PLASTIC SURGERY

VOLUME 6

THE TRUNK
AND
LOWER EXTREMITY

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PLASTIC SURGERY

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Reconstruction of the Trunk

CHEST WALL RECONSTRUCTION

The earliest surgical experiences with the chest wall were necessitated by penetrating chest injuries resulting from wars and accidents. While these injuries were considered generally hopeless, the surgical dilemma was whether or not to close them. Hewson and later Larrey, Napoleon's military surgeon, were credited with the practice of closing sucking chest wounds to prevent death from respiratory failure (Meade, 1961). Larrey astutely observed the importance of drainage in order to allow retained blood and other material to egress from the wound. During the American Civil War, Billings also adopted the practice of early closure and noted the improved survival rate. Many patients, however, suffered late chronic empyema cavities as a result of retained contaminated hematomas (Seyfer, Graeber and Wind, 1986). By World War I, the practice of early closure was adopted by all allied medical services. The not infrequent occurrence of empyema was treated by aggressive and repeated thoracentesis and, if needed, eventual conversion to an open empyema cavity.

Around the turn of the century, with the introduction of general anesthesia, more aggressive surgery became possible. Surgeons began to resect tumors of the chest wall. Initially, when such surgery was attempted, every effort was made to avoid entering the pleura to avoid the potentially fatal situation of an open pneumothorax. In fact, many ingenious methods were devised to avoid collapse of the lungs at the time of resection by preliminary procedures to create adhesions between the lung and rib cage (Seyfer, Graeber, and Wind, 1986).

Parham (1899) described two patients who underwent chest wall tumor resection. In the first patient he mobilized surrounding soft tissue to close a sucking surgical wound and saved the patient. In the second patient with inadvertent pleural rent and lung collapse, he employed a crude form of endotracheal tube to stabilize ventilation. This allowed him to close the wound in layers by soft tissue mobilization. He was thus credited for introducing positive pressure ventilation in surgery by using a respirator device originally described by Fell for physiologic experiments in dogs and the laryngeal endotracheal tube devised by Odwyer. In the ensuing decades, as the experience with pneumonectomy for the treatment of tuberculosis and lung cancer became more common, the basic principles of chest surgery using endotracheal ventilation, closed drainage and antibiotics became established. In World War II, with the increased firepower of the weapons resulting in more massive chest injuries, a manual for thoracic surgery was published in 1943 by the U.S. Government (Graham and associates, 1943; Ahnfeldt and Berry, 1963, 1965) and the concepts of surgical debridement and tension free soft tissue closure were emphasized. Numerous methods of closure were described, including the use of adjacent muscles such as the pectoralis major.

During the Korean and the Vietnam wars, with the improved survival from more rapid evacuation and resuscitation for shock, many more soldiers survived the initial injuries to become candidates for chest wall reconstruction. Radiation therapy to the chest wall became popular for various tumors, and not infrequently the resultant ulceration or necrosis became reasons for elaborate and multi-staged reconstructions. Recognizing the importance of maintaining semirigid support of the chest wall, surgeons introduced fascia and other synthetic materials for providing support. In addition, a number of local skin flaps, such as the deltopectoral flap, or distant transfers were introduced (Seyfer, Graeber, and Wind, 1986).

In the mid-1970's the use of muscle and musculocutaneous flaps was rediscovered and popularized. The availability of the latissimus dorsi, pectoralis major, and rectus abdominis muscle flaps greatly expanded the ability to provide coverage and to seal dead space. These major advances came fortuitously at a time associated with an increase in surgically related chest wounds such as dehiscence from median sternotomy following cardiac surgery and chest wall necrosis from radiation for breast cancer. The muscle flaps, along with customized implants, have also expanded the surgeon's ability to correct congenital or developmental contour deformities of the chest wall, such as pectus excavatum or Poland's syndrome. A major reassessment of the scope and methods of chest wall reconstruction has evolved (Dingman and Argenta, 1981; Scheflan, Bostwick, and Nahai, 1982; Arnold and Pairolero, 1984). Plastic surgeons have much to contribute to chest wall reconstruction (Table 76–1).

