C J Mieny, U Mennen: Principles of Surgical Patient Care - Volume II

Chapter 8: Cardiothoracic Surgery

Chapter 8.1: Chest Trauma

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Introduction

Technological developments of the motor-car have led to greater speed and to a parallel increase in the number of severe injuries of all kinds. Chest injuries are prominent and often fatal. In addition, the advent of efficient paramedical services and the rapid transportation of severely injured patients to a regional hospital has resulted in more patients with otherwise fatal cardiac wounds reaching the emergency room alive. It is estimated that 30% of deaths following motor-vehicle accidents are caused by chest injuries and ina further 20% chest injuries significantly influence the fatal outcome. Frequently major internal chest injuries are overlooked because of a paucity of direct external evidence of trauma, especially in the patient with multiple injuries. The surgeon must be constantly aware of the possibility of cardiac and major thoracic injuries in order to take appropriate action and salvage the patient. Many "minor" chest injuries require only observation or simple drainage, but the chest injury cannot be assumed to be unimportant. Changes can occur fairly rapidly and basic principles of maintaining a clear airway, relieving pulmonary compression by blood or air and maintaining the mechanical function of the thoracic cage have to be adhered to. Chest trauma may be classified into:

- penetrating trauma
- blunt trauma.

Penetrating trauma implies that the pleural space may have been breached and therefore pneumothorax and/or haematothorax must be actively excluded. Co-existent internal injuries are often unpredictable. Knife wounds may be inflicted with an upward or downward thrust. The upward thrust frequently causes the weapon to enter the chest through the abdominal cavity and diaphragm - these additional abdominal injuries increase the morbidity of the chest injury. The downward thrust usually involves the upper part of the chest. If a right-handed assailant stabs the victim from the front, the left chest is usually involved; if from behind, the right chest. A characteristic serious injury is the stab to the left side of the neck. Its downward and medial direction often results in injury of the trachea and oesophagus with the development of a pneumo- or haemothorax on the opposite side. Penetrating low-velocity bullets produce narrow tracts and effects similar to stab wounds. High-velocity bullets, however, produce far greater damage because of the greater kinetic energy released into the tissue. The position of entry and exit wounds, or the line from the entry to a retained foreign body, may indicate the possibility of mediastinal or diaphragmatic injury requiring surgical intervention.

Blunt trauma is most commonly the result of a motor vehicle accident but is seen following a variety of other causes. The mechanism of injury often produces characteristic injuries and may be due to either an acceleration/deceleration injury (the passenger in a car brought to a rapid abrupt halt), a compression injury (the pedestrian run over or compressed by a car) or a combination of the two (the driver of the car brought to a rapid abrupt halt and compressed by the steering wheel).

Careful elicitation of the history of the attack or event may therefore suggest a particular injury.

Clinical Assessment

The clinical state of the patient should be carefully assessed. Adequacy of ventilation, circulation and blood volume are prime considerations. Respiratory distress, cyanosis and tracheal deviation from the midline are frequently due to tension pneumothorax, massive haemothorax or massive atelectasis.

Dilated veins in the neck should raise the suspicion of cardiac tamponade or impaired myocardial function. Subcutaneous emphysema indicates leakage of air from an air-containing viscus such as lung, trachea, bronchus or oesophagus. It is rarely due to air entrained through the wound and it is also *not* diagnostic of pneumothorax since the pleural space may obliterated by previous pleural inflammation. If it appears first in the neck, it suggests tracheobronchial or oesophageal rather than more peripheral bronchopulmonary injury.

Abdominal examination may indicate the presence or absence of a thoraco-abdominal wound. Pain and rigidity may be secondary to a chest wound, thoraco-abdominal injury or purely an abdominal injury. A helpful diagnostic manoeuvre is an intercostal nerve block which usually relieves the abdominal pain and rigidity referred to the abdomen from a chest wound. If an intra-abdominal injury is present, such relief is less pronounced or entirely absent. Pain, tenderness and rigidity may be absent in patients with injuries to the lesser sac where only the diaphragm has been punctured and in those with no peritoneal irritation. Peritoneal lagave should be used in patients with doubtful signs and in whom an intra-abdominal injury is suspected.

Chest Radiographs

Chest radiographs are an indispensable means of making a prompt definitive diagnosis, of assessing the extent of injury and of continued assessment fo the patient. The situation rarely arises whereby urgent action is required prior to a chest radiograph. Radiographs of the chest should be taken in the upright sitting position with full inspiration. With proper co-ordination, even unstable patients can be held upright for the few moments required. Chest radiographs taken with the patient supine are often deceptive and unhelpful. A collection of blood and air may form a triple layered "sandwich" of air, lung and blood. The radiodense blood and the radiolucent air may cancel each other out and a significant haemo-pneumothorax may thus be missed. An erect chest radiograph should therefore be requested. Repeated clinical and radiographic assessment should be made routinely - after every invasive procedure, whenever there is a change in the patient's condition and until the patient is stable.

Contrast Radiography

Endoscopy and/or a dionisil contrast swallow is indicated if there is a possibility of an oesophageal injury.

Angiocardiography

If damage to major vessels is suspected, angiography is recommended if the patient is stable enough. This may be undertaken either with digital subtraction angiography or by direct angiography of the suspected vessel.

CT Scanning

CT scanning is virtually never required for the assessment of acute chest injuries but may be useful in chronic injuries.

Management

The airway must be maintained and if necessary an endotracheal tube is inserted and mucous and blood aspirated. Ventilation may be required.

Entry wounds should be occluded with air-tight sterile dressings. This converts an open pneumothorax to a closed pneumothorax. An intravenous route is established and hypovolaemia corrected.

A central venous pressure (CVP) monitoring line is essential to monitor volume replacement and as a means of assessing the chest injury (ie, raised in tamponade). The CVP line should be inserted preferably on the side of the injury as it is more accessible to the anaesthetist when the patient is positioned for a lateral thoracotomy and in addition, if a haemo- or pneumothorax complicates its insertion, it will be on the side likely to be drained or opened at thoracotomy.

Haemo- and Pneumothorax

All large haemo- or pneumothoraces must be drained. A small mantle pneumothorax or a haemothorax causing only blunting of the costophrenic angle should in principle be observed. If the patient is to be ventilated or placed under general anaesthesia one should be aware of the possible development of a tension pneumothorax.

The frequency with which the chest is inappropriately intubated justifies restatement of the basic principles of closed pleural drainage. The procedure is done under sterile conditions. The site of aspiration with a view to intubation should be selected on the evidence of the chest radiograph since pleural adhesions may cause loculation of air and liquid. Generally, if the pleural space if free, the drain should be inserted in the mid-axillary line above the sixth intercostal space. At this site muscle bulk is minimal, sub-diaphragmatic viscera are unlikely to be injured and the drain is comfortable for the patient. It drains blood and air equally effectively. After determining the site of aspiration the intercostal space is infiltrated with local anaesthesia, in addition to the intercostal nerve above and below this space. Small quantities of local anaesthetic injected into the periosteum of adjacent ribs may make the procedure less painful. Two types of drains are presently available. The plastic drain inserted over an internal trocar and a sterile, self-retaining catheter of Malecot type which is stretched over an introducer and inserted through a small cannula. The skin at the elected site is incised and thereafter all tissue down to the pleura is dissected bluntly with artery forceps or scissors. Penetration of the pleura results in the escape of blood or air. The intercostal tube drain is then carefully inserted. On no account is an internal trocar to be used to force a tract through the chest wall for the cannula, it should merely be used to guide the drain through the *dissected* tract and into a correct internal position - anterior for air or posterior for fluid. Excessive thrusting with internal trocars has resulted in fatal iatrogenic organ injuries. The drain is connected via tubing to a drainage bottle with an underwater seal of sterile water or saline. The drain is sutured to the skin and additionally strapped with elastoplast.

Errors in relation to chest drainage are frequently seen, but if the basic principles are carefully adhered to, these errors should be avoided. Common errors are:

- The incorrect interpretation of chest radiographs.

It is essential that a recent chest radiograph be visible while the procedure is being undertaken. A lateral radiograph is useful in that it may locate loculated fluid anteriorly or posteriorly. Not infrequently seen is:

- the wrong pleural cavity intubated

- a bulla misinterpreted as a large pneumothorax

- a diaphragmatic tear with herniation of a gas-filled stomach, misinterpreted as a pneumothorax - in this situation the insertion of a nasogastric tube with a repeat radiographs is useful.

- The insertion of a drain for a minor haemo- or pneumothorax.

A small mantle pneumothorax does not require chest intubation; similarly a small haemothorax causing blunting of the costophrenic angle does not require drainage. In these situations the patient is observed and a repeat chest radiograph taken after 12 hours and again 24 hours later. If there is no progression, the patient may be discharged and seen in one week or earlier if chest symptoms develop. If ventilation or anaesthesia is required, drainage of minor pneumothoraces may be indicated to prevent the onset of a sudden tension pneumothorax.

- Surgical emphysema.

Surgical emphysema is not synonymous with a pneumothorax. Air may be produced from an oesophageal or tracheal injury, or if the pleura is adherent from previous pleurisy, air may leak from the lung into the subcutaneous tissue. To insert an intercostal drain under these circumstances could be extremely hazardous for the patient. Surgical emphysema occurring after chest drainage is frequently the result of lung lacerations produced by the clinician. If in doubt, ask for another opinion or observe the patient and repeat the radiograph later.

- The drain inappropriately inserted/positioned.

It is important that prior to chest intubation, a significant quantity of liquid or air is obtained by using the aspirating needle in quantity. A small amount of air mixed with blood-stained bubbles may indicate that the needle is in the lung. Failure to do this simple procedure may result in intubation of the liver, spleen, stomach or subcutaneous tissues. The chest drain should hardly ever be inserted below the fifth interspace or medial to the mid-clavicular line.

- Drain inappropriately connected.

The drain is connected to the vent cannula rather than to the cannula lying beneath the liquid in the drainage bottle.

- Chest drainage when ventilation or anaesthesia is required.

This practice is to be condemned as it will lead to needless lung damage. The patient should be carefully observed and if his respiratory status changes, a chest radiograph should be taken and only if a pneumothorax develops should the chest be intubated.

Removal of Drain

The correct time to remove a drain is when its function has been served, or when the drain ceases to function. Radiographs and clinical evidence of complete pulmonary re-expansion, with no further drainage of air or blood in the next 12 hours, implies that the drain may be removed. There is no need to wait until the tube blocks before removing it, ie, there is no need to wait until it has "stopped swinging". The rise and fall of the water level in the glass tube in the water seal reflects only the changes of intra-thoracic pressure with respiration. A tube represents a foreign body in the pleural space and is always a potential source of infection.

Reassessment

Further clinical and radiographic assessment should be done at frequent intervals until the patient's condition has become stable.

If a pneumothorax was absent on initial chest radiographs, the radiographs should be repearted after six hours. If there is no change, the patient can be discharged and should return for a follow-up radiograph in one week or earlier if symptomatic.

A working rule is to attempt to obtain a near normal chest radiograph 48 hours after injury. If this does not occur, referral to a thoracic surgical centre should be considered.

Indications for Early Thoracotomy (Within 24 Hours)

Thoracotomy is required in only a small percentage of patients with penetrating chest injuries, predominantly in those with mediastinal injuries.

The thoracotomy should be done in accordance with the site and nature of the expected injury. Median sternotomy requires more time and specialized instruments, and provides poor access to the hilum of the lung and posterior mediastinal structures. In patients stabbed anteriorly between both mid-clavicular lines and down to the third intercostal space, the median sternotomy incision is probably better as the aorta and major vessels are likely to be damaged. In stab wounds in other areas a lateral thoracotomy is the preferred approach. If necessary this may be extended transsternally or across the costal margin. It provides ready access to the heart and lung and cardiac massage can easily be performed.

Indications for Thoracotomy are:

- Cardiopulmonary resuscitation.

If cardiopulmonary resuscitation is required, major intrathoracic injuries are usually present and must be controlled if resuscitation is to succeed. Additionally clamping of the descending thoracic aorta may limit distal continued blood loss, and direct available cardiac output to the brain for cerebral perfusion.

- Continued haemorrhage.

The amount of blood loss in addition to the time over which it has accumulated is of importance. A large volume of blood obtained after pleural intubation is suggestive that exploration may be required, but is not in itself an indication for exploration. The patient may have been seen hours after the injury and the blood had accumulated slowly. If, however, soon after injury, a large amount of blood is drained from the pleural space and there is evidence of continued haemorrhage, then thoracotomy should be considered. Continued blood loss after pleural intubation of > 300 mL/hour for more than two to three hours is an indication for thoracotomy. Bleeding is usually from a systemic vessel such as an intercostal artery, internal thoracic artery, the vena azygous or its tributaries, which may require ligation. Bleeding is unlikely to be from the lung because of the lower intrapulmonary vascular pressure. Transection of one of the large vessels in the pulmonary hilum usually results in immediate death. However, if this situation is found at thoracotomy, it is possible to control the pulmonary artery and veins by clamping the entire hilum with a vascular clamp. The site of bleeding is thereafter carefully assessed and repaired if possible. Occasionally pulmonary resection is required. This should be as conservative as possible.

- Cardiac tamponade.

Because of the unpredictable course of traumatic pericardial tamponade treated by pericardiocenthesis, coupled with advances in resuscitation and cardiac surgery, immediate thoracotomy for all patients with evidence of cardiac tamponade, indicative of penetrating wounds of the heart, is recommended.

- Oesophageal Injury.

The consequences of missing an oesophageal injury are so grave that the integrity of the oesophagus must be verified when damage to it seems possible. Any features such as haematemesis, difficulty with or pain on swallowing, and evidence that a bullet or a knife has traversed the mediastinum, requires evaluation of the oesophagus by contrast radiography and endoscopy. When demonstrated, a defect should be repaired immediately.

- Packing and Drainage.

During resuscitation the wound should be packed and the pleura drained. If the chest wall cannot be reconstituted, it may be necessary to use a musculo-cutaneous flap, covering marlex mesh and acrylic which is sutured to the bony structures forming the borders of the defect.

- Thoraco-abdominal injuries.

If a thoraco-abdominal injury is suspected and there are abdominal signs, a midline laparotomy incision is made: damage to intra-abdominal organs is repaired and the diaphragm is repaired using non-absorbable sutures. Indications for a thoracotomy are independently assessed as above. This approach is recommended as more often than not the abdominal component is the more serious and the thoracic component of the thoraco-abdominal injury can be dealt with conservatively. Pleural soilinhg by peritoneal contents may have been prevented by omentum sealing the tear.

In patients with gross soiling of the thorax, a separate small thoracotomy should be made and the thoracic cavity cleaned and drained. In those patients with no abdominal signs, right-sided injuries or with chronic injuries, the trans-thoracic approach provides the best exposure. If necessary, intra-abdominal injuries may be exposed and repaired by peripheral detachment of the diaphragm.

- Transfixion Injuries.

Objects transfixing the chest should be removed under conditions allowing for control of major bleeding or sudded deterioration of cardiopulmonary status. Generally this requires general anaesthesia and preparation for thoracotomy. The need, however, to proceed to thoracotomy or pleural drainage is remarkably infrequent. If there is an abrupt change in the cardiorespiratory state on removal of the object, a radiograph should be taken and a chest drain inserted, or thoracotomy done if circumstances warrant it.

Indications for Late Thoracotomy (After 24 Hours)

- Clotted Haemothorax.

If the patient has a large pleural opacity following chest injury, the chest should be aspirated in the correct position as assessed by lateral and PA chest radiographs. If the liquid is thin, this should be managed by aspiration rather than insertion of a chest drain as the likelihood of inducing infection is less and the need for observation for continued haemorrhage is not present. If only a small amount of liquid blood is obtained, a clotted haemothorax is probably present and thoracotomy is required for removal of the clotted blood and fibrin that is deposited on the visceral pleura so that there is no impediment to expansion of the lung. The cortex is shreddy and discontinuous for the first ten days and may be removed by wiping with a swab.

Later it forms a definite layer which is removed by blunt or sharp dissection - the operation of decortication.

- Massive Pleural Air Leak.

The amount of air lost through the pleural drain and the degree of lung expansion on serial radiographs are assessed. If the leak continues to be large and the lung fails to expand, bronchoscopy is indicated. If the bronchi of the damaged lung are full of mucous and pus, bronchoscopy should be repeated daily. Bronchoscopy might show a tracheal or bronchial laceration or if there is still no pulmonary re-expansion, thoracotomy with bronchial repair may be required.

- Post-Traumatic Empyema.

If a haemothorax is successfully managed by re-expansion of the lung to obliterate the pleural space, empyema is an infrequent complication. When an empyema has developed, it may respond, if the pus is thin, to intercostal underwater drainage; if the patient is toxic and the pus is thick, rib resection and drainage, followed later by decortication is necessary. In no-toxic patients decortication may be done as the initial procedure.

