CHEST SURGERY IN WAR

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ANATOMY, PHYSIOLOGY, AND PATHOLOGY OF WOUNDS OF THE CHEST

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In injury to the chest, as also in the case of the head, it is not so much the damage to the container as the damage to the contents that matters. Actual damage to the enclosed viscera may have a profoundly adverse effect on the respiratory and circulatory systems, and to this may be added a series of secondary changes that result from the opening of the pleural cavity. These factors in themselves may be a grave menace to life, but even if they are successfully countered the question of the later development of infection has to be considered. Consequently a chest wound offers problems that are not found in many other parts of the body where the extent and effect of the destruction can be more or less estimated immediately.

Before entering into any discussion of anatomy and physiology it is well to have one precept in mind, and that is that the course and the effect of any missile after contact with the body are almost unpredictable. A well-known surgeon once stated that he was quite prepared to believe anyone's story about the behaviour of any missile on any human frame, and could add a few himself. The varying resistance of tissues, the angles of impact, and a whole host of factors make it imperative that no one should take the apparent track of a wound for granted when it comes to the question of diagnosis and treatment. Nor should it be forgotten that multiple injuries are only too common and that a small and apparently trivial wound may disastrously be overlooked in face of a more urgent and obvious lesion elsewhere.

Some Relevant Anatomical Points

In considering the gross anatomy of the chest there are some quite elementary points that are not perhaps always fully appreciated. The first point that strikes one when looking at the thoracic cage stripped of its coverings is its tapering or cone-shaped upper part. The squared appearance of the human torso depends on the shoulder girdle with its attached structures: in the region of the shoulders the actual thorax is deeply placed and is well covered by muscle layers, in contrast to the lower part, where ribs are easily palpable and the form of the thorax is quite apparent. The practical application of this feature lies in the fact that a missile traversing the upper part of the chest will pass through thick muscle layers which tend to close on the track and prevent communication of the pleural sac with the open air. On the other hand, penetration through the lower part of the chest is apt to leave the pleural cavity open and produce the dangerous form of "sucking" wound.

Among other points that may be emphasized is the height to which the diaphragm rises into the chest. This "doming" upwards of the muscle infringes considerably on the long axis of the thorax and leaves at the periphery the deep costo-phrenic sinus, which, it should be noted, is deeper behind than before. A penetrating wound of the lower chest will frequently puncture the diaphragm after injuring the lung fringe and produce varying lesions of the upper abdominal contents. The blood supply of the

diaphragm is more extensive than might be supposed for such a thin sheet of muscle, and this should be remembered if incision through its fibres is practised.

A cross-section of the chest shows that the vertebral column projects far forward into the cavity, so that the distance between the sternum and the spine is relatively small (a matter of some 4 to 4½ inches), but on each side lies a large paravertebral gutter which accommodates much of the lung tissue. It is in these areas that fluid tends to accumulate in the pleural cavities, and that aspiration or drainage of the free pleural sac will be most effective.

The obliquity of the ribs is a feature that makes orientation and location in the chest much more difficult than if the thorax was a conveniently arranged system of transverse segments. A study of the normal antero-posterior radiograph illustrates the differences in level between the anterior ends of the ribs and their corresponding vertebrae. For example, the third costal cartilage lies in the same plane as the seventh thoracic vertebra, though clearly there will be individual variations according to whether the subject has a long flat chest or one of the barrel emphysematous type.

At this point it is not out of place to stress the importance of radiography, and indeed the absolute necessity for x-ray films in two planes, for the location of foreign bodies and other abnormalities. The ordinary antero-posterior view may reveal a foreign body lying close to the heart, but it requires a lateral film to show whether the abnormal shadow lies outside the chest or within it.

The anatomy of the ribs and intercostal spaces is important in view of the relationship of the associated vessels. The intercostal space is for all practical purposes a clear and safe area as regards the risk of haemorrhage—a feature that is taken advantage of in aspiration of the chest or when a trocar and cannula are inserted into the pleural cavity. The segmental vessels and nerve are under cover of the lower border of the corresponding rib, and will be injured only if the bone is broken. If it is uncertain whether active intrathoracic haemorrhage is coming from lung and/or chest wall the fact that ribs are intact exonerates the intercostal vessels, but if they are fractured arterial bleeding is a possibility.