Table 76–1. Clinical Problems in Chest Wall Reconstruction

Coverage	Pressure sores, radiation necrosis, tumor resection, burns
Skeletal stabilization	Severe pectus deformities, sternal clefts, major resections
Obliteration of Dead Space	Chronic empyema cavity, bronchopleural fistula
Complex Chest Wall Reconstructions	Median sternotomy dehiscence, massive chest wall resection for tumor or radiation necrosis, massive injuries
Esthetic Contour Corrections	Pectus deformities, Poland's syndrome, scoliosis

Anatomy and Physiology

The intimate correlation between anatomy and function throughout the body is uniquely illustrated in the design of the chest wall to provide simultaneously a hard shell for protection of the vital visceral organs (heart, liver, spleen, pancreas, and kidneys) while serving as a flexible frame for respiratory movements (Seyfer, Graeber, and Wind, 1986; Lambertsen, 1980). To accomplish this, the ribs are hinged posteriorly and superiorly against the spine and anteriorly and inferiorly at the sternal junction. With the sternum serving as a "bucket-handle" controlling the expansion of the rib cage, superior and anterior movement of the sternum results in an "unfolding" of the ribs and a greater thoracic volume. The costal cartilage provides additional flexibility between the ribs and sternum (Fig. 76–1).

Inspiratory Muscles. The sternocleidomastoid and the scalene muscles insert onto the clavicle and the first and second ribs, serving as elevators of the "superior aperture" of the rib cage and helping to expand the chest volume. Major resections of the upper sternum and ribs result in a partial "collapse" of the ribs inferiorly and a measurable functional loss in ventilation. Maximum inspiratory effort, for example, requires complete upward and lateral expansion of the ribs to achieve maximum chest circumference. This enlarges the frame for the diaphram to contract against, and it therefore further expands the chest cavity against the abdomen.

Expiratory Muscles. The muscles attached to the much larger "inferior aperture" of the rib cage (rectus abdominis, internal oblique, and external oblique muscles) serve to constrict the rib cage downward and to force the abdominal content upward against the diaphragm. In addition to postural control, they are important in the expiratory phase of respiration and during "cough" and "sneeze."