- Severe Pulmonary Parenchymal Damage with Haemoptysis and Sustained Hypoxia.

This is usually the consequence of a high-velocity missile injury. This injury requires a more radical approach than those discussed above. The early resection of irreversibly damaged (infarcted) lung removes the site of later sepsis and, more urgently, the source of endo-bronchial bleeding and ventilation perfusion imbalance. With this approach results are better than with previous conservative measures.

Specific Injuries

Intra-Thoracic Foreign Bodies

In general a foreign body in the pulmonary parenchyma especially if it is small (< 2 cm - ie, a bullet) is not an indication for thoracotomy. Objects in or near the tracheobronchial tree, the heart or the great vessels warrant surgical removal. A larger diameter foreign body, especially if it is irregular ie, a shell fragment which may carry with it foreign material - should be removed. A foreign body with associated symptoms - haemoptysis, persistent productive cough, or in the presence of an empyema, should be removed.

Pulmonary Lacerations

Infrequently patients with a massive haemothorax or air leak require thoracotomy. If the injury found at operation is a pulmonary laceration, bleeding points and air leaks should be oversewn. If the laceration is deep and the air leak large, the visceral pleura should not be closed because of the risk of air embolism. The pulmonary wound in this situation may be extended by dividing the deflated lung between soft clamps and the tissue directly sutured with absorbable sutures to control air leak and hemorrhage. Individual bronchi and vessels are sutured. Every attempt should be made to conserve lung tissue, but rarely segmental resection, lobectomy or pneumonectomy may be required.

Thoraco-Abdominal Injuries

The majority occur on the left side as a result of buttressing of the liver on the right, most assailants being right-handed, and the close relationship with this area to the intended target, the heart. The most common organs involved are the stomach, colon, small intestine and spleen. In some patients the diagnosis of penetration of the diaphragm is obvious, but in others it is missed and the patient may present years later with diaphragmatic herniation and resultant strangulation of bowel.

Signs of peritoneal irritation are fairly reliable indicators of diaphragmatic penetration. The abdomen may have referred signs related to haemo- or pneumothorax or even from the presence of a basal intercostal tube. The signs may improve on evacuation of the pleural space or after infiltration of local anaesthetic around the stab or drain site. Radiographs may show free gas under the diaphragm or intestinal shadows in the chest, or the disposition of a retained missile in relation to the diaphragm may suggest the diagnosis. A useful investigation with high sensitivity and specificity is peritoneal lavage. Patients with negative features of diaphragmatic penetration, but evidence of remaining haemothorax or some abnormality of the left base on chest radiographs, should have a barium meal contrast study with follow through, to exclude herniation.

Mortality and morbidity are higher in patients with thoraco-abdominal injuries and this is largely due to the intra-abdominal injury. Empyema is more common and should be considered if the patient develops a pyrexia and a pleural opacity remains after repair of the diaphragm.

Treatment of Thoracic Battle Injuries Versus Civilian Injuries

Civilian thoracic injuries contrast sharply with thoracic battle injuries because of the predominance of high-velocity missile and shrapnel injuries in the military situation and the predominance of low-velocity missile and stab wounds in a civilian practice.

High-velocity injuries are associated with more extensive and severe trauma often resulting in multiple injuries, persistent haemothorax despite chest tubes, cardiac tamponade and foreign objects in the mediastinum. There is increasing evidence supporting early thoracotomy for these injuries.

It is also a discussion point whether contused lung causing hemoptysis should become an indication for thoracotomy to resect the severely contused lung and thus prevent aspiration and pulmonary insufficiency.

A military report published in 1985, emphasized the changing phase of military trauma. 1992 Thoracic battle injuries incurred during the war in Lebanon were discussed. Ninety-seven per cent of the injuries were penetrating. Fifty-seven per cent were caused by shrapnel and 42% by gunshots; 1% were secondary to a blast, or blunt trauma.

This experience contrasts very sharply with that of civilian practice. The use of thoracotomy in 71% of patients and lung resection in 16% is much higher than in civilian practice, where only 15 to 30% of patients require thoracotomy and 2 to 3% need a pulmonary resection.

Every patient should be considered on an individual basis but it is important for surgeons involved in the management of high-velocity injuries to be aware of the fact that an early thoracotomy might often be essential and that aggressive resuscitation and trauma-readiness are imperative.

Early resuscitative steps are of the utmost importance and affect the outcome. All patients with thoracic injuries are admitted directly to a unit where all the facilities for rapid resuscitation as well as intensive care are readily available. Patients are not delayed in overcorwded casualty or X-ray departments.

A rapid, orderly evaluation is performed and vital signs obtained. Priorities are:

- airway control
- removal of clothes
- placing of multiple venous lines
- a reliable central venous line
- an arterial line
- infusion of crystalloids.

This should be well under way in a few minutes.

Blood loss is not replaced on a "volume lost to volume given" basis, but account is taken of the patient's cardiac output and tissue perfusion with transfusion given to an optimum ventricular preload (CVP). This avoids errors when haemorrhage is concealed.

When a tension pneumothorax is evident on clinical grounds, like absence of normal breath sounds on the affected side, or a massive air leak and bleeding is evident, a tube thoracostomy is performed without delay (before a chest X-ray is available). In stable patients a tube is usually only inserted after the chest X-ray becomes available.

When resuscitation is well under way, a Folwey catheter and nasogastric catheter are placed, history obtained, overhead radiographs are made, cardiac monitoring is instituted and an astrup sent off.

Senior staff and perfusionists are alerted when high-velocity injuries or shocked patients are treated. It is especially important to notify the operating room and have it prepared before the patient's condition deteriorates. This process takes place simultaneously with the resuscitation process.

If the patient responds to the resuscitation process and the other indications for early thoracotomy (previously discussed) clearly do not exist, the theatre is cancelled and the patient is placed on a program of observation in the trauma unit until he is stable.

As undiagnosed wounds of the oesophagus and diaphragm are associated with a significant mortality and morbidity, these are actively sought for.

Chapter 8.2: Blunt Trauma to the Chest Wall

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Simple Rib Fractures

Although common and often innocuous, the simple rib fracture if treated inadequately or overlooked, may result in disability or death. Rib fractures range in severity from the uncomplicated non-dislaced or green-stick fracture to one that is comminuted with associated haemothorax or pneumothorax. A degree of underlying pulmonary contusion is inevitable if sufficient kinetic energy is imparted to the chest wall while producing rib fractures. This contusion is greatest in young patients, since more force is required to fracture flexible ribs. In contrast, in elderly patients, there may be little or no underlying pulmonary contusion despite multiple rib fractures.

The position of the fractured ribs may indicate other associated injuries. For example, the first rib is a short, broad structure well protected by overlying muscular skeletal elements, and is therefore not easily fractured. The second rib is likewise well protected. Injury to either of these ribs implies that the patient has sustained a major impact and this should alert one to the possibility of multi-system injury. Associated adjacent injuries may include lesions of the brachial plexus, the subclavian artery or sympathetic chain. A fractured first rib is associated with an 8% incidence of major intrathoracic vascular injuries. Some therefore consider a first rib fracture to be an indication for emergency aortography. Fractures of the lower ribs may indicate injury to the underlying liver, spleen or kidney.

Management of rib fractures involves not only treating the current stauts of the patient but also the recognition and prevention of possible complications. The diagnosis may be suspected from the history and physical examination and confirmed with chest radiographs. Over penetrated and oblique views are best but still a fracture may not be demonstrable. If required, a bone scan obtained a few days after injury will confirm a fracture. A number of patients with rib fractures are at increased risk for the development of complications and require admission for observation:

- The elderly - in one series there was a 20% mortality from simple isolated rib fractures in patients over the age of 80. The elderly patient has a diminished ventilatory reserve and is at risk of atelectasis and pneumonia, secondary to pain and splinting.

- Patients with existing chronic pulmonary diseases.

- Initial arterial blood gas abnormalities - this may indicate moderate to severe underlying pulmonary contusion possibly not yet clinically evident.

- An initial pleural effusion indicates blood in the pleural space. This may increase in size or lead to post-traumatic empyema.

Management is primarily simple analgesics, but if the pain is severe, an intercostal nerve block may be performed with a long-acting local anesthetic. The actual fracture site may also be infiltrated to give added relief. The nerve block allows vigorous coughing and pulmonary toilet, previously limited because of pain. Thereafter the patient is observed for possible complications as indicated above. Should any arise, they are treated accordingly. Strapping and binding of the chest wall is contra-indicated and only leads to an increased incidence of respiratory complications.

Traumatic Flail Chest

Flail chest, that is a mobile portion of chest wall which moves inwards on inspiration and outwards on expiration (paradoxical movement), occurs when there are multiple rib fractures in more than one place with or without sternal involvement. Patients are frequently in respiratory distress and many ventilatory defects such as a decreae in vital capacity and functional residual capacity, reduced lung compliance and tidal volume, hypoxaemia and an increase in the work of breathing and airway resistance have been documented.

The therapeutic approach to patients with flail chest has varied. In the past, efforts were directed towards the visible problem - paradoxical motion of the chest wall. The chest wall was stabilized either by compression with sand bags, or through a variety of external traction devices such as wires and towel clips around the ribs. Avery and associates popularized the theory of internal pneumatic stabilization by means of positive pressure ventilation and thereby improved the prognosis of flail chest. Others advocated open operative stabilization of the chest wall with a variety of plates, struts and pins arguing that there is a number of disadvantages and dangers involved in prolonged ventilation including physical and psychological dependence, increased nursing staff requirements, expensive equipment, failure to correct deformities, prolonged gas leaks and the risks of tracheostomy.

Trinkle has advanced the theory that underlying pulmonary contusion is the major problem rather than paradoxical movement of the chest wall. Experiments in animals suggest that the contused lung is extremely sensitive to fluid overload, especially when intravenous crystalloid solutions are administered. He advocated treatment of the pulmonary contusion primarily, which includes:

- restriction of crystalloids to less than 50 mL per hour

- blood volume restoration with packed red blood cells and plasma
- diuretics
- Methylprednisolone 500 mg six-hourly for 72 hours in patients not requiring mechanical ventilation

- analgesics
- physiotherapy
- intercostal nerve blocks.

His results using this regimen and avoiding mechanical ventilation whenever possible, compared to a similarly injured group of patients treated with conventional internal pneumatic stabilization, showed a marked decrease in hospital stay, mortality and morbidity.

Patients with traumatic flail chest should not be routinely ventilated unless other multiple injuries necessitate it or unless there is hypoxaemia (pO_2 < 8.5 kPa) or hypercarbia (pCO_2 > 7.0 kPa) or if the patient is making excessive respiratory efforts. If pulmonary contusion is present or suspected, the regiment advocated by Trinkle should be used. When mechanical ventilation is used it is discontinued as soon as possible. Operative stabilization is reserved for those patients with gross chest wall deformities or traumatic thoracoplasty of the chest wall and in those in which a thoracotomy is being undertaken for other associated injuries such as traumatic rupture of the aorta or bronchus.

Scapular Fractures

Scapular fractures are infrequent, but they may, like first-rib fractures, indicate severe thoracic injury. Two-thirds of the fractures occur through the neck of the scapula and the remaining one-third through various portions of the body. It results in local pain and tenderness and the diagnosis is confirmed by chest radiography. Treatment is immobilization in a sling until the fracture site is stabilized by callus formation with resolution of pain. If there is a fracture of the acromion process or dislocation of the acromioclavicular joint, peripheral nerve injuries should be carefully excluded.

Fractures of the Sternum

These are uncommon but may occur following high-speed motor vehicle accidents, particularly when the driver is hurled against the steering wheel. The fracture occurs most commonly at the sterno-manubrial joint and may occur in the absence of rib fractures. The fractures may vary from simple undisplaced, displaced with overlapping fractures, to compound fractures associated with anterior flail chest. Patients with these fractures frequently have multi-system injuries. Myocardial contusion, pulmonary contusion and damage to the underlying aorta and its branches are all well documented associated injuries and should be actively excluded and treated accordingly.

Simple undisplaced fractures may not be clinically apparent and require little or no treatment. If displaced and overlapping there is severe pain and tenderness and a palpable ridge at the fracture site. Lateral chest radiographs or lateral tomograms usually reveal the overlap. If left untreated, a pseudo-arthrosis with persistent pain and tenderness results.

Therefore, in patients with overlapping fractures, open reduction and fixation is indicated as soon as the patient is stable with respect to associated injuries. The operative reduction is easier when done within the first ten days, prior to callus formation. After ten days the inflammatory reaction and callus formation at the fracture site makes reduction and fixation difficult.

Repair of the fracture site is accomplished through a vertical midline incision. Adequate stabilization is provided by passing wire sutures through both tables of the sternum, above and below the fracture site, and twisting the wires firmly in place.

Chapter 8.3: Laryngotracheal Trauma

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Etiology and Clinical Presentation

Motor-vehicle accidents in which the driver or passenger strikes the extended neck against the dashboard or steering wheel is the commonest cause of blunt laryngotracheal trauma. Similar injuries occur as a result of striking the neck against an unseen wire while driving a motor-cycle.

Associated injuries to the cervical spine may occur with the risk of spinal cord damage. If present, extension of the neck for intubation or endoscopy or flexion to relieve tension across an anastomosis must be avoided. The cervical oesophagus is frequently also injured. Endoscopy and contrast examination should be undertaken if this lesion is suspected but circumscpection is necessary whent the cervical spine is injured. Failure to recognize this concomitant injury may result in mediastinal sepsis, tracheo-oesophageal fistula or destruction of a tracheal anastomosis. Major vessels may be damaged and this should be excluded if necessary by angiography.

Penetrating trauma, the result of knife or gunshot wounds, is common in South Africa: a characteristic injury is the downward stab by a righ-handed assailant which penetrates the base of the left neck. This injury frequently damages the trachea and/or oesophagus and right lung resulting in a haemopneumothorax on the side opposite the entrance wound.

The characteristic injury presents with a combination of signs or symptoms of haemoptysis, localized pain, bruising, subcutaneous emphysema, hoarseness, stridor or respiratory distress and should alert one to the possibility of laryngotracheal injury. If not immediately recognized, progressive airway obstruction may result because of the fibrosis associated with healing.

Diagnosis

Plain radiography may reveal distortion or disruption of the tracheal air column. Subcutaneous emphysema is usually obvious. If other injuries are suspected these should be looked for - if necessary, request cervical spine radiographs. Dionisol swallow of the oesophagus or angiography must be requested. Tomograms and computer tomography may be useful in evaluating chronic injuries.

Occasionally surgery is undertaken urgently and the exact extent of damage is only demonstrated at exploration of the wound or with bronchoscopy. It is particularly important to recognize and repair associated oesophageal injury. If unrecognized, catastrophic mediastinal sepsis will result.

Management

The initial and most important consideration is to secure the airway. Attempts at trying to intubate by the oral or nasal route may be unsuccessful and may precipitate total obstruction. One should thus be prepared for immediate tracheostomy or consider this as the initial procedure. A divided trachea usually retracts into the mediastinum. It should be rapidly found and pulled up into the wound and intubated with an endotracheal tube.

Once the airway is protected, the extent of damage should be carefully assessed. If the oesophagus is damaged, this should be repaired. Tracheal and oesophageal suture lines should be separated by an interposed muscle flap - usually sternohyoid, to prevent the development of a tracheo-oesophageal fistula.

The recurrent laryngeal nerves may be damaged. It is recommended that no attempt is made to explore the traumatized wounds to specifically identify the recurrent nerves. The nerves are very difficult to identify in such patients and additionally the nerve may be damaged during dissection. If suspected, a tracheostomy may be necessary following tracheal repair - it should not be done through the repair site, rather at a separate site. Alternatively, if damage to the recurrent laryngeal nerves is only a possibility, an endotracheal tube may be left in situ. The patient should then be extubated in the operating theatre a few days later so that the airway can be assessed. If inadequate, a tracheotomy is then done.

In some circumstances, if there is concern about the ability to do primary repair because of the extent of injury, contamination of the wound, injury to the oesophagus or the inexperience of the surgeon, primary repair may not be advisable. The distal end of the trachea should be brought through the skin surface as an end tracheostomy and the proximal end either oversewn or brought out as a stoma. Every effort should be made to conserve viable tracheal tissue. Anastomosis can be undertaken by an expert.

If the larynx is damaged, this should be assessed and managed by an ENT surgeon, as often a stent is required. A tracheostomy must be performed when significant laryngeal injury is present.

Simple lacerations of the trachea should be repaired using absorbable interrupted sutures. Routine placement of a tracheostomy tube, especially through the laceration, should be avoided unless prolonged intubation is necessary.

Bronchial Rupture

The incidence of bronchial rupture is unknown since many patients will die of associated injuries before reaching hospital. Nevertheless, the majority of those who do reach hospital can anticipate a full recovery.

