Remarks
ON
PENETRATING GUNSHOT WOUNDS OF THE CHEST, AND THEIR TREATMENT.

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THIS paper is based on 500 cases which have come under our care during three periods, namely:

October 13th to December 12th, 1916	...	56 cases.
April 1st to April 25th, 1917	...	79 ,,
June 7th to August 31st, 1917	...	365 ,,

These periods cover different phases of warfare and include periods of heavy fighting and of relative quiet.

We have included all cases of penetrating wounds of the chest admitted to the casualty clearing station, however serious the complications, and have excluded those cases of concussion haemothorax in which the pleura had not been opened by the missile.

For the analysis of cases and results, shown in the subsequent tables, we have excluded the first two periods because:

1. It is uncertain that all chest wounds admitted to the casualty clearing stations were seen by us in those periods.
2. It is probable that the more serious cases were diverted by the field ambulances ahead of us to advanced operating centres.
3. The clearing stations at which we were working were so placed that a period of twenty-four hours elapsed between wounding and admission of patients. Thus many of the more seriously wounded must have died in advanced posts.
4. In this last period we have been able to follow up our cases to the base or England, and have thus been enabled to include base mortality with casualty clearing station mortality in the subsequent tables.

We think that the analysis of cases from one casualty clearing station will give a fairer conception of the mortality.

The objects of our investigation have been to determine accurately the cause of death, and the possibility of lessening mortality and shortening convalescence by early operation.

We wish to render our thanks to Surgeon-General O'Keefe, Surgeon-General Bruce Skinner, and Surgeon-General Porter, for facilities given for this investigation, and to Lieut.-Colonel J. E. Davey, O.C. Canadian Casualty Clearing Stations, and his staff, who have rendered us every possible assistance; also to the Medical Research Committee, which has furnished us with books and instruments.

CAUSES OF DEATH AND PROLONGED ILLNESS.

I. If the complicating wounds are disregarded the causes of death in pure chest wounds may be divided into three groups:

(*a*) Deaths a few hours after admission to a casualty clearing station, due to very extensive and severe injuries which can seldom be aided surgically.

(*b*) Deaths in a casualty clearing station after a few days. These are almost always due to sepsis of the pleural cavity and its contents.

(*c*) Deaths at the base; sepsis again is the great factor.

Similarly, prolonged illness is almost entirely due to sepsis.

Therefore treatment should be directed towards the elimination of infection in chest wounds as in any other wound.

II. The pleural cavity may become infected:

(*a*) By the missile and portions of cloth carried in by it. Splinters of indriven bone are a material factor both in causing and maintaining sepsis.

(*b*) Through the wound of the chest wall; a wound that opens directly into the pleural cavity, and through which air is sucked, will always lead to infection. Further, a wound even of moderate dimensions, through which air is not being aspirated, unless adequately dealt with may become septic in the course of one or two days, and unless the thoracic cavity is sealed off organisms pass through into the pleural cavity, where they find the blood a convenient medium. This accounts for many cases which show septic changes only after four or five days.

(*c*) From the wound of the lung in which foreign body, bone, or clothing may be retained.

PRINCIPLES OF TREATMENT.

A patient admitted with a suspected penetrating wound of the chest is put to bed and allowed to rest undisturbed for one or two hours to recover from shock. The only exception to this rule is when there is a large opening into the pleura through which air is sucked. In such cases the opening is immediately closed by temporary skin suture without anaesthetic. This gives the patient immediate relief. We are strongly of opinion that all such wounds might be sewn up with great advantage at advanced dressing stations. The procedure is easy, rapid, and much more efficient than plugging and strapping.

The Italian surgeon Bastianelli recommends the use of a dumbbell-shaped pneumatic bag, which when inserted into an open thorax and inflated prevents suction of air, and also controls intercostal bleeding. We have no experience of its use, but the idea seems excellent.

