THORACIC SURGERY

AND

RELATED PATHOLOGY

by

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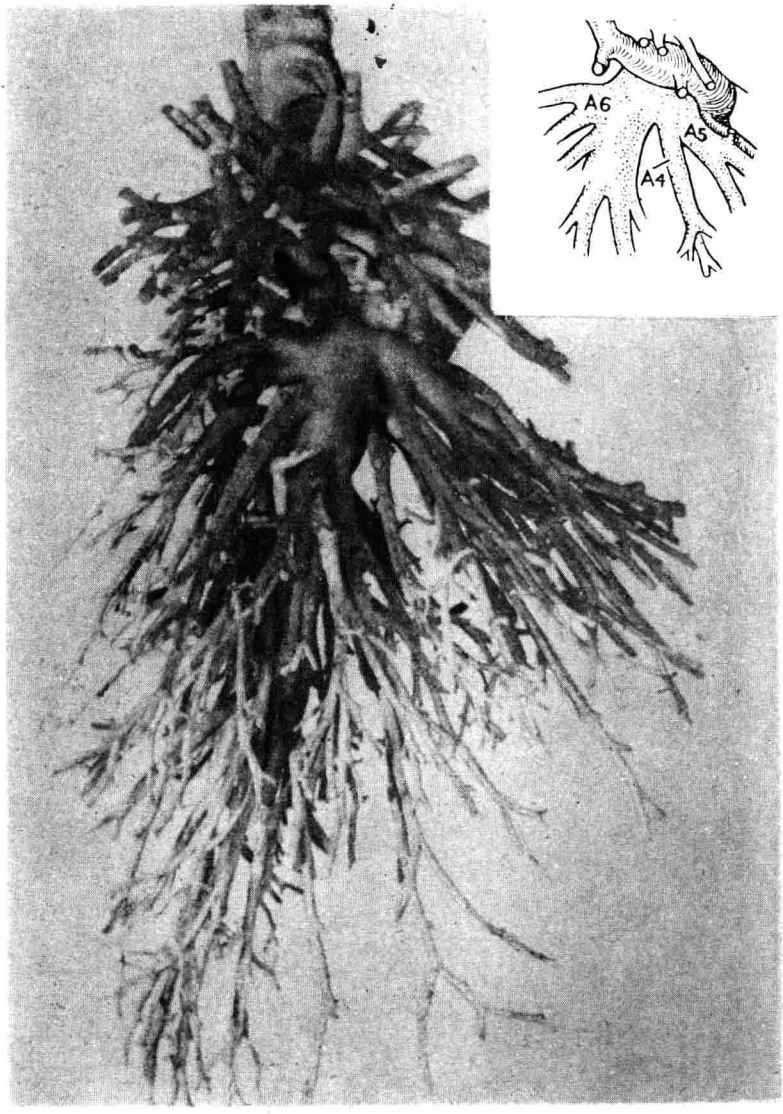


Lateral view of right lung showing structures in the horizontal fissure. Vinylite bronchovascular cast. The bronchi are in white, pulmonary arteries in red, and pulmonary veins in green. A5, medial basal segmental artery of middle lobe. A4, lateral segmental artery of middle lobe. A6, artery of superior segment. The black and white insert corresponds with structures in the color plate.

The arterial supply to the entire upper lobe is of recurrent type and there are no ascending branches. There is a single artery to the middle lobe that branches almost immediately. The artery to the superior segment (A6) arises at a slightly lower level. Just below this vessel, on the posterior aspect of the pulmonary artery, is a smaller artery to a large subsuperior segment. On the anterior aspect below this vessel is a branch to the medial basal segment and extending laterally a branch to the anterior basal segment. In the horizontal fissure can be seen a large vein that covers the intermediate portion of the artery. One large branch of this vein extends upward between the anterior and posterior bronchi and the other, a terminal branch, sweeps around the hilum to pass posteriorly of all other structures. This is representative of the mixed venous supply of the hilum. Either the posterior branch or the deep branch may be lacking. In the former instance this is representative of the arterial type of hilum. If the deep branch is lacking, the hilum is described as venous (From *J. Thoracic Surg.*, 18:616, 1949).