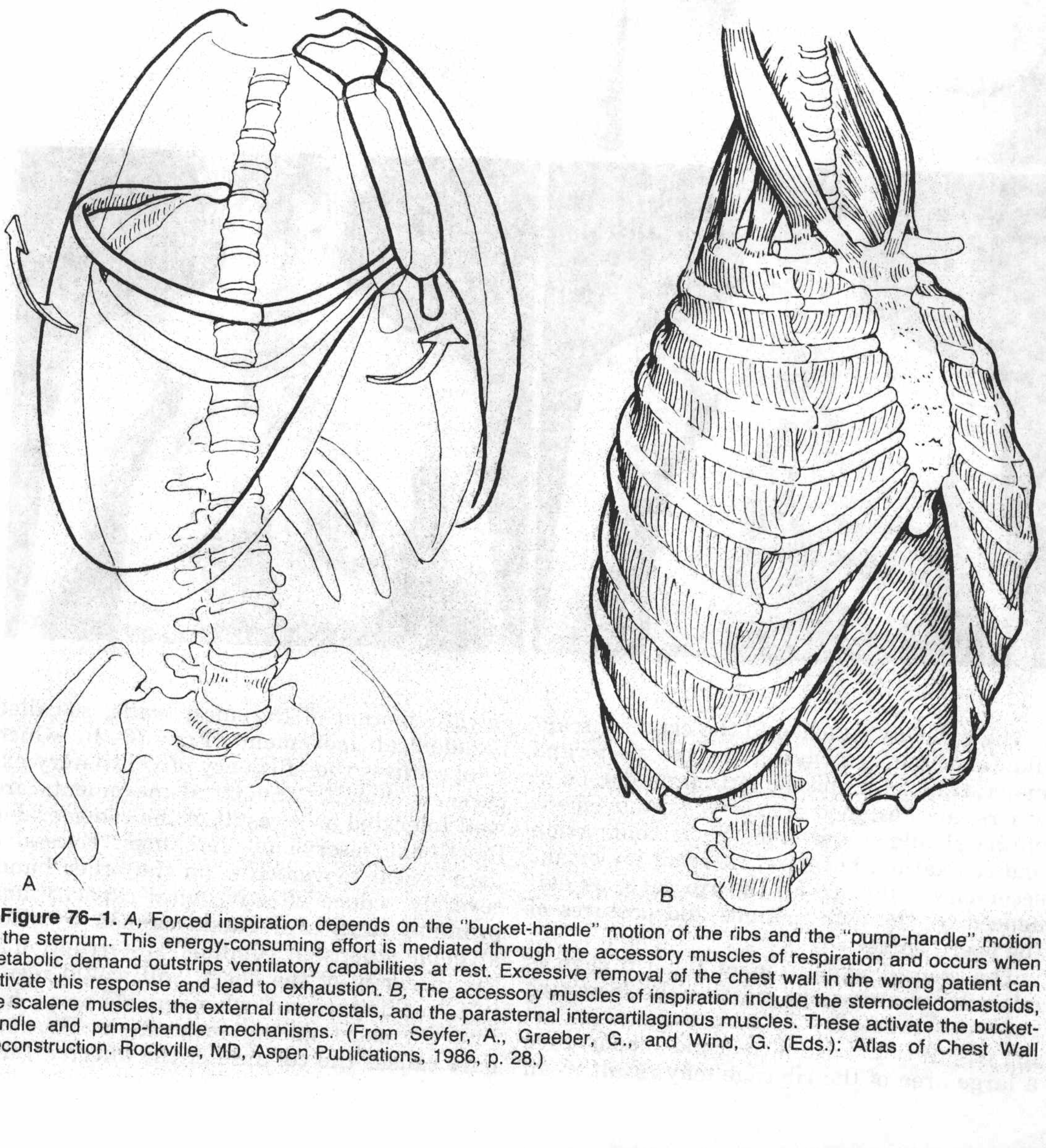

Figure 76–1. *A,* Forced inspiration depends on the "bucket-handle" motion of the ribs and the "pump-handle" motion of the sternum. This energy-consuming effort is mediated through the accessory muscles of respiration and occurs when metabolic demand outstrips ventilatory capabilities at rest. Excessive removal of the chest wall in the wrong patient can activate this response and lead to exhaustion. *B,* The accessory muscles of inspiration include the sternocleidomastoids, the scalene muscles, the external intercostals, and the parasternal intercartilaginous muscles. These activate the bucket-handle and pump-handle mechanisms. (From Seyfer, A., Graeber, G., and Wind, G. (Eds.): Atlas of Chest Wall Reconstruction. Rockville, MD, Aspen Publications, 1986, p. 28.)