A survey is then made of the whole patient, and all wounds examined; evidence of haemothorax, pneumothorax, or collapse of lung is sought. Much may be gained by careful examination of the movements of the chest as a whole; the position of the heart is of the greatest importance. The whole body should be searched for complicating wounds, especially with regard to abdominal and spinal injury. Cases in which the missile has not passed out of the body should be examined by *x* rays, by which valuable information may be gained concerning:

1. The position and size of the foreign body.
2. The existence and extent of haemothorax and pneumothorax.
3. The condition of the opposite lung, cardiac displacement, and movements of the diaphragm.

INDICATIONS FOR EARLY OPERATION.

The indications for early operation are:

1. A ragged wound of the soft parts.
2. Compound fracture of ribs.
3. Bleeding from parietal wound.
4. Suction of air into the pleural cavity.
5. Retention of a large foreign body in an accessible position.
6. Pain (often the result of indriven splinters of rib scratching the lung with every respiratory movement).
7. Rapidly increasing pneumothorax due to a valve-like opening into the pleural cavity, which allows air to be sucked in and prevents its expulsion.

TREATMENT WITHOUT OPERATION.

Where none of these indications is present—that is, when the wounds of the chest wall are small and clean, when there is no evidence of fractured ribs, when the foreign body retained in the lung or mediastinum is small—the case is treated on general medical principles. The patient is kept in bed, propped up or flat as he prefers, and a careful record is kept of the pulse, respiration, and temperature.

Haemothorax.

When the haemothorax is large enough to produce symptoms by its size it is aspirated; otherwise the chest is only needled if the condition of the patient suggests that a haemothorax is becoming infected, when a sample of blood is removed for bacteriological examination. The chief clinical signs of infection are a rising pulse rate, high temperature, sudden increase in the size of an effusion, or sudden occurrence of pneumothorax several days after the receipt of the wound.

Massive Collapse of Lung.

Apart from collapse of the injured lung as the direct result of an effusion of blood or air, we have noted massive

collapse in about 10 per cent. of cases (contralateral in 1 per cent.). It was invariably in the lower lobes, and is indicated by respiratory restriction of the chest wall with cyanosis and distress, diminution of percussion note, and bronchial breath sounds over the base of the lung. Theories as to the causation of this condition are numerous and unsatisfactory.

Cyanosis.

Cyanosis, which is often due to collapse of one or both lungs, is best treated by inhalation of oxygen for five or ten minutes every half-hour.

Pneumothorax.

Pneumothorax is frequently associated with haemothorax in the early stages, but, as a rule, the absorption of air is rapid, and when the chest is closed a pneumothorax may disappear completely within twelve hours after the receipt of the wound.

Occasionally the wound of the chest is of such a nature that some air may be sucked in by each inspiration, and yet none escape on expiration (valve-pneumothorax). The pneumothorax increases in size, and the distress of the patient is very marked. Aspiration is useless, and early operation, affording relief of pressure, followed by repair and closure of the chest wall, is the correct procedure.

Surgical Emphysema.

This is of frequent occurrence. Often it extends throughout the subcutaneous tissues, but does not require any special treatment even when very extensive.

Substernal Emphysema.—In addition to this general distribution it occurs in the extrapericardial fat and loose connective tissue of the anterior mediastinum. This "substernal emphysema" may give rise to physical signs, which are especially noticeable when the emphysema is localized to the mediastinal tissues. Such signs are:

1. Absence of the precordial area of dullness on percussion.
2. Crepitations which occur with each heart beat, and may more or less replace the heart sounds.
3. A pericardial, or pleuropericardial, murmur may be present, and may render a differential diagnosis from pericarditis very difficult. As a rule, the general condition of the patient, and a moderate heart rate with the absence of pain, will suggest that such a serious complication as pericarditis is not present.

Apart from the above physical signs the condition is of no significance, and usually disappears in a day or two.

A steam tent is sometimes necessary for the treatment of bronchitis. We endeavour to retain patients for ten days at least.

TREATMENT BY OPERATION.

TIME OF OPERATION.

The best time is as soon as possible after the patient has recovered from the initial shock, and with us has averaged about six hours after admission.