Preface

This text is written to provide a compilation of available knowledge in the field of thoracic surgery, with particular attention to those basic aspects of anatomy, physiology and pathology that are essential to a comprehension of this complex subject.

Thoracic surgery is a relatively young branch of general surgery. It began to attract special interest during and after World War I. The ensuing three decades have witnessed rapid developments of a scope and volume that demand synthesis and analysis. Certain shifts in emphasis and direction have become apparent. Antibiotic agents have reduced the incidence of such infectious lesions as abscess, empyema and bronchiectasis. A growing interest in resectional therapy for pulmonary tuberculosis and a concomitant decline in the use of collapse procedures have posed some problems in the presentation of this fluid therapeutic field. However, it has seemed wise to include an adequate description of those collapse procedures which have served a useful purpose within the past decade and are still a part of any complete therapeutic program although already sharply reduced in frequency of employment.

Considerable space has been devoted to the cardiac and vascular diseases which are susceptible of surgical correction, or in which substantial experimental progress has been made. This is a recognition of their growing importance. In the preparation of this section we have enjoyed the critical advice of Dr. William W. L. Glenn, but any defects in the text are our own responsibility. Dr. Glenn and Dr. Ruth Whittemore have generously provided certain illustrative material.

Our sincere appreciation is extended to the three formal collaborators; Dr. William E. Bloomer (Chapter 6), Dr. Frederick C. Warring, Jr. (Chapters 10 and 11), and Dr. Ralph D. Alley (Chapter 33).

Mr. Armin Hemberger, medical artist at Yale University School of Medicine, has executed almost all of the diagrammatic sketches and tone drawings. We believe the results reflect great credit on his artistic skill and upon his knowledge of anatomic, pathologic and surgical matters. Mr. Howard Reynolds, the medical photographer, has cooperated actively in photographic assignments to supplement the textual descriptions. In the same connection we wish to acknowledge the cheerful help rendered by the Department of Radiology at the Grace-New Haven Community Hospital, particularly Dr. Arnold Janzen and Miss Viola Jacobs.

Unless otherwise stipulated the roentgenograms, pathologic and other illustrative materials are derived from cases which have been treated in the wards or clinics of the University Service, Grace-New Haven Community Hospital. The thoracic section of the surgical department emerged in 1937-38; since then about 3,500 admissions have furnished a rich source of clinical material. The many Connecticut physicians who referred these cases can hardly be mentioned individually, but their interest has made this work possible.

Since 1946 the active interest and generous support of the Office of Naval Re-

search, United States Navy, has been a crucial factor in maintaining a laboratory devoted to investigation of problems in thoracic physiology and a study of related surgical pathologic materials.

The laborious stenographic work on both preliminary and final manuscripts has been carried out in a careful and highly intelligent manner by Miss Bertha Lavietes and by our respective departmental secretaries, Miss Dorothy Spencer and Miss Betsy Winters to whom we owe a debt of great magnitude. We are grateful to the staff of Appleton-Century-Crofts, Inc. for effective help and particularly to Mr. George McDermott for his expert and wise counsel during the preparation of the book.

It has not been our primary purpose to devote concentrated attention to the minutiae of operative technics. In our opinion this phase has been already well covered in several contemporary texts. Rather it has been our plan to consider the broader aspects of thoracic surgical disease. We hope that the results of these efforts will serve not only to guide the reader along existing paths of knowledge, but also to point out the challenge presented by many partially explored or as yet uncharted byways.

GUSTAF E. LINDSKOG
AVERILL A. LIEBOW

Contents

1

TRAUMA TO THE CHEST

FRACTURES OF RIBS

Fractures of ribs are more common in adults than in children. In the young the osseous structure is less brittle; the resilient cartilages and ribs tend to absorb the forces of trauma.

Depending on the type and degree of violence, one or many ribs may be fractured. There may be concomitant injury of the clavicle, sternum and thoracic spine. Direct violence concentrated over a small area drives the rib fragments inward and there is a corresponding tendency to confine the extent of the fractures and to lacerate the underlying pleura and lung. If the violence is a diffuse one applied to the sides of the chest, or anteroposteriorly, the ribs may buckle outward breaking several but often sparing significant penetration of the underlying structures. Rib fractures may be compounded, either by the traumatizing agent such as a shell fragment or secondary penetration of the overlying skin by sharp rib ends or fragments.