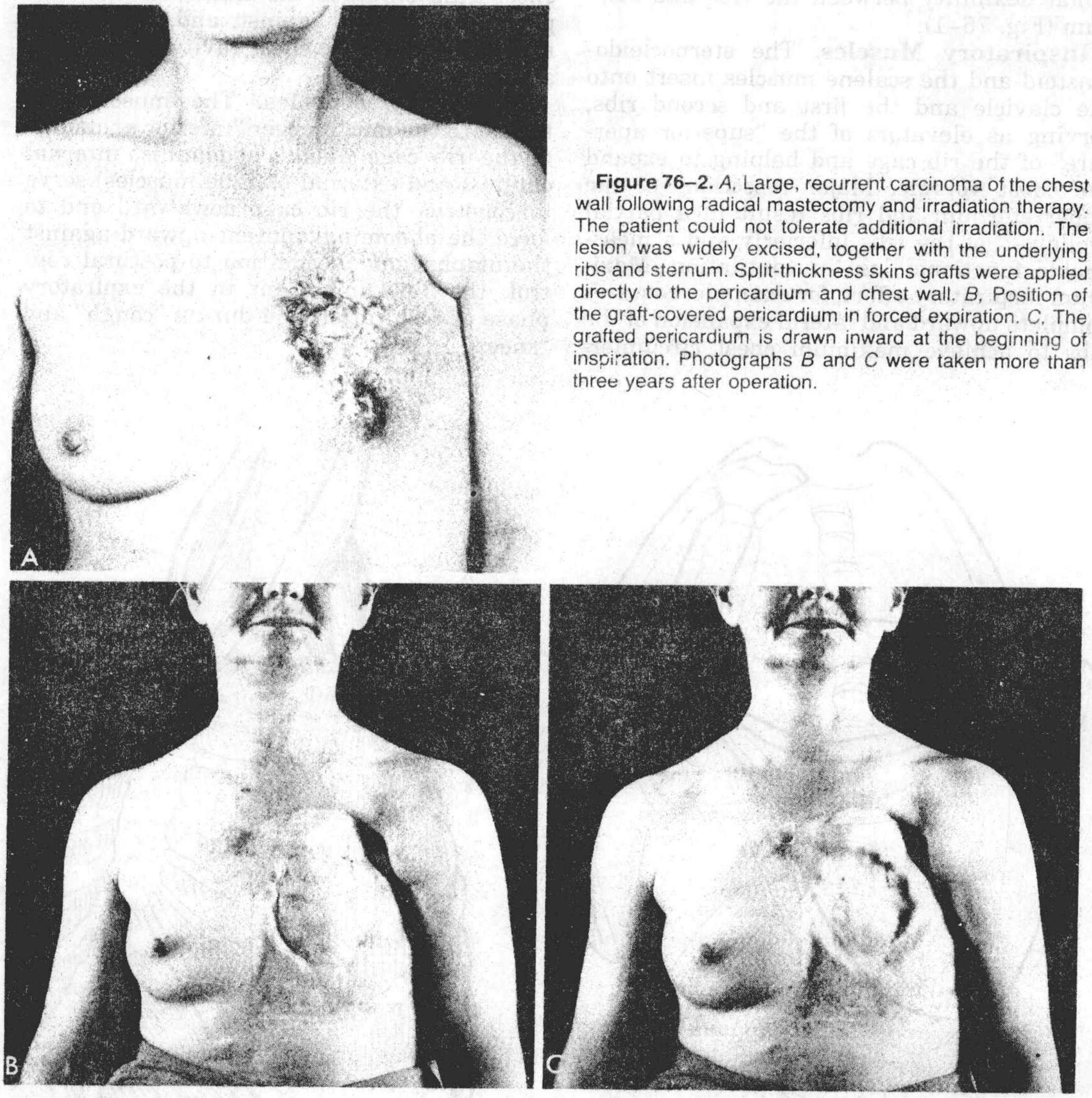

Figure 76–2. *A*, Large, recurrent carcinoma of the chest wall following radical mastectomy and irradiation therapy. The patient could not tolerate additional irradiation. The lesion was widely excised, together with the underlying ribs and sternum. Split-thickness skins grafts were applied directly to the pericardium and chest wall. *B*, Position of the graft-covered pericardium in forced expiration. *C*, The grafted pericardium is drawn inward at the beginning of inspiration. Photographs *B* and *C* were taken more than three years after operation.

The muscles attached to the clavicle, scapula, and humerus (such as the pectoralis major, trapezius, and the latissimus dorsi and others) are designed primarily for movement of the shoulder and arm. Their contraction and relaxation, however, exert an important secondary influence on the rib cage, as evidenced by the arm motions and postures of the opera singer.

The overall expansion of the rib cage is critically important in creating the "negative pressure" necessary for lung expansion during inspiration. Loss of the rigid support over a large area of the rib cage may result in an inward motion of the chest walls, so-called paradoxical movement (Fig. 76–2), which compromises the efficiency of ventilatory excursions. Small paradoxical movements are well tolerated as a result of the considerable functional reserve of the lungs. Excessive paradoxical movements, on the other hand, severely reduce effective vital capacity and promote lung atelectasis caused by poor alveolar expansion. Similarly, interruption in the integrity of the chest wall would result in a "sucking wound" when outside air rushes into the chest during inspiration. This not only causes the collapse of the affected lung but also may produce a "tension pneumothorax" when the air is unable to escape. Such a patient may go into shock and respiratory failure as a result of pressure on the cardiovascular system and the opposite lung.

Principles of Chest Wall Reconstruction

FUNDAMENTAL GOALS

The need to restore absolute integrity of the chest wall demands that the surgeon understand clearly the anatomic requirements involved, whether treating an open chest injury or resecting ribs to improve appearance. Failure to accomplish the essential reconstructive goals endangers the patient's survival and usually necessitates additional surgical procedures as well. The common components of the reconstructive problems encountered are listed (Table 76–2), and the specific reconstructive goals are discussed individually.

Debridement and Resection

An adequate debridement or resection prior to closure is essential. In trauma cases it entails removal of contaminated tissues to minimize the likelihood of infection; in radiation injuries it allows uncomplicated primary wound healing; and in tumor cases it maximizes the chances of cure or palliation. The inelasticity of the rib cage makes primary closure after any significant debridement difficult and prone to dehiscence and potentially serious complications. Inadequate margins of resection, on the other hand, result in the approximation of infected or irradiated tissue, a situation likely to result in persistent infection and breakdown. Even muscle flaps with their vigorous blood supply cannot be expected to "clean up" an infected wound. Placing a valuable muscle flap in an inadequately debrided wound commits one of the most unforgivable sins in reconstructive surgery, i.e., the wasting of precious tissue and rendering it unavailable for future use. With the many flaps available today, one should no longer be restricted in the initial debridement of a chest wound.

When aggressive wide debridement is difficult, such as in wounds involving deep sinuses around the heart or granulation tissue over coronary bypass grafts, the wound should be left open and treated with topical dressing changes until the gross infection is cleared. Flap reconstruction can then be done with more limited debridement.