WOUNDS OF THE SOFT PARTS.

If nothing further be done, wounds of the soft parts, unless small and clean—for example, rifle bullet wounds—should be excised, because otherwise they will suppurate, and infection will spread along the track of the missile into the pleural cavity, giving rise to empyema.

FRACTURE OF RIBS.

Excision of the wound of the soft parts leads the surgeon to the ribs. More often than not the ribs or scapula are broken, and whether or not further operative procedure be undertaken for opening the chest, the splinters of bone should be removed, ragged ends of rib cut clean off, and all dead tissue excised.

Examination of the wound in this way may reveal either a bleeding intercostal artery or a large hole, hitherto unsuspected, leading into the chest, and a finger introduced into the pleural cavity may discover splinters of bone, free or sticking into the lung. Such splinters should be removed, for we believe that they play a great part in the production and maintenance of infection.

At this stage the case has been converted into one of open haemothorax; if it is decided not to open the chest further the blood should be evacuated as far as possible by rolling the patient on to his side and then the chest should be closed in layers—pleura to pleura, muscle to muscle, and skin to skin. When there is a deficiency of pleura, muscle should be brought over the gap; where there is a deficiency of pleura and muscle, even if a flap has to be cut, skin should be brought over the gap. The chest must be closed.

RETENTION OF LARGE FOREIGN BODY.

By a large foreign body we mean a shell fragment about one inch by half an inch, with which are associated, as a rule, splinters of indriven rib and clothing; we do not include a rifle bullet.

It will be understood from this that we attribute much more importance to infection and damage caused by the missile than to the retention of the foreign body itself. But if the missile lies free in the pleura, or projects into the pleura either from the lung or the chest wall, it should be removed.

When it is decided that the removal of a retained foreign body is necessary, the operation may be undertaken either through the wound or by fresh thoracotomy. If the route chosen is through the wound, the procedure undertaken will be that detailed above for the excision of a wound, but instead of the removal of the broken ends of rib a resection of four inches will be necessary.

The choice of route for removal of a retained foreign body depends upon its position relative to the wound of entry. Where possible, thoracotomy through the wound is preferred, because in any case the wound has to be excised, and less damage is done to the chest wall.

A fresh thoracotomy may be done by resection of four inches of rib, or by an incision in the intercostal space. The easiest route is probably *via* the fifth rib in the mid or anterior axillary line; by this means, with the insertion of a retractor, any part of the pleural cavity can be reached.

On looking into the chest thus opened, the damaged lung can be seen, and the foreign body may be immediately visible; if blood obscures the view, it should be removed by rolling the patient or by mopping. If not visible, the foreign body may be sought by inserting the hand into the pleural cavity, and may be removed through the wound of entry into the lung, or by a fresh incision into lung tissue.

Lung tissue may be incised without fear, because any fresh bleeding following incision is easily controlled by suture. Continued bleeding from the lung is exceedingly rare, and in the few cases observed was due to inability of the lung to collapse, either from adhesions or splinters of bone. Early operation, even within twelve hours, with evacuation of the haemothorax, does not cause recrudescence of bleeding.

When readily accessible the wound of the lung should be cleansed either by excision or by wiping with gauze. It should always be sutured, because, if left open, organisms can pass from the lung into the pleural cavity, and there is evidence that the lung is capable of dealing satisfactorily with infections—gas gangrene of the lung, for example, is of very rare occurrence.

ABDOMINO-THORACIC INJURIES.

Injuries involving both the chest and the abdomen are not infrequent, either as the result of a single or multiple missiles. When a missile has traversed both chest and abdomen the diaphragm is necessarily injured and abdominal viscera may protrude into the pleural cavity. As efficient repair of the diaphragm can only be obtained from above it is better in such cases to open the chest first, replace the abdominal contents, suture the diaphragm, deal with the chest as already indicated, and then, if there is evidence of injury to the hollow viscera, laparotomy may be performed.

