the minor degrees of hæmorrhax, are accompanied by fever from 100° F. to 103° F. The fever is uniformly marked throughout the whole day and is not subject to great oscillations. This condition of fever is also exhibited in all extravasations of blood into serous cavities. It is due presumably to the absorption of fibrin ferment or other products of coagulation. Marked difference in the morning and evening reading is suggestive of empyma, more particularly when the tongue is furred and when the skin and conjunctivæ are jaundiced. An icterial tinge is usually marked in the conjunctivæ even in uninfected hæmorrhax.

In cases of hæmorrhax left untreated by aspiration the temperature tends to fall by the end of the second or third week, even though the physical signs of fluid still remain. Usually, however, coincident with the fall in temperature, appears a degree of return of tactile vocal fremitus and breath sounds. There is always a sharp fall in temperature after aspiration, though, in some cases, there is a tendency to rise again gradually after two or three days, but not to the previous height of fever. Re-accumulation of fluid is always accompanied by a sharp rise in temperature.

The development of empyma also is characterized by a gradual rise of temperature, with marked diurnal oscillations and other clinical evidences of pyogenic infection.

After efficient surgical drainage of empymata there is a sharp drop in temperature; the fall is maintained until convalescence is over. If, after drainage of empymata, there is a subsequent rise of temperature, it is found to be due to the presence of a quantity of infected clot. Not until this clot is removed by irrigation or by the exploring finger does the temperature finally subside. Only in the cases where it is necessary to remove infected clot is irrigation advisable.

Clinical Value of Haemoptysis.—Only in 75 per cent of cases is there any haemoptysis at any stage; 25 per cent only have an initial haemoptysis when the wound is inflicted; 50 per cent of the cases have haemoptysis about three days after being wounded. The early haemoptysis is always bright red and consists of pure blood only; the haemoptysis occurring on the third day is streaky and mixed with sputum, and may continue off and on for as long as two to three weeks. Aspiration has, as would be expected, a marked effect in the cessation of streaky haemoptysis; blood-spitting, however, may reappear with fresh bleedings and
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reaccumulations. There were no cases of pure hæmoptysis among those who arrived; these probably all die before they reach M., as also do the cases of rapid and gross pneumothorax. All the wounds, with one exception, seen by us in M. were closed and healed; they seldom appear to be of such size as to allow ingress and egress of air; this refers to wounds caused by shrapnel ball or rifle bullet. The extensive wounds with loss of bony rib, caused by shell casing, arrive in M. with established pneumothorax. The most dangerous of these wounds are those of a valvular nature, admitting air but not allowing egress of air. In these the presence of pneumothorax gradually increases; the dislocation of the heart is marked and the embarrassment of that organ grave. Immediate resection of a rib is urgently needed to relieve the great positive pressure inside the thorax.

Clinical value of dyspnœa as an aid to diagnosis and treatment is uncertain. At the moment of infliction of the wound there is a sharp pain in the chest and dyspnœa. Later on grave respiratory distress is not as common as would be expected. Most of the cases were able to adopt the recumbent position on board the hospital ship, but, during the process of disembarkation at M., some change seems commonly to occur, and on admission many cases of effusion, and especially of hæmopneumothorax, are in great respiratory and cardiac distress; they can only rest in comfort in the orthopœnic position. Aspiration or resection of a rib has an immediate and beneficial effect upon true dyspnœa; dyspnœa with cardiac displacement is an absolute indication for aspiration. It is surprising how great an amount of fluid and air is tolerated in the pleural cavity in men with big and roomy chests; in individuals with narrow, contracted chests a slight degree of effusion will sometimes cause a grave dyspnœa.