Mechanisms of Rupture

The exact mechanism is not fully understood and several theories are postulated. It may occur following trivial trauma but most follow either a fall from a height or a severe crushing injury. If the chest is compressed while the glottis is closed, a sudden increase in intrabronchial pressure will cause larger bronchi (or trachea) to burst rather than smaller bronchi, because the force acting on the bronchial wall at any given time is greater in larger bronchi than in smaller ones (Laplace's law: Wall Tension = Distending Pressure x Radius). Sheering forces at points of fixation, the result of rapid deceleration, may also cause bronchial rupture.

The majority of tears (90%) occur within 2,5 cm of the carina, and the lobar or segmental bronchi are seldom affected. The site of rupture is generally at bronchial bifurcation or at the union of the membranous and cartilaginous portion of the bronchi. The extent of rupture may vary from a small tear to an extensive linear tear and from partial to complete transection. Continuity may be maintained by peribronchial connective tissues.

Clinical Features and Diagnosis

The deep cervical fascia of the neck extends downwards into the thorax over the trachea and blends with the peribronchial connective tissue. This has importance clinically as ruptures which have not communicated freely with the pleural space may have, as the only clinical finding, surgical emphysema in the neck or mediastinum - the degree of surgical emphysema is variable and may be only slight. Pneumothorax is usually not present in these circumstances but if present, the lung readily expands with chest drainage. If the rupture is not immediately treated bronchial stenosis develops:

- if incomplete, bronchiectasis and irreversible lung damage may occur

- if incomplete, air is absorbed from the distal lung and the lung becomes atelectatic. The distal bronchial tree fills with non-infected mucus. These patients may be asymptomatic or have arterial desaturation due to intra-pulmonary shunting.

If the peribronchial connective tissue is torn at the same time as bronchial rupture, free communication with the pleural space results in a pneumothorax. If however, the pleura is obliterated (previous pleurisy) there may be no pneumothorax. These patients are dyspnoeic - the result of pneumothorax, airway interruption, pulmonary contusion or aspiration of blood into the contra-lateral lung and additionally may have haemoptysis and surgical emphysema. The pneumothorax should be drained as it is invariably large. The air leakage is large and characteristically, despite drainage, the lung persistently remains collapsed. If suction is applied to the drains, the patient invariably deteriorates and becomes distressed, since most of the inspired air sucked from the functioning lung.

In 50% of patients there are no associate injuries. Upper-rib fractures should raise the possibility of bronchial tear as the mechanisms of injury may be similar. Radiographically, the affected lung falls away from the mediastinum rather than collapsing towards the hilum as with a pneumothorax.

Bronchoscopy is done to confirm the clinical diagnosis and to determine the site of the tear. The rigid bronchoscope is preferred because excessive blood may be present in the tracheobronchial tree and because positive pressure ventilation may be necessary. Flexible bronchoscopy may be used if associated cervical spine injuries are present.

Management

Emergency treatment includes prompt and careful assessment of associate injuries, control of the airways and pleural space. A chest drain should be inserted if a pneumothorax is present.

The site, nature and extent of the tear must be carefully assessed bronchoscopically. Small tears may be treated conservatively, but most require surgical intervention. Primary reconstruction with presevation of the underlying lung should always be attempted. However, in some patients with extensive lacerations of the bronchi, pulmonary resection may be necessary.

The procedure should be carefully planned. Of particular importance is the maintenance of ventilation to the unaffected lung. Intubation with a double lumen endotracheal tube or selective intubation of the unaffected bronchus is advisable. The possibility of using a sterile endotracheal tube and connectors passed across the operative field should be considered. The thoracotomy should be on the side of the laceration. The bronchial edges should be carefully approximated with interrupted sutures (3/0 dexon or PDS) to obtain mucosal approximation.

The suture line should be reinforced by adjacent tissue or a pedicled intercostal muscle flap so that it is air tight.

Not infrequently, patients may be seen long after the injury. If a chronic fibrous stricture has resulted, bronchography should be undertaken to assess the state of the distal bronchi. If bronchiectasis is present and symptoms are severe, pulmonary resection may be necessary. Endoscopic resection or endoscopic laser vaporization may be considered because the stenosis is usually very short. However, endoscopic therapeutic attempts are rarely successful. Following complete disruption and the development of total bronchial constriction, assessment of the state of the distal lung is impossible. Nevertheless, excellent results can be obtained after repair of a lesion sustained many years previously. After prolonged atelectasis, good re-expansion, ventilation and circulation of the lung may be demonstrated. However, in some cases, gas transfer is markedly diminished. It is uncertain if that happens as a result of the mechanism, or whether it improves with time.

Chapter 8.4: Blunt Traumatic Rupture of the Diaphragm

J A Odell, U O von Oppell

A high index of suspicion is necessary to make the diagnosis of blunt traumatic rupture of the diaphragm. It should be suspected in any patient who after traumatic injury has an obscure or abnormal diaphragmatic shadow on the chest radiograph.

Occasionally the injury is missed for many years and only becomes obvious because of gastrointestinal obstruction secondary to herniation of intestinal contents into the chest or when the stomach is inadvertently intubated in the beliet that the patient has a pneumothorax with disruption of the diaphragm. Abdominal contents (omentum, stomach, spleen, small and large intestines, liver) may enter the thoracic cavity. Negative intrapleural pressure facilitates herniation and tends to cause air to be retained within the gastrointestinal system. The size and location of the diaphragmatic disruption determines which organs enter the thorax and to some extent, the potential for incarceration or strangulation. Depending on the extent of herniation and the degree of pulmonary compression, varyig degrees of respiratory embarrassment occur. When extensive, the mediastinum is displaced to the opposite side. If the diaphragmatic disruption is extensive, diaphragmatic excursion may be ineffective and the area may function as a "flail" segment aggaravating an already embarassed respiratory system.

Radiographic evidence of an "atypical pneumothorax", particularly if basal, should arouse suspicion regarding the possibility of ruptured diaphragm. A nasogastric tube should be inserted - this frequently improves respiratory embarassment because retained gas is allowed to escape from the stomach and a repeat radiograph will demonstrate the nasogastric tube curled up in the intathoracic stomach, thus confirming the diagnosis.

The majority of the ruptures occur on the left side, less frequently on the right side and rarely through the central tendon into the pericardium.

Treatment

Surgery should be undertaken when the general condition of the patient permits repair, since often there are other severe injuries. The surgical approach depends upon the side involved and whether the rupture is acute or chronic.

Chronic Diaphragmatic Ruptures

These should all be operated upon via a thoracotomy. It allows the abdominal content with their concomitant adhesions to be freed and mobilized easily under vision.

Acute Diaphragmatic Ruptures

- Left-sided ruptures are often associated with severe abdominal injuries and therefore a laparotomy and repair from below is usually indicated. If any difficulty is encountered a thoracotomy should be performed.

- Right-sided ruptures - should be repaired via a thoracotomy as the large lobe of the liver makes transabdominal repair extremely difficult.

The edges of the diaphragmatic tear are approximated with interrupted non-absorbable sutures. Occasionally, in patients who require surgery years after injury, Marlex mesh may be required to complete the closure.

Chapter 8.5: Injuries of the Heart and Great Vessels

J A Odell, U O von Oppell

Penetrating Trauma

The first successful repair of a penetrating wound of the heart was undertaken by Rehn in 1896. Today an aggressive approach to both the prompt diagnosis and direct suture repair of the lacerated heart is advocated; pericardiocentesis is no longer considered a primary therapeutic option. In South Africa the most common causes of penetrating cardiac trauma are knives, screwdrivers and other sharp implements followed by handgun missile wounds, unlike the situation in the USA where the greater proportion are gunshot wounds. The mortality of patients sustaining gunshot wounds of the heart is high, as usually there is multiple chamber and multiple organ involvement; high-velocity missile wounds are invariably fatal.

Pathophysiology and Clinical Presentation

The predominant site of injury is the right ventricle as it occupies the more accessible anterior surface of the heart. In most published series, the site of penetration in decreasing order of frequency is the right ventricle (40-60%), the left ventricle, the atria and the intrapericardial portion of the great vessels. Intracardiac injuries, although uncommon, are being recognized more frequently and include intraventricular septal defects, valvular injuries with resultant regurgitation and aorto-atrial, right ventricular or pulmonary artery fistulas.

Myocardial chamber penetration results in intrapericardial haemorrhage which manifests either as cardiac tamponade or as an exsanguinating intrapleural haemorrhage, depening upon the extent of the associated pericardial laceration and the degree to which the haemorrhage is contained within the pericardial cavity. Many patients with cardiac trauma die before reaching a hospital - a process of natural selection has thus already occurred when the patient is first seen by a medical doctor.

Cardiac Tamponade

Sixty-five to 80% of patients with penetrating cardiac trauma have the signs of cardiac tamponade. Unlike large pericardial effusions which accumulate slowly and therefore allow compensatory stretching of the pericardium are reasonably well tolerated, acute intrapericardial haemorrhage results in a rapid rise of intrapericardial pressure and severely affects cardiac function. By definition, cardiac tamponade is a collection of blood, fluid or, rarely, air of sufficient volume so as to interfere with cardiac filling resulting in diminished cardiac output.

Diastolic ventricular filling augmented by atrial contraction occurs primarily due to passive ventricular relaxation. Increased pericardial pressure results in external compression of the ventricle. The interference with ventricular filling results in diminished end-diastolic ventricular volume and therefore, a diminished stroke volume and consequent decrease in cardiac output. Myocardial ischaemia from decreased coronary artery bloodflow secondary to diminished aortic pressure also occurs and contributes to a progressive reduction in cardiac contractability.

The classical clinical presentation of tamponade consists of Beck's triad of:

- hypotension
- elevated central venous pressure higher than 12 cm H_2O
- muffled or distant heart sounds.

In addition, the following ancillary signs, although not diagnostic, are helpful:

- pulsus paradoxus greater than 15 mm Hg
- narrow pulse pressure
- extreme restlessnes due to decreased cardiac output and/or hypoxia
- poor urine output.

Pitfalls in the diagnosis of tamponade occurs in the following situations:

- Attributing hypotension to other associated injuries

This mistake will rarely occur if a central venous pressure line is inserted - it will be high in tamponade, low in hypovolaemia. Ensure that the central venous pressure line is properly positioned and carefully interpret readings. Hypotension that cannot be explained by apparent blood loss or that fails to respond to volume replacement is a significant finding, warranting further more careful assessment.

- False elevation of the central venous pressure

This may occur if the patient is shivering or straining or if the central catheter was inserted too far, that is into the right ventricle. The rapid oscillation of the water column may suggest this possibility and confirmation can be obtained radiographically. Inappropriate massive and rapid transfusion of volume expanders in a patient who has not sustained a significant blood loss, occasionally occurs in a trauma unit.

- Judicious observation in this situation may help to resolve the dilemma. The apex beat is commonly well seen, the patient passes large volumes of urine and is haemodynamically very stable.

- Mental state changes due to inebriation

Alcohol intoxication frequently complicates the issue. However, careful assessment of the patient's haemodynamic status must be made before attributing mental state changes to alcohol. Anxiety, agitation and lack of co-operation frequently occurs as a result of poor cardiac output and hypoxia.

Exsanguinating Haemorrhage

Intrapleural haemorrhage as a consequence of penetrating cardiac trauma is seen in only 20-30% of patients possibly because most patiens exsanguinate before reaching a hospital. A large pericardial laceration prevents intrapericardial accumulation of blood and the development of tamponade. These patients therefore have signs of a haemothorax in conjunction with hypovolaemia. Blood loss in excess of 1000 mL when a chest drain is inserted, and persistent chest drainage of greater than 100 mL/hr is an indication for surgical exploration.

Diagnosis and Management

The most important diagnostic feature is the presence of a precordial wound. This should alert the surgeon to the possibility of penetrating cardiac injury and the need to establish or exclude a cardiac injury. He should immediately institute the following:

- haemodynamic monitoring
- insert a properly positioned central venous pressure line
- establish a large-bore peripheral venous line.

A chest radiograph may show cardiac enlargement but this is inconsistent as the pericardium is unable to distend rapidly. It will, though, confirm the position of the central catheter and confirm the presence of a pneumo- or haemothorax. An electrocardiogram is not of diagnostic value.

An echocardiogram, if immediately available, will demonstrate a haemopericardium. However, this is only indicated in the stable patient with an equivocal diagnosis. Although diagnostic needle pericardiocentesis has been used, it is associated with both a significant false negative and false positive rate and is no longer routinely advocated. Subxiphoid needle pericardiocentesis performed by introducing a 16 gauge needle at 45° in the angle between the xiphisternum and left costal border and directing it towards the left scapula is the preferred approach, but failure to obtain blood does not exclude a haemopericardium because of clotting of intrapericardial blood, and there is also an attendant risk of producing a myocardial injury.

In the stable, ambiguous patient where tamponade is still strongly suspected and echocardiography is unavailable, exploration by means of a subxhiphoid pericardial window is of more value. This technique, easily performed under local anaesthesia, should be undertaken on the operating table with the patient cleaned and draped in preparation for a median sternotomy: if blood is found in the pericardium, general anaesthesia, endotracheal intubation and median sternotomy is immediately undertaken. The incision is centred on the xiphisternum which is divided with scissors; a cranially placed retractor elevates the lower sternum. Extrapericardial fat is displaced to expose the pericardium, which is grasped in two haemostats to tent it up and allow safe incision.

As with any syndrome there is a spectrum of clinical presentation which will in part dictate not only the urgency of treatment but also the extent of ancillary investigations. Initial resuscitation should include the rapid infusion of volume expanders as ventricular filling is entirely dependent upon a high atrial, or venous filling pressure, and the establishment of an adequate airway if indicated. Although therapeutic pericardiocentesis as discussed above may provide temporary relief of tamponade, its routine use is not advocated; instead immediate thoracotomy should be performed. It is important to remember that we are dealing with a naturally selected group of patients who have a good chance of survival. To rapidly rush into a thoracotomy as soon as the diagnosis is suspected while neglecting resuscitation and other injuries, may place the patient in great jeopardy.

Emergency room thoracotomy, however, does have a definite role in the management of a small group of moribund rapidly deteriorating patients. At the other extreme the stable patient may undergo diagnostic echocardiography, and some patients presenting late may be observed or operated on electively. The majority of patients will fall into a middle spectrum with progressive tamponade and require urgent operation but under controlled circumstances.

Surgical Approach and Techniques

The surgical incision may be either a median sternotomy or anterolateral thoracotomy; neither is of proven superiority. The possibility of associated injuries, especially to hilar structures of the lung and posterior mediastinum, will influence the decision along with the surgeon's experience and training. With both incisions the patient should be positioned flat and supine.

Median Sternotomy

This is the preferred incision for exploration of suspected cardiac injury by many. The incision extends from the suprasternal notch to just below the xiphisternum. The sternum is incised vertically in the midline. A vertical or circular oscillating saw, alternatively a Lebsche knife consisting of a vertical "chisel" and hammer or a Gigli saw may be used to transect the sternum. The tense distended haemopericardium is the incised with a knife and the incision extended with scissors while the fingers of the left hand displace the heart posterior to prevent iatrogenic injury. This incision gives exposure to all cardiac chambers, intrapericardial structures and to the anterior mediastinum, and can be easily extended into the neck for further exposure of the carotid and subclavian arteries. This incision is recommended for anterior pericardial stab wounds close to the sternum, especially if superior to the third costal cartilage, for multiple stab wounds and also if tamponade as opposed to pleural haemorrhage is the presenting feature. The incision is closed by approximating the sternal halves with a minimum of six to eight interrupted thick nonabsorbable sutures - preferably at least no 4 stainless steel wire or, failing this, a no 5 multifilament braided polyester.

Anterolateral Thoracotomy

An anterior lateral thoracotomy through the fift intercostal space on the side of the stab is favoured by many. It has the advantage of rapidity without the need for special instruments. The pericardium is incised anteriorly and parallel to the phrenic nerve. If wider exposure is required, transection of the sternum with bone shears and extension into the opposite intercostal space can be performed. The incision extended posteriorly allows easier access to concomitant injuries of the descending thoracic aorta, oesophagus and hilar structures of the left lung. Traction on the anterior pericardium allows wounds of the right atrium to be exposed and sutured through a left anterolateral thoracotomy. This incision is advocated in patients with laterally placed stab wounds and in patients presenting primarily with pleural haemorrhage as opposed to tamponade. Prior to closure of this incision the internal mammary vessels must be specifically sought for and controlled as they are invariably transected during the incision and may not immediately bleed. The ribs are then approximated, preferably with a thick absorbable suture.

