CHAPTER 8

Thoracic Incisions

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It is easy for the surgeon . . . to treat in a casual, sometimes cavalier, manner the only visible reminder to the patient of that procedure.

C. Frederick Kittle

The history of thoracic surgery is replete with vivid descriptions of morbid, often gruesome, surgical approaches to the chest (Fig. 8–1, *A* and *B*). The rigidity of the chest wall and the relative lack of mobility of thoracic viscera magnify the importance of a well-conceived incision to facilitate exposure for resectional procedures. A century of experience and technologic advancement has afforded the modern thoracic surgeon the luxury of choosing from a variety of surgical approaches to the chest. However, to successfully utilize this information, the surgeon must be facile with the surgical anatomy of the chest wall and contents, and must understand the advantages and limitations of each incision.

GENERAL CONSIDERATIONS

Regardless of size, the incision should be placed to allow for the best possible exposure of the area that will be the site of the most technically challenging part of the surgery. Consequently, for standard pulmonary resections, incisions should expose the hilum of the lung. Location of the incision must permit rapid extension should circumstances dictate. This mandates a wide sterile prep for most thoracic procedures. Options to widen an existing incision need not be restricted to the linear axis, as counter-incisions or perpendicular incisions can be used for greater surgical exposure. Retractors have been developed to improve exposure from otherwise less-than-adequate incisions (Cooper et al, 1988).

Although thoracotomies can be safely performed in octogenarians (Naunheim et al, 1991), physical condition and body habitus of the patient should be considered when planning the surgical approach. A cachectic, bedridden patient may develop pressure necrosis over a posteriorly placed thoracotomy incision versus a lateral one. Similarly, muscular individuals require much larger subcutaneous dissection if muscle-sparing thoracotomy approaches are considered, and may subsequently be at greater risk for postoperative seroma. Tall individuals with narrow costal flares who require pericardial drainage may be more easily treated from an anterior left minithoracotomy than from a subxiphoid approach. Standard risk factors for wound complications (obesity, diabetes, etc.) should be recognized preoperatively and considered when incisions are planned. Meticulous surgical technique, gentle tissue handling, and excellent hemostasis will minimize local wound problems.

Ancillary services at an institution can greatly impact the surgical plan. If reliable single lung isolation is available, incision size can be drastically reduced and postoperative recovery may be enhanced by epidural analgesia (Lubenow et al, 1994). Preoperative imaging studies are useful to define the pathology and may also help direct the location of the incision (Daly et al, 1991).

Finally, as postoperative survival progressively improves, the long-term sequelae of thoracic incisions must be considered. A muscle-sparing thoracotomy may be less painful and preserve arm function better than the *classic* postero-lateral approach (Ginsberg, 1993; Kittle, 1988), although objective data are insufficient to support this theory (Hazelrigg et al, 1991; Ponn et al, 1992). Post-thoracotomy neuralgia remains a problem without a definitive solution and brachial plexopathy can be a devastating complication of thoracotomy or sternotomy.

With these tenets in mind, the chest can be accessed from anterior, lateral, or posterior (posterolateral) approaches. Combined approaches are commonly utilized. A fundamental understanding of the regional musculoskeletal anatomy is valuable in reconstructing the wound and in predicting postoperative debility that might result.

ANTERIOR CHEST INCISIONS

The musculoskeletal anatomy of the anterior neck, chest and abdomen are represented in Figure 8–2. Important skeletal landmarks include the thyroid cartilage, the suprasternal notch, the sternal angle of Louis, and the xiphoid process. The suprasternal notch lies over the inferior aspect of the second thoracic vertebra (T2), the angle of Louis superimposes onto T4, and the xiphoid approximates T9. When mediastinal structures are projected through the anterior skeleton (Fig. 8–3), the origin of the left innominate vein is beneath the junction of the first right rib and sternum. The top of the aortic arch is posterior to the midportion of the manubrium, and the hila are located deep to the third ribs.

Major anterior muscles include the platysma, sternocleidomastoid (SCM), the pectoralis major, the serratus anterior, and the rectus abdominus. The direction of the muscles should be noted (especially the pectoralis major) to permit muscle-splitting, rather than muscle-dividing incisions if possible. The vascular supply to the pectoralis major is both medial, from internal mammary perforators, and lateral, from the thoracoacromial trunk and