Table 76–2. Principles of Chest Wall Reconstruction

Debridement and resection	Remove devitalized bone or cartilage; healthy margins
Requirements for Skeletal Reconstruction	Bone, fascia, synthetic mesh, acrylic
Coverage	Leak-free, tension-free, well vascularized
Obliteration of Potential Cavities (Dead Space)	Suction, mediastinal/diaphragm shifts, lung expansion, distant flaps
Esthetic Considerations	

Flap Requirements

The "semirigid" skeletal frame of the chest renders the surrounding soft tissue less mobile for use in closure, as compared with the abdomen. A large soft tissue defect, therefore, requires addition of tissue from a distance. The rigidity makes the chances less likely of a chronic chest cavity closing spontaneously by gradual contraction; therefore, any residual "dead space" must be filled with a sufficiently bulky flap. The closure of the surface defect or the dead space must also be "leak-free" to avoid the development of a pneumothorax. A secure closure of the surface and the dead space, which can withstand the repetitive and forceful respiratory movement of the ribs, must also be "tension-free." Finally, the flap should be "well vascularized" to offer the best chance for uncomplicated primary wound healing. In chest wall reconstruction any "minor" wound healing problems are likely to evolve into a "major" complication associated with significant morbidity and possible mortality.

Skeletal Reconstruction

Some loss or disruption of the sternum-rib complex is usually seen whether in penetrating injury or following tumor resection. Optimal skeletal restoration should always be the goal. Failure to stabilize the "semirigid skeletal framework" may result in paradoxical movement with ventilatory compromise, which may not be noticeable at rest but may manifest itself as limitations in exercise tolerance. Malangoni and associates (1980) reported a 31 to 74 per cent reduction of the forced vital capacity in six children who had undergone tumor resection and Marlex reconstruction. The importance of minimizing further loss of vital capacity cannot be overemphasized. Another reason for skeletal restoration is that the constant motion of the wound edges also interferes with healing.

Unless compromised by other associated factors, most patients can tolerate the loss of segments of up to four ribs without skeletal replacement. When the defect is covered by a thick flap, such as a latissimus dorsi musculocutaneous flap, the amount of flailing is also reduced compared with that of a thin skin flap. The loss of the lower portion of the sternum is less critical in the overall expansion of the rib cage, and skeletal reconstruction is often not needed. Finally, in many chronic conditions, there may be sufficient rigid scar formation to minimize the need for skeletal reconstruction.

In most massive chest wall resections, some form of skeletal stabilization should be considered. This goal may be accomplished with autogenous bone grafts, rigid synthetic materials, such as acrylic, or a semirigid replacement (fascia or synthetic mesh). Over the body of the ribs, this is effectively accomplished by any rigid membrane to minimize gross flailing of the defect and reconstruction with bone is needed only occasionally.

When the sternum is removed, however, the instability results in a more serious paradoxical movement of the entire chest. When the diaphragm contracts to expand the lungs, the rib cage is pulled toward the center, resulting in a counterproductive constriction of the chest and a reduction of the total lung capacity. Conversely, when the diaphragm relaxes during expiration, the ribs spring back to a larger frame, inhibiting a more complete expiration. Bisgard and Swenson (1948) used autogenous rib grafts to span the gap in the anterior ribs to prevent collapse of the ribs during inspiration. This maneuver converts the "median tie-beam" type of construction of the anterior chest to a continuous arch, or "Quonset hut" type of structure.

Obliteration of Potential Cavities (Dead Spaces)

In lobectomies or pneumonectomies, the potential void created is readily filled by lung expansion and shifting of the surrounding structures and elevation of the diaphragm aided by negative suction drainage. Following irradiation, chronic inflammation, or chronic cavitation, the lung and the surrounding structures are no longer pliable and a permanent cavity results. In cases such as chronic emphysema cavities, the cavity can be obliterated only by (1) exteriorizing the cavity, (2) surgically collapsing the rib cage, or (3) filling the cavity with soft tissue. The first two options may be functionally satisfactory, but the result is esthetically grotesque and functionally inconvenient. Omentum or muscle, therefore, is the preferred material for filling the dead space to achieve wound healing.

Esthetic Considerations

Although patients are always grateful for the restoration of function by successful chest wall reconstruction, the appearance remains important, especially in women. Massive wounds with depressed contours, hyperpigmented skin grafts, tight contractural bands, or distorted nipples and breasts are disturbing reminders to the patient. With the wide variety of flaps available today, every attempt should be made to achieve an esthetically acceptable reconstruction along with basic functional restoration (Arnold, 1981).