Effects of Various Types of Missile

As has already been stated, the effect of a penetrating wound of the chest is variable, but there are certain general tendencies which may be described briefly. A *bullet* produces a small-punctured entry wound, and by virtue of its high velocity drills a clean hole with a minimum of surrounding tissue damage. If it passes through an intercostal space on both sides of the chest it does not make an unduly large exit wound. If, however, a rib is touched an explosive effect is produced and bone is shattered and driven onwards. This impact reduces the velocity and may turn the bullet sideways or even reverse it. The wound track is consequently more extensive and the damage to soft tissues correspondingly increased.

Fragments of bomb are jagged and acquire a tremendous spin, though their velocity is lower than that of a bullet. The effect on the tissues is extreme laceration even though the entry wound may in some instances be small. Pieces of cloth, dirt, and so on are apt to be carried in with the metal and are potential sources of infection, particularly as torn

tissue and blood constitute a fertile soil for bacterial propagation. As against this last statement I must admit that most of the fragments that I have removed from air-raid victims have proved sterile on culture. The lower velocity of this type of missile accounts for so many fragments being retained, and it is interesting to note how often their track ends subcutaneously. Presumably the elastic skin yields at what would otherwise have been the site of exit and does not break. I have seen the same effect inside the chest on several occasions when a fragment has punched a hole in the far side of the chest wall and recoiled within the meshes of the lung tissue, from which it was removed.

Crush injuries may be held to cover damage from falling masses of masonry, direct compression, and the like, and are often responsible for gross and fatal visceral damage without any penetrating wound. Ribs are commonly fractured, several adjacent ones giving way close to the posterior angle. If the bone also breaks anteriorly a whole section of chest wall becomes functionally loose and may be driven in—"stove-in chest"—and may act paradoxically on respiration. Within the chest, lung may be avulsed from its root, and rupture of the heart and great vessels be found.

The effects of "blast" have attained some prominence recently, but a full description and an explanation of the findings have not yet been achieved. It would appear, however, that numerous small haemorrhages and effusions occur throughout the alveolar and interstitial lung tissue. Free blood in the air tubes accounts for haemoptysis and also for patches of atelectasis. The distribution of the lesions is erratic, but it is probable that the peripheral areas are most affected, as might be expected when the direct violence of the explosive wave is inflicted on the chest wall. Sometimes it is in the lung fringes that the lesion is well demonstrated, and this may be explained by nipping of the soft tissue between the lower ribs and the diaphragm, which is driven up by the impact on the abdominal wall.

Physiological Considerations

The essential point of the normal physio-mechanics of the chest lies in the fact that two elastic lungs are pulling like evenly balanced springs on each side of the mediastinum. The lungs in turn are held out against the chest wall in a state of tension by the subatmospheric or "negative" pressure in the pleural sacs. If one pleural cavity is violated the underlying lung is released and recoils towards its point of fixation at the hilum. From this point a number of changes in the function of respiration take place.

With the formation of a pneumothorax the balance of the lung pull on the mediastinum is upset and the heart becomes drawn towards the unaffected side, whose tractive force is undisturbed. Inspiration, with general expansion of the chest wall, increases the tension of the sound lung and draws the mediastinum even more towards itself. The result is that with each act of respiration the mediastinum swings to-and-fro or "flutters." The effect of inspiration is to draw air into the unaffected lung, but as it does so it rushes past the bifurcation of the trachea and abstracts some gases out of the collapsed lung. It also means that this lung becomes reduced in size. With expiration the reverse effect occurs and some gases are forced into the collapsed lung, which thus moves paradoxically on respiration.

The movement of gases from lung to lung—the "Pendelluft" of Brauer—results in a steady increase in the CO₂ content and diminution of oxygen, with consequent

inefficient and imperfect ventilation of the sound side. The sum of all these factors, if they occur to any marked extent, means that there is actual loss of ventilating surface by collapse of one lung, imperfect exchange of gases, and stimulation of the respiratory centre, besides the effects produced on the circulation by the to-and-fro movement of the heart and great vessels and interference with the venous return.