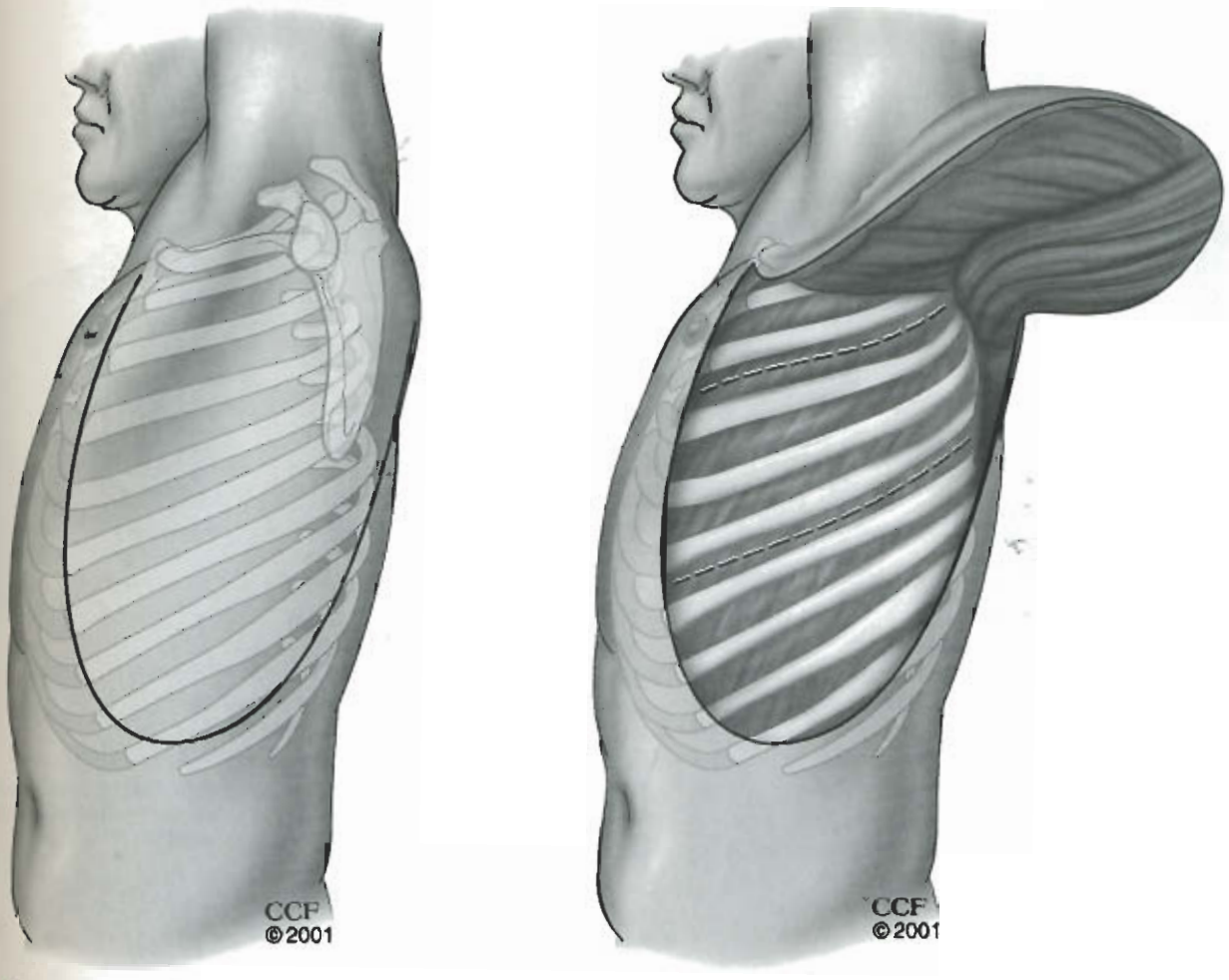


FIGURE 8–1 ■ *A,* Thoracic incision for esophageal resection in 1910. *B,* The scapula was completely mobilized, and the chest was entered at multiple interspaces *(dashed lines).* (Adapted from Meyer W: Some observations regarding thoracic surgery on human beings. Ann Surg 52:34, 1910; © Cleveland Clinic Foundation, 2001.)

intercostal artery perforators. This becomes relevant when mobilizing the muscle for reconstructive efforts.

Transverse Cervical Incision

The transverse cervical incision is the most common approach to access the thyroid, the cervical trachea, the proximal esophagus, and the superior mediastinum. The surgeon should be familiar with the anatomic relationships of the region (Fig. 8–4*A*). Patients are placed in a supine position on the operating table and arms are tucked at the sides (see Fig. 8–4*B*). Ulnar nerve compression is avoided by appropriate padding, and cervical exposure is augmented by neck hyperextension. For some tracheal procedures, intraoperative neck flexion and extension are necessary and should be permissible. Both surgeon and anesthesiologist should ensure that proper head support is provided prior to the placement of the drapes. Preoperative placement of central venous lines must be done with the operative plan in mind.

The neck is cleansed with alcohol, and a standard iodine-based gel is used to prepare the skin. It is customary to consider the entire neck (to the jaw angle) and the anterior chest as part of the operative field, although after the sterile preparation, these regions may be covered and exposed only if needed. Examination with the patient under anesthesia will help the surgeon identify anatomic landmarks (thyroid cartilage, suprasternal notch, SCM, etc.) prior to commencement of the procedure.

Depending on the patient's anatomy and indication, a standard transverse cervical incision (see Fig. 8–4*C*) is usually made midway between the thyroid cartilage and the suprasternal notch in a convenient skin crease. This location is consistent with the lines of Langer. The knife blade is used to carry the incision through the platysma, which allows for easy identification of this muscle when closing. The incision is easily carried across the SCM or in a cephalad direction toward the mastoid process for additional exposure. Myocutaneous flaps are raised as dissection subadjacent to the platysma is relatively bloodless. In the midline, the strap muscles are then easily identified and bluntly mobilized laterally to expose the thyroid gland.

The cervical trachea is exposed as the thyroid is cle-

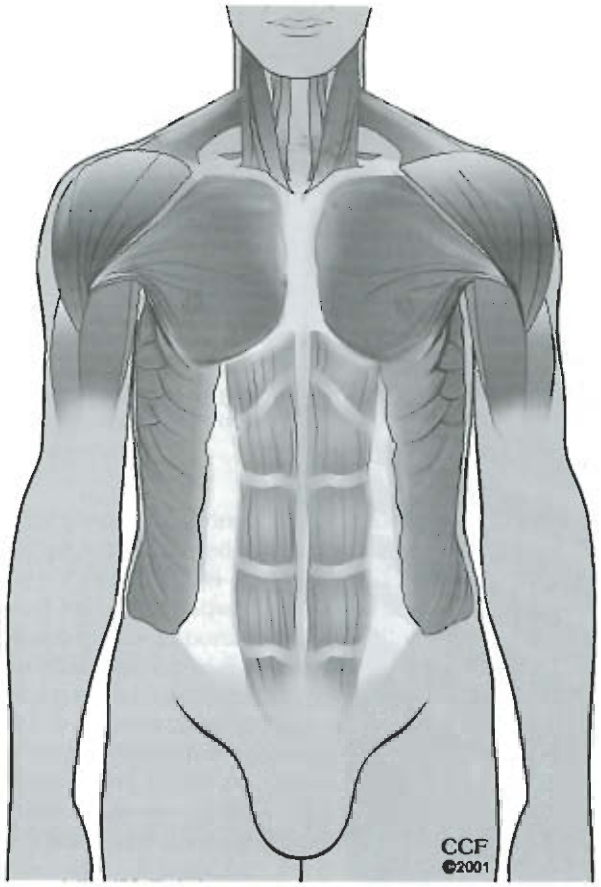


FIGURE 8–2 ■ Musculoskeletal structures encountered with anterior approaches. Important muscle groups include sternocleidomastoid, pectoralis major, serratus anterior, and rectus abdominis. (© Cleveland Clinic Foundation, 2001.)

