Lung contusion or laceration results in the formation of a hæmatoma. Hæmoptysis is usual and its presence always indicates lung damage. Radiologically, the appearances are those of a patchy or confluent consolidation. Infection of the damaged lung is common, especially if there is a pre-existing bronchial infection. Antibiotics and postural drainage should be employed to prevent its development.

Fractured Ribs

Isolated rib fractures due to direct violence are a common complication of many varieties of chest trauma. The condition is painful but rarely disturbing. Localised tenderness and crepitus are often elicited but the fractures may be difficult to demonstrate radiologically. Local support and analgesics are often all that is required for treatment.

Multiple rib fractures (indirect or burst) are produced by crushing. The ribs fracture at the site of maximum curvature and stress, at the anterior and posterior angles. The stability of the chest wall is often greatly disturbed and in addition to pain, paradoxical movement occurs with difficulty in breathing and coughing. Minor degrees of parodox can be controlled by strapping but the more extensive varieties are best treated by exposure of the fractured ribs and fixation with wire or nails. Pain unrelieved by analgesics, should be controlled by intercostal nerve block.

Stove-in Chest

This severe injury is produced by an extensive but localised crushing force which produces multiple rib fractures and a permanent indentation of the chest wall. The affected hemithorax may be considerably reduced in size and the function of the underlying lung markedly reduced. Some paradoxical movement is usually present. The compression of the underlying lung and its relative immobility results in the accumulation of broncho-pulmonary secretions.

The minor degrees of stove-in chest may require little specific treatment additional to that already outlined for rib fracture but the more severe forms require surgical correction. Under anæsthesia it is possible to elevate the depressed chest wall with towel clips placed around the ribs. If the deformity tends to recur, the ribs must be fixed to an external 'cage' with heavy stainless-steel wire loops passed around several ribs. Fixation will be required for several days.

Flail Chest

This type of injury is seen particularly after automobile accidents of the more severe type when it is often accompanied by other serious injuries.

Multiple rib fractures result in a flaccid unstable chest wall exhibiting paradoxical movement. With quiet respiration paradoxical movement may not be obvious but if the respirations are difficult or if the patient should cough the paradox becomes more obvious. The paradoxical movement produces imperfect ventilation with anoxia whilst defective coughing results in the retention of broncho-pulmonary secretions. Any attempt on the

The trachea and main bronchi with their lobar and first segmental divisions can all be examined visually by bronchoscopy. This investigation will demonstrate abnormalities in size (stenosis, obstruction or dilatation), movement (immobility or spasm), shape or position. The examination will also reveal the presence of a tumour or an intrabronchial foreign body. Material for biopsy and secretions for cytological or bacteriological examinations can be obtained. Only the proximal parts of the bronchial tree can be examined, even with the aid of the telescope, so that the examination has distinct limitations in the investigation of peripherally situated lesions.

A more detailed anatomical study can be made by bronchography, which consists of the introduction of radio-opaque material (iodised oil) into the bronchial tree. An attempt is made to fill all the branches of the bronchial tree on one side, and radiographs are taken in two or more planes. Bronchography provides information about the size and distribution of the bronchi, and will also demonstrate bronchial occlusion or narrowing.

INJURIES TO THE CHEST

Chest injuries are not common in civil practice; in war, however, they constitute nearly 10 per cent. of all wounds, whilst of those killed in battle, 25 per cent. have chest injuries. They can be divided into closed and open varieties. The former include crush and blast injuries; the latter are either simple or complicated.

First-aid Management

Chest casualties may require important and urgent life-saving first-aid measures not normally applicable to other casualties :

(1) A sucking chest wound (open pneumothorax) should be sealed with an occlusive pad.

(2) The paradoxical movements of a flail chest wall should be controlled by strapping.

(3) A tension pneumothorax or hæmothorax should be relieved by aspiration.

(4) The tracheo-bronchial tree should be kept clear of secretions by encouraging coughing or by bronchial aspirations.

(5) A tracheostomy should be performed as an urgent measure if ventilation is inadequate or bronchial secretion uncontrolled.

Crush Injuries

These are common both in war and in civilian practice. The injury may be produced by a localised blow or a more extensive crushing force. Similar injuries can also be produced by concussion waves from explosions conveyed either through air or water.

The injuries may include contusion of the chest wall, simple or complicated rib fractures and contusion or laceration of the underlying lung.

Air and blood in the pleural cavity occur commonly; their removal may be a matter of urgency but usually the accumulation is not excessive and can be removed more leisurely.

part of the patient to overcome these defects by over-breathing or coughing only aggravates the condition.

Tracheostomy is urgently required and will often result in dramatic improvement. The dead space of the mouth and pharynx is eliminated with a consequent reduction in the ventilatory requirements. The presence of a tracheostomy will permit ready and repeated removal of broncho-pulmonary secretions by a catheter and a clear airway will similarly result in a quieter respiration. Paradoxical movement is often 'cured' by tracheostomy but should it persist the affected ribs should be exposed and the ends joined by stainless-steel wire or nails.

With the acute ventilatory crisis adequately controlled by the tracheostomy attention must be given to the prevention and control of the broncho-pulmonary infection by breathing exercises and antibiotics.

Simple Penetrating Wounds

These are produced by small, sharp, clean missiles, such as bullets and knives. The external wounds are usually small and visceral damage often slight. A hæmothorax is the commonest complication requiring treatment.

Complicated Penetrating Wounds

These include cases with gross damage to the chest wall; an open or a tension pneumothorax; those with retained organic foreign bodies (particles of clothing); a large metallic foreign body; and those with serious lung damage or involvement of the mediastinum or diaphragm. Operative treatment will be required in the majority of cases, and should be carried out as soon as practicable after resuscitation. The only indication for emergency thoracotomy is uncontrollable bleeding.

Endotracheal anæsthesia is essential in order to ensure adequate ventilation and permit the removal of bronchial secretions during the operation. The chest wound is excised, rib fragments removed, and intercostal vessels ligated, if necessary. If the wound is conveniently situated, the pleural cavity can be explored through it, but if not, a separate thoracotomy is required. All blood, clot, and débris should be removed from the pleural cavity in addition to any retained foreign bodies. Lung lacerations should be sutured if small, or a formal resection carried out if more extensive. The pleural cavity should be drained through a separate stab incision. After operation it is essential that the lung should expand rapidly and completely; this should be encouraged by suction drainage, breathing exercises and early ambulation.

Thoraco-abdominal Wounds

These are always potentially serious owing to the involvement of both abdomen and the chest; their importance depends on whether or not one of the hollow abdominal viscera is damaged. The predicted course of the missile should be considered in order to anticipate the visceral damage. Apart from serious involvement of the chest, as outlined above, the main indications for exploration are signs of persistent bleeding or evidence of involvement of a hollow viscus. The thoracic approach has the advantage of permitting correction of the thoracic injuries, whilst giving adequate exposure of the upper abdomen through the diaphragm.

Kypho-scoliosis

Primary kypho-scoliosis is considered on p. 1312.

Deformities secondary to pleural and pulmonary disease are frequent unless preventive measures are taken; they can cause a considerable loss of pulmonary function, and may lead to repeated respiratory infections and cardiovascular disturbances. Vigorous breathing exercises can do much to prevent serious deformity provided they are initiated sufficiently early, but even in established cases some improvement can be expected.

Funnel Chest (Pectus Excavatum)

This deformity consists of a depression of the body of the sternum and the xiphoid process, combined with an inward curving of the costal cartilages and adjacent ribs. The deformity is primarily due to lack of development of the central tendon of the diaphragm which tethers the xiphoid process to the spine. The deformity is usually minimal at birth, but becomes progressively more obvious during childhood. It may predispose to repeated respiratory infections and to cardiovascular disturbances, whilst the cosmetic appearances are frequently embarrassing (fig. 1416).

FIG. 1416.—Funnel chest deformity.

Correction of the deformity is carried out through a midline or transverse incision: the sternum and costal cartilages are exposed and the deformed costal cartilages are resected subperichondrially. The attachments of the diaphragm to the xiphoid process are detached and the sternum separated from the mediastinal tissues. A wedge osteotomy of the anterior table of the sternum is performed at the manubriosternal junction and the mobilised sternal body can then be easily elevated. The sternum is maintained in an elevated position by encircling ligatures attached to a specially designed bridge and maintained in this position for one week. The cosmetic results of the operation are good.

Cold Abscess

The majority of cold abscesses of the chest wall are secondary to tuberculous intercostal lymphadenitis. A minority are associated with Pott's disease of the spine and tuberculosis of the ribs or sternum. The intercostal lymph nodes are situated posteriorly near the neck of the rib, or anteriorly in association with the internal mammary vessels. Tuberculous pus, forming in these sites, may track a considerable distance in the intercostal space before becoming subcutaneous. They usually reach the superficial tissue by following the lateral or anterior branches of the intercostal vessels, and are thus most commonly found in the anterior axillary line or the parasternal region. The abscess has all the characteristics of a tuberculous cold abscess. Involvement of the skin and rupture is common in neglected cases, resulting in a persistent discharging sinus surrounded by typical

Percival Pott, 1714–1788. Surgeon, St. Bartholomew's Hospital, London.

tuberculous granulation tissue. A cold abscess must be distinguished from a lipoma or an empyema necessitatis ; in the latter, the swelling is often tender and may exhibit an impulse on coughing, and is associated with the physical and radiological signs of an empyema.

The abscess should be treated by repeated aspirations through healthy skin with the instillation of streptomycin. If the abscess fails to respond to repeated aspirations, surgery will be required. The extent of the ramifications of the abscess should first be determined by the injection of iodised oil into the abscess. Ideally, the abscess and its ramifications should be completely excised, together with any secondary involved bone ; but if this is not practicable, the abscess should be evacuated, granulation tissue removed and the wound closed. Chronically discharging sinuses can sometimes be cured by regular instillations of streptomycin combined with systemic chemotherapy ; alternatively, excision of the track should be carried out.

Empyema Necessitatis

This is caused by an empyema perforating the chest wall and presenting with a subcutaneous collection of pus communicating, often by a tortuous channel, with the main pleural collection. The condition is seen either with a neglected or an undiagnosed empyema, or following aspirations of thin, highly infective pus from an empyema. In the latter case, the superficial tissues are infected by the seepage of pus through a needle track. The site of the subcutaneous abscess does not always correspond to the site of pleural perforation, as the abscess may track along the intercostal spaces before becoming superficial. The signs are those of a diffuse, fluctuant, tender swelling which may exhibit an impulse on coughing, and is associated with the clinical and radiological signs of an empyema. Treatment is primarily aimed at the empyema, which should be aspirated and drained. The superficial abscess may disappear as a result of aspirating the empyema or may itself require separate aspirations or drainage.

Tumours of the Rib

Rib tumours may be benign or malignant, and the latter either primary or secondary.

Benign tumours are frequently discovered by Mass Miniature Radiography. Many are symptomless and produce no external evidence of their presence. A few produce pain or an external swelling. The commonest is the chondroma (figs. 1417 and 1418), whilst osteochondroma, multiple exostoses, fibrous dysplasia, lipoid granulomata and multiple myelomata are less common. Benign tumours usually produce expansion of the rib, are less dense than normal rib, whilst pathological fracture is rare. Malignant change is not uncommon, particularly with the chondromata, and removal is therefore advisable.

Primary malignant tumours are rare, the commonest being chondrosarcoma ; they should be widely excised. Secondary deposits in rib are

FIG. 1417.—Chondroma of rib.

FIG. 1418.—Chondroma of rib (same case as fig. 1417).

particularly common in carcinoma of the lung and with breast cancer. The deposits are almost always painful and tender. They result in destruction of bone, and pathological fracture is common. X-ray therapy will usually relieve the pain.

Neurogenic Tumours

These are of two main types—neurofibroma (figs. 1419 and 1420) arising from the intercostal nerves and ganglioneuroma from the sympathetic chain. The former appear close to the neck of the rib, whilst the latter lie slightly more medially applied to the vertebral bodies. The majority are found on routine radiography. They are usually symptomless and single. Their growth is slow and the adjacent ribs and vertebral bodies are often distorted and eroded. A small percentage extend through the intervertebral foramen into the vertebral canal, where compression of the spinal cord may result in paraplegia (dumb-bell tumour). Removal of the tumour is safe and simple and is recommended owing to the risks of malignant changes. Dumb-bell tumours, and particularly those with spinal-cord involvement, require urgent treatment. A small intraspinal extension can easily be removed from the chest, but extensive intraspinal tumours will require laminectomy for their

FIG. 1419.—A large neurofibroma of the chest wall. The tumour is lying posteriorly.

FIG. 1420.—Tumour removed from case described in fig. 1419.

removal ; the latter can usually be carried out at the same time as the chest operation, but if very extensive, separate operations are advisable.

DISEASES OF THE PLEURA

Pneumothorax

A pneumothorax is produced by the presence of air between the layers of the pleura. The air may be present alone or associated with serous fluid (hydro-pneumothorax), pus (pyo-pneumothorax), or blood (hæmo-pneumothorax). Air may be deliberately introduced into the pleura (artificial pneumothorax), or be associated with trauma (traumatic pneumothorax), or may appear without any obvious exciting cause (spontaneous pneumothorax). The physical signs of a pneumothorax are a hyper-resonant percussion note with absent breath-sounds. Radiographs reveal translucency on the affected side with absence of lung markings ; the edge of the collapsed lung is usually visible.

Artificial Pneumothorax.—This is used therapeutically in the treatment of pulmonary tuberculosis to provide rest and relaxation for a diseased lung. It is occasionally used diagnostically to differentiate between pulmonary and chest-wall tumours.

Traumatic Pneumothorax.—This is a frequent complication of chest injuries, when it is often associated with blood as well. The air may reach the pleura through a defect in the chest wall (open pneumothorax or sucking wound) or from a tear in the lung or bronchus. Sufficient air may accumulate in the pleural cavity to compress the lung, displace the mediastinum, and produce considerable respiratory embarrassment (tension pneumothorax). Emergency treatment may be necessary to save life. A sucking wound should be sealed by an occlusive pad, whilst severe tension can be immediately relieved by plunging a needle into the chest and allowing air to escape. Less urgent collections of air should be removed by repeated aspirations with a pneumothorax apparatus or needle and syringe, but if re-accumulation of air is rapid, a small catheter should be inserted into the pleural cavity through the second or third space anteriorly and connected to an under-water seal. Aspirations of air and blood should be carried out until the lung is fully expanded.

Spontaneous Pneumothorax.—Causes :

(*a*) Tuberculous.

(*b*) Non-tuberculous.

(1) Emphysematous bullæ.

(2) Lung cysts.

(3) Honeycomb lung.

(4) Idiopathic.

A tuberculous spontaneous pneumothorax is usually associated with obvious clinical or radiological tuberculosis. The condition is produced by the rupture of a small subpleural tubercle or cavity, and is usually associated with infection or irritation of the pleura resulting in the appearance of fluid in the pleural cavity and a febrile reaction. Treatment depends on the underlying pulmonary lesion.

A non-tuberculous spontaneous pneumothorax by contrast is not associated with fluid formation or fever. In approximately half the cases an obvious underlying pulmonary lesion, such as an emphysematous bulla, a lung cyst, or a honeycomb lung, can be demonstrated. Absorption may occur spontaneously and rapidly, or may be considerably delayed (chronic spontaneous pneumothorax). Attacks may be single or repeated (recurrent spontaneous pneumothorax). With a first attack, in the absence of an underlying cause, air can be allowed to absorb spontaneously or expansion can be encouraged by occasional aspirations. Should tension occur, however, air should be removed with a pneumothorax apparatus, but if reaccumulation is rapid, a fine catheter should be introduced into the pleural cavity and attached to an under-water seal or suction motor. A soft catheter is preferable to a rigid needle or cannula as it will not lacerate the lung as it expands.

Failure of absorption (chronic spontaneous pneumothorax), or repeated attacks (recurrent spontaneous pneumothorax), demand full investigations to determine the cause. The most useful investigations are tomography and thoracoscopy (inspection of the lung). These investigations may reveal :

(*a*) A localised lesion, such as a cyst.

(*b*) Generalised lesions, such as emphysema or honeycomb lung.

(*c*) Nothing abnormal.

A localised condition is best treated by thoracotomy and excision, but the latter two groups should be treated by artificial obliteration of the space (pleurodesis). This is achieved by the use of chemical or other irritants (5 per cent. silver nitrate, 25 per cent. kaolin, talc, 0·5 per cent. camphor in oil) introduced either through a needle or painted on the lung surface at thoracoscopy. These irritants set up a diffuse pleuritis which will result in the fusion of the visceral to the parietal pleura if the two surfaces can be maintained in apposition. It is thus important to ensure that the lung expands rapidly and completely after pleurodesis by using catheter drainage with suction.

Hæmothorax

Blood in the pleural cavity may occur in a variety of conditions and is often associated with air as well. The respiratory and cardiac movements defibrinate the blood as it reaches the pleural cavity so that the collection remains fluid. Massive clotting only occasionally occurs. Blood is a pleural irritant and its presence produces pain and shock in the early stages and later excites the formation of a considerable effusion. It is also an excellent culture medium, and infection is relatively common.

FIG. 1421.—A small left hæmothorax with two retained metallic foreign bodies.

Causes.—(1) Trauma (fig. 1421).

(2) Post-operatively, following pulmonary, cardiac or œsophageal operations, thoracoscopy for division of adhesions, cervical sympathectomy and after refills of an artificial pneumothorax.

(3) Associated with new-growths of lung, mediastinum or pleura.

(4) Leaking aneurysms.
(5) Spontaneous.

The signs are those of a collection of fluid in the pleura, and the diagnosis is confirmed by exploring with a needle.

Treatment.—The initial treatment should be aimed at relieving pain, shock and blood loss. Aspirations of blood for therapeutic purposes is only indicated in the early stages if respiration is embarrassed. If signs of persistent bleeding are present, thoracotomy is advised. In all other cases the aim should be to remove the blood by aspiration as early and as completely as possible. Aspirations can be safely started twenty-four hours after the onset and should be repeated daily until no more fluid is obtained and the X-rays appear clear. Air replacement should be avoided. Early and vigorous breathing exercises are advised.

A clotted hæmothorax is diagnosed when the aspirating needle fails to remove a collection of blood. Liquefaction of the clot is often possible by injecting a streptokinase-streptodornase mixture. An initial dose of 200,000 units is injected into the clot and aspirations performed after twenty-four hours. Further doses can be given if the initial injection is not effective. In many instances, however, the result is unsatisfactory and thoracotomy with evacuation of clot and decortication of the lung is required.

An infected hæmothorax should be treated initially with repeated aspirations and the instillation of suitable antibiotics. Early drainage or decortication will probably be required, owing to the difficulty of sterilising and aspirating the hæmothorax if clotting has occurred.

Empyema

An empyema is a pleural abscess and consists of a collection of pus in the pleural cavity. The term is often wrongly used in a much wider sense to include all phases of pleural infection from an infected turbid effusion to a mature abscess containing thick pus. In the management of an empyema, it is just as important to consider the degree of localisation and pus formation as it is in other forms of septic cellulitis.

Ætiology.—An empyema is never primary. The majority are secondary to pulmonary infection, particularly pneumococceal pneumonia and bronchopneumonia, but any infective process, such as tuberculosis, lung abscess and bronchiectasis may be complicated by an empyema. Any inflammatory condition in the vicinity of the pleura may give rise to an empyema, namely :

(*a*) Chest wall (wounds, osteomyelitis of rib).
(*b*) Lung (pneumonia, lung abscess, bronchiectasis, tuberculosis, new-growth).
(*c*) Post-operatively (thoracotomy).
(*d*) From the œsophagus (perforations, carcinoma).
(*e*) From below the diaphragm (subphrenic abscess).

Pathology.—In the common post-pneumonic empyema actual pleural infection is preceded by the development of a serous effusion. The pleura is subsequently invaded by organisms from the lung with associated inflammatory changes and further exudation of fluid. Fibrin is deposited on the surfaces of the pleura, whilst intrapleural clotting is common in certain

types which form a protein-rich exudate (pneumococcal empyema). The natural defences of the body are aimed at encircling the septic area by a barrier of fibrous tissue : this is initially achieved by the fusion of the lung to the chest wall at the periphery of the collection of fluid. Subsequently the fibrin deposits on the pleura are invaded by blood-vessels from the adjacent lung or chest wall with the formation of granulation tissue, and later of fibrous tissue. This process is progressive with an ever-increasing thickness of the wall of the empyema. Left to her own devices, nature will try to obliterate the empyema by converting it into a plaque of fibrous tissue. As the empyema becomes walled off by adhesions, the fluid thickens so that the presence of thick pus is a good indication that the empyema is localised and is unlikely to spread farther. A mature empyema consists of visceral and parietal layers of fibrous tissue on the lung- and chest-wall surfaces respectively with pus and débris between them. There is usually a good plane of cleavage between the wall of the empyema and the pleura which is important in the operation of decortication. Secondary changes in the surrounding structures appear as the fibrous tissue contracts. The ribs are drawn together and lose their mobility. The diaphragm is elevated and fixed, and the mediastinum drawn towards the affected side. The lung is encased in a rigid covering of fibrous tissue and is immobile and functionless. The ultimate picture of a neglected chronic empyema is that of a rigid contracted chest with relatively functionless lung underneath (frozen chest).

Clinical Features.—Empyemata, for convenience, can be divided into three groups : (1) Acute. (2) Subacute. (3) Chronic.

The commonest organisms found are pneumococci and streptococci, but a wide variety of organisms, either alone or in combination, can be encountered.

Acute Empyema.—The acute fulminating toxic empyema is now rare except when it follows perforation of the œsophagus or rupture of a lung abscess. There is profound toxæmia and shock with pleural pain and rapid, shallow respiration. The signs are those of pleural fluid, which should be confirmed by needle exploration. Early thoracotomy is required if the condition follows rupture or perforation of the œsophagus. Other cases should be treated by repeated aspirations with systemic and intrapleural antibiotics in an attempt to control the infection. If these measures fail to control the toxæmia, drainage should be carried out with an intercostal catheter inserted through a cannula and connected to an under-water seal even though the pus is thin and the empyema not walled off. Subsequent management will be that of the subacute empyema.

Subacute Empyema.—The majority of empyemata present in a less severe form largely owing to the general use and efficiency of the antibiotics administered for the primary condition. As a result, the symptoms produced by an empyema are often slight and may be completely overlooked. The development of an empyema should always be considered in cases of pneumonia with delayed resolution, slow convalescence, or persistent fever or malaise. Likewise, it should be suspected where the physical or radiological

signs of resolution are incomplete. Clinical signs are those of fluid with stony dullness, absent breath-sounds, diminished chest movements, and displacement of viscera.

Chronic Empyema.—Many chronic empyemata are the result of mismanagement of the acute or subacute stages, some are due to failure to diagnose the original condition, and the remainder to some underlying pathology in the lung (bronchiectasis, lung abscess, tumour), pleura (foreign bodies, actinomycosis), or chest wall (rib sequestrum). Toxic absorption from the empyema is slight but symptoms of vague ill-health, febrile bouts, anæmia etc., may occur. A chronic empyema may present in one of several ways, namely :

(1) A closed collection of pus completely walled off from its surroundings (localised empyema).

(2) An empyema which is discharging either continuously or intermittently into a bronchus (bronchopleural fistula).

(3) An empyema which is discharging either continuously or intermittently through a sinus in the chest wall.

Diagnosis.—An empyema is diagnosed by finding pus with an exploring needle. Failure to find pus may be due to :

(1) Use of too narrow a needle or the employment of an inefficient, leaking syringe.

(2) Selection of the wrong site for aspiration.

(3) The presence of clot or fibrin tags which block the aspirating needle.

The commonest cause of failure is selection of the wrong site, but this should be avoided by a careful clinical and radiological examination beforehand. If pus is found, it is an advantage to keep two specimens—one for bacteriological studies and the other for comparison with subsequent specimens.

Iodised oil can be injected into the empyema so that in subsequent radiographs the lowest limits of the space will be outlined (fig. 1422).

Having confirmed the diagnosis, it is important to determine the under-

FIG. 1422. — Postero-anterior and lateral radiograph of an empyema after injection of iodised oil to delineate the lower limits of the space prior to drainage.

lying cause ; if the empyema is secondary to a carcinoma, lung abscess or a subphrenic abscess etc., the primary lesion will demand appropriate treatment.

Management.—The principles of management of an empyema are basically the same for all varieties though the emphasis tends to vary in the different types. Following diagnosis and the determination of the cause, management resolves itself into controlling infection and eliminating the dead space. Every case requires vigorous breathing exercises if residual deformity and limitation of movement are to be avoided.

Control of Infection.—Initially all empyemata should be treated by aspirations repeated on alternate days, with the removal of as much pus as possible and the introduction of antibiotics. Sterilisation is usual within seven to ten days. Only occasionally do aspirations fail to control infection, in which case drainage should be carried out.

Elimination of Dead Space.—(*a*) *Aspirations.*—Repeated aspirations without replacement of air will often result in full expansion of the lung and cure of the empyema. This is often the case with children and is more likely after the use of streptokinase. Aspirations should be continued until fluid is no longer obtained and the X-rays show no residual opacity.

(*b*) *Drainage.*—Simple tube drainage after rib resection is indicated when aspirations fail to produce expansion of the lung.

The operation is carried out under local anæsthesia. The site selected for drainage lies immediately above the lowest limit of the empyema posteriorly. The lower posterior site is preferred because this is the most dependent part of the empyema with the patient sitting up in bed. A vertical incision is made over the selected rib and the muscles divided in the line of incision. The periosteum of a 3-inch (7·5-cm.) segment of rib is elevated and the segment removed. The intercostal bundles should be securely ligated. The empyema is entered through the posterior periosteal bed and the hole enlarged to permit complete evacuation of the empyema and a thorough inspection and biopsy of the pleura. Drainage should at first be closed, using an under-water seal, but when the discharge is reduced to 2 ounces (60 ml.) daily open drainage should be instituted. Drainage must be maintained until the empyema cavity is completely obliterated, which may take as long as six to eight weeks. Premature removal of the tube is a frequent cause of chronicity. Control is effected by carrying out serial pleurograms with opaque oil injected into the empyema cavity at intervals of three weeks. The tube should project 1 inch to 2 inches (2·5 to 5 cm.) into the empyema cavity and will require little alteration until the final stages when it should be adjusted to keep it 1½ inches (4 cm.) shorter than the empyema track.

(*c*) *Decortication* (Excision of Empyema).—This operation, as an alternative to drainage, has become popular since the last war, when experience showed that satisfactory results could be obtained. The operation aims at a complete removal of the empyema with its fibrous-tissue walls, leaving the lung and chest wall free to expand. It gives excellent functional results with minimal pleural thickening. Convalescence is rapid without the necessity for repeated dressings, and return to work is possible within a few weeks. The operation is, however, a major one requiring skilled anæsthesia and blood transfusion. It is indicated particularly for large and chronic empyemata, and for those secondary to bronchiectasis, lung abscess, or carcinoma where the underlying lung condition can be dealt with at the

same time. It is contraindicated in the frail and elderly, or where complete resolution of a pneumonic process has not yet occurred.

(*d*) *Operations on the chest wall*, such as a thoracoplasty, the deroofing procedure of Schede, Roberts' flap operation, and the use of muscle grafts have been almost entirely replaced by the operation of decortication.

Tuberculous Empyema.—May be either a simple tuberculous infection or one complicated by secondary infection or a bronchopleural fistula. The majority are complications of an artificial pneumothorax or surgical treatment. They are much less common than they were, partly due to the widespread use of streptomycin but also to the decreased popularity of artificial pneumothorax. The treatment is fundamentally the same as for any empyema, namely control of infection and obliteration of the pleural space, but is coloured by the presence of active tuberculous disease of the lung or a bronchopleural fistula. Control of infection is often possible with regular aspirations and the use of systemic and intrapleural streptomycin, P.A.S., or I.N.A.H. The method adopted to obliterate the empyema depends on the condition of the underlying lung. If active pulmonary disease is present, either a thoracoplasty or a pleuropneumonectomy will be required. If the lung disease is controlled and inactive, obliteration may be possible by repeated aspirations over a prolonged period, or alternatively, by excision of the empyema. The operations of decortication and pleuropneumonectomy have dramatically altered the outlook in these cases.

Interlobar Empyema.—An interlobar empyema is a rarity but one which is wrongly diagnosed with remarkable frequency. It can only occur when the interlobar space is completely shut off from the general pleural cavity. Occasionally a collection of pus remains localised in the fissure in cases of generalised pleural infection when the main collection has been adequately dealt with by aspiration. The diagnosis is largely a radiological one. The collection of fluid is oval or fusiform in shape with the long axis lying in the plane of one of the fissures. The appearances are easily confused with those of segmental atelectasis ; if suspected, pus should be sought with an aspirating needle. Treatment consists of repeated aspirations with chemotherapy, or drainage if aspirations fail.

Intrabronchial Foreign Bodies

Inhalation of foreign bodies is by no means an uncommon occurrence, particularly in children. In many instances the patient does not realise that such an accident has occurred as the initial choking may soon pass. The commonest foreign bodies are teeth, mutton and rabbit bones, peanuts, pins,

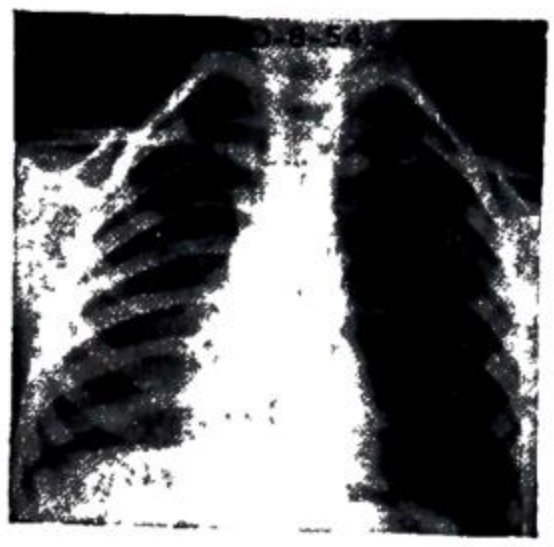


FIG. 1423.—Obstructive emphysema of the left lung due to an inhaled peanut.

FIG. 1424.—Peanut removed bronchoscopically from case described in fig. 1423.

screws and nuts. The changes produced depend upon the size and nature of the foreign body. Small, smooth metallic foreign bodies produce little reaction, whilst larger foreign bodies may lead to partial or complete obstruc-

Max Schede, 1844–1902. Professor of Surgery, Bonn.
James Ernest Helme Roberts, 1881–1948. Surgeon, St. Bartholomew's Hospital and Brompton Hospital, London.

tion of one of the bronchi. Organic foreign bodies, particularly peanuts, produce marked inflammatory changes in the bronchial wall.

The clinical features may be :

(1) Wheezing, irritating cough and signs of unilateral obstructive emphysema (figs. 1423 and 1424).

(2) Symptoms due to atelectasis or pulmonary suppuration ; cough, sputum, fever, etc.

(3) The patient may be symptomless.

Radiography is an essential investigation in every suspected case. If the foreign body is radio-opaque, it should be visible either in the postero-anterior or lateral film, but in many instances the foreign body is either not opaque or is obscured by secondary inflammatory changes.

Treatment.—Bronchoscopy should be performed in all cases of proven or suspected foreign bodies. Removal is easier before secondary swelling and inflammation of the bronchial wall have occurred. Many can be removed without special equipment. Prolonged attempts at removal should not be made owing to the risks of œdema of the glottis or of damaging the bronchial tree further. Operative removal is preferable in such cases. Antibiotics should be given beforehand to minimise the inflammatory reaction. Removal is often possible by bronchotomy but if suppurative changes have already occurred in the lung, resection will be necessary.

Bronchiectasis

The term bronchiectasis strictly describes any abnormally dilated bronchus. Bronchial dilatation may follow many inflammatory conditions of the lung, especially those associated with obstruction of the bronchus. These changes are found in pulmonary tuberculosis, following a lung abscess and after suppurative pneumonia, and occur with obstructive lesions due to tumours. Clinical 'bronchiectasis,' however, is usually applied to one variety of the above where the involvement of the bronchi is more universal and usually follows an anatomical pattern, e.g. a segment, a lobe or a lung. It is infection in these abnormally dilated bronchi which produces cough, sputum and hæmoptyses ; these together form the pattern of the clinical condition of bronchiectasis.

Ætiology.—Many cases are considered to be congenital in origin, though there is no good evidence to support such a thesis. The majority are the aftermath of bronchial obstruction in childhood due usually to enlargement of lymph nodes associated with whooping-cough, measles or primary tuberculosis. This enlargement readily leads to compression of the small relatively soft bronchus of a child, and the obstruction is often completed by the presence of viscid secretions. Bronchial obstruction produces atelectasis. (The majority of cases of pneumonia complicating whooping-cough are really atelectases.) The subsequent course depends on whether secondary suppurative changes occur in the atelectatic lobe or not. If no infection occurs and the obstruction is relieved, the lobe will expand without exhibiting any abnormality. If suppuration occurs, the bronchial walls are severely

damaged and distended by purulent secretions. They lose their elasticity and mobility, and when obstruction is eventually relieved they remain as inert, dilated tubes.

Pathology.—The bronchi appear thickened and irregular, whilst histologically there is marked destruction of all the normal elements and extensive infiltration of the remnants with inflammatory cells. The columnar epithelium is either replaced by granulation tissue or by squamous or cuboidal epithelium. The lung supplied by the affected bronchi may be fibrotic and airless with loss of the alveolar pattern and infiltrated with inflammatory cells (bronchiectasis with an atelectatic lobe) (fig. 1425). In other cases the abnormal bronchi are surrounded by aerated lung tissue but the latter is usually emphysematous and relatively functionless.

Clinical Features.—The majority of cases date their symptoms from an attack of whooping-cough, measles or pneumonia in childhood. The symptoms may persist from that time or the attack may be followed by a latent period of some duration. They may subsequently be intermittent and are often regarded as repeated attacks of bronchitis. Frequently, especially in the severe cases, they are persistent throughout the year but with exacerbations from time to time. Characteristically, the patients have a loose cough productive of purulent sputum; the latter may be offensive and is often blood-stained, whilst frank hæmoptyses are not infrequent. Acute exacerbation with fever and increase of cough and sputum are frequent during the winter months. In children, both physical and mental retardation may occur. Finger clubbing is frequent and persistent râles and rhonchi are audible over the affected areas. Dullness and bronchial breathing with mediastinal shift occurs with an atelectatic lobe.

Diagnosis. — The diagnosis is usually possible on clinical grounds from a prolonged history of cough and sputum associated with finger clubbing and physical signs over a localised area of the lung. Bronchography is essential, not only to demonstrate the presence of bronchiectasis but also to determine its extent (fig. 1425). Bronchoscopy is advisable in order to exclude the presence of a foreign body or tumour.

FIG. 1425.—Bronchogram showing bronchiectasis and atelectasis of right middle and lower lobes.

Treatment.—(*a*) *Prophylactic Treatment*.—Much can be done to prevent the development of bronchiectasis by treating the respiratory complication of measles and whooping-cough with antibiotics and breathing exercises and carrying out bronchoscopy at an early date should atelectasis occur.

(*b*) *Conservative Treatment*.—Considerable reduction of infection can be achieved by postural drainage, percussion therapy and chemotherapy.

Such medical treatment, however, cannot cure the condition as the essential abnormality still remains. Relapse is frequent even though treatment is maintained for long periods. Postural drainage is carried out in a position designed to place the affected lobe above the draining bronchi so that pus will gravitate from the lobe into the bronchus from whence it can be expectorated. Periods of half to one hour several times daily are advisable. Chemotherapy is reserved for acute attacks or as a preparation for surgery.

(*c*) *Surgical Treatment*.—Extirpation of the diseased area is the only available method of curing the condition but is not applicable to every case. It is essential in all cases to carry out complete bronchograms on both sides. Resection is only practicable if less than half of the total lung tissue is involved. Ideally, all abnormal areas should be removed (radical treatment) but in certain circumstances it is justifiable to remove a grossly diseased lobe and leave behind less severely damaged tissue (palliative resection). Children will tolerate the removal of more lung tissue than adults, but bilateral resections are rarely advisable after the age of thirty-five years. Removal should be as conservative as possible, particularly in the more extensive cases. Prior to operation, the patient should have intensive treatment with postural drainage and chemotherapy in order to reduce sputum to a minimum, whilst after operation, rapid and complete expansion of the remaining lung is encouraged by breathing and coughing exercises and suction drainage to reduce the risks of empyema and bronchopleural fistulæ. The results of surgical treatment are best in cases with limited bronchiectasis in an atelectatic lobe. Disappointing results are encountered in patients with generalised bronchitis in addition to bronchiectasis.

Lobectomy.—The operation is carried out through a postero-lateral thoracotomy. The passage of pus from the bronchiectatic lobe into normal lung is prevented by intrabronchial balloons or by posture (face down position). The hilum is approached either from its posterior or interlobar aspect. The relevant bronchus, artery and vein are isolated by blunt dissection using long curved artery forceps. The bronchus is divided between clamps and the vessels are securely ligated. The bronchus is closed by interrupted sutures of silk, thread, nylon or steel wire. The lobe is then freed from its attachments to the parieties and mediastinum. The chest should be temporarily drained by a basal tube, with an additional apical tube if leakage of air is at all prominent.

TUMOURS OF THE LUNG AND BRONCHI

With one or two rare exceptions, all pulmonary tumours arise from some part of the bronchial tree.

Classification

Benign.—Adenoma.
Hamartoma (fibroma, chondroma, lipoma, angioma).

Malignant

Primary.—Carcinoma (common).
Alveolar-cell carcinoma (rare).
Sarcoma (rare).

Secondary.—Sarcoma.
Teratoma of testis.
Carcinoma (bowel, breast, thyroid, kidney).

Symptomatology.—The symptoms produced by a tumour may be due to:

(1) The presence of an irritating lesion in the bronchial tree producing cough, sputum, wheezing and hæmoptysis.

(2) The occurrence of partial or complete bronchial obstruction giving rise to obstructive emphysema or atelectasis respectively.

(3) Secondary inflammatory changes in the lung producing consolidation, suppuration or abscess formation.

(4) Symptoms due specifically to the presence of a primary tumour or of its secondary deposits—malaise, anorexia and loss of weight.

(5) Pressure on the œsophagus (dysphagia), trachea (stridor), or superior vena cava.

Benign Tumours

These represent about 2 per cent. of all pulmonary tumours. They are slightly more common in women and more frequent in the younger individual.

Pathology.—The tumours fall into two main anatomical groups, those arising from the larger bronchi and those situated in the periphery of the lung. The former are usually visible through the bronchoscope. The intra-bronchial portion of the tumour, however, usually only represents a portion of the whole as there is frequently a large extra-bronchial portion (iceberg tumours). The peripheral tumours are not visible through the broncho-scope.

Histologically there are two main types—adenoma and hamartoma. The adenoma is the more common; the cells are regular, well formed and consistent in appearance and tend to be arranged in solid acini or cylinders. Mitoses are infrequent. The hamartoma is a composite tumour composed of two or more tissue elements. They represent an abnormal mixing or development of the normal components of the organ in which they occur. Thus, in the lung, cartilage, fat, glandular or vascular tissue and respiratory epithelium may be found. The hamartomas are usually described according to the preponderant tissue, e.g. chondromatous, hæmangiomatous hamartoma, etc.

Clinical Features.—(1) Many are symptomless and found on routine radiography; this particularly applies to the peripheral types.

(2) Recurrent hæmoptysis. The adenoma is one of the causes of repeated large hæmoptyses occurring over a period of years. There is frequently complete freedom from symptoms between attacks, though occasionally wheeziness and an irritating cough are present.

(3) Symptoms due to bronchial obstruction and lung infection. Simple uninfected atelectasis or pulmonary suppuration with abscess formation and bronchiectasis both occur commonly (fig. 1426). Cases sometimes present with a lung abscess or an empyema with the underlying adenoma completely unsuspected until bronchoscopy is performed.

Diagnosis.—The diagnosis is often suggested by the history but can only be confirmed by bronchoscopy. The adenoma appears as a round, smooth or slightly lobulated raspberry-like tumour which is neither ulcerated nor

necrotic. Tumours containing cartilage appear pale and hard and biopsy may be difficult. Bronchography is necessary to determine the presence and extent of any secondary lung changes which will influence subsequent treatment.

FIG. 1426. — Adenoma of bronchus producing secondary bronchiectasis of the left lower lobe.

Treatment.—Surgical resection is the treatment of choice. This can be planned conservatively as the risk of recurrence is negligible. Treatment by radon implantation, curettage or irradiation is ineffective and cannot be recommended. One or other of the following methods may be applicable to the individual case:

(1) *Bronchoscopic Removal.*—This is only practicable for the rare, strictly intra-bronchial and pedunculated tumours. Bronchoscopy is advisable at regular intervals after removal in order to detect a recurrence.

(2) *Bronchotomy.*—Local removal of the tumour with part of the bronchial wall is practicable for tumours of localised extent without extra-bronchial extension and without secondary lung damage.

(3) *Lung Resection.*—A conservative resection, either segmental, lobar, or total, is required in those cases associated with permanent lung damage. The extent of the resection is determined by the bronchographic findings.

Carcinoma of the Bronchus

Ætiology.—Carcinoma of the bronchus has shown a fifteen-fold increase during the last thirty years. It is ten times more common in men than women, and most frequently occurs during the fifth and sixth decades, but is not unknown in children and young adults. Recent statistical surveys suggest that heavy cigarette smoking over many years predisposes to the development of lung cancer, but so far experimental confirmation has not been forthcoming. The exposure to other irritants, such as arsenic and radio-active substances (Schneeberg cancer), exhaust fumes, sulphurous smoke and fog, and tarry particles from the roads may possibly be implicated. Workers in the chromate industry show a high incidence of lung cancer.

Pathology.—Three main macroscopic types are described:

(1) *Main Bronchus Tumours.*—These arise in the main bronchus or one of its primary or secondary divisions. They produce bronchial irritation and ulceration at an early stage and frequently give rise to bronchial obstruction. They are usually visible through the bronchoscope (fig. 1427).

(2) *Peripheral Tumours.*—These arise from the smaller bronchi beyond the range of bronchoscopic vision and rarely produce secondary lung changes. Many are discovered at routine radiography (figs. 1428 and 1429).

(3) *Pancoast Tumours.*—These are essentially peripheral lung carcinomata arising at the apex of the lung. Enlargement of the tumour in the confined apical space

FIG. 1427.—Carcinoma of the left upper lobe bronchus. The upper lobe is atelectatic and its bronchi are dilated and filled with mucopus. The lower lobe is normal.

FIG. 1428.—Peripheral carcinoma of the lung showing thick-walled irregular cavity.

results in compression of the brachial plexus and the sympathetic chain and erosion of the upper ribs producing the Pancoast syndrome (lower brachial plexus lesion, Horner's syndrome, an apical shadow, and rib erosion).

Histology.—Three main histological types are recognised. (1) Squamous-cell carcinoma = 60 per cent. (2) Anaplastic, oat-cell or round-cell carcinoma = 30 per cent. (3) Adenocarcinoma or columnar-cell carcinoma = 10 per cent. The anaplastic carcinomata are poorly differentiated tumours exhibiting rapid growth with early metastases. They are more common in young individuals.

FIG. 1429.—Peripheral type of lung carcinoma, showing typical lobulated outline and absence of secondary changes in the lung.

Metastases.—A carcinoma of the bronchus spreads by :

(1) Direct extension into the mediastinum, the pleura, the chest wall or the pericardium.

(2) The lymphatic system to the hilar lymph nodes and thence to the subcarinal nodes or the paratracheal chain. The upper nodes of the chain are continuous with the inferior deep cervical group and may be detected by digital palpation deep to the insertion of the sternomastoid muscle.

(3) The blood-stream to the liver, brain, and bone (ribs, vertebræ, pelvis particularly). Other tissues and organs may all be involved.

Clinical Features.—Symptoms produced by a carcinoma of the bronchus are many, but the most important are cough, sputum, hæmoptysis, dyspnœa, pain and wheezing. It is important to recognise the early manifestations as it is at this stage that treatment is likely to be most effective. Any of the above symptoms appearing for the first time in a middle-aged individual

Henry Khunrath Pancoast, 1875–1939. Professor of Röntgenology. University of Pennsylvania, U.S.A.
Johann Horner, 1831–1886, Professor of Ophthalmology, Zürich, described his syndrome in 1864.

and tending to become more severe with time, demand early investigation. Only some 10 per cent. of cases present initially with an hæmoptysis; more frequently, the first symptoms may occur suddenly with an influenzal-like illness which fails to resolve satisfactorily. A number start insidiously with cough and dyspnœa, whilst in the case of the chronic bronchitic there may be an alteration in the typical pattern of his symptoms. Occasionally, first symptoms are due to the presence of secondary deposits (especially in the brain) or invasion of the mediastinum. A diagnosis of unresolved or virus pneumonia should always be made with reservations, and if recovery is not complete, carcinoma should be suspected. Finger clubbing is a frequent and important sign.

Investigations.—The suspicion of a lung cancer demands a thorough investigation. *A chest X-ray* is the most important single investigation and it is usual for some abnormality to be revealed. The appearances vary from that of a hilar or peripheral shadow due to the presence of the tumour to those of obstructive emphysema, atelectasis or consolidation due to secondary lung changes.

Bronchoscopy.—This is not only an essential diagnostic procedure but produces important information regarding operability. The examination will reveal the presence of the tumour in those lesions which are centrally placed. Paralysis of a vocal cord, compression of the trachea, widening of the main carina, and involvement of the main bronchus within 1·5 cm. of the carina are regarded as evidence of inoperability. It should be emphasised that bronchoscopy may not reveal the presence of some tumours, particularly those arising in the segmental divisions of the upper lobes, or the peripherally placed tumours.

Cytological examination of sputum may reveal malignant cells in cases where biopsy material is not available during bronchoscopy.

Barium Swallow.—This may provide evidence of extension of the growth into the mediastinum or the enlargement of mediastinal lymph nodes. If œsophageal distortion is considerable, adequate removal is improbable.

Bronchography.—This may provide valuable information in cases of doubtful diagnosis but has little place in the investigations of the proven case.

Diagnosis.—A positive histological diagnosis is available in about 60 per cent. of cases, whilst malignant cells in the sputum or pleural fluid provide positive evidence in some of the remainder. In about one-third of cases, however, only a presumptive diagnosis can be made.

In the unproven case, a carcinoma is most likely to be confused with chronic suppurative pneumonia, a lung abscess or solid tuberculous lesions, and occasionally with a benign tumour. Careful consideration of the history and response to antibiotics will often provide strong circumstantial evidence against a carcinoma, whilst bronchography and tomography may be helpful in doubtful cases.

Treatment.—*Radical Pneumonectomy*.—The removal of the lung, together with the mediastinal lymph nodes, at present offers the best prospects of cure. The operation should be carried out in a plane as far removed from

the growth as practicable. Where the lung is adherent to the chest wall, it should be freed extrapleurally ; the bronchus should be divided as close to the trachea as possible (fig. 1430). If the pericardium is adherent to the lung, the involved portion should be resected. The paratracheal, subcarinal and para-aortic lymph nodes should be removed (fig. 1431).

Only 20 per cent. of lung cancers are considered suitable for exploration, and of these one in five is found inoperable on exploration. The mortality of radical resection is 10 per cent. Of those surviving resection, 25 per cent. are alive in five years' time.

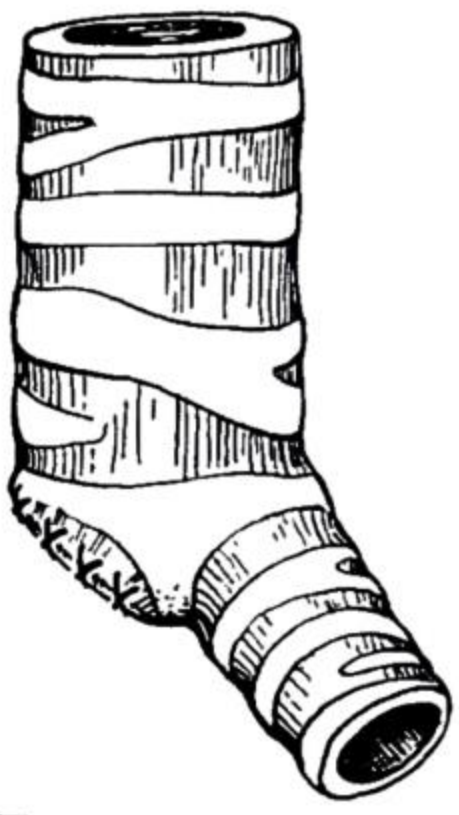


FIG. 1430. — Sutured bronchus after right pneumonectomy. Note oblique division, absence of stump, and figure-eight stitches.

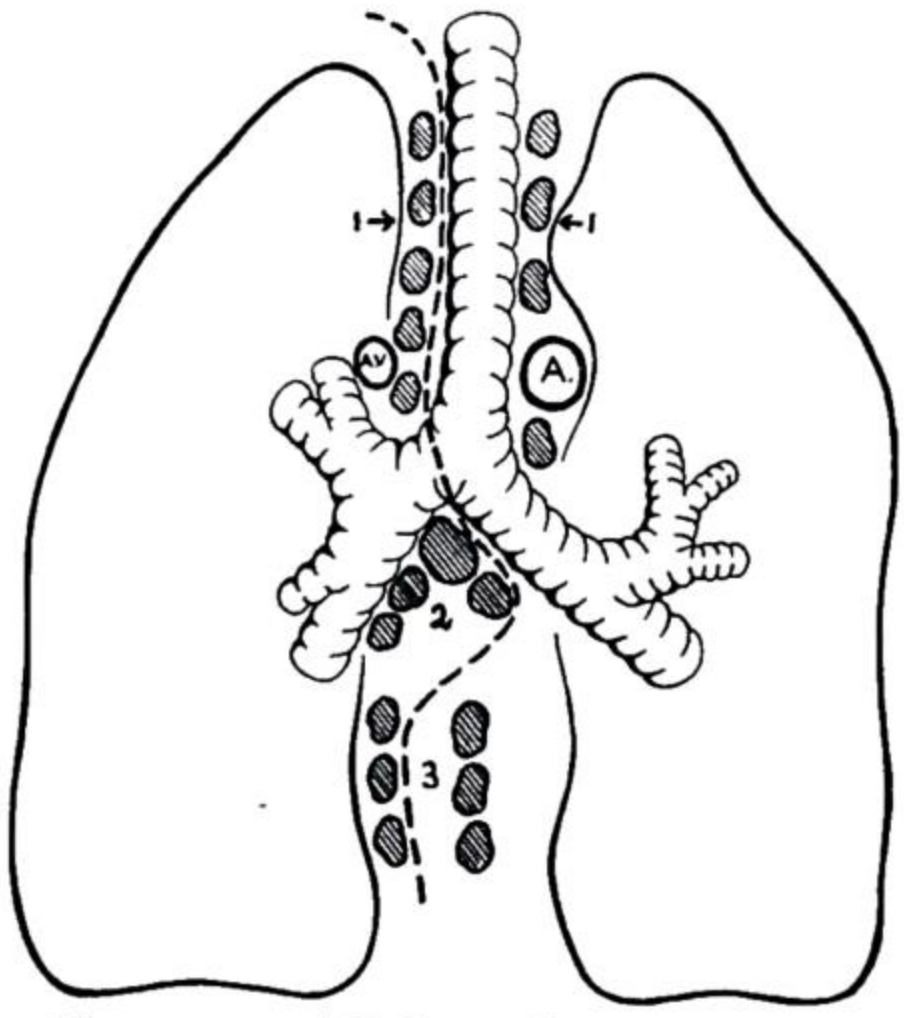


FIG. 1431.—Right radical pneumonectomy. The dotted lines indicate the plane of dissection. A.V. = azygos vein. A. = aorta. 1 = paratracheal nodes. 2 = subcarinal nodes. 3 = para-aortic nodes.

The following are contraindications to resection :

(1) A growth which involves the trachea or the first 1·5 cm. of the main bronchus.

(2) Evidence of spread into the mediastinum with involvement of the œsophagus, recurrent laryngeal or phrenic nerves, vena cava or pericardium.