Surgical emphysema is often remarked in the neighbourhood of the exit wound—usually local, but sometimes general. It is in the majority of cases only in the neighbourhood of the exit wound and can be explained by the fact, so constantly established at autopsy, that the exit wound is plugged by lung tissue. Coughing or any violent expiratory effort is sufficient to force air into the tissues. More particularly in the case of perforating shrapnel wounds is this surgical emphysema seen. Surgical emphysema is of academic interest only and does not seem to affect the progress of the case. In one of our cases there was a hernia of the lung beneath the unbroken skin, where a shrapnel ball had broken the rib without perforating the skin.
The position of the wound in the lung seems to affect the incidence and amount of hæmo- and pneumo-thorax. Wounds, the track of which can be estimated by the exit and entry wounds, passing obliquely through the apices or anterior margins of the lung, are more commonly associated with pneumothorax and not with gross hæmorrhax. Wounds passing directly through the lung, especially in the neighbourhood of the root of the lung, are associated more often with the massive effusions. One of our cases, complicated by an aneurysm of the first part of the axillary artery, was an instance of gross hæmorrhax from a wound of the axillary vein. In this case after two large aspirations the wound in the vein healed; here the fluid remained uninfected throughout. The third part of the subclavian artery was subsequently ligatured with great success.

The clinical value of colour of the effusion after aspiration is very great. In cases where a prompt bacteriological examination both by slide and by cultivation is not possible or valuable time cannot be spared, determination of empyemata by smell, colour and deposit can be made. Effusions are very varied: they are clear and colourless, cloudy and turbid, clear port-wine red, bright scarlet with deposit, chocolate colour, opalescent and greenish, pale pink with deposit. The clear port-wine red is characteristic of uninfected effusions and is the effusion most commonly met with. Effusions with deposits are always suspicious. Chocolate-coloured and opalescent effusions are certainly empyemata. All smelly effusions also are, without doubt, empyemata.

The reports of bacteriologists bear out this rough colour test very generally. The pleural effusions are not all pure hæmorrhax by any means. There is always a mixture of blood with pleural effusion due to trauma and irritation of the pleural surface, just as will be found in ordinary medical cases of general effusion. For the blood in the pleural cavity acts as a foreign body and sets up pleural irritation. One of our cases of bomb wound of the thorax was characterized by a clear pleural effusion, apparently purely traumatic. It is this admixture of pleural effusion with blood from the vessels of the injured lung which probably accounts for the fact that effusions of blood-stained fluid in the pleural cavity, and after aspiration, do not conform to the usual rules governing clotting of blood. None of the pleural effusions behave in the recognized way as regards coagulation. The regular separation of serum and fibrin is not to be recognized in fluid obtained by aspiration after prolonged standing. The reaccumulation of fluid is not
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due to true secondary haemorrhage from the wound in the lung, but rather to a pleuritic effusion tinged with colour from the remaining clot.

The condition of the contralateral lung and pleural cavity has an important bearing on the treatment. In many cases there is a marked bronchitis, probably from hypostatic congestion; and in some cases a true lobar pneumonia of the other lung complicates the case. Here the value of aspiration is most marked. Cough, hitherto almost constant, causing the greatest damage to the wounded lung, clears up immediately after aspiration. We have had cases of bronchitis, with an amount of sputum sufficient to fill one or more pint pots in the day, clear up at once after aspiration in a most remarkable way. Similarly pneumonia of the uninjured lung shows a tendency to rapid progress towards cure—marked diminution in the respiration-rate, distress, dyspnœa and fever.

In one of our cases of true emphysema is an elderly fibrotic man; aspiration of a moderate effusion only had a most marked effect in the improvement of the bronchitis in the contralateral lung.

X-ray findings are of great value, especially in those cases where the presence of patchy pneumothorax masks the symptoms, and when, after ineffectual needling of the pleural cavity, the signs of fluid still persist. The dislocation of the heart is clearly visible, and the cardiac pulsation that can be felt immediately below the right clavicle in cases of gross effusion is apparently conducted from the right ventricle. There is suggestive evidence of a rotation of the heart upon the great vessels. The diaphragm is fixed and immobile, and very greatly depressed by the effusion, for blood is a very heavy fluid. This bears out the immobility of the affected side of the abdomen which, clinically, is correctly attributed to a fixed and immobile diaphragm. Pneumothorax shows up as a clear bright area which transgresses the middle line as the pleural cavity in question is distended.