Puncture of the chest wall or lung may lead to an open pneumothorax, but if the opening is not valvular little harm will result. But, unfortunately, in traumatic surgery it often happens that a ragged external wound through the parietes constitutes a valve and admits more air than can be expelled. Air bubbling and frothing through blood at the skin wound indicates the "sucking" wound that is potentially so dangerous to the respiratory economy. Within the free pleural sac air accumulates steadily—a feature that is made worse by bouts of coughing, which are an almost inevitable concomitant of thoracic injury—and a state of intrathoracic pressure or tension is produced. *Tension pneumothorax* or pressure caused by a haemothorax is a common occurrence in thoracic surgery: the mediastinum is pushed over and encroaches on the ventilation capacity of the opposite lung.

For recognition of this phenomenon there is a physical sign that is often overlooked—namely, the position of the trachea in the neck. The tube is easily palpable in the suprasternal notch, and any deviation is readily apparent. The sign is valuable, since the apex beat and cardiac dullness are sometimes obscured by pleural fluid and are difficult to assess in a patient covered with dressings and bandages. The early recognition of a tension pneumothorax is of the utmost importance, since its neglect may lead to death from direct mechanical embarrassment, whereas its rapid relief could be obtained by putting a needle into the pleural cavity and letting the air escape.

It should also be remembered how tension phenomena can give rise to misleading signs and symptoms. The patient is cyanosed and distressed, and has a persistent cough. Where fluid is present the chest is dull, and on auscultation distant but definite bronchial breath sounds and rales are heard. The diagnosis of pneumonia may be made, but the audible breath sounds are conducted through fluid from a lung completely collapsed on to its root and the rales are transmitted from the opposite side, where the ineffective cough has been unable to expel mucus and secretions. There is no zone of partially collapsed lung to act as a damper between the air current in the bronchi and the chest wall to which the stethoscope is applied. To make an error in diagnosis as described may seem unnecessary, but in a very distressed and mutilated patient it is not always easy to practise the thorough and complete examination which would lead to the recognition of the true state of affairs. One can only emphasize the importance of remembering the possibility of "tension" occurring and deciding whether or not the trachea is in the midline.

Subcutaneous Emphysema

This is a common accompaniment of thoracic injury. The air usually comes from torn lung and is expelled through a breach in the chest wall, but does not escape adequately through an external skin wound even if one is present. The axilla and clavicular fossae demonstrate the typical crackling sensation, and in a severe case the whole head and neck may blow up, making the patient unrecognizable and the eyelids so swollen that he is unable to see. The condition is always more alarming than dangerous, and when it occurs in a crush injury without a surface wound it suggests damage to lung by broken rib fragments.

Haemothorax

The possible origins of blood in the pleural cavity are threefold: the intercostal or internal mammary vessels may be torn, pulmonary vessels may be ruptured, or the heart and great vessels may have been damaged. Clinically it is important to decide whether the bleeding is active or whether it has undergone spontaneous arrest. Section of an intercostal artery is likely to lead to uncontrolled haemorrhage and may therefore require urgent attention; but pulmonary haemorrhage, unless rapidly fatal, tends to check itself. The reason for this latter lies in a balance between two groups of opposing factors. On the one hand, vessels in the lung have a wide lumen and the capacity of the pleural sac to receive blood is considerable; but as against these features there are the potent influences of the relatively low pressure in the pulmonary circulation and the tendency of the lung to retract and so reduce the actual size of the wound in itself. To put it in another way, blood and air in the pleural sac form a pad which acts against the bleeding area. A haemothorax of several pints capacity is not incompatible with life, though prompt blood transfusions have certainly saved many lives.

Blood in a haemothorax has one most unusual character in that it tends to remain fluid in a large number of cases. Infection and tissue laceration may produce massive clotting, but in many instances the effusion shows little if any clot and can be aspirated efficiently through a needle. I have on a number of occasions estimated the haemoglobin and fibrinogen content of both the circulating and the free pleural blood within a few hours of injury. The haemothorax fluid shows on an average a reduction of 35 to 50% haemoglobin and an almost complete absence of fibrinogen. The inference is that the movements of the heart and lungs have whipped up and defibrinated the blood as it wells into the pleural cavity. To account for the reduced haemoglobin figure it is suggested that the blood is diluted by a serous effusion poured out from the pleural endothelium in response to the irritation by blood. The amount of clot, if any should be present, is so small that it seems improbable that a concentration of red cells in it would account for the low haemoglobin figure.