(3) Extensive invasion of the chest wall.

(4) Evidence of distant metastases.

(5) Patients over the age of sixty-five unless remarkably fit.

(6) Patients with poor respiratory reserve. (This can be assessed on clinical grounds with simple exercise tests. Detailed physiological studies are only necessary occasionally.)

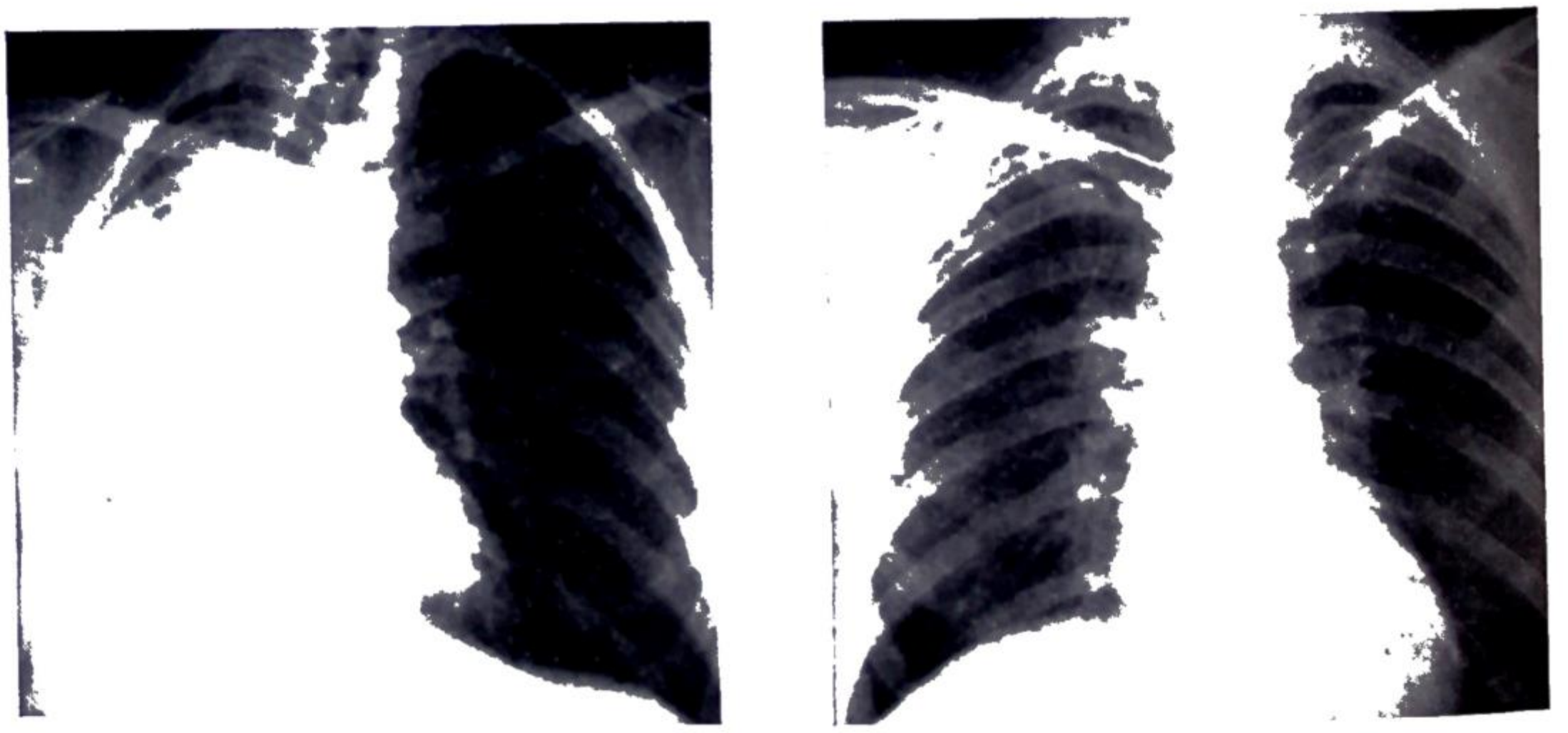
(7) Symptoms due to cardiovascular disease, such as angina, auricular fibrillation, etc.

(8) Chronic bronchitis with persistent signs in the normal lung who are likely to be severely crippled by dyspnœa and bronchitis after operation.

Palliative Resection.—At thoracotomy it is advisable to remove the lung with the primary tumour whenever possible even though the growth is not completely removed. Patients are better off without the primary tumour and die more peacefully from secondary deposits. Occasionally a deliberate palliative resection is justified in cases with repeated hæmoptyses or with much pulmonary suppuration.

Lobectomy.—Lobectomy is indicated for tumours involving only one lobe or in patients with a poor respiratory reserve. Removal of the hilar and mediastinal lymph nodes should be carried out as for pneumonectomy.

X-ray Therapy.—Radical X-ray therapy, particularly with super-voltage machines, is employed in cases which are considered operable from the point of view of the tumour, but inoperable on other grounds. Survival rates of some years have been recorded but no extensive series is available (figs. 1432 and 1433). Palliative X-ray therapy is designed to relieve superior vena caval obstruction, bronchial obstruction and the pain of bone involvement. Considerable relief is obtained by such treatment but survival is not appreciably lengthened.



FIGS. 1432 and 1433.—Main bronchus carcinoma, showing total atelectasis of right lung before, and aeration of the lung after, irradiation.

Pre-operative X-ray therapy has given disappointing results largely due to an increased incidence of broncho-pleural fistulæ following resection.

Post-operative treatment is used occasionally where small areas of growth have not been removed (e.g. on the chest wall). Only fit patients should be treated if serious debilitating reactions are to be avoided.

DISEASES OF THE LUNG

Lung Abscess

A lung abscess is a collection of pus in the lung substance. All cases are secondary to some pre-existing condition, such as foreign bodies, tumours, or bronchostenosis, or to the inhalation of infective material. There is no such condition as primary or idiopathic lung abscess, and in all cases the cause should be elucidated.

Classification.—*A. Due to specific pneumonias*

(1) Staphylococcal.
(2) Actinomycotic.
(3) Friedlander's pneumonia.
(4) Amœbic.

B. Due to bronchial occlusion

(1) Carcinoma.
(2) Benign tumours.
(3) Intrabronchial foreign bodies.
(4) Atelectasis.

C. Due to vascular embolism
(1) Infarct.
(2) Pyæmic.
D. Traumatic
(1) Infected hæmatoma of lung.
(2) Foreign body in lung.
E. Aspiration (inhalation) pneumonia. Non-specific suppurative pneumonia.

The most important group is that due to an aspiration pneumonia. In these cases infected particulate matter, usually from the upper respiratory passages, is inhaled into the lung where various grades of infection ensue from a relatively benign bronchopneumonia to more severe states with necrosis, suppuration and abscess formation.

The most important factors in the production of a lung abscess are :
(1) A source of infected material (dental sepsis, sinus infection, vomit, operations on the upper respiratory tract).
(2) A disturbance of the natural defence mechanisms of the body by depression of the cough reflex (with drugs, in coma, or after anæsthesia or alcohol).
(3) A disturbance of the normal mucous production and ciliary action of the bronchial mucosa (Negus).

Pathology.—Infected particles are inhaled into the bronchial tree and impacted in one of the smaller bronchi. The resulting atelectatic segment is invaded by pathogenic organisms producing pneumonic consolidation. Suppuration and necrosis develop in varying degrees within the involved segment, first with the production of a suppurative pneumonitis which later matures into an abscess. As pus accumulates, tension rises and eventually the abscess ruptures into the bronchus. This may be followed by complete expectoration of all sloughs and pus, and the inflammation may then subside. More commonly, however, a state of chronic infection with persistence of the abscess occurs (fig. 1434). Progressive involvement of adjacent lung tissue or spread to other parts of the lung may occur.

FIG. 1434.—Chronic lung abscess showing irregular cavity filled with inspissated pus and sloughs and surrounded by an area of chronic pneumonia.

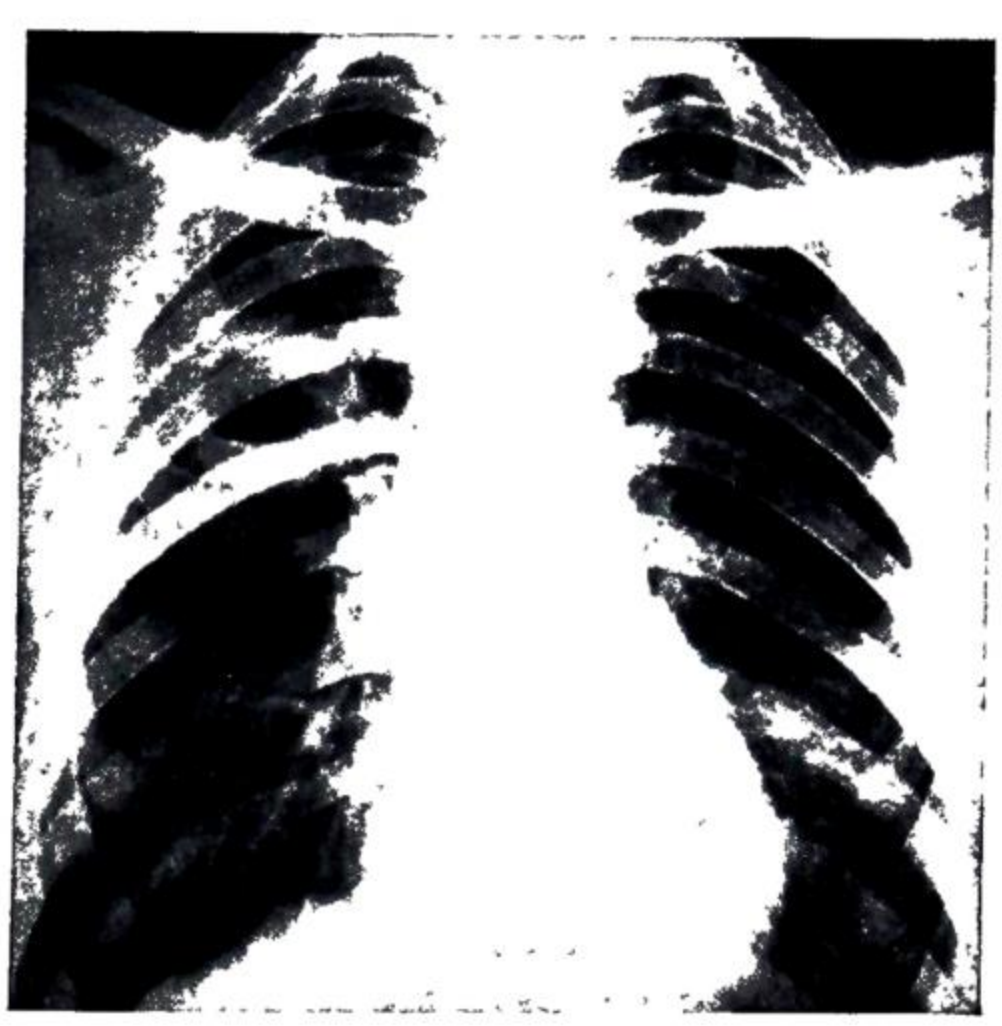


FIG. 1435.—Lung abscess in the right upper lobe. There is an ill-defined area of consolidation surrounding the cavity which shows a fluid level.

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Clinical Features.—The onset is often acute with influenzal-like symptoms and variable toxæmia, but usually without any localising symptoms. After some days of ill-defined illness, pleural pain and a dry irritating cough may appear ; the latter becomes worse and is later associated with the appearance of ' fumes ' in the mouth. About the tenth day, rupture of the abscess results in the sudden expectoration of considerable quantities of offensive blood-stained pus. With successful treatment, resolution occurs slowly with reduction of toxicity and diminution of cough and sputum, but healing takes several weeks and can only be regarded as complete when cough and sputum have disappeared and radiographs are clear. Chronicity is suggested by the persistence of cough with the expectoration of purulent sputum and the presence of cavity on X-ray (fig. 1435).

Complications.—(1) Spread of the disease to other parts of the lung by direct extension or by bronchial embolism : this is suggested by an exacerbation of symptoms and fresh radiographic changes.

(2) *Empyema.*—This may occur spontaneously or following surgical drainage but is less common following the introduction of antibiotics. Persistent fever, pleural pain, and signs of a pleural effusion call for exploration of the pleura with a needle.

(3) *Cerebral Abscess.*—Pyæmic emboli reach the brain through the paravertebral system of veins (Collis). The resulting abscesses are usually multiple but occasionally single. The onset is usually accompanied by headaches and fever. A fit is occasionally the first symptom. The incidence of cerebral abscess has fallen markedly since the introduction of antibiotics.

(4) *Secondary Hæmorrhage.*—Hæmorrhage may occur from either a drained or an undrained abscess. It is often no more than blood-staining of sputum or discharge, but occasionally severe or fatal hæmorrhages occur.

Diagnosis.—The diagnosis is suggested by a history of a sudden, acute influenza-like illness, followed later by the production of purulent sputum and the demonstration of an area of lung consolidation, with or without cavitation. All cases should be thoroughly investigated to determine the cause by :

(1) Bronchoscopy to exclude foreign bodies or neoplasm.
(2) Complete bacteriological examination of the sputum.
(3) Examination of the teeth and upper respiratory tract.

Treatment.—Eighty-five per cent. of lung abscesses respond to conservative measures and surgery is only required for the minority which do not respond. Medical treatment consists of :

(1) *Chemotherapy.*—The majority of organisms are sensitive to penicillin and this should be administered in large doses (2 million units a day) and continued for several weeks whilst there is still clinical or radiological improvement. Other antibiotics should be used if the organisms are resistant to penicillin. The response to antibiotics is often slow and treatment must be continued for some weeks.

(2) *Postural Drainage.*—This should be carried out for periods of up to one hour three to four times a day with the patient placed in such a position that the abscess lies above the appropriate draining bronchus.

(3) At the same time, percussion over the site of the abscess should be carried out to encourage drainage.

Conservative treatment is continued whilst there is clinical and radio-

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logical evidence of improvement, or until symptoms have disappeared and the X-ray is clear.

Surgical treatment is indicated in those cases where resolution does not occur with the above régime. In the majority of cases a formal resection (lobectomy) is possible. External drainage of the abscess—once the standard operation—is now only occasionally required in patients who show no response to chemotherapy and who remain too ill for resection.

Lung Cysts

These may be divided into four groups :

(1) *Epithelial Cysts.*—These are developmental in origin and may be solitary and large or multiple and small. They are lined by a well-developed respiratory epithelium and may have traces of cartilage, muscle or glands in their wall.

(2) *Emphysematous Cysts.*—These include a wide variety of conditions where the normal alveolar framework is destroyed or disrupted, resulting in large air spaces which may become further distended with air.

(3) *Parasitic cysts*, of which the commonest is the hydatid.

(4) *Pseudo-cysts.*—Certain inflammatory conditions of the lung result in cavity formation, and in many instances the cavities may closely resemble epithelial cysts. The cavities, when chronic, are often lined by squamous epithelium. These pseudo-cysts may occur in association with staphylococcal pneumonia, pulmonary tuberculosis, or following a lung abscess. Their true nature is often suggested by their history, course, and radiological features, but the distinction is often difficult.

Epithelial Cysts.—These are developmental and often associated with other congenital abnormalities (cervical rib, pulmonary stenosis, patent ductus) (fig. 1436). They appear as spherical shadows in the X-ray with a thin, sharply defined wall. They may containair, fluid, or both air and fluid. Symptoms may be produced by :

(1) The size of the cyst which compresses the lung and produces dyspnœa, tightness in the chest, etc. This is particularly so in infants and children where the thorax is small and the cyst often relatively large.

(2) Infection is common with the production of fever, cough and sputum. Radiography will demonstrate a fluid level in the cyst. Infection is usually readily controlled with antibiotics, but recurrence is frequent and removal indicated.

(3) Hæmorrhage from cysts is usually associated with infection.

(4) Spontaneous pneumothorax is uncommon with epithelial cysts.

FIG. 1436.—Simple congenital epithelial lung cyst containing fluid and air in patient with a congenital pulmonary stenosis. (Note the prominent left pulmonary artery.)

Treatment.—Solitary cysts producing symptoms should be excised. Symptomless cysts can be kept under observation. Infection of multiple cysts should be controlled by antibiotics if excision is not practicable.

Emphysematous Cysts.—Although many cases are acquired and due to degenerative changes in the lung, others cannot be explained on this basis. The latter may be due to a congenital deficiency of the elastic tissue of the lung or to absence of cartilage in the walls of the bronchus. Either of these conditions may lead to abnormal distension of the lung with rupture of the alveolar walls. Progressive coalescence of alveolar spaces combined with distension with air may result in the development of an enormous cyst (figs. 1437 and 1438). These cysts have no epithelial lining, and when large the remnants of the more resistant bronchi and blood-vessels are seen stretching across the space. The changes may be limited to a small area of the lung, such as a segment or a lobe, or the condition may be generalised and bilateral.

FIG. 1437.—Giant emphysematous cyst of right lung.

FIG. 1438.—A giant emphysematous cyst which presented through the wound on opening the chest.

Clinical Features.—The most important symptom is dyspnœa, which is due to a combination of compression of normal lung tissue by the cyst, increase in the dead space, and a poor gaseous exchange. Emphysematous cysts are frequently associated with chronic bronchitis. In such cases, persistent coughing tends to distend the cysts still further, whilst the presence of bronchial secretions impair respiratory function still more. The presence of bronchitis is a serious complication which renders radical treatment more hazardous.

Spontaneous pneumothorax is a common and serious complication and may be the first presenting feature. Infection and hæmorrhage are unusual (cf. epithelial cysts).

Treatment.—Emphysematous cysts which are not associated with generalised emphysematous changes should be excised, but if changes are widespread, excision is impracticable. Obliteration by multiple ligatures has given good results, it is applicable to multiple and widespread cysts and does not remove potentially functioning lung tissue. Removal of the pulmonary

autonomic nerves can be combined with the above procedures; its chief value lies in the reduction of bronchial spasm. In cases complicated by a spontaneous pneumothorax, pleurodesis should be carried out to prevent further attacks of this serious complication.

Hydatid Disease of the Lung.—Hydatid disease is endemic in Australia, Iceland, and the Middle East, but sporadic cases occur throughout the world. In Britain the majority of cases come from Wales.

Pulmonary hydatid cysts occur in about 15 per cent. of all cases; the cysts are usually solitary, but multiple and bilateral cysts are not uncommon. The disease is commoner in children and young adults.

The cases may present in any of the following ways:

(1) On routine clinical or radiological examination and without symptoms.

(2) Dyspnœa, pain or tightness in chest due to the presence of a large cyst.

(3) Hæmoptysis due to ulceration into a bronchus.

(4) Rupture into the bronchial tree produces symptoms of suffocation, coughing up watery fluid and 'grape skins.'

(5) Symptoms due to secondary infection of the cyst, viz. cough, purulent sputum and fever.

Radiology is the most helpful investigation:

(1) An uncomplicated cyst appears as an almost spherical, sharply defined dense homogeneous opacity (fig. 1439).

FIG. 1439.—Hydatid cyst.

(2) Communication with the bronchial tree may result in a crescentic cap of air overlying the cyst (perivesicular pneumo-cyst).

(3) Rupture of the cyst permits air to enter the cyst and the laminated membrane collapses. This floats on any fluid which may be present, producing an irregular projection above the fluid level (water-lily appearance).

(4) Infection results in disintegration of the laminated membrane with appearances simulating a lung abscess.

(5) Varying degrees of pneumonitis, atelectasis, or pleural effusion may accompany any of the above and modify the radiological appearance.

Diagnosis.—The most important point is to remember the condition. A history of residence in an endemic area may support the diagnosis. The intradermal test of Casoni will give a positive result in 75 per cent. of uncomplicated cysts provided fresh hydatid fluid is used. An eosinophilia of over 4 per cent. is suggestive of the condition.

Treatment.—Removal of the cyst is indicated in all cases owing to the considerable risk of serious or even fatal complications. The earlier operation of marsupialisation has been almost completely replaced by thoracotomy with enucleation of the cyst or lobectomy. Enucleation is employed for uncomplicated cysts without significant associated lung damage. Excessive care and utmost gentleness is required to remove the laminated membrane intact without spilling the contents with the risk of infecting the pleura or wound. The adventitia is carefully incised and the laminated membrane will usually slowly extrude itself. It should never be grasped with forceps as it is friable and is sure to tear. After removal, any bleeding-points or open bronchi are tied; there is no need to close the adventitious cyst wall. The pleura is drained as some leakage of air is inevitable.

Tomaso Casoni, 1880–1933. Italian Physician.

Complicated cysts are best treated by a more formal resection (lobectomy), particularly if there is any surrounding lung damage.

Secondary Pleural Hydatid Disease.—This is an occasional but serious complication of rupture of a cyst into the pleura or of ill-executed surgery. Multiple cysts grow widely throughout the pleura and may invade the chest wall, diaphragm, or mediastinum. Radical pleuropneumonectomy offers the only hope of eradicating the disease.

SURGICAL TREATMENT OF PULMONARY TUBERCULOSIS

In a book of this nature it is not possible to give more than an outline of the principles involved in the surgical treatment of pulmonary tuberculosis. Such treatment is usually an incident in the long-term management of the case, and as such can only be satisfactorily determined by consultation and discussion between physician and surgeon.

Principles of Treatment.—(1) *Rest*.—This can be either local or general, and is an essential part of all forms of treatment. General rest is obtained in bed, whilst local rest is achieved by the various methods of collapse therapy, phrenic paralysis, and pneumoperitoneum.

(2) *Chemotherapy*.—The introduction of streptomycin, para-aminosalicylic acid (P.A.S.), and iso-nicotonic acid hydrazide (I.N.A.H.) have revolutionised the treatment of tuberculosis. They are now employed in the vast majority of cases as a definitive treatment or as an adjunct to surgical methods of treatment. The drugs should always be given in combination to prevent the emergence of resistant strains of bacteria.

(3) *Relaxation*.—Tuberculosis heals by the production of fibrous tissue resulting in the contraction of the diseased area and the collapse and obliteration of the destroyed areas and cavities. Complete contraction and healing is often prevented by anatomical structures (bony chest wall), so that artificial methods of relaxing the diseased lung are required in many instances. These are divided into the minor and major methods. The former include artificial pneumothorax, phrenic paralysis, and pneumoperitoneum, whilst the latter include thoracoplasty, extrapleural pneumothorax, and plombage.

(4) *Excision of Diseased Lung*.—Prior to the introduction of streptomycin, excision of tuberculous lungs usually met with disaster. Streptomycin, however, has enabled resection to be carried out safely, and this method is now widely employed. Resection has the advantage over collapse therapy of removing the major foci of disease, leaving the body with the less formidable task of dealing with the residual disease.

(5) *Drainage of Pus*.—Apart from the drainage of an empyema, this method has little application now though in the past tuberculous lung cavities were treated by catheter drainage (Monaldi), or open external drainage (cavernostomy).

Management.—All cases should be treated with bed rest and chemotherapy for several months before any active measures are undertaken. In many instances prolonged treatment will result in complete arrest of the disease; in others a tuberculous cavity, a positive sputum, or bronchial damage requires more active treatment. Surgical measures are almost entirely employed for dealing with residual lesions which persist after

Vincenzo Monaldi, Contemporary. Director, Tuberculosis Clinic, University of Naples.

adequate conservative treatment. The choice of the actual surgical procedure depends largely on the extent and site of the disease, the age, general condition, and respiratory reserve of the patient, and the presence of complicating bronchial or pleural disease.

A. COLLAPSE THERAPY

I. Minor Procedures

Artificial Pneumothorax.—This is a simple procedure consisting of the introduction of air between the layers of the pleura. The resulting collapse of the lung is maintained by regular refills of air for several years. Adequate collapse is often prevented by the presence of adhesions between the lung and the chest wall ; these can be divided with the actual cautery guided by a telescope introduced through a cannula (thoracoscopy). Extensive adhesions or close adherence of the lung to the chest wall are unsuitable for division, and in such cases the pneumothorax should be abandoned.

Phrenic Paralysis.—Paralysis of the diaphragm produces both rest and relaxation of the lung. The paralysed diaphragm is raised by the positive intra-abdominal pressure and the rise can be increased by a pneumoperitoneum. Phrenic paralysis should be regarded as a temporary method of treatment and used in conjunction with rest and chemotherapy. Crushing the nerve produces paralysis for three to six months. Permanent paralysis by phrenic avulsion or phrenic division is referred to on page 1036.

II. Major Procedures

Thoracoplasty.—This is the standard method of treatment employing major collapse therapy. The operation is ideally indicated for cavities in the

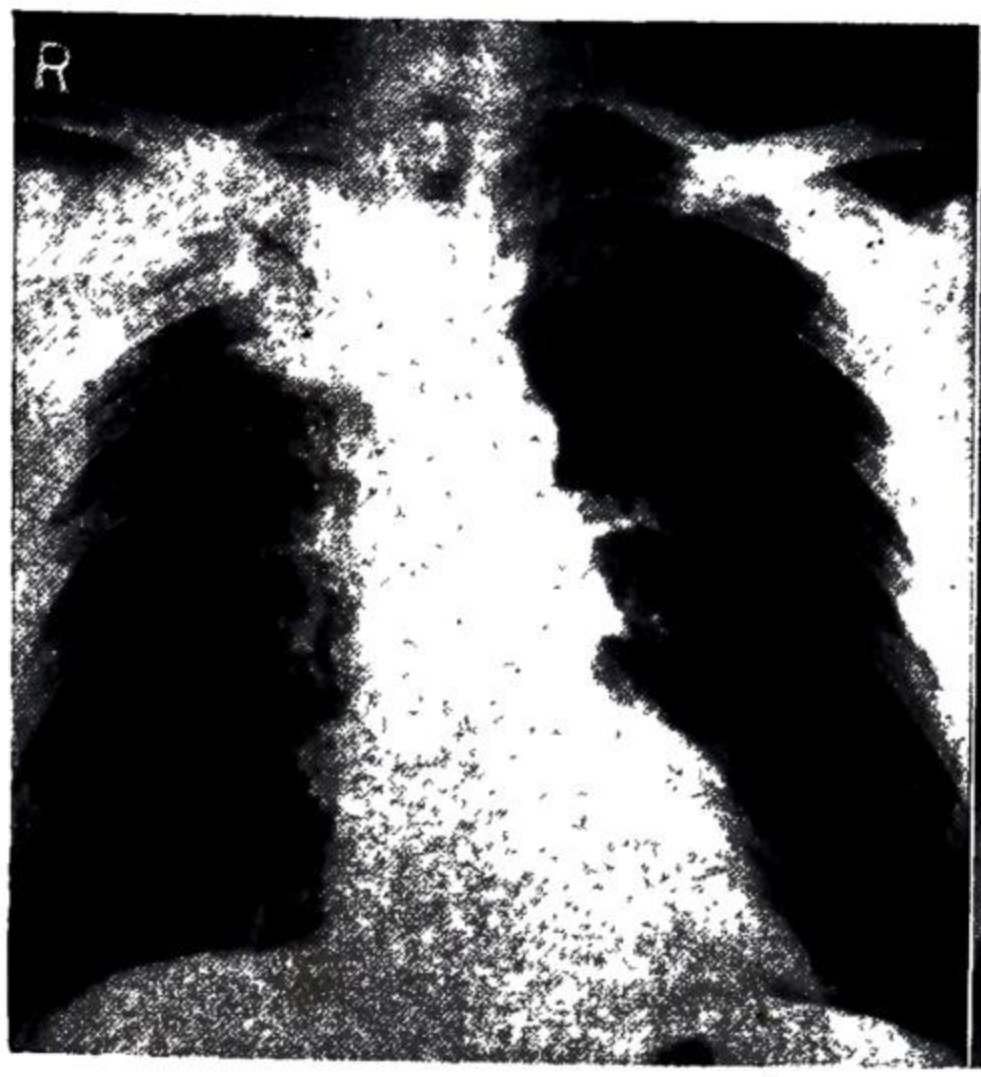


FIG. 1440.—Chronic tuberculous cavity at the right apex.

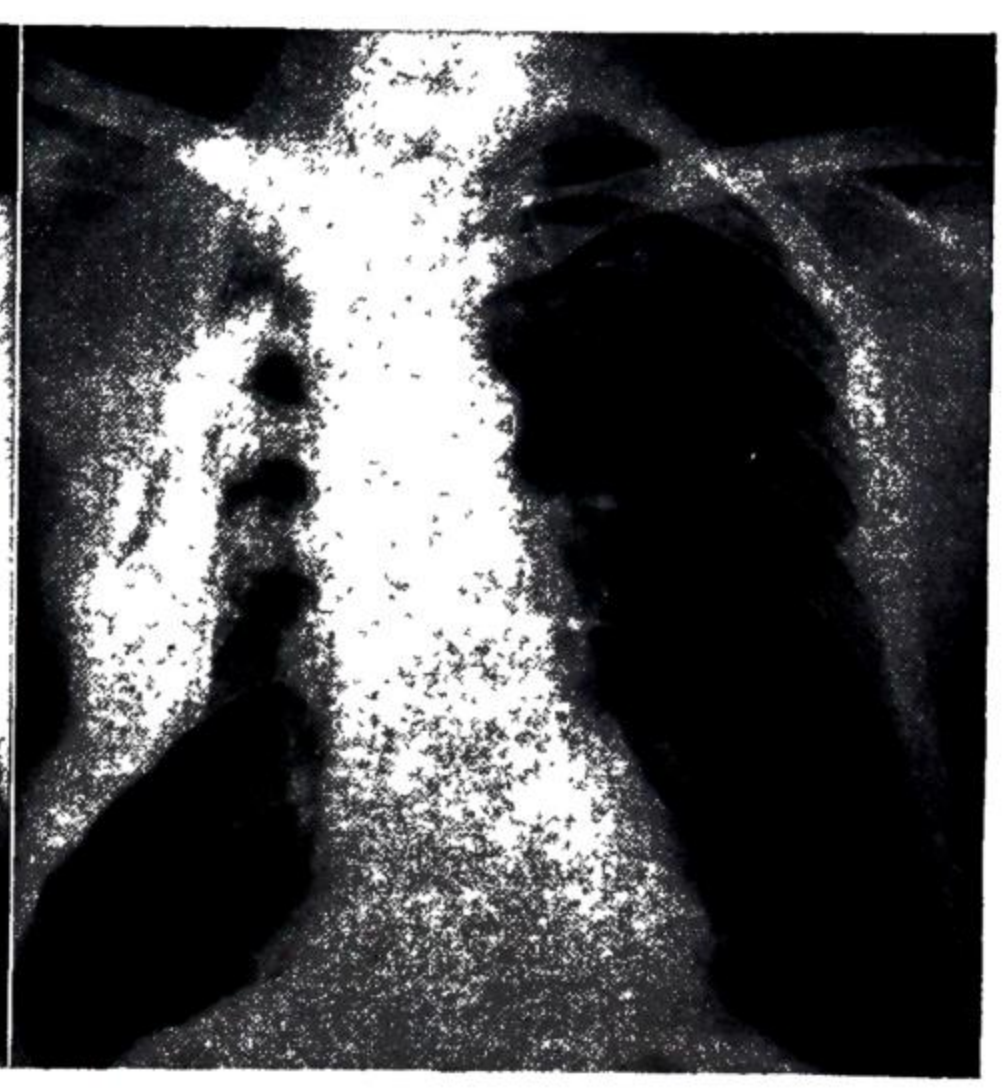


FIG. 1441.—Same case as in fig. 1440 after thoracoplasty.

upper lobe (figs. 1440 and 1441), but can be employed for a wide variety of lesions. The aim of the operation is to relax the diseased area from all sides so that it will retract concentrically towards the hilum. Lateral relaxa-

tion is produced by removal of the upper ribs whilst apical relaxation is achieved by separating the lung from the apex and the mediastinum. The original operation was introduced by Sauerbruch and consisted of removal of ribs only (lateral thoracoplasty), but this operation has been replaced by Semb's modification which includes apicolysis in addition to rib removal.

The operation is carried out in stages under local or general anæsthesia. A 'J' shaped incision is used with the vertical limb placed parallel with the spine and 2 inches (5 cm.) from it, extending from the first thoracic spine downwards and curving forwards beneath the angle of the scapula. The trapezius, rhomboids, latissimus dorsi, and serratus anterior are divided in the line of the incision. This permits the elevation of the scapula with the exposure of the upper ribs. Portions of the third, second, and the whole of the first rib are resected subperiosteally in that order. The apex of the lung is then freed by a combination of blunt and sharp dissection from the apical and mediastinal structures. The intercostal bundles and muscles are divided. The wound is closed without drainage. At subsequent stages further ribs are resected in order to relax the lung to a point immediately below the lowermost limit of the obvious disease. Usually two or three stages carried out at intervals of two weeks are necessary.

Extrapleural Pneumothorax.—In this operation the lung is relaxed by separating the parietal pleura from the chest wall over the diseased area and maintaining the resultant space by refills of air. The operation achieved some measure of popularity as an alternative to thoracoplasty and as a method of overcoming some of the disadvantages of the latter, particularly as regards the deformity and multiple stages. Infection and hæmorrhage into the space occur frequently and the operation is now rarely employed.

Plombage.—Plastic materials were first used to replace air in extrapleural operations, but the results were no better than with extrapleural pneumothorax. A more satisfactory procedure is now employed modelled on the operation of thoracoplasty, but the ribs are not removed.

The periosteum is stripped from the ribs and together with the intercostal muscles remains attached to the lung, and apicolysis is carried out as for a thoracoplasty. The space between the denuded ribs and the mobilised lung is filled with one of the inert plastic materials to maintain collapse of the lung. Various materials have been used, but the most satisfactory have been polythene balls and polystan sponge. The operation is performed in one stage; post-operative complications are negligible and the results of treatment are comparable with thoracoplasty. Infection in the plomb space is infrequent. The operation is particularly indicated in cases with extensive disease and poor respiratory function, and in those who are anxious to avoid the deformity or multiple stages of a thoracoplasty.

III. Indications for Major Collapse Therapy

(1) The ideal case for collapse therapy is where persistent apical cavitation is combined with evidence of fibrosis and shrinkage in a patient whose disease is relatively stable (figs. 1440 and 1441).

(2) Cavities in the apical and posterior segments of the upper lobe or apical segment of the lower lobe are suitable for collapse. (Cavities in the anterior segment of the upper lobe, the lingular segment or middle lobe, and the basal segments of the lower lobe are unsuitable.)

(3) Persistent fibrocaseous disease in the upper lobes not associated with definite cavitation.

(4) Bilateral apical disease considered unsuitable for resection.

Ernst Ferdinand Sauerbruch, 1875–1951. Professor of Surgery, Berlin.
Carl Boyce Semb, Contemporary. Surgeon, Ullevaal Hospital, Oslo.

(5) Destroyed lobes or lungs where resection is impracticable owing to age or contralateral disease.

(6) Prophylactic where simpler measures have closed a cavity but permanent collapse is desirable to prevent reopening.

B. LUNG RESECTION

Since the introduction of streptomycin, resection of tuberculous lesions has been widely practised and has given good results. Complication rates of the operation are slightly higher than with thoracoplasty and may be more serious (e.g. broncho-pleural fistula and empyema). The operation has the advantage of removing much diseased tissue, it leaves no deformity, and respiratory function is little disturbed. The operation, however, can only be safely employed in those with limited disease where it is possible to remove the greater part of the diseased area. Resections are thus mainly employed in cases of limited extent where the remaining lung tissue is normal. Before embarking on resection it is necessary to determine by tomography and bronchography whether the lung and bronchi to be left behind are free from disease. Pre-operative bronchoscopy is advisable, and if active tuberculous bronchitis is discovered, resection should be delayed until it is controlled by further chemotherapy. At operation it is advisable to remove all the obvious tuberculous disease, although small healed nodules may be safely left behind. The remaining lobes must be prevented from over-expanding either by temporary phrenic paralysis or by performing a small apical thoracoplasty. Over-distension of the lobe is likely to cause reactivation of dormant foci. It is unwise to carry out a resection if the organisms are resistant to streptomycin.

FIG. 1442. — Tuberculous cavity in the apex of the lower lobe with several adjacent caseous foci.

Indications for Resection.—Certain lesions do not do well with collapse therapy and can be regarded as absolute indications for resection provided the disease is limited in extent and the organisms are streptomycin sensitive.

(1) Solid lesions (tuberculoma), especially where the diagnosis is in doubt and a cancer cannot be excluded.
(2) Lesions associated with broncho-stenosis.
(3) Tuberculosis in the lower lobe (fig. 1442).
(4) Failure of collapse therapy to control the disease.
(5) Destroyed lobe or lung.
(6) Anteriorly placed cavities.

(7) Tuberculous bronchiectasis.
(8) Tuberculous empyema associated with active disease in the underlying lung.

There remain a number of conditions where either collapse therapy or resection are equally applicable, and the decision for operation is largely a personal matter. These lesions include :

(1) Segmental lesions. These include nodular disease remaining in one or more adjacent segments following chemotherapy where it is anticipated that the lesions may reactivate if more definitive measures are not employed.
(2) Cavities in the apex of the lower lobe.
(3) Tension cavities (large thin-walled cavities distended with air).
(4) Fibrocaseous nodular disease in the upper lobe with or without cavitation.

POST-OPERATIVE PULMONARY COMPLICATIONS OF SURGERY

The pulmonary complications of general surgery are the cause of serious morbidity and an appreciable mortality, and yet they can be largely prevented by adequate pre-operative and post-operative care.

Predisposing Factors.—(1) *Type of Operation.*—Operations on the upper abdomen and on the upper respiratory tract are more commonly implicated than others, but no operation is entirely exempt. Operations for septic conditions are more prone to be followed by complications.
(2) *Sex.*—Males are much more commonly affected than females.
(3) *Age.*—Complications are particularly frequent in the very young and the elderly.
(4) *Chronic Bronchitis.*—A pre-existing chronic bronchitis is an important pre-disposing condition.
(5) *Smoking.*—Probably through the production of chronic bronchitis, heavy smokers are more prone to complications than non-smokers. Morton records 60 per cent. of complications occurring in heavy smokers and less than 10 per cent. in non-smokers.
(6) *Anæsthetic.*—The anæsthetic plays some part though this is less than is usually thought. Trauma to the tracheo-bronchial tree should be avoided and prolonged post-operative unconsciousness is undesirable.
(7) *Pain.*—Post-operative pain is an important factor as it restricts coughing and deep breathing.
(8) Lack of mobility in bed and dehydration predisposes to venous stasis and thrombosis.

Excessive Bronchial Secretions

Abnormal bronchial secretions account for the majority of the chest complications of surgery. Many patients are a little ' chesty ' following even the most trivial operation. This ' normal ' post-operative bronchitis, however, may lead to very serious and perhaps fatal sequelæ unless adequately controlled.

Preventative Measures.—Adequate time should be devoted to preparing patients for operations of election. This can usefully be done in a regular pre-operative clinic where breathing exercises and coughing instruction is given, dental sepsis is attended to and bronchitis treated by antibiotics. A routine chest X-ray may reveal unsuspected tuberculous or other lesions. Smoking should be forbidden for several days before operation.

The following complications may be encountered, but it should be realised that one may merge into another or neglect of one frequently leads to the production of more serious conditions.

Hugh John Vivian Morton, Contemporary. Senior Anæsthetist, Hillingdon Hospital, Uxbridge.

(1) *Bronchitis.*—This is the commonest complication and is important in that it is a precursor to more severe changes. It may arise *de novo* or represent an exacerbation of a pre-existing bronchitis. The attack may vary considerably from a simple post-operative cough with mucopurulent sputum to severe suppurative bronchitis. Signs in the lungs are generalised and there are no radiographic changes to be seen.

(2) *Bronchopneumonia* (Aspiration Pneumonia).—This is usually a sequel to the above. Patchy consolidation occurs with more profound systemic changes. Signs are more localised and bronchial breathing may be heard. Radiographs will reveal patchy mottling.

(3) *Atelectasis.*—This is produced by occlusion of a bronchus by viscid secretions and again usually follows bronchitis. The secretions may consist of mucus or infected pus. The obstruction leads to absorption atelectasis of the involved lobe. Secondary invasion of this lobe by pathogenic organisms results in particularly serious changes. Depression of the cough reflex by pain or sedation and poor ventilation are important predisposing factors. Atelectasis usually occurs after the second post-operative night, frequently following heavy sedation. Secretions accumulate during sleep, and by morning have blocked the bronchus. The patient does not feel quite so well and there may be slight fever, tachycardia and breathlessness. Cough and sputum may not be obvious as the latter cannot be expectorated. Signs consist of restricted movement of the affected side of the chest with diminished breath-sounds and impaired percussion note over the affected lobe. Radiography will reveal the dense opacity of the atelectatic lobe.

(4) *Lung Abscess.*—This usually follows bronchopneumonia or atelectasis and is often the result of ineffective early treatment. It is a particularly serious complication often resulting in spreading suppuration throughout the lung by organisms which are by then often resistant to all drugs.

(5) *Empyema.*—This is an occasional complication of any of the above; its management is no different from the average case.

Treatment.—*Prophylactic.*—At the conclusion of an operation the tracheo-bronchial tree should be aspirated if any secretions are suspected. Early return of consciousness and the cough reflex are desirable. Subsequently coughing and breathing exercises combined with regular rolling of the patient from side to side are desirable. Pain should be controlled by repeated small doses of analgesics of which pethidine (50–100 mg.) is the most useful as it does not depress respiration.

The Established Case.—It is important to encourage the expectoration of sputum by all possible means. Much can be done by the physiotherapist and the nurse, whilst steam inhalations and saline expectorants help to loosen the sputum. When the secretions cannot be adequately removed naturally, they must be removed by catheter suction. If the simpler measures are not soon effective *bronchoscopy* should be carried out. This can readily be performed in the ward if the patient is too ill to move. It should be performed under minimal local anæsthesia so that the cough reflex is preserved. A careful and unhurried clearance of the whole bronchial tree

should be the aim. Bronchoscopy usually results in the aeration of an atelectatic lobe but the condition may recur and further bronchoscopies be required. In such cases it is often preferable to perform a *tracheostomy*, particularly when secretions are profuse or the patient dyspnœic. The operation is performed under local anæsthesia and can be carried out in the ward in an emergency. Tracheostomy reduces the dead space air and greatly improves the efficiency of respiration and it also provides easy access for repeated and atraumatic aspiration of the tracheo-bronchial tree. In addition to post-operative complications it has an important place in the management of severe chest injuries, head injuries, bronchopneumonia and polio-myelitis.

Subphrenic Abscess (see also p. 489)

This condition should be suspected when an unexplained fever appears after an abdominal operation, particularly when associated with sepsis, such as the repair of a ruptured peptic ulcer or for septic appendicitis. Symptoms are often masked by the use of antibiotics. The signs are notoriously ill-defined but can usually be elicited if the condition is suspected. Amongst the most valuable signs are :

(1) Restricted lower chest movements on the affected side.

(2) Slight bulging of the lower ribs on the affected side with tenderness on compression of the chest and œdema of the chest wall.

(3) Dullness and absent breath-sounds over the affected lung base.

(4) Radiography shows a raised diaphragm which moves poorly. Gas or a fluid level may be visible below the diaphragm and pleural fluid present above.

In all cases of suspected subphrenic infection, surgical exploration of the affected space is justified.

Broncho-pleural Fistula

This complication is one peculiar to thoracic operations involving resection of lung tissue. Several factors may be involved in its production.

(1) Poor surgical technique in closing the bronchus (sutures too tight or imperfectly placed).

(2) Infection of the bronchial stump (pyogenic or tuberculous).

(3) Indifferent healing (elderly and debilitated patients and after deep X-ray therapy).

Symptoms usually appear towards the end of the first week after operation ; fever and blood-stained sputum are the first signs. Subsequent developments depend on the size of the fistula.

A small leak allows air to enter the pleural cavity producing a pneumothorax and collapse of the lung whilst pleural fluid enters the bronchial tree giving rise to a persistent cough with much thin blood-stained sputum.

A larger fistula may give rise to serious flooding of the bronchial tree and the development of a tension pneumothorax.

Treatment.—The first essential when a fistula is suspected is to antici-

pate and prevent flooding of the bronchial tree by early aspiration of fluid from the pleural cavity and by nursing the patient with the affected side down.

A small leak may be controlled by repeated aspirations or by temporary tube drainage until the fistula heals.

Larger fistulæ should be treated by re-opening the chest and resuturing the bronchus. The suture line should be reinforced by a pedicled intercostal muscle graft. If the pleural cavity is grossly infected, however, it is better to drain the pleura and carry out bronchial repair at a later date.

Pulmonary Embolism

Between 2 and 3 per cent. of all hospital deaths are due wholly, or in part, to pulmonary embolism. The condition is by no means limited to surgical wards. The clot most commonly originates in the veins of the calves, thighs or pelvis. Two types of venous lesions occur :

(1) *Thrombophlebitis.*—The thrombosis is secondary to infection or trauma. There is a marked inflammatory reaction and the resulting clot is firmly adherent to the vessel wall and is rarely dislodged.

(2) *Phlebothrombosis.*—Clotting is secondary to venous stasis and there is no inflammatory reaction in the veins. The clot is soft and insecurely attached to the vessel wall. Detachment of the clot is easy, particularly as the condition is often unsuspected and movements uninhibited.

Predisposing Factors.—Abdominal and pelvic operations are more commonly implicated than others. During operation it is essential that the venous return from the lower limbs is not impeded in any way. Pressure of the calf on the operating table can be limited by elevating the heel on a sand-bag or sorbo-rubber pad. Conditions which predispose to a sluggish circulation after operation, such as immobility of the lower limbs, dehydration, and delayed venous return should be avoided by massage, leg movements, adequate hydration and early ambulation.

Detection of Thrombosis.—Phlebothrombosis is often symptomless, but there may be a complaint of pain in the affected calf. Any unexplained elevation of temperature or pulse-rate should arouse suspicion of thrombosis, especially when occurring towards the end of the first post-operative week. In all cases where thrombosis may be anticipated the calves should be examined regularly, and if suspicions are aroused, the soles, popliteal fossæ and adductor regions should be carefully palpated for tender areas. Homan's sign (pain in the calf on dorsiflexing the foot) is a less reliable sign than tenderness elicited by pressure along the course of the posterior tibial and peroneal veins or by squeezing the calf muscles.

Treatment of Phlebothrombosis.—In the suspected case, the patient should be kept in bed with the affected limb immobile. Anticoagulants are essential to prevent further thrombosis. The most effective treatment is given by a combination of heparin with tromexan or dindevan. Heparin can be given intravenously or intramuscularly; it produces an immediate effect which can be equally rapidly counteracted by protamine sulphate. It is, however, difficult to control over long periods. Tromexan or dindevan are

John Homans, 1877–1954. Clinical Professor of Surgery Harvard Medical School 1928–34; William H. Camalt, Professor of Surgery, Yale University School of Medicine; Professor of Clinical Surgery Tufts College Medical School.

administered orally but take thirty-six to forty-eight hours to produce their effect. They are counteracted by the administration of vitamin K_1 but elimination of their action takes some hours. Satisfactory therapy is obtained as follows :

(1) 15,000 units of heparin intravenously followed by 10,000 units intramuscularly eight-hourly for five doses. Alternatively, heparin can be given as a continuous intravenous drip.

(2) 100 mg. of dindevan given orally with the initial dose of heparin and repeated in twelve hours.

(3) On the second day, two doses of 50 mg. of dindevan.

(4) On the third day, two doses of 25 mg. Subsequent dosage of dindevan is guided by the prothrombin time, which should be maintained at approximately twice the normal value.

Anticoagulants should be continued for eight to ten days. Ligation of femoral veins or of the inferior vena cava has not produced a significant reduction in the incidence of pulmonary embolism. Vena caval ligation is frequently followed by troublesome vascular disturbances in the lower veins. Femoral vein ligation may be of value in cases where anticoagulants are not indicated.

Treatment of Pulmonary Embolism.—This is the most feared complication of phlebothrombosis. Much depends on the size of the embolus ; many are small and produce only transient lung changes ; larger emboli result in pulmonary infarction, whilst an embolus impacted in the main pulmonary artery is rapidly fatal. It is estimated, however, that two-thirds of all cases recover. A massive pulmonary embolus may produce immediate death from ventricular fibrillation or complete obstruction of the circulation. Such cases often have an urgent desire for a bed-pan but are dead before one is produced. Those who survive complain of severe præcordial pain, tightness in the chest, and marked dyspnœa. Shock is marked and the patient becomes grey and cold with a rapid, feeble pulse, low blood pressure, and raised venous pressure. Death may occur at any moment, but the longer the patient survives the better are his prospects of recovery. Every effort is made to support the circulation. The patient is nursed flat and given oxygen ; aminophyllin (0·24 G.) and coramine (2–5 ml) are given intravenously. Eupavarine (1 mg. intravenously) is given to encourage dilatation of the pulmonary vessels. Trendelenburg's operation (pulmonary embolectomy) has been successfully performed in a few cases, but the necessary surgical skill and equipment is rarely available. Pulmonary infarction which occurs in less severe cases produces pleural pain, hæmoptysis and dyspnœa. Radiography reveals a wedge-shaped segmental shadow. Symptomatic treatment only is required.

THE DIAPHRAGM

Herniation of an abdominal viscus through the diaphragm into the chest may occur through a congenital or acquired defect ; the former occur at certain well-recognised points (fig. 1443) and are due to a failure of fusion of

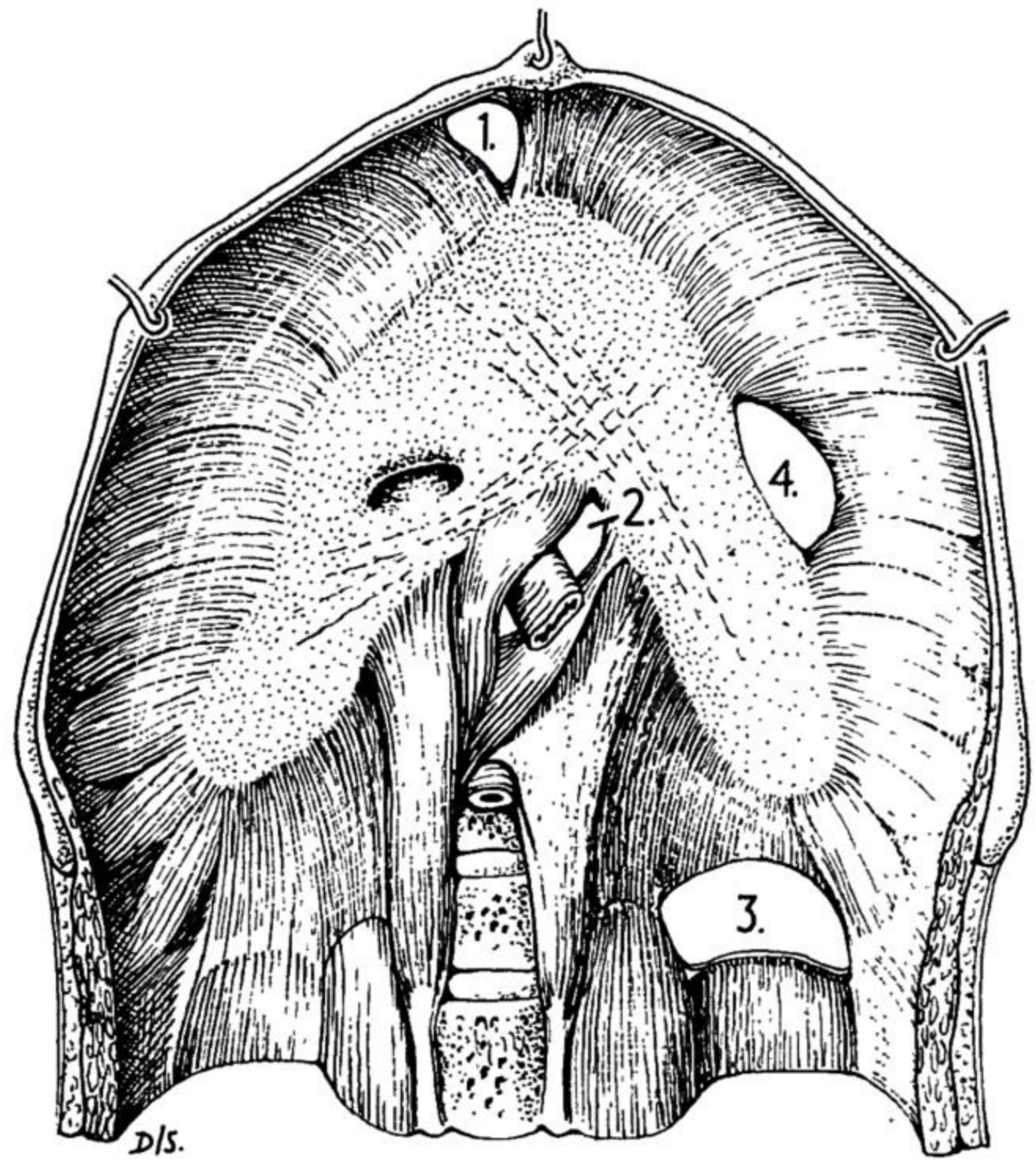
Friedrich Trendelenburg, 1844–1924. Professor of Surgery, Leipzig.

the various elements which make up the diaphragm. Such herniæ usually have a well-defined sac and adhesions are uncommon. Other congenital malformations may be present.