Control of Myocardial Haemorrhage

After rapid and wide opening of the pericardium, accumulated blood and clots are evacuated. Relief or tamponade will immediately result in a significant haemodynamic improvement. Thereafter the surgeon must control ongoing haemorrhage. Haemorrhage from a laceration of the aorta, pulmonary artery or ventricle is usually obviously spurting, and easily controlled by relatively light digital pressure. Partially occluding vascular clamps are useful for the pulmonary artery or aorta but are unsafe on the ventricle. The source of haemorrhage from the atria, venae cavae or pulmonary veins is less obvious and is seen as a continued "welling" up of blood in the pericardial cavity - rapid and careful examination utilizing a strong suction nozzle is necessary. Digital pressure is not as successful and the application of a partial occluding vascular clamp may be necessary. The edges of the laceration may have to be grasped with forceps or by traction sutures prior to the application of the clamp. Failing this, a balloon type catheter (Foley's, embolectomy catheter, endotracheal tube) can be inserted into the laceration, the balloon inflated and traction applied to control ongoing haemorrhage.

In the event of torrential haemorrhage or a complex laceration that cannot be defined or controlled, cardiac inflow may be arrested by clamping the superior and inferior vena cavae independently with atraumatic vascular clamps.

Inflow occlusion may be maintained for 3-4 minutes only, thus limiting blood loss while allowing more definitive control of the laceration.

Once tamponade has been relieved and haemorrhage controlled, one should attempt to maintain calmness in the operating theatre, restore volume loss and obtain cardiac stability.

Suturing the Heart

A 2/0 or 4/0 non-absorbable suture on an atraumatic needle is used to suture the heart or great vessels. The authors preferentially use a 4/0 polypropylene suture or a 2/0 braided polyester suture with teflon pledgets. Ventricular muscle is surprisingly soft and especially for the nervous and inexperienced surgeon simple sutures tend to cut out and complicate laceration. Ventricular wounds controlled with digital pressure may be sutured with interrupted horizontal pledgeted mattress sutures. The pledgets, approximately 0.5 x 1.0 cm in size, are of teflon or dacron felt; strips of pericardium may also be used. These are used to buttress the horizontal mattress sutures. Widely spaced and deep bites approximately 3-5 mm from the edge of the laceration are placed, care is taken not to include adjacent coronary arteries. These are tied firmly but not tightly so as to cut through the friable muscle. If a coronary artery is immediately adjacent to the laceration, the mattress suture is brought deeply below the artery as illustrated. The finger applied to the ventricular laceration is gradually moved to expose small sections which are sutured - either the assistant tying them down, or alternatively all sutures are inserted and then gently tightened and held by the assistant while the surgeon ties them individually. The lacerations on the atria and great vessels are closed with figure of 8 propypropylene sutures, horizontal pledgeted sutures or alternatively a simple running suture.

After the obvious anterior lacerations have been controlled and sutured, a posterior laceration should be looked for.

Transection of the coronary arteries may occur but is uncommon, possibly because these patients do not survive. If a branch or distal coronary artery is involved, this may be ligated or sutured. Division of a major proximal coronary artery is a possible indication for cardiopulmonary bypass and coronary artery bypass grafting, but only if there is obvious diminishing cardiac function. The longer the elapsed period from the injury to the time of repair, the greater the likelihood of irreversible damage.

Although intracardiac damage may be suspected because of transfixing wounds or palpable thrills, cardiopulmonary bypass and immediate repair is not indicated if there is haemodynamic stability. The chest should be closed and elective cardiac catheterization performed to delineate the exact pathology. Repair is usually undertaken later.

When restoration of volume and cardiac stability has been obtained, the pericardium is loosely approximated. A size 28 Argyle drain is inserted into the pericardial cavity and a second drain into the anterior mediastinum. Prior to closure of the sternum the tract of the instrument should be followed and significant extracardiac injury excluded; if necessary the pleural cavities are opened. Specific attention must be paid to possible transection of the internal mammary artery.

Blunt Trauma

With the advent of high speed motor-vehicle accidents nonpenetrating cardiac injury is becoming more frequent and some form of cardiac injury has been estimated to occur in up to 75% of victims with severe blunt trauma. In a postmortem series myocardial rupture was found in 10-15% of fatal motor-vehicle accident victims. In another series traumatic aortic rupture was found in 10-15% of fatal vehicular accidents. The extent and severity of these injuries vary according to the mechanism and type of force the heart is exposed to and include:

- acceleration and deceleration forces - producing tears between relatively fixed structures and more mobile structures having greater inertia

- percussion and compression of the heart between sternum and vertebral column

- sudden increases in intra-thoracic or intra-abdominal pressure producing rapid increases of intravascular pressure and a "hydraulic ram" effect on the myocardial chambers.

By these mechanisms, blunt thoracic trauma produces a variety of injuries including:

- pericardial disruption and cardiac herniation with resultant haemodynamic embarassment

- pericarditis

- myocardial injury ranging from myocardial contusion to cardiac rupture, rupture of valvular components, coronary artery injury and delayed ventricular aneurysm formation

- aortic rupture, commonly occurring at the isthmus.

Although a number of rare injuries have been documented, the following are of more significance. Of importance is the need to be aware of the possibility of a cardiovascular injury.

Traumatic Myocardial Contusion

Although myocardial contusion may seem trivial, death following this lesion was first reported in 1764 and today is reported to be the most common visceral injury responsible for death in trauma victims. It has been estimated that approximately 25% of patients with suspected chest injury will have myocardial contusion.

Pathophysiology and Clinical Presentation

The histological appearance of the myocardium in myocardial contusion is similar to that of an acute myocardial infarction. The transition from normal to damaged myocardial tissue is, however, abrupt and varies from subpericardial petechiae to full-thickness myocardial haemorrhage and disruption. Cardiac contusion is frequently asymptomatic although up to 70% of patients will admit to angina like chest pain. This pain, as it is unrelated to coronary occlusion or any abnormality of coronary blood flow, is unrelieved by nitrates.

The extent of myocardial disruption will determine the residual cardiac function and if extensive will result in cardiac failure. Death, though, occurs usually from an arrhythmia, specifically ventricular fibrillation. The clinical presentation therefore may vary from an asymptomatic patient, angina like chest pain, life-threatening cardiac arrhythmia or finally overt cardiac failure. On examination, there may or may not be musculoskeletal injuries of the chest wall.

Diagnosis and Management

The diagnosis of cardiac contusion should be suspected therefore in any patient sustaining blunt injury to the chest with or without external evidence of injury. Serial twelve lead electrocardiograms are useful. Persistent new abnormal electrocardiographic findings - varying from non-specific ST to T wave changes, Q waves, conduction defects or tachyarrhythmias - should be considered indicative of myocardial contusion. False diagnosis do arise, particularly from hypotension, hypoxia, head injuries and electrolyte abnormalities, producing electrocardiographic changes. In addition, patients with post-mortem diagnoses of myocardial contusion have retrospectively been found to have had normal electrocardiograms.

However, the ECG remains the only immediately available diagnostic tool and at least one-third of patients will show ischaemic ST and T wave changes in the first 24 to 48 hours, though a normal ECG does not conclusively exclude myocardial contusion.

The use of the MB-band fraction and creatinine kinase (CK-MB) has also been used diagnostically but again because of the occurrence of this fraction in skeletal muscle, it lacks specificity and sensitivity but is should nevertheless be determined and interpreted appropriately, Radionuclide imaging of the heart also lacks sensitivity and specificity.

The initial treatment of myocardial contusion should be directed at overall support and thereafter is similar to that for a myocardial infarction. Close haemodynamic monitoring may be necessary during resuscitation and volume expansion, due to the possible associated decreased cardiac function. The contused heart has the potential to develop lethal arrhytmias and therefore continuous electrocardiographic monitoring for at least 48 to 72 hours is necessary.

Prophylactic anti-arrhythmic agents and coronary vasodilators are not indicated. If a cardiac arrhythmia appears, it should be appropriately treated. Pain may be relieved with opiates. Similarly the onset of congestive cardiac failure warrants specific therapy. After the acute phase, bed rest should be encouraged and physical activity restricted for two to four weeks. The prognosis for the majority of patients is good.

Traumatic Myocardial Rupture

The first successful management of cardiac rupture due to blunt trauma was by DesForges in 1955. It is present in approximately 64% of autopsy cases of non-penetrating traumatic injury to the heart. It has also been reported following closed chest massage or cardiopulmonary resuscitation.

Pathophysiology and Clinical Presentation

Ventricular rupture usually takes place at the time of injury, but may be delayed for up to two weeks post trauma. Delayed rupture, however, should be considered a complication of myocardial contusion. The verntricles appear to be more prone to rupture if a compression injury occurs during the isovolumetric contraction phase of early systole. The majority of patients sustaining ventricular rupture die shortly after the injury, although 10-30% survive 30 minutes to three days after the event. The high mortality is confirmed by autopsy reviews where the commonest chambers of the heart that rupture are the right and left ventricles with a 30% incidence of multiple chamber involvement and associated aortic rupture in 25% of cases.

In contrast to these autopsy series, clinical publications of successfully managed cases report that the commonest chambers that rupture are the right and left atria. The rupture being sited most often either at the atrial appendage, at the junction of the right atrium and the inferior vena cava or where the pulmonary veins enter the left atrium, and usually due to a deceleration type trauma.

As discussed with regard to penetrating cardiac injuries the clinical presentation will depend upon the integrity of the pericardium. Tamponade is the usual clinical presentation of myocardial rupture although approximately one-third of cases will present with exsanguinating haemorrhage due to an associated pericardial rupture.

Diagnosis and Management

The presence of multiple injuries make the diagnosis and management of this condition extremely difficult. A high index of suspicion cannot be overemphasized if these patients are to be successfully managed. Remarkable stability before the initiation of definitive treatment has commonly been reported in the survivors of blunt atrial tears. The presence of tamponade though, takes priority and immediate exploration supercedes further investigations.

Surgical Approach and Techniques

The incision of choice for exploration of a patient with tamponade and suspected blunt cardiac rupture is a median sternotomy. This affords optimal exposure for control of the most likely injury - a right atrial tear. Guidelines for the control and suturing of this injury have been discussed before. If there is a high index of suspicion of extensive associated injuries, ie, aortic rupture, a bilateral transternal thoracotomy is advocated.

Traumatic Aortic Rupture

The incidence of acute traumatic rupture of the thoracic aorta has increased over the past few decades, since the first successful repair was performed by Passaro and Pace in 1959, coincident with the production of high-speed vehicles. In 1966 a 16% incidence of this lesion in fatal motor-vehicle accidents was reported by Greendyke, and interestingly a higher incidence of 27% was found in those fatally injured victims ejected from the motor-vehicle as opposed to a 12% incidence in those not ejected. Without treatment it is estimated that approximately 85% of persons who suffer traumatic rupture of the thoracic aorta in a motor-vehicle accident will die at the scene of the accident, 10% will die within two weeks, and 5% will survive and develop a chronic aneurysm. In the majority of patients with a chronic aneurysm, 42% will develop signs or symptoms of aneurysm expansion or die from sudden rupture within five years of the injury.

Pathophysiology and Clinical Presentation

The predominant site of rupture (60%) is at the aortic isthmus, the region between the origin of the left subclavian artery and the ligament arteriosum. The descending thoracic aorta and multiple sites of rupture are involved in a further 20% and the ascending aorta and arch are involved in the final 20% of cases. If there is an associated cardiac injury, a higher incidence of ascending aortic involvement is found.

The mechanism of injury is usually a violent deceleration type impact. Horizontal deceleration as in motor-vehicle accidents, produces severe inertial and flexion forces causing rupture of the aortic isthmus - a transition zone between the relatively mobile aortic arch and fixed descending thoracic aorta (fixed by the intercostal arteries). A vertical type of deceleration, as in a fall from a height, generates inertial forces causing ascending aortic rupture by displacement of the heart downwards and to the left and resultant traction on the ascending aorta transmitted to the now relatively fixed aortic arch (fixed by the head and neck vessels).

The resistance and integrity of the adventitia of the aorta at the time of the accident determines the patient's immediate survival. Only the intima and media are ruptured and the mediastinal haematoma is limited by the adventitia. It is this contained mediastinal haematoma that accounts for the radiographic manifestations of this injury. If all three layers rupture on impact, death is rapid. The risk of delayed secondary rupture of the mediastinal haematoma through the adventitia is greatest from the eight to 12th day post-injury. Subadventitial dissection of the haematoma may cause compression of other vessels and account for some ischaemic complications of the spinal cord and kidneys.

The rupture is usually transverse and linear and may be complete/circumferential in 40-60% of cases, in which case the ends of the intima and media retract for up to 3-6 cm, or may be incomplete.

There is no characteristic clinical presentation and in fact 20% of patients will be asymptomatic with respect to the aortic injury and furthermore many patients will have no external evidence of thoracic trauma. Shock and dyspnoea is reported in 20-50% of cases while retrosternal or intercapsular chest pain is found in 30-50% of patients. Stridor, dysphagia and hoarseness as a result of mediastinal compression are all late and rare symptoms. If a discrepancy in the blood pressure between arms and legs (a pseudocoarctation syndrome) is found, it is significant.

Diagnosis and Management

A high incidence of suspicion in all patients who have sustained a violent deceleration type of impact is necessary. The single most important diagnostic study is the chest radiography. If possible an erect anteroposterior film at a distance of 2 m should be obtained. The only consistent but not specific feature on the chest radiography is a widened mediastinum - greater than 8 cm at the aortic knob. Other radiological signs are listed in table 8.5.1. All have some degree of sensitivity and specificity although none are diagnostic.

Of major concern is the problem that a normal radiograph does not exclude the diagnosis of aortic rupture and in fact a 27% incidence of normal admission chest radiographs is reported. In the elderly over the age of 65 years this incidence is even greater. Therefore the physician should request and insist on aortography whenever there is even the slightest indication that the patient may have suffered injury to the thoracic aorta. A higher incidence of negative aortograms is a small price to pay in order not to miss the lethal injury, The morbidity and mortality of a negative aortogram is far less than the morbidity and the mortality of this missed injury, as within six hours of admission 30% of untreated patients will fatally rupture through the adventitia.

Table 8.5.1. Radiological signs of traumatic rupture of the descending thoracic aorta

- Wide mediastinum, greater than 8 cm at the aortic knob.
- Left apical pleural cap, opacification of the supramedial aspect of the left upper lobe at the apex.
- Blurring of the sharp aortic contour.
- Obliteration of the normal clear space between the aorta and left pulmonary artery.
- Tracheal shift to the right.
- Oesophageal shift to the right at the aortic knob, as evidenced by displacement of a nasogastric tube.
- Depression of the left main bronchus to an angle less than 40°.
- Left haemothorax.
- Fracture of the sternum or first rib (controversial).

The angiographic appearance of a traumatic ruptured aorta is based on the detection of a false aneurysm or para-aortic mediastinal haematoma contained by the tunica adventitia and/or an intimal tear or flap. This appearance can vary from a slight irregularity of the aortic outline, a narrowing or pseudocoarctation, dissection, a transverse linear defect produced by a flap of intima and media or finally a definitive large false aneurysm. In addition, one should ascertain with certainty if there are multiple lesions.

The initial management of the patient with a ruptured thoracic aorta is similar to the medical management of dissecting aneurysms of the thoracic aorta. After initial resuscitation and replacement of blood losses, hypertension is common. Although immediate surgery is advocated, delays do occur, and ideally antihypertensive therapy should be instituted in the emergency room prior to aortography. This therapy is directed first at reducing the ejection force of the left ventricle with a beta blocking agent such as propranolol (0.5-1 mg IVI) and secondly at the control of systemic hypertension with sodium nitroprusside.

Surgical Approach and Techniques

A left posterolateral thoracotomy is performed entering the pleural cavity above the fifth rib. Double lumen endotracheal tubes, while useful, are not essential and in fact may be hazardous if inserted by an inexperienced anaesthesiologist. The aortic arch between the left subclavian and carotid arteries, the descending thoracic aorta and the left subclavian artery should all be carefully dissected with blunt dissection and encircled with tapes without entering the mediastinal haematoma. There are two controversial aspects of some importance:

Protection of the Lower Body

The major complication of this injury is paraplegia, which has been reported in 2-10% of patients. Contributing factors are:

- Variable spinal cord vascularization

The spinal cord is supplied by three arteries extending caudally from the vertebro-basilar system:

- two postero-lateral arteries supplying the posterior columns

- one anterior spinal artery supplying 75% of the cord.

This artery narrows in the mid-thoracic region and must therefore be augmented by a radicular artery - the artery of Adamkiewicz. This artery is variable in its origin and is found anywhere between T5 and L2.

- Duration of aortic crossclamping

Simple aortic crossclamping without augmentation of the distal circulation will invariably result in some degree of distal spinal cord ischaemia. If the duration of aortic crossclamping is less than 20 minutes, paraplegia will rarely occur. If the intercostal artery giving rise to the artery of Adamkiewicz is ligated, or is included in the segment clamped even when using distal circulatory augmentation, paraplegia may still occur.