The passage of a small missile through the diaphragm may not necessitate repair; in such a case, with evidence of injury to hollow viscera, the abdomen is afforded preferential treatment.

Similarly, with multiple injuries involving both chest and abdomen, it is probably better to deal with the abdominal injury first, but when the patient's condition allows the chest injury should be dealt with in addition, even if only a minimum can be done.

INFECTED HAEMOTHORAX.

We believe that the incidence of infection will be diminished when more attention is paid to complete excision of wounds of the chest wall. But infection of the intrapleural contents occurs also in cases of small clean wounds where no foreign body is retained, and also after excision of the parietal wounds, and particularly in men who have lost a large quantity of blood.

The infecting organism and resulting toxaemias vary considerably; in our experience, while a mixed infection is always severe, the anaërobic bacilli are among the most benign, and the streptococci—especially if haemolytic—are the most dangerous. Evidence of infection is rarely seen before the third day after the wound and may be delayed for many days. The only certain evidence of infection is either a positive bacteriological finding or the removal of stinking fluid. By clinical signs it is often possible to diagnose the presence of infection before organisms can be detected by the bacteriologist.

As soon as infection is proved or suspected, the essential treatment is to empty the chest of all infected blood and clot. This cannot be done by aspiration, and must be done by open operation.

The common practice has been resection of one inch of rib and insertion of a tube. Provided that the operation is done within a few days of the receipt of the wound, we believe that it is better to do a wider resection, by which means all clot can be removed and the pleural cavity washed out with eusol, and then to close the chest in layers.

This method offers the following advantages:

1. The chest may remain closed, the organisms not developing.
2. The lung is allowed to expand, and adhesions may form which will prevent complete collapse, even if the pleural cavity is subsequently drained.
3. Respiratory distress is much less with the closed chest.

The condition of the pleural contents can be determined by post-operative needling. If infection persists the chest must be opened and drained; this can be done by the removal of sutures from the resection incision, provided only that the incision has been made in a suitable place, that is, low and postero-laterally.

ANAESTHETICS.

Patients bear operation well, and take a general anaesthetic satisfactorily. We believe that any patient on whom an intrathoracic operation is to be performed should have a general anaesthetic.

We have generally administered chloroform through a Shipway's apparatus. One side of the chest can be opened without danger of respiratory failure, except when there is damage or collapse of the opposite lung, as evidenced by inspiratory retraction of the chest wall.

A short experience of gas and oxygen anaesthesia leads us to the belief that it is an ideal anaesthetic for such cases.

CIRCULATORY DISTURBANCES.

When one side of the chest is open, either as the result of an operation or the original injury, and also in cases of pneumothorax, respiratory variations in pulse volume are very marked. During inspiration pulse volume diminishes and pressure falls; the pulse may become imperceptible. This condition is not of serious import, and, when the chest is closed, diminishes considerably or disappears altogether. We mention it as it is apt to alarm the anaesthetist.

CONTRAINDICATIONS FOR OPERATIONS.

1. Shock and collapse, such as would be contraindications for any surgical procedure.
2. Small clean wounds, without evidence of serious intrathoracic injury.
3. Retention of a small foreign body in the lung or mediastinum. In our experience of early convalescence the foreign body, if small, may be disregarded. We are not in a position to speak of the ultimate results.
4. Collapse of the opposite lung, as indicated by inspiratory retraction of the chest wall on the side opposite to the wound. In this condition an anaesthetic and opening of the chest may be fatal.

In one of our cases a plug of blood and mucus had been sucked into the bronchus of the opposite lung, and the patient died of respiratory failure when the injured side of the chest was opened.

OPERATIVE TECHNIQUE.

THORACOTOMY THROUGH THE WOUND.