The acquired group are either traumatic or post-operative. They may occur anywhere in the diaphragm and extensive adherence to surrounding structures is usual. Stomach, small or large bowel, omentum or spleen are commonly found occupying the hernia. Liver and kidney are less frequently seen.

Symptoms may only occur when either obstruction or strangulation supervene. Many patients, however, complain of vague dyspeptic symptoms but if the hernia is large, especially in children, respiratory embarrassment may occur.

Surgical repair is recommended in all cases in order to avoid serious complications. Access is best obtained through a low thoracotomy incision. The sac is excised and the defect is repaired by a double row of thread or silk sutures. Occasionally reinforcement with fascia lata is required.



1. Foramen of Morgagni
2. Oesophageal hiatus
3. Foramen of Bochdalek
(PLEURO-PERITONEAL HERNIA.)
4. Dome

Diagram after Gray

FIG. 1443.—The usual sites of congenital diaphragmatic herniæ.

(1) **Eventration.**—This condition is due to defective development of the whole or part of the muscle of the diaphragm; the latter consists of a sheet of fibrous tissue covered with pleura and peritoneum. The thin, flaccid diaphragm is raised and immobile. Symptoms are uncommon and the condition is usually discovered on routine X-ray. It is important to distinguish eventration from true herniation.

(2) **Œsophageal Hiatus Hernia.**—This is the commonest of congenital abnormalities but may also occur as an acquired condition in the middle-aged or elderly. It is considered fully on p. 307.

(3) **Hernia through the Foramen of Morgagni.**—The defect lies between the sternal and costal attachments of the diaphragm; it is more common on the right side (fig. 1444).

(4) **Hernia through the Foramen of Bochdalek** (Pleuro-peritoneal Canal).—The canal may remain open with free communication between the abdominal and pleural cavities. The hernia in such instances has no sac and the abdominal organs move freely in the chest. More commonly the canal is covered by pleural or peritoneal membranes but muscle is absent, and in these cases the hernia has a sac.

(5) **Hernia through the Dome.**—These are usually left-sided and may occur anywhere in the diaphragm. They are commonest, however, at the junction of the muscular and tendinous portions.

(6) **Traumatic Diaphragmatic Hernia.**—The diaphragm may be torn directly by a missile (thoraco-abdominal wound) (fig. 1445) or ruptured by

FIG. 1444.—Colon occupying a Hiatus of Morgagni hernia. (*Dr. Oliver Smith.*)

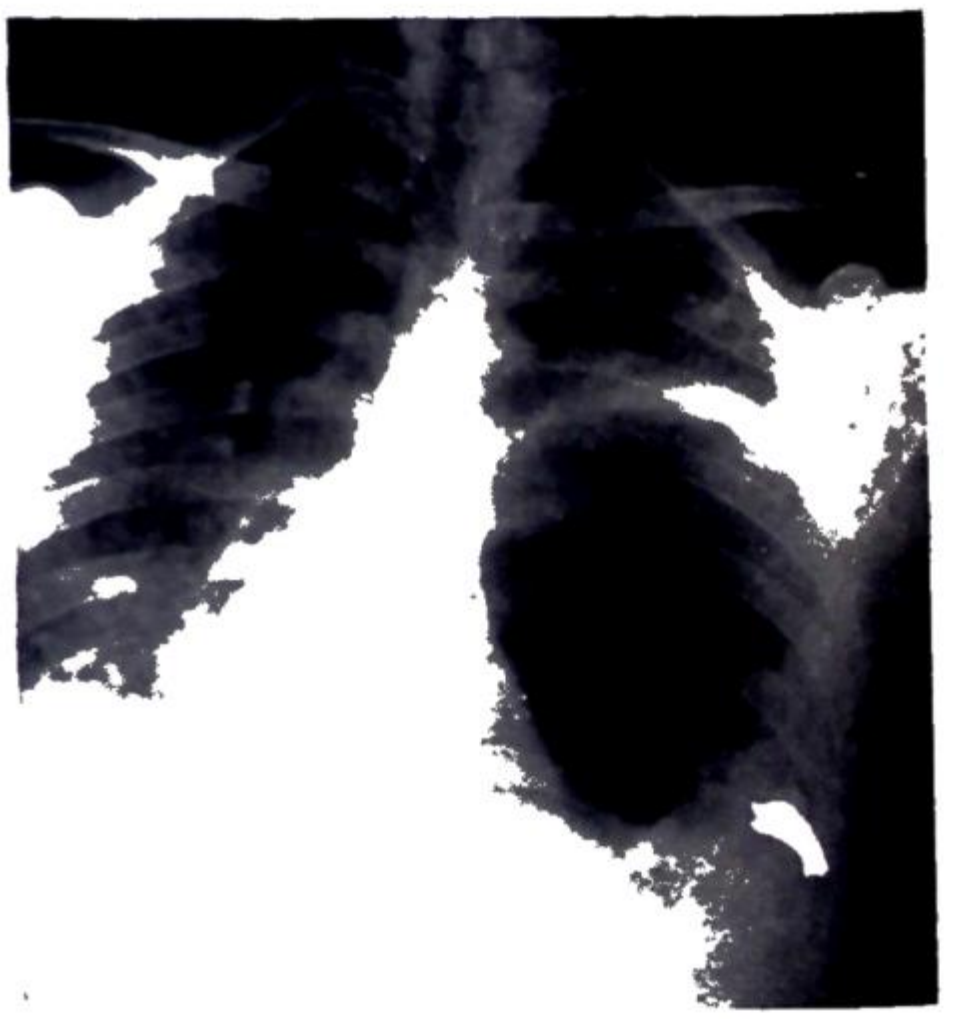


FIG. 1445.—A large traumatic diaphragmatic hernia due to penetrating thoraco-abdominal wound with a retained foreign body.

severe lower thoracic or abdominal compression (crush injury) without an external wound.

The defect may occur anywhere in the diaphragm in the former instance, but with crush injuries the dome is usually torn. Herniation may occur immediately or be delayed for some considerable time. A peritoneal sac is not present and adhesions between the lung and the herniated viscera always occur.

Dyspeptic and obstructive symptoms are common and strangulation occasionally occurs.

Repair of the hernia should always be undertaken.

(7) **Post-operative Diaphragmatic Hernia.**—Occasionally herniation follows oraco-abdominal operations, particularly those involving an intra- ophagogastric anastomosis. Herniation may occur around the

i B a Morgagni, 1682–1771. Professor of Surgery, Padua. He held the chair for fifty-six years.
t Al ander Bochdalek, 1801–1883. Anatomist at Prague.

new hiatus or through the sutured diaphragm. Great care should be taken in suturing the diaphragm to the stomach or jejunum in these cases, whilst the diaphragm is best closed with a reasonable overlap of the edges and with two rows of sutures.

Diagnosis may be extremely difficult as there are many other causes of vomiting, pain, etc., in the post-operative period. Radiography is often of little use as the suspected area is so often obscured by effusion, etc.

An early exploration is advisable if the condition is suspected.

MEDIASTINAL TUMOURS

The term ' tumour ' covers a wide variety of conditions which are often difficult to distinguish, but precise diagnosis is not of great practical importance as the majority of innocent ' tumours ' require removal, and those which are not amenable to surgery, e.g. secondary carcinoma, lymphosarcoma, lymphadenoma and reticulosis, are usually readily recognised. Innocent ' tumours ' should be removed owing to the risks of malignant degeneration or compression or involvement of the mediastinal structures. The most important feature in differential diagnosis is the position of the tumour in the mediastinum, and a useful practical classification is as follows :

(1) **Anterior Mediastinal Tumours**
Retrosternal goitre.
Thymic tumours and cysts.
Persistent or enlarged thymus.
Teratoma.
Pleuro-pericardial cyst.

(2) **Posterior Mediastinal Tumours**
Neurogenic tumours (neurofibroma, ganglioneuroma).
Foregut cysts (paratracheal, para-œsophageal cyst, gastric cyst of mediastinum).
Œsophageal hiatus hernia with thoracic stomach.

(3) **Tumours arising anywhere in the Mediastinum**
Lymphadenopathies (these are often multifocal and the lesions are characteristically lobulated). Secondary carcinoma, tuberculous adenitis, lymphadenoma, reticulosis, and sarcoids are the commonest varieties.
Lymphogenous cysts.
Lipoma.
Fibroma.

Diagnosis in the difficult lymphadenopathies can often be made by a scalene node biopsy or by diagnostic radiotherapy.

The majority of the solitary lesions demand operative removal if serious complications are to be avoided.

Retrosternal Goitre (see p. 234).—This produces an anterior mediastinal tumour, often of characteristic shape and distribution. It is frequently bilateral though usually larger on one side. The tumour has a broad base superiorly which merges and cannot be separated from the tissues of the neck on radiological examination. Calcification is not uncommon. This is one of the few tumours which compress the trachea.

Removal through a cervical incision is usually possible, and only occasionally is a sternal-splitting approach required.

Thymic Tumours (see p. 254).—Persistence or enlargement of an otherwise normal thymus is not infrequently discovered in young children on radiological examination. Only very occasionally is the thymic enlargement sufficient to produce mediastinal obstruction and stridor (thymic asthma). In such cases deep X-ray therapy should be tried, and if this does not cause a diminution in size, operative removal may be necessary.

A variety of tumours arising in the thymus have been recorded, e.g. lymphosarcoma, lymphadenoma, perithelioma and epithelioma. Of these, only the latter has been found associated with myasthenia gravis, and 10 per cent. of myasthenics are found to have tumours. The epitheliomata are slowly invasive malignant tumours; they are often calcified. Excision is often possible, but recurrence is likely. Relief of myasthenia in cases where this co-exists is less dramatic than in the non-tumour group. Pre-operative irradiation is recommended by Keynes. The tumours are removed through the sternal-splitting incision (Keynes).

FIG. 1446.—Teratoma of the mediastinum. The tumour lies anteriorly.

Teratoma.—The commonest 'inclusion' tumour is the teratoma; true dermoid cysts are only occasionally encountered. The tumours are almost always situated anteriorly with a pedicle attached deeply beneath the aortic arch (fig. 1446). They are often slightly lobulated and may project into either side of the chest. Irregular areas of calcification, bone or tooth formation are sometimes seen. Rapid increase in size without malignant change is sometimes associated with pregnancy. Occasionally a positive Aschheim-Zondek test is obtained in non-pregnant patients. Infection and malignant transformation are not uncommon complications. Removal is indicated in all cases and is best carried out through a wide lateral thoracotomy.

Mediastinal Cysts.—These are usually developmental in origin and may be associated with the trachea, bronchi, or œsophagus (foregut cyst), pericardium (pleuro-pericardial, spring-water cyst), or lymph nodes (lymphogenous cysts).

They are characteristically low-tension cysts and so may alter their shape with posture, respiration or after the induction of an artificial pneumothorax.

Foregut cysts are likely to become infected and may rupture into the œsophagus, lung or bronchus. Removal is desirable.

Neurogenic Tumours.—These have already been considered under chest-wall lesions (see p. 1092). They consist of neurofibromata arising from the intercostal nerves and ganglioneuromata from the sympathetic chain. They lie posteriorly in the costovertebral gutter. Occasionally they extend through the intervertebral foramen into the spinal canal (dumb-bell tumours). Malignant change may occur.

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CHAPTER XLIV

THE HEART AND PERICARDIUM

WILLIAM P. CLELAND

SPECIAL METHODS OF INVESTIGATION

MODERN cardiac surgery demands precise methods of investigation to provide accurate anatomical and physiological details of the various cardiac abnormalities. It is only when such information is available that an accurate diagnosis can be made and surgical treatment planned. The most important available methods are :

(1) **Radiology,** including standard techniques, kymography and fluoroscopy. Such examinations provide details of the cardiac contour and

FIG. 1447.—Normal angiocardiogram showing the right side of the heart and pulmonary arteries.

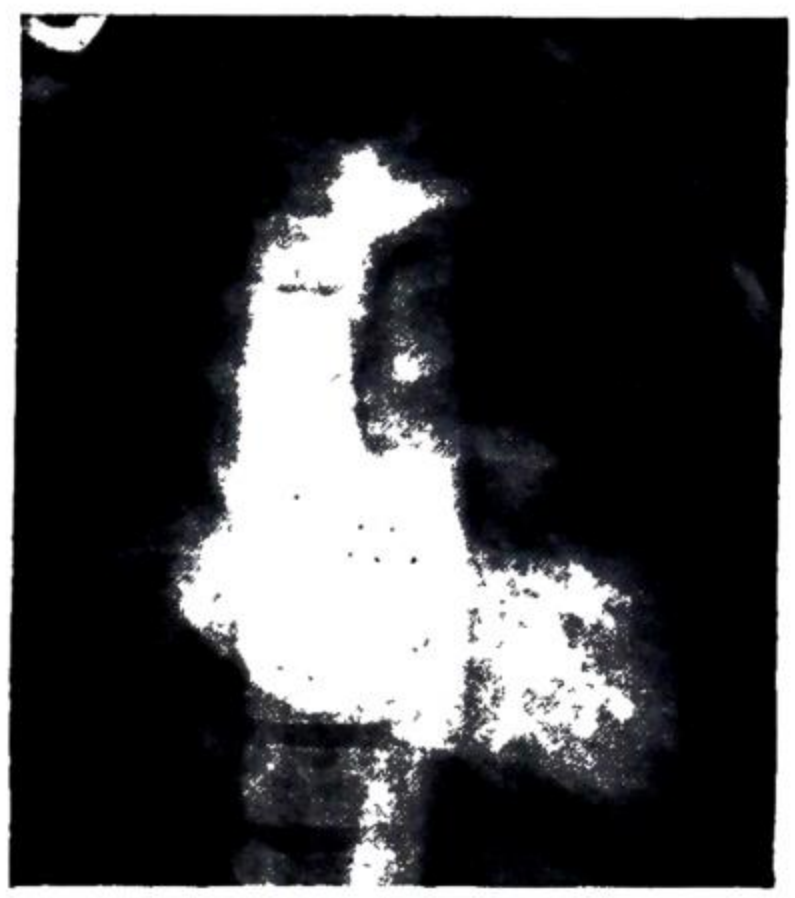

FIG. 1448.—Normal angiocardiogram showing the left side of the heart and aorta.

variations in size of the chambers ; it also provides information about the pulmonary circulation.

(2) **Angiocardiography** (figs. 1147 and 1448).—By the injection of 70 per cent. diodone the chambers of the heart and great vessels can be outlined and films taken at frequent intervals during the passage of the opaque material through the heart. Important anatomical information concerning the size of the heart chambers, the presence of a right to left shunt, and of valvular stenoses may be provided. The aorta and pulmonary arteries and their branches will also be outlined. Recent progress with ciné angiocardiography holds promise of providing more information about the dynamics of the cardiac circulation than is obtained by the routine methods.

(3) **Cardiac Catheterisation.**—A fine catheter is introduced through

a vein into the heart where its passage can be followed by fluoroscopy and blood samples and pressure tracings recorded. This investigation supplies functional as well as anatomical data (fig. 1449).

CARDIAC ARREST

Cardiac arrest may occur in any hospital department. It is more commonly associated with major surgical procedures especially those performed for cardiac conditions, but minor operations and diagnostic procedures are not immune. If lives are to be saved, it is essential that the mechanism of production and the methods of correction of cardiac arrest should be clearly understood. Not only should vulnerable departments be supplied with the necessary basic instruments (sterilised) for opening the chest but the medical personnel should clearly understand how to perform cardiac massage.

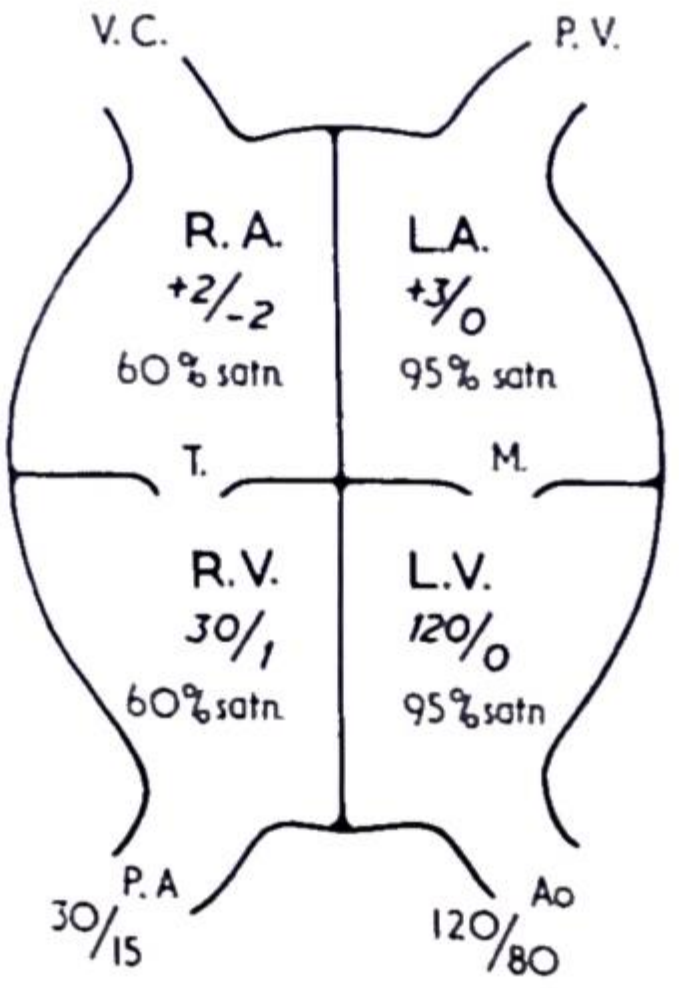

FIG. 1449.—Normal intracardiac pressures and oxygen saturations.

Causes of Cardiac Arrest.—The following are the factors usually responsible for cardiac arrest :

(1) **Anoxia.**—Myocardial anoxia is probably the most frequent and important precipitating cause of arrest. It can be produced by a variety of means, such as respiratory obstruction, serious hæmorrhage, a sudden severe fall in blood pressure or coronary air embolism. Hæmorrhage from the heart is always more serious than that from the peripheral circulation owing to a marked decrease of cardiac output and rapid fall in blood pressure. Most cardiac manipulations produce a temporary fall in blood pressure, but if they are repeated or prolonged, severe and irreversible changes may develop.

(2) **The State of the Myocardium.**—A healthy myocardium will stand moderate manipulation and anoxia without ill effect, but a diseased myocardium has less reserve, and relatively minor disturbances may cause failure.

(3) **Toxic and Irritating Drugs.**—Certain drugs have a direct depressing or irritating action on the myocardium whilst others affect it indirectly through the circulation. In the latter group, the vasodilators are the most important ; these include many anæsthetic agents, procaine, etc. Chloroform, cyclopropane and adrenaline may produce cardiac irregularities, whilst marked excess of potassium may lead to cardiac arrest.

Types of Cardiac Arrest.—Sudden acute cardiac failure may be produced by :

(1) **Circulatory Obstruction.**—By a massive pulmonary embolism, air embolism, or accidental occlusion of one of the main vessels.

(2) **Asystole.**—This is usually due to severe myocardial depression. The heart beat becomes slow and feeble and finally stops. The myocardium is flabby, dilated, and cyanosed. Later ventricular fibrillation may appear.

(3) **Ventricular Fibrillation** occurring without preceding asystole is usually associated with an irritable heart as a result of manipulation, trauma or drugs. In such cases, the myocardium is less depressed and more likely to recover than in the former group.

Management of Cardiac Arrest.—Speedy recognition is essential if the circulation is to be restored before irreversible damage has been done to

the brain. Diagnosis is easy if the heart is exposed or an electrocardiographic record is being taken. Disappearance of the pulse is the most important sign. If the carotid pulse cannot be felt by the anæsthetist, cardiac arrest must be assumed and appropriate action taken. Time should not be wasted on preliminaries but cardiac massage should be started without delay. If the circulation can be restored within five minutes of cessation, recovery is possible, but it is unlikely after an interval of ten minutes.

A clear-cut plan of campaign along the following lines is advisable if disasters are to be avoided.

Cardiac Massage.—Cardiac massage requires no special skill. Every doctor should know how to carry it out. It will maintain a forward flow of blood sufficient to supply the vital centres with oxygen until a normal beat returns. It is most efficiently performed through the chest. Time should not be wasted on aseptic precautions such as gloves or skin sterilisation. (Transdiaphragmatic massage through an upper abdominal incision is not as effective as transthoracic massage, but can be employed temporarily to maintain the circulation.) The chest should be opened through the fifth intercostal space on the left side by an intercostal incision extending from the sternum to the axilla. The wound does not bleed as there is no circulation. The only instrument required to permit bi-manual massage is a rib-spreader, but should this not be immediately available massage is quite possible with one hand. Massage is most efficient with two hands with the pericardium widely opened. One hand should be placed above and the other below the ventricular mass, and massage should be carried out with the flat of the hand and fingers rather than with the finger-tips. The rate should be about 30 to 50 times per minute, though this is guided by the need for sufficient pause to permit diastolic filling. Massage should always be carried out gently as considerable damage to the myocardium is possible if excessive force is used. The object of cardiac massage is to improve the tone of the myocardium, to increase the coronary flow, and ensure a supply of oxygenated blood to the nervous centres. The arrested heart is distended, flaccid, and cyanosed, but after massage it should become smaller, firmer, and pinker. When tone has returned, attempts should be made to obtain normal beating.

Elevation of Aortic Pressure.—Further improvement of the coronary and cerebral circulation can be obtained by placing a non-crushing clamp (sponge-holding forceps) across the aorta beyond the left subclavian artery.

Pulmonary Ventilation.—It is essential that adequate ventilation of the lungs be maintained throughout to ensure that the blood which is circulating through them is adequately oxygenated.

Reduction of Irritability.—Procaine (50 to 100 mg.) or pronestyl (procaine amide) (100 to 200 mg.) should be administered intravenously in all fibrillating cases. This may produce a normal rhythm or arrest ; the latter may be succeeded by a normal beat after massage.

Increase of Myocardial Tone.—Calcium chloride in doses of 5 to 10 ml. of a 10 per cent. solution should be injected in cases where myocardial tone does not return with massage.

Electric Shock.—Electric defibrillation is indicated where fibrillation persists after cardiac massage has resulted in the return of myocardial tone. It should not be employed on the toneless, flaccid heart, nor until cardiac massage has been carried out for some time. The shock produces cardiac arrest, and in a proportion of cases this is followed by a normal rhythm.

Adrenaline.—An intracardiac injection of 5 to 10 ml. of 1 : 10,000 solution should be made into the right ventricle where cardiac arrest persists in spite of massage and adequate myocardial tone. This frequently results in the establishment of a normal rhythm, though occasionally it produces ventricular fibrillation. It is also of value when fibrillation remains feeble and the heart toneless in spite of massage ; the coarse fibrillation and better tone which it produces improves the chances of conversion to a normal rhythm by electrical means.

To summarise the Procedures in Cardiac Arrest

(1) Provision of an adequate pulmonary ventilation.

(2) Immediate cardiac massage to maintain the circulation.

(3) Re-establishment of myocardial tone by massage, calcium chloride and aortic clamping.

(4) Reduction of irritability by intravenous procaine or pronestyl.

(5) The use of the electric defibrillator if other methods are not effective.

(6) The intracardiac injection of adrenaline to restore a normal rhythm if other methods have failed.

THE SCOPE OF CARDIAC SURGERY

Operative treatment of cardiac abnormalities is advancing steadily particularly with the advent of new techniques for controlling the circulation. The procedures can be, for practical purposes, placed in one of three groups:

(1) **Extracardiac Operations.**—These are carried out on the main vessels outside the heart or on the pericardium. The ventricles or atria are not directly interfered with so that cardiac function is not unduly disturbed. Examples include ligation of a patent ductus, excision of coarctation, systemic pulmonary anastomoses, resection of aneurysms, pericardectomy and operations for ischæmic heart disease.

(2) **Closed Intracardiac Operations.**—These are blind intracardiac procedures performed by instrument or finger and controlled by touch. Access is obtained to the interior of the heart through either the ventricular or atrial walls or through the base of one of the great vessels. Cardiac action is interfered with to some extent so that irregularity of heart action is liable to be encountered. These operations are mainly designed for the relief of stenosis of the pulmonary, mitral or aortic valves.

(3) **Open Cardiac Operations.**—The desire of every surgeon is to operate with safety under direct vision on the open and motionless heart. The following procedures have come near to achieving this goal :

(*a*) *Hypothermia.*—By cooling the body to 29–30° C. the basic oxygen requirements of vital organs is so reduced that they can withstand periods of up to ten minutes of complete circulatory arrest without suffering irreparable damage. This time is sufficient to enable the surgeon to correct straightforward conditions such as atrial septal defects and pulmonary or aortic valve stenosis.

The desired temperature is obtained either by cooling the whole body (surface cooling) by immersion in cold water or by cooled blankets ; alternatively the blood alone can be cooled (veno-venous cooling) by cannulation of both venæ cavæ, removing blood from the superior cava, passing it through a cooling chamber and returning it to the inferior cava.

(*b*) *Extra-corporeal Circulation.*—Several clinically proven heart-lung machines are now in regular use. Basically each consists of a pump and an oxygenator. Blood is withdrawn from the venæ cavæ, passed through the oxygenator and returned into the arterial circulation through a subclavian or a femoral artery. The blood is thus diverted completely from the heart

and lungs but a good supply of well oxygenated blood is made available to the vital organs. These machines provide the surgeon with longer periods for intracardiac surgery than is available with hypothermia. By the use of an extra-corporeal circulation more complicated cardiac anomalies can be corrected and such conditions as ventricular septal defects, Fallot's tetralogy and valvular incompetence are being so treated.

(*c*) *Elective Cardiac Arrest*.—The injection of potassium citrate into the coronary vessels produces cardiac arrest which persists only as long as the drug remains in the coronary vessels. Its use in conjunction with a heart-lung machine provides the surgeon with a motionless heart which enables him to carry out surgical procedures more accurately and quickly.

THE PERICARDIUM

Aspiration of the Pericardium.—The pericardium should be explored with a short-bevelled needle introduced alongside the xiphoid process in an upward and backward direction with the needle at an angle of 45 degrees to the skin. This site has the following advantages :

(*a*) It does not transgress the pleura.

(*b*) It is more likely to encounter fluid which frequently gravitates between the diaphragm and the heart.

(*c*) It is less likely to damage the coronary vessels.

Cardiac Tamponade.—A rapid accumulation of fluid in the pericardial sac will compress the heart and prevent diastolic filling ; this results in an increase of the venous pressure and a reduction of the cardiac output. Occurring rapidly (e.g. after injuries or cardiac surgery), it produces a shock-like state and if not relieved may prove fatal. The cardiac dullness and silhouette are enlarged and the heart sounds weak ; the pulse may be paradoxical (weaker on inspiration). Immediate relief can be obtained by aspiration but, if symptoms recur, pericardial exploration will be required.

Acute Pericarditis.—Purulent pericarditis is now a rare complication of septicæmia, pyæmia, pneumonia or empyema. Signs and symptoms may be vague, consisting of fever, tachycardia or retrosternal pain. A friction rub may be heard and felt. X-rays may show a large pear-shaped cardiac outline, whilst the electrocardiograph shows a characteristic elevation of the S-T segment. The pericardium should be aspirated and suitable antibiotics injected. Drainage of the pericardium is required if aspirations prove ineffective in controlling the infection.

Chronic Pericarditis (Constrictive Pericarditis ; Pick's Disease).—In this condition there is marked thickening, fibrosis and calcification of the pericardium which confines the heart in a rigid inelastic casing preventing it from filling in diastole and emptying in systole. The majority of cases are a sequel to a tuberculous pericarditis, but occasional cases follow purulent pericarditis or a traumatic hæmopericardium.

Hæmodynamics.—Decreased diastolic filling leads to an accumulation of blood on the venous side. The jugular veins are engorged, pleural effusions may

Friedel Pick, 1867–1926. Professor of Laryngology, Prague.

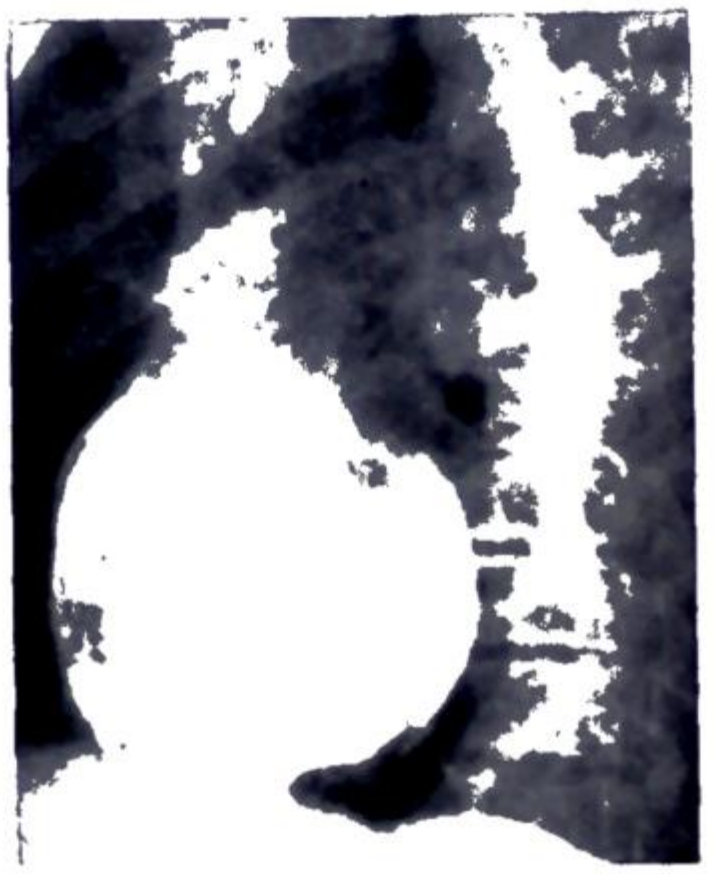

FIG. 1450.—A calcified pericardium.

occur, the liver is enlarged, and ascites and œdema of the ankles may appear. On the arterial side, the blood pressure is low with a small pulse volume due to a reduced cardiac output. Fluoroscopy shows decreased or absent cardiac pulsation and pericardial calcification is commonly seen (fig. 1450).

Treatment.—Surgical removal of the constricting pericardium is the only effective treatment; this will allow the heart to fill and empty normally.

The patient should be prepared by salt and water restriction, diuretics, acupuncture, Southey's tubes and aspiration of pleural or ascitic fluid. At operation (pericardectomy) it is essential to remove the thickened pericardium from the ventricles, but thickened or calcified plaques covering the atria or venæ cavæ should also be removed (Holman).

CONGENITAL HEART DISEASE

Congenital anomalies account for about 2 per cent of all cases of organic heart disease. Many are severe and complicated so that survival beyond a few weeks or months is unlikely. Of those who do survive infancy, the expectation of life is often markedly reduced so that surgical correction is desirable wherever possible.

The lesions are divided into those associated with a normal arterial oxygen saturation (acyanotic group) and those with reduced saturation (cyanotic group).

Acyanotic Congenital Heart Disease

I. PATENT DUCTUS ARTERIOSUS

This is one of the commonest abnormalities, accounting for 15 per cent. of all types. It may occur as an isolated condition (simple patent ductus) or as part of a more complex abnormality (complicated patent ductus). The mechanism of normal closure of the ductus and the causes of patency are not fully understood.

Hæmodynamics—The ductus connects the left pulmonary artery with the aorta just distal to the origin of the left subclavian artery. As the pressure is higher in the aorta than in the pulmonary artery, blood will flow from the former into the latter vessel. As much as 10 to 20 litres of blood per minute, representing two to four times the normal cardiac output, can flow through a patent ductus. On the systemic side, the systolic blood pressure rises and the diastolic pressure falls, producing a water-hammer or collapsing pulse. The amount of blood in the lungs is markedly increased and the pulmonary vessels are dilated (pulmonary plethora) (figs. 1451 and 1452) and their pulsation increased (hilar dance). The additional circulation of blood through the lungs and the left side of the heart results in left ventricular hypertrophy.

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Reginald Southey, 1835–1899. St. Bartholomew's Hospital, London.

FIGS. 1451 and 1452.—Patent ductus arteriosus—before and after ligation, showing a marked reduction in heart size and pulmonary congestion.

Clinical Features.—Many cases are discovered on routine examination in childhood. Soon after birth, when the pressures in the pulmonary and systemic circuits are nearly equal, only a systolic murmur is audible and diagnosis is difficult. As the child grows, the difference between pressures increases and the typical continuous machinery murmur develops ; this is best heard in the second and third spaces to the left of the sternum. Breathlessness on exertion and retardation of growth may be present in childhood, but symptoms are often absent until complications ensue. Fluoroscopy shows enlargement of the left ventricle with markedly enlarged pulsatile pulmonary arteries. The diagnosis is usually obvious from the presence of the continuous murmur, an increased pulse pressure with a water-hammer pulse, and the X-ray findings. Atypical cases should be investigated by cardiac catheterisation.

Complications.—(1) *Cardiac Failure.*—This is the most important complication and probably accounts for one-third of the deaths. Failure is preceded by progressive cardiac enlargement.

(2) *Bacterial Endocarditis.*—Before the advent of antibiotics this was a frequent and fatal complication accounting for one-third of all deaths. Chemotherapy now permits control of the majority, but relapse is likely unless the ductus is ligated.

Prognosis.—The outlook for a simple patent ductus is difficult to determine. The disease is common in children and rare in adults. It is unlikely that a patent ductus ever closes spontaneously, and it must be assumed that some patients die from cardiac failure in early adult life.

Treatment.—The results of surgical closure are so satisfactory and the mortality rate is at such a level (2 to 3 per cent.) that ligation can be recommended in all cases. Recanalisation is rare. Division and suture is practised by Gross and others in order to reduce the risks of recanalisation, but is probably only necessary for the short wide ductus which cannot be safely ligated.

The operation is carried out through a left-sided postero-lateral incision through the fourth space. The mediastinal pleura is incised over the aortic arch and the

Robert Edward Gross, Contemporary. Surgeon, Children's Hospital, Boston.

vagus nerve and its recurrent branch are retracted posteriorly. The areolar tissue is removed from the surface of the ductus and the latter gently mobilised by blunt dissection. Occlusion is achieved by using two stout non-absorbable ligatures placed at either end of the ductus with a transfixion ligature between (Blalock).

II. COARCTATION OF AORTA

Narrowing of the aorta may occur at any site, but, in the vast majority of cases, the stenosis lies immediately beyond the origin of the left subclavian artery in close relationship to the ligamentum arteriosum.

Two main types are described :

(1) **Infantile Coarctation.**—In these cases the ductus remains patent and enters the aorta below the stenosis. The pressure in the distal aorta is low so that venous blood passes from the pulmonary artery into the thoracic aorta, resulting in cyanosis of the lower half of the body, whilst the upper half remains pink. Other cardiac abnormalities are frequent. It is compatible with only a few months of life, hence the term ' infantile coarctation.'

(2) **Adult Coarctation.**—In these cases the ductus is obliterated, or if patent opens into the aorta above the stenosis. The stenosis may be complete or, more commonly, an orifice of 1 to 2 mm. persists. The external appearances are characteristic, being beak-shaped or purse-string in appearance (fig. 1455). More rarely a longer hypoplastic segment occurs.

Clinical Features.—The obstruction results in hypertension above and hypotension below the constriction with collateral vessels linking the two areas. Symptoms can be divided into three groups :

(1) Those of hypertension above the block; headaches, irritability, excessive heart action, throbbing and pulsation in head and neck.

(2) Those due to hypotension below the block; cold legs and intermittent claudication.

(3) Complications secondary to hypertension; left ventricular failure, intracranial hæmorrhage, rupture of the aorta.

Characteristically there is marked pulsation of the carotid and subclavian arteries with evidence of a left ventricular enlargement. Systolic murmurs are frequently audible over the præcordium and elsewhere over the thorax, due usually to the collateral vessels, although sometimes caused by associated aortic valve disease. Blood pressure in the arms is considerably elevated. Collateral vessels can be seen and felt over the thorax, particularly in the scapular region. Femoral, dorsalis pedis and posterior tibial pulses may be absent or weak. The femoral pulse, if present, is delayed when compared with the radial. Oscillometry reveals defective pulsation in the lower limbs. X-rays show evidence of left ventricular enlargement, a prominent ascending aorta and an absent or abnormal aortic knuckle (fig. 1453). Notching of the ribs due to large tortuous intercostal vessels is seen in adults but rarely in children.

Investigations.—Venous angiocardiography or retrograde aortography (fig. 1454) are employed to demonstrate the actual site and type of the coarctation, but these investigations are by no means essential pre-operatively if an aortic graft is available at the time of operation.

Prognosis.—The condition is a serious one and it is estimated that very

Alfred Blalock, Contemporary. Professor of Surgery, Johns Hopkins University, Baltimore; Surgeon-in-Chief Johns Hopkins Hospital, and Honorary Associate Consulting Surgeon, Guy's Hospital, London.

few patients survive beyond the age of forty-five years; the majority die from the effects of hypertension.

Treatment.—Both Crafoord and Gross independently in 1945 demonstrated that the stenosis could be excised and an end-to-end anastomosis

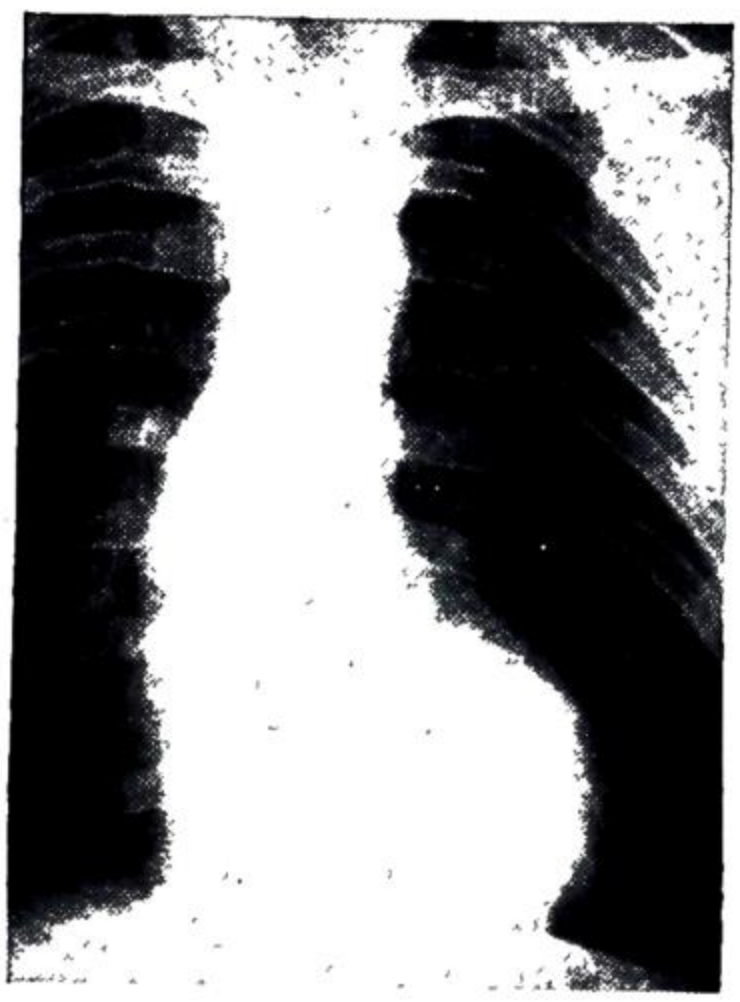

FIG. 1453.—Coarctation of aorta showing a prominent ascending aorta, double aortic knuckle and rib notching.

FIG. 1454.—Coarctation of aorta. Aortogram showing the stenosis and the marked collateral vessels.

safely performed. The operation is now a well-accepted one and the mortality should not be above 10 per cent. In the majority, excision with an end-to-end anastomosis is possible. Occasionally a graft is required to bridge a wide defect in cases with a long hypoplastic segment or with a post-stenotic aneurysm. The most satisfactory material has been freeze-dried aortic homografts, but grafts prepared from poly-vinyl alcohol sponge (Ivalon) or Terylene cloth are satisfactory substitutes (Rob). All children and young adults should be operated upon. The results in children are excellent with the blood pressure usually returning to normal. In adults the blood pressure rarely falls to normal levels but the reduction is nevertheless important; symptoms are relieved and the risks of serious or fatal complications reduced.

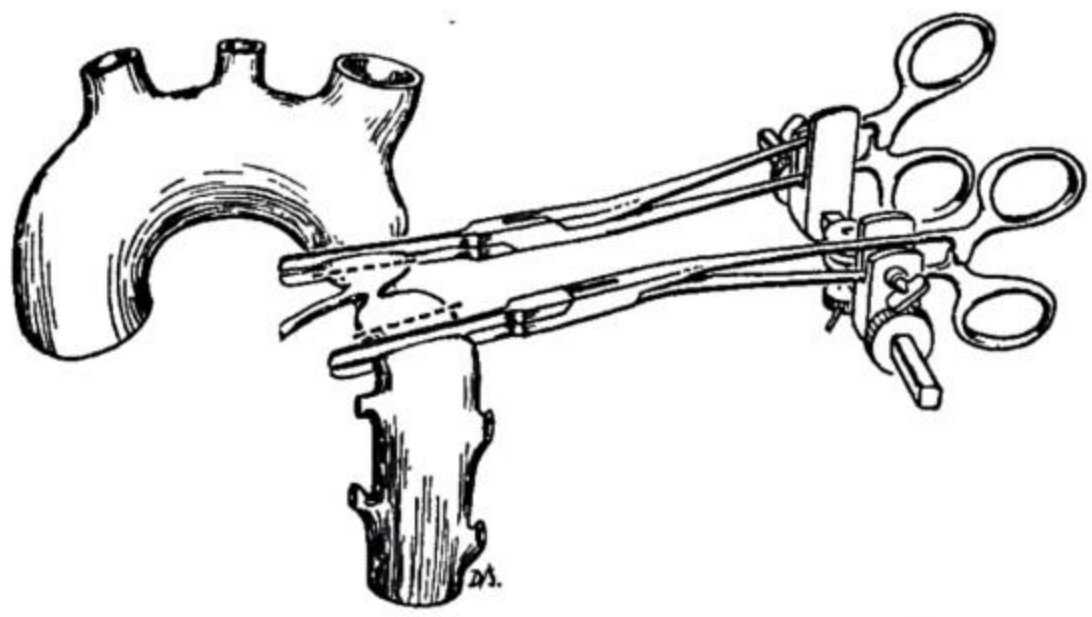

FIG. 1455.—Coarctation of aorta. The mobilised aorta is clamped prior to excision and anastomosis.

The operation is carried out through a left postero-lateral incision through the fourth intercostal space. The large anastomotic vessels in the chest wall are ligated. The aorta is mobilised widely both above and below the constriction, great care being taken not to injure the large thin-walled intercostal and mediastinal vessels arising from the distal segment. The ligamentum arteriosum is divided: the aorta is clamped above and below the constriction and the latter excised (fig. 1455). An

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Charles Rob, Contemporary. Professor of Surgery, St. Mary's Hospital, London.

(Potts) is applied to the former. This allows a flow of blood through the aorta whilst excluding a small portion of its wall for anastomosis to the pulmonary artery. The opening in the aorta and pulmonary artery should not exceed 4 mm., as too large an orifice will flood the lungs with blood and produce heart failure.

(3) **Pulmonary Valvotomy.**—This operation was developed and perfected by Brock and has already been described for the valvular type of pulmonary stenosis. A certain percentage of cases have an infundibular stenosis instead of, or in addition to, a valvular stenosis. The infundibular narrowing occurs as a muscular ridge on the ventricular side of the valve and is not suitable for incision and dilatation. In these cases the obstruction is relieved by a specially designed punch forceps (infundibular resection). One advantage of the direct operations is that one of the abnormalities present in these cases has been relieved, whereas with both the Blalock and the Potts' operation an additional abnormality has been created. The mortality rate and the results are comparable with the operations of Blalock and Potts.

(4) **Pleurectomy.**—Occasionally cases are encountered which are unsuitable for any of the above methods of treatment. Such cases are those where the pulmonary arteries are hypoplastic or absent, where the pulmonary circulation is carried on through the bronchial vessels. In these and similar cases some improvement in the pulmonary blood flow can be obtained if the parietal pleura is completely excised and the lung encouraged to adhere to the chest wall. Blood-vessels enter the lung through the adherent zone and may carry a considerable quantity of blood for oxygenation.

(5) Complete correction of the abnormality is now possible with the aid of an extra-corporeal circulation. The mortality rate is at present too high for general use and the operation can only be carried out in specially equipped units.

Clinical Features.—The appearance of the 'blue baby' is characteristic. They are poorly developed with marked cyanosis, gross finger clubbing and hypertrophy of the gums. Attacks of bronchitis and upper respiratory infection are common. All grades of severity are, however, encountered, and in some instances exercise tolerance is quite good and cyanosis is not particularly marked except after exertion or in cold weather. More commonly these children are markedly incapacitated; their mental and physical development is poor and they are often incapable of even the slightest exertion. It is essential in all cases to obtain the expert view of a cardiologist, and to carry out a full and complete series of investigations as already outlined.

Indications and Requirements for Operation.—The following points are important when considering operation:

(1) The presence of symptoms severe enough to justify the performance of a major operation. In this connection it is important to emphasise that the extra demands made on the heart and circulation during and after adolescence are often sufficient to precipitate cardiac failure; such changes should be anticipated and preceded by surgical treatment if practicable.

(2) The demonstration of a defective pulmonary circulation, particularly by fluoroscopy, angiocardiography and possibly by cardiac catheterisation.

(3) The demonstration of a pulmonary artery. This is sometimes difficult and negative information is not reliable.

(4) The demonstration of a subclavian artery and the position of the aortic arch.

(5) The determination of the type and degree of the pulmonary stenosis.

Results of Surgical Treatment.—The results of any of the methods of treatment already described in Fallot's tetralogy are very gratifying. The mortality rate is below 10 per cent., and 75 per cent. of the survivors give good or excellent results. With the more complicated abnormalities, however, the risks of operation are higher and the results not so striking, but the

poor prognosis without surgery completely justifies submitting these patients to operation.

ACQUIRED HEART DISEASE

Inflammatory and degenerative changes are responsible for the majority of the acquired lesions of surgical interest although cardiac injuries and tumours represent a small but important group. The inflammatory lesion (rheumatism, syphilis) mainly attack the valve whilst degenerative lesions involve either the aortic valve or the coronary vessels and myocardium.

Mitral Stenosis

Narrowing of the mitral valve is by far the commonest result of rheumatic carditis. The condition affects women more frequently than men, and symptoms are commonest during the third and fourth decades, although the original infection is usually in childhood.

Pathology.—The cardiac manifestations of rheumatism are widespread with involvement of all three layers but it is mainly the mitral and aortic valve involvement which leads to later disturbances. The essential lesion is the Aschoff nodule. These produce swelling and roughening of the valve cusps and fibrin is deposited on the roughened surfaces. Later organisation with fibrosis and calcification may occur. As a result the valve leaflets become fused, thickened, rigid and immobile. All grades are encountered from simple fusion of the commissures and mild fibrosis (but with preservation of mobility) to grossly calcified, fixed and functionless valves. The valve orifice is oval or slit-like with an average opening of 1 cm. in its long axis.

Clinical Features.—These can be briefly considered here under four headings :

(1) Those due to a low cardiac output : tiredness, shortness of breath on exertion, a small volume pulse and pale, cold extremities.

(2) Those due to disturbances of the pulmonary circulation : exertional dyspnœa, pulmonary œdema, nocturnal dyspnœa or asthma, hæmoptysis and bronchitis.

(3) Those due to failure of the right ventricle : congestive heart failure with engorged veins, large liver, ascites and œdema.

(4) Systemic embolism from clot dislodged from the left atrial appendage.

In all cases a full cardiological examination and investigation are required, not only to confirm the diagnosis but to determine the presence or absence of other cardiological abnormalities (figs. 1459 and 1460).

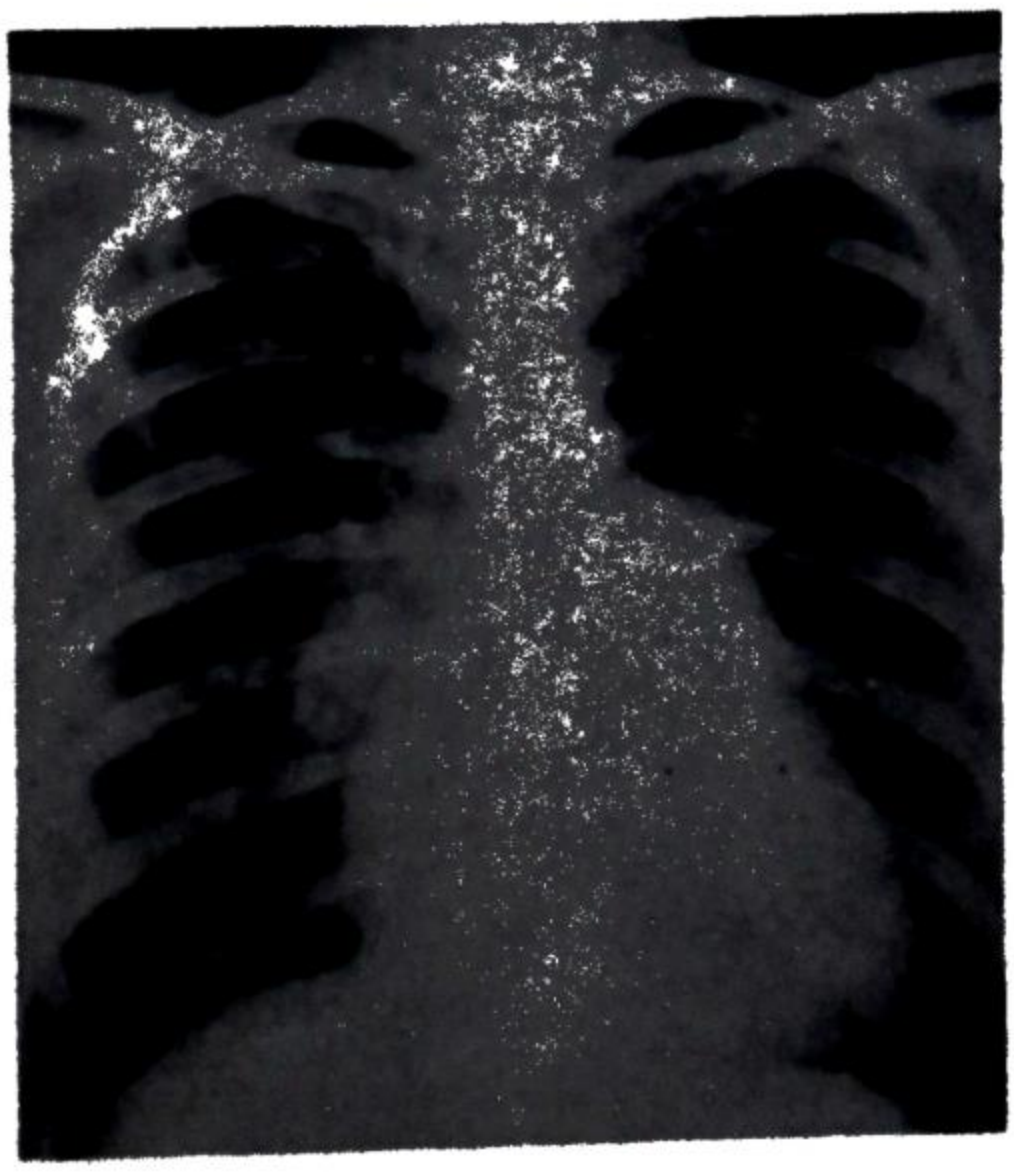

FIG. 1459.—Mitral stenosis showing enlargement of the 'pulmonary bay' and the pulmonary arteries.