- Proximal hypertension

Severe proximal hypertension for the duration of aortic clamping will result in a raised intracranial cerebrospinal fluid pressure which is transmitted distally around the spinal cord. This will, by external compression, diminish the distal differential perfusion pressure as distally the arteria pressure will be low, with resultant aggravation of spinal cord ischaemia. Hypertension should therefore be treated but not excessively, as this will produce inadequate collateral perfusion during the cross-clamp period.

- Peri-traumatic spinal cord injury

The same flexion forces transmitted to the aorta will have been transmitted to the spinal cord with possible resultant injury, and occasionally a neurological assessment is not possible preoperatively.

The Surgical Options are therefore the following:

- No distal protection.

Simple aortic crossclamping. As long as the crossclamp period is less than 30 minutes, this method is expedient and safe with a low incidence of complications. The crux, of course, is that no surgeon can guarantee that he will not require a longer crossclamp period at the commencement of the procedure.

- The heparin-bonded shunt (Gott or TDMAC shunts)

A 9 mm, 90 cm shunt is inserted between the ascending aorta or left ventricular apex and the descending thoracic aorta or left iliac/femoral . This technique has been shown to not entirely prevent paraplegia, and occasionally does not augemtn the distal circulatory pressure to an acceptable level (> 50 mm Hg). Excessive bleeding at the insertion sites may also occur.

- Partial cardiopulmonary bypass

Left atrium to left femoral artery or femoral vein to femoral artery. If a roller pump with oxygenator is used systemic heparinization is required. This is contraindicated if there is severe associated craniocerebral injuries. Again, this technique has also been shown to entirely prevent paraplegia. It is advocated though in patients with chronic false traumatic aneurysms.

Alternatively, partial cardiopulmonary bypass can be performed without an oxygenator and without heparinization if a centrifugal pump is used. At present, the authors advocate this to be the technique of choice.

No matter which approach is used, the surgery must be performed expeditiously, collateral vessels should be preserved and the crossclamp should be placed as close as possible to the aortic laceration. If available, the intraoperative measurement of cortical somatosensory evoked potentials is the only sure way of detecting and therefore possibly preventing spinal cord damage.

Aortic Repair

Primary end-to-end suture repair of the circumferentially ruptured and retracted aorta, after mobilization of both ends, is the ideal. However, the majority of surgeons (70%) will interpose a short segment of tubular Goretex or Dacron, and often utilize a diamond-shaped patch in cases of partial rupture. A continuous running suture of 3/0 or 4/0 polypropylene is normally used.

Chapter 8.6: Injuries of the Oesophagus

J A Odell, U O von Oppell

Oesophageal Rupture

The first case of *spontaneous oesophageal rupture*, described by Boerhaeve in 1724, concerned Baron van Wassenaer, Grand Admiral of the Fleet of Holland. This syndrome follows a severe bout of vomiting and is often referred to as *Boerhaeve syndrome.*

Etiology

The major factor appears to be vomiting and retching. It occurs almost uniformly in the lower third of the oesophagus - the weakest area of the oesophagus. The tear has almost always been longitudinal in clinical and experimental studies. This is possibly due to the greater weakness of the longitudinal muscle and in addition, less tension is required to cause rupture in a longitudinal as opposed to a horizontal direction.

Tidman and Johns found that an oesophagus removed at autopsy ruptured at pressure of 119 mmHg; in the intact cadaver it ruptured at 238 mmHg. During vomiting, pressures as high as 850 mmHg have been measured in the stomach. It is therefore not surprising that if the markedly raised pressure of vomiting is confined by a closed cricopharyngeal sphincter, the intraoesophageal pressure may exceed the strength of the wall of the oesophagus and rupture will result.

The longitudinal rupture normally involves the left wall and varies in length. More than 80% of ruptures occur in the lower third, approximately 15% in the middle third, while a small number affect the cervical oesophagus.

The rupture may be contained within the mediastinum resulting in mediastinitis. The mediastinitis is at first chemical but later bacterial infection occurs. This mediastinal inflammation often produces a sympathetic pleural effusion. Air in the mediastinum may progress upwards into the neck.

If the ruture extends through the pleura at the time of rupture, mediastinitis may be less severe but the pleural surface is also involved in the initial chemical and bacterial inflammation. If operated soon after the injury, the mediastinum and pleura are red and oedematous.

Circulatory collapse and toxicity develop rapidly and have been explained by the intense chemical inflammatory reaction in the mediastinum and pleura and the interference with cardiorespiratory function. Occasionally the event is associated with few initial symptoms and it may be recognized that the patient has a perforation only after finding food content in an empyema that has been drained.

Diagnosis

The patient usually prefers a sitting position. He may be shocked and dyspnoeic. Surgical emphyseam can be felt in the neck in approximately 50% of the patients. If present in the mediastinum it may be heard as a "mediastinal crunch" with a stethoscope. If the rupture has been into the pleura, the clinical signs of pneumothorax or pyopneumothorax may be found. In a number of patients abdominal signs of tenderness and rigidity may be elicited and in some patients an explorative laparotomy has been undertaken in the mistaken belief that the patient had a perforated ulcer.

Radiological findings are:

- mediastinal and subcutaneous emphysema
- pneumothorax, hydropneumothorax, or pleural effusion - found more frequently on the left but may be present on the right or bilaterally
- extravasation of contrast material

Oesophagoscopy is not necessary if the diagnosis has been confirmed with a contrast study. Examination of the pleural fluid may demonstrate squamous cells of saliva or food particles. The pH of pleural fluid has been shown to be lower in patients with spontaneous rupture than in patients having a pleural fluid collection for other reasons.

Treatment

The patient should be resuscitated with oxygen and intravenous fluids. A CVP line, inserted preferably on the side chosen for thoracotomy or the side requiring chest drainage, may be useful. Appropriate broad-spectrum antibiotics should be given.

A chest drain should be inserted if a pleural collection is contributing to respiratory distress. A tube passed into the stomach may prevent further contamination of the mediastinum and pleura.

Immediate thoracotomy for closure of the rupture and drainage is necessary in early cases, as the mortality is increased in those operated on late. The mortality was 22% in one series if operated on within 12 hours; within the next 12 hours it was 36% and beyond 24 hours the mortality was 64%. The lateral thoracotomy is on the left for lower oesophageal rupture, on the right for the mid-rupture. Food and gastric juice is removed from the pleura. The mediastinal pleura is widely opened through its entire length to provide adequate drainage of the mediastinum into the pleura which is itself later drained. The tear in the oesophagus is repaired in two layers. Some surgeons have used various tissues such as diaphragm, fundus of the stomach, or a pleural flap for reinforcement.

In patients who are diagnosed late or neglected, appropriate pleural drainage, usually by rib resection, is required. The method of management thereafter has varied considerably, possibly indicating that no method is uniformly satisfactory. Intravenous hyperalimentation and antibiotics are used by most surgeons and have increased survival. An important factor in successful therapy is whether the lower oesophageal sphincter is competent or stenotic as massive reflux complicates aby form of treatment. In this respect some authors advocate glucagon, a potent suppressor of gastric juice. Cimetidine may also be helpful.

Operative closure may be difficult or impossible, but may be attempted in a fit patient who is a reasonable risk. The area of repair or rupture should be covered by gastric fundus or parietal pleura (usually thick and oedematous). Other surgeons have concentrated on eliminating the possibility of gastric reflux. Some authors advocated division and closure of the cardia and cervical oesophagus with a cervical oesophagostomy for drainage of saliva and later reconstruction of alimentary continuity retrosternally. Others have used a side cervical oesophagostomy and used tape or silicone tubing to tie around the cardia. Others have placed a large soft T-tube through the opening in the oesophagus in order to construct a controlled fistula.

An interesting approach with excellent results is advocated by Santos and Frater. The perforation is continuously irrigated by a saline solution, either ingested orally or infused via a nasogastric tube positioned proximal to the perforation. The effluent is drained into a chest drain. Spontaneous healing of the perforation results.

In the acutely treated patient the majority of the ruptures heal. Complications depend on the degree of mediastinal and pleural contamination and the presence or absence or leaks after surgical closure. The contralateral side to that initially involved and in which the thoracotomy was done, would be observed for the possible late development of empyema.

Instrumental Perforation

In contradistinction to "spontaneous" rupture, instrumental perforation is usually recognized at the time of the procedure or soon thereafter. The perforation may occur during oesophagoscopy, gastroscopy, dilatation of the oesophagus, endotracheal intubation or the passage of a naso-gastric tube. When dilatation is used, the incidence is highest with pneumatic dilatation, followed by metal olives and least with mercury bougies.

Pathology

Perforation is more likely to occur at the following sites:

- cricopharyngeaus
- the lower third of the oesophagus where it deviates anteriorly and to the left as it traverses the hiatus of diaphragm
- at the site of an oesophageal lesion
- at the site of removal of a foreign body
- deep biopsy sites.

Involvement of the peri-oesophageal tissues is usually rapid in onset in the upper oesophageus saliva containing numerous anaerobic organisms, leaks into surrounding tissues; in the lower third gastric juice may cause severe chemical inflammation followed by bacterial invasion. The symptoms depend on the site and size of perforation but pain is predominant. In the neck it may be aggravated by swallowing and movement. In the chest the pain is substernal or commonly in the back; in the abdomen, it is predominantly in the epigastrium. Symptoms of respiratory distress depend upon the involvement of the mediastinum and pleural cavity. Radiographically air may be demonstrated in the mediastinum, soft tissues or lying freely in the abdomen. In the neck, radiographs in two planes may be necessary to demonstrate extra-oesophageal air. A contrast examination will confirm the perforation.

Treatment

An instrumental perforation identified reasonably early after the injury should be closed immediately and the contaminated area adequately drained. Small lacerations in the neck associated with minimal symptoms, however, may be managed expectantly and if an abscess or septicaemia develops, should then be drained. This approach, however, is not generally advocated.

In patients with obstructive lesions, simple closure of the perforation is unlikely to succeed. Patients with achalasia of the oesophagus should have a myotomy in addition to closure of the perforation; the patient with a benign stricture should have this resected or dilated. If carcinoma is present, this should be resected if feasible. In patients with marked debility and extensive carcinoma who would not normally be considered for resection of the tumour, the management is not defined and will depend on the surgeon's attitude and experience. Some surgeons will heavily sedate the patient and accept the inevitability of death; some will attempt to exclude the area of perforation by intubation, but one should be cautious not in fact to enlarge the perforation; some will do a retrosternal gastric bypass so that alimentary continuity is restored and the area of perforation is excluded - if empyema develops this is drained. Another theoretical option is end-cervical oesophagostomy for the collection of saliva, exclusion of the thoracic oesophagus and the creation of a feeding gastrostomy.

Other Traumatic Perforations or Ruptures

The oesophagus, because of its protected position anterior to the vertebrae and posterior to other vital structures, is infrequently the site of isolated trauma. Injury to the oesophagus association with trauma to its neighbouring organs, is frequently rapidly fatal and the oesophageal lesion may be found only at autopsy. Occasionally, however, isolated injuries may result from a knife, bullet or similar weapon. In patients with injuries that traverse the mediastinum (ie, bilateral pneumothorax with only one entrance wound, left neck stab with right haemopneumothorax) a careful assessment of the integrity of the oesophagus by endoscopy and/or contrast examination is necessary to exclude injury to the oesophagus - if found this should be promptly repaired as the mortality increases markedly if missed. Pharyngo-oesophageal barotrauma is a rare occurrence and is produced by the sudden release of compressed air into the mouth, resulting in pharyngeal and oesophageal tears. This may occur after biting off a herniated pressurized inner tube of a tyre, an exploding gas cylinder or fire-extinguisher. Conlan and colleagues described six cases in children who had attempted to open pressurized soft-drink containers with their teeth. In their experience the injuries were extensive. They were managed surgically in three and managed conservatively in the remainder with full recovery occurring in all patients.

Comment

Early Diagnosis and Treatment

The single most important aspect related to prognosis after oesophageal perforation is the time interval before prompt diagnosis and treatment are instituted.

The possibility of this condition should not only be kept in mind, but actively sought for after all endoscopies, penetrating neck and thoracic injury and when the mere suspicion of a spontaneous rupture arises.

Early recognition depends largely on the interpretation of the characteristic radiographic findings:

- mediastinal widening
- mediastinal emphysema
- air in the deep cervical tissues along the erector spinae muscles in the neck
- pneumothorax
- pleural effusions
- pneumoperitoneum
- retropharyngeal swelling.

The time interval, the site of the perforation and the integrity of the mediastinal pleura can influence the radiographic findings and a "normal" radiographic appearance does not exclude perforation.

A radiopaque swallow carried out as an emergency usually demonstrates the site of perforation, its relationship to a pre-existing lesion and the extent of involvement of the neighbouring tissues. We use thin barium for the purpose. Early surgical treatment is indicated in most cases of oesophageal perforation. If cervical instrumental perforation is to be managed conservatively, the disruption should be contained within the mediastinum with drainage of the cavity back into the oesophagus. There should be minimal symptoms and no sign of clinical sepsis. If these conditions are met, it is reasonable to treat the patients conservatively with hyperalimentation, antibiotics and cimetidine to decrease gastric acidity and inhibit pepsin activation. Oral intake is resumed in seven to 14 days depending on subsequent radiographic examination.

Desperately Ill Patients With Overwhelming Sepsis Due to Mediastinitis and Necrosis

When extreme debility or gross sepsis as a result of late diagnosis or other reasons threatens to overwhelm the patient, the situation becomes a significant challenge to the surgeon. Although different modalities of treatment exist, it is important to identify principles of treatment and to take advantage of various supportive measures.

The principal considerations which govern the management of such cases are:

- Adequate drainage of the mediastinal and pleural sepsis
- Critical care of physiological support (nutrition, fluids, acid base, etc)
- Safe and expeditious surgical management.

We have the following policy:

- The patient is immediately transferred to the isolation cubicle of the ICU.

- While the operating room is being prepared, all modalities of intensive care are made available (antibiotics effective against anaerobic and aerobic micro-organisms, fluids, correction of acid base defects, etc).

- Theatre procedures

The patient is placed in a supine position with the affected side of the chest slightly elevated.

A rigid oesophagoscopy is performed to determine the direction, position and extent of the tear, to evaluate the presence or absence of other lesions and to aspirate fluid from the mediastinum.

First a gastrostomy is performed and then a cervical oesophagostomy which is done in continuity.

The chest is then opened using a small anterolateral thoracotomy. A double lumen tube that allows the lung on the operation side to be collapsed is of great help to allow rapid identification of the oesophagus. The mediastinal pleura is widely opened and all lobulations are broken down.

Methylene blue injected into the proximal oesophagus assists to display the tear. The oesophagus is ligated with an absorbable vicryl ligature below the tear to assure temporary exclusion of stomach contents.

All fluids and debris are evacuated from the pleural cavity and fibrous plaques are peeled of the lung. The pleural cavity is irrigated with an irritating Betadine solution and the inside of the rib cage abraided with a swab to encourage rapid adhesion of the lung and localization of the empyema.

The chest is drained with two large-bore 36 Fr silicone-coated tubes with multiple holes. These are introduced through a small rib resection, below the thoracotomy wound, and kept in a dependent comfortable position, because the patient can be expected to be eventually managed as an empyema. One tube is placed anterior to the hilum up to the apex and one posterior to the hilum. After assuring that the lung is completely expanded, the chest is irrigated and closed.

- Postoperative care

The patient is transferred to the ICU where he spends at least 24 hours, specifically to ensure adequate analgesia and physiotherapy. Meticulous attention to chest drains, underwater suctioning to assure lung expansion, and drainage are important to prevent atelectasis and pneumonia which are often associated. Gastrostomy feeds are commenced using a low residue predigested feed (Reabilan - Roussel).

Intravenous antibiotics are continued and attention given to fluid balance.

Postoperative irrigations are used via a tube placed through the cervical oesophagostomy with its tip near the perforation. When the patient has recovered from his infection, he is managed as an empyema and further teratment such as reconstructive procedures are planned as indicated.

Chapter 8.7: Foreign Bodies in the Trachea, Bronchus and Oesophagus

J A Odell, U O von Oppell

The first endoscopic removal of a foreign body was performed by Killian in 1897. At that time the mortality of an inhaled foreign body was approximately 50%, whereas today with modern anaesthesia and bronchoscopic techniques, it averages 1%. Although the incidence is declining, foreign body inhalation still causes the death of over 500 children per year in the United States of America. Koch believes that of foreign bodies, 80% will enter the gastro-intestinal tract and 20% will go into the tracheobronchial tree.