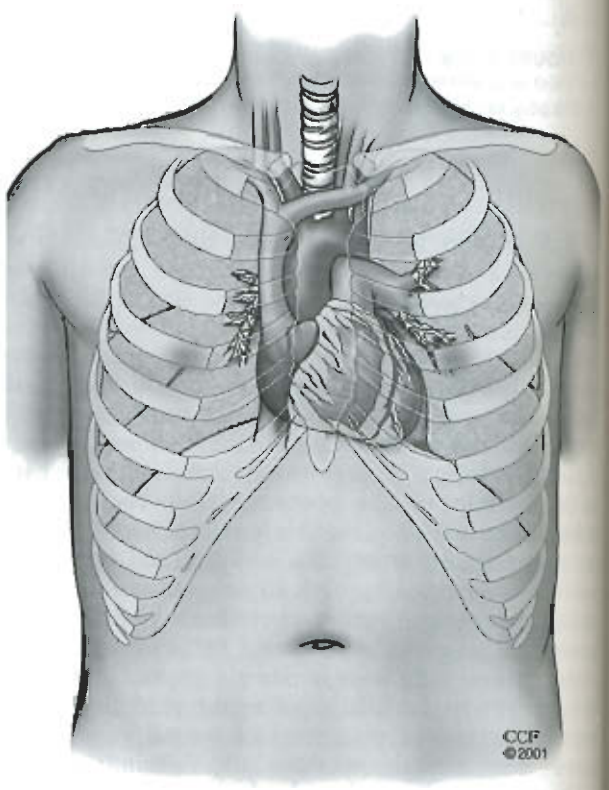
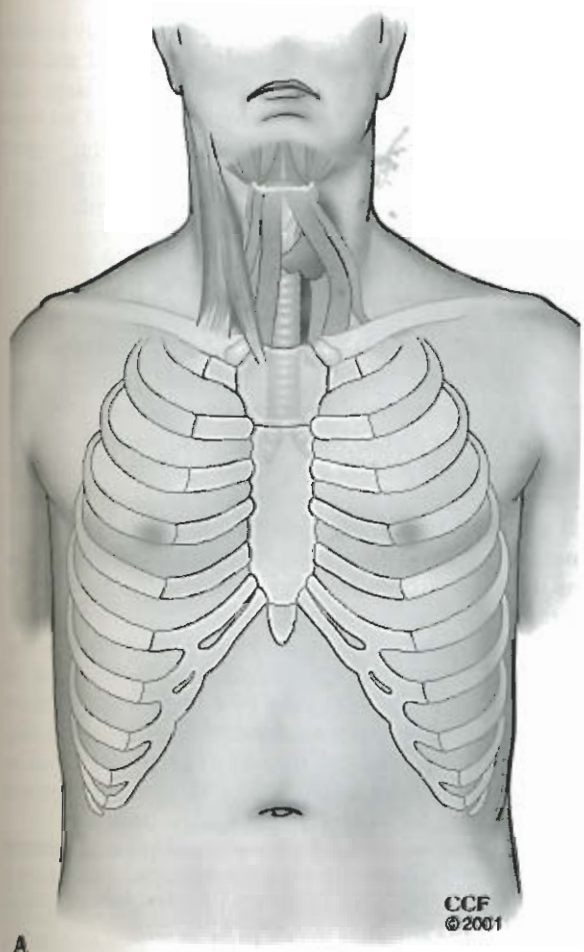


FIGURE 8–3 ■ Anterior projection of major mediastinal structures through the chest wall. (© Cleveland Clinic Foundation, 2001.)



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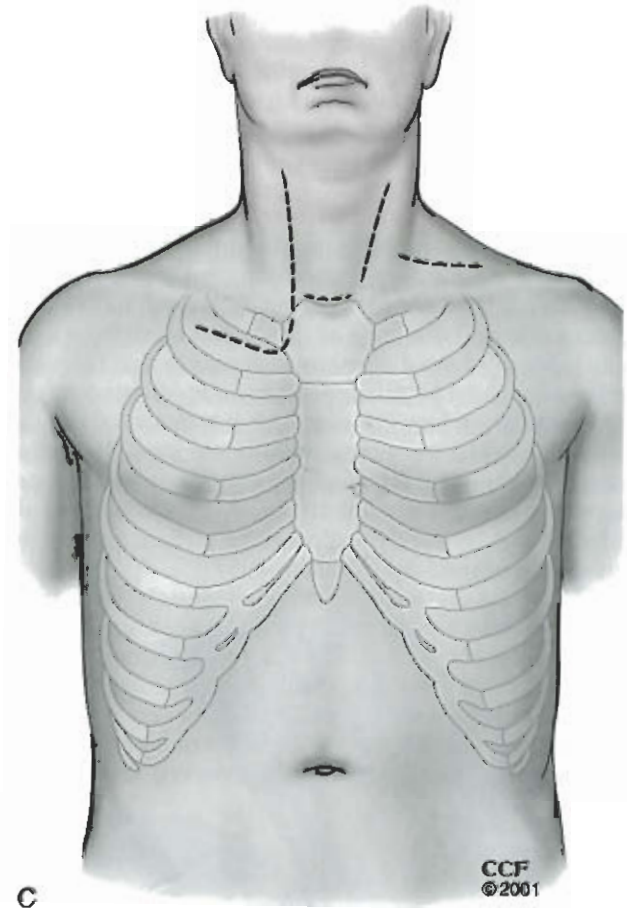

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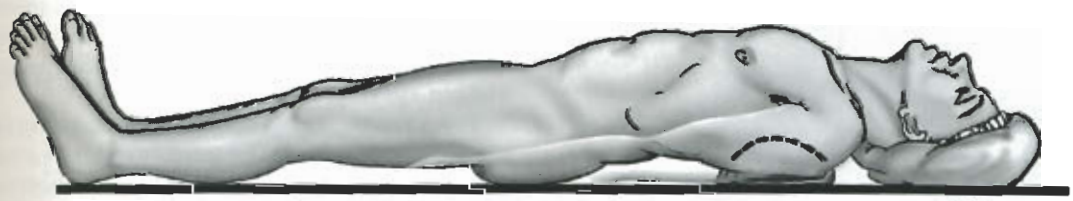

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FIGURE 8–4 ■ *A,* Exposure of the neck. With the platysma cut away, the relationship of the deeper cervical muscles should be understood. Exposure to the trachea mandates lateral mobilization of the strap muscles and elevation (or division) of the thyroid isthmus. *B,* Standard position for midline cervical incisions. *C,* Variety of common cervical incisions.

vated superiorly (or the thyroid isthmus divided) and pretracheal (thymic) fat mobilized laterally. This approach is recommended for tracheotomy or tracheal resection (Grillo, 1969). Elevation of the pretracheal fascia permits access to the mediastinum for mediastinoscopy. The transcervical approach to the mediastinum has been used for thymectomy (Cooper et al., 1988) and is occasionally helpful in reoperative parathyroid surgery (Wells and Cooper, 1991) and substernal goiter.