AVAILABLE FLAPS

The flaps used for chest wall reconstruction closely parallel the evolution of flap surgery in general. With the popularization of skin flap surgery following World War I and II, the previous simple type of closure was supplemented with a variety of local rotation flaps, often delayed in stages (Aston and Pickrell, 1977) (Fig. 76–3). For difficult wounds, flaps from the abdomen were carried via the wrist in stages as "jump flaps" and eventually transferred to the chest (Fig. 76–4). "Tube flaps" were also "waltzed" from the back or abdomen in many laborious stages (Fig. 76–5). The opposite breast was divided or mobilized to cover defects resulting from irradiation injuries. Such multistaged flaps were often limited in size, disfiguring, cumbersome, and often unsuccessful. They have been largely replaced by the newer generation of flaps that entail shorter periods of reconstruction and provide a more reliable blood supply. The principles previously learned regarding

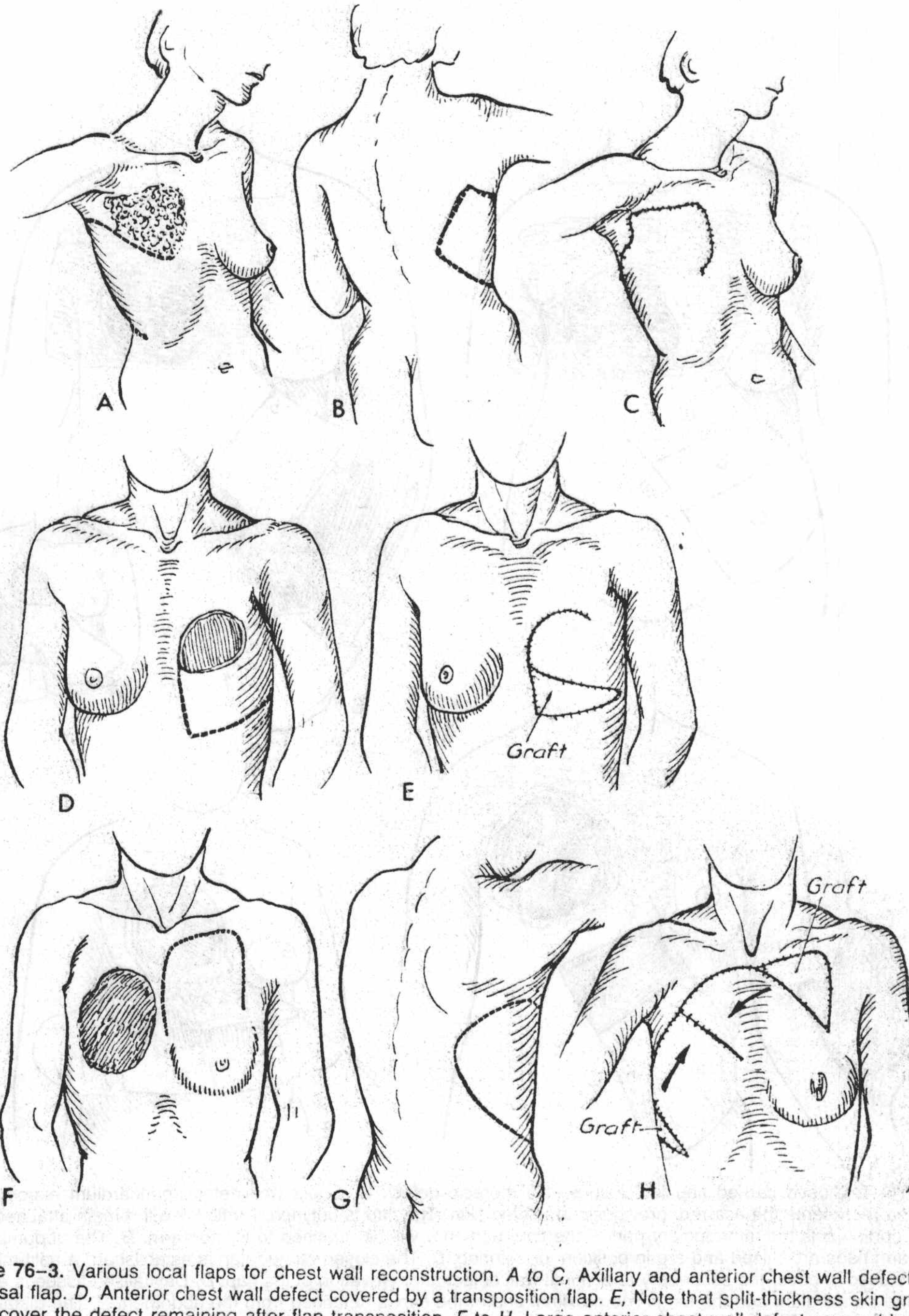

Figure 76–3. Various local flaps for chest wall reconstruction. *A to C,* Axillary and anterior chest wall defect covered by a dorsal flap. *D,* Anterior chest wall defect covered by a transposition flap. *E,* Note that split-thickness skin grafts were used to cover the defect remaining after flap transposition. *F* to *H,* Large anterior chest wall defect covered by a dorsal and anterior chest wall transposition flap.