Indications for Operation.—Every case of mitral stenosis with

Ludwig Aschoff, 1866–1942. Professor of Pathology, Freiburg.

symptoms which are beginning to cause inconvenience should be carefully considered from the point of view of operation.

The following factors will influence surgical treatment :

(1) **Active Carditis.**—Any suggestion of active rheumatic carditis constitutes an absolute, but perhaps temporary, contraindication to surgical treatment. Such evidence as fever, a raised E.S.R., unexplained tachycardia, unexplained recent cardiac enlargement, and a recent history of respiratory infection and joint pains all call for a postponement of operation.

(2) **Age.**—The ideal age for operation lies between twenty and fifty ; below twenty the chances of further rheumatic activity are appreciable, and surgery should be delayed if practicable, but should never be withheld in severe cases. Over the age of fifty it is important to exclude ischæmic changes in the myocardium, hypertension and renal abnormalities before recommending surgical treatment.

(3) **Other Valvular Abnormalities.**—Aortic stenosis, aortic incompetence, mitral incompetence and tricuspid lesions may all be associated with mitral stenosis.

FIG. 1460.—Mitral stenosis. The enlarged left auricle causes an indentation of the œsophagus.

FIG. 1461.—Mitral stenosis. Valvular calcification seen on tomography.

Diagnosis in these multiple cases is sometimes difficult and determination of the significance of co-existing valve disease is even more difficult. Where mitral stenosis is the dominant lesion, mitral valvotomy should be carried out, but if other valvular lesions are playing a significant part in the dynamics and symptomatology, mitral valvotomy should be deferred.

(4) **Mobility of the Mitral Valve.**—Best results are obtained when the mitral valve retains some mobility, where after valvotomy, reasonable restoration of function can be expected. A mobile valve is suggested by the presence of a tapping apex beat, marked accentuation of the first sound at the apex, and the presence of an opening snap. Rigidity is suggested by a poor first sound, the absence of an opening snap and calcification of the mitral valve (fig. 1461).

(5) **Auricular Fibrillation.**—The operative risks are slightly higher, and the post-operative results slightly inferior in cases with auricular fibrillation. This is probably merely an indication of more severe myocardial damage in these cases.

(6) **Embolism.**—The majority of emboli are associated with auricular fibrillation ; they constitute a severe complication and account for a significant number of deaths in the medical series. Cerebral, aortic bifurcation and femoral emboli are both frequent and serious. Multiple emboli are common and the chances of further emboli increase steeply with each incident. In the majority of instances the clots are

washed out of the left atrial appendage. Valvotomy is urgently indicated to relieve stagnation in the left atrium with the removal of the appendage at the same time.

(7) **Pregnancy.**—Mitral valvotomy should always be considered in cases where symptoms of mitral stenosis are aggravated by pregnancy. Mild cases can usually be nursed through pregnancy without difficulty, though there are risks of pulmonary œdema and serious pulmonary hæmorrhage even in these cases. More severe cases within the first three months of pregnancy can be treated by abortion or valvotomy, but after three months mitral valvotomy is preferable to termination of the pregnancy. After the seventh month of pregnancy, the chances of continuing to term are reasonable with rest, etc., and mitral valvotomy can be deferred until after delivery. Sterilisation should never be considered until the possibility of relief by valvotomy has been fully explored.

(8) **Size of Heart.**—The size of the heart, and particularly the size of the right ventricle, indicates the degree of strain thrown upon the heart and also the state of the myocardium. Operative risks in patients with large hearts are considerable, and even should a successful valvotomy be performed, subsequent improvement may be disappointing unless the myocardium is capable of considerable improvement.

(9) **Congestive Heart Failure.**—Persistent congestive heart failure is an indication that the heart has broken down completely and is unlikely to improve if a valvotomy is performed. The operative risks are high in this group.

Treatment.—Careful pre-operative preparation, with a period of rest, fluid and salt restriction, diuretics and breathing exercises is necessary. All cases should be digitalised as there is a 30 per cent. risk of auricular fibrillation developing in the post-operative period in cases in normal rhythm. Bronchopulmonary infections should be relieved by antibiotics.

The operation is performed through an antero-lateral or lateral thoracotomy through the fifth intercostal space. The pericardium is opened widely by an incision parallel with the phrenic nerve. If there is clot in the appendage or atrium, the great vessels arising from the aortic arch should be isolated so that they can be temporarily occluded during intracardiac manipulations to reduce the risks of a cerebral embolus. The appendage can be controlled with an auricular clamp or with a purse-string suture placed around its base controlled by a special tourniquet (Rumel). The index finger enters the atrium through an incision in the appendage. An attempt should be made to split both commissures fully with the production of an orifice of 3 or more centimetres.

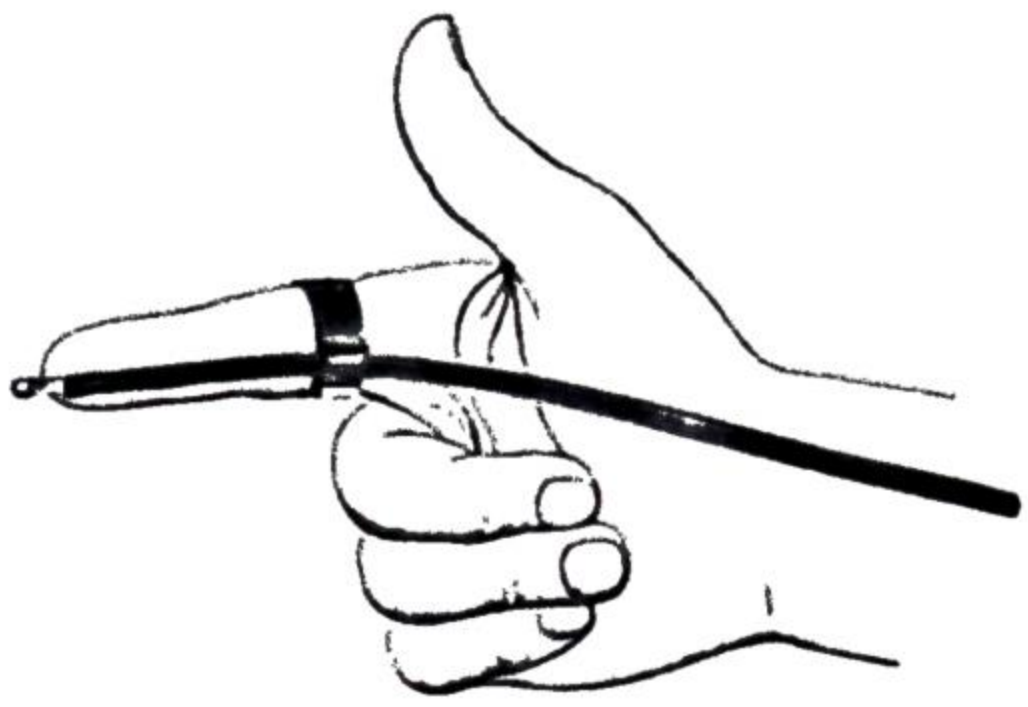

FIG. 1462.—Mitral valvotomy knife (Brock).

In approximately 25 per cent. of cases digital splitting is not possible; in such cases the edge of the commissure must be incised, after which digital splitting is usually possible. There are a variety of instruments available for this purpose (fig. 1189). Alternatively the valve can be split by a mechanical expanding dilator inserted through the ventricle. The right index finger remains in the atrium to guide and control the dilator. The appendage is amputated at the completion of the operation, the pericardium loosely closed and the chest drained.

All intracardiac manipulations should be carried out gently and carefully with adequate pauses between stages to allow the heart to recuperate.

In the post-operative period the most troublesome complications are :

(1) Systemic embolism.
(2) Suppurative bronchitis.
(3) Cardiac failure.
(4) Pulmonary embolism.

William R. Rumel, Contemporary. Surgeon, University of Utah College of Medicine.

All peripheral vessels should be palpated at the end of operation to exclude embolism. Occlusion of one of the major vessels should be treated by immediate embolectomy ; involvement of smaller vessels should be treated by antispasmodics (papaverine, Priscol) and by keeping the affected part locally cool and producing reflex vasodilatation by warming the rest of the body. The majority of emboli occur at the time of operation ; late embolism is uncommon.

Active breathing and coughing exercises are started early and full mobility in bed is encouraged. Bronchitis should be treated vigorously with postural coughing and antibiotics. A close watch is kept on the fluid balance ; if water retention occurs, if the venous pressure rises or if pulmonary œdema is imminent, a mercurial diuretic (mersalyl) should be given.

Troublesome tachycardia may develop and is usually a sign of underdigitalisation. Small repeated doses of digoxin intravenously will usually control it.

Results of Treatment.—The operative mortality in reasonable cases should not be above 5 per cent., representing the accidents and irreducible hazards of the operation (cerebral embolism, cardiac arrest, auricular tears). Good results are obtained in 75 per cent. of all cases. The majority of the poor results are due to the production of mitral incompetence. About 2 per cent. of patients per annum develop signs of re-stenosis. A second valvotomy should be carried out in favourable cases.

Aortic Stenosis

The aortic valve may be affected by congenital, degenerative, rheumatic or syphilitic processes producing either stenosis, incompetence or combined lesions.

At the present time no satisfactory method of dealing with incompetence has been devised but stenotic lesions are readily amenable to surgery.

Aortic stenosis impedes the forward flow of blood giving rise to symptoms of dyspnœa, syncope and angina. The pulse is characteristically slow rising and sustained (plateau pulse) and the pulse pressure is low. The left ventricle is enlarged both clinically and radiologically and in severe cases the E.C.G. shows evidence of left ventricular strain. The condition is more serious than mitral stenosis once symptoms have developed as death is likely within two years.

The stenosis can be relieved by closed mechanical dilatation either through the ventricle or the aorta but more accurate operations are possible by open trans-aortic valvotomy with the aid of hypothermia.

Cardiac Ischæmia

There are two aspects of cardiac ischæmia which have a surgical bearing, viz. the relief of the pain of angina pectoris, and the improvement of the blood supply to the myocardium.

Relief of Angina.—The afferent sympathetic fibres from the heart pass

through the stellate and upper three or four thoracic ganglia on both sides. Interruption of these pathways relieves anginal pain in many instances.

Alcohol injection of the stellate and upper thoracic ganglia has the attraction of being a simple procedure not normally classed as an operation. It is, however, a procedure which carries considerable risks. Not only is it difficult to place the alcohol accurately but it is easy to inject it into undesirable or dangerous places (lung, spinal canal, brachial plexus). It is not a procedure which can be generally recommended.

Cervico-dorsal Sympathectomy.—This is performed through either a supraclavicular or a posterior approach. In the former, good retraction and lighting are essential ; the clavicular head of the sternomastoid and the insertion of the scalenus anterior into the first rib are divided. The thyroid axis is divided and the subclavian artery retracted to expose the neck of the first rib and the stellate ganglion. The pleura is mobilised to expose and remove the upper three or four thoracic ganglia.

An extrapleural exposure through a posterior approach has the advantage that it throws less strain upon the cardio-respiratory apparatus than does a transpleural one. A paravertebral incision is made to expose the third rib, and a short segment is removed. The parietal pleura is mobilised from the apex to expose the dome and mediastinum. The sympathetic chain is readily identified and resected. Operation is indicated in severe angina which does not respond to more conservative methods of relief.

Revascularisation of the Myocardium.—The coronary arteries and their branches are virtually end arteries with practically no communication between them. Occlusion of one artery or a branch usually results in infarction of the cardiac muscle. An infarct not only weakens the ventricle but may act as an irritable focus with the production of ventricular fibrillation.

Much experimental work has been carried out by Beck, O'Shaughnessy and others to overcome the inherent shortcomings of the coronary circulation and thereby improve the blood supply to the heart muscle but no universally satisfactory method has yet been developed.

The procedures employed fall into three categories :

(1) Those which aim at producing pericardial obliteration so that mediastinal vessels can pass through the adhesions into the myocardium. Abrasion of the epicardium and pericardium and powdering with asbestos or talc or painting with phenol or silver nitrate have all been employed.

(2) Those which introduce an extracardiac source of blood to the myocardium ; omentum, lung, muscle and the internal mammary artery fall into this category.

(3) Those which aim at improving the intracardiac anastomoses between the branches of the coronary arteries by producing a traumatic epicarditis and narrowing of the coronary sinus (Beck).

SURGERY OF THE AORTA

The surgery of the aorta has made considerable strides since the introduction of aortic grafts and the advent of hypothermia. It is now possible to occlude the aorta with safety for reasonable periods and to bridge considerable defects so that the two chief deterrents to reconstructive aortic surgery have largely disappeared.

Aortic Aneurysms.—Aortic aneurysms due to syphilis or degenerative changes may be fusiform, saccular (fig. 1463) or dissecting. The diagnosis may be straightforward, but is often notoriously difficult, although angiocardiography has provided a useful diagnostic weapon.

Professor of Surgery, Cleveland, Ohio.
London County Council Cardiovascular Clinic, London. Died from

CHAPTER XLV

INFECTIONS OF THE HAND

HAMILTON BAILEY

IN 30 per cent. of cases the infection commences without known injury; an epithelial crack from chapping or a forgotten prick is then the most probable portal of entry of the causative bacteria.

Pathology.—The initial lesion consists of a cluster of organisms surrounded by zone of reaction. At this stage the condition may resolve—how often is not known. In at least 80 per cent. of cases the infecting organism is a *Staphylococcus aureus* which, by its powerful exotoxin, causes early death of tissue. The extent of the resulting necrosis is governed by the resistance of the host and by the ability or otherwise of the tissues to swell without hindrance. Sloughing is conspicuous in the fibro-fatty subcutaneous tissue of the pulp spaces of the fingers and the palm.

Clinical Features.—Infections of the hand, which are encountered most commonly in manual workers and housewives, commence frequently as cellulitis, and unless the infection can be aborted, suppuration will follow. The early detection of the presence of pus and its accurate localisation are of cardinal importance. If the patient complains of throbbing pain, worse when the hand is dependent, and if *this pain interferes with sleep*, it is highly indicative that pus is present somewhere in the zone under suspicion. The exact location is determined as follows: Palpation of the inflamed area is carried out with a blunt-pointed probe or a burnt match-stalk, rather than with the finger; by this means the site of maximum tenderness can be determined accurately.

FIG. 1464.—Œdema of the dorsum, which is often present in infections of the hand, gives rise to swelling that pits on pressure. (*The late Professor Felix Mandl, Vienna.*)

Œdema is an outstanding feature in all infections of the hand. Due to the rich network of lymphatics in the subcutaneous tissues that receive efferent vessels from the palm and to the loose pliable skin covering the back of the hand, œdema is always most in evidence on the back of the hand, irrespective of the site of the lesion (fig. 1464). It is highly important that this œdema should be kept in abeyance by elevation

of the forearm, as it is a potent cause of subsequent stiffness of the hand.

POORLY LOCALISED SUBCUTANEOUS INFECTIONS

Lymphangitis.—Organisms, nearly always streptococci, gain entrance through an abrasion that may be microscopic. Within a few hours the adjacent portion of the hand becomes swollen and painful, and there is often considerable elevation of the temperature. Because superficial lymphatic vessels pursue the shortest course to the dorsum, œdema, which comes on early, is most in evidence on the back of the hand. A little later red streaks, so characteristic of lymphangitis, can be seen coursing up the arm. Especially in lesions of the ulnar half of the hand, the first lymph node to become enlarged and tender is the supratrochlear. In a few instances of infection entering the middle finger, the first lymph node to become enlarged is *above* the clavicle (fig. 1465), in which case infection is liable to enter the general circulation and give rise to severe constitutional symptoms. The lymphatics of the thumb and index finger pass straight to the axillary nodes. Lymphangitis can occur without any other demonstrable manifestation of inflammation, or as an accompaniment of one of the entities to be described, particularly terminal pulp-space infection and fulminating tenosynovitis.

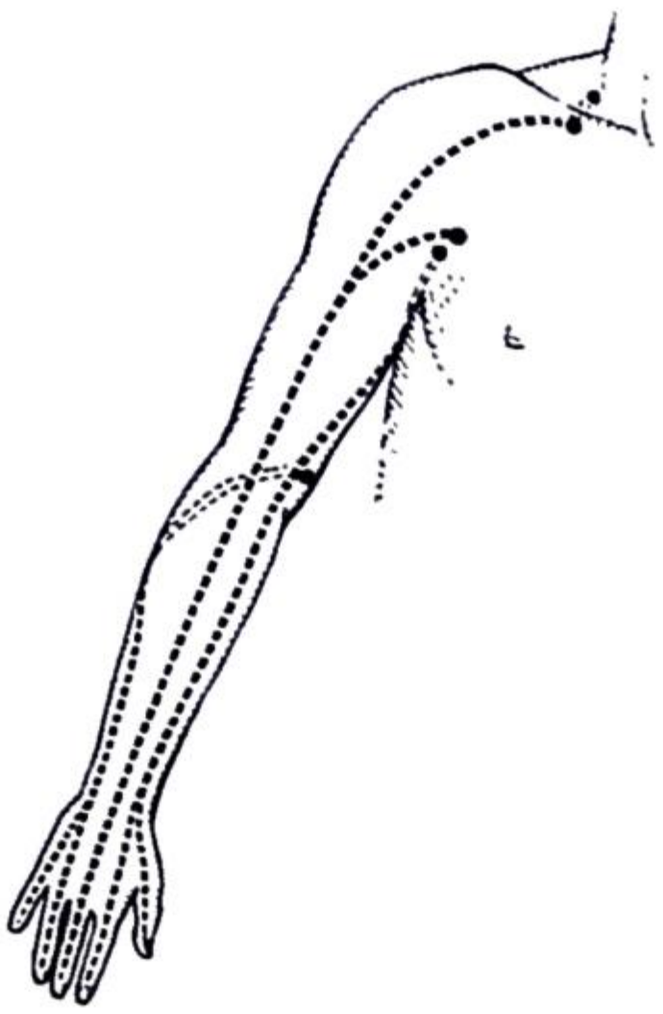

FIG. 1465.—The main lymphatic trunks of the fore arm and arm. (*After Kanavel and Mason.*)

Deep lymphangitis may, or may not, be associated with red streaks passing up the arm. In their absence considerable constitutional symptoms and swelling not only of the back of the hand but of the whole hand and forearm, with complete absence of pain, limitation of movement and localised tenderness call for the provisional diagnosis of deep lymphangitis.

Treatment.—Lymphangitis responds well to the conservative measures detailed on p. 108, and provided the infecting organism is sensitive to the antibiotic employed, residual abscesses (e.g. an axillary abscess, from suppurating lymph nodes) are now rather infrequent.

Cellulitis is the initial lesion of the fascial-space infections about to be described. In a proportion of cases, higher in loose subcutaneous spaces than those more confined, the inflammation resolves. In the remainder a localised abscess forms. Incision during the stage of active cellulitis is highly mischievous. On the other hand, it is emphasised that fluctuation must not be awaited in infection of closed and deep spaces. Swelling, induration, and localised tenderness—a triad of signs that in the days of the pre-Listerian Masters was known as the stage of brawny swelling—now indicate that the time is ripe for incision.

See also Erysipeloid, p. 19.

Lord Lister, 1827–1912. Professor of Surgery at Glasgow, Edinburgh, and London.

LOCALISED CUTANEOUS AND SUBCUTANEOUS INFECTIONS

The superficial abscesses of the hand, including the digits, can be :

(*a*) Intra-epidermal (purulent blister) (fig. 1466 *a*).

(*b*) Intradermal (fig. 1466 *b*).

(*c*) Subcutaneous (fig. 1466 *c*).

(*d*) The superficial loculus of a collar-stud abscess (fig. 1466 *d*).

FIG. 1466.—Superficial abscesses at various levels. (*After R. Pilcher.*)

The volar surface of the hands of manual workers is often covered with greatly thickened epithelium. Especially in such individuals, a subcutaneous abscess may burst through the dermis and extend in the layers of the epidermis (fig. 1466 *d*), in which event it is impossible to differentiate it from a purulent blister until the deeper loculus has been discovered at operation. This variety of collar-stud abscess is also encountered frequently in the pulps of the fingers and thumb.

Paronychia is the commonest infection of the hand (30 per cent.). Unlike the others, which occur more frequently in working men, paronychia is encountered in every walk of life, in both sexes, and from infancy to old age. The infection arises from a hang-nail, careless nail paring, or a manicurist's unsterile instrument, the original infecting organism, being a *staphylococcus aureus* in nearly every case. The inflammation commences beneath the eponychium (called by manicurists the nail cuticle). Usually suppuration follows. Confined by the adherence of the eponychium to the base of the nail, the pus tends to track around[1] the cutaneous margin (fig. 1467) and in 60 per cent. of cases it extends beneath the base of the nail ; in neither situation does the pus extend deeper than the dermis (R. Pilcher). Untreated, spontaneous rupture occurs in about one-third of the cases, but suppuration continues, and not infrequently the abscess cavity becomes secondarily infected with *Esch. coli* and other organisms. Only occasionally is paronychia seen within twenty-four hours of infection ; at a very early stage it is possible that the infection may be aborted by antibiotic therapy. As a rule, acute paronychia requires an operation for its cure.

FIG. 1467.—Paronychia. Often organisms enter through a 'hang-nail.' In this instance the pus has extended to the contralateral side and under the nail.

[1] The colloquial American term for paronychia is 'run around.'

Robin Sturtevant Pilcher, Contemporary. Director of the Surgical Unit, University College Hospital, London.

Operation.—The nail fold is stripped away from the base of the nail. This will evacuate the contents of the abscess, and also give exit to a subungual extension if pressure is exerted over the nail. All pus is wiped away with wisps of gauze ; loose cuticle is cut away, and should there be a pocket under the corner of the nail fold, a wedge of overlying skin is removed to ensure healing from the bottom. Only when pus has extended beneath half or more of the width of the nail is excision of the proximal third of the nail required.

Chronic Paronychia[1].—The history is measured by months, rather than days, and the onset is insidious[2]; seldom does it follow acute paronychia. The infection is a mixed one. The lesions are often multiple. Classically washerwomen were especially prone to this condition ; today the housewife who does not wear rubber gloves when ' washing-up ' is the usual sufferer. Antibiotic therapy has little or no effect, and the surgical treatment, so successful in acute cases, is most disappointing.

The best method of treating these indolent infections is by 1 : 500 bradosol (domiphen bromide) in spirit, or penotrane tincture (hydraphen) dropped into the nail-fold twice daily. It should be noted that the solution should not be applied with wisps of gauze or cottonwool, which are liable to be incompletely removed. When the pockets become filled with granulations the treatment is discontinued, and the hands must be kept as dry as possible until epithilialisation occurs. Superficial radiotherapy assists in clearing up especially resistant cases.

Apical space infection arises from a prick (including a splinter) beneath the nail, causing infection of the space between the subungual epithelium and the periosteum (fig. 1468 *a*). The lesion (fig. 1468 *b*), which is exquisitely painful, gives rise to comparatively little swelling. Tenderness is greatest just beneath the free edge of the nail, and pus comes to the surface here or beneath the nail. The condition is often confused with a terminal pulp-space infection, or when, as is not uncommon, there is redness around the nail, with paronychia.

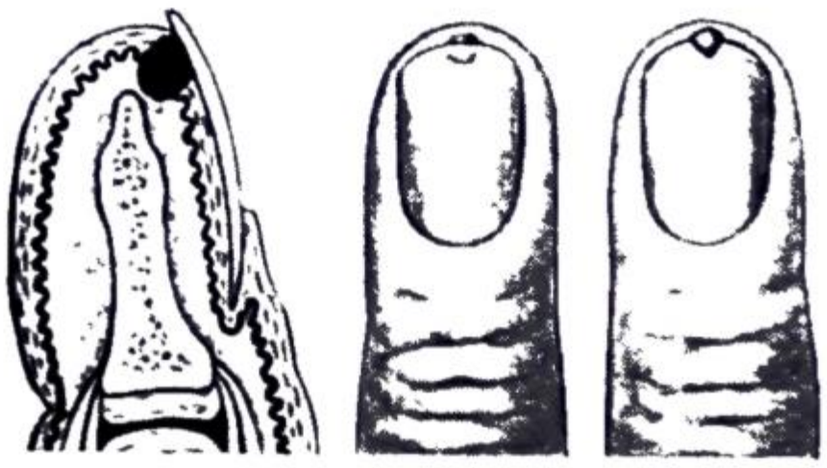

FIG. 1468.—(*a*) Showing the anatomical relations of an apical abscess. (*b*) Apical abscess; clinical presentation. (*c*) Method of evacuating the contents of the abscess.

Operation.—A small V is removed from the centre of the free edge of the nail, and a little wedge of the full thickness of the skin overlying the abscess is excised also (fig. 1468 *c*). The amount of pus and débris evacuated is surprisingly small ; commonly the abscess cavity extends down to the bone, but osteitis is unusual. Following the operation, relief of symptoms is immediate and the wound heals in under a week.

Infection of the terminal pulp space rivals paronychia as the most frequent infection of the hand. The index finger and the thumb are affected most often. The origin of the infection is usually a prick.

Surgical Anatomy.—The deep fascia, which is attached to the thin skin of the distal flexion crease, fuses with the periosteum just distal to the insertion of the deep flexor tendon, thereby closing the terminal pulp compartment at its proximal end. Through the space, which is filled with compact fat feebly partitioned by fibrous septa, run the terminal branches of the digital artery and thrombo-arteritis of these vessels accounts for the frequency with which osteomyelitis complicates infection of this closed space.

Clinical Features.—Dull pain and swelling are the first symptoms. By the third day there are severe nocturnal exacerbations of throbbing pain

[1] Called by some dermatologists (quite descriptively) chronic *peri*onychia.
[2] A sharp look out must be kept for the occasional case resulting from neuropathy, e.g. syringomyelia.

interfering with sleep. Light pressure over the affected pulp increases the pain. Frequently the corresponding supratrochlear lymph node is enlarged and tender. If the pulp is indurated and has lost its normal resilience, pus is present (fig. 1469). Untreated, the abscess tends to point towards the centre of the pulp beneath a patch of devitalised skin. A collar-stud abscess then occurs; still untreated, the abscess bursts.

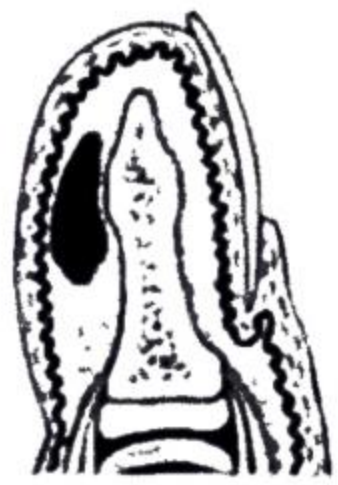

FIG. 1469.—The location of pus in terminal pulp-space infection.

Conservative Treatment.—If the case is an early one (under forty-eight hours), penicillin therapy for twenty-four hours is advised, for on no account should operation be undertaken during the stage of cellulitis; only if local improvement is undeniable should operation be withheld.

Operation.—A transverse incision is made through the skin at the point of greatest tenderness. The beginner is warned not to be beguiled by entering the superficial loculus of a collar-stud abscess. Removal of slough, which is frequently present, is most desirable, but great care must be taken not to traumatise the periosteum.

Osteomyelitis of the terminal phalanx is rather a common sequel of terminal pulp-space infection. At operation in a case of some standing, that part of the bone bereft of its blood supply is sometimes found to be loose, and can be lifted out of the abscess cavity at the time of the operation. More often the sequestrum separates some weeks after the abscess has been evacuated, in which case the wound continues to discharge. Repeated radiographs (fig. 1470) and probing will indicate when the sequestrum has separated. Only then must it be removed, after which healing will proceed apace. In the case of a child, regeneration of the diaphysis is possible, provided the periosteum is relatively undamaged. In the adult no regeneration occurs, and the patient is left with a shortened terminal phalanx covered by an ugly curved nail.

FIG. 1470.—Commencing osteomyelitis in a case of terminal pulp-space infection.

Infection of the Middle Volar Space of a Digit.—The fibro-fatty tissue occupying this space is more loosely packed than that of the terminal pulp space. The middle volar space is separated above and below by fibrous partitions while, like the proximal space, it is shut off from the dorsal cellular tissue by fibrous septa extending from the skin to the periosteum.

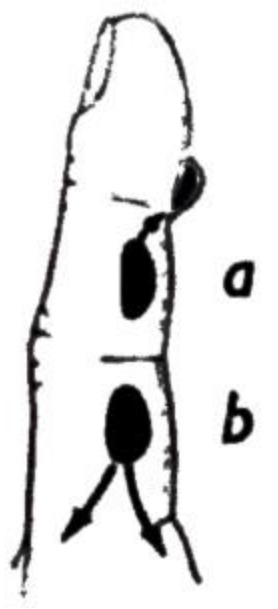

FIG. 1471.—The direction of spread of an abscess of (*a*) the middle volar space; (*b*) the proximal volar space. (*After M. Iselin.*)

Clinical Features.—Infection of this space is considerably less common than that of the terminal pulp space. The finger is held in semi-flexion. In about one-third of cases attempts to straighten it are painful. There is tender induration over the space, while the [illegible] of the terminal and proximal segments, although swollen, are indurated. In late cases frequently a purulent bleb

appears in the distal flexion crease (fig. 1471). In early cases it is difficult to distinguish infection of the middle volar space from infection of the underlying flexor tendon sheath; however, in the former extreme tenderness over the base of the tendon sheath is completely lacking.

FIG. 1472.—An abscess of the proximal pulp space. (*After M. Iselin.*)

Infection of the Proximal Volar Space.—While this space is well partitioned from the middle space below, it communicates freely with the web space. Once localisation has occurred, infection of this space is comparatively easy to diagnose (fig. 1472). There is tender induration in the proximal volar space, and because frequently a web space becomes involved also, the swelling is usually asymmetrical.

Operation.—In the case of either of the above spaces, after pus has become localised it should be evacuated through a transverse incision made at the site of greatest tenderness.

When the diagnosis is uncertain (localised tenosynovitis cannot be excluded) the space should be explored through a lateral longitudinal incision (see fig. 1483).

FIG. 1473.—The three web spaces between the divisions of the palmar fascia.

Infection of a Web Space

Surgical Anatomy.—The web spaces are three triangular regions between the dorsal and volar skin filled with loose fat that bulges between the divisions of the palmar fascia (fig. 1473). The spaces, when filled with pus, straddle the deep transverse ligament, and although most of the pus is volar, the abscess points dorsally, viz.—→ Anatomically it is possible for the pus to track along a lumbrical canal to the middle palmar space; in practice it seldom does so.

FIG. 1474.—Web-space infection showing fan-shaped blush extending from a web on to the dorsum.

The infection arises (1) from a skin crack, (2) from a purulent blister or from beneath a callosity on the forepart of the hand, or (3) via a lumbrical canal from an abscess in the proximal volar compartment of a digit related to the space. As the constitutional symptoms are severe, patients with this condition are often seen before localisation of the infection has occurred. At this stage there is œdema of the back of the hand, and although the condition can be strongly suspected from the location of the tenderness, a precise diagnosis cannot yet be made. The patient should be put to bed with the arm splinted and elevated by suspension. Penicillin is administered intramuscularly. Once localisation has occurred, the signs of infection of a web space become manifest.

Localising Signs.—The base of one finger is swollen, and in severe cases the fingers immediately adjacent to the space are separated. Often there is a

fan-shaped blush extending from the web on to the dorsum (fig. 1474). The maximum tenderness is found in the web and on the anterior surface of the base of one of the fingers extending a short way into the palm. Untreated pus can track across the base of the finger into an adjacent web space, and also up the sides of the proximal segments of the digits related to the infected web.

FIG. 1475. — Web-space infection showing incision for evacuating pus placed in the crease at the base of an involved finger.

Operation.—If there is an area of devitalised skin, the abscess is entered by paring away cornified epithelium. In other circumstances a transverse incision is made in the flexion crease at the base of the finger most affected (fig. 1475) or below the web, whichever is the more indurated. A few strands of palmar fascia have to be divided; the walls of the abscess cavity, which is often the size of a thimble, are curetted gently. When the abscess communicates with a dorsal pocket a counter-incision is advisable.

FIG. 1476. — Carbuncle situated in the skin of the dorsal aspect of the proximal segment of the index finger.

Carbuncle of the Hand—The dorsal aspect of a proximal segment of a digit (fig. 1476) and the dorsum of the hand are rather common sites for a carbuncle, infection often being carried thither by wiping the mouth or nose with the back of the hand. The condition is encountered much more often in males than females, because in males these areas are often hairy. A carbuncle in either of these situation is liable to involve an extensor tendon, and is slow to heal.

The treatment of carbuncle is discussed on p. 935.

INFECTIONS OF THE FASCIAL SPACES OF THE PALM

Subaponeurotic Infection.—Following pricks, splinter penetration, and the like, occasionally suppuration occurs beneath the palmar fascia (fig. 1477), but superficial to the flexor tendon sheaths. Collar-stud abscess formation is a common sequel, the pus tracking through the original puncture in the palmar fascia into the layers of the skin. It should be noted that there is no subcutaneous space in the centre of the palm; the palmar fascia is normally adherent to the skin.

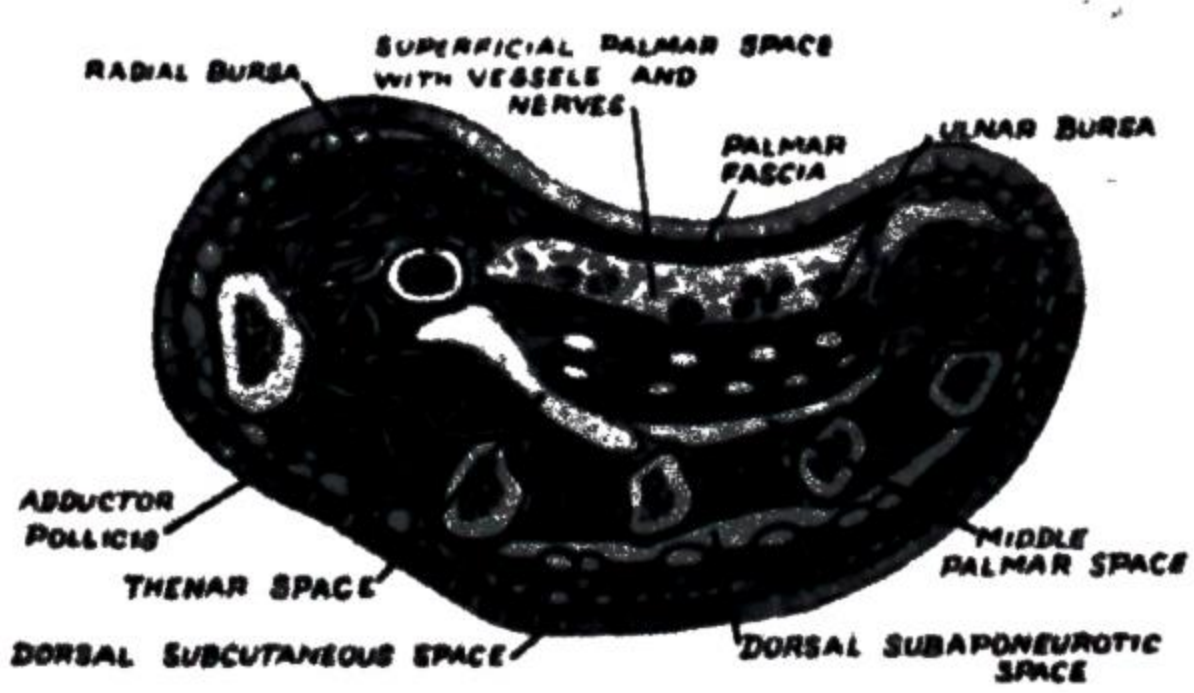

FIG. 1477. — Transverse section through the palm proximal to its middle.

Operation.—In the case of both subcutaneous and subaponeurotic abscess of the palm, a small transverse incision is made in the line of the nearest skin crease over the

most tender area or, when pus can be seen beneath the thickened epidermis, the abscess is entered by paring away the superficial layers of the skin. The interior of the abscess cavity must be inspected and probed with accustomed care; should an opening be found leading to a deeper collection, it is essential to enlarge the opening sufficiently to be enabled to remove slough and infected granulations from its wall.

FIG. 1478. — The thenar and middle palmar fascial spaces. The three diverticula from the middle palmar space are the lumbrical canals.

Middle palmar space infection lies very deeply. It is situated between the flexor tendon sheaths and the fascia covering the interosseous muscles, being separated from the thenar space by a fibrous septum, extending from the palmar fascia to the middle metacarpal bone (fig. 1478). Infection of this space, which is now rare, usually occurs via the lumbrical canals from rupture of an infected tendon sheath of the middle, ring, or little finger. It gives rise to enormous swelling of the hand which has been likened to a whale's flipper. Obliteration of the concavity of the palm with slight bulging thereof is almost pathognomonic of an abscess of the middle palmar space.

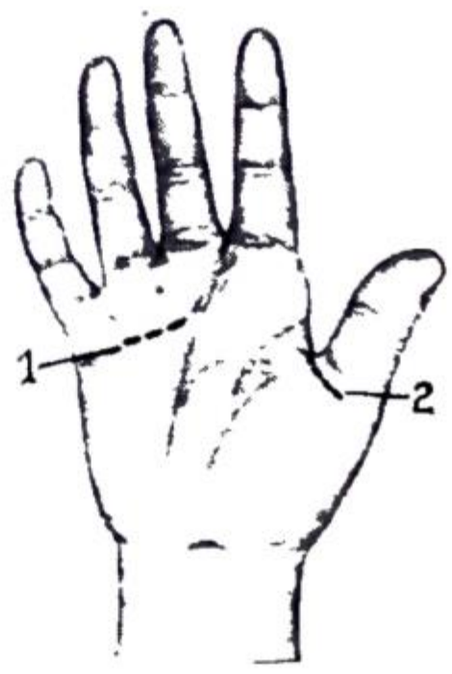

FIG. 1479.—Incisions for draining (1) the middle palmar space; (2) the thenar space.

Operation.—The middle palmar space can be drained through an incision in the middle third of the distal flexion crease (fig. 1479), keeping to one or other side of the flexor tendon of the ring finger, but when it is associated with suppurative tenosynovitis with a sloughing tendon, amputation of the affected finger, together with the head of its metacarpal bone, is the most satisfactory method of dealing with this complex situation.

FIG. 1480. — Empyema of the thenar space due to a penetrating wound.

Thenar space infection is bounded, *on the palmar aspect* by palmar fascia, *on the dorsal aspect* by the adductor pollicis (transverse head), and *on the ulnar aspect* by the fibrous septum referred to above. The space can become infected by bursting of a suppurating tendon sheath of the index finger or of the thumb, or from a penetrating wound. Ballooning of the thenar eminence (fig. 1480) causing abduction of the thumb is characteristic of this lesion.

Operation.—An incision through the skin and superficial fascia, parallel with and ½ inch (1·25 cm.) below the carpo-metacarpal flexion crease (see fig. 1479), and keeping towards the web, opens the abscess, which is usually walled off from the muscles of the thenar eminence.

INFECTION OF THE DORSAL SPACES

Owing to the frequency with which pitting œdema accompanies pus in the volar aspect of the hand, it has been rightly taught that (in these circum-

stances) it is the essence of bad surgery to incise the back of the hand. This praiseworthy endeavour to emphasise a fundamental dictum has resulted in neglect of an appreciation of the dorsal fascial spaces as a site of infection, and a reluctance to incise the dorsum of the hand.

The most frequent causes of dorsal space infection are a boil of the overlying skin, or a penetrating wound. Infection of the dorsal subcutaneous space of the hand is fairly common, as also is infection of the corresponding space in a proximal segment of a digit; that of the dorsal subaponeurotic space (see fig. 1477) is rare. If swelling of the dorsum is accompanied by persistent tenderness, induration, and, perhaps, redness lasting a few days, fluctuation should not always be awaited.

Operation.—An incision about ½ inch (1·3 cm.) long, which in this instance can be vertical, is made over the point of greatest tenderness.

ACUTE SUPPURATIVE TENOSYNOVITIS

Usually infection of the sheath of a flexor tendon is due to bacteria introduced by the point of a needle or other sharp object penetrating the tendon sheath. Exceptionally the sheath is infected by extension from its terminal pulp space, in some cases from the scalpel transgressing the hallowed ground of the septum that closes the proximal end of the space (see fig. 1469).

FIG. 1481.—The flexor tendon sheaths. This typical arrangement is present in 75 per cent. of cases. (*After J. C. B. Grant.*)

Acute fulminating tenosynovitis involves the whole sheath rapidly, and is nearly always due to a streptococcal infection. The classical local signs are:

1. Symmetrical swelling of the entire finger.
2. Inability to flex the finger. (Slight movement occurs at the carpometacarpal joint due to contraction of the lumbrical.)
3. Flexion of the finger (the 'hook' sign) with exquisite pain on extension. (Unfortunately this sign is not always present, and it occurs also in infection of the middle pulp space (Iselin)).
4. Tenderness over the infected sheath, especially over its proximal *cul-de-sac* (fig. 1481).

Due to very early administration of penicillin by the patient's doctor, cases of fulminating tenosynovitis have become less common. The infection is often either aborted before the whole sheath has become implicated, indeed, before the diagnosis of tendon-sheath involvement can be made with assurance, or the infection becomes limited by adhesions to a portion of the sheath.

Localised suppurative tenosynovitis.—In this instance the organism is frequently a staphylococcus. Swelling and tenderness are limited to one portion of the digit, rendering confident diagnosis prior to exploration difficult.

Marc Iselin, Contemporary. Surgeon, American Hospital, Paris.

Treatment.—In very early cases one mega-unit of penicillin is given *bis die*. The forearm and hand, the latter being placed in the position of rest (see fig. 1486), are splinted and elevated. Clinical re-examination is made every six hours. Only when the local as well as the general response to conservative measures is unquestionable is non-operative treatment continued, for within forty-eight hours necrosis of some part of the tendon commonly occurs in cases where decompression is not carried out. Therefore adequate incision and drainage under antibiotic cover, as soon as the diagnosis can be established with confidence, is the best method of treatment.

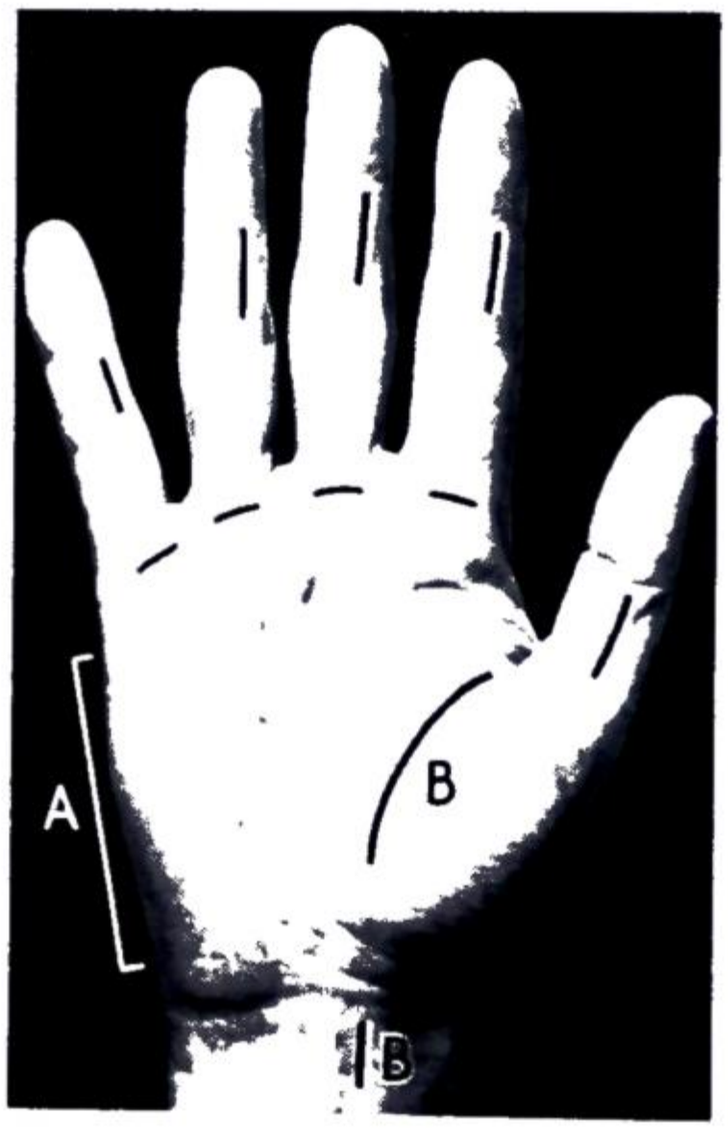

FIG. 1482.—Incisions for opening infected tendon sheaths. A, additional incision when the ulnar bursa is implicated; B, B, additional incisions when the radial bursa is infected.

Operation.—An incision is made along the lateral aspect of the middle segment (fig. 1482) of the affected digit. The fibrous portion of the sheath is divided (fig. 1483), when the thin, bulging theca will be displayed. Some of the fluid within it is aspirated and sent for bacteriological examination; the theca is then incised. A short transverse incision (see fig. 1482) is made over the proximal *cul-de-sac*, which is opened. Through this incision a ureteric catheter is introduced into the sheath, which is irrigated with normal saline solution; 100,000 units of penicillin in 5 per cent. saline solution is then injected.

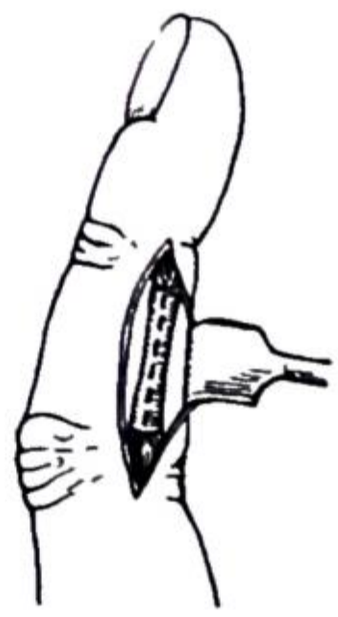

FIG. 1483.—Exposure of the flexor tendon sheath of the middle segment of the index finger.

Results.—70 per cent excellent, 16 per cent fair, and 14 per cent poor.

In cases of *localised tenosynovitis* the operation is limited to opening the sheath through an incision along the lateral aspect of the involved segment.

Infection of the ulnar bursa is characterised by:

1. Œdema of the whole hand, especially the dorsum, due to lymphatic spread.
2. Moderate swelling of the palm.
3. Sometimes a fullness immediately above the flexor retinaculum.
4. The flexed fingers resist extension, the maximum difficulty being experienced in the little and the least in the index finger.
5. Especially valuable is Kanavel's sign: the area of greatest tenderness is over that part of the ulnar bursa lying between the transverse palmar creases (fig. 1484).

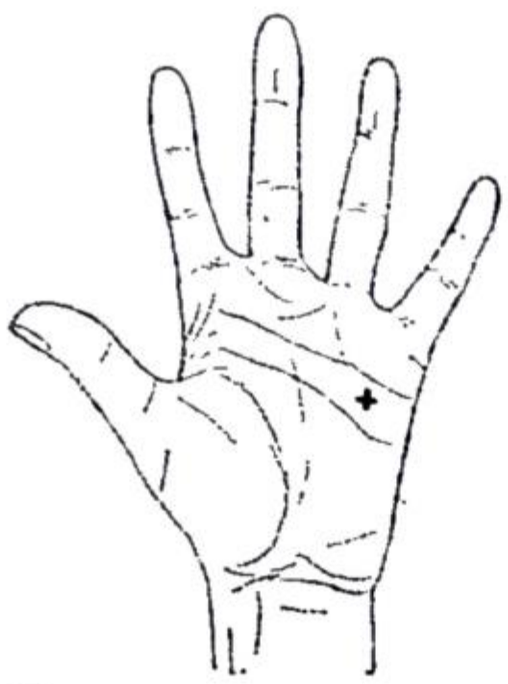

FIG. 1484.—Kanavel's sign.

It should be noted that the ulnar and radial bursæ intercommunicate in 80 per cent. of cases, and often when an untreated infection of one has persisted for more than forty-eight hours, the other becomes involved also. It should be noted, that recent anatomical studies have determined that in no less

Allen B. Kanavel, 1874-1938, Surgeon, Cook County Hospital, Chicago, was largely responsible for the proper understanding of infections of the hand.

than 25 per cent. of cases the tendon sheath of the index, or the middle, or the ring finger communicates with the ulnar bursa. This little-known fact is of great surgical importance.

Operation : *Henry's Approach.*—After the skin and deep fascia have been incised over the antero-medial aspect of the fifth metacarpal (see fig. 1482), the abductor and flexor digiti minimi are separated from the bone and retracted forwards, displaying the opponens, which is divided close to its attachment to the bone (fig. 1485). The fascia deep to this muscle is incised, and the distended bursa bulges into the wound. If the bursa has been emptied via the infected tendon sheath, a curved probe passed from the original incision will enable the wall of the bursa to be identified and incised.

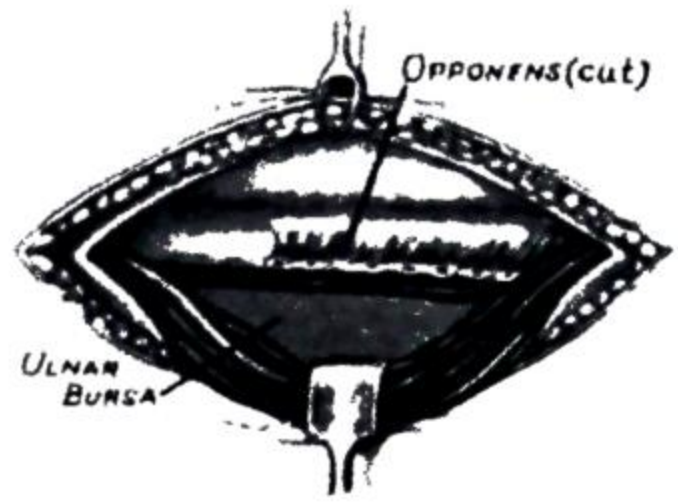

Fig. 1485.—Henry's approach to the ulnar bursa.

Infection of the radial bursa is characterised by :

1. Flexion of the distal phalanx of the thumb, with rigidity and inextensibility ; the other digits can be extended fully.
2. Tenderness over the sheath of the flexor pollicis longus.
3. Sometimes swelling just above the flexor retinaculum.

Treatment.—While in early cases antibiotic therapy should be given a trial, the perils of leaving this sheath undecompressed include extension to the ulnar bursa, and because the sheath is particularly unyielding, necrosis of the tendon of the flexor pollicis longus.

Operation.—The sheath can be decompressed adequately by the incisions shown in fig. 1482, being vigilant not to extend the proximal incision nearer than half an inch (1·3 cm.) distal to the flexor retinaculum, lest the branch of the median nerve to the muscles of the thenar eminence be injured. Should pus well up when pressure is exerted over the wrist a ureteric catheter is passed down the sheath, and a third incision is made on to the catheter above the retinaculum. In this way the proximal *cul-de-sac* can be safely opened and drained through a small incision. Irrigations with saline solution, followed by penicillin solution, are carried out as directed on p. 1154.