Variations of this incision are frequently used (see Fig. 8–4C). With the neck extended and turned to the contralateral side, a transverse incision is started at the lateral border of the SCM and carried laterally across the supraclavicular fossa to facilitate scalene node biopsy. The platysma is incised sharply and the ipsilateral external jugular vein ligated. The SCM can be mobilized medially with cautery to expose the internal jugular vein. The omohyoid muscle courses obliquely in the field and can be mobilized or divided without consequence. The fat pad can then be harvested off the scalene anticus muscle after the phrenic nerve has been identified and preserved. The subclavian artery courses at the inferior aspect of the field, and the thyrocervical trunk can be skeletonized. The left-sided approach may bring the thoracic duct in the field, mandating additional caution when the medial aspect of the fat pad is being mobilized.

The cervical esophagus is exposed with an oblique incision along the anterior border of the SCM (see Fig. 8–4C). After the SCM is mobilized laterally, the omohyoid is divided if necessary. To properly mobilize the carotid

sheath requires division of the inferior thyroid artery and middle thyroid vein. As the thyroid, trachea, and strap muscles are gently retracted medially and the carotid sheath and SCM moved laterally, the esophagus is approached. Blunt dissection posteriorly along the anterior border of the cervical spine provides the safest route to control the cervical esophagus.

The anterior transcervical approach to superior sulcus tumors (Dart et al, 1979; Dartevelle et al, 1993) permits controlled cervical mobilization for anterior lesions. After appropriate positioning, intersecting incisions are made along the anterior border of the SCM and transversely across to the inferior edge of the medial clavicle (see Fig. 8–4C). Much of the dissection is similar to that discussed previously. Notable differences include division of the SCM and the scalenus anticus. After removal of the scalene fat pad, the tumor is carefully assessed. If deemed resectable, the medial half of the clavicle is resected and vascular control is obtained (Fig. 8–5). Division of the scalenus anticus nicely exposes the stellate ganglia for dorsal sympathectomy (Nanson, 1957).

Closure entails repair of divided muscle with interrupted absorbable suture. For large neck procedures, platysma closure should allow a Silastic drain to hold bulb suction. A fine, absorbable, subcuticular suture is used for skin closure. Wound infection is very rare unless a viscus (e.g., esophagus) has been opened or the tissues have been previously irradiated. However, an enlarging hematoma in the neck can rapidly lead to airway compromise. Thus, meticulous hemostasis is required and close postoperative observation is warranted for large neck dissections. Postoperative hoarseness heralds a recurrent nerve injury and ipsilateral diaphragm elevation suggests a phrenic nerve palsy. Familiarity with the surgical anatomy of the region should greatly reduce complications.

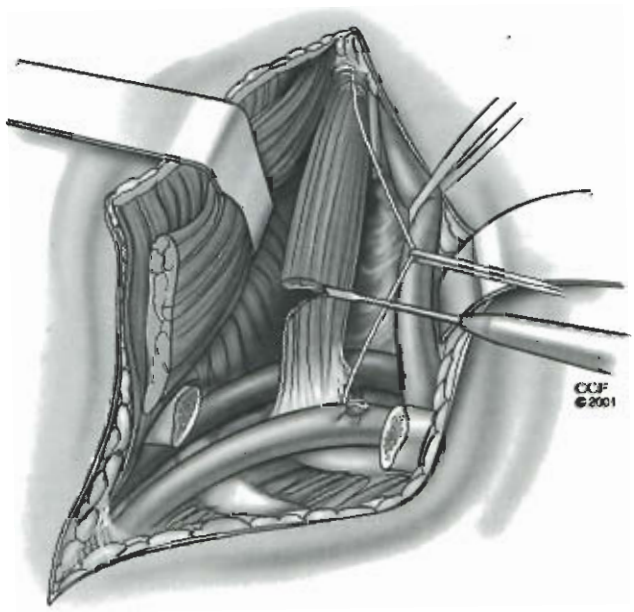


FIGURE 8–5 ■ Anterior transcervical approach to superior sulcus tumors as described by Dartevelle and associates (1993). Schematic represents a right-sided approach. The medial portion of the clavicle *(bottom of the picture)* has been resected. A retractor *(left)* distracts platysma and the cut end of the sternocleidomastoid muscle, exposing the scalene anticus. The phrenic nerve should be mobilized medially to permit safe division of the scalene muscle. (Adapted from Dartevelle FG, Chapelier AR, Macchiarini P, et al: Anterior transcervical-thoracic approach for radical resection of lung tumors invading the thoracic inlet. J Thorac Cardiovasc Surg 105: 1025, 1993; © Cleveland Clinic Foundation, 2001.)

ANTERIOR MEDIASTINOTOMY

The original description of anterior mediastinotomy (McNeil and Chamberlain, 1966) entailed a 6-cm incision along the second intercostal space and removal of the entire cartilaginous portion of the second rib. The internal mammary pedicle was ligated and divided, and the retrosternal extrapleural space was entered by blunt dissection. The procedure was devised to identify patients with unresectable cancer (mediastinal spread) to prevent unnecessary exploratory thoracotomy. Current indications for the procedure are considerably narrower, as accurate radiographic staging and alternative surgical approaches (mediastinoscopy and VATS) have largely supplanted the technique. Occasionally, it is still used for staging patients with left upper lobe bronchogenic cancer. More commonly, anterior mediastinotomy is used to diagnose primary mediastinal masses after percutaneous attempts (e.g., fine-needle aspiration) have failed to provide adequate tissue for complete pathologic analysis.

A preoperative computer tomography scan can help place the incision directly over the pathology, simplifying the procedure. The ipsilateral thorax should be prepped in the event the incision needs to be extended to improve exposure or control hemorrhage. If a mediastinoscope is used to assist in the exposure, seldom is more than a 3-cm incision required. The selected interspace may be widened enough to accommodate the mediastinoscope without rib resection (Fig. 8–6).

The skin incision should be placed directly over the site of the pathology. The pectoralis major muscle can be separated bluntly in the direction of its fibers. To remain in the extrapleural plane, sharp dissection is used to identify the internal mammary pedicle and to distract it laterally. The mediastinum is then entered bluntly, and the mediastinoscope is inserted. If additional space is needed, the medial aspect of the rib cartilage over the internal mammary vascular bundle is removed carefully and sharp dissection is used to expose the vascular pedicle. Rarely will the internal mammary artery need to be sacrificed.

If an intrapleural approach is preferred, the pleural cavity should be entered lateral to the mammary pedicle. When a mediastinoscope is used, lung isolation is generally not needed. The surgeon must be careful not to mistake hilar lymph nodes (N1) for mediastinal lymph nodes (N2), since both may be biopsied through this approach. At the conclusion of the procedure, air is evacuated through a soft catheter left in the pleural space. Suction is applied to the catheter as pectoralis muscle is tightly closed around it with absorbable suture. The catheter is pulled out during a deep breath-hold, and the muscle layer is cinched tight. If a parenchymal lung injury was incurred, a chest tube is warranted.