The diagnosis of emphysema is helped by screening. There is no level of shifting dulness as is seen in recent hæmothorax or hæmopneumo-thorax. The dark area is seen fixed by adhesions. In empyemata there is marked displacement of the heart, far greater than the amount of dyspnœa would lead one to believe; the slight amount of cardiac embarrassment is due to the ease with which the heart accommodates itself to gradually increasing intra-thoracic pressure.

Later on, the X-ray is not reliable in determining the difference
between fluid and thickened pleura or organizing clot. Here an aspiring needle is far superior and more reliable than the X-ray or the stethoscope.

The treatment of wounds of the lung and chest wall is directed towards healing the injured lung vessels and the leak in the smaller bronchioles or alveoli, from which the air escapes into the pleural cavity. To this end absolute rest in a recumbent position, unless there is dyspnœa from respiratory or cardiac embarrassment, is essential for at least three weeks; this is followed by comparative rest for another three weeks. In no case has any patient suffering from perforating wound of the lung been sent to England under six weeks from the time of admission. The proof of this lies in the fact that only one of our thirty-seven cases, sent by hospital ship to E., has developed fresh accumulation of fluid on the voyage or upon arrival in E. None of our cases has developed the sudden pneumothorax which is the danger of too early and rapid convalescence. In cases of dyspnœa the sitting-up posture is adopted.

In one of our earlier cases of hæmorthorax, in which aspiration had removed the effusion and, beyond slight thickening of the pleura, the patient appeared to be well, a sudden attack of syncope developed after slight exertion three weeks after admission. Clinical examination showed a rapid reaccumulation of fluid and an apical pneumothorax, but before aspiration could be attempted death supervened. The condition was confirmed at autopsy.

During the period of absolute rest in bed, the patient is not allowed to wash his own face or perform any duty for himself nor to use his arms, while all attempt at straining or exertion is forbidden.

The drug treatment adopted consists in the regular administration of urotropin to keep the pleural effusion from becoming infected, and of substances to promote coagulation of blood and to contract the muscular tissue of the minor vessels of the lung. Morphine and ergotinin citrate have been largely administered for their effect upon the blood-vessels, and animal serum to promote coagulation. Of these measures we have felt inclined to place most value in regular injections of serum; in default of horse serum we have been in the habit of using antistreptococcic serum. This serves the double purpose of promoting coagulation and correcting possible infection by some strain of streptococcus. The bacteriological findings show that the streptococcus is the dominating organism in the empyemata which may subsequently develop. Enemata of calcium chloride for three days at the commencement
of treatment have also been given with a view to promote coagulation.

The treatment of effusion is by early aspiration in every case in which there is clinical evidence to lead to the belief that any considerable amount of fluid can be withdrawn. This may be repeated weekly in uninfected cases. In no case has aspiration been attempted before the seventh day, for our cases have not reached us in M. until seven to twelve days have elapsed from the infliction of the wound. If aspiration is conducted slowly, and a careful watch upon the respiration and heart be maintained, as much as three pints may be slowly abstracted without any dangerous symptoms; a large trocar and cannula or a Dieulafoy evacuator may be used. In every case there is relief of symptoms of heart and lung disturbance, and a feeling which is constantly described as of "comfort" in the chest.

In the minor degrees of haemothorax or effusion there is no necessity for aspiration, as this condition clears up rapidly under expectant treatment; in any case only a few drops of fluid can be obtained and with a big needle there is always a risk of producing a pneumothorax.