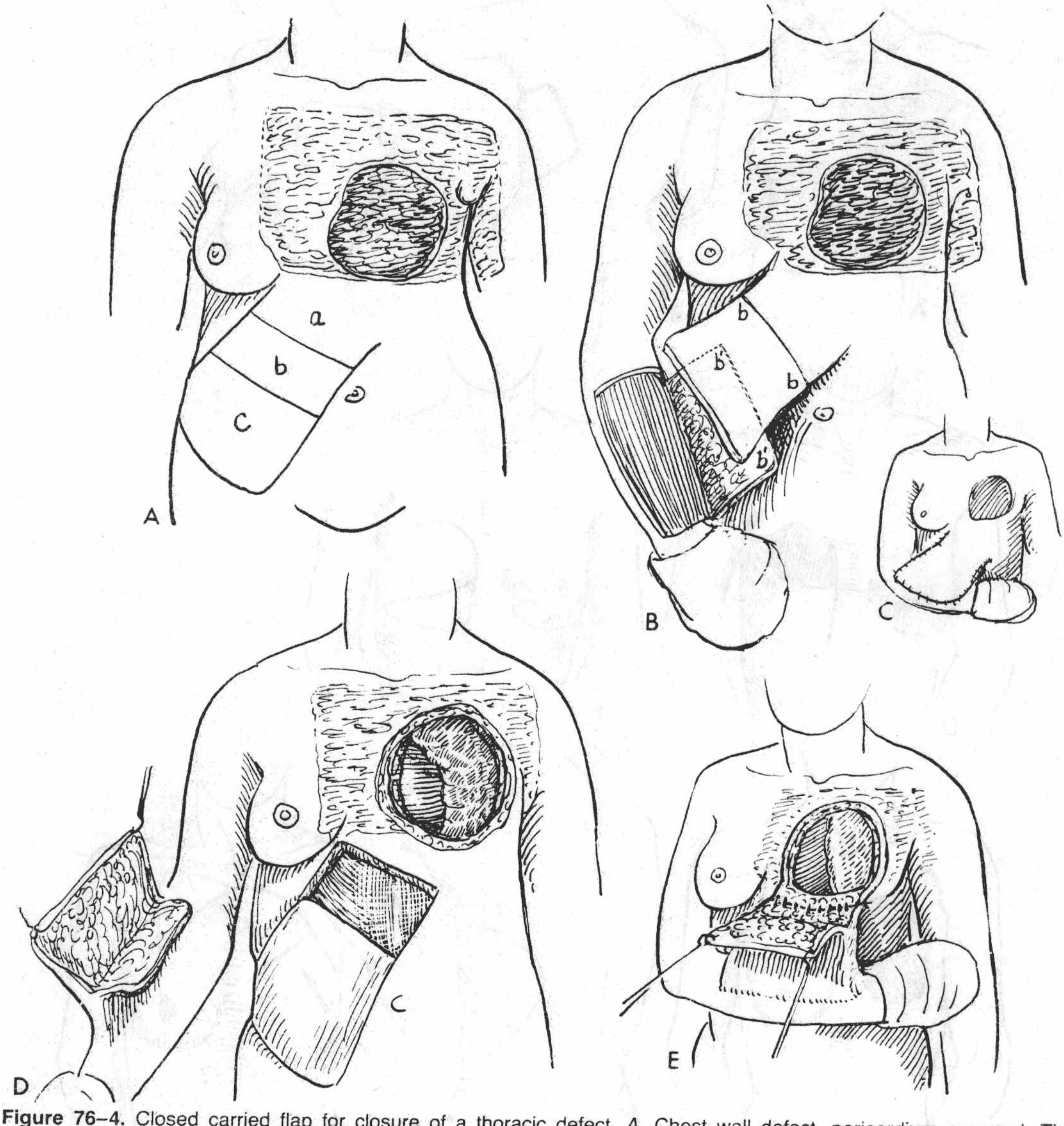

Figure 76–4. Closed carried flap for closure of a thoracic defect. *A,* Chest wall defect, pericardium exposed. The shaded area represents the scarred, previously irradiated skin. The flap is outlined. Portion *a* will remain attached to the abdomen; portion *b* is the intermediary part of the flap; portion *c* will be attached to the forearm. *B,* The abdominal and hinge forearm flaps are raised and are in position for suturing. *C,* The closed carried flap is established. A split-thickness skin graft is used to cover the secondary abdominal wall defect after elevation of the flap. *D,* Devitalized tissue is excised, exposing the pericardium and the lung. The proximal end of the flap is detached from the abdomen. *E,* The distal end of the forearm flap is sutured to the inferior end of the thoracic wall defect.

