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INDICATIONS FOR SURGERY IN PENETRATING WOUNDS OF THE CHEST THE IMPORTANCE OF PULMONARY INJURY*

BY

G. QVIST, F.R.C.S.

Lieut.-Col., R.A.M.C.; Officer Commanding Surgical Division, 16 (Br.) General Hospital. M.E.F.

The most important object in treatment of injuries involving the pleura is early pulmonary re-expansion, since by this means pleural infection is limited and respiratory efficiency restored. Although this is well recognized and has been emphasized again recently (Thomas and Cleland, 1945), expansion of the lung, and in fact the pulmonary condition altogether, is usually regarded as a factor secondary in importance to the pleural lesion, and attention is focused mainly on haemothorax. It is one of the purposes of this communication to suggest that the prognosis of penetrating wounds is influenced as much by the condition of the lung as by that of the pleura.

It is a matter of experience that, on the average, expansion of the lung is slower after penetrating wounds than after non-penetrating injuries, quite apart from infection. This can be seen in a comparison of different types of haemothorax following these two varieties of chest injury, and is shown diagrammatically in Fig. 1. Thus in both haemothorax and

thorax is an unfavourable influence and greatly increases the chances of pleural infection. The most important predisposing cause of empyema is the association of infected foreign matter and haempneumothorax. If the lung is fully expanded, infection may not occur even in the presence of a large foreign body, and if it does it will be localized. Such cases are not uncommon, and it is to be assumed that the foreign body has entered the pleura without damage to the lung so that pneumothorax has not occurred and infection has been avoided or limited.

Elimination of the pleural space is of such significance that it is reasonable to regard early pulmonary re-expansion as even more important than avoidance of infection—first, because the former is a most useful means of promoting the latter, and, secondly, because the prognosis of localized basal empyema is much better than that of persistent total haempneumothorax, even if this remains sterile.

FIG. 1

FIG. 2

FIG. 1.—(i) Haemothorax. (ii) Haempneumothorax. (iii) Apical or total haempneumothorax.

FIG. 2.—Treatment of chest injuries.

FIG. 3

FIG. 3.—Aspiration of large haemothorax.

haempneumothorax pulmonary re-expansion is less rapid after penetrating wounds, while with total haempneumothorax prognosis is good in the case of non-penetrating injuries; but after penetrating wounds the chances of persistent pulmonary collapse are high even in the absence of infection, and it is this type of case which calls most frequently for surgical evacuation of pleural haematoma. It is suggested that in most cases this difference is due to pulmonary injury which is not always recognized, and that treatment directed to the pleura alone therefore will not always result in re-expansion of the lung. It is significant that, with non-penetrating injuries, if there is difficulty in resolution of haempneumothorax it is nearly always due to pulmonary injury with broncho-pleural fistula.

In addition to less favourable expansion of the lung after penetrating wounds, prognosis is worse also because of the greater risks of infection. Here again the presence of pneumo-

With the majority of small penetrating wounds the chances of both pneumothorax and infection are small, and conservative treatment is usually justified. With large penetrating wounds, however, the amount of damage to lung and to chest wall makes both pneumothorax and infection almost inevitable, so that surgery is essential. Thus we can summarize the main principles of treatment of penetrating wounds as: (1) early elimination of pneumo- and haemo-thorax, and (2) early surgical toilet of large wounds of the lung and pleura.

There are three zones at which treatment may be necessary—forward, base, and at home. The last includes late removal of foreign bodies and treatment of chronic empyema, and will not be discussed here.

Treatment in the Forward Zone

Apart from special wounds involving the diaphragm or pericardium and primary haemorrhage, there are two groups of penetrating wounds, large and small, from the point of view of

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treatment. The former require operation, while the latter should be included for treatment with non-penetrating injuries as *simple haemothorax* and treated by aspiration (Fig. 2).

Indications for Operation

Decision on the need for operation is often difficult, and must be made on the individual case. As a general rule, however, it can be said that if a penetrating wound is larger than about 1 cm. it will probably need operation. If there is a pneumothorax as well, the necessity for surgery is almost certain, because there is enough damage to the chest wall or to the lung, or to both, to endanger life or to render infection probable. If there is no air in the pleura the pulmonary lesion will be localized and the outlook favourable; the best prognosis in penetrating wounds of the lung and pleura is undoubtedly in those cases in which there is an adherent pleura.