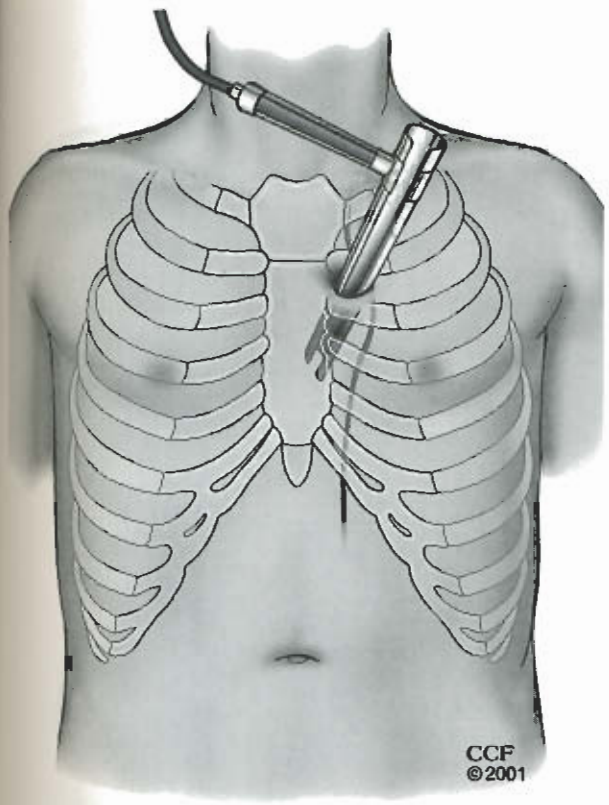


FIGURE 8–6 ■ Modified Chamberlain procedure for access to the superior-anterior mediastinum. A mediastinoscope is used to facilitate exposure and minimize the incision length and morbidity. The scope is inserted medial to the internal mammary pedicle for most applications. (© Cleveland Clinic Foundation, 2001.)

ANTERIOR THORACOTOMY

Anterior thoracotomy has both general thoracic and cardiac surgical applications. It is advantageous in that the patient can remain supine with the expected result of improvement in cardiopulmonary function. The right middle lobe is easily approached anteriorly. Bilateral anterior thoracotomy is gaining popularity for double lung transplantation (Meyers et al, 2000; Pochettino et al, 2000). Moreover, open lung biopsy on critically ill patients can be safely conducted through anterior exposure, as can partial pericardectomy. Similarly, reoperative cardiac surgeries are often approached via anterior thoracotomy (Byrne et al, 2001; Kerr et al, 2001). Because the posterior hilum and the esophagus are poorly exposed, the anterior approach is infrequently used for pulmonary or esophageal resections.

The patient should be placed in a supine position with a paraspinal roll elevating the ipsilateral chest by 20 to 30 degrees (Fig. 8–7, *A* and *B*). A double-lumen endotracheal tube should be placed for lung isolation. Arms are tucked at the sides and elbows are padded. The ipsilateral elbow is elevated if excessive stretch is perceived on the shoulder. After a standard sterile prep and drape, the angle of Louis is identified. This palpable landmark identifies the second rib. For entrance into the chest at interspace 4, an incision is made in the inframammary crease from the sternal edge to the anterior axillary line. The pectoralis major muscle should be divided slightly superior to the skin incision to prevent suture lines from overlapping. Breast tissue is mobilized from the pectoralis fascia with cautery. The cephalad portion of the pectoralis muscle is mobilized medially off the sternum and inferiorly from the ribs until the desired interspace is reached. Internal mammary artery perforators are controlled with cautery or clips.

The ipsilateral lung should be deflated well before the thorax is entered. We do not routinely dissect rib periosteum for a thoracotomy unless the rib is to be resected. Cautery is used to incise the intercostal muscles from the superior aspect of the rib below the interspace. Laterally, serratus muscle is split along the course of its fibers. Slips of pectoralis minor muscle are divided. The pleura is initially entered bluntly to prevent parenchymal injury. Once the lung is collapsed, or retracted, the rest

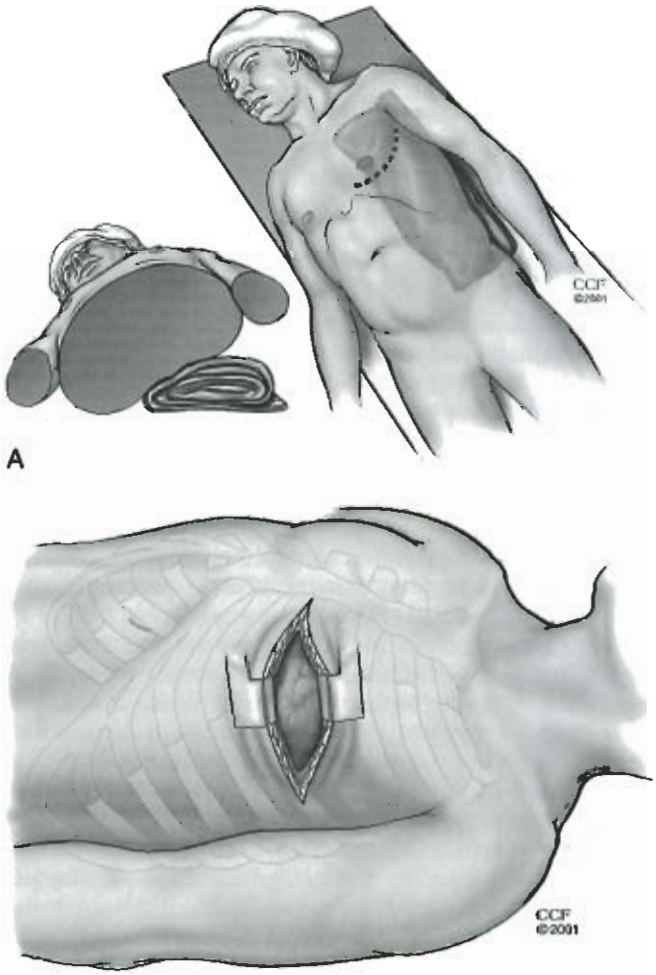


FIGURE 8–7 ■ *A*, Position for anterior thoracotomy. A roll is used to elevate the patient on the ipsilateral side. The ipsilateral arm can be positioned at the side *(as shown)* or elevated across the body. *B*, The pleural cavity is commonly entered at interspace 4. Resection of the sternocostal junction at rib 3 allows sufficient exposure for single lung transplantation *(not shown)*. (© Cleveland Clinic Foundation, 2001.)

of the interspace is opened with cautery. If additional exposure is necessary, the internal mammary pedicle can be divided. This may be facilitated by resecting a small piece of rib cartilage anterior to the bundle. If cephalad exposure is required, the cartilage of the rib above the interspace can be divided. To further increase rib distraction, the intercostal muscles and pleura can be divided posteriorly, well beyond the limits of the incision. Gauze pads are used to cushion the ribs and soft tissues when the rib spreader is applied.