GENERAL PRINCIPLES OF TREATMENT IN ALL CASES OF INFECTIONS OF THE HAND

The five principles in the treatment of infections of the hand can be summarised as follows :

(i) Provision of rest to the affected limb.
(ii) Antibiotic therapy.
(iii) Early recognition of the presence of pus and its accurate localisation.
(iv) Evacuation of pus and, in the case of fascial spaces, débridement of the walls of the abscess cavity.
(v) Adequate after-treatment.

To consider these principles in more detail :

Rest and Elevation of the Hand.—If it is considered possible that resolution will occur, and also following operation, the hand must be placed in the position of rest (fig. 1486). When it is anticipated that in all probabil-

Arnold Kirkpatrick Henry, Contemporary. Professor of Anatomy, Royal College of Surgeons, Ireland.

ity some portion of the hand will become stiff, as soon as the ultra-acute stage has passed the digits should be arranged in the position of function

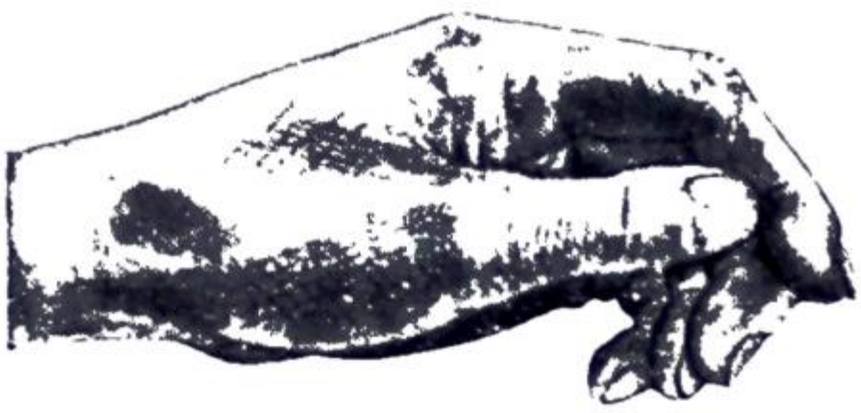

FIG. 1486.—The position of rest taken up by an acutely inflamed hand. The index finger is not flexed as much as the others. (*After Wood Jones.*)

FIG. 1487.—The position of function.

(fig. 1487). For ambulatory patients a light plaster-of-Paris slab, moulded to fit the volar surface of the hand and forearm, cannot be bettered. In addition, the forearm is supported in a sling as high as possible towards the opposite shoulder, in order to lessen œdema. For in-patients a Cramer wire splint, which is suspended readily (fig. 1488), is both efficient and comfortable. Full elevation in the manner shown, by decreasing œdema, lessens throbbing pain, which even so requires anodynes such as Tab. codeine co. 10 to 15 grains (0·65 to 1 G.), repeated if necessary, for its relief.

FIG. 1488. — A case of suppurative tenosynovitis being treated by immobilisation and elevation. The inflamed finger is surrounded by a viscopaste bandage.

These remarks concerning elevation do not apply to cases of uncomplicated paronychia and minor superficial abscesses; for these an ordinary sling is all that is required.

In all cases rest for an inflamed hand should be insisted upon. When the acute phase has abated, gentle voluntary movements are encouraged.

Antibiotic Therapy.—Except in trivial or superficial infections, antibiotic therapy is given without delay. Because in over 90 per cent. of cases of infection of the hand the original infection is caused by staphylococci or streptococci, or both, penicillin is still the antibiotic of choice. It is true that the number of pencillin-resistant strains of these organisms is increasing, but, excluding those acquired in hospital, only about 5 per cent. are penicillin resistant. If penicillin resistance is suspected, and it should always be suspected in the case of anyone working within the precincts of a hospital (e.g. a nurse), while awaiting bacteriological confirmation, another antibiotic (e.g. one of the tetracyclines) should be substituted.

Antibiotic therapy is given in the following circumstances :

(*a*) *In very early cases*, with the aim of possibly aborting the infection.

Friedrich Cramer, 1847–1903. Surgeon, St. Joseph's Hospital, Wurzburg.

Should the inflammation show signs of regression, daily injections are continued until resolution is completed—often on the fifth day.

(*b*) *As an adjuvent to operation.*—In the majority of cases of infection of the hand, pus is present by the time a patient seeks advice. One mega-unit of penicillin is then given intramuscularly three-quarters of an hour before operation, with further injections on the first and second post-operative days. Most of the cases just referred to are ones that can be undertaken safely as out-patients.

(*c*) *In serious infections* with considerable constitutional symptoms. Several hours. sometimes up to twenty-four or more, of in-patient treatment, including antibiotic therapy, is given before the most opportune time for operation (if such be required) arrives. In such cases antibiotic treatment is continued until at least forty-eight hours after the temperature and pulse-rate have become normal. It must be realised that antibiotics can, by subduing local reaction, modify the signs of inflammation, but if pus is present local tenderness will persist. It is futile, damaging, and often disastrous to rely on antibiotics when suppuration has occurred. If there is pus in any part of the hand it must be evacuated.

Pre-medication is given three-quarters of an hour before operation, and with it penicillin, as described above.

Anæsthesia.—For the distal part of the finger regional anæsthesia with 2 per cent. procaine or xylocaine (without adrenaline) is excellent. After raising a weal, the hypodermic needle is introduced at a point shown in fig. 1489. While injecting the anæsthetic solution the needle is advanced distally and forward until it is judged that the digital nerve has been reached; ¾ ml. of the anæsthetic solution is deposited here. The procedure is repeated on the contralateral aspect of the affected finger. By the addition of 300 international units of hyaluronidase to a 5-ml. bottle of either of these solutions (which must be stored in a refrigerator to prevent deterioration of the hyaluronidase) the rapidity of action of the anæsthetic solution is enhanced and œdema, both pre-existing and that caused by the injection of the fluid, is absorbed rapidly.

FIG. 1489.—Points of puncture for anæsthetising a digit.

In the case of an abscess of the hand proper, a full general anæsthetic is administered. On no account should a short anæsthetic, e.g. nitrous oxide gas, be employed. Complete muscular relaxation and ample time are most desirable when operating in this area.

A bloodless field is essential. Only under these conditions can the exact site and extent of the lesion be determined and damage to tendon sheaths and nerves be avoided. The cuff of a sphygmomanometer is applied to the upper arm. The limb is then elevated for two minutes, after which the bag is inflated to a pressure of 200 mm. Hg.

Operation is undertaken at a time when there is a high penicillin level in

the blood. With the possible exception of tendon-sheath infection, it is insufficient merely to evacuate the pus. The operation must be meticulous. Slough is removed unless it is densely adherent and, what is extremely important, granulations are abraded by gauze or scooped away with a curette, avoiding the latter in situations where it might damage the periosteum or a tendon sheath. Only after granulation tissue has been removed, leaving the walls clean and oozing blood, will the injected antibiotic from the blood enter the cavity freely. Provided every nook and cranny has been attended to in this manner, no drainage material is employed, for no further pus is expected to form; merely a little serum containing at first blood, and perhaps a few dead bacteria, is all that oozes from a cavity thus treated. This lessens in amount about the third day, when quick healing is to be expected.

After-treatment of Serious Infections of the Hand.—In all cases dry dressings are employed. The dressings are changed at the end of twenty-four hours after operation. Thereafter often an interval of two days can elapse between re-dressings. The patient must be instructed not to get the dressings wet. These instructions differ only in the case of paronychia ; in this instance the patient is instructed to wash the hands frequently, dry them thoroughly on a towel kept for the purpose, and re-apply the dressing himself. Physiotherapy and exercises form an important part of the late after-treatment.

A Stiff Digit Results.—In the case of finger, it should be remembered that in many walks of life total amputation of a digit is less of a handicap than a stiff finger, but amputation should seldom be undertaken until the infection has subsided completely. In the case of a thumb the surgeon's watchword for the infections as well as lacerations is always ' Save all possible.'

Continuation of Suppuration.—Provided these principles have been followed, continued suppuration is rare. If it occurs, the first thing to consider in most situations is the possibility of extension of the infection to another fascial space or tendon sheath. Should suppuration continue for fourteen days, the hand should be radiographed for evidence of bone necrosis. In relevant cases the possibility of a non-opaque retained foreign body should also be borne in mind. Sloughing tendon is a potent source of prolonged suppuration and much time will be saved by excising the diseased portion, care being taken to anchor its proximal end by sutures to prevent the cut end being carried into the forearm by muscular contraction, and thereby spreading infection.

Involvement of the Forearm from the Hand.—When a radial or ulnar bursa, distended with pus, bursts, or an infected middle palmar space remains undrained, pus travels up the forearm between the flexor profundus ventrally and the pronator quadratus and interosseous membrane dorsally. It is here, in the space of Parona, that a quantity of pus can collect without giving rise to much swelling. There is, however, brawny induration above the wrist, unless the original lesion has been incised and continues to discharge pus. Therefore, in cases of infection of the radial or ulnar bursa, if pus can be expressed by pressure over the wrist at the time of operation or

Francesco Parona, 1861–1910. Surgeon, Ospedāle Maggiore, Milan

subsequently, it is essential that the forearm be drained in the following manner:

FIG. 1490.—Incisions for draining the space of Parona.

Operation.—The styloid process of the ulna is palpated and an incision is commenced 1½ inches (3·75 cm.) above this point over the flexor surface of the ulna, and passes down to the periosteum. The incision is at least 2 inches (5 cm.) long. A hæmostat is thrust beneath the flexor tendons, and the jaws of the forceps are opened, as a result of which the proximal extremity of the infected bursa is ruptured thoroughly into the space beneath the flexor tendons. In the case of a radial bursa infection, a counter-incision is made on the radial side (fig. 1490).

Suppurative arthritis in a related joint occurs occasionally as a complication of suppurative tenosynovitis. In these circumstances timely amputation of any digit except the thumb will reduce the period of disability (S. Bunnell). Less infrequently suppurative arthritis occurs as a result of an infected laceration. In this instance a conservative operation (excision of all infected tissue, including infected articular cartilage) should be attempted as soon as the condition is diagnosed.

Human Bites.—Because the wound becomes contaminated with many types of bacteria, including Vincent's organisms from the mouth, if the patient is not treated in a radical manner very early, a human bite can prove very dangerous. Although not strictly a bite, a common type of injury of this kind is an incised wound over the knuckles resulting from a clenched first of one combatant striking the front teeth of his opponent. The joint is usually penetrated, but the track closes when the fingers are extended. In such a case the wound must be excised and, if the capsule has been penetrated, a portion of the capsule must be included in the débridement. Because of heavy contamination, the question of primary closure of the wound resulting from excision of a human bite never arises.

Symbiotic infection, a combination of *micro-aerophilic non-hæmolytic streptococcus* and *hæmolytic staphylococcus aureus*, produces a destructive lesion of the skin and subcutaneous tissues. The gross appearance is quite characteristic; there is an outer zone of erythema, an intermediate dark purple zone, and an inner zone of gangrenous skin. The centre of the lesion becomes a granulating ulcer. The lesion continues to spread until the patient dies, or the infection is brought under control. The usual antibiotics are of little avail, but F. L. Meleney has found that bacitracin is of considerable value.

Paralysis of the Median Nerve.—When signs of median-nerve palsy develop in a case of infection of the hand, early decompression of the carpal tunnel by severing the flexor retinaculum is recommended (D. Bailey). In these circumstances, palsy of the median nerve is due to compression by inflammatory exudate in the radial or the ulnar bursa, or (more frequently) in both bursæ.

Sterling Bunnell, 1882–1957. Consultant to the Surgeon-General of the United States Army.
Jean-Hyacinthe Vincent, 1862–1950. Professor of Epidemiology, Val de Grâce Military Hospital, Paris.
Frank Lamont Meleney, Contemporary. Professor Emeritus of Clinical Surgery, Columbia University, New York.
David Alan Bailey, Contemporary. First Assistant to the Surgical Unit, University College Hospital, London.

CHAPTER XLVI

INJURIES TO BONES

JOHN CHARNLEY

Contusion of bone is encountered where bones are subcutaneous, and is therefore most commonly seen on the shin. A small subperiosteal hæmatoma is produced, which usually subsides rapidly, leaving no residual mark. In a few cases a small bony boss may develop in the hæmatoma, but this will cause no trouble; sometimes the hæmatoma may become infected from an overlying abrasion.

Treatment is usually unnecessary; resorption is helped by rest and a pressure dressing.

FRACTURES

Fractures are caused by two types of mechanical violence—*direct* violence, as by a local blow; and *indirect* violence, as by a bending or twisting force applied to the limb at a point remote from the site of the fracture.

VARIETIES OF FRACTURE

A large number of descriptive adjectives are used to qualify and describe fractures; the most important of these are:

(1) *Simple* (*syn.* 'Closed')—meaning that the fracture hæmatoma is not exposed to infection. A fracture may still be 'simple' or 'closed,' in the presence of a large skin wound, if the wound does not actually communicate with the fracture.

(2) *Compound* (*syn.* 'Open')—meaning that the fracture communicates with the external air. Infection is the obvious danger. Indirect violence extrudes a bone-end through skin which was intact at the moment of fracture; direct violence, as by a missile or machinery, breaches the skin before the fracture is sustained. The former is usually less contaminated by bacteria, clothing, or road-dirt than the latter.

(3) *Comminuted.*—The bone is broken into three or more parts.

(4) *Transverse or Oblique.*—Descriptive of the shape of the bone-ends.

(5) *Spiral.*—Sometimes mistaken for oblique. Interesting to recognise in that, more than with any other shape of fragment, the violence causing it can be deduced accurately, i.e. torsion.

(6) *Greenstick.*—A type of fracture only occurring in children. The bone bends and stays bent; one cortex remains intact, while the other crumples or cracks (fig. 1491).

(7) *Impacted.*—One fragment is driven into the substance of the other fragment, so that no abnormal mobility will be evident. Impacted fractures

are usually seen where a shaft of cortical bone joins the cancellous bone forming the expanded extremity of the shaft; the dense cortical bone is thus impacted into soft cancellous bone. Two cancellous fragments can impact

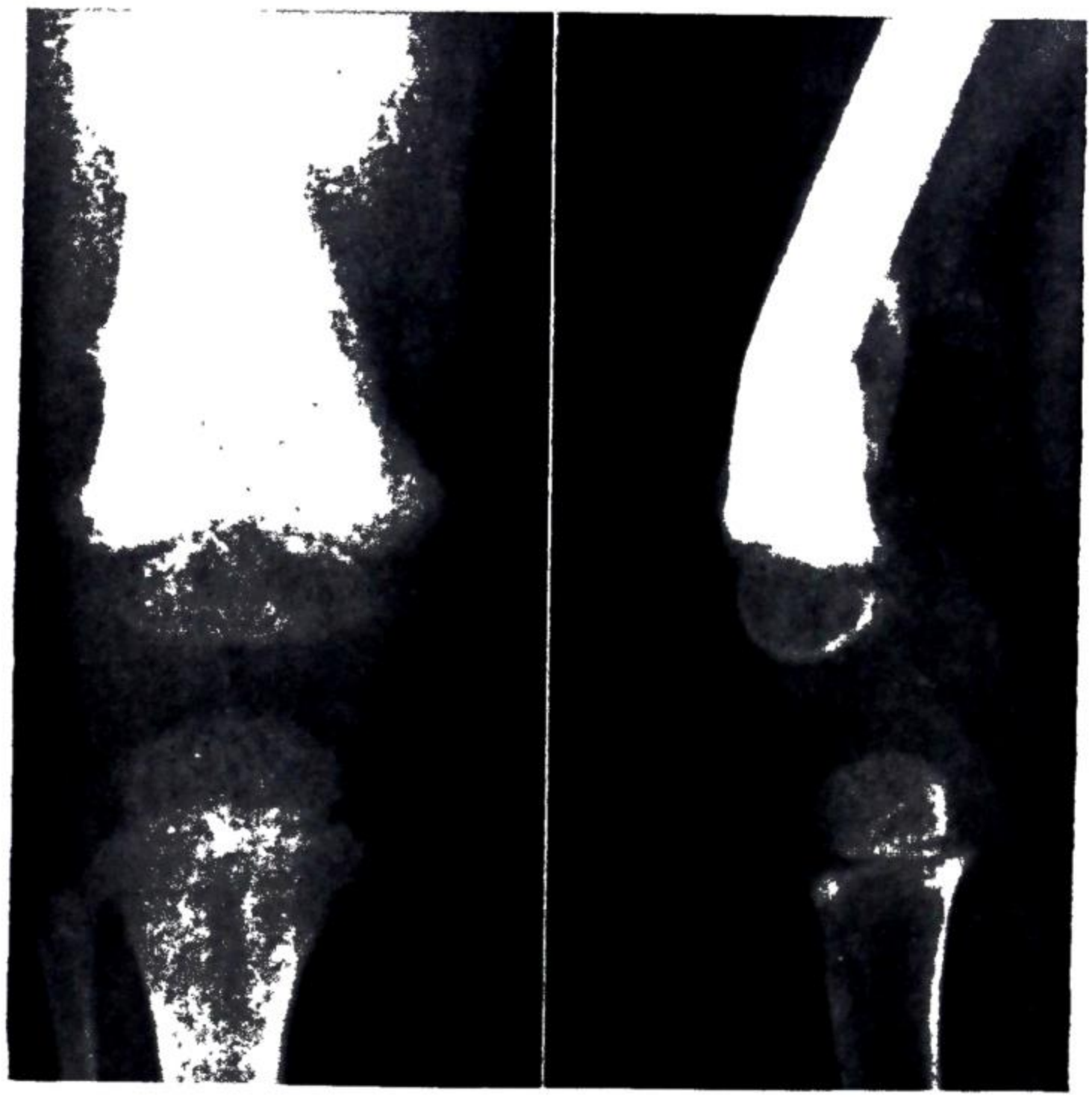

FIG. 1491.—Greenstick fracture of femur.

one into the other, as in fractures of the spinal vertebræ, but two cortical fragments cannot impact.

(8) *Complicated.*—Associated with nerve or vascular injuries or injuries of adjacent viscera.

(9) *Pathological.*—Where disease renders the bone abnormally brittle, as in Paget's disease, or has eroded the bone, as in secondary carcinomatosis.

(10) *Fatigue* fractures are rare fractures where a bone, which is otherwise apparently normal, develops a minute crack in the course of ordinary use, e.g. 'march' fracture of the second or third metatarsal bones.

THE SIGNS OF FRACTURE

There are five clinical signs indicating a fracture in addition to the pain, swelling, and bruising which can be present without a fracture:

(1) Deformity.
(2) Abnormal mobility.
(3) Crepitus.
(4) Loss of function.
(5) Local bone tenderness.

In a fracture of the midshaft of the femur or the humerus, all of these physical signs will easily be elicited, but there are many other examples

where only some of these five signs are represented. Which is the most important sign of the five? Let us examine each sign in detail.

(1) *Deformity*.—Though deformity is usually characteristic of a fracture, a bone can be broken without any deformity. Deformity means that the soft parts, the fascia, intermuscular septa, etc., have been so extensively torn that the fragments are able to separate from each other. The fragments can be *angulated* in relation to each other, *displaced laterally*, or they can even *over-ride*, in which case *shortening* will be present. If the violence has been expended entirely on breaking the bone, the soft parts will be intact and the fracture will often remain *undisplaced*.

(2) *Abnormal Mobility*.—This is characteristic of a fracture; the limb wobbles about and can be moved in a direction which is anatomically impossible. Abnormal mobility is, however, absent in *greenstick* and *impacted* fractures.

(3) *Crepitus*.—This is the grating sensation imparted to the examining fingers when the bone-ends move against each other. It is an absolute proof of fracture, but it can be elicited in only a minority of cases, because it usually evokes intense pain (though not much pain in the period of slight shock following immediately after the injury). Crepitus is never present in *greenstick* and *impacted* fractures.

(4) *Loss of Function*.—This might appear at first sight rather obvious. It is, however, a subtle point when all the other clinical signs of fracture seem to be negative. Thus a patient who has sustained an injury which could have fractured the pelvis, even in the absence of physical signs, probably has such a fracture, *if he cannot walk*. Unlike sprains or bruises of soft parts, fractures involving the extremities render it impossible for the patient to exert any significant force by pushing or pulling against resistance (i.e. loss of function, though not necessarily complete loss of the ability to move).

Impacted fractures may present great difficulty in clinical diagnosis. Not infrequently this injury is missed even by experienced general practitioners in obstinate old ladies who will try to walk, though with a severe limp, on an impacted fracture of the femoral neck. It is to be noted, however, that in these 'missed' cases the patient is unable to walk in the days immediately following the injury. In the absence of obvious signs suggesting a fracture, the difficulty in walking is erroneously attributed to the effects of a 'bruise,' and the fact that the old lady cannot take weight on the limb is sympathetically attributed merely to her age and frailty. In these cases the fracture is frequently only suspected two or three weeks later, at which time a patient with a contusion ought to be able to walk quite easily. Though the clinician will be alarmed for his own reputation in having 'missed' an impacted fracture, he can be consoled with the knowledge that, as far as the welfare of his patient is concerned, only rarely is subsequent drastic treatment required.

(5) *Local Bone Tenderness*.—If bone tenderness can be demonstrated, and is accurately localised to that part of a bone where a classical fracture occurs, it is highly probable that an impacted fracture is present, *even though all other signs of fracture are lacking*. Thus an elderly woman who

falls on her outstretched hand and sustains an impacted Colles fracture with trivial displacement will have : (1) no deformity ; (2) no abnormal mobility ; and (3) no crepitus. The fact that she will have (4) loss of function in that she cannot exert any grip may be attributed to contusion and its significance overlooked. But if she has (5) tenderness localised to a point approximately ¾ to 1 inch (2 to 2·5 cm.) above the radial styloid, then this patient has an impacted Colles fracture.

What, then, is the most important sign of a fracture? In most fractures with abnormal mobility and deformity the problem does not arise. In impacted fractures, local *bone tenderness* is the most important clinical *sign* ; loss of function is the most important *symptom*.

Other Signs of Fracture.—Three other clinical signs exist which are strongly suggestive of fracture :

(1) *Shock*.—Though by no means a constant finding, patients who sustain fractures in parts not easily examined clinically, such as the pelvis or spine, are frequently more shocked after the injury than might be expected from a bruise. The old lady with the impacted fracture of the neck of the femur will usually have signs of shock, and therefore not much pain for some hours after the injury, and the doctor can move the limb about without her showing much obvious discomfort.

(2) *Ecchymosis*.—Discoloration of the skin which comes to the surface seven to ten days after an injury and at some distance from the site of injury is strongly suspicious of a fracture. A contusion will cause local discoloration almost immediately after the injury and at the site of the contusion. Dislocation will also be followed by late ecchymosis in parts distal and dependent from the injury.

(3) *Fracture Blisters*.—Undiagnosed and neglected fractures often proclaim themselves to the experienced eye by the appearance of cutaneous vesicles, not unlike those of second-degree burns. The vesicles appear four or five days after the injury, when the skin is unsupported by the pressure of external dressings. They are most commonly seen below the knee in fractures of the tibia, ankle joint, and tarsus (particularly the os calcis). It is important to use pressure dressings as first-aid treatment of fractures to prevent these blisters because, if neglected, they may become infected and possibly involve the underlying fracture.

Radiographic Proof of Fracture.—It cannot be too strongly emphasised that even in cases in which there is but the merest possibility that a bone is fractured, an X-ray of the whole bone should be taken in at least two planes. Otherwise the ' reasonable skill and care ' of the practitioner may be questioned, and no other branch of surgery is more damaging to a practitioner's reputation. A wise and experienced Irish surgeon taught his pupils that " bones are not filled with red marrow, but with black ingratitude."

UNION OF FRACTURES

The dense bone which composes the cortex of a long bone is very complex in its minute structure, resembling, in fact, a piece of ' plywood ' in that

it has a large number of layers which are laid down so that the fibres of each layer cross those in the next layer. Great strength is thus obtained with minimum weight. It is obvious that to lay down a specialised tissue like this cannot be done quickly, and thus the complicated stages of fracture healing arise from the fact that the ' callus ' which holds the bone-ends together is a primitive tissue comprising a series of transitional tissues, each one of which is stronger and denser than its predecessor. Thus the hæmatoma between the bone-ends is first replaced by a delicate spindle-celled tissue capable of progressing to mature fibrous tissue, cartilage, fibrocartilage, and bone. The texture of callus is unlike the bone of the original shaft in that it has no ' plywood ' structure. The later stages of union are concerned with the removal of the temporary callus and its replacement by permanent ' lamellar ' bone.

In cases where union is slow, the first primitive tissue passes not to bone but to mature scar tissue, thus giving a ' fibrous ' union. In other cases of slow union the first primitive tissue may specialise into cartilage and synovial membrane and a ' pseudarthrosis ' may result.

The factors responsible for delayed union seem to be local factors in the fracture itself. Diet, systemic disease, and vitamin deficiency have all been incriminated from time to time, but the fact remains that delayed union of the tibia is exceedingly common in healthy men of military age, whereas old and debilitated subjects often unite their fractures quite well. If the cause of delayed union were systemic, how could one explain the common fact that a patient sustaining two fractures at the same accident may have rapid union in one fracture but non-union in the other ?

Tests for Union.—In describing the state of union at any moment, the physical state of the fracture is conveniently labelled by the following three terms :

(1) ' *Trace of Give* ' or ' *Sticky* '—Here the fracture is not freely mobile, but careful examination will suggest a few degrees of movement. The movement here is so slight that it may even be disputed by different examiners. Sometimes this movement is present only in one plane if the fractured bone is splinted by another intact bone; thus the fibula splints and masks movement in the tibia. Union here is only by fibrocartilage.

(2) *Clinically United.*—The fracture feels solid when strained vigorously by the examining hands. The fracture will still be clearly visible in the X-ray, but it will be surrounded by a haze of bony callus.

(3) *Radiological Union* or *True Bony Union.*—Here the fragments of the original fracture are no longer clearly visible and, at least in some part of the fracture, a newly formed piece of cortex can be seen running continuously across the site of the injury. The external callus originally seen as a haze outside the fracture will now have disappeared.

In deciding when to abandon splintage and when to permit graded use of the limb, we usually accept the clinical tests for union without too much dependence on X-ray. On the other hand, we wait for radiological proof of true union before permitting the patient to take dangerous strains on the

clinical union and especially, in the case of the long bones of the lower extremity, before discarding crutches completely.

The tests for clinical union are, of course, the converse of the Five Signs of Fracture: i.e. (2) no abnormal mobility (i.e. not even 'sticky'); (3) no crepitus; (4) return of function; (5) no local tenderness over the callus. Where is (1)?—if the fracture has been adequately treated, there should be no deformity!

First-aid Treatment of Fractures.—The cardinal principle is to immobilise the joint above and below the fracture. In the upper extremity, being relatively light in weight, the arm can be held to the side of the body with slings and bandages, and the forearm is splinted against any flat piece of wood suitably padded. The elbow and shoulder may need a sling. The lower extremity is best splinted on a Thomas splint passed over the outside of the trousers and held on with a clove-hitch round the boot (but not left in strong traction for more than about four hours or the skin on the dorsum of the foot may slough). The tibia and ankle is easily splinted with a wooden 'back splint and footpiece,' but take care to protect the heel from pressure sores.

Care should be taken not to convert simple fractures into compound fractures, and bones protruding through the skin should not be reduced at the scene of the accident, but the whole wound should be dressed with some bland antiseptic such as Dettol, Cetavlon or acriflavine.

PRINCIPLES OF THE TREATMENT OF FRACTURES

The treatment of a simple fracture falls under three headings, i.e. (1) reduction; (2) fixation; and (3) rehabilitation.

(1) **Reduction.**—A fracture needs reduction only if it is displaced. Not so obvious is the degree of displacement which can be tolerated without reduction being necessary. Speaking very broadly, reduction is needed only if deformity can be detected on clinical inspection; there are many exceptions to this sweeping statement, but the principle is still true that we do not reduce X-rays but only clinical deformities.

We do not reduce fractures to make them unite; we reduce them so that when they are united they are in good position for function. Unreduced fractures often unite very quickly, but they give deformity—i.e. 'mal-union.' Fractures fussily over-treated by elaborate mechanical means in order to get a perfect radiological reduction often unite with the greatest difficulty. To some extent non-union is a product of civilisation; rapid mal-union is the natural state of the uncivilised fracture.

Reduction cannot be achieved with accuracy unless muscle spasm is abolished by anæsthesia. The manipulative reduction of a fracture is always easier if done without unnecessary delay, before the surrounding tissues have become swollen and turgid.

(2) **Fixation.**—In most fractures the reduced position can usually be maintained by the use of a skilfully applied plaster cast, in spite of the return of normal muscle tone which follows recovery from anæsthesia. Fractures of the shaft of the femur are, however, a special exception, being unsuitable for this

sequence of 'manipulative reduction and plaster fixation,' because the powerful thigh muscles will continue to cause shortening and because the soft tissues of the thigh are so bulky that no plaster case can control the contained fragments. This is an instance where continuous traction must be employed to keep length.

The technique of manipulative reduction and plaster fixation can only be learned by apprenticeship, but certain guiding principles are worth stating:

(*a*) Displacement indicates the tearing of soft parts which allow the fragments to move away from each other.

(*b*) Usually the torn tissues are confined to one side of the fracture—the *convex* side.

(*c*) By making use of the intact tissues on the *concave* side of the fracture, the fragments can be aligned to each other.

(*d*) Reduction consists of attempting to hold the fracture in an 'over-corrected' position; by this means the intact tissues are stretched and the torn tissue relaxed.

(*e*) Fixation by plaster is based on perpetuating the slightly over-corrected position by moulding the plaster. Therefore, paradoxical though it may sound, it needs a plaster slightly curved in the direction of over-correction to produce a straight limb (fig. 1492).

(*f*) Plasters which exert a positive moulding force do not exert an even pressure over the whole surface of the limb. A positive moulding force can always be resolved into a 'three-point' system, where the two distal points of pressure simulate those applied by the surgeon's hands, and the third point is situated proximally in the plaster towards the root of the limb.

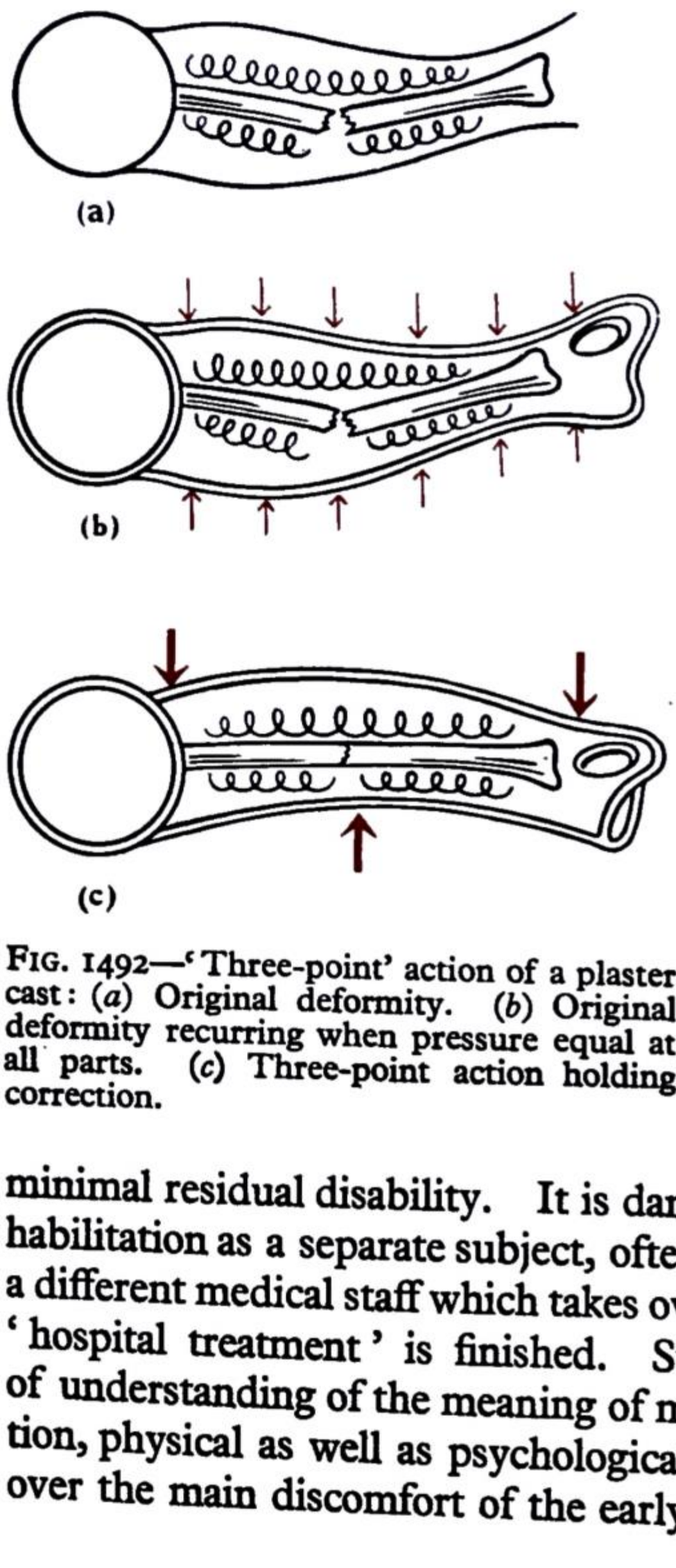

FIG. 1492—'Three-point' action of a plaster cast: (*a*) Original deformity. (*b*) Original deformity recurring when pressure equal at all parts. (*c*) Three-point action holding correction.

(3) **Rehabilitation.**— The general principle and aim of rehabilitation is to return the injured person to work in the shortest period, with the minimal residual disability. It is dangerously easy, however, to think of rehabilitation as a separate subject, often in a different building, generally with a different medical staff which takes over the patient when the main part of the 'hospital treatment' is finished. Such a concept shows a complete lack of understanding of the meaning of modern fracture treatment. Rehabilitation, physical as well as psychological, should start as soon as the patient is over the main discomfort of the early days of treatment.

Böhler was the first to teach the importance of encouraging the patient to "use the splinted limb" (figs. 1493 and 1494). By this means the circulation of the limb is maintained, atrophy of muscles is minimised, and the duration of joint stiffness is reduced. In other words, this teaching emphasised that the ill-effects of prolonged disuse are avoidable. Böhler

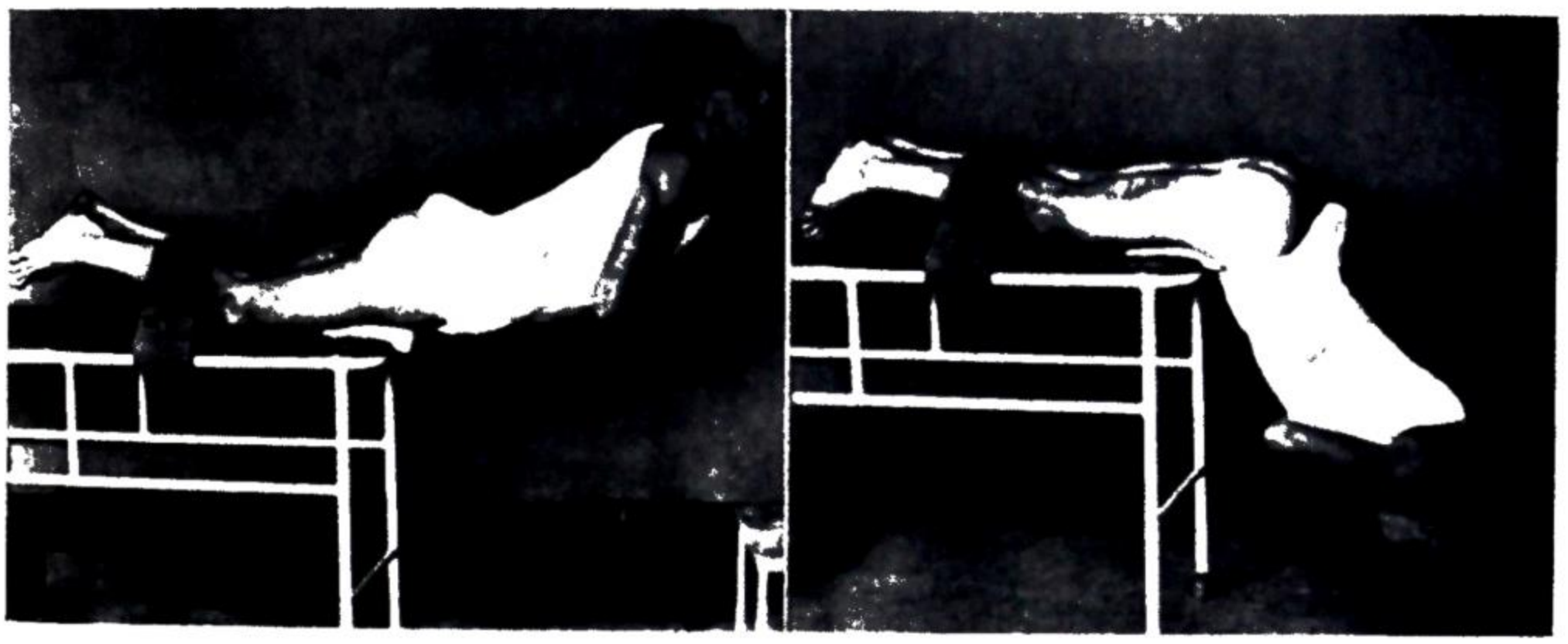

FIG. 1493.—Rehabilitation in plaster—extreme example. *(Lorenz Böhler.)*

vigorously drove home the lesson that many bad results of fracture treatment were not the results of the fracture itself, but the results of bad splintage.

The first step in rehabilitation is therefore the training of the surgeon to apply a plaster which will be comfortable and which will, at the same time as immobilising the fracture, permit the limb to be used. Pain from a bad

FIG. 1494.—A rehabilitation class.
(Pilkington Bros., Ltd., St. Helens.)

plaster, or a joint fixed in an unsuitable position, may make it impossible for the patient to follow the surgeon's command that he should "use the splinted limb." Thus, to take as an example a fracture of the forearm, the shoulder should be exercised from the start, the wrist should be fixed in the anatomical position of 'cock-up,' and, whenever the fracture will allow, in the middle position of rotation; similarly, the plaster should be so moulded round

Lorenz Böhler, Contemporary. Director, Hospital for Accidents, Vienna.

the fingers and palm that it is possible to use fingers without restriction. In the lower extremity, the foot should as far as possible be fully plantigrade and a good walking heel should be used so that the patient can walk with a normal 'heel-and-toe' action. A pressure sore from a badly fitted plaster may render it impossible for the patient to use the limb.

While still in plaster, patients should be made to attend fracture rehabilitation centres in groups and classes. The physiotherapist or remedial gymnast can then scrutinise their attempts to use their spiinted limbs and encourage the weaklings. The psychological aspect of this type of rehabilitation is of paramount importance ; cheerful personalities in the fracture team, interested in patients as human beings, get patients back to work more quickly than gloomy intellectuals who concentrate on X-ray appearances and interesting complications. By all means let surgeons encourage the honest intellectual approach and let us candidly discuss our not-so-good results, but never let it be done in the hearing of the patient. With many patients one careless word may hold up rehabilitation for very many months.

Under this régime the fractured limb will do more than half its rehabilitation while still inside the plaster. The plaster should be retained until the patient can walk in it almost as well as in a boot, so that when the plaster is removed he should be able to walk away with relatively little difficulty. This idea of functional activity in plaster thus puts the patient in the position of merely requiring the residual stiffness removed in the rehabilitation centre. This is quite a different story from that of those rehabilitation centres which see the patient for the first time weeks after the injury, by which time they are faced with the almost insuperable problem of overcoming both the physical and the mental ill-effects of mediocre treatment.

Close liaison with an almoner during this phase is important in solving financial and domestic worries produced by the accident and which if allowed to persist may have an ill-effect on recovery.

Under the emergency conditions of war, where large groups of patients lived together in communities away from their homes, rehabilitation was much easier to organise than in peacetime. Organised games play a very useful part in rehabilitation. Billiards, darts, quoits, skittles, etc., interest most patients. Competitions can be arranged, during the excitement of which a patient will often involuntarily exercise a limb far more efficiently than if he were conscious of his effort.

Vocational training is provided by the Ministry of Labour for patients who have suffered from permanent disability, as a result of which they cannot follow their original employment.

COMPLICATIONS OF A FRACTURE

The complications of a fracture are general and local.

1. General

(1) *Surgical Shock.*—Shock which does not recover within an hour of injury by such simple methods as heat, morphia, and splintage is probably of

the 'oligæmic' variety. A fracture of the tibia rarely produces severe shock, because not much blood is lost locally in the calf; in the thigh, on the other hand, as much as 3 pints (1·7 l.) of blood can be accommodated without arousing any more comment than the fact that the thigh is very swollen. To give an anæsthetic to such a case, too early and without fluid replacement, may abolish the vaso-constrictive mechanism keeping up the blood pressure, and a fatal fall of pressure may occur.

(2) *Fat Embolism.*—In its clinicaliy diagnosable form fat embolism is a rather rare condition following a fracture of a large bone after an interval varying from a few hours to two or three days. Fat globules get into the circulation and pass into the brain, causing convulsions and coma. Occasionally it has been reported after soft part injuries without a fracture. Fat embolism is diagnosed by the appearance of petechial hæmorrhages in the skin, usually in the front of chest and face, and also, and very characteristically, in the conjunctivæ. Fat globules can sometimes be found in the sputum and urine. In the absence of gross petechiæ the condition is probably much commoner than previously suspected and may be responsible for many cases of fatal shock which do not respond to repeated transfusions, and it may also be responsible for the fits and coma attributed in the past to 'delirium tremens.'

(3) *Hypostatic Pneumonia.*—This is particularly liable to occur in elderly patients confined to bed for the treatment of fractures of the neck of the femur.

2. Local

The local complications of a fracture can be summarised :

1. Nerve injury	early
2. Arterial injury	early
3. Infection	early
4. Avascular necrosis	late
5. Ischæmic contracture	late
6. Delayed union	late
7. Non-union	late
8. Mal-union	late
9. Pressure sores	late
10. Joint stiffness	late

(1) **Nerves.**—Nerves, particularly those which lie adjacent to bones, are liable to be involved as a result of contusion, traction, or laceration by the jagged fragments. Appropriate tests should always be carried out when the patient is first seen in order to test the function of any nerve which may have been injured.

Contusion, which gives rise to transient block (neurapraxia) is the commonest lesion, and recovery usually occurs within two or three weeks.

Axonotmesis, or lesion in continuity, occurs if a nerve is crushed so that the axis cylinders only are damaged. The sheath of the nerve is intact, so a

good functional result is to be expected after a few months as axons reunite with a minimum of ' shunting.'

Neurotmesis, or complete division of the nerve, only occurs when there is considerable displacement of fragments.

Nerves which are frequently injured at the time of the fracture are the median, in the case of supracondylar fracture of the humerus, and the radial in fractures of the shaft of the humerus as it lies in its groove on the bone.

(2) **Blood-vessels.**—Arteries or veins are sometimes ruptured at the time of the fracture. Vessels are occasionally occluded by spasm due to bruising, or by the pressure of displaced fragments. The commonest example is occlusion of the brachial artery in association with supracondylar fractures of the humerus, but pressure on the popliteal artery by the diaphysis of the femur in the case of separation of the lower epiphysis may also occur. If the circulation of the limb is unsatisfactory after reduction of a fracture, exploration of the adjacent artery is often advisable if attempts to block the sympathetic chain with local anæsthetic have produced no improvement (p. 1171).

(3) **Infection.**—The infection of a compound fracture is a very serious matter because, if osteomyelitis results, there may be a persistent discharge of pus for months or even years. With antibiotics and the ability to operate within a few hours of the injury, the serious effects of osteomyelitis are much less common than formerly. Before the advent of antibiotics, infected compound fractures were particularly prone to *secondary hæmorrhage* by the erosion of a large vessel in the neighbourhood of the fracture ; fortunately this complication is now very rarely encountered.

Sequestration of dead fragments of bone may occur in the course of the later stages of osteomyelitis, and until all the sequestra have been removed, the discharge cannot be expected to stop.

Gas gangrene is a particularly serious complication of a dirty compound fracture, and though this also is less frequently seen to-day than formerly, it still occurs despite the use of antibiotics. The development of gas gangrene is favoured by erroneous judgment in closing wounds which contain large amounts of dead muscle (i.e. deprived of blood supply by the injury), and by failing to search for radio-translucent foreign bodies, such as clothing and pieces of wood, which may be buried in the depths of the wound.

(4) **Avascular Necrosis.**—This occurs when the fracture completely interrupts the blood supply to one of the fragments. The anatomical arrangement of the blood supply to special bones makes this complication common in certain sites, as in the head of the femur after fracture through the neck, and in the proximal fragment of the carpal scaphoid after a fracture through the waist. If the fragments are closely coapted and rigidly fixed the blood supply may re-establish itself, but more often the changes of aseptic death supervene and the bone crumbles and collapses. This is later followed by osteoarthritic changes.

(5) **Ischæmic contracture** is a rare sequel to arterial complication of a fracture. The best-known example, fortunately uncommon, is *Volkmann's*

contracture of the flexor muscles of the forearm after fractures at the elbow or in the forearm in children (p. 1185), but even more rarely it can occur in the leg and calf. If arterial spasm persists long enough to cause aseptic necrosis of the flexor muscles, these will eventually be replaced by scar tissue which will contract. At the same time ischæmia of nerve trunks may cause changes which impair conduction. The reason why the arterial spasm can persist, despite all attempts to dilate the arteries, is still obscure. Though the arterial spasm is usually precipitated by inexperienced handling of a fracture, cases have been encountered where adequate skill and care has been used and undoubtedly cases must exist where the fracture itself is responsible for the initial spasm.

Volkmann's contracture is notoriously prone to follow the reduction of supracondylar fractures in children. The child always has persistent severe pain after the reduction, and the whole of the damage is sustained within the first twenty-four hours after the reduction (and quite probably within six or twelve hours). The hand can be white or dusky. There will be anæsthesia of the whole hand if tested by pinprick (the child, of course, not being allowed to see the pin).

Perhaps the most important physical sign—because if detected early it is still not too late to institute remedies—is inability of the surgeon passively to straighten the patient's fingers and at the same time extend the wrist (fig. 1495). If this can be done, no damage is occurring in the flexor bellies.

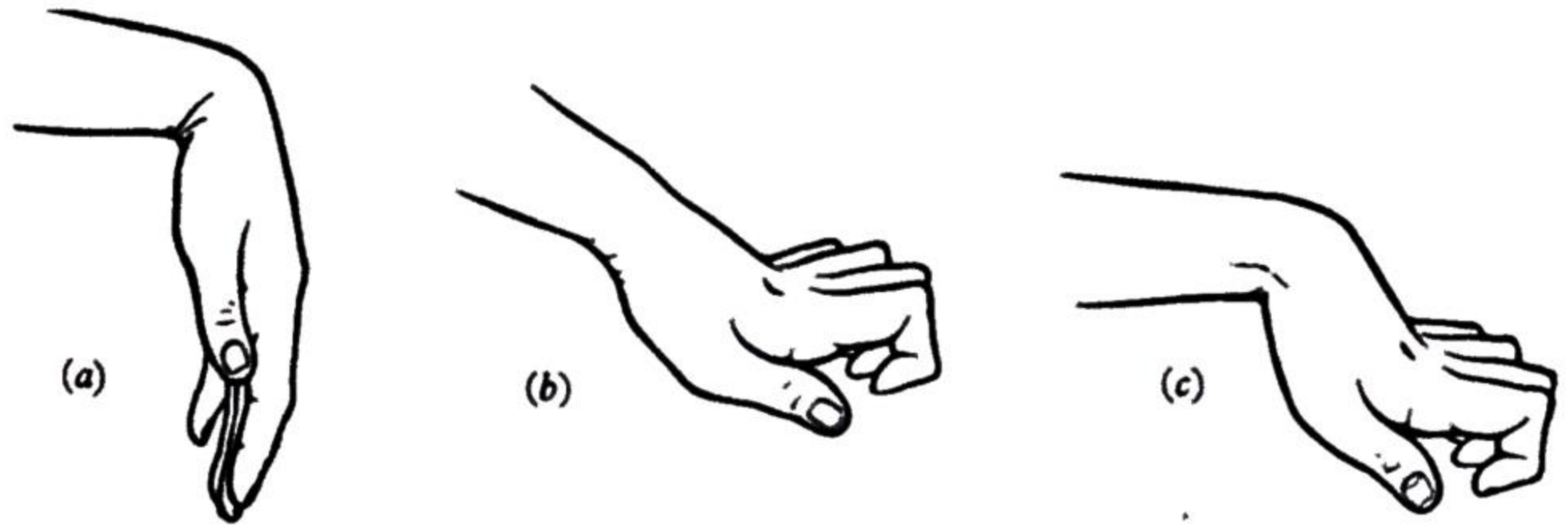

FIG. 1495.—Volkmann phenomenon : (*a*) Mild case : wrist flexed—fingers straight. (*b*) Mild case : wrist extended—fingers flexed. (*c*) Severe case : wrist flexed—fingers flexed.

It goes without saying that the radial pulse will be absent in these threatened cases, but an absent radial pulse by itself need not always cause serious worry if severe spontaneous pain is absent (i.e. not just ' tenderness ' evoked on being touched but spontaneous pain when the limb is immobile) and especially if the fingers can be passively extended. In these cases the local spasm of the brachial artery obviously has not spread to the collateral vessels which is the fundamental danger of a Volkmann's contracture. If the radial pulse is absent, it is important to release the elbow from too acute flexion to see whether this may restore the pulse.

If danger signs are present, the following routine should be adopted : (1) release all flexion from the elbow and allow it to extend beyond the right angle ; (2) immediately block the stellate ganglion with novocaine without any undue delay in trying trivial remedies ; (3) heat the child's body with a radiant heat cradle but expose the naked arm to the air to keep it cool ; (4) administer the latest fashionable drug for vasospasm (in appropriate dosage for a child) ; (5) if all these measures fail after two or three hours, consider exploration of the brachial artery in the antecubital fossa.

It must be confessed that there is not much evidence to show that exploration of the artery often helps very much—it merely exposes to view the vessel in intractable spasm and reduced to the size of a piece of string, but it can be painted with ½ per cent. procaine in an attempt to relax spasm. It is no longer considered wise to perform

Richard von Volkmann, 1830–1889. Professor of Surgery, Halle.

arterectomy on the theory that a damaged segment was the source of irritation causing the spasm.

Late treatment in the established case is mainly concerned with stretching the contracted fingers and preventing further contracture.

Tight Plasters.—Patients have frequently suffered tragic losses of limb, all too often after relatively trivial fractures, and surgeons have had heavy damages awarded against them when there has been evidence of circulatory obstruction after the application of plaster. The problem is complicated because arterial spasm may sometimes, though rarely, be caused by the injury itself, and the surgeon who fails to examine the circulation and sensation in the hand or foot *before* applying a plaster will be unjustly penalised. If a tight plaster, or a tourniquet, is left in position too long, the circulation does not return when the constriction is released because a secondary arterial spasm supervenes, which may resist all measures at relaxation.

Apart from remembering to examine the circulation and sensation before commencing treatment, the most important advice to the inexperienced is not to make the common mistake of thinking that *pain is to be expected* as a normal accompaniment of a recent fracture, either reduced or unreduced. Persistent, spontaneous pain (i.e. not pain evoked merely by movement) is positive evidence of a serious complication, and usually a vascular complication, even if the circulation in the digits 'seems adequate.' Pain after a fracture, especially if it returns in unabated form after partial relief by an analgesic, must be investigated instantly; the mistake must never be made of ordering another dose of analgesic by telephone and 'seeing it in the morning.'

After orthopædic operations it is a sound rule always to split the plaster if the soft tissues of the limb are not already swollen at the time of the operation.

(6) **Delayed Union.**—There are wide variations in the time taken for bone to demonstrate 'clinical union,' and wide differences may occur even in different bones in the same patient. Clinical union should be present in six to ten weeks. If a fracture does not feel solid three months after an injury, we can certainly diagnose 'delayed union.'

Radiographically, the characteristic feature of a delayed union is that no evidence of repair is present. The outline of the bone fragments is almost as clearly defined as in a recent fracture and no callus will be visible. The only indication that the fracture is not recent may be slight generalised disuse osteoporosis. Such a fracture may easily be mistaken for a fracture six weeks old, when in actual fact it is six *months* old; it seems to be 'in cold storage' (fig. 1496 *a*).