While there are numerous recognized indications for operation, such as the presence of a sucking wound, compound fracture of rib, retention of a large foreign body, or a large wound of the chest wall, these nearly all depend for their surgical importance on the existence of conditions in which pneumothorax is likely, which in practice are provided by a wound larger than about 1 cm. in the visceral or parietal pleura. If the pleural wound is smaller than this it will be blocked by haematoma or muscle, and none of these indications for operation will arise. In this type of case little is to be gained by wound excision, whereas there are operative risks such as the undesirable initiation of pneumothorax by disturbing the wound, and increase in size of haemothorax due to rise in blood pressure under anaesthesia.

If the pleural wound is larger than 1 cm. it usually means that there is also a fractured rib or sucking wound with potential or actual pneumothorax, or a large wound of the chest wall, for any of which surgery is necessary. Prognosis in such cases depends above all on the amount of pulmonary damage. It has been pointed out that open pneumothorax is often tolerated very well—as, for example, with thoracotomy under local analgesia—and that some patients from Dunkirk were alive five or six days after injury in spite of an open wound of the pleura (Barrett, 1940-1). The explanation is probably to be found in the absence of pulmonary injury: a sucking wound is much less serious if the pneumothorax is due to injury of the chest wall alone than if there is also a broncho-pleural fistula.

The size of the pulmonary wound is thus important as an immediate danger in the production of pneumothorax. In addition it is also of great influence later in the development of infection or delayed pulmonary expansion, so that adequate surgical toilet is essential for such wounds.

Indications for Aspiration

Treatment of small penetrating wounds is by aspiration of haemothorax and instillation of intrapleural penicillin. While this does not need discussion here, there are two practical points which are of importance in the forward area. These are: (a) Selection of the most urgent cases for immediate treatment, while others may be evacuated to the base hospital. The case with displacement of the apex of the lung requires aspiration more urgently than one with haemothorax limited to the base, because the prognosis of persistent apical haemothorax is very much worse. (b) Employment of the most rapid method of treatment with the minimum of apparatus. It is convenient to aspirate small effusions with a syringe and two-way tap, and large effusions by means of a blunt aspirating cannula or wide-bore needle attached to a water-seal bottle. A large A.P. refill needle is satisfactory, and the flow can be regulated at a steady drip by means of a standard blood-transfusion drip connexion (Fig. 3). The use of general anaesthesia, suction bottles, or laborious aspiration with syringe is usually not necessary. In this way the minimum of attention is required—a point of some importance to the busy C.C.S. physician—and several cases may be dealt with at the same time, the only really essential apparatus being a sufficient number of suitable needles.

Treatment at the Base

There are two conditions which call most often for treatment at this level—viz., delayed pulmonary expansion and infection.

1. Delayed Pulmonary Expansion

Expansion of the lung may be delayed by the condition of the pleura or of the lung; the former usually receives the maximum of attention as the problem of the unresolved haemothorax; but probably the latter, the condition of the lung itself, deserves as much care.

(i) *Unresolved Haemothorax*.—If aspiration fails to eliminate haemothorax within two weeks, surgical evacuation of the haematoma must be considered in order to avoid pleural fibrosis with an incompletely expanded lung. It is important, however, to select only the cases in which this is essential. The prognosis of persistent apical haemothorax is very much worse than that of basal haemothorax, because pulmonary efficiency is much poorer with collapse of the lung at the apex than at the base. In fact, the outlook for a sterile apical haemothorax is worse than for a basal empyema so far as final function is concerned. Hence, if the apex is well expanded there is no need for early surgical evacuation of the basal haematoma, and in fact such treatment is dangerous, because thoracotomy involves pneumothorax with the possibility of apical collapse. It is wiser to defer operation in order to ensure firm union of the pleural layers at the apex. On the other hand, if aspiration of haemothorax with collapse of the upper lobe is proving difficult, evacuation of the haematoma should be carried out as soon as possible.