The middle and lower true ribs are the ones most commonly involved in fracture, the upper two or three ribs being relatively well protected by the shoulder girdle and its musculature. The floating ribs (tenth to twelfth) although exposed to violence are somewhat more mobile and yielding. However, extensive involvement of all ribs, including the first, sometimes occurs (Figure 1).

Spontaneous rib fractures can occur in the absence of external trauma. These are not uncommon complications of chronic respiratory illness when associated with severe cough. *Cough fractures* are likely to be located in the sixth to ninth ribs, and in the axillary area. Osteoporosis may play a role. Metastatic malignancy, primary tumors of bone such as multiple myeloma and also primary hyperparathyroidism must be ruled out.

Symptoms. Pain is the usual and most marked symptom of a rib fracture. It tends to be localized, sometimes quite sharply so, but a complicating serofibrinous pleural exudate may lend it a pleuritic and radiating quality. The pain is aggravated by coughing, straining at stool, deep breathing, and bodily movement. Dyspnea may be present. It is sometimes severe when there are complications in the underlying lung and pleural cavity, or in elderly patients with already depleted cardiorespiratory reserve. Breathing may have a quite characteristic grunting quality, since the inspiratory phase is sharply inhibited by pain.

Physical Signs. There is some restriction of respiratory excursion on the side of fracture. The chest is rarely much deformed except after crushing injury. There may be visible local swelling from hematoma and from edema in thin patients. Exquisite point tenderness usually exists over the fracture site with abnormal mobility and sometimes crepitus. Crepitus may be felt during cough or movement, and may also be heard as a grating harsh sound with the stethoscope. One should

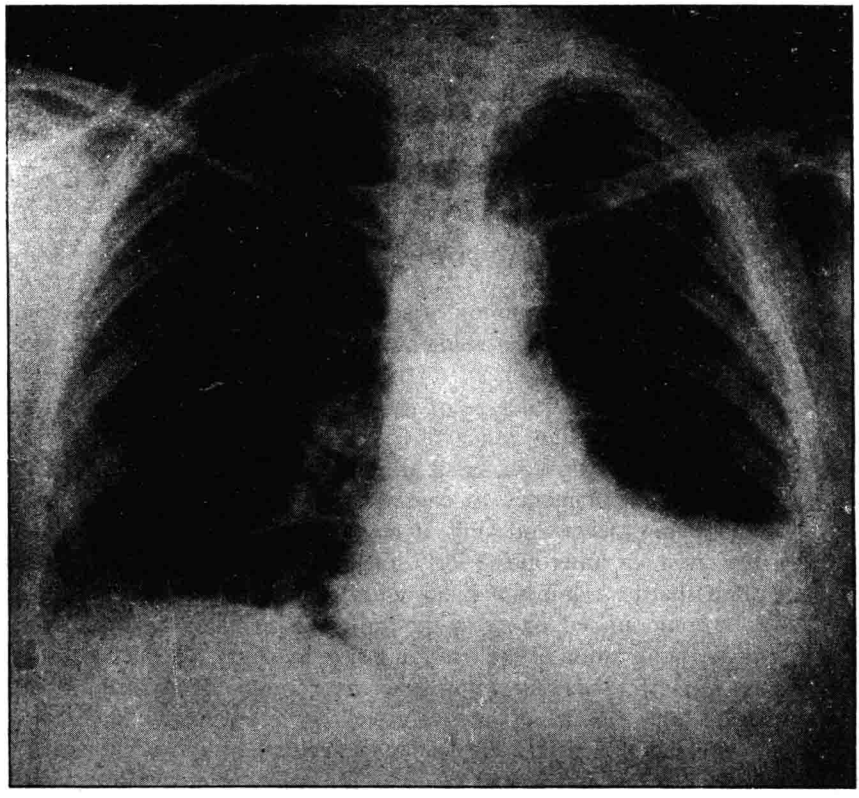


Fig. 1. Complete transverse fractures of all ribs on the left side. There is a hemopneumothorax fluid level at the ninth rib, mediastinal and subcutaneous emphysema, and right basilar infiltration. The patient recovered.

not persist unduly in attempts to elicit this sign since it is not necessary to diagnosis. A leathery friction rub due to concomitant fibrinous pleurisy sometimes appears.