Delayed union implies that spontaneous union is still possible, and treatment consists of continuing the fixation and of encouraging the patient to use the limb.

(7) **Non-union.**—'Non-union' is the end-result of a minority of cases of 'delayed union' which do not eventually unite spontaneously by continued fixation. Non-union is a permanent end-result; union can only be obtained if operative intervention is undertaken and some form of bone graft is performed.

Radiographically, ' non-union ' is diagnosed by evidence of sclerosis, by rounding-off of the bone-ends, and by closure of the medullary canal by dense

(*a*)

FIG. 1496.—(*a*) Delayed union—no sclerosis. (*b*) Non-union—sclerosis.

(*b*)

FIG. 1497.—A false joint following an ununited fracture of the shaft of the humerus.

bone at the site of the fracture. In its fully established state (fig. 1496 *b* and 1497) this rounding-off of the bone fragments shows that a false joint or pseudarthrosis has formed. Clinically, a pseudarthrosis is shown by the presence of 5 or 10 degrees of free mobility in a fracture six months or more old. In these cases the false joint is lined with irregular cartilage and contains synovial fluid and synovial membrane.

Causes of Non-union and Delayed Union.—It is customary to mention *general causes* of delayed union, such as old age, debility, vitamin deficiency, and systemic disease, such as syphilis, but none of these are constant factors, and everything seems to point to the greater importance of some local factor.

Local Factors are numerous and may be summarised as follows :

(*a*) Infection.
(*b*) Inadequate immobilisation.
(*c*) Impaired blood supply.
(*d*) Over-distraction.
(*e*) Interposition of soft parts.

(*a*) *Infection.*—Severe osteomyelitis in a fracture undoubtedly delays union, but a mild infection which clears up in a month or two usually is without ill-effect.

(*b*) *Inadequate Immobilisation.*—If the bone fragments are continuously in motion, the new cellular tissue attempting to bridge the gap may develop a plane of cleavage and the attempt to bridge this gap may be permanently foiled by the ends becoming insulated from each other by mature scar tissue. Once this has happened, the bone tends to become rounded off and sclerosed.

Failure of immobilisation, however, does not seem to be the whole story because we know that fractures in the shaft of the femur and the humerus are often capable of uniting in the presence of movement. It seems that certain bones—especially the lower one-third of the tibia—have no natural capacity for generating profuse periosteal callus. In these cases it would seem reasonable that a scanty growth of callus could be compensated by greater attention to immobilisation but, unfortunately, no external splint applied outside the skin (such as a plaster cast) can prevent a certain amount of movement in a fracture.

A fruitful source of non-union, especially at sites such as the lower one-third of the tibia where callus production is scanty, is repeated late attempts to readjust the position of the fracture. Ideally, all manipulations and adjustments to a fracture should be completed within the first week, and thereafter the plaster should be left untouched until the time when the fracture is likely to be clinically solid ; a final change can then be made to a close-fitting plaster in which weight-bearing can be safely permitted.

(*c*) *Lack of Blood Supply*.—In certain parts of the skeleton the fracture will itself deprive one of the fragments of its natural blood supply and so cause non-union. It is doubtful whether any displaced subcapital fracture of the neck of the femur would ever unite without absolute fixation, and the same applies to fractures through the waist of the carpal scaphoid.

(*d*) *Over-distraction*.—A fruitful cause of delayed union and non-union is the excessive use of skeletal traction. Excessive traction pulls the bone-ends apart and so favours the growth of fibrous tissue which insulates the bone-ends from each other. Modern ideas emphasise the use of the minimum traction force to achieve the desired result.

(*e*) *Interposition of Soft Parts*.—Fascia or ligaments appear to be a more effective barrier to the growth of callus across a fracture than the interposition of muscle. Examples of callus growing considerable distances through muscle are not uncommon. In fractures of the patella, the medial malleolus, and the olecranon, a flap of ligamentary tissue is often found to have fallen into the fracture line, so that accurate apposition of the surfaces cannot be obtained unless the flap is removed. Without operation there is a strong tendency for fibrous union in the patella and olecranon, and the fibrous tissue may stretch under the tension of the inserted tendons.

Treatment.—In *delayed union* all that is necessary is to persist with plaster fixation and to encourage the use of the limb. If there is no evidence of sclerosis and rounding-off of the bone-ends, there is always a chance that further fixation will still produce union. If, however, the fracture is rather freely mobile, i.e. is not just ‘ sticky ’ and there exists considerably more than 2 or 3 degrees of movement, it is frequently economically wise to treat the case operatively by bone grafting, as if it were already a non-union, rather than to waste further time and then eventually to find that operative treatment is necessary.

Three techniques of *bone grafting* are in common use :

(*a*) *Massive Onlay Graft*.—A heavy piece of autogenous bone is cut from the

normal tibia and screwed across the surface of the non-union, after preparing a suitable bed. In a number of cases, where the ununited fracture is at the junction of thirds, it may be possible to perform a ' sliding graft ' without taking bone from the opposite leg. In these cases the graft is taken from the longer fragment, slid across the area of the non-union, and recessed into the shorter fragment (fig. 1498).

(*b*) *Cancellous Bone Graft.*—Modern practice is tending to supplant the cortical graft by the cancellous graft because of its greater power of union and its resistance to slight infection. If there is only a little movement in the non-union, the Phemister technique can be used ; the periosteum is elevated on one or two sides of the fracture, without disturbing the fibrous union of the bone-ends, and slices of iliac bone are laid across the non-union and the wound closed. After three months in plaster the fracture will be solid and the site of the fibrous union will disappear slowly and spontaneously. It is to be noted that no attempt is made to resect the bone-ends and cut away sclerosed bone as was often done with massive onlay grafts in the past. Cancellous bone grafting by this technique is a very safe and reliable operation and has a high success rate, even in cases which have only recently overcome local infection (where a massive onlay graft would be disastrous).

FIG. 1498.—Massive onlay cortical bone graft.

(*c*) *Metallic Fixation plus Cancellous Chips.*—If there is excessive mobility at the non-union, it is often desirable to procure fixation by stainless steel or vitallium plates and screws and then to stimulate osteogenesis by means of chips of iliac bone packed round at the same operation.

It takes approximately three to four months for a bone graft to become incorporated and strong enough to abandon all external fixation.

Bank Bone.—Recently there has been a wide use of bone stored in the ' deep-freeze ' refrigerator. This ' homogenous ' bone (commonly ribs removed at thoracoplasty) does not have quite such good powers of incorporation as autogenous bone, and therefore is not to be recommended for non-union in fractures of long bones. Stored bone is, however, very useful in filling gaps, and is apparently successful in spinal fusion, though taking longer to consolidate than autogenous bone.

(8) **Mal-union.**—Mal-union is the union of a fracture in defective position. The two most serious deformities of mal-union are (*a*) angulation and (*b*) excessive shortening. Angulation throws out of line the correct transmission of stress through joints above and below the fracture and, in the lower extremity, leads to osteoarthritis in the disturbed joints. Gross shortening can always be corrected by a raised boot. An adult can usually compensate for as much as ¾ inch (2 cm.) of shortening without needing a surgical raise on the shoe. It is also important to observe that a shortening of 1 inch (2·5 cm.) does not necessarily need the full raise of 1 inch ; in such a case, ½ inch on the heel alone is often enough to avoid a noticeable short-leg dip when walking, and the minimum amount can be determined by experiment.

If angular deformity is great, it will need surgical correction by osteotomy because no surgical appliance can compensate for it.

(9) **Pressure Sores.**—Pressure sores are produced by ridges or local pressure. Ridges are due to the uneven application of a bandage or to the alteration of the position of a joint after a loose plaster has been applied. Local pressure occurs if bony prominences are unprotected, or if pressure is allowed to indent the cast before the plaster has set. Persistent localised

D. B. Phemister, 1882-1951. American Orthopaedic Surgeon, University of Chicago.

discomfort or pain must not be ignored, and the gradual diminution of the pain should not lull the surgeon into a sense of false security, lest it indicates the onset of gangrene (as with gangrenous appendicitis). Recurrence of œdema of the digits after initial swelling has subsided usually indicates a pressure sore. If infection occurs, it can be recognised by a local patch of warmth or discoloration of the plaster, and later by the odour which emanates from beneath it. When a sore is suspected an inspection window is cut in the plaster, and if no sore is discovered the gap is packed with cottonwool and firmly bandaged in order to prevent œdema. If a sore has occurred, the window must be enlarged beyond the area affected, and suitable antiseptic dressings are applied.

(10) **Joint Stiffness.**—Some temporary joint stiffness is to be expected after a fracture ; what is most important is that there should be no permanent stiffness.

Fractures involving joint surfaces, or very close to joints, are more prone to cause stiffness than fractures of the shaft of the bone at a distance from the joint. Thus fractures involving joints must be moved earlier than fractures of the shaft of long bones. Anatomical restoration of joint surfaces by open operation in theory is the ideal procedure if combined with early movement, but strangely it often does not give as good a range of movement as does early movement without operation and with acceptance of some deformity.

INDICATIONS FOR OPERATION ON FRACTURES

The indications for operative intervention in connection with a fracture can be classified as immediate, intermediate, or remote.

Immediate.—(*a*) *Complicated fractures*, as in the case of rupture of, or pressure on, the main vessels of a limb, may require operative intervention in order to control hæmorrhage, or to diminish or obviate the risk of gangrene or ischæmic contracture.

(*b*) *Compound fractures* must be operated upon immediately in order to diminish the risk of infection. Each hour's delay allows infection to become more firmly established and devitalised tissues are particularly susceptible to bacterial invasion. A delay of six hours usually means some degree of infection.

The aims of the treatment in compound fractures have been considerably modified since the introduction of antibiotics. Open fractures received in a fully equipped fracture service within a few hours of injury are nowadays ideally treated by suturing the skin wound and so converting the fracture into a closed fracture. In suitable circumstances skin cover by immediate skin grafting may be advisable. In a few cases (though certainly not as a routine) the experienced operator may with advantage use internal fixation in open fractures, just as he would in fractures which were originally closed.

If the compound fracture is over six hours old, and especially if it is obviously contaminated with road dirt or agricultural earth, it is unsafe to close the wound completely, and this applies even with the protection of antibiotics.

In these cases the Winnett Orr method can be used, following the technique popularised by Trueta in the Spanish Civil War. In this technique the wound is surgically debrided, left open, and packed with petroleum jelly gauze, and the whole limb is fixed in plaster after reduction. The plaster is left untouched for two or three months, and any accumulation of foul-smelling discharges is counteracted by various nursing manœuvres (open-air wards and odour-absorbent dressings containing activated charcoal). When the plaster is eventually removed the gauze will be found to have been extruded on to the surface and the wound itself will appear as a flat area of healthy granulation tissue under which the united fracture is sealed off.

Very severe compound fractures of the leg, if complicated by nerve damage and especially if at the same time it is doubtful whether the blood supply is adequate to nourish the foot, are best treated by immediate amputation without wasting further time. Failure to make a firm judgment in these cases may invite the risk of gas gangrene ; also a limb may perhaps be saved, after weeks of grave illness to the patient, which is of little use and which later must be amputated because it is painful and useless.

Internal Fixation.—It must be confessed that the internal fixation of recent fractures is more often governed by the personal experience of the surgeon rather than by any absolute surgical rules which at the moment can be clearly enunciated. Thus, some surgeons may advise the internal fixation of all fractures of the tibia by plates and screws, while others will not consider the tibia suitable yet will advise the plating of fractures of both bones of the forearm. Sometimes the combination of two fractures sustained simultaneously may be difficult to treat conservatively and the problem is simplified if one of the two is operated on ; thus a fracture of the femur and the tibia on the same side is commonly treated by operative fixation of the tibia and conservative treatment of the femur.

FIG. 1499.—Küntscher intramedullary nail.

Certain fractures give such excellent results by open operation and internal fixation that there is no disputing that these are best treated in this way rather than by closed methods. The best known are :

(1) Fractures of the neck of the femur, (2) the patella, and (3) the olecranon.

The recent introduction of the intramedullary nail (Küntscher) has now gained a permanent place in the treatment of fractures of the shaft of the femur in the *middle and upper thirds*, though it is unsuitable in the neighbourhood of the knee (fig. 1499). It often enables a patient to leave hospital in three weeks and to have a full range of knee movement and a perfectly straight thigh ; the alternative conservative method necessitates three months of bed rest under splintage and a total stay in hospital of four or five months.

Hiram Winnett Orr, 1877–1956. Surgeon, General Hospital, Lincoln, Nebraska, U.S.A.
Joseph Trueta, Contemporary. Professor of Orthopædic Surgery, Oxford.
G. Küntscher, Contemporary. Orthopædic Surgeon, Kiel, Germany.

FRACTURES OF CHILDHOOD

In teaching the principles of fracture treatment, the time-honoured method of dealing with each fracture in turn, interpolating a few paragraphs concerning management when occurring in the child, has serious disadvantages. Childhood fractures are quite different from adult fractures, and the principles of treatment have very little in common with the adult. Moreover, the treatment of childhood fractures is one of utter simplicity (with one or two notable exceptions), and this simplicity is obscured when overshadowed by the complex problems of the adult fracture.

The simplicity of fracture treatment in the child is the result of the following features :

(1) Delayed union practically does not exist. In childhood all the osseous tissues (endosteum, periosteum, and possibly even the cortex itself) are strongly osteogenic and callus can bridge wide gaps. There are only two exceptions to this statement : non-union of the capitellum (due to rotation of the fragment out of the elbow joint) and ' congenital pseudarthrosis of the the tibia,' which in all probability has some obscure pathological basis.

Fig. 1500. — Overriding femur in child age 6 with 1¼ inch (3·2 cm.) shortening; was eventually neutralised by increased growth.

(2) Permanent joint stiffness is unknown. Thus prolonged fixation (if ever needed) can be countenanced and early movement is unnecessary.

(3) Spontaneous correction of deformity. The younger the child the more easily does a fracture deformity diminish or even disappear. A child of five years, unlike an adult, will not have the same bones by the time he has reached fifteen or twenty years of age.

It is sometimes stated that at all costs *angular deformity* should be corrected because this might persist. Though a *severe* angular deformity may never completely disappear with growth, it will certainly diminish to some extent. The nearer the age of the child to puberty the less the chance of complete correction. The fear of angular deformity in children arises from the unwarranted belief that growth will continue *in the line of the deformity*, in which case it would obviously get worse.

Spontaneous Correction of Length. — In a growing child some obscure mechanism exists which stimulates the growth of an extremity which has been made shorter than its fellow by an over-riding fracture. The success with which this occurs depends on the age at the time of the fracture (fig. 1500).

Ease of Manipulation.—The *greenstick* fracture of children is malleable, and even when it is converted into a complete fracture by over-correcting the deformity there is much less tendency for the fracture to become displaced as in adult fractures. The reason is that the child has

relatively much stronger connective tissues, and the periosteum is absolutely stronger than that of the adult as it is five or six times thicker and very much tougher.

Epiphyseal Arrest and Ischæmic Necrosis.—It might be thought that danger to growth by involvement of epiphyses would be common. In fact it is very rare—the only well-recognised site being the uncommon complication of fracture through the lower tibial epiphysis. Similarly, ischæmic necrosis of epiphyses might be imagined as a likely sequel, but in fact it is exceptionally rare in children after injury.

Immunity of Certain Bones.—In children some of the sites which cause the greatest trouble in adults are immune from fracture. Thus the spine in children is so resilient that after ordinary injuries it is almost never fractured and paraplegia is practically unknown. Similarly, the pelvis is seldom injured and visceral complications are remarkably rare, even after being ' run over ' by car wheels. The carpal scaphoid never fractures in young children and so never suffers from ischæmic necrosis.

Difficult Childhood Fractures.—There are two common fractures in childhood likely to cause difficulty ; i.e. the supracondylar fracture of the humerus (p. 1185) and the fracture of the capitellum (p. 1187). In the former the vascular complications are the main problem ; in the latter the late development of cubitus valgus and late ulnar paralysis (p. 1319). A much rarer injury than either of the preceding, though very sinister when it occurs, is separation of the lower femoral epiphysis. This can cause pressure on the popliteal vessels and gangrene of the foot.

SPECIAL FRACTURES

FACIO-MAXILLARY

The **Maxilla** is fractured as a result of a direct localised blow, or a portion of the alveolar border is broken off in efforts to extract a tooth. In the former case comminution is probable, and the fracture is frequently compound, on account of involvement of the maxillary antrum. If the fracture extends to the alveolar border, crepitus can usually be elicited and dental occlusion is impaired. Treatment consists in mouth-washes, and if the alveolar border is involved, a dental splint is advisable. Complications which sometimes follow are extensive extravasation of blood, surgical emphysema, infection, necrosis of bone, and aspiration pneumonia.

FIG. 1501.—Elevation of a fractured zygoma.

The **Zygomatic Arch** may be fractured and depressed by a direct blow. The important physical signs indicating the necessity for reduction are : diplopia and obstruction to opening of the mouth. Unsightly deformity results, and anæsthesia of the cheek may occur owing to pressure on the infraorbital nerve. Pain on mastication is commonly noticed. A small incision is made in the hair margin above the bone (fig. 1501), through which a blunt instrument is inserted. This is manipulated beneath the arch so that the fragments can be elevated. Reposition of the depressed arch should always be performed, otherwise the cheek is permanently flattened.

The **Nasal** bones are commonly fractured as a result of direct violence. The fracture usually occurs near their lower margin, but in more severe injuries the root of the nose may be driven in towards the base of the skull. In these cases the septum is commonly fractured and displaced. Epistaxis, considerable swelling, and surgical emphysema may result. Consolidation speedily occurs, hence replacement should be undertaken without undue delay, although reduction may be successful within two weeks of the injury. Under anæsthesia one blade of a pair of long forceps, protected with rubber tubing, is introduced into each nostril alternately, and the fragments levered into position. It may be necessary to exert external digital pressure on the fragment in the direction of the deformity, so as to disimpact it, before reduction is possible.

The **Mandible** is usually fractured in one of three situations (fig. 1502):

(1) The *neck of the condyle* is occasionally fractured, in which case it is displaced forwards and inwards by the pull of the attached external pterygoid muscle. Localised pain occurs on movements of the jaw, and crepitus is detected by the patient or surgeon.

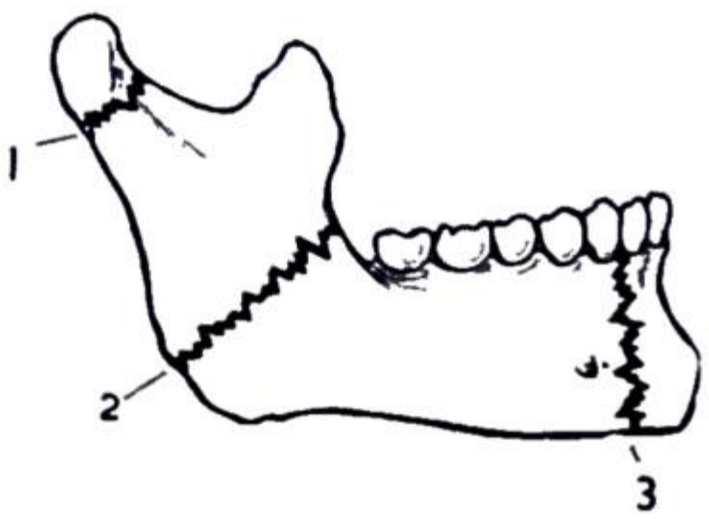

FIG. 1502.—Lower Jaw.
1. Neck of condyle.
2. Through the angle or ascending ramus.
3. Commonest site, anterior to the mental foramen, through the canine fossa.

(2) The *ascending ramus* may be fractured, usually in the region of the angle of the jaw. Little displacement occurs, as the masseter on the outside and internal pterygoid muscle on the inner aspect sandwich the fragments between them. The injury is suspected on account of persistent localised pain, and is confirmed by an X-ray. Mastication is limited to soft food for three weeks.

(3) The *body of the jaw* is the part most commonly fractured, sometimes as the result of a blow with a fist. The fracture frequently occurs at the site of the socket of the canine tooth, the cavity of which weakens the bone, and also this region is the junction of two curves. Occasionally the fracture is bilateral, in which case the central portion of the jaw is displaced downwards by the anterior belly of the digastric muscle and the muscles attached to the genial tubercles. Owing to the firm attachment of the mucoperiosteum to the bone, the fracture is nearly always compound.

Diagnosis is usually obvious, as speech and swallowing are impaired. Blood-stained saliva trickles from the mouth, and irregularity of the line of the teeth is apparent. Crepitus can be elicited with ease.

Treatment.—As a first-aid measure the fracture is supported by a barrel bandage,[1] which is a great improvement on the 'four-tail' method, in that it supports the jaw without any backward pull, which pull maintains the deformity instead of overcoming it. A 2-inch (5 cm.) bandage is used. It is passed under the jaw so as to support it firmly, and tied in a simple knot over the vertex. The knot is then opened, and one loop is manipulated over the forehead and the other over the occiput. The twist in the bandage on one

[1] So-called, as it is the method by which draymen secure barrels when lowering them into vaults.

side thus comes to lie above one ear, and on the opposite side the long end of the bandage is passed beneath the part encircling the head so as to form a corresponding twist. The two long ends are then tied over the vertex (fig. 1503).

FIG. 1503.—The barrel bandage.

As soon as possible the patient is referred to the dental surgeon for fixation, the most satisfactory appliance being an interdental splint which fits over the teeth adjacent to the fracture. A corresponding splint is fitted to the upper jaw, so that fixation of the two splints secures immobilisation. Any obviously infected teeth, or an interposed tooth, are removed when the splint is being fitted.

As the fracture is compound, infection from the mouth is likely, particularly if pyorrhœa or infected teeth are present. Warm antiseptic mouth-washes are therefore used almost continuously. The diet is confined to fluids, which are taken temporarily through a rubber tube.

Complications are mainly due to infection. Thus necrosis of bone and delayed union are not uncommon, while submaxillary cellulitis may require operative interference. Aspiration pneumonia is a grave danger, particularly in old or alcoholic patients with pyorrhœa.

UPPER EXTREMITY

The **Clavicle** is the commonest long bone to fracture, indirect violence by a fall on the shoulder, usually at sport, being the usual cause. Fractures occur in two principal situations (fig. 1504):

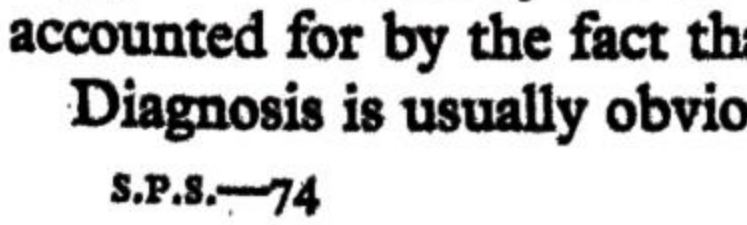

FIG. 1504.—Clavicle.
1. Acromial end.
2. Commonest site, at junction of outer flattened and inner pyramidal portions.

(1) *Acromial End.*—Displacement is slight in this position because the fracture occurs between the trapezoid and conoid ligaments, and thus the two fragments are held in position. Localised pain and tenderness suggest the presence of the fracture, which often requires a radiograph for confirmation. The application of strapping and a sling for three weeks is adequate.

(2) *Greater Convexity.*—This is an exceedingly common fracture, and is usually due to indirect violence, such as falls on the hand or shoulder. It is frequently met with in the hunting-field and on the football ground.

A greenstick variety occurs in children, and is liable to be overlooked, but the definite localised tenderness and reluctance to move the arm should suggest the necessity for an X-ray. The frequency of fracture at this site is accounted for by the fact that it is the junction of two curves.

Diagnosis is usually obvious, even at a distance, as the patient is seen sup-

porting the elbow on the injured side with the opposite hand, and flexing his head to the affected side in order to relax the sternomastoid muscle. The outer fragment is displaced in three directions—downwards by gravity, forwards by the pull of the pectoral muscles, and inwards by contraction of the muscles inserted into the bicipital groove of the humerus, notably the latissimus dorsi. The inner fragment is tilted slightly upwards by the sternomastoid muscle, and is made the more prominent by the displacement downwards of the lateral fragment.

If displacement is slight, all that is necessary is to place a pad in the axilla, steady the fragments by passing strapping over the site of fracture, and apply a sling for three weeks. If deformity is pronounced, the Three-slings Method is adopted.

The Three-slings Method.—Though a number of rather elaborate splints have been devised in an attempt to introduce an element of precision into the treatment of a fractured clavicle for general use, it is difficult to beat the simplest method of all, the Three-slings Method.

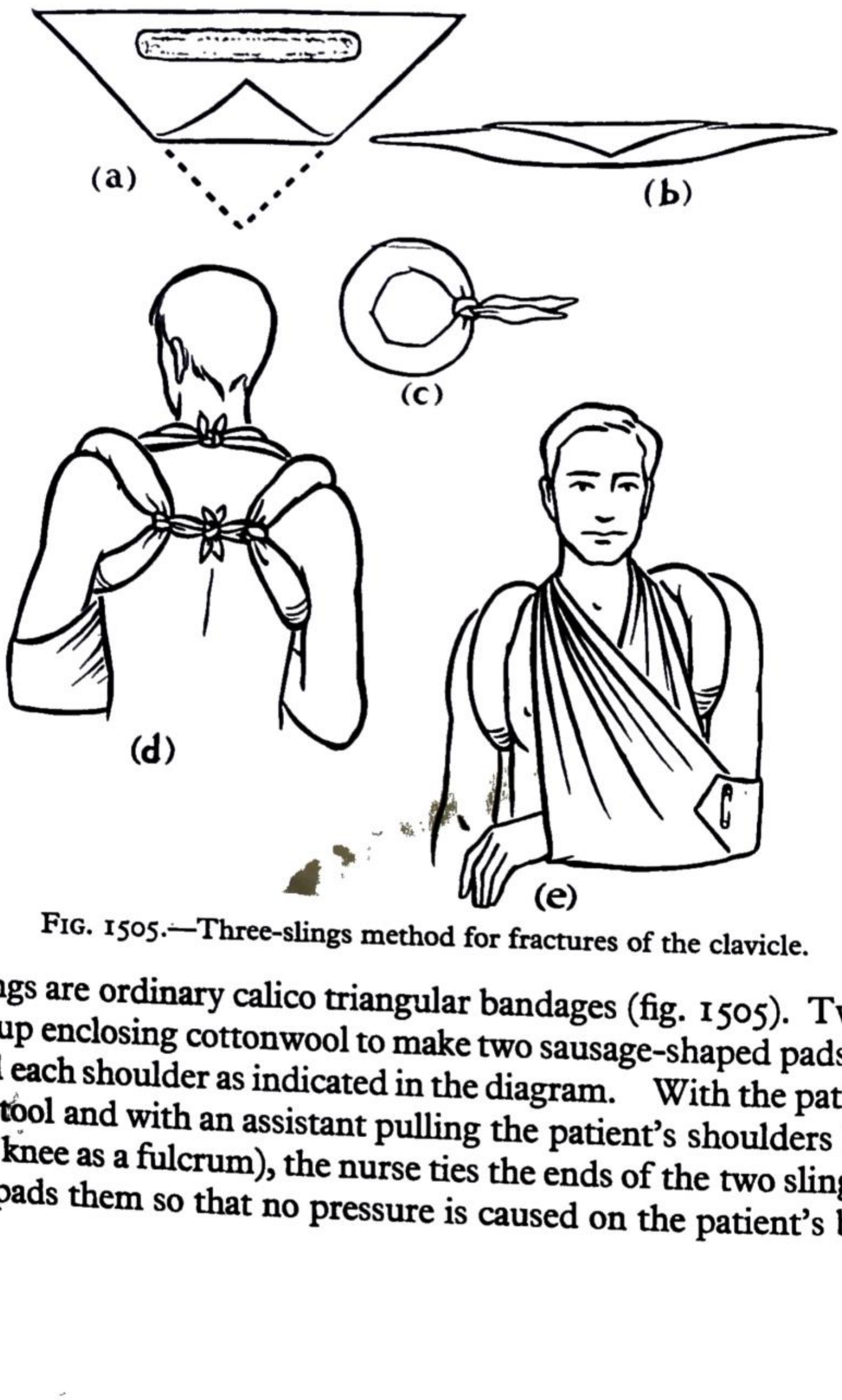

FIG. 1505.—Three-slings method for fractures of the clavicle.

The slings are ordinary calico triangular bandages (fig. 1505). Two of these are rolled up enclosing cottonwool to make two sausage-shaped pads which are tied round each shoulder as indicated in the diagram. With the patient sitting on a low stool and with an assistant pulling the patient's shoulders backwards (using his knee as a fulcrum), the nurse ties the ends of the two slings together and then pads them so that no pressure is caused on the patient's back.

The third bandage is used to support the elbow on the affected side and to elevate the shoulder. The first two bandages thus brace the shoulder backwards and outwards, while the third supports the shoulder; thus are counteracted the three deforming forces which the broken strut of the clavicle can no longer resist.

Average period of disability—light work five weeks, heavy work eight weeks.

Some degree of mal-union is common, but no disability results. Any cosmetically offensive bony boss can be removed by a simple local operation if the patient specially desires it, but if time enough is allowed to elapse (one to two years) even the most objectionable bony lumps become unobtrusive by the remodelling of bone. If fracture of the clavicle is caused by direct violence, the subjacent structures are sometimes injured, e.g. the subclavian vessels, brachial plexus, or pleura.

Fractures of the **Scapula** occur in the region of the neck and the body of the scapula. No clinical deformity occurs, and unless crepitus should happen to be felt the diagnosis can only be made radiologically (fig. 1506).

FIG. 1506.—Scapula.
1. Surgical neck.
2. Stellate fracture of the body.

Treatment consists in supporting the weight of the arm and forearm by a sling and movements of the shoulder joint are begun after about ten days, as stiffness is more to be feared than inaccurate apposition of the fragments.

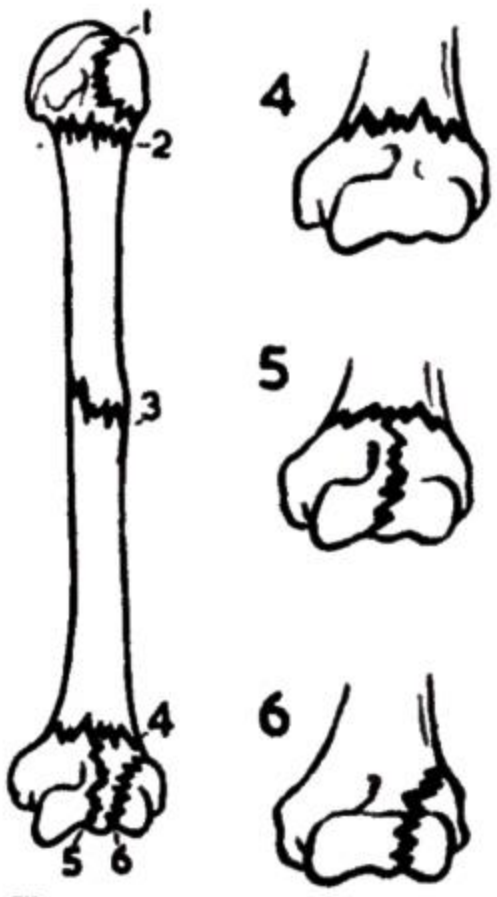

FIG. 1507.—Humerus.
1. Greater tuberosity.
2. Surgical neck.
3. Midshaft.
4. Supracondylar.
5. Y-shaped into the elbow joint.
6. External condyle.

Fractures of the **Humerus** (fig. 1507).

(i) *Upper End.*—Fractures of the upper end of the humerus occur most commonly in elderly persons, and particularly women, as a result of a fall on the outstretched hand. Various classifications have been used, such as '*surgical*' *neck* and '*anatomical*' *neck* fractures, or as *abduction* or *adduction* fractures, but as there is no very great difference in their method of treatment, they are all best grouped together as 'fractures of the surgical neck.'

The dominating factor in fractures of this region is that the fracture is close to a joint and early movement is to be encouraged at all costs. The fracture is usually comminuted but, being in cancellous bone, it unites easily in the presence of movement. There is rarely any necessity to attempt accurate reduction of these fractures, because the mobility of the scapula makes up for some residual stiffness in the shoulder joint itself (fig. 1508). If the fracture is very grossly displaced, an attempt may be made to improve the position by a manipulation, consisting principally of powerful traction, but otherwise to break down any impaction which may be present is meddlesome.

The type of elderly patient sustaining this injury is prone to develop a stiff shoulder even from a simple contusion ; thus early movement and the most conscientious attendance at a physiotherapy department is imperative. Abduction splints are exceedingly uncomfortable and, though quite logical and popular in the past, have now been abandoned in favour of the axillary muff and collar and cuff (fig. 1509). This simple device abducts the arm 30 degrees

FIG. 1508.—Fracture-dislocation of shoulder in elderly subject. Early movement—position accepted.

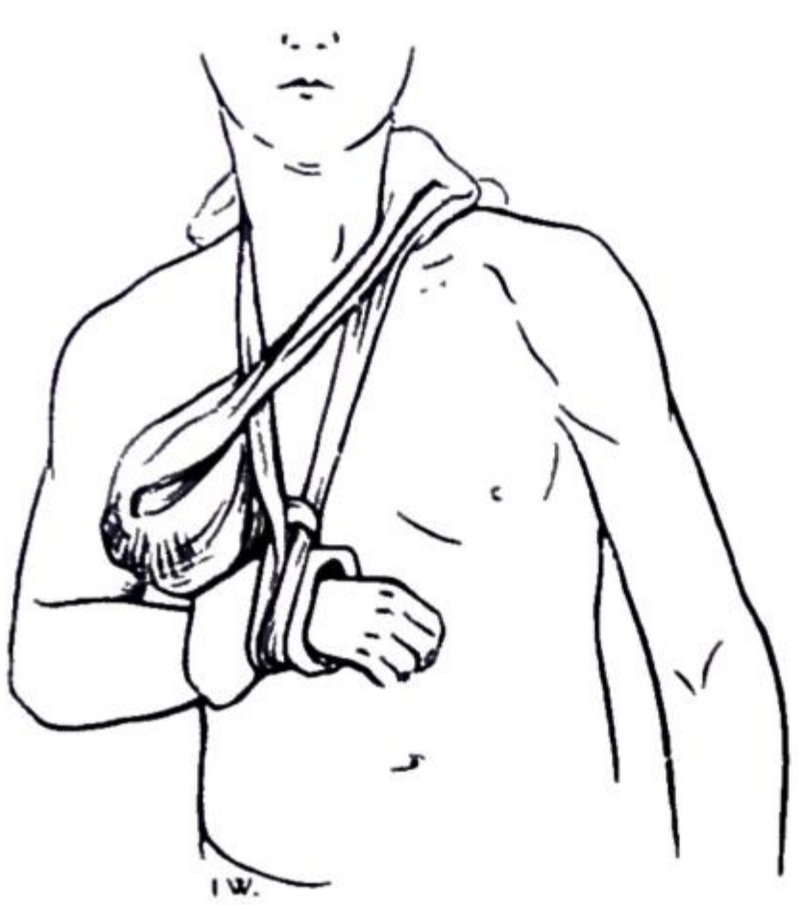

FIG. 1509.—Collar and cuff with axillary muff.

from the side and the arm is easily freed for exercise. Swinging movements with the arm hanging vertically should be practised after one week of rest, and thereafter more and more enterprise with 'auto-assisted' movements whereby the patient slightly pushes the injured shoulder by means of the sound arm.

Fracture-dislocation.—This is a severe injury, and the shoulder joint is usually more or less disorganised. In elderly patients, in whom it is common, the shoulder should be abducted to about 30 degrees for three weeks and the radiological appearance ignored. In the case of young and active patients, if traction and manipulation fail, exploration is indicated, so that the dislocation can be reduced and bony fragments approximated.

The *greater tuberosity* may be avulsed in association with dislocation of the shoulder joint (fig. 1507). A crack in the greater tuberosity merely requires a temporary sling. If the tuberosity is avulsed and separated by some distance, it is usually impossible to close the gap by abducting the shoulder (as will be seen by attempts under X-ray). Moreover, many separated great tuberosities complicate dislocation of the shoulder, which should never be treated in abduction lest recurrent dislocation of the shoulder should thereby be incurred.

(ii) *Shaft.*—Fractures of the shaft of the humerus occur most frequently near the midpoint. They are easily diagnosed by the obvious deformity and abnormal mobility.

Immediate injury to the radial nerve is not uncommon, and to test for the

presence of 'wrist-drop' in the clinical examination of a fracture of the shaft of the humerus must never be neglected.

Treatment consists in the application of a U-shaped plaster slab from the axilla under the elbow joint (fig. 1510), after which the arm is supported in a collar and cuff and the whole arm bandaged to the side. Reduction under anæsthesia is rarely required, as the weight of the limb and plaster maintains the fragments in position. General anæsthesia is particularly to be avoided because the horizontal position obstructs reduction; the sitting position of the patient enormously assists the reduction and application of plaster. Local anæsthetic is ideal if the fracture is recent.

FIG. 1510.—A 3-inch (7-cm.) U-shaped slab extends from the axilla round the elbow to the acromion. It is fixed by one gauze and two plaster bandages.

(iii) *Lower End.*—Fractures at this site are either (*a*) supracondylar, (*b*) T- or Y-shaped fissured into the elbow joint, or (*c*) of the lateral condyle alone.

Supracondylar fractures and fractures of the lateral condyle (capitellum) are injuries of childhood; T- or Y-shaped fractures of the lower end of the humerus are adult injuries. Supracondylar fractures result from falls on the outstretched hand, T-shaped fractures usually from direct falls on the elbow.

To the inexperienced a supracondylar fracture may be mistaken on clinical examination for a posterior dislocation of the elbow joint, but in the case of fracture the normal relationship of bony points around the elbow is unaltered (fig. 1511).

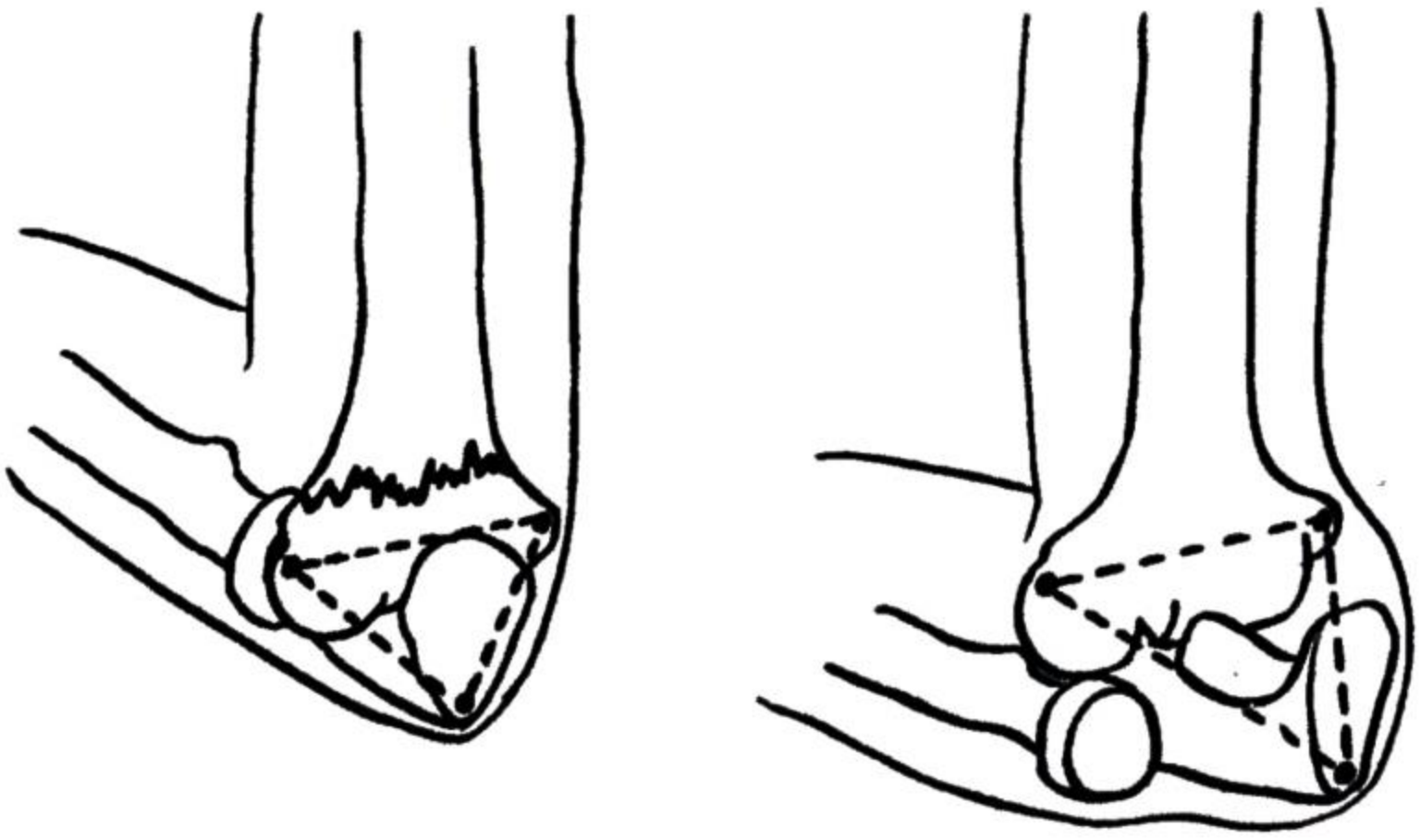

FIG. 1511.—Bony points in the elbow: (1) in the normal elbow, or the elbow with a supracondylar fracture, the triangle formed by tip of olecranon and the two epicondyles is roughly equilateral. (2) When the elbow is dislocated the tip of the olecranon is displaced and the triangle is no longer equilateral.

Less common than the ordinary supracondylar fracture, with posterior displacement of the distal fragment, is the more rare deformity of anterior displacement of the distal fragment.

The *supracondylar* fracture in children is notorious for the serious nature of its nerve and circulatory complications (fig. 1512). Sometimes, though by no means always, these complications can be partly attributed to in-

expert treatment, and it is therefore of the utmost importance to record in the preoperative examination the presence or absence of the radial pulse or other signs of serious circulatory embarrassment as well as to test for anæsthesia in the distribution of the median and ulnar nerves.

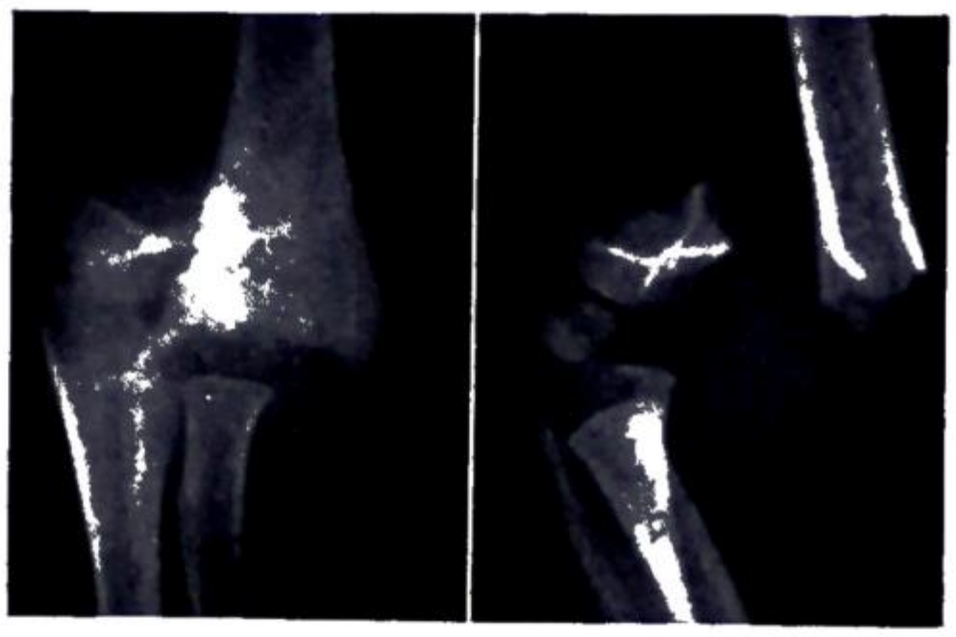

FIG. 1512.—Supracondylar fracture. Danger to neurovascular structures between fragments.

Treatment.—Reduction is not possible without full general anæsthesia. The danger of causing damage to the circulation in this reduction is so considerable that only an operator with some experience should be entrusted with the reduction, but as the best results are achieved in the early hours after the injury before swelling is severe, it is incumbent on the casualty officer to study the details, as he may be in a better position to reduce the fracture than a more experienced person the next day. The crucial manœuvre is the final flexing of the elbow, but this must not be done until the fragments have been disengaged by careful traction. If the elbow is flexed without disengaging the fracture, irreparable damage may be inflicted or neurovascular structures trapped between the displaced fragments.

Firm traction is applied to the extended elbow to disengage the fragments and release any neurovascular structures which threaten to be trapped between the bone-ends. This should be maintained for a minute or so till all lateral displacement has been overcome. Then, still maintaining traction in the length of the arm, the hand is slowly swung round to flex the elbow and draw the displaced lower fragment from its posterior position into line with the axis of the humerus. If a reduction is secured, it should be possible easily to flex the elbow 20 or 30 degrees under the right angle (i.e. 20 or 30 degrees above the horizontal with the patient standing) without obliterating the radial pulse. In this flexed position the reduction is locked by the tone of the triceps and only a collar and cuff is necessary to maintain it. If the elbow can only be made to reach 90 degrees, there is every danger that the fracture will slip because the fracture has not been completely reduced.

Depending on the severity of the swelling and the home circumstances, it is so important to keep a careful watch on the circulation of the hand during the next twenty-four hours that the surgeon will have to consider whether or not this apparently trivial injury should be admitted to hospital for at least one night. If allowed to go home, it should only be with instructions to the parents to bring the child back if *persistent, spontaneous pain is evident.* A supracondylar fracture which has been successfully reduced becomes progressively more comfortable with each succeeding hour ; not so the limb which has threatened vascular damage.

After reduction, the elbow is left in its flexed position in a collar and cuff, under the shirt, for three weeks, and is then given an outside collar and cuff for another two weeks before allowing full movement of the elbow joint. The recovery of full extension after this injury sometimes takes one or two years.

Traction.—When a child with a supracondylar fracture has a very swollen elbow it is often impossible to 'lock' the reduced position by flexing the elbow under the right angle because if this is done the radial pulse may disappear. Rather than take the slightest chance of ischæmia it cannot be too strongly urged that the child should be put to bed with the fracture in a 'semi-reduced' position with skin traction on the forearm, as illustrated in Fig. 1513. By this means it is possible to maintain a reasonable position and guarantee an intact circulation. After a week in bed on traction the position will no longer slip and the patient can then walk about with the arm in a simple collar and cuff.

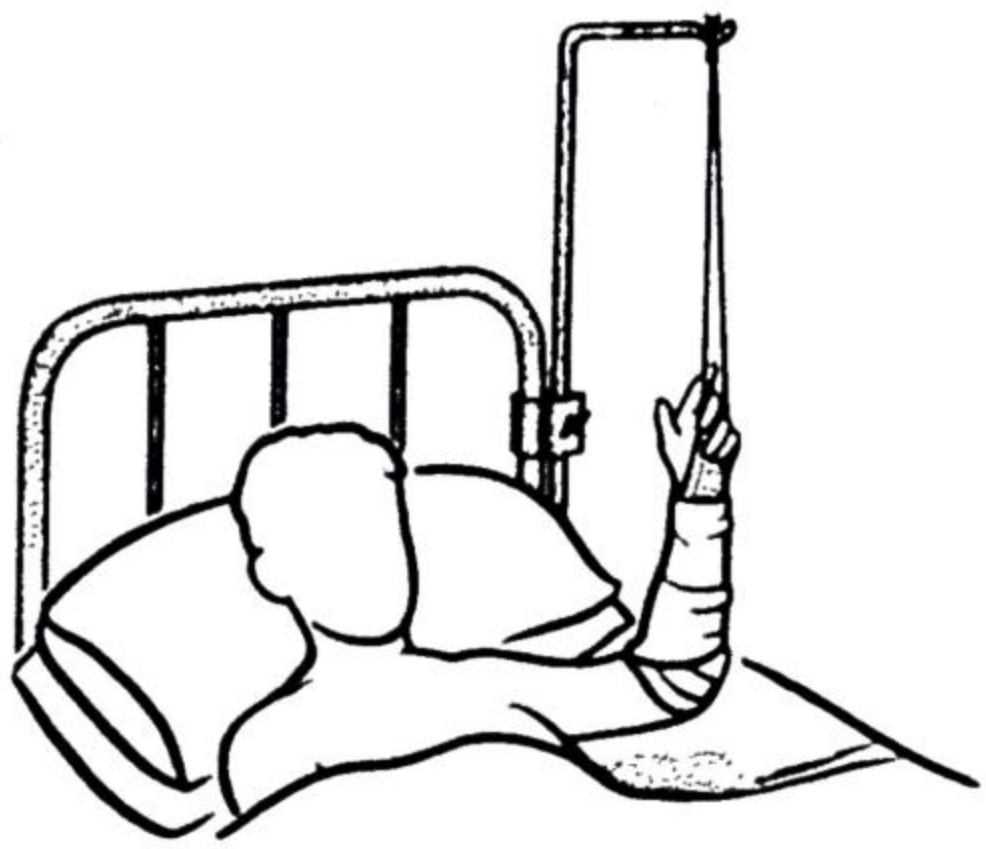

FIG. 1513.—Supracondylar fracture treated by suspension with skin traction on the forearm. Note that the elbow is held with a gap of 1 to 2 inches (2·5–5 cm.) between it and the surface of the bed.

FIG. 1514.—The upper radiograph shows an incompletely reduced supracondylar fracture which remodelled to the appearance seen in the lower illustration over the course of two years with full return of function.

Spontaneous Remodelling.—In young children the capacity of bones to remodel themselves after union has taken place in faulty position is nowhere better exemplified than in supracondylar fractures at the elbow. So vigorous is this capacity to remodel that in children under the age of ten years no risk should ever be taken, in the name of perfect anatomical reduction, by performing multiple re-manipulations, or by open operative reductions. The illustration in Fig. 1514 shows very well the degree of remodelling of a partially reduced fracture which occurred in two years; this is only the radiological appearance of the elbow and it is important to mention that a full range of motion was recovered.

Fractures of the Capitellum.—An isolated fracture of the capitellum is a not uncommon injury of childhood and is one of considerable importance. If only

FIG. 1515.—Recent fracture of capitellum in child—operative treatment essential.

slight displacement is present, the elbow can be treated merely in a sling or collar and cuff, and movement started after three weeks or so. Cases with severe displacement are not infrequent, and in these the whole capitellum is often rotated through 180 degrees so that the articular surface of the capitellum faces the fractured surface of the humerus (fig. 1515). Unless open reduction is performed, non-union in this fracture is inevitable and non-union of the external condyle results in the deformity of cubitus valgus with the possibility of late ulnar paralysis (p. 1319) due to unequal growth in length of the capitellar and trochlear surfaces of the humerus (fig. 1516).

T- or Y-shaped fractures of the lower end of the humerus, usually as a result of a fall on the point of the elbow, are very difficult fractures to treat and both occur in the adult.

Being fractures into a joint, the cardinal principle is early movement, and the modern tendency is to favour this at the expense of the anatomical position of the fragments. Experience in Britain has shown that the operative reposition of the fragments may give excellent X-ray appearances, but the functional result is frequently not as good as when the fracture is ignored and early exercise encouraged.

FIG. 1516.—Adult non-union of fracture of capitellum neglected in childhood. Eventual ulnar palsy—cubitus valgus.

FIG. 1517.—Radius.

Fractures of the **Radius** occur at the following common sites: (1) Head, (2) Neck, (3) Shaft, (4) Colles Fracture, (5) Radial Styloid (fig. 1517).