(ii) *Pulmonary Contusion*.—If the lung is uninjured its re-expansion will be hindered only by the pleural contents, as in the majority of non-penetrating injuries. But if there is a pulmonary contusion or laceration, this will delay re-expansion, quite apart from the state of the pleura. It is significant that the problems of unresolved haemothorax arise almost exclusively in penetrating wounds, suggesting that it is indeed the pulmonary injury which is vital, so that "delayed pulmonary expansion" is probably a better term than "unresolved haemothorax" for this condition. Inasmuch as its extreme vascularity makes the lung very resistant to infection, it also renders the pulmonary tissue extremely liable to contusion after injury, although in comparison with the more dramatic responses of the pleura this tends to escape notice. The effect of pulmonary contusion is to cause obstruction to the air-passages and thus lead to atelectasis of lobar or lobular type. Pulmonary re-expansion will then be slow and may even be incomplete. It will be found in nearly every case of haemothorax in which the lung does not re-expand easily that there has been penetration or perforation of the pulmonary tissue by the missile. Further, in refractory apical haemothorax the injury is nearly always of the upper lobe, with the result that the apex has not re-expanded. These cases can be contrasted with the non-penetrating chest injury where without pulmonary damage (or only superficial damage) aspiration of haemo- or pneumo-thorax is almost invariably followed by rapid and complete pulmonary re-expansion. Thus it is suggested that pulmonary contusion or laceration is the main cause of slow or incomplete pulmonary re-expansion following penetrating wounds.

Pulmonary contusion due to penetrating wounds is a condition well recognized in the absence of pneumothorax. The prognosis is usually good and resolution occurs fairly rapidly. But if a pneumothorax were initiated in such a case, the condition would be very similar to that in delayed re-expansion under discussion. It is a matter of common experience in chest disease that, in the presence of partial bronchial obstruction due to any pathological process, initiation of pneumothorax will often precipitate total atelectasis, which is difficult of resolution. This is seen commonly in tuberculosis and neoplasm, while it has been shown that, in atelectasis following lobectomy, resolution occurs very much more rapidly in the absence of a pneumothorax (Sellers, Thompson, and Qvist, 1944). In a comparable way, therefore, haemorrhage into the lung after injury might be expected, owing to interference with the air-passages, to show this lethargy in re-expansion in the presence of a pneumothorax.

Looked at from another aspect, it would be very surprising if, after penetrating wounds, there were no cases intermediate between immediately fatal lacerations and small contusions of the lung. It seems much more likely that it is just these cases of refractory haemothorax which represent the badly injured

lungs that have survived but are in a state of contusion unfavourable to adequate aeration, and in point of fact the vast majority of these difficult cases of haemothorax are severe penetrating and perforating wounds of the lung. If, even with the best treatment, some lobes never re-expand completely, it is not always the treatment that must be blamed, but the original injury, in the same way as loss of function of a limb may be determined by severe injury.

There is an interesting parallel to be found between the recognition of the relative importance of pleura and lung in haemothorax following trauma and that following lobectomy. In the earlier days of lobectomy delayed pulmonary expansion was regarded as secondary to pleural changes, but in 1939 it was pointed out by Tudor Edwards that pulmonary collapse was in fact the primary lesion in such cases. It is suggested that, in penetrating wounds similarly, the pleural condition is of secondary importance, and that injury of the lung is the main cause of delayed pulmonary re-expansion.

From the above considerations it would seem that treatment should be directed to both pleura and lung. If the apex of the lung is still unexpanded after 14 days, surgical evacuation of the pleural haematoma should be carried out. The object of this is to avoid pleural fibrosis so that subsequent expansion of the lung is not impaired.

Surgical evacuation of the pleural contents alone, however, would not always be expected to result in complete pulmonary re-expansion if there is also a contusion of the lung—which has in fact been borne out by experience of the operation. Treatment must be directed to expansion of the lung, and the most promising method at present is probably by suction. This method has been described recently by Thomas and Cleland (1945), and good results reported by the use of decortication, followed by suction for three or four days, using apical and basal pleural catheters.

The value of decortication is debatable. According to Thomas and Cleland (1945) it is important to perform radical operation to mobilize the whole lung, while this is not regarded as important by Sellors (1945). It would seem that such differences of opinion might well be explained according to the stage at which operation is undertaken. If surgical evacuation of haemothorax is carried out within two or three weeks of injury decortication should not be necessary. If, after evacuation of the haematoma and adequate post-operative drainage, preferably with suction, the lung does not expand, then re-expansion would probably not have occurred even if decortication had been performed, because the cause of delayed expansion is in the lung itself after its laceration and not in fibrosis of the visceral pleura. If surgical evacuation of the haematoma is delayed more than four weeks, then decortication may have a place in treatment; but again prolonged post-operative suction drainage is probably more important, even if such extension of drainage means development of secondary empyema.