For closure, after chest drains are placed, ribs are reapproximated with heavy gauge (e.g., #2) absorbable suture. We do not routinely drill holes in ribs or tunnel suture subperiosteally to prevent intercostal neuralgia. Rather, sutures are placed to incorporate intercostal muscle from the interspace below to cushion the neurovascular bundle and excessive force is avoided when sutures are tied down. Anteriorly, it is seldom possible to obtain rib-to-rib apposition. Trying to do so predisposes to neurovascular bundle injury. Instead, attention should be paid to meticulous soft tissue closure. The perichondrium should be identified and reapproximated if divided. The medial aspect of the rib is anchored to the sternum with heavy, non-absorbable monofilament suture if necessary. The pectoralis major muscle is repaired with either continuous or interrupted suture technique. Deep dermal tissues and skin are closed with continuous absorbable suture.

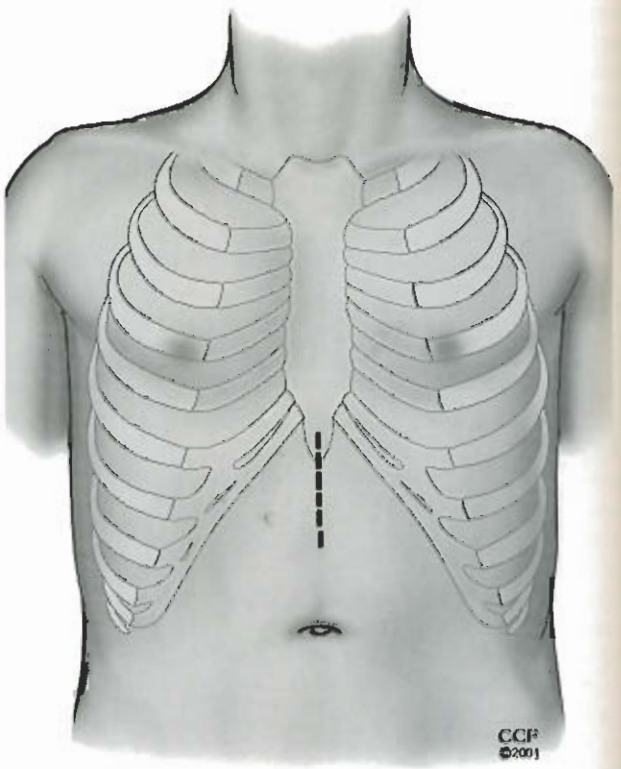


FIGURE 8–8 ■ Location of the incision for a subxiphoid approach to the pericardium. (© Cleveland Clinic Foundation, 2001.)

UPPER MIDLINE

The upper midline abdominal incision has wide application in thoracic surgery. In addition to providing access to the abdominal viscera, the pericardium can be drained, and the gastroesophageal junction can be easily exposed. Moreover, the incision is routinely coupled with other incisions during two- or three-field approaches. Contraindications are few, although a previous laparotomy incision may deter a subxiphoid approach to the pericardium.

Although there remains some disagreement as to the best surgical strategy to manage effusive pericardial disease (Hankins et al, 1980; Larrieu et al, 1986; Piehler et al, 1985), the subxiphoid approach to the pericardium is rapid, effective, and if needed, can be performed without general anesthesia (Stewart, 1974). In obese or tall patients with narrow costal arches, subxiphoid exposure of the pericardium can be difficult (Prager et al, 1982).

Patients with hemodynamically compromising effusive disease (pericardial tamponade) are stabilized medically and percutaneously drained prior to surgery. This should be done the day before; pericardial drains should be left in place. If the pericardium cannot be decompressed, the surgeon must remain with the patient while the patient's abdomen and chest are sterilized and draped prior to anesthesia induction. If the patient is too unstable, the procedure must be done with the patient under local anesthesia and conscious sedation.

The patient is placed supine on the operating table (Fig. 8–8). A roll should be placed behind the lumbar spine so that the patient assumes a lordotic posture. A midline incision is made from the xiphisternal junction to 8 to 10 cm below the tip of the xiphoid. The linea alba is divided, with care being taken to avoid entering the peritoneal cavity. The soft tissue plane behind the xiphoid should be developed bluntly; the xiphoid can be dislocated from the xiphisternal joint after being freed from its fascial and muscular attachments. The diaphragm is depressed posteriorly with a sponge stick, and blunt dissection proceeds superiorly until the pericardium is exposed. The sternum is elevated anteriorly with a hand-held retractor. If a preoperative pericardial catheter was placed, the pericardial space can be filled with 100 to 200 ml of body-temperature, sterile saline to facilitate its identification and permit safe entrance. Once identified, the pericardium is grasped and sharply incised (Fig. 8–9). The space is drained after manual deloculation. A mediastinoscope (Santos et al, 1977) can be used to identify and biopsy pericardial implants. A generous segment of pericardium should be resected (16 to 25 cm^2) to decrease recurrence rate (Larrieu et al, 1986; Piehler et al, 1985; Santos et al, 1977). A chest tube is left in the pericardial space and tunneled out of a separate stab incision for postoperative drainage.

Complications, although rare, can be catastrophic. If the preoperative diagnosis was incorrect and an obliterative pericardial process exists, a coronary artery or ventricle can be lacerated in the surgical attempt to enter the space (Prager et al, 1982). Similarly, for a postcardiotomy, loculated, posterior effusion, a transthoracic approach would be prudent.

Proper reapproximation of the linea alba with heavy suture is necessary to prevent postoperative ventral her-

FIGURE 8–9 ■ Subxiphoid pericardial exposure. When the xiphisternum is elevated and the diaphragm depressed, the inferior pericardium is brought into the operative field. The pericardium is then incised sharply to create the window. (© Cleveland Clinic Foundation, 2001.)

nia. Heterotopic ossification is sited as an uncommon late sequela of midline incisions (Reardon et al, 1997). Patients tolerate the incision well and can be mobilized early. Although follow-up echocardiogram is not imperative, it is recommended prior to chest tube removal.