In our earlier cases we were in the habit of cocainizing the skin and the pleura before aspiration, but we discovered that the most careful cocainization with 2 per cent novocain could not be certain of blocking the intercostal nerves, which are compressed between the cannula and the rib at each expiratory movement. There is also great emotional distress when the process of aspiration is continued, as it has to be, for fifteen to twenty minutes. To avoid the risk of movement all operations are conducted in bed in the ward. For this reason we employ chloroform, after a preliminary injection of morphine and atropine, in every case; and the orthopneic position is adopted. This position ensures the most complete evacuation of fluid and causes the least embarrassment to the contralateral lung. The employment of a general anaesthetic gives complete comfort and absence of emotional disturbance.

In no case has there been any respiratory or cardiac difficulty arising from chloroform, and the pulse improves most markedly during the process of aspiration. In the cases of urgent dyspnea and cardiac embarrassment, due to gross effusion and the pressure of an apical pneumothorax under great positive pressure, the administration of chloroform has been attended with the greatest success. There is always an element of fear in these cases of extreme dyspnea and palpitation which is corrected by the general anæs-
thetic, so much so that improvement is observed before the aspiration is commenced.

Displacement of the heart is always an indication for aspiration. We have always found that the cases which are most likely to develop grave symptoms are those in which an apical pneumothorax exists with a gross haemothorax. In these cases the displacement of the heart is extreme. The pressure of air also is liable to sudden increase, resulting in syncope.

Especially is this sudden increase of pressure in a pneumothorax to be feared in the cases with persistent cough.

Among our earlier cases were some with considerable effusion treated only by drug and expectant treatment. The clinical result after two months' observation and X-ray examination was interesting. The diaphragm remained fixed and comparatively immobile, even in deep inspiration; there was much flattening of the chest on the affected side, and clinical evidence of very great pleural thickening, as shown by wooden dulness and diminution of breath sounds, combined with a return of vocal resonance and tactile vocal fremitus. Respiratory exercises begun with care did not appear to effect much result before the patients were transferred.

The treatment of pneumothorax is called for by the amount of intrathoracic positive pressure; this is to be judged by the degree of cardiac displacement and the severity of the dyspnoea and palpitation. Death occurs often from heart failure and dilatation of the right heart owing to the rapid dislocation of that organ. Aspiration of the fluid or resection of a rib relieves the pressure of air without any necessity of withdrawing air in cases of gradual collection; but in acute and rapid pneumothorax it is necessary not only to empty the chest of fluid but also of air. We believe that early resection of a rib in selected cases is most valuable. In the majority of cases, air is more or less rapidly absorbed, especially if a coexisting haemothorax is aspirated. There was no case in this series of the collection of gas due to gas-producing organisms.

Empyemata developed in less than ten per cent of the cases comprising this series. The cause, except in the cases of fracture of ribs with a ragged external wound caused by fragments of shell and bomb casing, is largely due to infection from within, from the interior of the lung. Bacteriological examination of the fluid obtained by aspiration showed the presence of streptococci, staphylococci and bacilli presenting all the variety of morphological characters of mouth organisms. In empyemata the streptococcus is the dominant organism, though, at first, its presence may be
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masked by other coexisting forms. Effusions with deposit on
standing, chocolate or opalescent green fluids are always to be
-treated as empyemata without waiting for bacteriological con-
firmation.

The treatment is resection of a low rib; as the diaphragm is
depressed by the weight of blood effused, it is easy to resect a
portion of the tenth rib and to obtain thereby excellent drainage.
Temperature falls at once after this operation and remains low;
if, however, there is a recrudescence of fever the cause must be
looked for in the infection of clot. This clot should be removed
by careful manipulation with the gloved fingers; care is to be
taken that fresh bleeding does not result from injury to the wound
in the lung. Only in the cases of infection of the clot is irrigation
advisable; in the cases of foul discharge—and in some cases there
is a *Bacillus coli* infection superimposed—irrigation with hypo-
chlorite solution or iodoform in ether rapidly clears up the odour
and profuseness of the discharge.