2. Infection

The rate of infection of haemothorax following penetrating and perforating wounds has been given as 21.9% (Tudor Edwards, 1943) and 33% (Nicholson and Scadding, 1944). In 400 such cases at a chest centre in the B.L.A. empyema occurred in less than 14%. Considering that these cases of haemothorax included particularly those which were not progressing well and those which were already infected, it suggests that the figures of infection usually given are inclined to be rather too high.⁴ This is very likely, since a large number of simple haemothorax cases resolve rapidly with aspiration in the general base hospitals and never find their way into chest units, so that these good results are not included in the estimate. It seems likely, then, that infection in haemothorax after penetrating wounds is not more than 14%. Apart from this apparent decrease in infection rate, there is probably also a real diminution due to the prophylactic use of penicillin and to more adequate early treatment in the forward areas both in elimination of haemopneumothorax and in surgical toilet.

The association of haemopneumothorax with infected foreign material is the most common cause of empyema, so that the two essentials in prevention are early pulmonary re-expansion and adequate surgical toilet. Penicillin therapy is of value in

prophylaxis, but is second in importance to radical surgery in the elimination of potential infection. Once infection has occurred it is best to carry out drainage immediately, since penicillin therapy for infected haemothorax is rarely successful, and its continued use leads to pleural fibrosis and loculation.

Infection of the chest wall is of small importance in the absence of pleural damage. If there is a communication with the pleura, however, the condition is serious, since there is always an associated empyema and the patient suffers from toxæmia and open pneumothorax. This condition is seen most commonly with wounds of the anterior chest wall, where anatomical conditions favour infection, since the costal cartilages show poor resistance and there is often difficulty in closing a wound after adequate excision owing to lack of available muscle. There is always an associated empyema, and often contusion or atelectasis of a section of injured lung, which is usually the upper lobe corresponding to the anterior wound.

Treatment consists in the first place in prevention of sepsis by adequate excision of wounds, particularly those in the region of costal cartilages. With established sepsis and a secondary sucking wound, the first step is drainage of the empyema with temporary packing of the wound. The general condition usually improves considerably, after which secondary closure with muscle flap is carried out.

Infection of the lung is nearly always associated with empyema, and as a rule takes the form of a superficial infection with secondary sloughing into the empyema cavity. Abscess of the lung without empyema is rare, since pulmonary injury large enough to produce suppuration will also result in initial pneumothorax. Surgical treatment for pulmonary infection following injury is therefore usually incidental to the treatment of empyema, and is limited to the removal of sloughs or foreign bodies through the empyema tube.

Summary

The prognosis of penetrating wounds is worse than that of non-penetrating injuries because pulmonary re-expansion is slower and pleural infection is more likely.

Pneumothorax is of great significance in penetrating wounds and has an unfavourable influence both in the occurrence and resolution of infection and in the resolution of pulmonary contusion.

Pulmonary contusion and laceration are important causes of delayed expansion of the lung and are nearly always found in the condition of unresolved haemothorax.

Penetrating wounds of the upper lobe have the worst prognosis and are nearly always present with total or apical unresolved haemothorax.

If apical haemothorax persists for more than two weeks surgical evacuation is indicated, but this is contraindicated for basal haemothorax.

After surgical evacuation of haemothorax complete expansion of the lung may still not occur owing to residual pulmonary damage. Treatment for this condition is unsatisfactory, and the best at present is probably prolonged pleural drainage, preferably with negative pressure. Decortication is probably of value in late cases.

Infection of haemothorax following penetrating and perforating wounds occurred in less than 14% in 400 cases.

I should like to point out that most of the clinical experience on which this paper is based was obtained at a Chest Centre in the B.L.A., in which responsibility was shared with Major N. Lloyd Rusby, R.A.M.C., and Captain (Miss) Joan Cheale, R.A.M.C., to whom my thanks are due—to Major Rusby especially for the views expressed on the significance of pulmonary injury.

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