The first essential is the complete excision of the wound including the skin, muscles, and broken ends of rib. This having been completed, the chest should be opened with fresh instruments. An incision is made from the edge of the wound through the skin along the line of the broken rib, either forwards or backwards, to obtain the best access to the cavity of the chest. Then the muscles are incised down to the rib, retracted, and the periosteum incised along the middle line of the exposed rib. Along this line the periosteum is stripped off with a rugine. A Doyen's periosteal rib elevator is then slipped in and the periosteum entirely separated. The bone is then cut through with a pair of rib shears or bone forceps and removed. To allow free access to the pleural contents and insertion of the hand it is necessary to take away four inches of rib.

The posterior layer of periosteum of rib with the parietal pleura attached is next incised with a pair of scissors along the middle of the gap. Then a retractor or rib spreader is inserted and the chest opened widely.

THORACOTOMY BY FRESH INCISION.

As previously stated, this operation may become necessary when thoracotomy through the wound will not allow access to the injured portion of lung, for instance, when the wound is in the lower and posterior part of the thorax and the foreign body near the hilum or in the upper lobe of the lung.

Choice of Route.

Resection of four inches of the fifth or sixth rib in the anterior axillary line gives a good exposure of the thoracic contents, and if there are no other considerations this is probably the best and easiest route to follow. It has to be remembered, though, that if drainage of the pleural cavity has to be performed later on, it cannot be done effectively through this incision. Therefore, if the nature of the wound and missile is such as to indicate probable future infection, it may be advisable to choose a lower rib and make the incision more posteriorly.

Operation.

A six-inch incision is made along the line of the selected rib, and continued down to the periosteum, which is stripped off the anterior surface with a rugine. With rib elevator and shears four inches of the rib is resected. The posterior layer of periosteum with the parietal pleura attached is then incised along the whole length of the middle of the gap, and the retractor or rib spreader inserted.

This is the method we have usually adopted with good results.

Alternative Methods of Opening Thorax by Fresh Incision.

1. Incision through an intercostal space, with or without section of one or two costal cartilages. A good exposure may be obtained by this method, provided the patient is young and has elastic ribs. We have found some difficulty in closing the chest efficiently afterwards, and prefer the resection method.
2. Before the war the pleuro-costal flap method was advocated. This is unnecessary, and prolongs the operation.
3. Cowell has suggested that the rib should be split along its longitudinal axis. This method merits trial.

PROCEDURE WITHIN THE THORACIC CAVITY.

After the chest has been widely opened, either through the wound or by fresh incision, it is advisable to remove the blood from the pleural cavity, first, because it is easier to see what has to be done, and, secondly, because removal of the blood relieves respiratory difficulties by lessening pressure on the mediastinum. The blood can be removed

by rolling the patient on to his side. Probably, however, it is better to do it by swabbing with gauze and scooping out the clot with the gloved hand; less disturbance is caused to the patient by this method.

This done, the gloved hand should be inserted into the pleural cavity and swept round in order to detect and remove any splinters of bone which may be lying free, or the missile and portions of clothing. These are most likely to be found in the pleuro-diaphragmatic reflexion.

Next the foreign body, if retained in the lung, may be detected by the fingers, and with the aid of two pairs of lung forceps the affected area is brought into the opening of the chest. The lung can be handled as easily as a coil of intestine, and without causing a great fall of blood pressure.

Treatment of the Wounded Lung.

A foreign body, when present, seems to lie generally near the surface of the lung, and can easily be removed; if necessary, a small incision may be made through the lung substance.

The hole in the lung should now be explored for splinters of bone and shreds of clothing, and cleansed as far as possible by swabbing. When there is a large ragged wound, and it is anatomically possible, a wedge of lung may be removed, or the edges of the hole clipped with scissors.

In any case, whether the wound is excised or not, it should be closed by catgut sutures, in either one or two layers, according to the depth of the wound. Bleeding is easily controlled by such suture.

Cleansing of the Pleural Cavity.

In most cases it is only necessary to cleanse the pleural cavity by swabbing it dry and clean. If, however, there has been much soiling, it is advisable to wash it out with either warm saline or eusol. In any case, however, the chest should be left dry, an essential factor in the early expansion of the lung.

Closure of the Chest.