Radiographic Findings. These may be quite obvious, but at other times difficult to determine. Simple bending fractures (greenstick) occur, and the only finding may be a slight distortion of the long axis of the rib, or a separation of the cortex along one border. Fractures in the axilla may be obscured by the natural declivity and overlap of costal patterns. Fracture separations at the costochondral junction are not visualized at all. Late fractures associated with callus formation are occasionally confused with primary tumors of the rib, especially when no history of violence is elicited. Careful search is indicated in each instance of rib fracture for evidences of preexisting bone disease.

After crushing injuries of the chest, it is important to include lateral films of the thoracic spine to rule out compression fractures, and anteroposterior films to detect separation of the transverse processes. Small accumulations of intrapleural and interstitial air should not be overlooked.

Complications. The complications commonly encountered are subcutaneous emphysema, pneumothorax, hydrothorax (or hemothorax), contusion of the lung,

secondary pneumonitis, and atelectasis. These are discussed individually in appropriate sections. Delayed complications are rare. They comprise nonunion with persistent pain, intercostal neuritis, and osteomyelitis of the fracture site. Intercostal aneurysm is an exceedingly rare complication.

Treatment. The time-honored treatment for rib fracture consists of strapping the chest with adhesive plaster. This has much to recommend it as to general availability, ease of application and relative effectiveness. Certain disadvantages are, however, inherent in the method. These are skin irritation with erythema and vesication, limitation of respiratory activity, reduction of ventilatory reserve and inability to examine the chest adequately through the extensive adherent dressing. Wide chest strapping is especially adapted however to cases where there is unusual mobility of the thoracic parietes, with paradoxical depression of the ribs on inspiration and mediastinal flutter.

When adhesive strapping is employed, it should be preceded by shaving or chemical depilation of hairy areas. The skin should be liberally anointed with tincture of benzoin which acts both as a protective film and as an adhesive agent. Strapping should extend from the midclavicular line or anterior axilla on the sound side, around the involved hemithorax to the posterior axilla on the first side. The patient is instructed, if possible, to expire forcefully during the moment when each adhesive strip is tightened. Elastic ace® adhesive may be employed with considerable addition to the comfort of the patient.

Oxygen administration may be required temporarily, especially in elderly and complicated cases. Morphine should be administered with caution, not at all in children, and only with care in the elderly. It can usually be supplanted rapidly by codeine and aspirin.

One contribution to this problem from World War II experience was the frequent employment of **intercostal nerve block.** This technic immediately reduces pain, improves the depth of respiration and the effectiveness of the cough mechanism, thereby decreasing the incidence of atelectasis. Procaine block should be performed as soon after injury as possible. Five to 10 ml. of 1 per cent procaine are injected paravertebrally to reach the intercostal nerve below each fractured rib, including also one or two intact ribs adjacent to the fracture sites (see page 617). One treatment may suffice, but the injection can be repeated in 12 or 24 hours as required. Procaine injected directly into the fracture site has also been employed.

Late fractures are rarely the subject of surgical intervention. Even marked displacements and comminutions of rib require no orthopedic correction, especially in young patients who show great reparative powers.

Persistent intercostal neuralgia may require intercostal neurectomy, or exploration and resection of the callus; in these cases, an impingement on the intercostal nerve can usually be demonstrated. Such involved nerves should be dissected free, then resected or translocated into the muscle overlying the fracture site.

Where multiple and particularly bilateral fractures are present in association with sternal or sternoclavicular injury, it may be necessary to employ some form of skeletal traction to selected rib areas or to the sternum, thus stabilizing the anterior chest wall for a period of several days.

FRACTURES OF THE STERNUM

This is a rare type of injury, almost always associated with rib fractures or other skeletal damage. It is customarily produced by a direct and blunt blow or squeeze to the anterior chest. There is rarely a significant displacement of fragments but comminution of the gladiolus may occur.