(i) *Head of Radius.*—Fractures of the head of the radius are most commonly seen in adults, and two main types occur—(*a*) Chip fractures involving a third or less of the periphery, (*b*) Comminuted fractures involving the whole of the head with considerable disturbance of the surface articulating with the capitellum. The comminuted type frequently occurs in combination with a transient subluxation of the elbow which may not be recognisable in the X-ray taken later.

Diagnosis is made by X-ray. Small chip fractures are treated by early mobilisation of the elbow joint (fig. 1518). Severely comminuted ones are treated by excision of the radial head.

(ii) The **Shaft** of the radius can be fractured at any level between the junction of the upper and middle one-thirds, and the middle and lower one-

thirds. If above the junction of the middle and upper one-thirds, the upper fragment is supinated by the biceps and supinator brevis, the lower portion being pronated by the pronator radii teres and the pronator quadratus. Therefore with a fracture above this level the forearm must be fixed in supination, whereas at all other levels the forearm is best fixed in the mid-position. These positions are maintained by means of a plaster cast, which extends from above the elbow to the heads of the metacarpals.

FIG. 1518.—Chip fracture involving a third of the periphery.

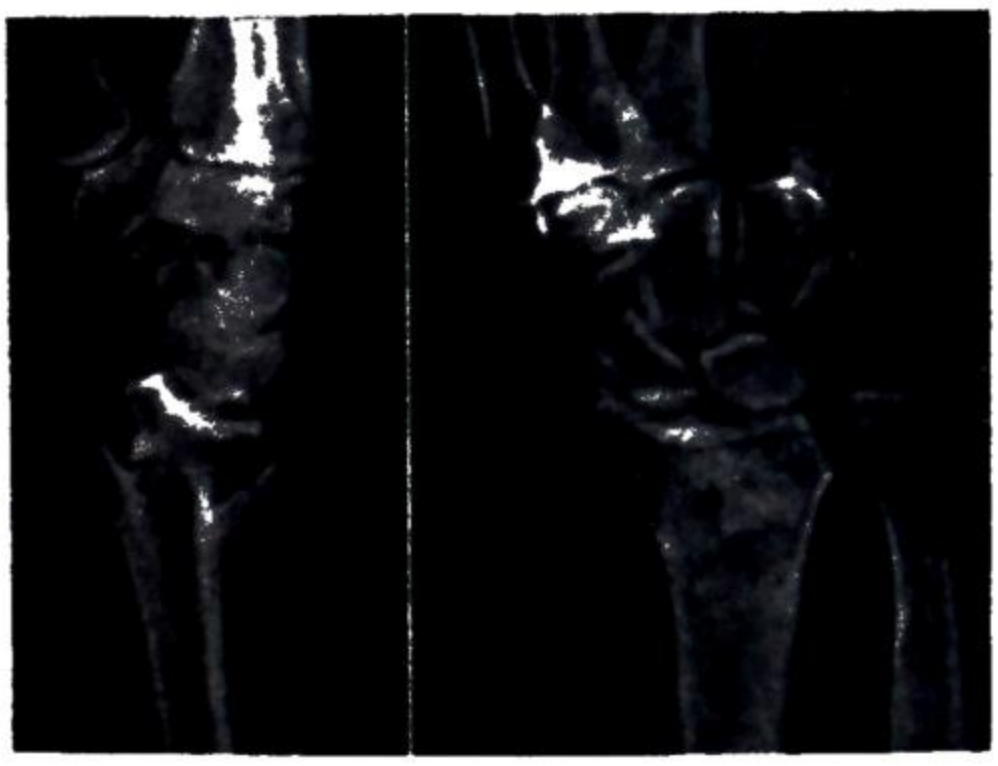

FIG. 1519.—Colles fracture. Dorsal displacement—dorsal tilt.

When the radius is fractured at the junction of the middle and lower one-thirds (the ulna being intact) there is a strong tendency for the radius to shorten and so cause subluxation of the lower radio-ulnar joint. This does not happen if the ulna is also fractured and shortens an equal amount. This isolated lower one-third fracture of the radius is best treated by open reduction and internal fixation, and this opinion is even shared by most fracture surgeons who are otherwise reluctant to employ operative intervention.

(iii) Fractures of the **lower end** of the radius are common, the most important being **Colles fracture.** This fracture commonly occurs in old ladies who fall on the outstretched hand. The fracture is situated 1 inch above the wrist joint, and it is associated with either avulsion of the styloid process of the ulna or rupture of the triangular fibro-cartilage of the wrist joint. The shortening of the radius causes subluxation of the lower radio-ulnar joint and excessive prominence of the ulnar styloid. The lower fragment of the radius is

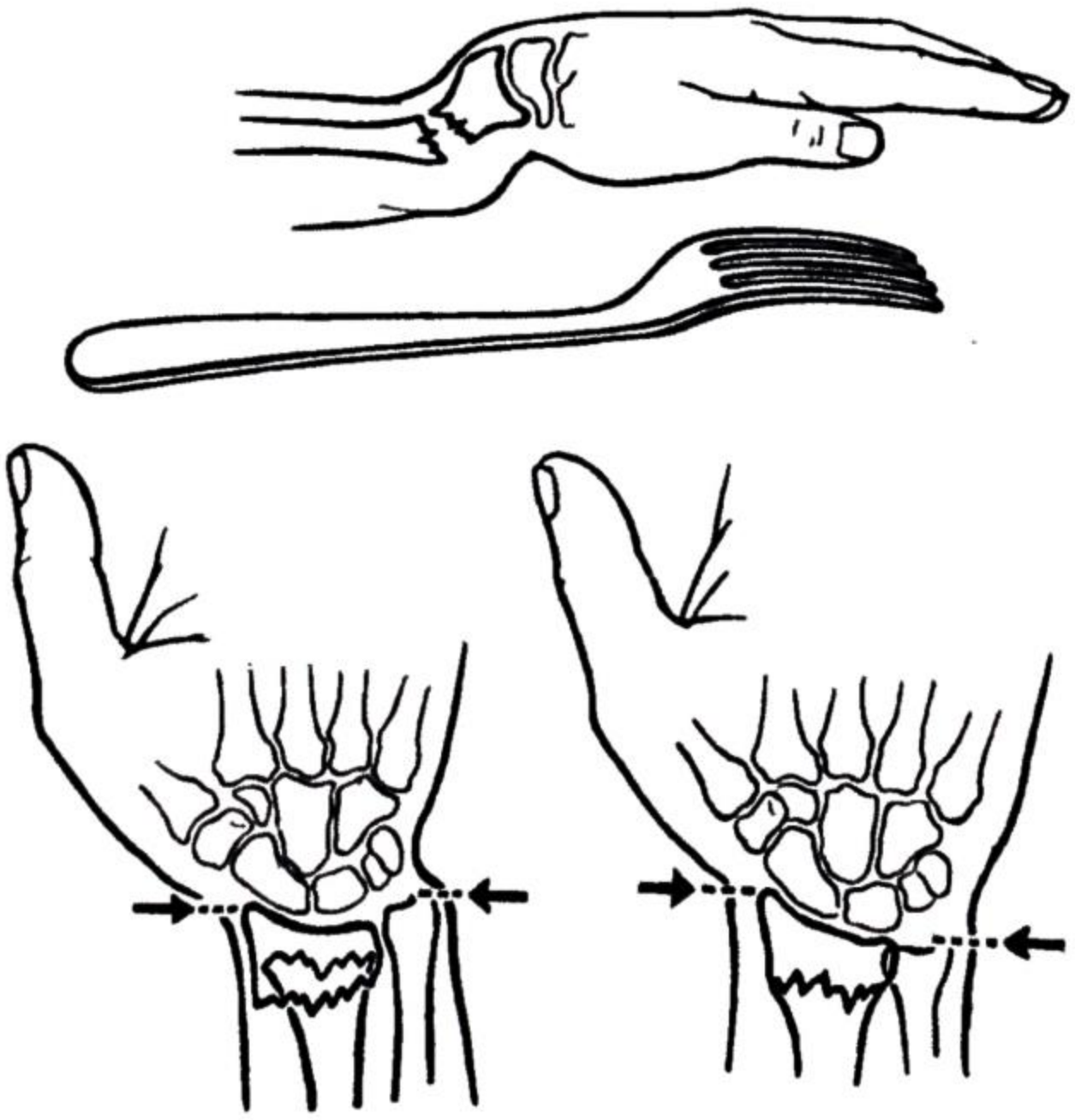

FIG. 1520.—Dinner-fork deformity of Colles fracture. Levels of radial and ulnar styloid processes before and after reduction.

Abraham Colles, 1773-1843. Professor of Surgery, Dublin, Surgeon at St. Stephen's Hospital. He journeyed on foot from Edinburgh to London, and declined a baronetcy.
Robert William Smith, 1807–1873. Professor of Surgery, Trinity College, Dublin.

displaced backwards and radially, and also rotated so that the articular surface looks backwards, i.e. it is both displaced and rotated in the direction of the violence (fig. 1519). These deformities thus produce the clinical 'dinner-fork' deformity (fig. 1520). On palpation the radial styloid process, instead of being ½ inch (1·25 cm.) below that of the ulna, is on a level with it.

Smith's fracture, which is very much less common, is due to falling with the hand behind the body, and the deformity is the reverse of that which occurs in Colles fracture, the distal fragment being displaced in front of the lower end of the radius (fig. 1521).

Treatment of Colles fracture consists in disimpaction and reduction. General anæsthesia is to be preferred. The surgeon grips the wrist with one hand above and one below the level of the fracture, changing his hands to suit according as the fracture is of the patient's left or right wrist. In the case of the patient's left wrist, the surgeon places the palm of his left hand on the palmar surface of the patient's wrist above the level of the proximal fragment; the palm of his right hand is then applied to the dorsal surface of the patient's wrist distal to the level of the fracture. It is convenient to have an assistant to hold the patient's elbow and to apply counter-traction.

FIG. 1521.—Smith's (reversed Colles) fracture.

First Movement. — Disimpaction. The surgeon applies traction with the right hand and gently increases the deformity very slightly by extending the wrist. Still maintaining traction, this is followed continuously by the next movement.

Second Movement.—Palmar flexion. Keeping traction so as to disengage the broken fragments, the distal fragment is gently but firmly flexed. This movement ends by direct pressure being exerted by the right hand on the dorsal surface of the distal fragment and, in an opposite direction, by the left hand against the proximal fragment. To localise these forces they are exerted by the surgeon's thenar eminences over an area of about 1 square inch (6·5 square cm.).

Third Movement.—Still maintaining the differential pressure above and below the level of the fracture, the patient's wrist is now finally pronated by the surgeon forcibly pronating his own right hand. During this movement the surgeon's left hand remains stationary in its original position so as to deter the proximal fragment from following the distal fragment. It will be found that the position of full pronation will also result in ulnar deviation of the patient's wrist, and this is the final position of reduction i.e. (1) slight palmar flexion, (2) ulnar deviation, and (3) pronation.

The reduction is maintained by applying a wet plaster slab to the dorsal and radial surfaces of the wrist and bandaging it in position with a wet gauze bandage. There is very great danger of the fragments slipping during the application of this plaster slab, and it is wise to apply it very quickly so that

the surgeon can repeat the previous manœuvre of reduction and can steady the fragments while the slab is setting.

It is important that the slab should be of adequate size. It must extend in length from the heads of the metacarpals to the elbow (but not too long to prevent flexion of the elbow). In width it must be sufficient to meet at the front of the wrist to leave a gap not more than ½ to ¾ inch (1·25 to 2 cm.) wide. To maintain ulnar deviation a tongue of plaster should be passed round the radial aspect of the head of the second metacarpal so as to reach the palm. The final appearance of the plaster in slight palmar flexion and ulnar deviation is seen in fig. 1522.

In addition to a routine inspection of the plaster the day after the reduction, it is often necessary to inspect the cast several times during the first ten days, because Colles fracture is often followed by considerable swelling of the fingers, and if tender points develop where the plaster is 'cutting in' the return of good finger movements may be delayed.

The patient is encouraged to use the limb, and suitable exercises of the fingers, elbow, and especially the *shoulder* are arranged in the rehabilitation department, and four to six weeks later the cast is removed. Full return of function is usually obtained after two to three months.

In the case of feeble old women reduction is often unnecessary, all that is needed being a temporary support to the wrist and encouragement regarding movements of the fingers. In fact, medical advice is not always sought, the condition being regarded as a sprain, and the functional result in these cases is usually very satisfactory though considerable deformity may be evident.

Sudeck's osteoporosis is an obscure condition which occasionally follows Colles fracture, but which can occur after a mere sprain; it also sometimes affects the foot.

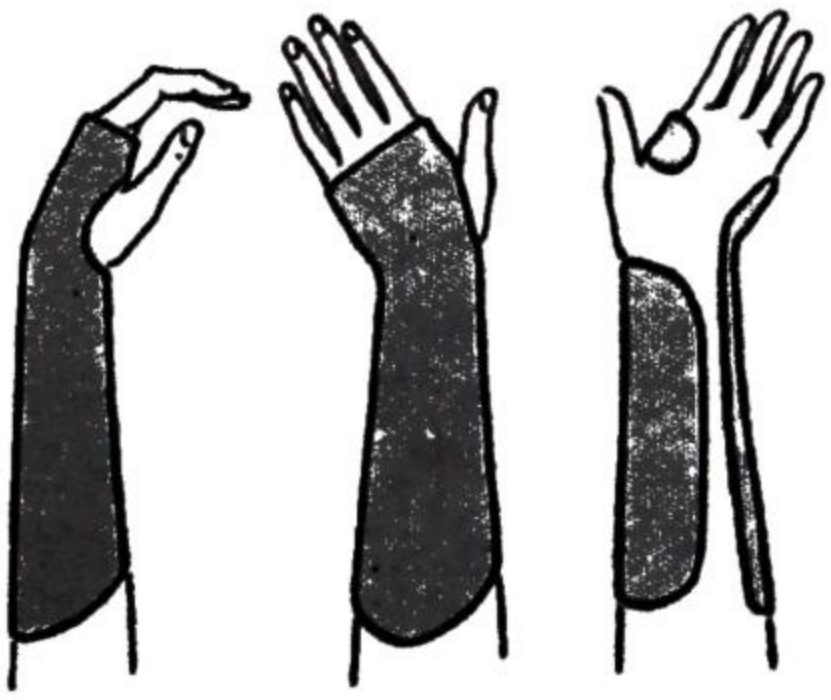

FIG. 1522.—Plaster slab in ulnar deviation and slight palmar flexion as used for the Colles fracture.

FIG. 1523.—Sudeck's osteoporosis.

As a sequel to Colles fracture it affects the small bones in the neighbourhood of the wrist, and is supposed to be due to reflex hyperæmia occasioned by trauma. It is characterised by pain, vasomotor changes, and atrophy of the bones (fig. 1523). It has been mistaken for tuberculous disease, but differs radiologically in that the outlines of all the carpal bones are intact and the bone detail is quite clear, even though so porotic as to appear like a phantom. Very gradual voluntary movements are indicated, but if the condition persists sympathectomy is rational provided

obtained to blockage of the ganglion with novocaine.

longus pollicis tendon in about 0·5 per cent. of cases follows a

also apt to follow a posterior marginal fracture of the radius.

the tendon over the ridge of the fracture, occurs a few

Paul

of Surgery, Hamburg.

weeks following the injury. The distal end of the tendon should be sutured to the extensor indicis tendon.

Average period of disability after Colles fracture—light work six weeks, heavy work twelve weeks.

Separation of the lower radial epiphysis is a fairly common injury and in childhood is the counterpart of the Colles fracture. It is most often seen in children from the age of eight to sixteen. The epiphysis is displaced backwards, and the deformity and treatment are similar to those already described in the case of Colles fractures. Usually the displaced epiphysis takes with it a small chip of bone from the dorsal surface of the lower end of the radius (fig. 1524). Reduction of the displacement is usually easy, especially if treated without delay, and the characteristic sensation of 'muffled crepitus' will be felt during the manipulation. This muffled crepitus is caused by the grating of bone against epiphyseal cartilage, which gives a softer sensation than the grating of bone on bone.

FIG. 1524.—Slipped radial epiphysis.

FIG. 1525.—Fracture of radial styloid.

One might expect that injury to this epiphysis might cause premature fusion of the epiphysis and late deformity of the wrist due to unequal growth of the radius and ulna, but in fact this is an extremely uncommon complication (unlike the corresponding injury at the lower end of the tibia where arrest of growth of the tibia is common).

FIG. 1526.—Ulna.
1. Olecranon process.
2. Upper third of shaft, which may be associated with dislocation of the head of the radius.
3. Lower part of shaft, as from direct violence.
4. Styloid process.

Fractures of the **radial styloid** most often occur in men through a fall on the hand, and in the past were one of the so-called 'chauffeur's' fractures sustained by 'back-fires' when cranking internal-combustion engines.

The fracture line, which involves the radio-carpal joint surface, is usually without significant displacement, and often involves a much longer piece of the radius than the term 'styloid process' usually evokes in the mind (fig. 1525). Treatment is by a simple 'cock-up' plaster for three weeks and later adhesive strapping.

This injury is sometimes associated with dislocation of the carpal semilunar (p. 1260) as part of a very serious mid-carpal dislocation—and the inexperienced surgeon may look no farther than the obvious injury to the radial styloid. If the wrist is more grossly swollen on clinical examination

than is to be expected from a small injury such as the radial styloid, the other possibility must be remembered.

Fractures of the **Ulna** (fig. 1526).

(i) The *olecranon process* is usually fractured as a result of falls on the elbow. Separation commonly occurs through the constricted base of the process, and may be almost negligible if the triceps expansion remains untorn. If wide separation is present diagnosis is easy, as the gap between the process and the shaft can be palpated, and the power of extension is lost.

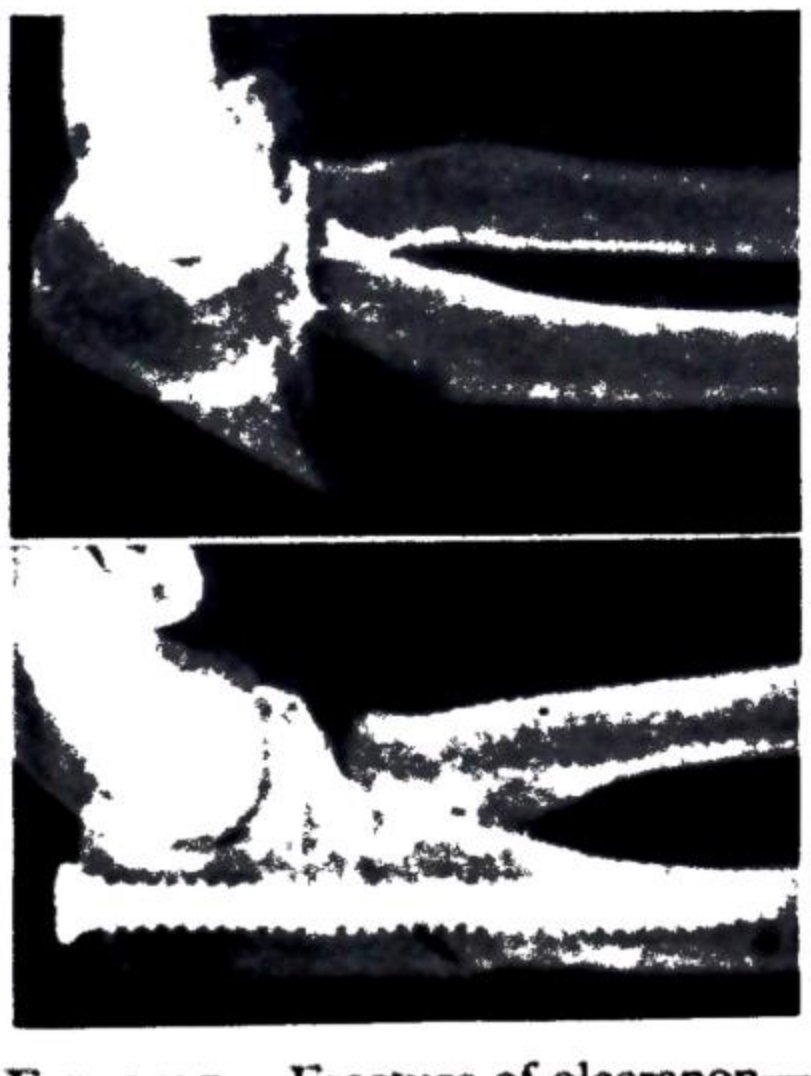

FIG. 1527.—Fracture of olecranon—internal fixation, early movement.

If separation is sufficient to require operation, the fragment is easily fixed in position by means of a vitallium screw (fig. 1527), wire, or silk. No plaster fixation is necessary, and active movements are encouraged after two or three days.

FIG. 1528.—Fractures of radius and ulna treated by plating.

(ii) Fractures of the *shaft* of the ulna are due to direct or indirect violence. In the latter case they are sometimes associated with dislocation of the head of the radius (Monteggia's fracture, p. 1261). The diagnosis of the ulnar fracture is easy, as the bone is subcutaneous, and displacement or localised tenderness is readily palpable.

(iii) The *styloid process* of the ulna is commonly avulsed in association with a Colles fracture. The maintenance of the hand in a position of adduction, which is an integral part of the treatment of Colles fracture, approximates the position of the ulnar styloid process, but it often remains ununited though usually symptomless.

Fractures of the **Radius** and **Ulna** are due to direct or indirect violence. In the former case the bones are fractured at approximately the same level, which depends upon the site of injury. If the fractures are due to indirect violence, the radius usually fractures in its lower third, and the ulna about its centre.

Reduction is attempted by an assistant exercising traction on the hand with counter-extension to the upper arm, while the surgeon applies interosseous pressure in order to separate the broken bones. The application of plaster is greatly facilitated by suspending the arm from an overhead support and hanging it by the thumb and index. In this way the traction is maintained while a full plaster is applied. Should manipulation fail, *open reduction* is advisable and the bones fixed with plates and screws (fig. 1528). In some cases operation on the radius alone will be sufficient because the radius suffers more displacement than the ulna.

Giovanni Battista Monteggia, 1762–1815. Professor of Anatomy and Surgery, Milan.

This injury is very common in children, and is one of the commonest examples of a *greenstick* fracture. The child's forearm is visibly bowed (usually concave dorsally). Reduction is quite simple and it is merely necessary to bend the forearm straight. It is usually advisable to complete the fracture under this bending force in order slightly to over-correct the deformity. If the deformity is not over-corrected, there is a great danger of the original deformity redeveloping inside the plaster. In the forearm fractures of children it is most important to use wool padding as the limb will swell after reduction, especially if the fracture has to be completed, causing the little patient unnecessary pain and even threatening a Volkmann's ischæmic contracture (p. 1171).

FIG. 1529.—Fracture through the waist of the scaphoid. There is abnormal density of the proximal fragment indicating ischæmia of that fragment and threatened non-union.

Carpal Scaphoid.—The commonest bone to be fractured in the wrist is the *scaphoid*. A 'sprained wrist' in a young man after such an incident as falling on the hand, or receiving a jerk from the starting-handle of a car, should arouse suspicion. If a fracture is present, inspection of the backs of the hands, with fingers and thumb fully extended, will reveal some fullness of the anatomical 'snuff-box,' and on palpation of that area local tenderness is experienced by the patient. X-rays will confirm the diagnosis (fig. 1529), and many fractures show best in an oblique X-ray. Some fractures are only visible after two or three weeks (when absorption has occurred along the fracture line). Unless treated efficiently, a fracture through the waist of the bone will pass inevitably into non-union, causing permanent weakness of the wrist and subsequent osteoarthritis. This is a tragedy in a working man, and the more so since in the majority of cases adequate treatment can prevent non-union. The erroneous diagnosis of a 'sprained wrist' when the scaphoid has been fractured is a mistake which is now so well known that courts of law now have little sympathy for a medical man making this mistake. The very words 'sprained wrist' should immediately arouse the suspicion of a fractured scaphoid. If localised tenderness in the 'snuff-box' suggests a clinical diagnosis of a fractured scaphoid, even if the X-ray is negative, it is advisable to treat the wrist in plaster and X-ray again after three weeks. The type of patient who sustains a fractured scaphoid greatly narrows down the diagnostic field: a fall on the outstretched hand in an elderly woman or a child is most unlikely to cause a scaphoid fracture; the vast majority of these injuries are in men between the ages of twenty and forty.

As soon as the condition is diagnosed, the hand must be fixed in a 'cock-up' plaster cast. The plaster must not interfere with movements of fingers, and the metacarpal bone of thumb must be included. The cast embraces the sides of the forearm and wrist so as to prevent lateral movement. The wrist

is immobilised absolutely and completely until there is X-ray evidence of bony unions. If 'shearing' movements are allowed to occur between the fractured surfaces, the capillaries attempting to bridge the fracture will be ruptured and bony union thereby discouraged. The plaster is retained *until X-ray shows radiological union*, which is usually in eight to ten weeks. A leather or plastic support may be worn with advantage for another three to six months if there is evidence of delayed union. If the diagnosis is made late, i.e. six weeks or more after the injury, there is no point in applying plaster, and these cases should be encouraged to use the wrist in the hope that a painless pseudarthrosis of the scaphoid will develop, and that symptoms of traumatic arthritis will not occur in the wrist for many years.

Cases of *delayed union*, or *non-union*, of the carpal scaphoid are often treated by bone grafting. There is some doubt whether the results are worth the trouble and whether this operation prevents the development of arthritis. Similarly, operations to excise fragments are nowadays regarded with less favour than formerly. Patients with ununited scaphoids can often enjoy surprisingly long periods of relative freedom from symptoms if their work does not involve heavy strain, and, if comfortable, are perhaps best left alone.

FIG. 1530.—Fracture of tubercle of scaphoid.

Fractures of the **Tubercle of the Scaphoid** (fig. 1530) are often erroneously confused with fractures through the waist and a period of six weeks of irksome plaster fixation inflicted on them. They are fractures which have a good blood supply on both sides of the bone and show no tendency to non-union. Plaster fixation is quite unnecessary and the support of strapping alone is needed for three to four weeks.

Metacarpal fractures involving the shaft of one or more of the inner four metacarpals are produced by the knuckles striking objects, as in boxing, or by objects striking the dorsum of the hand, as in industrial injuries.

Fractures of the shafts of the inner four metacarpals are to a large extent splinted by the adjacent metacarpals. Emphasis should primarily be on early movement, because radiological deformity is of little moment. A little recession of the normal prominence of a metacarpal head is of no significance if full movement and a good grip is present.

Transverse fractures of the metacarpals sometimes may give trouble with delayed union, but all other fractures unite well.

If reduction is deemed necessary, simple manipulation of the fractured metacarpals is attempted and the hand enclosed in a 'cock-up' plaster to leave the fingers free.

Fracture of the first metacarpal requires special mention, as a fracture of the base (**Bennett's fracture**), due to a blow on the point of the thumb, may be overlooked. This fracture is sometimes called the 'stave' fracture, which indicates its origin in boxing. Unless efficient treatment is instituted, permanent weakness may result. An oblique fracture occurs through the articular surface of the metacarpal, which allows subluxation of the joint. The shaft of the bone is drawn backwards and outwards (fig. 1531).

FIG. 1531.—Bennett's fracture-dislocation.

This fracture-dislocation is easily reduced by traction and pressure over the base of the thumb. Continuous traction is best obtained by means of a plaster cast applied to the forearm, in which is incorporated a loop of thick wire to take the adhesive traction applied to the end of the thumb. It is often possible to reduce and hold this fracture without traction, provided the metacarpal is in full extension and local pressure is moulded over the base of the bone to hold it in.

Phalanges are commonly fractured by direct violence, e.g. by a blow with a hammer, or crushed by a door or slipping window-sash.

FIG. 1532.—Typical angulation in fracture of shaft of phalanx.

Fractures of the proximal phalanges are more difficult to treat than metacarpal injuries because the flexor tendon sheath will be involved if the fracture is displaced. It is often difficult to align the injured finger with the other digits if splinted separately, but these errors can be minimised if the fractured digit is splinted side by side with an adjacent normal finger. A slab of plaster, suitably curved so as to give a fulcrum on the palmar aspect of the proximal phalanx over which the finger can be flexed, will eliminate the dorsal concavity which is the constant deformity in these fractures (fig. 1532). It is rarely necessary to immobilise the digit more than three weeks, and thereafter the callus will be strong enough to allow movement without redisplacement occurring. In the later stages of rehabilitation the simple trick of holding the finger to the next digit with adhesive strapping is useful in recent fractures with little or no displacement.

Ribs and **Sternum.**

Fractures of the **Ribs** occur as a result of direct or indirect violence. In certain nervous diseases, e.g. tabes dorsalis, very slight trauma may cause a fracture and pathological fracture occurs in secondary malignancy, multiple myelomatosis, and osteomalacia.

(i) Fractures due to *indirect violence*, by crushing of the chest, may be single or multiple and involve the fifth to the eighth ribs a short distance in

Edward Hallaran Bennett, 1837–1907. Professor of Surgery, Trinity College, Dublin.

front of the angle of the rib. This site is the junction of the long anterior curve and the short acute posterior curvature.

The fracture is suggested by the history of injury and localised pain on deep inspiration. Pain is referred to the site of fracture if simultaneous pressure is exerted upon the sternum and spine.

(ii) Fractures due to *direct violence* affect the ribs most exposed to injury. The first and second ribs are rarely fractured, as they are protected by the clavicle, and trauma sufficiently severe to smash the clavicle and upper ribs is likely to inflict fatal injuries on adjacent structures. Similarly, the lower two ribs are protected by muscles, and enjoy a degree of mobility which diminishes the risk of fracture.

Fractures due to direct injury are more serious than those due to indirect causes, as bone fragments may be driven inwards and damage the pleuræ, lungs, diaphragm, liver, kidneys, spleen, pericardium, or heart. Surgical emphysema is likely to follow laceration of the lung.

The treatment of fracture of the ribs depends on the severity of the pain and distress. Often no treatment is needed. If several ribs are fractured and coughing causes severe distress, then the chest should be strapped. Strips of adhesive strapping, from 4 to 6 inches (10 to 15 cm.) wide, depending upon the size of the patient, are applied around the chest, reaching from the opposite side of the spinal furrow behind to the opposite nipple line in front (fig. 1533). These strips are applied at the end of expiration—the patient is requested to emit a long-drawn breath, the strapping being applied at the end of expiration. Additional support is provided by the application of a flannel bandage.

FIG. 1533.—Strapping applied for fractured ribs.

In elderly patients chest complications may endanger life. Local anæsthetic injected at the site of the fractures gives a temporary relief from pain, so that breathing and expectoration can be performed in comfort.

A close watch is kept for evidence of hæmothorax or pressure pneumothorax (p. 1093).

Ribs, in spite of lack of immobility, unite readily, and support for three weeks is usually sufficient.

The **Sternum** is occasionally fractured as a result of direct violence, e.g. by the steering-wheel of a car as the result of a collision. If displacement is gross, death is likely, owing to injury to or pressure on the heart and great vessels. In less severe cases the patient is confined to bed with a pillow or sandbag between the shoulders, and strapping applied to steady the fragments.

Fracture due to indirect violence can be associated with a fracture-dislocation of the spine, due to excessive flexion of the trunk. Treatment is symptomatic, as the more serious injury to the spine takes precedence.

LOWER EXTREMITY

Fractures of the **Pelvis** comprise fractures of the iliac crests or of the true pelvis.

(i) Fractures of the **Iliac Crests** are not of any significance because displacement is slight, as the iliacus muscle on the inner side, and gluteal muscles on the outer side, support the bone.

A firm flannel bandage is applied to the pelvis and the patient confined to bed till symptoms have settled, which usually will take two to three weeks.

(ii) Fractures of the **True Pelvis** can occur either in the oblique diameter, i.e. through the obturator foramen on one side and the ala of the sacrum on the opposite side, or the pelvic ring can be fractured in two places on the same side. The cause is a severe crush, such as a horse rolling over its rider or a light car passing over a pedestrian.

Occasionally the injury may not be suspected if it results from a simple domestic accident to an elderly patient, such as a fall down the stairs. Clinical examination of the pelvis may not be conclusive if there is no displacement or crepitus and if there are local bruises which might themselves explain the pain; but very suggestive of a fracture of the pelvis in these circumstances is a degree of shock greater than might be expected from a contusion and inability to walk or stand alone.

The most important aspect of a fractured pelvis is the liability to injury of viscera—the male urethra commonly, the bladder in both sexes frequently, and the rectum rarely. Therefore the patient should be instructed not to attempt to pass urine until an exploratory catheterisation can be made under fully aseptic conditions.

Blood escaping from the external urinary meatus in the male immediately suggests rupture of the urethra, which is confirmed if a soft rubber catheter cannot be passed into the bladder. Steps must be taken to suture the urethra (p. 869). Should no blood be escaping and a catheter can be passed easily to produce only a small quantity of blood-stained urine, this will suggest rupture of the bladder, especially if there is reason to suspect that the bladder might be full at the time of the injury (which is a precipitating cause) (p. 791). A rectal examination is made, and in rare cases a fragment of jagged bone may be encountered, in which case laparotomy will be necessary, and iliac colostomy. Wounds of the vagina are rare and can usually be sutured.

Having methodically excluded or dealt with visceral lesions, attention can be directed towards the fracture, but if the patient is seriously ill from the complications, no special measures need be adopted. A plaster cast is unnecessary in fractures of the pelvis, and simple nursing between sandbags is all that is needed. The pelvic bones readily unite, but walking is prohibited for two to three months, depending on the site and nature of the fracture.

Fractures of the *acetabulum* occur either in connection with dislocation of the hip joint (p. 1262), when the posterior margin is broken off, or following a heavy fall on the great trochanter, in which case a ' central dislocation ' may be produced.

The *sacrum* is fractured by either direct or indirect violence. The latter is usually associated with fracture of the pelvis and anæsthesia of part of the perineum may result from damage to sacral nerves if sacral foramina are involved in a displaced fracture. Direct violence, as by falls or kicks, rarely produces any deformity and needs no treatment.

The *coccyx* may be fractured as a result of kicks or falls. Pain, which is often severe, occurs on walking, sitting, or actions which cause contraction of the levator ani, such as defæcation or coughing. Rectal examination reveals local tenderness and often deformity.

In some cases these symptoms are produced when no fracture is evident, the condition being known as *coccydynia*, a condition which is of unknown origin.

If adequate rest and symptomatic treatment by heat or anæsthetic injections are of no avail, excision of the coccyx should be performed, but there should be no haste in making this decision as many of these patients are neurotic and find some other complaint after operation.

Fractures of the **Femur** are of the greatest surgical importance, both on account of the difficulties in treatment and also because of the serious disability if treatment is inefficient.

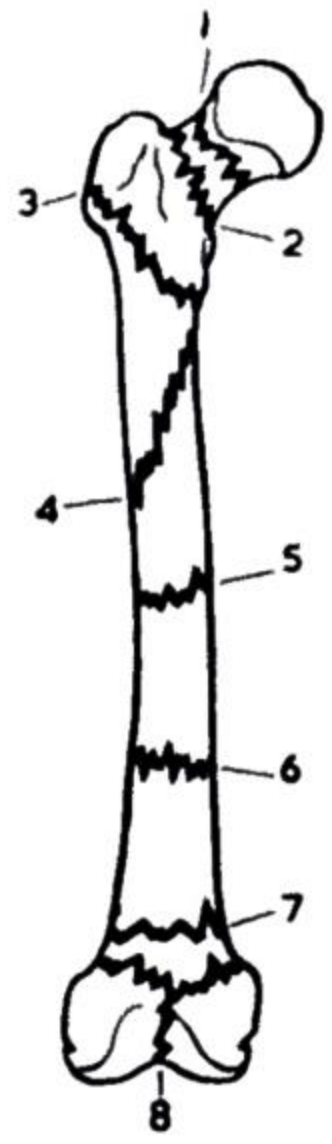

FIG. 1534.—Femur.

1. Subcapital and mid-cervical fracture of the neck.
2. Basal fracture of the neck.
3. Pertrochanteric fracture.
4. Spiral fracture of upper third of shaft.
5. Transverse fracture of the middle of shaft.
6. Junction of middle and lower one-thirds.
7. Supracondylar.
8. T-shaped into joint.

(i) Fractures of the **Neck of the femur**. Fractures of the neck of the femur since the days of Sir Astley Cooper have been divided into *extracapsular* and *intracapsular* fractures. This broad division is still a good one, as it emphasises the two different problems which treatment presents. In the absence of treatment, *intracapsular* fractures are almost totally devoid of any natural capacity to unite, because the fracture frequently deprives the head of the blood supply it receives by way of the neck. In a minority of cases where the intracapsular fracture is impacted, union may occur without treatment, but in all others it is imperative to reduce the fracture accurately and to hold it completely immobilised by internal fixation with a stainless-steel nail until union has occurred.

Extracapsular fractures, on the other hand, occur in the cancellous bone of the trochanters at the base of the neck, and the power of union of the bone is good because there is no disturbance of blood supply. The essential difficulty in this group of fractures is the advanced age of the patients most commonly

Sir Astley Cooper, 1768–1841. Surgeon, Guy's Hospital, London.

afflicted. In general, the extracapsular fracture is an injury of the senile (seventy years or more) and these patients have such disuse atrophy of their femoral necks that it takes only the slightest trip or stumble to cause them to fracture. The problem in treating this fracture is often therefore the problem of old age rather than any inherent difficulty in the treatment of the fracture itself. The problem of the *intracapsular* fracture is not so much the age of the patient but rather the technical difficulty of its strong tendency to non-union.

Whenever possible, the ideal method of treating both these fractures is operative because (1) in the intracapsular fracture, operation is necessary to get fixation and union, and (2) in the extracapsular fracture, operation is necessary to get the patient out of bed early so that the ill-effects of decubitus in the elderly will be prevented.

Intracapsular Fractures.—These are anatomically subdivided into subcapital and mid-cervical fractures. The danger of ischæmia of the femoral head is greater in the subcapital fracture than in the mid-cervical, because the synovial membrane of the hip-joint does not extend as far down the back of the neck of the femur as down the front, and therefore some blood supply can still get into the head in most mid-cervical fractures.

The deformities which result from all fractures of the femoral neck (at whatever level) are twofold: external rotation and coxa vara (and hence shortening). The element of coxa vara (*syn.* adduction fracture) is the most serious because the fracture line is thus exposed to a shearing strain if the patient attempts to take weight. The shearing strain in coxa vara is an important factor in the tendency to non-union in the fracture. In impacted fractures the deformity is usually negligible. Sometimes a coxa valga is produced (*syn.* abduction fracture), and in this position the strain of weight-bearing will further impact the fracture. This latter group (unfortunately not common) needs no special treatment other than bed-rest and protection from full activity for three or four months.

Treatment.—The treatment of mid-cervical and subcapital fractures is operative. If the patient is very old and shocked, it may be necessary to delay surgery a day or two until resuscitated.

The technique of internal fixation in universal use is the insertion of a Smith-Petersen tri-flanged nail under X-ray control. Under gas and oxygen anæsthesia this is not an operation which causes shock, as the operative exposure is very small.

The hip is manipulated and the patient fixed on a special operating table incorporating traction to the feet and counter-traction via a post in the perineum. The hip is held with traction in abduction and internal rotation. If the reduction is satisfactory (as checked by X-ray of the neck of the femur in two planes), a small lateral incision is made over the great trochanter and a guide wire 2 mm. in diameter is inserted into what is estimated as being the line of the axis of the femoral neck. X-rays are taken, and if the direction of the guide has to be changed, various devices are available for directing a second wire in relation to the first so as to be exactly in the axis of the neck. The tri-flanged nail is provided with a central cannula, 2 mm. wide, which enables it to be slid over the guide wire and hammered into the head. After finally impacting the fracture, the wound is closed and the patient is returned to bed without any fixation (fig. 1535).

After operation the patient can be allowed out of bed in a few days, but weight-

Marius N. Smith-Petersen, Contemporary. Professor of Orthopædic Surgery, Harvard

bearing is not permitted until some evidence of osseous union is suggested in the X-ray—which may take three to four months. Sixty to seventy per cent. of these cases achieve a result which is indistinguishable from normal.

Complications.—Non-union of the neck of the femur occurs in approximately 30 to 40 per cent. of all intracapsular fractures, even when skilfully treated by the Smith-Petersen nail. This is in part due to mechanical inadequacy of the nail as a method of fixation in very comminuted fractures, and in part the result of ischæmia of the femoral head.

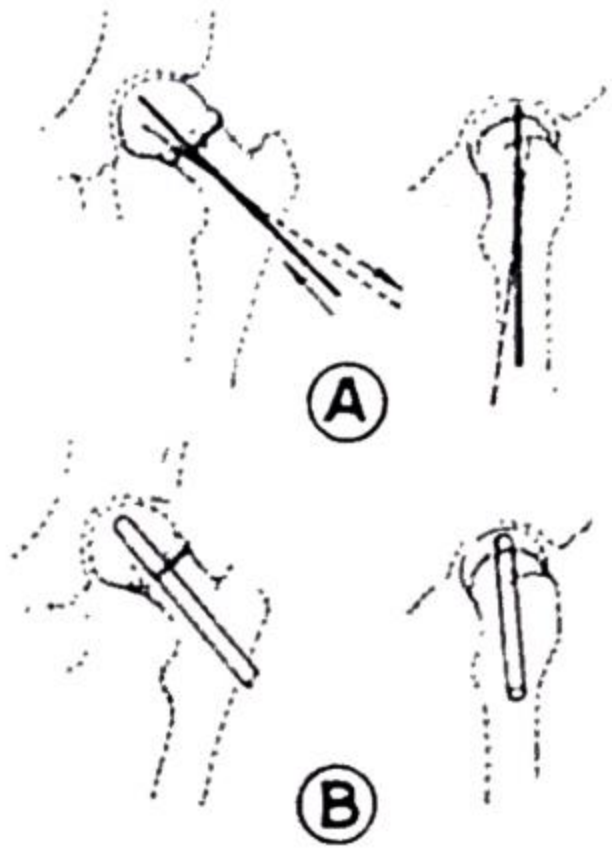

FIG. 1535.—A. Insertion of guide wires. The one in good position is retained. B. The nail is inserted and the wire withdrawn.
(A.P. and lateral views.)

Non-union can be treated by the following methods :

(1) *Subtrochanteric osteotomy* with displacement of the shaft under the head. In this way the shearing strain of weight-bearing is taken off the fracture line (fig. 1536).

(2) *Replacement of the head* by a head prosthesis of stainless steel or suitable plastic (Judet operation).

FIG. 1536.—Smith-Petersen nail being extruded from intracapsular fracture with ischæmic necrosis. Treatment by displacement osteotomy.

(3) *Insertion of a bone graft* (suitable only in cases where the head is alive and the patient is relatively young).

Extracapsular Fractures of the Neck of the Femur.—Two subdivisions of this fracture are recognised on anatomical grounds, though the distinction has no bearing on treatment : (1) *Basal fractures* are those occurring just where the base of the neck springs out of the trochanters ; (2) *Pertrochanteric fractures* where the fracture lies entirely within the trochanteric mass. In the latter the degree of comminution may be very great

Jean and Robert Judet, Contemporaries, Paris.

and the neck, lesser and greater trochanters, and the upper end of the shaft may all be separate mobile fragments.

These injuries are becoming more common than the intracapsular fractures because they usually occur in the oldest age groups and the average age of the population is steadily increasing.

Clinically the diagnosis is made, as in the case of the intracapsular fracture, by the combination of external rotation and shortening (which indicates traumatic coxa vara). In the pertrochanteric fracture the degree of external rotation is considerably greater than in more proximally sited fractures of the neck. In some pertrochanteric fractures the foot of the affected extremity will be found to be lying with its outer surface flat on the examination couch, so indicating a full 90 degrees of external rotation. On the other hand, an intracapsular fracture of the femoral neck will have an external rotation of perhaps only 45 degrees.

This important clinical point can be remembered if the mechanical explanation is understood. External rotation after fracture of the neck occurs in the long axis of the femoral shaft, and the ' stub ' of the fractured neck will rotate so that the broken end tends to face forward. If the stub is short or non-existent (extracapsular), there is nothing to prevent full external rotation, but if the stub is long (as in a subcapital fracture) it would have to sweep round in an arc of considerable radius and the presence of the capsule round it will prevent this.

Treatment.—It is quite a simple matter to treat a pertrochanteric fracture, without operation, merely by applying weight-traction to the limb and confining the patient to bed for three months until the fracture is clinically united. The traction will restore the length, and if the leg is abducted and internally rotated this will correct the deformities of coxa vara and external rotation. Because many of these old patients are incontinent, it is difficult to prevent bedsores if the patient cannot be turned periodically on to the face, and senile dementia is also common and may make the maintenance of an efficient traction system impossible.

FIG. 1537.—Pertrochanteric fracture treated by "blade-plate."

Internal fixation of the pertrochanteric fracture is therefore more attractive than conservative treatment, but it requires a rather larger internal splint than the simple Smith-Petersen tri-flanged nail. The apparatus used is a 'blade-plate' which has one limb screwed to the shaft of the femur and the other limb driven into the neck of the femur (fig. 1537). Without the angle-iron principle the long proximal fragment in the extracapsular fracture, comprising head and neck, offers such leverage that the force causing the fracture to pull into coxa vara is too great to be resisted

by a simple Smith-Petersen nail. The instrument is inserted with X-ray control very much in the same way as described for intracapsular fractures. The patient is allowed out of bed in a chair within a few days of the operation. There are no failures of union after this method, as the blood supply of the fragments is good and the only mechanical failures are technical.

Nélaton's Line, Bryant's Triangle.—It is convenient at this point to describe two classical measurements which formerly were important in the clinical diagnosis of hip conditions in the pre-radiological era. Though not often needed at the present day, every educated surgeon should know them.

Both these tests demonstrate the presence of shortening between the pelvis and the great trochanter of the femur; that is to say, shortening which could be caused by dislocation of the hip, fracture of the neck of the femur, coxa vara, tuberculous destruction of the femoral head with ' wandering acetabulum,' etc.

Nélaton's line is a line drawn between the anterosuperior iliac spine and the most prominent part of the tuber *ischium*; in the normal hip the tip of the great trochanter should lie on this line, but if the neck of the femur is short the tip of the great trochanter will be at a higher level.

To carry out the test the patient should lie on his side with the affected hip uppermost and slightly flexed so that the knee falls slightly forwards. The tip of the great trochanter is palpated and a skin mark made to indicate the level. Nélaton's line is then marked by passing a tape measure from the anterosuperior iliac spine round the great trochanter to the tuber *ischium* (fig. 1538).

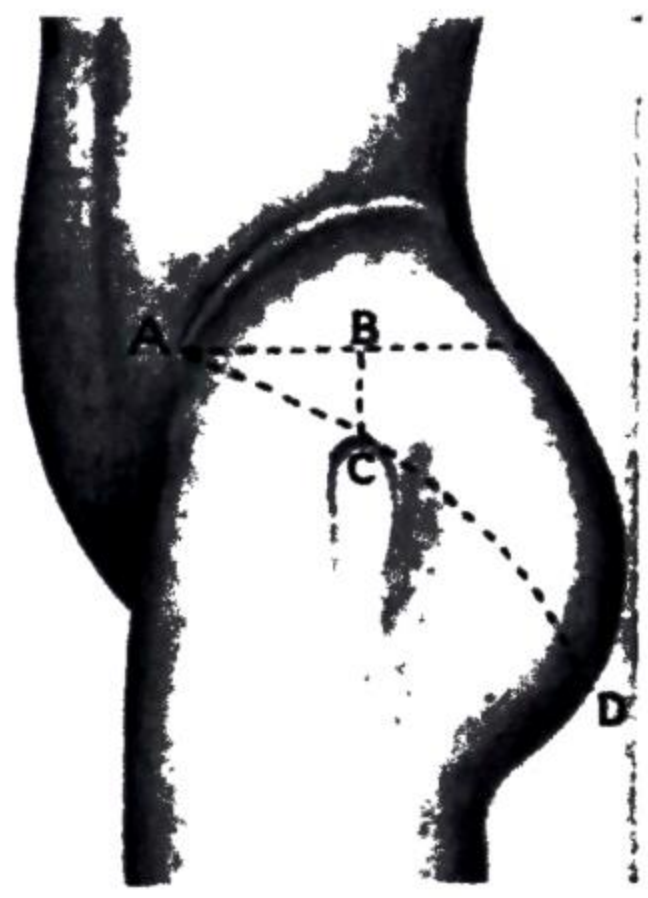

FIG. 1538.

A D = Nélaton's line.
A B C = Bryant's △, of which B C is the essential measurement.

Bryant's triangle is another way of arriving at the same result. The patient lies supine and the tips of both great trochanters are palpated and skin marks made to indicate their levels; perpendiculars are then dropped from the anterosuperior iliac spines and the distances from the tips of the trochanters to the perpendiculars are measured on both sides. If the neck of the femur is short on one side, the distance to the perpendicular will be correspondingly reduced. It will be noted that though it is traditional to call this Bryant's ' triangle,' the hypotenuse of the triangle is not needed.

In obese patients it may be difficult to detect the precise position of the tips of the great trochanters to within an inch, and as the test is only of value for differences of this magnitude, it will be realised that the modern usefulness of the test is limited, even though the instructional value and clinical exercise is still of importance.

Separation of the epiphysis of the head of the femur is not an uncommon occurrence, but it is not a simple traumatic lesion. The centre appears during the first year, and unites at the age of twenty. The clinical features resemble those of an intracapsular fracture, see *slipped epiphysis* (p. 1327).

Avulsion of the lesser trochanter is sometimes caused by sudden contraction of the ilio-psoas. The commonest age for this accident is about puberty. The condition is unlikely to be diagnosed without the assistance of X-rays. Treatment consists in immobilising the limb for four weeks in slight flexion.

(ii) Fractures of the **Shaft** of the femur.

Displacement depends on the direction of violence, muscular contraction, and gravity. In the upper third the upper fragment is flexed by the ilio-psoas, abducted by the gluteal muscles, and everted by the external rotators. The lower fragment is adducted by the adductor muscles, drawn proximally by the hamstrings and quadriceps, and everted by the weight of the limb.

Auguste Nélaton, 1807–1873. Professor of Clinical Surgery in the University of Paris.
Sir Thomas Bryant, 1828–1914. Surgeon, Guy's Hospital London.

In middle-third fractures and lower-third fractures, the deformity is one of backward angulation and shortening. The distal fragment is the main element in the backward angulation (fig. 1539).

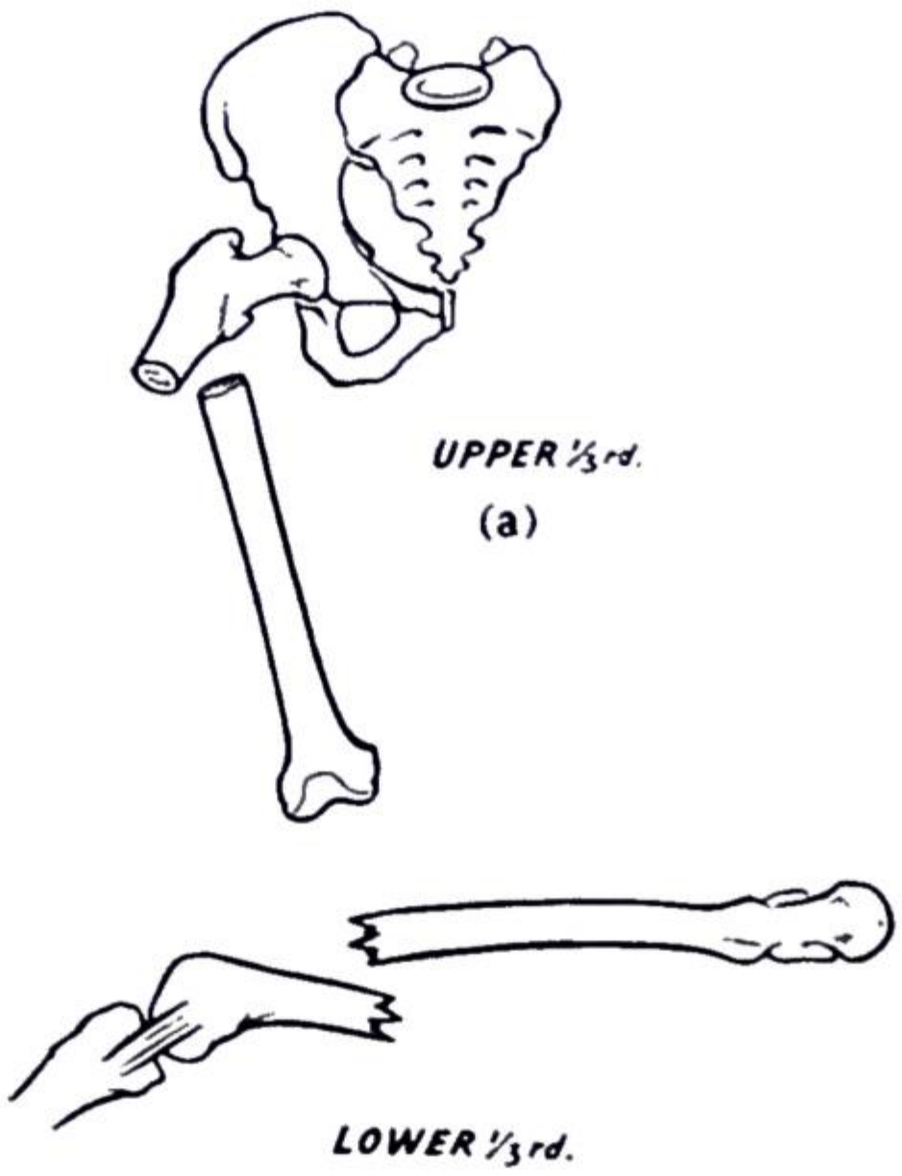

FIG. 1539.—Characteristic deformities of fractures in upper and in lower thirds of shaft of femur.