When the upper midline incision is extended down to the umbilicus (Fig. 8–10*A*) and self-retaining retractors are properly placed, the esophageal hiatus can be exposed. After the left lobe of the liver is separated from its ligamentous attachment to the diaphragm and gently tucked beneath the retractor, the hiatus is brought into full view (see Fig. 8–10*B*). Access to the posterior mediastinum can be achieved by vertical division of the diaphragm from the hiatus or through a transverse semicircular incision in the central tendon that spares the hiatus (Thirby et al, 1993). When dividing the diaphragm, attention should be paid to controlling the inferior phrenic vessels and preserving the phrenic nerves. The technique of transhiatal esophagectomy through this approach is described in Chapter 57 of *Esophageal Surgery*.

STERNOTOMY

Median sternotomy was originally described for the management of mediastinal tuberculosis (Milton, 1897). Median sternotomy has since become the most common thoracic incision due to the development of cardiac surgery. By virtue of its midline and anterior location, it has broad applications for noncardiac chest operations as well. The transsternal route is the most direct for thymectomy and other anterior mediastinal tumors. Tracheal (Grillo, 1969; Grillo, 1979) and upper esophageal exposure (Orringer, 1984) is greatly enhanced when cervical incisions are combined with full or partial sternotomy. Median sternotomy can simplify bilateral pulmonary metastasectomy (Regal et al, 1985; Takita et al, 1977) and bilateral lung volume operations (Cooper et al, 1995). Anatomic pulmonary resections can be safely performed through a sternotomy incision (Asaph and Keppel, 1984; Cooper et al, 1978; Urschel and Razzuk, 1986). Transsternal repair of postpneumonectomy bronchopleural fistula has also been reported (Baldwin and Mark, 1985). Sternotomy permits early hilar control for completion pneumonectomy cases and should be considered for uncontrollable hemorrhage that may occur during mediastinoscopy. An additional advantage of sternotomy is the ease of instituting cardiopulmonary bypass from this approach.

The sternotomy incision is performed with the patient supine (Fig. 8–11*A*). Arms should be tucked and elbows padded. Depending on the indication for surgery, the sterile drape may include the entire neck and abdomen. Similarly, the groins may be included if additional access for cardiopulmonary bypass is needed. A double lumen endotracheal tube is preferable for most pulmonary operations except tracheal resection. The standard sternotomy incision is from the suprasternal notch to a point midway between the xiphoid and umbilicus in the midline. The knife is used to carry the incision to the pectoral fascia and linea alba. Cautery can then be applied to control superficial bleeding, score the periosteum, and divide the linea alba. The superior end of the skin incision is retracted in a cephalad manner to expose the top of the manubrium and allow for control of crossing jugular tributaries in the space of Burns. The interclavicular ligament can be divided sharply or with cautery; care must be taken to avoid an anterior coursing innominate artery or vein. Blunt digital dissection is used to open the retrosternal space both superiorly and inferiorly.

Once the sternum is fully exposed, deliberate palpation of the interspaces allows for an accurate assessment of the true midline. If necessary, this can be re-marked with cautery. A reciprocating saw is used to divide the sternum either from top down or bottom up (see Fig. 8–11*B*). Prior to splitting the sternum, the lungs are transiently deflated to prevent unintentional entry into a pleural space. Bleeding is immediately controlled with gauze packing, while periosteal bleeders are selectively cauterized. Marrow bleeding can be controlled by bone wax without significantly increasing infectious complications (Baskett et al, 1999), although biocompatible sealants now exist for this purpose (Kjaergard and Trumbull, 2000).

A choice of sternal spreaders can be used to distract the sternal edges (see Fig. 8–11*C*). Inferior (caudad) placement of retractors seems less frequently associated with rib fracture and brachial plexus injury (Baisden et al, 1984). Sternal edges should be spread only far enough

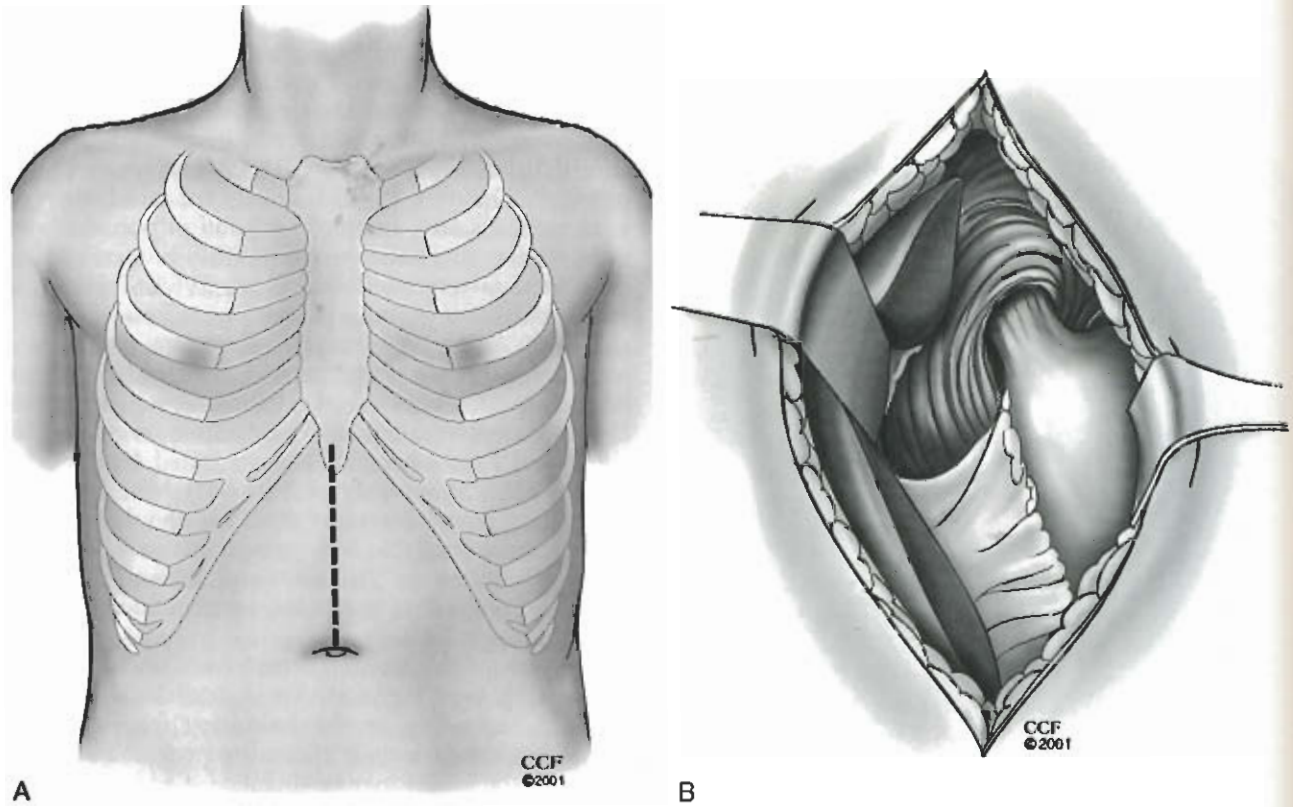


FIGURE 8–10 ■ *A*, Placement of upper midline incision for distal esophageal and diaphragm exposure. *B*, After the left lateral segments of the liver are mobilized toward the midline, the esophageal hiatus is brought into full view. An *upper-hand* retractor greatly improves exposure. (© Cleveland Clinic Foundation, 2001.)