Foreign Bodies in the Tracheobronchial Tree

The peak incidence of foreign body inhalation is in the second year of life. Approximately 80% of all patients are less than three years of age and boys are affected twice as often as girls. The predomination of this age groups occurs because small children have relatively inefficient airway protective mechanisms, in addition to an inqusitive orally orientated tendency to put whatever comes within their grasp into their mouths.

The most common etiological agent is a peanut although a wide variety of objects have been removed. The objects lodge in the right bronchi, 45-56%; the left bronchi, 40-45%; the trachea, 10-15% and rarely bilaterally. Vegetable foreign bodies are more dangerous than metallic or plastic as they are more irritating, swell, obstruct the bronchus to a greater degree and, in addition, are likely to break up on attempted removal.

Pathophysiology and Clinical Presentation

The initial stimulation of the respiratory mucosa by contact with a foreign body produces paroxysmal coughing, gagging and wheezing. Objects lodged in the trachea produce more symptoms than those lodged in the bronchus and if the larynx or trachea are obstructed, death will result from asphyxia unless the object is immediately disimpacted. Thereafter the initial symptomatology abates as the mucosa accommodates to the presence of the foreign body. After the inceptive episode the patient may become asymptomatic, or symptoms may remain (annoying cough), continued wheeze or stridor, haemoptysis, pain), or they may develop increasing respiratory failure depending upon the size and nature of the foreign body and the site of lodgement.

The majority of patients with foreign bodies, when first seen, have survived the acute phase and on examination may have minimal or no respiratory distress. An audible wheeze may be heard on auscultation but more frequently diminished or absent breath sounds overlying an area of lung is noted.

The classical presentation is therefore the triad of a sudden onset of:

- paroxysmal coughing
- wheezing
- diminished air entry on the affected side.

Although 75-91% of patients will have at least one component of this triad, all components are only present in 39% of patients. If the foreign body is not removed timeously an initial "silent period" may the be followed by the development of infection distal to the obstruction, due to interference with normal bronchial toilet. Late complications include pneumonia, bronchiectasis, organic bronchial stenosis, lung abscess and empyema.

Diagnosis and Management

Reviews have shown that despite the fact that around 85% of patients were known to have inhaled something, only approximately 45% are seen early (within 24 hours). This is in most part due to parental delay. In the group presenting late (after 24 hours) the complete diagnostic triad is present more frequently.

Radiographic examination, although important, is not essential for the diagnosis and in fact a negative radiograph is a common cause of failure to detect an inhaled foreign body early. Inhaled foreign bodies are rarely radio-opaque (less than 6%) and plain chest radiographs are often normal within the first 24 hours. Radiographic features to be looked for are:

- Obstructive emphysema (air trapping) produced by an inspiratory ball-valve effect whereby air enters but cannot escape, producing local hyperinflation. Apart from a shift in the mediastinum to the opposite side, there is increased radiolucency and diminished vascularity of the affected lung field. This radiographic sign may be accentuated by obtaining inspiratory and expiratory films. The affected side will show retension of radiolucency, restricted motion of the ipsilateral hemidiaphragm and accentuation of mediastinal shift on expiration.

- Atelectasis due to total bronchial occlusion from a foreign body with distal air reabsorption or by an expiratory ball-valve effect.

- Consolidation. Indicative of possible distal infection. The most important component in the diagnosis of aspiration is a history of a choking episode. The diagnosis and site of impaction of the foreign body may be accurately delineated with clinical and radiographic signs in 80-85% of patients, an endoscopy should, however, never be omitted because of a normal chest radiograph if the clinical history is suspicious.

Bronchoscopy is necessary if there is any suspicion of aspiration of a foreign body and if properly performed, is an extremely safe procedure. Foreing bodies in the bronchial tree are seldom expelled spontaneously and preoperative postural drainage or physiotherapy is never indicated. Uncontrolled disimpaction of a foreign body might produce total airway obstruction and asphyxiation. Only in situations in which the patient is in extremis may such desperate measures of probing the pharynx blindly with a finger, turning the patient upside down, pounding between the shoulder blades, or performing the Heimlich manoeuvre be condoned.

Surgical Techniques

All patients with a possible foreign body in the airway should be bronchoscoped; this procedure, however, should not be undertaken lightly by the inexperienced especially if ill-equipped. A few hours delay in transfering a patient to a properly equipped unit is far safer.

Bronchoscopy should be performed with a rigid bronchoscope under general anaesthesia with the patient breathing spontaneously. Extraction of the foreign body under vision will then be possible in more than 90% of cases. The flexible fibre-optic bronchoscope is rarely helpful and should not be used. The Storz-Hopkins 0 and 30 telescopic bronchoscopes and optical grasping forceps are a distinct advantages and should be available especially for infants.

After insertion of the bronchoscope the unaffected bronchus is examined first for foreign bodies, anatomic abnormalities or inflammation. Thereafter the foreign body in the involved bronchus is carefully visualized. Depending upon the duration of impaction there may be adjacent bronchial oedema and overlying secretions obscuring the object and these should be removed with atraumatic suction and saline washouts. Any over-vigorous manipulations at this stage will aggravate the existing oedema, produce bronchial haemorrhage and unnecessarily complicate the procedure. A duplicate of the foreign body may be useful to preliminary select test the appropriate forceps. Removal may be totally impossible with inappropriate forceps. The standard foreign body forceps have a firm grasp and are used on dense objects, while "peanut forceps" which are lighter, fenestrated and more delicate, are used on friable vegetable matter.

Foreign bodies in the distal tracheobronchial tree may require more than one technique for extraction, i.e., disimpaction with a Fogarty balloon catheter and removal with a four-prong grasping hook. Having selected the optimum forceps it should be introduced till the tip lies just before the foreign body, it is then opened and carefully advanced around the object which is then grasped. Frequently the foreign body is too large to be drawn through the bronchoscopic tube and it is then held against the tube mouth and the entire unit is withdrawn as one. Once the foreign body has been removed the bronchoscope must be reinserted and the tracheobronchial tree again carefully scrutinized for any retained or dislodged fragments, and evidence of possible trauma.

If the first attempt at removal of a foreign body from a child is unsuccessful it is better not to persist beyond a 15 miute period since the possibility of complications will increase. Referral to a better equipped centre for a second procedure should be done. Postbronchoscopy complications are normally infrequent and confined to vocal cord oedema, which responds to nebulized adrenaline therapy. Pneumothorax or pneumomediastinum indicative of bronchial perforation are occasionally noted and the pneumothorax should be treated with intercostal tube drainage. Open bronchotomy to remove the foreign body is rarely indicated but occasionally necessary.

After successful removal of a foreign body the patient should have a repeat chest radiograph in addition if there was evidence of distal infection or bronchial inflammation antibiotics and active chest physiotherapy with nebulization should be instituted.

If a foreign body has been present for longer than a week distal bronchiectasis of the subtended bronchi is likely. After the acute inflammatory response has been allowed to settle, usually after three months, a bronchogram should be obtained to document the presence of bronchiectasis. Pulmonary resection may then be indicated if the patient is symptomatic.

Occasionally patients are seen months or years after inhalation of a foreign body, now with obvious bronchiectasis. In these patients the foreign body is impacted and removal is often impossible. In these circumstances pulmonary resection of the involved segment of lung is necessary.

Foreign Bodies in the Oesophagus

The majority of foreign bodies in the oesophaguc occur in the paediatric age group, 70-80% being less than 12 years old. There is, however, a significant incidence in adults in the following groups:

- underlying oesophageal disease
- edentulous adults
- prisoners
- psychiatric patients.

The type of foreign body impacted in the oesophagus differs between children and adults. In a child the commonest offending object is a coin, whereas in adults chunks of meat are the norm.

The oesophagus is at risk for retention of swallowed material because of relatively weak peristalsis and physiological narrowings at the:

- cricopharyngeal muscle
- level of the aorta
- gastro-oesophageal junction.

The majority of the objects, however, lodge in the upper third of the oesophagus. Because the oesophagus is a relatively thin-walled flexible tube it is easily perforated and the lack of a serosal layer increases the potential for serious complications.

Pathophysiology and Clinical Presentation

Acute obstruction of the oesophagus produces two physiological effects: a reflex-increased production of saliva and an inability to swallow. The patient therefore presents with increased salivation and drooling. Secondly, increased peristalsis of the oesophagus, in an attempt to propel the object forwards, produces variable chest pain or discomfort. This latter abataes partly from fatique and also as the oesophagus adjusts to the presence of the object.

In adults a history of dysphagia following the ingestion of food, occasionally superimposed on a background of excessive alcohol intake, lack of dentures, improper or hasty chewing or mild chronic dysphagia, will be obtained. In patients in whom a bone causes an abrasion and then passes on, the reported pain and sensation of an object impacted in the pharynx or chest is usually not quite as severe and disappears after some time. However, this cannot be differentiated from an actual foreign bodyt except by further investigations.

Acute respiratory embarrassment may be produced by impaction of a large piece of meat at the level of cricopharyngeus with resultant anterior pressure on the trachea causig respiratory obstruction. This "cafe coronary" might require immediate action by dislodgement of the food with a fork or finger or by means of the Heimlich manoeuvre.

Perforations results in increased chest pain and fever, in addition to mediastinal and cervical emphysema, detected clinically as subcutaneous crepitations in the neck.

Special mention concerning miniature button battery ingestion is necessary because of the high incidence: 510-850 cases annually in the USA. These alkaline batteries found in calculators, watches and other miniaturized electronic components carry a severe morbidity if impacted in the oesophagus. Leakage of the alkaline electrolyte solution, 45% potassium or sodium hydroxide and the known corrosive effect of mercuric oxide, can produce rapid liquefaction necrosis of tissue. Second-degree burns and perforation of the oesophagus have been well documented, usually within four to six hours of impaction in the oesophagus. Therefore any patient ingesting a button battery must have an immediate chest X-ray and if it is seen to be lodged in the oesophagus, immediate oesophagoscopy and removal must be performed. However, when the battery has transversed the oesophagus without incident and the patient is asymptomatic, it usually passes spontaenously; the patient may be monitored radiographically and clinically.

Diagnosis and Management

Although chest and neck radiographs are obtained, a large proportion of these foreign bodies are not radio-opaque. Fish bones are radiolucent. However, these radiographs may demonstrate surgical emphyseam indicative of perforation. In addition associated aspiration pneumonitis can be evaluated, and acute obstruction additional to underlying chronic obstruction might well be seen as a dilated oesophagus with an air-filled fluid level. Coins, is lodged in the upper third of the oesophagus, will demonstrate the flat surface on anterior/posterior radiographs whereas if lodged in the trachea, will be seen edge on.

If a foreign body is not seen on routine radiographs, a careful barium contrast study, with or without cotton fibers, is usually successful in demonstrating the location of the impacted foreign body. In patients with persistent symptoms for more than a few hours, oesophagoscopy is indicated despite negative radiographic investigations.

Impacted foreign bodies in the oesophagus, of whatever nature, must be removed under direct vision by oesophagoscopy once the diagnosis has been made. In the case of alkaline button batteries as mentioned above, this is a matter of extreme urgency.

Surgical Techniques

Rigid oesophagoscopy with general endotracheal anaesthesia is preferred, although in adults flexible endoscopes have been successfully used in selected cases. The rigid endoscope used by properly trained personnel is safe with morbidity rates of less than 1%. Rigid endoscopy is contra-indicated though if there is marked cervical spine deformities and should be performed with great care if there is an associated aortic aneurysm.

Many foreign bodies cannot be brought out through the oesophagoscope because of their size and therefore are brought out as a unit with the forceps holding the foreign body onto the mouth of the scope. Care must be taken to prevent sharp objects from penetrating the oesophagus during withdrawal. Always withdraw pins with the point trailing and if necessary this must be accomplished by drawing the object into the stomach where it can be turned around before it is removed.

The most common and serious complication of oesophagoscopy is perforation. Perforation usually occurs in the region of cricopharyngeus due to forceful pressure against the weak posterior wall. Pain in the chest and/or subcutaneous emphysema of the neck immediately after oesophagoscopy is indicative of perforation.

Blunt foreign bodies may also be removed by inserting Foley's catheter into the oesophagus beyond the object, inflating the balloon and withdrawing it slowly. There is, however, a danger of lodging the foreign body across the glottis and therefore when this method is used, it should be done with the patient in a head down (Trendellenburg) and lateral decubitus position. Other methods previously used such as digestive enzymes (papain), lower oesophageal sphincter relaxants (glucagon) and magnets are no longer advocated.

After successful removal of the foreign body, repeat oesophagoscopy should always be performed to examine the oesophagus for trauma and/or underlying disease. A postoperative chest X-ray to exclude perforation should always be obtained.

Chapter 8.8: Empyema Thoracis

J A Odell, U O von Oppell

Empyema thoracis may be localized within the pleural space (encysted or encapsulated, interlobar, mediastinal, subpulmonary) or it may involve the entire pleural space. The distinction between acute and chronic empyema is a matter of time and is arbitrary. Chronicity, as in tuberculosis, may be determined by the nature of the causal organism, but it usually implies failure of diagnosis and inappropriate management in the acute stage. Some consider empyema "chronic" if it fails to respond to treatment within a reasonable length of time; others define it in terms of pathological changes in the pleural space and the surrounding tissues - ie, the walls become thicker and fibrous.

The American Thoracic Society divides empyema into three stages that relate to the natural course of the disease: exudative, fibrinopurulent and organizing. In the exudative, early stage, the pleural liquid is thin and it has a low cellular content and the visceral pleura and related lung are mobile. In the fibrinopurulent, transitional stage, large numbers of polymorphonuclear leucocytes have appeared in the liquid, and fibrin deposition on both pleural surfaces has begun to limit the extent of the empyema and immobilize the lung - the so-called "cortex". In the final stage of organization, the liquid content is thick and fibroblasts have invaded the thickening fibrous layers over the visceral and parietal pleura. These differences have important therapeutic implications.

Historical Background

The practice of thoracic surgery began with the drainage of pus from a chest. In the 19th century today's mundane thoracic procedures were considered to be significant advances, such as:

- underwater seal drainage
- open drainage
- rib resection
- thoracoplasty
- decortication.

In 1918 the United States Armies Empyema Commission was able to reduce the mortality (30%-70%) of streptococcal empyema in military personnel to 15% by the simple process of resorting to closed and not open drainage. Many of these deaths were due to pneumothorax and mediastinal instability rather than the infection, because lytic enzymes associated with streptococcal infection prevented the rapid development of a stabilizing cortex as seen with pneumococcal empyema. The consequences of open pneumothorax are obvious today but it is interesting to observe that this fact required a commission instituted at the time of the great flu epidemic to make this obvious.

Pathogenesis

Empyema does not normally result from primary infection of the pleural space. It usually complicates a pulmonary infection. The route by which the primary process infects the pleural space is uncertain. Direct spread of the infection through the visceral pleura is probably common. Lymphatic and haematogenous routes are also possible. Chronic pulmonary infection, which damages bronchi sufficiently to make it bronchographically recognizable, may sometimes be complicated by empyema, or an empyema may complicate pulmonary infection distal to any bronchus-obstructing lesion such as a carcinoma. Although the lung is the most common source of infection of the pleural cavity, it is not the only source. The mediastinal visceral nodes, rupture or instrumental perforation of the oesophagus, subphrenic viscera and spaces, the chest wall, the neck and the thoracic spine may all be the site of the primary infection.

Lymph drainage from the subphrenic spaces is cephalad through the diaphragm, and this is the likely route of early transference of subphrenic infection to the pleural space. In some 8% of patients with empyema the preceding lesion is a known subphrenic abscess, or the patient will have undergone a previous abdominal, urologic or pelvic operation. Pleural amoebiasis is a frequent complication of hepatic amoebiasis. Empyema thoracis though, does not, for practical purposes, extend caudally through the diaphragm.

Trauma is an extremely common cause of empyema thoracis. During World War I and the early part of World War II empyema occurred in 25-30% of all thoracic casualties. Clothing and organic foreign bodies, carried into the pleural space, more often caused empyema than did shell fragments and other metallic foreign bodies. In South Africa the most common provocation is a stab wound. The frequent finding of multiple resistant organism suggests that the initial haemothorax/pneumothorax becomes infected from unskilled and often unnecessary attempts at chest drainage, and is rarely consequent to primary contamination of the pleural space at the time of the stabbing. A haemopneumothorax very nearly doubles the likelihood of the development of empyema. In one series empyema developed in 36% of patients with traumatic haemopneumothorax but in only 18% of those with traumatic haemothorax without pneumothorax.