Whether the operation has been performed through the wound or by fresh incision, the chest should always be closed. The relief afforded the patient is instant and marked. An attempt should be made to repair the chest wall in layers—pleura to pleura, muscle to muscle, and skin to skin.

Where a large hole has been blown through the chest wall it may be impossible to make the edges of the pleura meet; in that case muscle should be made to cover the gap, even if a flap has to be cut. Finally, the skin should be closed by interrupted sutures. In the majority of cases healing will be by primary union.

Instruments.

The following instruments have been found of service:

(1) A self-retaining retractor or rib-spreader. This is of great value, and allows easy manipulation of the pleural contents. We use one obtained from Schaerer's, instrument makers, of Berners Street, London, W. Another pattern, Tuffier's *écarteur*, can be obtained from Parisian instrument makers.

(2) Doyen's periosteal rib elevator, and (3) Doyen's rib shears, can both be obtained from the ordinary English instrument makers.

(4) Duval's lung forceps (Pince de Poumon à Duval), Maison Collin, Rue de l'Ecole de Médecine, Paris.

(5) An electric head lamp.

Table of Results, showing Casualty Clearing Station and Base Mortality.

Total number of cases	365
Total deaths	76 = 20.8%
Deaths from complications:	
Chest and head	6
Chest and abdomen	14
Chest and spine	4
Chest and heart	4
Chest and large systemic vessels	2
Chest and multiple wounds	14
Chest and lethal gas	1
Total	45

If the above 45 deaths from complications are excluded there remain 320 cases. Of these 31 died (9.6%) of chest injuries.

Causes of deaths from chest injuries:	
Shock and haemorrhage	19
Sepsis	10
Bronchitis	2
Total	31 = 9.6%

Table of General Results.

	Recovered.	Died.	Total.
Cases operated on	83	21 (20.2%)	104
Cases not operated on	206	55 (21.07%)	261
Totals	289	76	365

Average stay in casualty clearing station ... ... 6.7 days.

Table of Operation in 365 Cases.

Operation.	Total.	Subsequent Empyema.	Recovered.	Died.
Excision of wounds of parietes	36	—	34	2
Thoracotomy for repair of chest wall and lung with evacuation of haemothorax and closure of chest	24	4	15	9
Thoracotomy for removal of foreign body, repair of lung, evacuation of haemothorax, and closure of chest	16	2	13	3
Thoracotomy for infected haemothorax, and closure of chest	15	12	10	5
Abdomino-thoracic operations for repair of chest, replacement of viscera, suture of diaphragm	12	4	10	2
Laparotomy, with small wound of diaphragm not requiring suture	1	—	1	—
Aspirations	48	—	—	—
Total (excluding aspirations)	104	22	83	21

Table showing the Nature of the Missile and the Percentage Mortality in 290 Cases.

		Mortality.
Rifle bullet, entry only	12	16.6%
Rifle bullet, entry and exit	62	9.68%
Shell fragment (including bombs)—		
Entry only	158	20.9%
Entry and exit	19	47.3%
Shrapnel ball	11	9.09%
Multiple shell wounds	28	21.43%
Total	290	

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A NOTE was published last week on the experiments of Hanzlik and Karsner on albuminuria and haematuria after the use of salicylates. We have since received a report of a meeting of the Section of Medicine of the Royal Academy of Medicine in Ireland, on October 26th, at which Dr. Boxwell mentioned the case of a soldier in whom an attack of haematuria immediately followed the exhibition of sodium salicylate on two occasions. Blood was present at first, but later the corpuscles disappeared, though the urine remained a deep brown colour for some time. The spectroscope appearances were negative. At the same meeting Dr. Wallace Beatty described a case of sporotrichosis in a boy aged 15½ years, a worker in a brush factory, who was injured on the front of the wrist by a piece of bass. Professor McWeeney confirmed the diagnosis by cultures. This, it was stated, was the first case recorded in Ireland. Dr. Walter G. Smith pointed out that the condition might be confounded with syphilis, tuberculosis, and purulent inflammation. It could be cured by potassium iodide.