Massive Collapse

Massive collapse or pulmonary atelectasis is a feature that is quite often encountered, particularly with a crush type of injury. At first sight it may seem difficult to understand how an injury to one side of the chest can cause collapse on the opposite side, but the present conception of atelectasis as being basically caused by obstruction to a bronchus makes the explanation fairly straightforward. Blood or mucus in the bronchial tree may not be removed effectively when the expulsive cough reflex is reduced by shock or pain. The foreign matter obstructs an air tube, and as a result of this the gases distal to the block are rapidly absorbed into the blood stream. The alveoli become emptied and their walls fall together so that the affected area of lung is represented by a wedge of bronchi, vessels, and airless connective tissue. This elastic mass now affects the surrounding structures and draws them toward itself. The mediastinum is pulled over, the diaphragm elevated, and the chest wall retracted, and the adjacent lung develops compensatory emphysema. If the atelectatic area fails to re-expand, as it does in some cases, the pull of the elastic fibres is finally directed on the only structures which are left for it to affect—the enclosed bronchial elements. In the early stages the cartilaginous bronchial walls tend to resist the external traction, but the continued centrifugal pull finally results in their stretching and becoming dilated. In short, in any case of persistent collapse bronchiectasis will inevitably follow, and it is a question of later secondary infection which determines

whether or not the classical signs of infective bronchiectasis will develop.

Pathological Changes

The pathological changes in traumatized lung are very much what would be expected, laceration and haematoma formation being the principal features. The extensive blood supply of the lung accounts for the fact that many badly torn fragments remain viable though their liability to later infection is considerable. A haematoma of the lung presents as a tense firm swelling of rubber-like consistency and of a purple or violet colour, with the visceral pleura stretched almost to breaking-point over its surface. Extravasation into alveoli produces a condition of consolidation which is demonstrated clinically by stained sputum, which later becomes purulent as the condition resolves. The detailed effects of infection on the lungs and pleura will not be discussed here, though their role in the subsequent fate of the patient is clearly of the utmost importance.

Distant Reflex Complications of Chest Injuries

These complications are often considerable though some of the effects may be attributed to damage inflicted elsewhere in the body. There are, however, certain features associated with what appears to be chest injury alone, and of these retention of urine is the most common and most easily remedied. Acute dilatation of the stomach is apt to be overlooked in its early stages and, if untreated, may cause considerable and serious trouble. Among these abdominal complications may also be mentioned "blast," in which multiple and diffuse haemorrhages in the mesentery and under the bowel peritoneum may result in a fatal peritonitis: I have encountered two such cases accompanying a penetrating wound of the chest.

DANGEROUS DRUGS IN INSTITUTIONS

The Home Office has issued a new Order, to be known as the Dangerous Drugs (Approved Institutions) No. 25 Order (1941), approving certain institutions where persons in charge of laboratories may be in possession of and supply drugs and/or preparations to which the Dangerous Drugs Act, 1920, applies. The institutions named in Schedule A are as follows:

All Universities (including Colleges of Universities) of Great Britain.

The University College, Nottingham.

The University College, Southampton.

The University College of the South West of England, Exeter.

The University College, Glasgow (The Glasgow Royal Technical College).

All Medical Schools recognized by any of the licensing bodies specified in Schedule A of the Medical Act, 1858, as amended by any subsequent Act.

Royal College of Surgeons of England.

The National Institute of Medical Research.

The Royal Veterinary College, London.

The Royal (Dick) Veterinary College, Edinburgh.

The Glasgow Veterinary College.

The School of Pharmacy of the Pharmaceutical Society of Great Britain.

Institute of Chemistry of Great Britain and Ireland.

Approval under the Order will remain in force only so long as the Home Secretary is satisfied that the following conditions are complied with:

The person in charge of the laboratory: (1) shall keep all supplies of the drugs and preparations under lock and key and in his own charge, and shall only issue to persons working in the laboratory such quantities as shall be immediately required in the course of research or instruction; and (2) shall keep records of all amounts of drugs and preparations purchased by him in the forms prescribed in the First Schedule to the Raw Opium Regulations, 1937, and in the Second Schedule to the Dangerous Drugs Regulations, 1937, and shall furnish to the Secretary of State whenever required a copy of these records together with a statement of the amounts of each of the drugs and preparations remaining in his possession.