Microbiology

Causal organisms vary widely and the types identified depend on the use of antibiotics, microbiologic techniques and the original provocation. In the pre-antibiotic era pneumococci and streptococci were frequently found. As antibiotics effective against these organisms became available, the incidence and mortality of empyema markedly diminished. In infants and children the mortality fell dramatically from 26% in 1946 to 1.6% in 1970. In the late 1950s, pleuropulmonary infection with *Staphylococcus aureus* resistant to antibiotics then available increased in incidence, especially in children. More recently *Haemophilus influenzae* has become a common causal agent in children. The use of antibiotics probably aborts many pleural infections, diminishes the number of empyemas that follow "pneumonia", and prophylactic perioperative use probably prevents the development of empyema in postoperative pleural effusions. The proliferative use of antibiotics without reference to the sensitivity of organisms, is often the cause of failure to establish a microbiological diagnosis and chronicity. Anaerobes, clinically suspected because of malodorous pus, can be found in 19-76% of empyemas and frequently multiple organisms are found.

Antimicrobial therapy is only an adjunct to proper drainage, to be used while the patient is toxic or has evidence of generalized infection, and prophylactically for short periods in patients who undergo more complex surgical procedures. Once the space has been adequately drained there is no point in continuing antimicrobial therapy. Cure in these circumstances may take time and continued antibiotic use only promotes the development of resistant strains. Furthermore, antibiotics are unlikely to penetrate a thick fibrous cortex. Because of multiplicity of organisms frequently found in an empyema it is recommended that a broad-spectrum antibiotic effective against anaerobes and aerobes be used initially.

Clinical Manifestations

Empyema may manifest widely, from absence of symptoms to severe illness with toxaemia. Early recourse to antimicrobial therapy without an established diagnosis in a patient with the general features of an inflammatory, probably respiratory illness, will mask many an empyema. With chronicity, lassitude and debility related particularly to anaemia, may be the only symptoms.

Pus in the pleural space may result in dyspnoea, diminished movement of the hemithorax, dullness to percussion, diminished breath sounds and, if the empyema is large, displacement of the mediastinum to the opposite side. If there is a bronchopleural fistula the patient often has characteristic symptoms. The volume of pus expectorated is frequently large and may be related to position. In some cases sudden large volumes may drown the patient, in which case getting the patient to lie on the side of the empyema, may be life saving.

An empyema may track through to the skin surface - empyema necessitans (empyema necessitatis/pointing empyema). Such an empyema usually points between the ribs but may reach the lumbar region or groin. If it has not ruptured spontaneously, the clinical features are those of a subcutaneous abscess. The majority of cases of pointing empyema are tuberculous. A posttraumatic or postoperative empyema may discharge spontaneously at any site where the chest wall was previously breached.

Diagnosis

An empyema, unless it complicates thoracotomy, is nearly always posteior and lateral, and extends caudally as far as the diaphragm. If localized it is one of the common causes of a posterior situated D-shaped radiographic opacity. A large empyema may occupy most of the pleural space, but when any aerated lung remains, its translucency is usually visible anteriorly. In some circumstances it may be difficult on radiographic grounds to distinguish between lung abscess and empyema. The presence of a fluid level is not helpful, as an empyema may contain air from gas-forming organisms, a previous pneumothorax, a bronchopleural fistula, or be the result of aspiration. Bronchography and CT scanning may be useful diagnostic adjuncts.

On radiographic grounds it may be impossible to distinguish between empyema, pulmonary tumours with or without fluid levels, mediastinal and pleural tumours, and hydatid cysts. In the absence of other evidence, caution in resorting to diagnostic thoracocentesis should sometimes be exercised lest tumor cells or parasites be disseminated. In these patients bronchoscopy and bronchography are undertaken to determine whether there is a remediable ipsilateral pulmonary cause of empyema, followed by thoracotomy with decortication, together with pulmonary resection if there is a related pulmonary abnormality. Bronchoscopy and bronchography should be undertaken at some stage in the management of every patient with an empyema that has occurred spontaneously ie, one that does not follow trauma or pulmonary resection. Bronchial carcinoma, an inhaled foreign body, or bronchiectasis may be demonstrated. In addition, patent airways are necessary for re-expansion of the lung after closed drainage of empyema or decortication.

Management

Following drainage of an abscess elsewhere in the body, the space is readily obliterated by accommondation of surrounding tissues. In contrast, an empyema, if not managed in the acute exudative phase, tends to persist because it is bound by a rigid chest wall and a thickened, immobile visceral cortex. It is the rigidity of the walls of the space that make management of chronic empyema complex.

There are two major aims in management:

- control of the infecting organism (usually by specific antimicrobial therapy)

- evacuation of the contents of the empyema and obliteration of the empyema space.

Algorithm for management of patients with spontaneous occurring empyema. In posttraumatic empyema bronchoscopy and bronchography are not necessary before decortication.

Empyema Algorithm

Initial Management

- Resuscitation
- Enclosed tube drainage
- Investigation

Further Options

- Prolonged open tube drainage
- Decortication
- Semi-permanent rib resection
- Thoracoplasty.

In the group of patients in whom the diagnosis is unmistakable, this is confirmed by aspiration. The fluid is examined microbiologically with gram stain, culture and assessment of antibiotic sensitivity. Culture for anaerobic organisms should be routine. Typical findings characteristic of the causative agent are:

- anchovy sauce pus - amoebic
- gaseous material - tuberculosis
- sulphur granules - actinomycosis.

With the widespread use of antibiotics the liquid aspirated from the pleural space may be only slightly turbid and in many patients culture fails to yield an organism. Microbial activity may persist despite the lack of growth on culture because of the masking effect of antibiotics. A simultaneous sputum culture may be helpful as the organism responsible for the original "pneumonia" is frequently the cause of empyema.

Further management depends on the consistency of the aspirated pus. This pus may be removed by needle aspiration or by continuous drainage through a chest drain. Thick pus is unlikely to be completely drained and the alternative forms of management, either open drainage (rib resection) or decortication, are used. The ill "toxic" patient in whom the pus is thick is unsuitable for management by decortication because the risks of a major procedure are higher. Therefore open drainage by rib resection is the preliminary procedure. In the relatively well patient with an empyema in whom the pus is thick, bronchoscopy and bronchography are initially undertaken with a view to decortication. This determines whether there is a remediable ipsilateral cause for empyema which can be managed at the time of decortication. In summary, therefore, the management decision is mainly dependent on two factors: the clinical state of the patient and the consistency of the pus.

Drainage of pus will result either in obliteration of the pleural space and cure, or persistence of the pleural space. Closed drainage is unsatisfactory if there is persisten toxicity and no diminution of the radiographic signs. This implies that drainage has been incomplete, and open drainage should be undertaken. Open drainage is unsatisfactory if the pleural space is not obliterated, in children in 10-14 days, and in adults in four to six weeks. Decortication is now necessary after bronchography has been done to assess the underlying bronchi. The need for bronchography does not arise with posttraumatic empyema because the patient is assumed to have a normal underlying lung.

Closed Drainage

This is reserved for patients with thin pus that can escape through an underwater chest drainage tube. The exact location of the drain must be determined. A recent posterior/anterior and lateral chest radiograph made with the patient erect is necessary. Most empyemas are posterior and inferior with a characteristic D-shape on the lateral radiograph. The angle of the scapula, easily palpable, and visible on the chest radiograph, is a useful reference point to determine the site of thoracocentesis. It is advisable that the tube should be introduced close to the caudal limit of the empyema space, thus producing good dependent drainage. On the right side, the opacity of the empyema is often indistinguishable from that of the liver, and it may be impossible to determine with certainty the caudal limit of the empyema on plain radiographs. On the left the empyema may be contrasted against the translucency of the stomach bubble. Alternatively the most dependent site of the empyema may be determined radiographically by injecting a small amount of contrast into the empyema space. The location of the lowest part of the empyema is confirmed by needle aspiration prior to insertion of a drain.

Instillation of appropriate antibiotics, antiseptics, or fibrinolytic enzymes into the empyema space has been described as beneficial but their use is not generally accepted.

If the empyema is well drained and the underlying lung is normal, obliteration of the space is rapid in the exudative, acute phase, but more prolonged with less acute empyemas. The chest radiograph soon appears normal and the drain is removed once the volume of pus being drained becomes minimal. If the volume of the pus drained diminishes but continues, closed drainage may be converted to open drainage to increase the patient's mobility.

Open Drainage

Open drainage by rib resection is undertaken for patients who are systematically ill and in whom pus in the empyema space is too thick to drain through a closed system or where closed drainage fails to resolve the empyema.

Drainage must be complete and dependent therefore the caudal limit of the empyema must be accurately localized by the method earlier described. In most, this is at the posterior angle of the 8th, 9th, or 10th ribs. Open drainage may be undertaken with either local or general anaesthesia. If it is thought necessary to undertake the procedure with general anaesthesia, a double-lumen endotracheal tube must be used to prevent possible spillage of the empyema into the healthy lung. Local anaesthesia has the advantage that the cough reflex is retained and the empyema contents will not spill into the contralateral lung. Postoperatively the tube is cleaned, sterilized and reinserted, with fresh dressings applied as frequently as is necessary. Once the outline of the space can no longer be followed on plain radiographs, a sinogram using radiopaque oil to judge reduction in size of the space radiographically is made. Once there is only a persisting tube tract, the length and bore of the drainage tube are steadily decreased in size until the tube can be removed.

Obliteration of an empyema space after open drainage is generally slow, except in children, and occurs by re-expansion of the underlying lung and by the formation of granulation tissue at the margins of the empyema cavity. The thick layer of fibrous tissue left by progressive fusion of the two parietal surfaces is gradually absorbed. If progress is unduly slow and if the patient is fit, decortication should be considered after assessment of the underlying lung. Decortication and drainage should be considered complementary rather than competitive. It is safer generally to have an empyema adequately drained and infection under control before decortication is undertaken.

A more permanent form of drainage - Eloesser flap, "fenestration" or "open window thoracostomy" can be fashioned by suturing skin to the parietal pleura. This form of management is of value in patients with calcified empyema, in the management of empyema where the site of tube drainage would be uncomfortable and in patients who are mentally obture or unfit for any other form of therapy. This form of drainage is easier to care for and is generally cleaner than tube drainage.

Decortication

Decortication is the removal of thickened cortex which restricts movement and expansion of the underlying lung. Obliteration of the empyema space occurs with re-expansion of the lung and if this is maintained, cure of the empyema results. Adequate demonstration of a normal underlying lung is thus a prerequisite for the operation.

Decortication is an elective operation for selected patients. It is undertaken in fit patients whose empyema contains thick pus and patients with a radiographic opacity likely, but not proved, to be an empyema. In patients responding slowly to other forms of drainage it may be undertaken to hasten cure. There is no place for decortication in the acute exudative phase of empyema as a cortex is unlikely to have formed, or in those who are ill and toxic.

In patients who develop an empyema following trauma it may reasonably be assumed that the underlying lung is normal but this assumption may not be correct in patients with "spontaneously" developing empyema. There may be underlying bronchiectasis, or a bronchus obstructing lesion such as a carcinoma or a foreign body. It is thus inappropriate to submit a patient to thoracotomy for decortication and later to find a remediable ipsilateral cause for the empyema that could have been managed during the same operation. An underlying abnormal lung, in any event, will result in inadequate expansion of the lung following decortication, resulting in an unsuccessful outcome. The patient who is fit enough for decortication is well enough to be examined bronchoscopically and to have a complete bronchogram made. If a remediable ipsilateral cause for the empyema is found, this and the empyema are managed at the same thoracotomy.

The incision used is a lateral thoracotomy. In longstanding cases because of approximation of ribs, excision of a length of rib may be necessary to facilitate entry into the hemithorax. Some surgeons mobilize the empyema in the extrapleural plane without entering the empyema space, because this manoeuver is completed quickly and easily. When mobilization is complete extra-pleurally and the ribs are spread, the empyema space is emptied and decortication of the lung undertaken. Others deliberately empty the empyema space as a first manoeuvre and then spread the ribs without mobilizing the parietal cortex. The visceral cortex is incised, and when the visceral pleura is reached, the underlying lung will begin to herniate through the incised cortex. The cortex is then gently separated from the visceral cortex by a combination of sharp and blunt dissection. Usually the operation is easy and successful but occasionally removal of the visceral layers produce multiple air leaks. Sometimes areas of cortex may have to be left behind. Postoperatively, expansion of the lung should be maintained to obliterate the empyema space. If there is a significant air leak, either suction is applied to the drainage tubes or additional tubes are inserted. If a haemothorax develops, it is evacuated. If there is pulmonary collapse, the result of mucous in the bronchus, therapeutic bronchoscopy is required.

Empyectomy

This refers to the complete excision of the empyema and its contents without entering the empyema cavity. The purpose is to avoid soiling the interior of the hemithorax. Any preliminary drainage procedure or the presence of a broncho-pleural fistula precludes this operation. The operation is usually suitable only for quite a small empyema. Dissection is begun in the extrapleural plane and when the edges of empyema sac are reached, the surgeon "turns the corner" and then decorticates the inner surface of the empyema from the underlying visceral pleura. Dissection is particularly difficult over the diaphragm where the endothoracic fascia is thin and the extrapleural plane poorly developed.

Thoracoplasty

The purpose of a thoracoplasty is to establish contact between chest wall and residual lung, thus obliterating the space or, after pneumonectomy, to encourage adhesion of the mediastinum to chest wall by granulation tissue to obliterate an empyema space. In contrast to decortication, the space is now obliterated by inward movement of the outer wall of the empyema, ie, the chest wall. Thoracoplasty may be a valuable manoeuvre if an empyema is associated with loss of normally functioning lung tissue, but it has no place in the management of spontaneously occurring empyema if the underlying lung is normal. Ideally, thoracoplasty should entail excision of ribs and parietal pleura over an empyema space without injury to related structures, it should lead to closure of fistulas, and should be achieved in one stage to allow suture of the wound with primary healing. Concern regarding instability of the chest wall is unnecessary because the cortex that overlies the mediastinal or residual lung obviates paradox. With the Roberts thoracoplasty ribs are excised but the parietal cortex is retained and mobilized at its anterior edge. The parietal flap is hinged or cut so that it lies weel in against the remaining lung or mediastinum. Preservation of the blood supply from behind was thought to be necessary, but intercostalnerves were sacrificed. Later modifications of this operation included preservation of intercostal nerves, muscles and vessels after removal of ribs, thereby creating longitudinal ribbons of tissue which were laid in the cavity.

Thoracoplasty generally must be extensive and is mutilating so that the trend away from it is understandable, but it retains a place in the management of empyema, if only as a last resort.

Initial Management

Hospitalization, Resuscitation, Tube Drainage, Ribresections, Possible Cure and Decisions

The management of an empyema patient should be carefully planned and prolonged hospitalization avoided. The priorities are proper drainage and resuscitation.

Many of the patients are anaemic, toxic and malnourished (especially children). They are treated promptly with chest-tube drainage and suction, nutritional support, chest physiotherapy, blood transfusion and hydration when indicated. Adults receive a course of penicillin and Flagyl and children Cloxacillin and metronidazole. Other antibiotics are given as indicated by sensitivitry studies. Associated diseases are treated.

If progress is slow, or tube thoracostomy is obviously unsuccessful because of multiple loculations and inaccessible purulent collections, a small thoracotomy for pleural debridement and drainage is performed including a rib resection.

Suction at about 20 cm H_2O is appliedf to the underwater drainage bottle. The patient is allowed out of the bed and encouraged to exercise as soon as possible. On such occasions the tube can be disconnected from the suction apparatus, but it is reconnected whenever the patient is in bed.

X-ray examination is repeated weekly to show the diminution in size of the pleural space. When this is no longer visible on direct radiography the space can be outlined by filling it with a radio-opaque material such as Dionosil. The tube should be at the bottom of the cavity and is not removed until the pleural space has become completely obliterated and only the tube tract in the chest wall remains.

At the end of a three-week period it usually is quite clear in most cases whether further progress can be expected. Most patients will have no further benefit from conservative treatment. Special investigations such as bronchograms are completed now and taking all information into account and carefully evaluating the patient's general condition, a decision regarding further treatment is made.

Further Options

Cure by Prolonged Tube Drainage

In general it can be said that if tubes are left in for prolonged periods they usually result in resolution of empyema by the process of granulation. This however, requires patience, aggressive use of chest drains, often multiple, and removal of the tubes only when the pleural space has been obliterated. This also results in a rigid thorax with loss of lung function and excessive hospitalization.

Decortication

Long-term hospitalization, prolonged drainage and the odour and discomfort of the chest tubes are unacceptable to many patients.

Since decortication can be performed with a low mortality, rapid cure and excellent functional results, this is the procedure of choice for all cases in good general condition and reasonably expandable lungs who do not respond fast to conservative treatment.

This is, however, not a minor procedure and should be performed only by trained surgeons in hospitals where one-lung anaesthesia, blood banks and intensive care facilities are available.

After the operation two intercostal tubes are connected to meticulously maintained underwater suction systems. The care with which these tubes are managed determines the outcome of the procedure.