The patient complains of severe precordial pain and dyspnea; there may be cyanosis. There is usually an abrasion or hematoma over the sternal area, marked local tenderness, crepitus and depression at the fracture site. In severe cases, a pectus excavatum type of deformity results. There may be signs of cardiac contusion which should always be searched for in this connection (page 397).

Treatment. Special treatment may not be required beyond that directed to the associated rib injury. If the fracture is a clearly transverse one with depression, it may be reduced by elevating the patient's arms over the head, hyperextending the thoracic spine, and making external pressure on the distal fragment. If reduction is difficult and deformity is great, it is preferable to carry out an open reduction. This is accomplished through a vertical midline incision over the fracture site employing only local anesthesia. A blunt periosteal elevator is used to engage the fracture site and to manipulate the two ends into position. The fragments may be drilled to permit wiring. Primary wound closure is employed without drainage after the fragments are reduced and tied in place. For further stabilization of the chest wall, wire traction may be employed as described under the treatment of pectus excavatum (page 30).

HEMOTHORAX

Pathogenesis. The accumulation of blood within the pleural cavity, termed **hemothorax,** is almost a constant accompaniment of thoracic trauma. The source of this bleeding may be the lung itself, vessels of the mediastinum, heart, pericardium, diaphragm and chest wall or any combination of these.

Unless a very large vessel at the pulmonary hilum is wounded, bleeding from the lung tends to be self-limited due to the natural elastic property of pulmonary tissue and to the effect of accumulating fluid. Bleeding from the pulmonary parenchyma may be initiated by penetrating trauma (as imposed, for example, by a rifle bullet, knife blade or fractured rib end), or by contusion and concussion, including the effect of blast. A small percentage of patients who suffer from spontaneous pneumothorax have an associated hemothorax. It may be a complication of any surgical operation in the chest. It is an occasional very undesirable sequel of internal pneumonolysis (see Chapter 13).

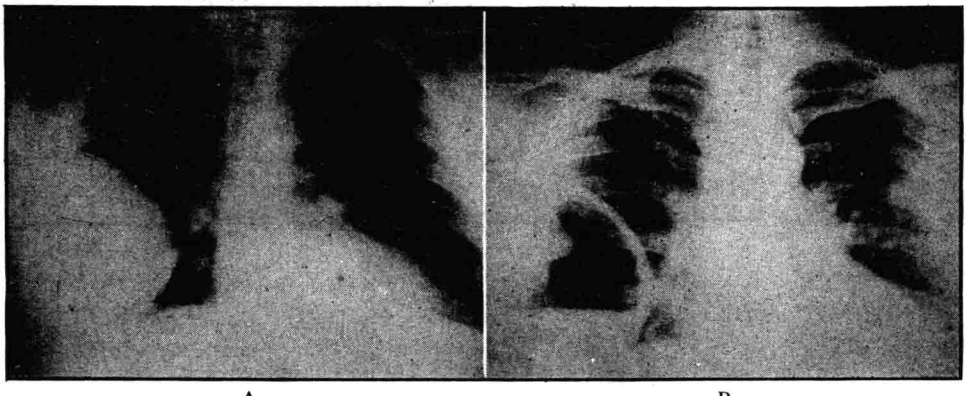
The volume of blood which accumulates in the hemithoracic space varies from a few milliliters to several liters. In general, blood shed into the pleural space remains at least partially liquid for long periods. This may be due, in part, to mechanical defibrination caused by respiratory and cardiac movements; the fibrin is deposited on the pleural surfaces as a shaggy yellowish-gray membrane. On the other hand, rapid and complete clotting may occur and these cases pose special problems in treatment.

When the right hemidiaphragm and liver are injured together, the hemothorax

is likely to be contaminated by bile and the organisms which may invade the biliary tract. When the left diaphragm, stomach or intestine are involved together, the hemothorax may be rapidly contaminated by gastric or intestinal contents.

An untreated hemothorax shows at first an increase in volume. This is the effect of the autolyzing blood, of increasing osmotic tensions due to a breakdown of proteins into smaller molecules and sometimes to infection.