The clinical diagnosis of empyema is helped by X-ray examina-
tion; the fixation and immobility of the diaphragm, the displace-
ment of the heart and the shadow of the effusion are well shown.
There is no level of shifting fluid as is seen in early cases of
haemothorax; in empyema the effusion is limited by pleural
adhesions.

But the aspirating needle is of greater value than the
X-ray or the stethoscope. For, owing to the thickening of pleura,
there is often much masking of the clinical signs.

No attempt should be made to remove rifle bullets or shrapnel
balls lodged within the lung or chest wall unless they are quite
superficial, or unless at a subsequent resection of rib the projectile
comes easily within reach.

Operation findings, when a rib has to be resected, show the
value of early aspiration. The exploring finger finds a mass of
semi-organized clot, often one inch deep, covering the diaphragm
and filling the sulcus between the diaphragm and the parietal
pleura.

In cases of fracture of ribs with ragged external wound great
care must be taken to explore and thoroughly drain the original
wound. Broken and comminuted fragments of rib are very liable
to acute spreading osteomyelitis, which, by causing pain and much
irregular temperature, may cause erroneous conclusions to be drawn
with regard to the condition of the interior of the pleural cavity.

One of the cases of this series was instructive: a ragged external
wound with fracture of ribs resulted in a valvular wound opening into the pleural cavity. Air was sucked in at inspiration, but the egress of air was prevented by the valvular opening. There was a rapidly progressive pneumothorax with great displacement of the heart and urgent symptoms. Immediate resection of a rib allowed free air exit and corrected the cardiac condition.

Post-mortem examination provides the essential confirmation to the clinical conclusions. In cases of apical pneumothorax there is an escape of air under positive pressure when the pleural cavity is opened. In cases of empyema there is great thickening of the parietal pleura with semi-organized and adherent clot.

The lung wounds are instructive. Clean perforating wounds are not seen in the cases which come to autopsy. There is much tearing and laceration of lung tissue. The lung is firmly adherent, by bands of lung tissue the thickness of the finger, to the entry and to the exit wound. The exit wound, in the cases of perforating wound by shrapnel ball, is plugged with lung tissue, thus accounting for the cases of surgical emphysema in the neighbourhood of the exit wound.

In one case of this series the pulmonary vessels were thrombosed from an injury caused by shrapnel ball not amounting to solution of continuity of the vessels. Here the whole lung had broken down into a gangrenous and friable pulp. The physical signs in this case were particularly misleading.

Infarction of the lung, red hepatization of true lobar pneumonia, hypostatic congestion and much thickening of the visceral pleura are observed in cases of long standing.

The heart remains fixed in its position of displacement in cases of empyema of long standing. This is also observed in cases where there is long delay before aspiration is performed in cases of hemothorax. Even after aspiration within ten days of the development of the hemothorax the displacement of the heart is very slowly corrected; by clinical examination the apex beat only slowly returns to its former position.

Where the lung is floated up upon the surface of fluid, rising to about the level of the fourth rib, it is compressed between the fluid and the unyielding chest wall. At autopsy the anterior margins and surface of the lung are emphysematous and the margin of the lung is pushed across the mid-sternal line.

A specially well-aired ward was established at ——— Hospital for the sole care of these cases of wounds of lung and chest wall.
One advantage lies in the removal of these cases from contact with surgical cases of compound septic wounds of long bones and cases of gangrene and cellulitis. This care has been justified by the small number of cases of infected hæmothorax; of this series only six cases of empyema developed. There is also the additional advantage of continuity of treatment at the hands of one medical officer and the special organization which leads to swiftness and accuracy in performing aspiration or resection of rib.

Of this series there have been six deaths: two from empyemata, in which the clot became so infected as to poison profoundly the patients in spite of attempts at complete removal of infected clot and lavage. Four deaths occurred from rapid development of apical pneumothorax in cases of hæmothorax.

To Colonel Gulland, A.M.S., for the special care in supervision of our treatment of wounds of the lung and pleura the credit of our success in the treatment of this condition is due.