Semi-Permanent (Elloeser Type) Ribresection

Patients in poor general condition, poor nutritional status, with poor lung function or calcified, densely fibrosed cavities where maximal pleural symphysis had been established and the volume of the residual space minimized by closed drainage, are not candidates for decortication because of a high associated mortality and morbidity. Continued hospitalization and tubes on suction in this situation make no sense. Tubes dangling in the chest wall for an indefinite length of time are uncomfortable and a nuisance.

An Elloeser procedure is a good option as it is associated with low mortality and morbidity even in very sick individuals and it allows mobilization.

Chapter 8.9: Lung Abscess

J A Odell, U O von Oppell

Lung abscess may be defined as an area of pulmonary necrosis, usually with cavitation. It may develop after aspiration of liquid from the oropharynx into the lungs as a sequel to specific pneumonia (Staphylococcal, Klebsiella), as a complication of persistent or inactive healed lung disease, or metastatic from a septic focus elsewhere in the body.

Aspiration from the Oropharynx

The human mouth usually contains a number of microaerophilic and anaerobic commensals. The number of anaerobes in the mouth is greatly increased by oral infection, particularly of the teeth. Any patient with an abnormally diminished mental state, for example, alcoholic stupor, head injury or anaesthesia, particularly if they have poor dental hygiene, may aspirate large volumes of saliva.

This may result in a typical anaerobic lung abscess. If the aspirate contains gastric acid this may induce a chemical pneumonitis which additionally predisposes to subsequent bacterial invasion. Particulate matter within the aspirate will also promote infection both because it acts as a contaminated foreign body and by causing bronchial obstruction with entrapment of distal bronchial secretions.

The pathogenesis and pathology of anaerobic lung abscess is well described by Le Roux et al. Aspiration pneumonia may progress to necrosis of lung tissue to form micro-abscesses in the area of consolidation (necrotizing pneumonia) or if the necrotic area is larger, lung abscess. Coalescence of micro-abscesses with increasing destruction of lung tissue may result in a communication with the pleura and the development of an empyema. If the abscess openly communicates with a bronchus, large volumes of fetid pus will be produced.

The sequelae of aspiration pneumonia depend on the volume and composition of the inoculum, the resistance of the host which may be modified by malnutrition, anaemia or the presence of underlying damaged lung, ie, previous pulmonary tuberculosis, and the adequacy of antibiotic therapy. Aspiration pneumonia will therefore vary from an acute localized curable pneumonia to lung gangrene with confluent necrosis of lung tissue which in its severest form, may extend to the chest wall. Chronicity is said to be established at approximately six to eight weeks.

A variant of chronic suppurative pneumonia in African patients, called chronic destructive pneumonia, is well documented. It is probably a suppurative pneumonia, the course of which has been modified by the use of powerful antibiotics, often in combination, prescribed late and erratically taken. The patient is ambulent, apyrexial and with a cough productive of purulent sputum, often blood-stained and fetid. Periods of quiescence and recurrence or steady ingravescence over months or even years is characteristic. In chronic destructive pneumonia bronchial and parenchymal damage extend to tissues adjacent to the abscess and this may involve a whole lobe or even extend across fissures.

The Specific Pneumonias

Except for *Klebsiella pneumoniae, Pseudomonas aeruginosa, Staphylococcus aureus,* and to a lesser extent certain of the *Streptococci,* the propensity of the aerobic pathogens to cause lung necrosis seems not to be great.

Although aerosol inoculation is the mode of infection in certain of the pneumonias, it would seem that aspiration of liquid from the oropharynx in a colonized individual is the more usual mode of infection. In contrast to anaerobic aspiration pneumonia, where aspiration of liquid contents is the important initiating event, colonization of the oropharynx and upper respiratory tract is normally a prerequisite for infection to take place in the lower respiratory tract. Colonization is particularly likely to occur in immunosuppressed patients, those with AIDS, alcoholics, those receiving irradiation, the elderly, in those with diabetes, lymphomas, multiple myelomas or those patients with renal and cardiac failure. Following viral infections such as influenza or measles the capacity of alveolar macrophages to clear organisms which have gained access to the alveoli is diminished.

In the specific pneumonias enzymes and toxins specific to the various micro-organisms probably account for the increased ability of these organisms to induce tissue necrosis.

Gram Negative Bacteria

Klebsiella pneumoniae and *Pseudomonas aeruginosa* are the common organisms causing a pneumonia that results in lung abscesses. Other *Pseudomonas* species, *Proteus vulgaris, Proteus mirabilis, Escherichia coli, Enterobacter* and *Acynetobacter* species may occasionally also cause abscesses.

Klebsiella pneumoniae is frequently associated with abscess formation. Although it may be segmental in distribution it is usually lobar, especially upper lobar and particularly on the right. Classically the lobe is distended, with downward bowing of the fissure. Sputum is mucoid and often blood-stained, with a "red current jelly" appearance. Lung necrosis is often extensive, with lung gangrene and even autolobectomy occurring. This may result in time in the formation of a large thick-walled cavity.

Pseudomonas aeruginosa carries a much higher mortality. The involvement is often bilateral and lower lobar, with multiple small abscesses being present.

Gram Positive Pneumonias

Abscess formation from the *Pneumococcus* is rare. *Staphylococcus aureus* and the group A *Streptococci* frequently induce abscess formation. Influenza and measles with resultant diminished immune activity often precedes infection with these organisms.

Staphylococcal lung abscesses occur frequently in the first of life and are frequently associated with pneumatocoeles and the development of a pyopneumothorax. Pneumatocoeles are thin-walled, cyst-like, air-filled spaces, often multiple and frequently large enough to displace the mediastinum. Pneumatocoeles are not abscesses in the conventional sense because they do not contain liquid pus. With time the pneumatocoeles disappear. Streptococcal abscesses are frequently multiple and are rarely large. Pneumonia caused by pathogenic aerobic bacteria in contrast to anaerobic suppuration is generally acute in onset. Lung necrosis, if it occurs, develops later. Fetor is absent, and there is not the predilection for the pneumonia to occur in the dependent segments of the lung. Patients who are immuno-compromised may feel and appear reasonably well whereas in fact they are probably mortally ill.

Secondary Lung Abscess

Lung abscess may occur secondary to bronchial carcinoma, pulmonary sequestration, broncho-oesophageal fistula, foreign body inhalation, cavitated tuberculosis, bullous emphysema, lung cysts and pulmonary infarction. A cavitated, usually but not always squamous carcinoma, may become infected and resemble both clinically and radiographically a primary lung abscess. It is often difficult to distinguish a cavitated squamous carcinoma from a lung abscess.

Diagnosis

In the typical patient with an anaerobic lung abscess a history suggestive of aspiration, the finding of dental caries and malodorous sputum are useful clues. Symptoms may be insidious and the initiating episode of aspiration may be poorly remembered. The abscess frequently involves the dependent portions of lung. Haemoptysis is common and may be severe enough to require emergency surgery.

In aerobic infections fetor is absent and there is not the predilection for the pneumonia to occur in the dependent segments of the lung. The patients frequently have co-existing diseases, have had a recent viral infection or are immunocompromised.

The radiographic appearances vary widely. A cavity with a fluid level, a solid spherical opacity, pneumonic infiltration with a distinct cavity or areas of rarefaction, a multiloculated cavity or a lung abscess that has ruptured into the pleura to produce a pyopneumothorax may all be demonstrated. Haemoptysis may alter the picture - the cavity may fill to varying degrees and blood may be aspirated elsewhere into the lung. CT scanning may demonstrate cavitation not obvious on plain radiographs. Multiple bilateral abscesses may suggest pyaemia with metastatic abscesses.

Staphylococcal pneumatocoeles are often difficult to distinguish radiographically from a tension pneumothorax - often the patient with a large tension pneumatocoele is suprisingly well.

In addition, it must be stressed that there is nothing distinctive or diagnostic that radiographically differentiates a cavitated carcinoma from other causes of cavitation.

Sputum should be carefully examined microbiologically to identify the organisms causing the abscess. Mycobacterium tuberculosis and malignant cells need to be actively looked for by the microbiologist and the cytologist if tuberculosis or malignancy is suspected. Expectorated sputum may be contaminated by mouth organisms necessitating transtracheal aspiration or direct needle aspiration of the lung abscess to obtain accurate and relevant bacteriological reports.

Bronchoscopy should be undertaken early in order to exclude a bronchial obstructing lesion such as a tumour or foreign body. Rigid bronchoscopy is advisable especially if large volumes of pus are anticipated, ie, post-removal of foreign body.

Management

Lung abscess should be treated in combination with the administration of an appropriate antibiotic, drainage of the pus by some means, and by pulmonary resection if there is permanent lung damage with symptoms or if massive haemoptysis occurs. A recent revivial of interest in drainage of lung abscesses suggest that this form of therapy is regaining its rightful place in the management of lung abscess. There are no published trials, however, that compare medical and surgical means of management of lung abscess. Depending on the clinical state of the patient (size of the abscess, etc), most physicians would initially treat the patient with a combination of antibiotics and intensive physiotherapy with postural drainage.

Antibiotic therapy should be based on the results of a gram stain of sputum or pus, but frequently antibiotic therapy is empirically used. If the abscess is thought to be due to anaerobic organisms, treatment should be penicillin and clindamycin or metronidazole. Cephalosporins in combination with the above have also been used because of excellent tissue penetration, with good results. If the abscess is the result of a staphylococcus, a penicillinase-resistant penicillin should be used. If gram-negative organisms are found, an aminoglycoside in combination with a cephalosporin is given.

Although surgical drainage as a method of treatment of lung abscess is increasing in popularity it should not be considered as the definitive method. Cavitated carcinoma is often difficult to differentiate radiographically from lung abscess. Percutaneous drainage of a cavitated carcinoma results in needless spread of tumour cells, which may compromise later surgical resection once histologic confirmation is available, or may result in fungating carcinomatous bronchocutaneous fistula. The possibility of carcinoma should be considered and excluded in heavy smokers with minimal fever and toxicity. Similarly, if the abscess is chronic, empty and thick-walled or less than 6 cm in diameter, it is wise to delay the decision to drain until bronchoscopy has been undertaken.

Surgical drainage should be undertaken if there is a large acute absces, if there is a small abscess with persistent fever and toxicity despite antibiotic therapy, of if the pneumonia or necrotic process is shown to be progressive on serial radiographs.

Drainage may be either internal through the bronchi or external through the skin surface. Internal drainage is undertaken with rigid bronchoscopy and the insertion of a bougie or suction catheter into the appropriate draining bronchus. The procedure is frequently unsuccessful because of the angulation of the bronchus and oedema of the bronchial wall. Some, however, have recommended the use of angiographic catheters with a guide wire. One should be aware of the possibility of excessive spillage of pus during the procedure resulting in contamination of normal lung, or suffocation. If this occurs the patient should be turned on to the side of the abscess and placed in a head-down position while bronchoscopically directed suction rapidly removes the pus.

External drainage may be done percutaneously or as an open procedure. Percutaneous drainage is indicated in patients with distended pneumatocoeles causing distress and in those with thin puss. Of importance is the determination of the exact site of drainage - a recent lateral and postero-anterior radiograph should be available and the intended site confirmed by needle aspiration. Fluoroscopy may be helpful. Open drainage is indicated in patients with thick pus or lung slough. It may be undertaken under local or general anaesthesia. If the latter, a double lumen endotracheal tube is mandatory to prevent spillage into the opposite lung. The appropriate site is the centre of the abscess close to the pleural surface for it is here that the pleural space is likely to be obliterated and contamination of the pleural space will thus not occur. An overlying portion of the rib is excised and the site of abscess is confirmed again by needle aspiration. The lung is incised and the abscess entered. Pus and lung slough are evacuated. Adherent slough should not be removed as this frequently causes excessive bleeding. The abscess wall is biopsied. A soft drain is inserted and removed after two to three days. If bleeding is excessive the abscess cavity should be packed temporarily with a swab.

If the pleural space is free a de Pezzer catheter is inserted into the abscess cavity and a purse string suture placed around it. The catheter is passed through the chest wall. Traction of the catheter results in lungs being brought into contact with the parietal pleura. The pleural space is additionally drained with a separate intercostal cannula.

Lung abscesses are occasionally managed by pulmonary resection if life-threatening haemoptysis develops, if the abscess is chronic with persistent symptoms, if an abscess redevelops after so-called cure - "the second bite" - and if the "abscess" is known or likely to be a malignant tumour. In relation to massive haemoptysis the extent of resection is determined by the radiographic appearance, the findings at bronchoscopy and the operative findings. With more chronic lesions bronchography should be done in a quiescent stage (no fever or toxicity) to determine the extent of pulmonary damage and thus to determine the extent of pulmonary resection.

Comment

Cardiothoracic Surgery

Johan de Villiers

I agree that CT scanning has very little place in the assessment of acute cardiothoracic trauma. However, I believe that non-invasive sonar has a definite benefit. In a patient with multiple injuries sonar of the abdomen is often used and can be extended to the thorax. This can help to guide the surgeon to aspirate or intubate the pleural space. At the time of these procedures, time has elapsed and the patient is often in a different state to when the X-ray was taken. Sonar guidance is also very helpful in the draining and aspiration of patients with empyema or localization of the clotted haemothorax. Rigid bronchoscopy must also be intubated, and many trauma units use this as a standard procedure in the multi-injured patient, especially where aspiration was a possibility.

In closed pleural drainage, the often used Foley's catheter is not a good drain because of its small internal lumen in comparison with its diameter. Connectors must always be at least of the same internal diameter as that of tubing and drains. I agree that prophylactic drainage of the pleural cavity for pneumothorax under anaesthesia is not indicated, except in the situation where high PEEP is used and where tube thoracotomy is difficult, due to the operational situation or sterile drapes. This must not be done by the inexperienced, and done with direct palpation of the pleural space to prevent a drain being put into the lung.

Added to the underwater drainage, suction of 30 cm of water is a great help to speed up the expansion of a lung and this is used routinely in our unit. Tubes must be removed while a patient is doing the valsalva maneuvre to prevent air being aspirated into the pleural space during removal.

A useful guide to the indication for thoracotomy in continued haemorrhage is the drainage of more than 10% of blood volume in the first hour, 8% in the second hour and 6% in the third hour after tube thoracotomy. This could also be used in children.

A continued air leak after one week should also be considered as an indication for thoracotomy, due to the danger of developing empyema.

I believe that a rib resection rather than a thoracotomy is more appropriate in managing a clotted haemothorax in the first 10 days. This is a smaller surgical procedure without the sacrifice of large-muscle function. A guideline for timing of decortication in a clotted haemothorax is six weeks, when a definite layer between the lung and the clot has developed. In pulmonary lacerations, the use of the stapler is very effective in controlling air leaks and bleeding.

I would like to stress the importance of the physiotherapist in managing blunt trauma with rib fractures. Quite a number of patients with traumatic flail chest can be managed and intubated, with the aid of CPAP - without mechanical ventilation. The advantage of spontaneous breathing with CPAP over mechanical ventilation is well known and quite a number of patients are unnecessarily ventilated.

As far as tracheo-bronchial trauma is concerned, it is interesting to note that the vascular structures are usually not damaged in bronchial rupture. It is important to separate the bronchial suture line from the vascular sutures to prevent damage to the vasculature.

The importance of anaesthesia in operations for cardiac tamponade must not be overlook. Sudden circulatory collapse with induction of anaesthesia for cardiac tamponade is a reality. The reason for this is a fixed low cardiac output which cannot be increased on demand. The cardiac output is suppressed by anaesthetic drugs, positive ventilation, reduction of venous return to the chest and the cessation of internal catecholamine stimulation due to the sedation. It is important that the surgeon, theatre sister and instruments be ready before induction of anaesthesia since the only way to manage caridac arrest in this situation is immediate thoracotomy. The role of a subxiphoid pericardial window before induction of anaesthesia as an initial procedure may be helpful to prevent arrest in some patients.

I maintain that the Swan-Ganz catheter for monitoring of left atrial pressure in patients with blunt cardiac trauma with an unstable circulation is essential.

With regard to foreign bodies in the trachea, I maintain that the complicated long-standing case where X-ray changes have developed, should be referred to a specialized unit for treatment and should not be managed by an inexperienced surgeon.

The use of muscle flaps in the management of empyema as an alternative to thoracoplasty is an important consideration. This can obliterate the pleural space and enhance healing. Different muscles can be used and this procedure could play an important part in the treatment of patients with bronchopleural fistulae.

I agree that the ill toxic patient with different fluid levels or loculations in the pleural cavity should be managed by rib resection as the preliminary procedure. Open drainage after rib resection is often not indicated because the cortex and the lung are still moveable and these patients must be treated by underwater seal drainage through the lowest part of the empyema space, with the rib resection closed to prevent collapse of the lung. Pleural installations with antiseptic, like 25% Povidone iodine in saline as a preliminary management in preparation for definite surgical treatment, also has merit and ought to be considered.