Pathology. Hemorrhagic exudates consequent upon trauma may suffer several fates. Infection of the shed blood by invasive organisms results in empyema. It may happen, however, that the hemorrhagic material contains viable bacteria that multiply but do not invade the pleural tissues nor even produce a systemic response. Such infections may take place with anaerobic bacteria of the sporogenes group. Furthermore, bacterial growth even in obviously infected wounds of the pleura, such as those caused by penetrating objects, may be kept in check by effective antibacterial substances. Under these circumstances the pleura and its contents may be little modified by the presence of organisms. The infecting agents, however, may in other instances be responsible for a more violent tissue response with earlier and denser organization and with persistence centrally of encapsulated purulent material.

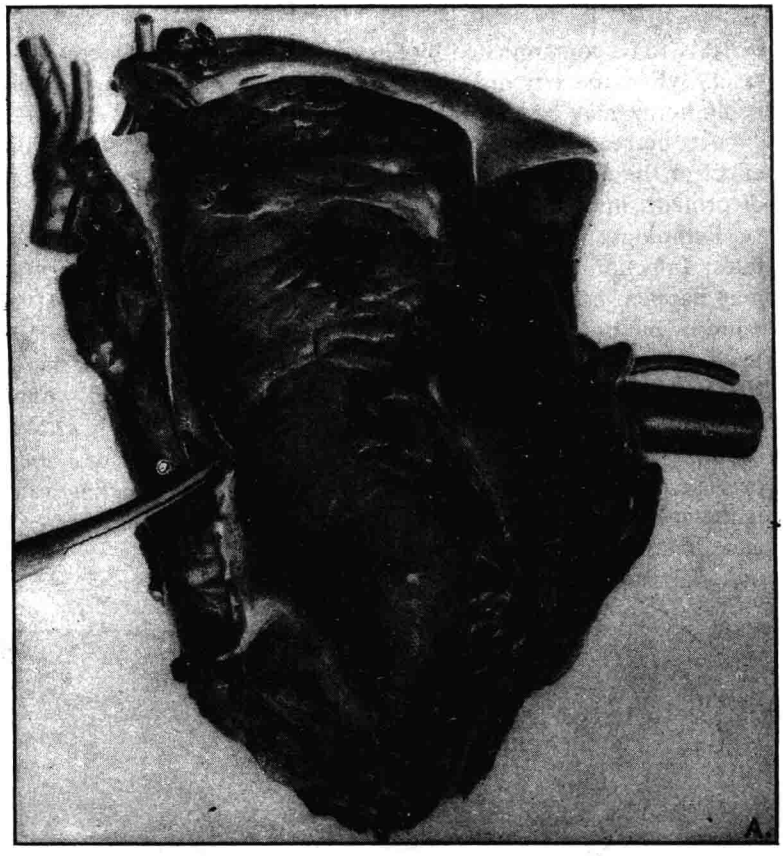


A B

Fig. 2. Post-traumatic encapsulated hemothorax, resembling a cystic tumor.
A, before tapping and withdrawal of fluid.
B, after removal of 400 ml. dark reddish brown fluid and air replacement. This lesion was excised and its wall showed only fibrous connective tissue. The lung expanded completely.

On occasion, the blood and exudate fail to clot. The liquid blood then changes gradually in character over a period of months or years. At first it assumes a brown color, like the contents of certain chocolate cysts of the ovary, with conversion of hemogoblin into hemosiderin and its breakdown products, largely by the activity of phagocytic cells. Later the fluid may become almost colorless but retains a content of cholesterol crystals that give it a shimmering opalescent appearance. One source of these crystals is the remnants of red cell membranes. The pleura in the meantime suffers sclerosis in some degree, and the relatively avascular membranes encapsulate the fluid intrapleural material (Figure 2 A and B).