In rare fractures just above the condyles, the distal fragment is often rotated backward through 90 degrees and may press upon the popliteal artery to cause gangrene of the foot if the obstruction is not quickly diagnosed and rectified.

Aims of Treatment.—There are three essential aims in the treatment of a fracture of the shaft of the femur: (1) restoration of alignment, (2) restoration of length, (3) prevention of knee stiffness.

(1) *Restoration of alignment* is essential in the femur because mal-alignment throws an abnormal strain upon the knee joint, and osteoarthritis is prone to develop in later life.

(2) *Restoration of adequate length* is essential unless the patient is to wear an ugly raised shoe. Even so, one need not fear even as much as ¾ inch (2 cm.) of shortening, as this amount is easily concealed by tilt of the pelvis, and slight shortening greatly favours rapid and sound osseous union. Almost all the ill-effects of treatment can be traced to over-anxiety to restore full length, and these ill-effects are the results of delayed union.

(3) *Severe knee stiffness* is a common complication of fractures of the shaft of the femur, especially in the lower half, as a result of scarring of the muscles of the extensor mechanism. Delayed union is especially prone to result in permanent knee stiffness. It is preferable to have a femur which is a little short with a fully mobile knee, than a femur which is full length with delayed consolidation and limitation of knee movement.

Traction and Counter-traction.—Because of the muscular tone generated by the bulk of the muscles of the thigh, an untreated fracture of the femur may easily develop 4 or 5 inches (10 or 12·5 cm.) of shortening ('overriding') and the maintenance of length against this constant tendency to shorten is the special problem presented in this fracture. It is therefore essential to have a clear understanding of the principles of traction and counter-traction in fracture treatment.

In most fractures, other than that of the femur, it is a common practice to overcome shortening by a manipulation under anæsthesia and, if the bone-ends have been successfully 'hitched' against each other, then to maintain this length merely be encasing the limb in plaster. This is quite impossible in the femur because, even if the fragments could be 'hitched,' the soft bulk

of the thigh would allow them to slip again soon after the plaster was applied. If the fracture is oblique or comminuted it would be impossible to obtain stable end-to-end contact against muscle tone.

In applying *traction* to the distal fragment so as to hold the thigh muscles at normal (or nearly normal) length, it is always necessary to use *counter-traction* to the proximal fragment to prevent the trunk and pelvis following the traction force and again allowing the thigh to shorten.

There are two entirely different methods of applying traction and counter-traction and both have their own special spheres of usefulness : they are (1) Sliding traction and (2) Fixed traction.

(1) **Sliding Traction** (*syn.* Weight Traction, Balanced Traction).—There are dozens of modifications of detail in applying sliding traction, but only the essential principles need be considered :

(*a*) *Traction* is applied to the distal fragment by weights and pulleys attached to the limb either by skin strapping or by skeletal traction. Skeletal traction is to be preferred as it is more comfortable and more precise ; a 4-mm. thick stainless steel Steinmann pin is driven into the upper end of the tibia for this purpose and a Böhler stirrup attached.

(*b*) *Counter-traction* is provided by using the weight of the body ; this is brought into action by elevating the foot of the bed so that the patient's trunk and pelvis tend to slide away from the source of traction. With a traction force of 20 lb. (9 kg.) the foot of the bed is raised about 9 inches (22·5 cm.) (fig. 1540).

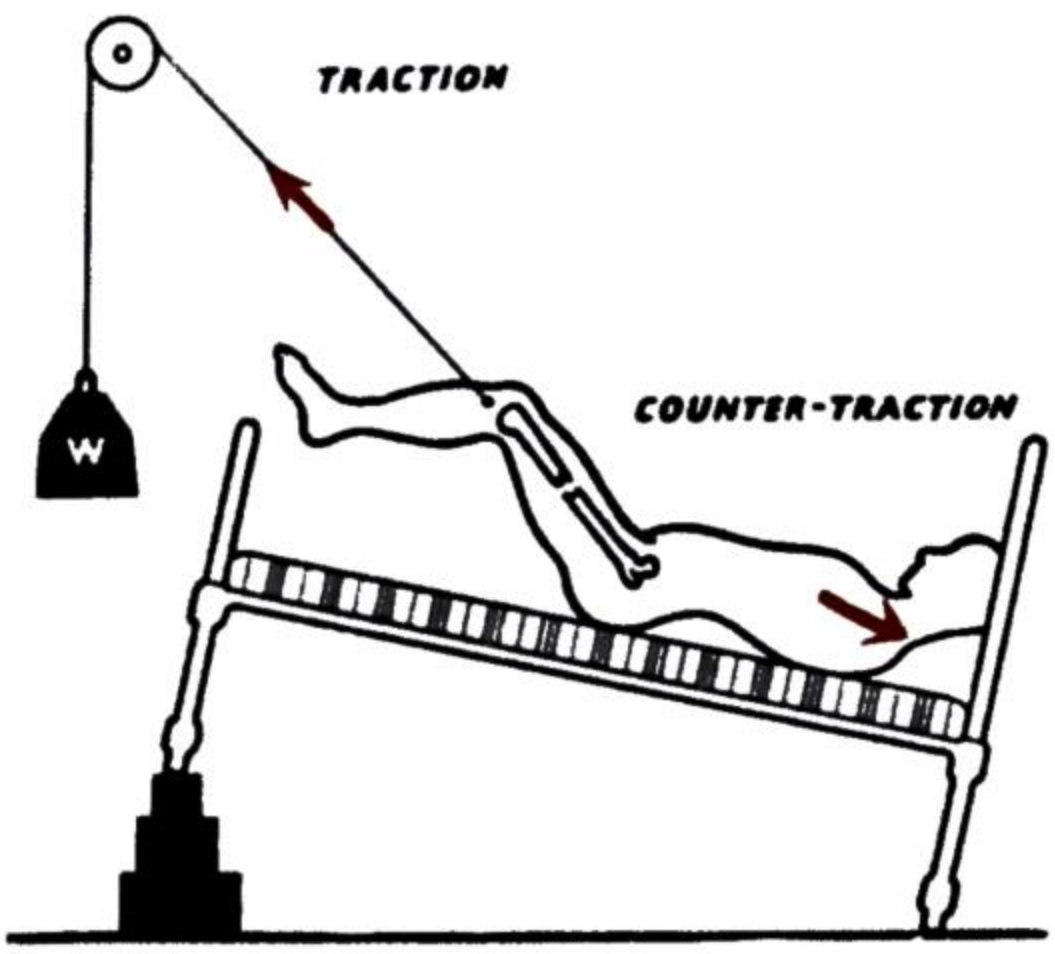

FIG. 1540.—Principal elements in sliding traction: traction and counter-traction.

(*c*) *Support for the Back of the Thigh.*—This can take almost any form and is the source of most of the detailed variations in any sliding traction system.

Because of the tendency for the thigh to sag under the influence of gravity, the original deformity of backward angulation tends to persist and must be controlled by slings or supports under the thigh to restore its normal anterior bowing. Frequently the method of supporting the thigh is further complicated by gadgets for permitting knee movement, for holding the foot in dorsiflexion (to prevent equinus deformity), and to counterpoise the whole apparatus so that it floats with the patient as he moves in bed.

Sliding traction is attractive in that it is very comfortable. It is especially useful in fractures of the shaft of the femur at, or above, the upper third (pertrochanteric fractures also). The main danger of the method is that bone contact may be lost (' distraction ') through excessive traction, and if the

Fritz *of Surgery, Berlin.*

traction force has to be reduced because of this the fixation and alignment of the femur is prejudiced.

(2) **Fixed traction** is quite unlike sliding traction, and because it depends entirely on the use of the Thomas splint, its modern application hardly differs from the original method used by H. O. Thomas nearly one hundred years ago.

In this method of traction, cords are attached to the distal fragment, either by skin extensions or by a skeletal pin, and after passing the Thomas splint over the limb so that the padded leather ring takes a purchase against the ischial tuberosity, traction is applied by tying the cords to the foot of the splint. Counter-traction is thus exerted by the pressure of the ring against the soft tissues and the tuber ischii (fig. 1541).

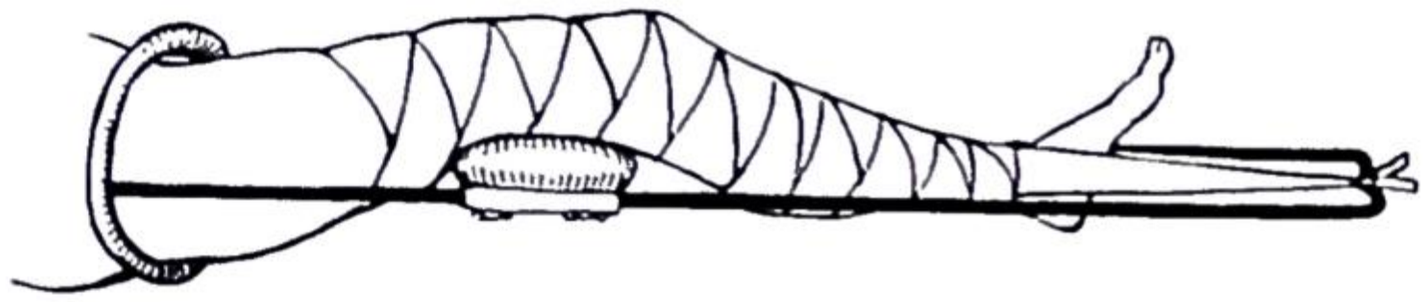

FIG. 1541.—Thomas splint with fixed skin traction. Counter-traction against ring.

The tendency to backward angulation of the fractured shaft of the femur is combated by slings passed between the side-bars of the splint behind the thigh. Fixation of the fracture is obtained by enclosing the limb and the splint in a bandage.

It is evident that this method can exert only a relatively slight traction force, because the skin of the perineum would not be able to withstand the equal and opposite counter-traction force as great as that used in sliding traction. It is the great art of this method to get results with minimum force. It is a fundamental requirement, therefore, that the fracture should be capable of reduction under anæsthesia and that the Thomas splint with fixed traction be used merely to *retain* a reduction already achieved.

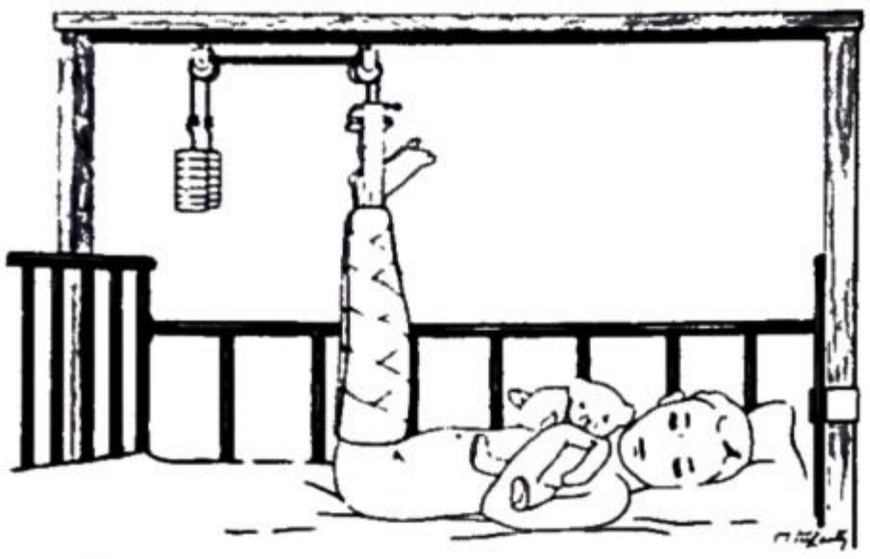

FIG. 1542.—A 'gallows' splint.

A *gallows splint* (fig. 1542) is useful for children below the age of five years. Traction is applied by means of strapping, and the legs are slung up to the cross-piece, so that the pelvis is just lifted from the mattress. The child's weight acts as counter-traction, and this position is very convenient for nursing purposes.

Separation of the lower epiphysis was more common in the days of horse-drawn vehicles, when children enjoyed the excitement of riding on the rear axle. Entanglement of the foot in the spokes caused violent hyperextension of the leg and forward separation of the epiphysis. The lower end of the diaphysis projects backwards, and gangrene sometimes followed pressure on the popliteal vessels. The deformity is reduced by traction on the flexed knee with the patient lying on his back on the floor, the pelvis being fixed by assistants. After reduction the limb is bandaged in slight flexion, the pulsations of the dorsalis pedis artery being a guide to the circulation of the limb. If manipulation fails, open operation must be performed.

Hugh Owen Thomas, 1834–1891, of Liverpool, the son of a famous bone-setter, and the founder of orthopædic surgery, introduced his splint in 1886.

Fractures of the **Patella** are due to direct or indirect violence.

If due to *direct violence*, a comminuted or star-shaped fracture usually results. Separation of the fragments is not extensive, and may be absent, owing to the intact aponeurosis of the quadriceps expansion and periosteum, which hold them in position. Considerable bruising and effusion into the joint are to be expected. Aspiration of the joint is often advised, but as it is full of solid blood-clot it is rather meddlesome. A posterior plaster slab is applied for a week, after which active movements are encouraged.

Fractures due to *indirect violence* occur when the knee is semi-flexed. The fracture in this case is typically *transverse* (fig. 1543). In this position

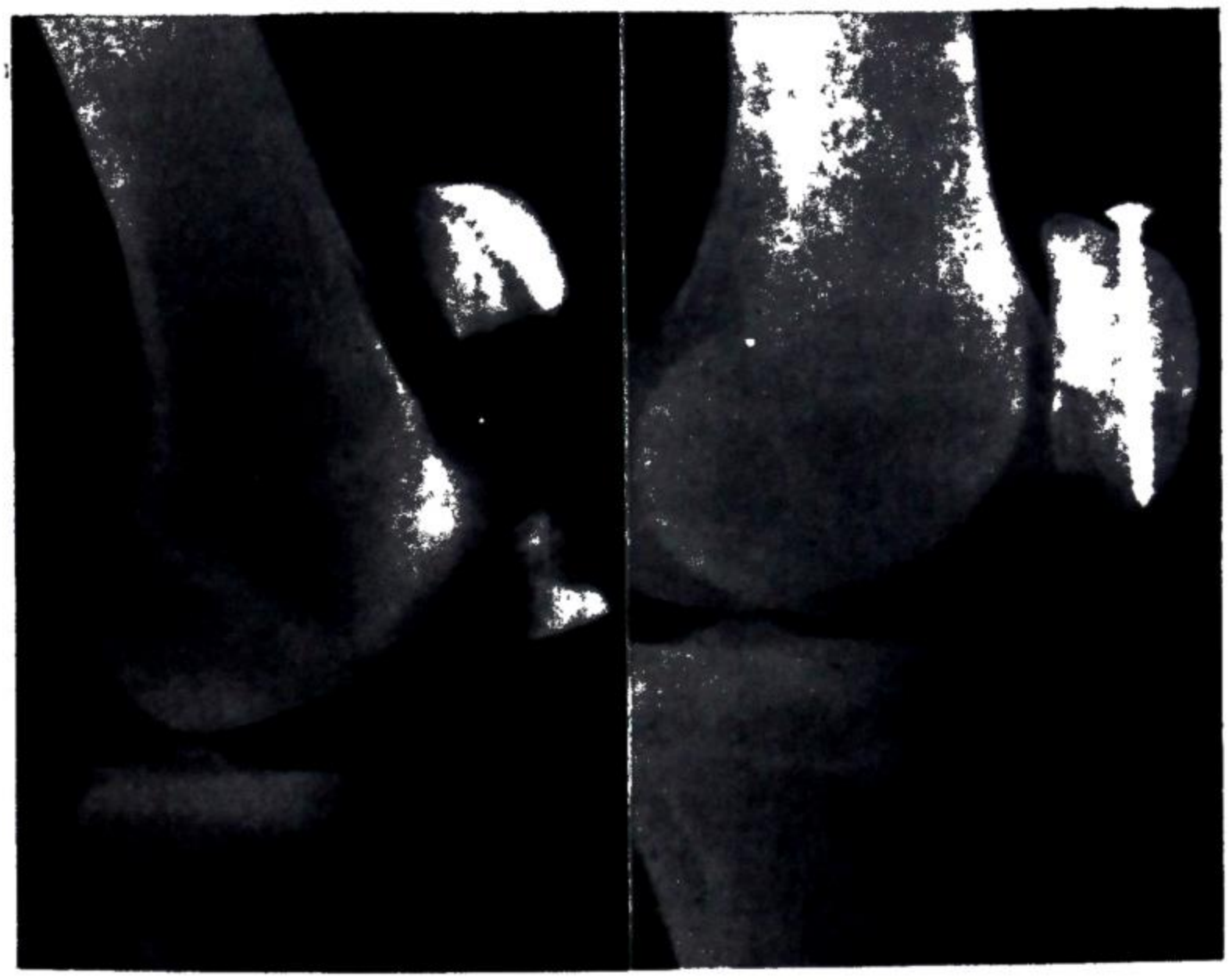

FIG. 1543.—Transverse-fracture of patella.

the patella is balanced on the front of the condyles, and sudden contraction of the quadriceps, as in an effort to regain balance, snaps the bone in the same manner as a stick is broken across the knee. Local pain and loss of power to extend the leg are prominent symptoms. The joint rapidly fills with blood, and the gap between the fragments can sometimes be seen, and in any case is readily palpable, this feature distinguishing the condition from rupture of the quadriceps tendon (p. 1294). Owing to separation of the fragments and the interposition of torn aponeurosis, fibrous union will occur unless operation is undertaken. Moreover, in cases treated conservatively, the band of fibrous tissue which unites the fragments will stretch, and eventually the fragments will be widely separated.

Treatment is operative and for transverse fractures with separation the aim is to coapt the fragments by internal fixation. The operation is performed as follows :

The flaps of aponeurosis which cover the raw surfaces of the fragments are excised and blood-clot scraped away with a sharp spoon. The bone is drilled and approximated by strong braided silk or wire ; some surgeons prefer to use a screw.

After the fragments are approximated the torn quadriceps expansion is carefully sutured on each side of the patella and the wound closed. Though the internal fixation may be strong, it is advisable to splint the knee for about four weeks before starting active flexion movements.

Excision of the whole of the fractured patella is often indicated if the fracture is comminuted (Brooke).

The fragments are easily dissected from the tendinous attachments, and the torn aponeurosis is sutured. The gap resulting from excision of the patella is closed with vertical sutures as accurately as possible, but some slight inadequacy is of no moment. As with all operations on the knee joint, a firm bandage is applied over voluminous wool dressings to control oozing. Active contraction of the quadriceps is begun after three days and graduated active flexion in one week. Patients are enabled to return to work in from three to six months, according to the nature of their occupation.

Fracture of one patella is occasionally followed by fracture of the other at a later date; there is no clear reason for this tendency.

Fractures of the **Tibia** (fig. 1544).

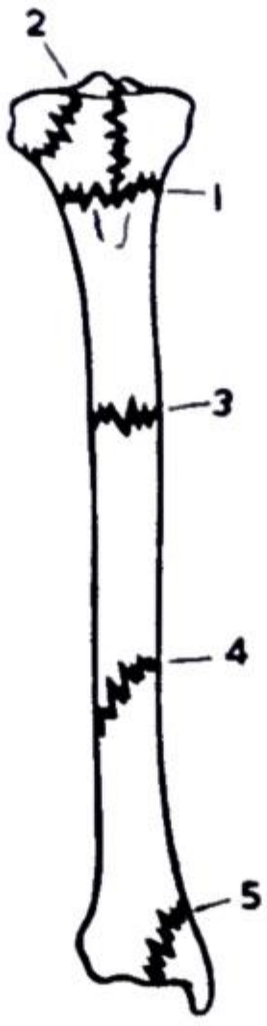

FIG. 1544.—Tibia.

1. Y-shaped fracture involving the knee joint.
2. Outer tuberosity.
3. Transverse fracture due to direct violence.
4. Oblique and spiral fractures due to indirect violence.
5. Internal malleolus.

(i) Fractures of the *upper end* are usually due to direct violence, one or other tuberosity being separated, and occasionally a Y- or T-shaped fracture is produced. The knee joint is involved and rapidly fills with blood. A 'bumper' fracture is due to a severe blow on the outer side of the joint, e.g. impact with the bumper of a car which strikes the outer side of the leg just below knee level; the external condyle of the femur impinges on and crushes the outer tuberosity of the tibia (fig. 1545). Because these fractures involve joint surfaces, the ideal treatment combines accurate restoration of the joint surfaces with early mobilisation. In young people it is sometimes advisable to perform open reduction and fix the fragments at the correct level by means of a screw.

Most cases, however, do remarkably well with early joint movement provided that there is no gross valgus deformity and that weight-bearing is delayed. This 'bumper' fracture is one which is very frequently seen in elderly patients knocked down by motor-cars, and these patients do extremely well with early mobilisation and the acceptance of 10 or 20 degrees of valgus deformity. In these elderly patients a mobile knee, capable of bearing weight in less than three months, is the prime object of treatment and, as most of these patients are women, even a severe valgus deformity is easily concealed by the skirt.

FIG. 1545.—'Bumper' fracture.

Ralph Brooke, Contemporary. Surgeon, Royal West Sussex Hospital Chichester, England.

(ii) Fractures of the *shaft* of the tibia, without implication of the fibula, are usually due to indirect violence, in which case the fracture is oblique or spiral. Diagnosis is easy, as the bone is subcutaneous and irregularity or localised tenderness is readily palpable.

Treatment.—When the fibula remains intact, the displacement of a fractured tibia is relatively slight, and as angulation is rarely more than 5 degrees, it is usually sufficient to apply a simple plaster without any attempt at reduction. Manipulative reduction is obviously unlikely to be successful (even if it were needed) because the intact fibula would obstruct manipulative manœuvres.

Though it might appear that fractures of the tibia when the fibula is intact would be unlikely to give rise to difficulty in treatment, in fact delayed union is not uncommon. It is probable that the intact fibula acts as a 'strut' to prevent the fragments of the tibia coming into close contact. For this reason there are many surgeons who believe, with some justification, that these fractures are best operated on, and fixed with screws and plates. This operation is certainly to be considered in the adult, but is unnecessary under the age of about twenty years, because the powers of fracture union in youthful bone are very great.

Fractures of the shaft of the **Fibula** alone are usually due to direct violence. The procedure of 'springing' the fibula assists diagnosis, and consists in compressing the fibula against the tibia, local pain being referred to the site of a fracture. A radiograph confirms the diagnosis, and treatment, if any is required, need be nothing more rigorous than the application of an adhesive support.

Fractures of the Tibia and Fibula commonly occur either as a result of direct or indirect violence and are very frequently seen as the result of traffic accidents. In direct violence the bones are fractured at the same level, but if due to indirect violence the tibia is usually broken at the junction of its lower and middle thirds, and the fibula at about its centre. In the fractures of civil life the tibia is the most common *compound* fracture because it is subcutaneous bone in the whole of its length and displacement is likely to cause one of the fragments to penetrate the skin.

With the help of modern antibiotics, the treatment of open or closed fractures of the leg bones is very much the same. An open fracture must be converted into a closed fracture by cleansing the wound, excising contused tissue, and then closing to cover exposed bone. In some cases an immediate skin graft may be necessary.

In some severely comminuted fractures, with gross soiling by road dirt, it may be better to amputate forthwith if complicated by nerve or vascular injury.

Fractures of the leg bones can be held either (*a*) by plaster after manipulative reduction, or (*b*) by internal fixation with plates and screws. Both these methods are extensively used and, with the aid of antibiotics, if the wound is recent and not grossly contaminated many open fractures are now being successfully treated by internal fixation, a form of treatment which in the past was considered unjustifiable.

If plaster fixation is used, the limb is manipulated into alignment and a plaster cast applied from the toes to the groin. Modern practice strongly condemns the use of traction appliances for the tibia, as these seem to be one of the most fruitful sources of the delayed union, which is a constant source of trouble in the tibia.

In general, the tibia takes about twelve weeks to unite, and it is rarely fit to take weight without external support under sixteen weeks.

Fractures involving the Ankle Joint.

Specialised text-books of fracture surgery devote much space to attempts to classify the fractures which involve the ankle joint; the classification is based on the direction of the force causing the injury. Even the most elaborate classifications fail to cover every fracture encountered, and therefore, for the sake of simplicity, only a broad generalisation will be given.

There are four principal directions in which injurious forces can be transmitted to the ankle: (1) *Internal rotation*, (2) *External rotation*, (3) *Inversion*, (4) *Eversion*. Some text-books use the terms 'abduction' and 'adduction,' and in this description these are taken as synonymous with 'eversion' and 'inversion.' The joints of the tarsus are much more flexible in the direction of inversion and internal rotation than in eversion and external rotation. Inversion and internal rotation therefore produce the common *sprained ankle* in which the external lateral ligament of the ankle joint is partially torn. On the other hand, external rotation and eversion forces the tarsal joints into a solid bone-block, and the force is thus expended on the ankle joint to produce a fracture. By far the commonest fracture, and the least important, is the isolated, and undisplaced, fracture of the *external malleolus*. This is generally an oblique or spiral fracture involving the lower end of the fibula for about 2 inches (5 cm.) and extending into the malleolus itself.

Fracture of the external malleolus is diagnosed clinically by the site of maximum tenderness being over the bone of the lower end of the fibula; this simple clinical test differentiates it from *sprain of the ankle*, where the maximum tenderness is just below and in front of the tip of the external malleolus.

Treatment.—Fractures of the external malleolus do not need reduction because they are undisplaced. If very little swelling is present, a firm elastic dressing is all that is necessary and, with active movements, full function should be recovered in six weeks. If excessive swelling is present, it may be more convenient to apply a walking plaster for four weeks, and this may enable the patient to get about his business more quickly than with strapping. Whatever the treatment, if the fracture is undisplaced the result will be 100 per cent. successful.

Pott's Fracture.—The essential features of the Pott's fracture are that (1) it is a fracture-dislocation of the ankle joint, and (2) it requires accurate reduction and fixation. Various patterns of Pott's fracture are recognised, and these differ as the result of the different types of violence causing them.

The common Pott's fracture results from a continuation of the same force which causes an uncomplicated fracture of the external malleolus—i.e. ex-

Percival Pott, 1714–1789, St. Bartholomew's Hospital, wrote surgical papers while recovering from a compound fracture of the tibia and fibula.

ternal rotation and eversion. The external malleolus is fractured spirally (because of the rotation element) or obliquely; this is then followed by fracture of the tip of the medial malleolus and thereafter by postero-lateral subluxation of the talus from its surface of contact with the tibia (fig. 1546 *a*). In this movement a chip of bone is frequently taken off the posterior surface of the tibia, the so-called 'third malleolus.'

Two other types of ankle fracture, not quite so common, are also easily recognised:

(1) *Eversion Fractures* (*syn.* abduction fractures).—Here the talus presses against the lateral malleolus and the fibula breaks transversely 2 or 3 inches (5 to 7·5 cm.) above its lower end. If the talus subluxates laterally, the tip of the medial malleolus is avulsed (fig. 1546 *b*).

(2) *Inversion Fractures* (*syn.* adduction fractures).—Here the talus inverts and tends to move medially. The medial malleolus is fractured vertically through its base and the external malleolus is fractured transversely at the level of the ankle joint (fig. 1546 *c*).

A variant of the eversion injury includes rupture of the lower tibio-fibular ligaments with 'diastasis' of the ankle joint—i.e. widening of the mortise by separation of the malleoli with or without fractures of the lateral malleolus or fibular shaft (fig. 1546 *d*).

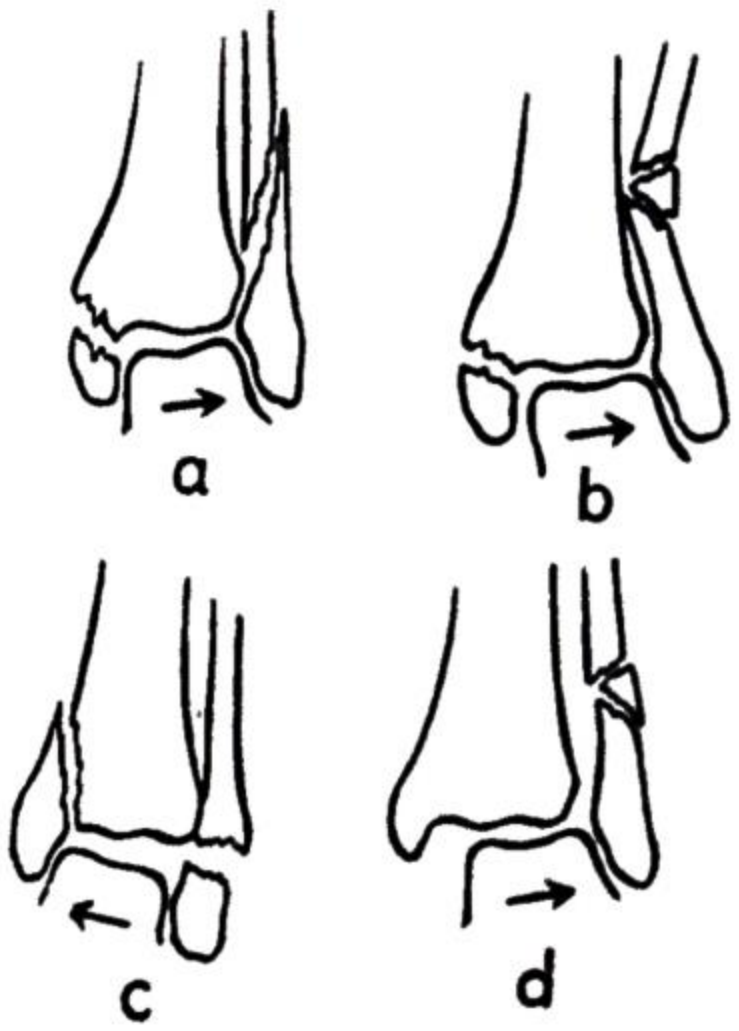

FIG. 1546.—Types of ankle fracture.
(*a*) Abduction—external rotation.
(*b*) Eversion or abduction.
(*c*) Inversion or adduction.
(*d*) Diastasis of tibio-fibular joint.

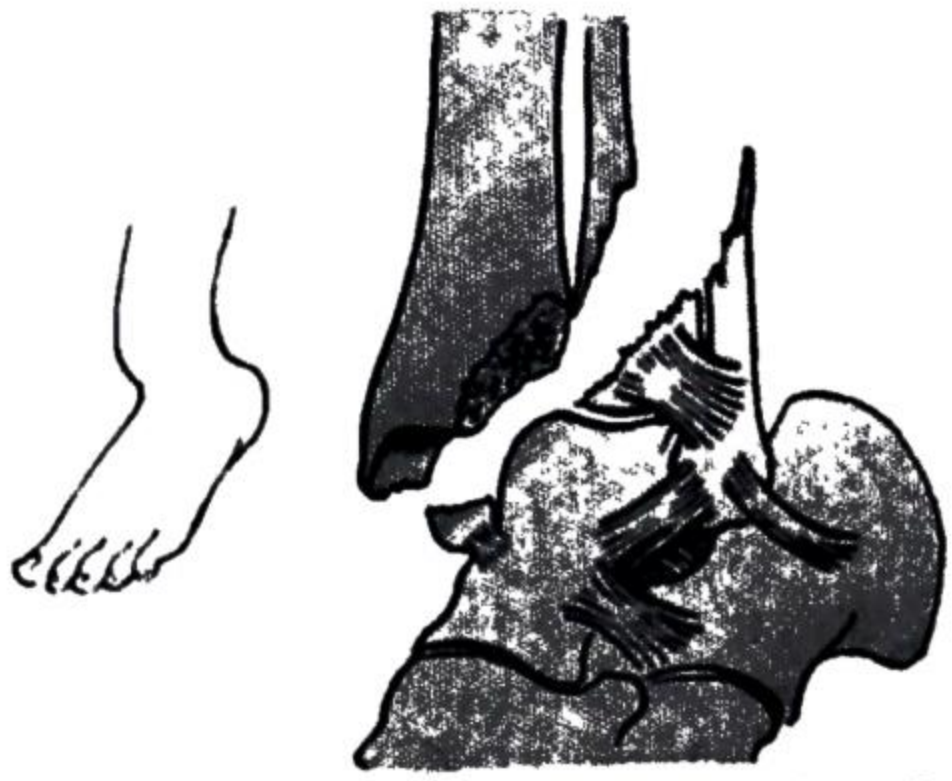

FIG. 1547.—Gross mechanism of Pott's fracture. Foot displaced in relation to shaft of tibia.

Treatment.—The reduction of a Pott's fracture requires the complete relaxation of full anæsthesia. As judged from the pre-reduction X-rays of a severely displaced fracture, to the inexperienced it may appear unlikely that a satisfactory reduction could ever be obtained without operation, but the result of a skilful manipulation is often surprisingly good. The essential feature of the reduction is to concentrate on restoring the alignment of the *foot* to the *tibia* rather than on entertaining the idea of reducing the separate fragments by local manipulation directly on the ankle joint. In the ordinary Pott's fracture with postero-lateral displacement of the talus, the separated fragments of the medial and lateral malleoli move as one piece with the foot

and talus, because they are attached to these structures by their ligaments (fig. 1547). The manipulation thus consists of reversing the direction of the forces which caused the original injury (a general principle in all fracture work). The common Pott's fracture is caused by external rotation and eversion; therefore reduction is produced by internal rotation and inversion, assisted in this case by correcting the backward displacement of the foot in relation to the tibia.

The reduced Pott's fracture is immobilised by encasing the ankle in a closely fitting plaster cast with the foot as near as possible in the plantigrade position. Weight-bearing is best avoided for six to eight weeks in badly displaced cases and then only permitted after a new plaster has been applied. It is of paramount importance to check the maintenance of the reduction by weekly X-ray examinations during the first month after reduction.

There is a growing tendency to try to eliminate late re-displacement of a reduced Pott's fracture by operating on the medial malleolus. Once the medial malleolus has been fixed, the key to the reduction is held. This operation is certainly to be advised in fractures with gross displacement (fig. 1548), but if a perfect reduction is obtained by manipulation it is possible to obtain an excellent result with careful conservative treatment.

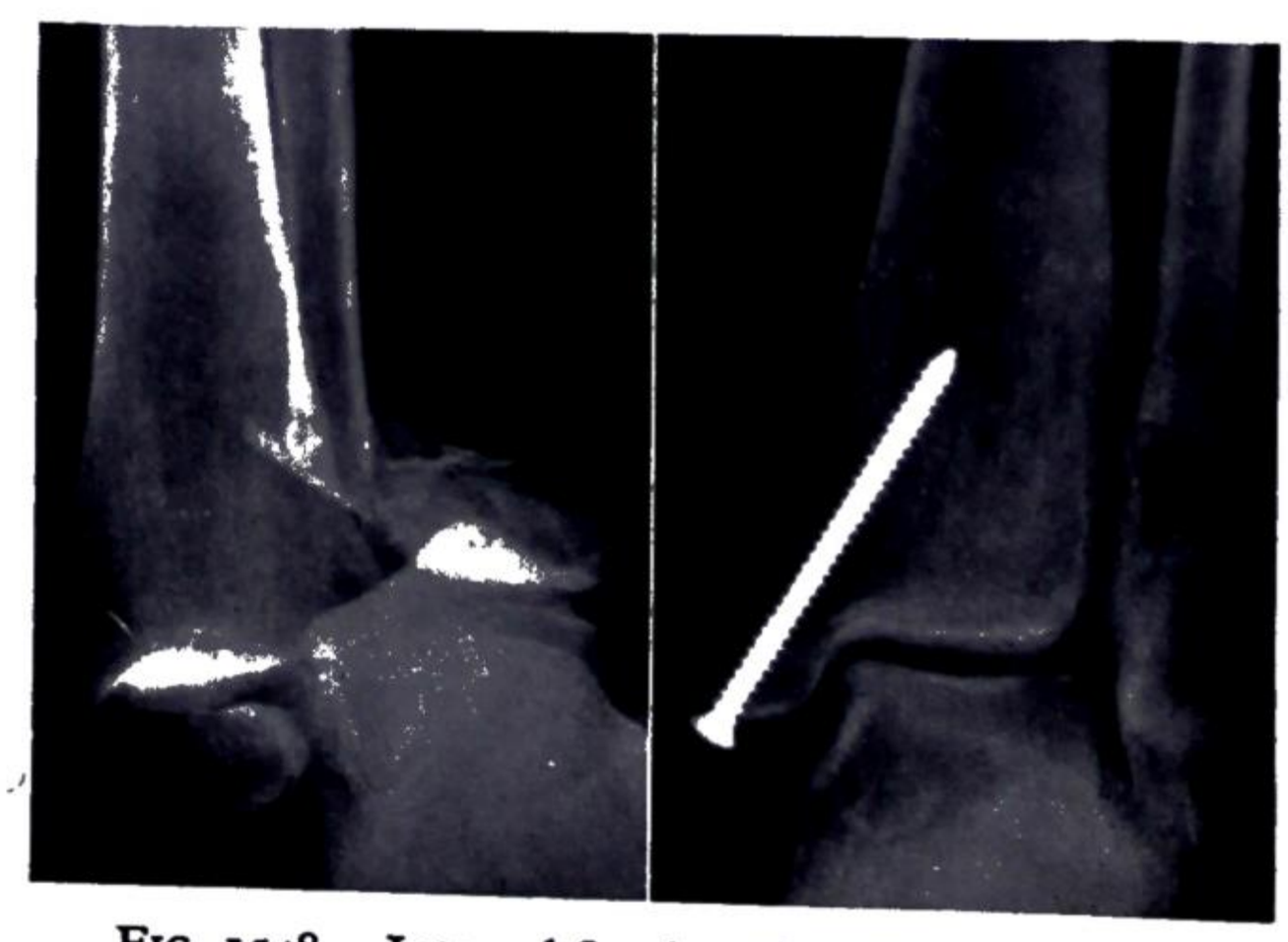

FIG. 1548.—Internal fixation of medial malleolus.

FIG. 1549.—Mal-union following a Pott's fracture.
(*Macewen: Fractures.*)

Old-standing cases of mal-union occasionally require osteotomy of the tibia and fibula, or even reconstruction of the fracture with more adequate reduction and possibly fixation by screw or peg (fig. 1549). Old mal-united fractures are frequently best treated by arthrodesis of the ankle joint if the patient complains of pain due to traumatic arthritis.

The average disability after Pott's fracture is approximately light work in twelve weeks, heavy work six to nine months.

Fractures of the **Tarsal Bones.**

Os Calcis.—The os calcis is almost always fractured by falls from heights by builders, steel erectors, and window-cleaners. In war many compound fractures of the os calcis were caused by the explosion of mines under

transport vehicles. The os calcis is usually shattered like an eggshell and the injury thus involves the subastragaloid joint (fig. 1550).

The degree of displacement varies according to the violence. In some cases there is little or no displacement ; in others the whole os calcis is flattened and widened. The tendo Achillis pulls up the loose fragment of the tuberosity and the heel is always everted to give a severe ' traumatic flat-foot.'

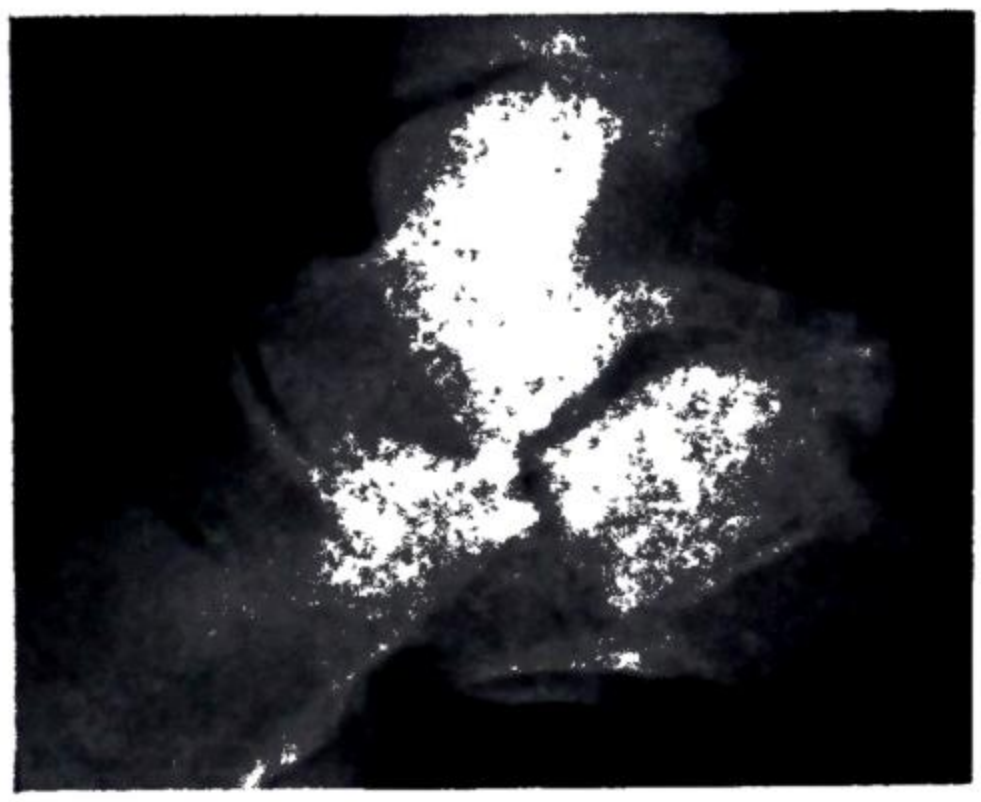

FIG. 1550.—Fracture of the os calcis.

This injury is one which, despite all the different forms of treatment which have been tried, leaves the foot stiff in the subastragaloid region. This means that walking is difficult if the workman has to traverse an inclined plane, such as a sloping roof, because he cannot place the sole of the foot flat on the sloping surface. Similarly, walking out of doors on irregular ground is difficult, though walking on a flat pavement may be fairly comfortable. Frequently pain is experienced for many months, but this is sometimes difficult to assess because heavy compensation claims usually cloud the picture. The fact remains, however, that though this is indeed a very severe injury to a working man, and will prevent him from carrying out his original employment if this involves working at dangerous heights, the end-results are sometimes not as bad as is usually suggested. Very few cases have incapacitating pain if examined three to five years after the injury, and to some extent they will have readjusted themselves to the stiff subtaloid joint in their new occupation. For this reason the modern tendency is to abandon all the elaborate mechanical methods which in the past have been tried in an attempt to restore the normal anatomy. The best results are achieved by accepting the deformity and concentrating on early mobilisation. Weight-bearing should be encouraged in eight to twelve weeks.

The **Astragalus** is sometimes fractured as a result of a fall from a height. The neck of the bone may be shorn through by the sharp anterior articular surface of the tibia ; comminution is common, and injuries to neighbouring bones are often associated. Frequently the body of the astragalus is extruded from the ankle joint by the force of the injury, leaving the head and neck *in situ*, and the displaced body may be palpable under the skin and defy all attempts at closed reduction. As in the case of the os calcis, considerable swelling rapidly develops and obscures the diagnosis, which is often only established after radiography.

Treatment.—Manipulative reduction using skeletal traction is sometimes successful, but usually operative reduction is necessary. If the body of the astragalus is deprived of blood supply, an osteoarthritis of the ankle joint may later necessitate ankle fusion.

Fractures of the Metatarsals.—These are frequently caused by crushing

injuries, such as weights falling on the foot or the wheels of vehicles running over them. In general, they need little or no attempt at reduction unless some part of the shaft, in a grossly displaced case, is projecting into the sole of the foot. If only one or two metatarsals are fractured, they are already splinted by adjacent bones.

FIG. 1551. — March fracture of the third metatarsal.

Plaster is not required and early mobilisation with non-weight-bearing exercises is to be encouraged. Return to activity is by taking weight on the heel as soon as the patient feels he can, which may be two to three weeks. Almost full function is possible in eight to twelve weeks, even after very severe injuries, in patients of good morale.

Avulsion of the Styloid Process of the Fifth Metatarsal.—This is a minor injury which causes unnecessary inconvenience if treated in a walking plaster. The styloid process is avulsed by the pull of the peroneus brevis and, though the fragment is frequently detached by $\frac{1}{16}$ inch (1·5 mm.) or more, it always unites in the absence of treatment and in the presence of active movement. It is unnecessary to apply anything more incommoding than adhesive strapping.

March fractures (*syn.* pied forcé, pied de jeune soldat) occasionally occur near the necks of the second or third metatarsals. The fracture occurs spontaneously, and is predisposed to by a short first metatarsal. This common atavism causes undue strain to fall on the heads of the second and third metatarsals during such exertions as standing on the toes. The fracture is also encouraged by loss of muscular tone, which is predisposed to by wearing heavy boots. Sudden pain, localised over the dorsal aspect of the bone, is characteristic. An immediate X-ray will often fail to reveal the crack, but if repeated in three weeks callus will be obvious (fig. 1551). Strapping and restricted activity only are required. A plaster shoe encourages further atrophy of muscles and renders rehabilitation necessary. Many cases are doubtless treated as ' foot strain ' and more or less ignored, with good results!

CHAPTER XLVII

DISEASES OF BONES

JOHN CHARNLEY

ACUTE INFLAMMATION

TRAUMATIC PERIOSTITIS is a misnomer for the tender swelling which follows bruising of the periosteum and which is a subperiosteal extravasation of blood. Pressure dressings limit further extravasation. Repeated trauma may result in the formation of periosteal nodes of bone, as on the irregular shins of footballers. If the resistance of the patient is low, or if infective foci are present elsewhere, the subperiosteal hæmatoma, in common with hæmatomata in any part of the body, may become infected, since blood-clot is an excellent nidus for organisms circulating in the blood-stream. A subperiosteal abscess results, and unless the pus is evacuated without delay, necrosis of superficial bone may occur.

ACUTE PYOGENIC OSTEOMYELITIS

Predisposing causes of this condition are as follows :

(i) *Trauma.*—Before growth has finished, the weakest part of a long bone is at the diaphyseal side of the epiphyseal line. At this level (the metaphysis) loops of blood-vessels penetrate the epiphyseal cartilage, and any strain imposed on the bone may rupture one or more capillary loops with the formation of a hæmatoma.

(ii) *An Infective Focus.*—Such conditions as infected scratches, tonsillitis, or impetigo allow organisms to enter the blood-stream. A hæmatoma in any situation then forms an excellent culture medium, in which organisms rapidly multiply. Frequently the bone foci are multiple and mere incidents in a true septicæmia; these patients are, of course, much more ill than in the ordinary case which follows from a simple bacteræmia.

(iii) *Lowered General Resistance.*—In the past the disease was most frequent in industrial areas, where overcrowding and malnutrition were common.

Pathology.—The causative organism in the majority of cases is the *Staphylococcus aureus*, other organisms which are less frequently responsible being the *Streptococcus*, *Staphylococcus albus* and *pneumococcus*.

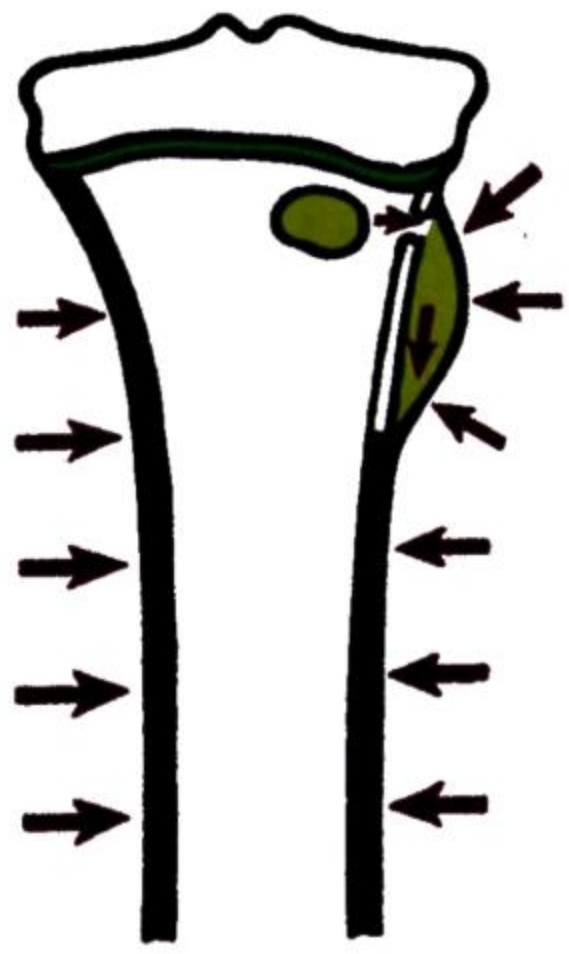

FIG. 1552.—Spread of pus in osteomyelitis.

From its commencement as a small abscess on the metaphyseal side of the epiphyseal line, the pus immediately starts to extend to the surface of the bone, to appear under the periosteum ; it does not spread from the metaphysis directly along the medullary cavity of the diaphysis as might be expected (fig. 1552). The conditions associated with inflammation

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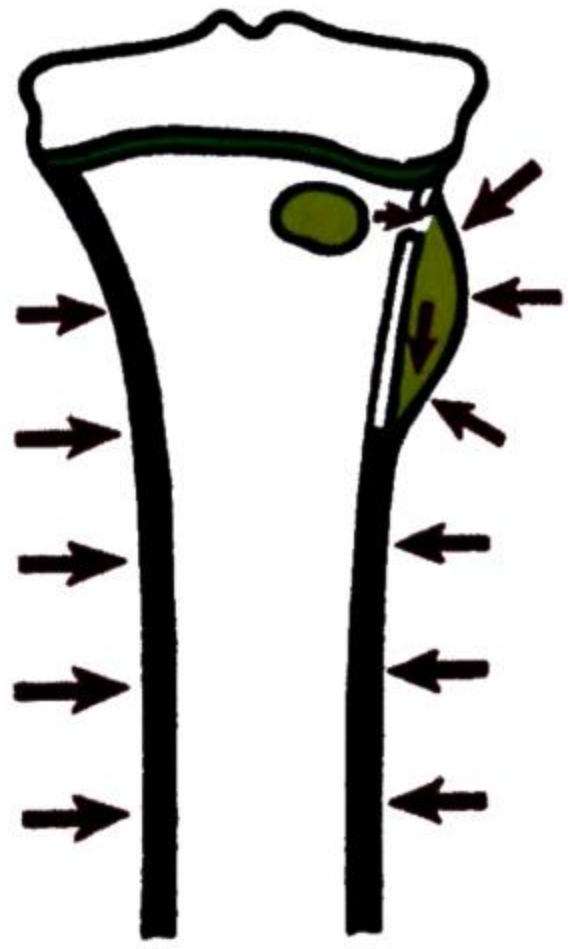

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