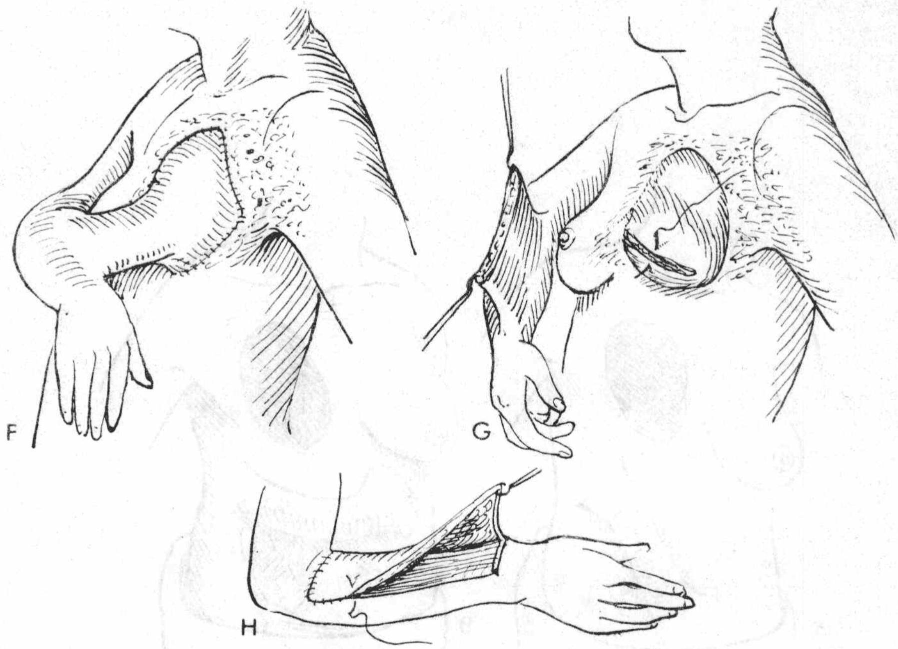

Figure 76–4 *Continued F,* Suture of the flap to the thoracic defect is completed. *G,* The flap is cut from its attachment to the chest. *H,* The forearm flap is returned to its original position. (From Converse, J., Campbell, R., and Watson, W.: Repair of ulcers situated over the heart and brain. Ann. Surg., *133*:95, 1951.)

chest wall reconstruction, however, remain valid.

The development of the epigastric (Shaw and Payne, 1946) and deltopectoral (DP) (Bakamjian, Culf, and Bales, 1967) flaps represented the beginning of trunk flaps based on specific arterial supply. Muscles, although used earlier by Campbell (1950), became popular and were more systematically studied in the 1970's and 1980's. Arnold and Pairolero (1984) utilized 142 muscle flaps in 92 of 100 consecutive patients for chest wall reconstruction. More experience was also gained with using omentum, initially for treatment of lymphedema and later as microvascular free flaps. The excitement generated over muscle and axial-pattern arterial skin flaps eventually matured into a more comprehensive view of the regional blood supply of the trunk and a more versatile concept of fasciocutaneous flaps. Finally, microvascular free flaps from the lower extremity or lower abdomen provided large flaps when regional flaps were not available. An understanding of the regional blood supply and the characteristics of the commonly used flaps is critical in the planning of any chest wall reconstruction (Table 76–3).

Skin Flaps

Vascular Architecture of the Trunk Skin. Palmer and Taylor (1986) studied the arterial blood supply of the chest. The skin blood supply of the upper torso more or less mirrors that of the lower torso (abdomen) (see Chapter 10). A series of "segmental" vessels branch off the intercostal vessels and supply the skin through anterior, lateral, and posterior perforators. They interconnect extensively in the subcutaneous layer across "choke zones" with a predominantly horizontal orientation (Fig. 76–6). Thus, in addition

Table 76–3. Common Flaps in Chest Wall Reconstruction

Skin Flaps	Simple rotation, deltopectoral, lateral thoracic, scapular, etc.
Muscle or Musculocutaneous Flaps	Pectoralis, serratus, latissimus, rectus abdominis
Other Regional Tissues	Omentum, double breast, total arm, diaphragm, etc.
Free Flaps	Rectus abdominis, latissimus, tensor, lateral thigh, etc.