More commonly, blood within the pleura ultimately clots and undergoes organi-



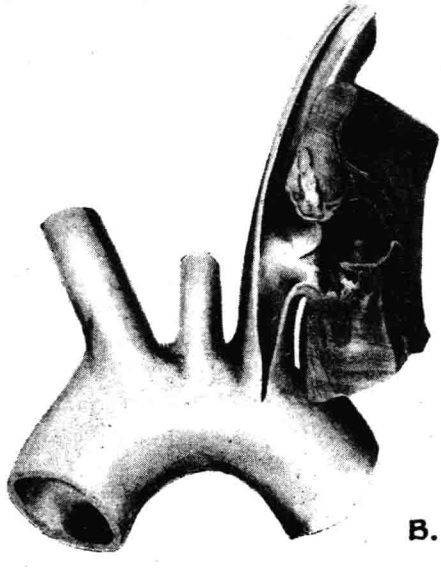


Fig. 3. Traumatic aneurysm of the left subclavian artery (war wound). Organizing hemothorax. The patient seemed on the way to recovery but died suddenly from renewed massive intrapleural hemorrhage.

A, necropsy specimen comprising the arch of the aorta, and great vessels and the left lung with the visceral and parietal pleura. A drainage tube is shown *in situ*. At the apex of the pleura a curved shell fragment is seen to have penetrated the parietal pleura and to be in contact with the wall of a ruptured aneurysm of the left subclavian artery. The pleura is now greatly thickened by fibrous tissue in this region. Partly organized clotted blood covers the visceral pleura of the lung that has collapsed against the mediastinum.

B, close-up of the arch of the aorta showing a tear in the aneurysm and a portion of the thickened pleura that has been removed with the specimen.

zation. In the early stages, this process is incomplete and a peripheral membrane of organization tissue surrounds the clotted material. The contained red blood cells are soon altered and are slowly removed as the hemorrhagic mass becomes gradually fibrinous and assumes a pale gray-tan appearance (Figure 3). In the central unorganized mass pockets of fluid and, in the case of infected clots, masses of pus may persist. That portion of membrane which is on the parietal pleura as a rule is thicker than that adjacent to the visceral surface. This membrane, or *peel,* can

Fig. 4. Organizing hemothorax. Histologic section of the *peel.* The elastic layer of the pleura visible as an undulating black line has been stripped with the organization tissue. Below the lower margin of the photograph was a cavity containing blood that had not as yet undergone organization.

be stripped off at certain stages without too much difficulty from the visceral surface of the pleura and with only slightly greater difficulty from the parietal side where the tendency to pachypleuritis is greater. The plane of dissection from the parietal side is usually in the endothoracic fascia. On the other hand, the plane of cleavage from the lung may be along the original mesothelial visceral surface. It may, however, lie deeper than the original pleural membrane as indicated by the inclusion of the subpleural elastic layer in the peel (Figure 4). The thickened subelastic areolar tissue of the visceral pleura then provides an easy plane of dissection; enough of this tissue is left behind during decortication to keep the alveoli adequately sealed.

If a clotted hemothorax is neglected the organization tissue becomes more extensive, more dense and more firmly adherent both to the lung and to the parietal pleura. The lung eventually becomes entrapped as it does in organized empyema. The technical difficulties attending surgical treatment are greatly increased. The decortication procedure may nevertheless be at least partially rewarding in overcoming the untoward functional and postural results that attend a fibrothorax.

Symptoms and Physical Signs. The reaction of the patient to acute hemothorax will depend on the amount and the rate of blood loss. There may be little or no disturbance so that the diagnosis is apparent only from the nature of the injury or upon later roentgenographic study. With a larger hemothorax, there are the early signs of internal hemorrhage; namely, pallor, rapid shallow breathing, thirst, cool moist skin, rapid weak pulse, arterial hypotension, restlessness and anxiety. There may be a feeling of intrathoracic pressure, and shortness of breath. Cough may be present even when the lung itself is not wounded due to pressure and nerve irritation. If the lung itself is injured, there may be frothy blood-stained or frankly hemorrhagic sputum.

The physical signs in the chest are those of hydrothorax and are described under Pleural Effusion (Chapter 3). In addition, there may be external wounds or contusion and evidences of rib fracture. Low grade fever for several days or weeks after injury is common.

Diagnosis. The definitive diagnosis is made by roentgenography and by the aspiration of blood on thoracentesis. A possible point of confusion is the withdrawal of fresh blood from an entry into the lung. The fresh color of the blood and an admixture of air will usually settle this diagnostic point. Blood already residing in the pleural cavity is usually dark and thinned out by defibrination. The red cells tend to appear crenated on microscopic examination of the wet smear. Another point of possible diagnostic difficulty is a needle entry into the liver which can be prevented by carefully avoiding the lowest interspaces (Figure 30, page 52).

Treatment. In military field medicine, and in the management of civilian catastrophes, the triage (sorting) of hemothorax cases for conservative treatment as opposed to immediate thoracotomy is important. In general, most cases of hemothorax will cease bleeding spontaneously during or after supportive treatment. This includes rest, sedation with morphine or barbiturates and transfusion when required. Thoracentesis should be carried out for diagnosis and more especially for relief of compression in the early phases of the treatment. Attempts to evacuate completely the hemothorax and bring about rapid reexpansion of the compressed lung should be postponed for one or two days until bleeding points are well thrombosed and pulmonary air-leaks likewise sealed. The World War I dictum of air replacement during therapeutic aspiration has been discredited by modern experience. Air replacement of aspirated bloody fluid postpones complete reexpansion and predisposes to extensive empyema.

If hemorrhage continues or recurs after preliminary thoracentesis, with persistence of shock despite transfusions and other supportive measures, the indication is then for emergency thoracotomy. The bleeding area is less likely to be in the lung with its relatively low intravascular pressures than in a systemic vessel such as the intercostal, pericardiophrenic or internal mammary.

Should rapid clotting of the hemothorax occur, or subsequent loculation appear, so as to prevent satisfactory needle aspirations, there are two possible courses of action. One is to perform a thoracotomy, evacuating the clot and carrying out **decortication.** The second alternative is **enzymatic debridement** according to the technic of Tillett and Sherry (1949).

THE PROCEDURE OF DECORTICATION. One of the very important results of medical experience in World War II was the demonstration that the seemingly radical approach of thoracotomy for hemothorax with evacuation of the clot (frequently infected) and decortication of the membrane investing the pleura gave vastly improved results with respect to rate of healing, reduction in the frequency of empyema, and preservation of function in comparison with other methods. The development of the decortication technic has been made possible by better anesthesia, by control of secondary infection with appropriate antibiotics and by the availability of banked blood to prepare the patient for surgery and to sustain him during and after operation.

The operation is an adaptation of the Delorme procedure as practised by that French surgeon in the 1890's. Under general endotracheal anesthesia in the lateral position, a long incision is made over the seventh rib, sometimes a space lower or higher, depending on the roentgenographic findings. The incision is carried through the sixth intercostal space and rib retractors are placed. If there have been rib fractures with the causative trauma around the line of incision, these may be debrided or excised to give additional exposure.

The hematoma-containing pleural space is entered and all gross clot and exudate are evacuated. The recognition and removal of any foreign bodies such as bone or metallic fragments are important. The layer of organizing blood and exudate covering the visceral pleural surface is incised lightly while the anesthetist exerts slight positive pressure on the lung. The *peel* is reflected bluntly until an easy cleavage plane appears between this and the underlying visceral pleura. The decortication proceeds carefully until the entire lung and the diaphragm have been liberated. The normal interlobar fissues should be also cleared. If the dissection exposes any bronchial fistulae or pulmonary lacerations, these should be repaired with infolding silk sutures. It is not absolutely necessary to remove the parietal *peel;* this may be done if the patient is in good condition and the operative dissection is proceeding with uncomplicated ease. Parietal decortication is especially indicated in children with beginning scoliotic contracture.

The pleural cavity is lavaged with physiologic saline solution, and the lung carefully expanded using controlled positive pressure. Two intercostal catheters are placed for postoperative suction drainage. The operation is concluded with layer by layer interrupted silk closure of the chest wall after injecting the adjacent intercostal nerves with procaine. Postoperatively, bronchoscopy may be desirable in patients with abundant secretions and persistent atelectatic areas in the decorticated lung.

The postoperative care then follows the general lines described in Chapter 33 The likelihood of a completely successful result is excellent when the operation is performed about the fourth week after the initiating trauma (Figure 5). During the first two weeks the granulation tissue is thin, the membrane ill-defined and too