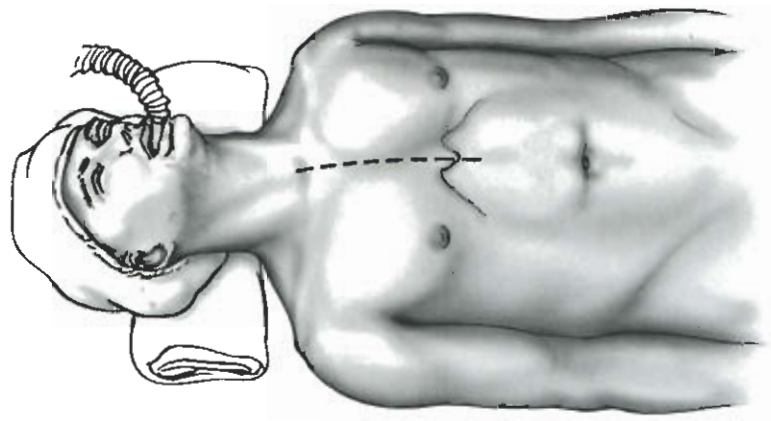
to permit adequate exposure for safe completion of the operation. Anterior diaphragm fibers may prematurely restrict sternal spreading and can be divided. In addition to brachial plexus and rib injury, excessive tension on the innominate vein limits sternal distraction.

Multiple modifications to the skin incision have been made to improve cosmetic results. Common to all is extensive soft tissue mobilization, which allows for complete sternal division. Candidates for skin-sparing operations should be fit and well-nourished, because significant wound healing is required. Steroid use is a relative contraindication.

A limited 10- to 12-cm vertical incision can be made beginning below the angle of Louis. This keeps the scar below the neckline. Subcutaneous flaps are raised laterally off the pectoralis fascia and rectus sheath. Internal mammary perforators are encountered as the flaps are raised. Depending on the size of the incision it may be necessary to undermine the subcutaneous flaps laterally to the midclavicular line. Superiorly, the soft tissue is universally more lax, requiring less dissection for adequate mobilization. Prior to splitting the sternum, the incision should be able to provide exposure from the suprasternal notch to the xiphoid. Because the decreased length of the incision limits the view of operative field, intraoperative repositioning of the sternal retractor is frequently necessary. Subcutaneous drains and compressive dressings should be used postoperatively. A limited "Y" incision has also been described and is similarly performed (Nandi et al, 1979).

The submammary exposure of the sternum is popular for young women (Laks and Hammond, 1980; Martinez-Sanz et al, 1990). Patients are positioned supine with elbows slightly flexed at the patient's side to expose the anterior axillary line (Fig. 8–12). The submammary folds can be marked preoperatively. Beginning just lateral to the nipple, the incision is made in the submammary crease and elevated to a point level with the nipples in the midline. Cautery dissection is used to elevate the breasts and soft tissues, in a triangular fashion, toward both the suprasternal notch and the xiphoid (see Fig. 8–12). The lateral extent of the dissection should not interrupt the lateral perforating branches of the intercostal arteries that perfuse the flap. After completion of the dissection and exposure of the sternum, the superior and inferior flaps are handled gently and retracted with sutures. A standard sternotomy is then performed. When closing, the flaps can be loosely tacked down to the pectoral fascia and closed over vacuum drains. The deep dermis and skin are reapproximated with fine absorbable suture. Compressive dressings are applied to the wound and breast support is provided with an elastic bra.

Wound hematoma and skin necrosis in the central part are observed in 5% to 10% of cases. A horizontal (versus elevated) connecting incision across the sternum has a higher incidence of wound breakdown (de la Riviere et al, 1981). Healing by secondary intention still results in an acceptable cosmetic outcome. Hypertrophic scarring has been noted in 10% to 20% of patients (Deutinger and Domanig, 1992; Martinez-Sanz et al, 1990).



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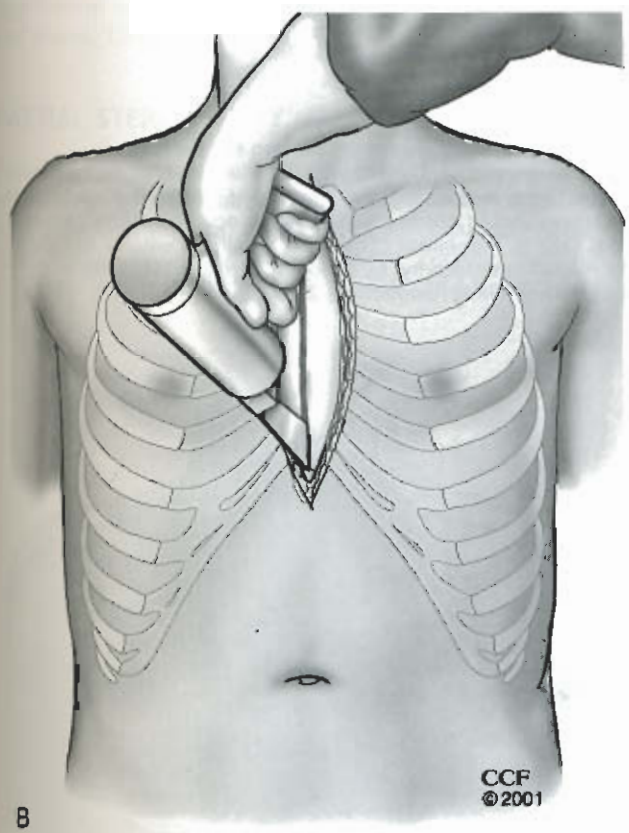

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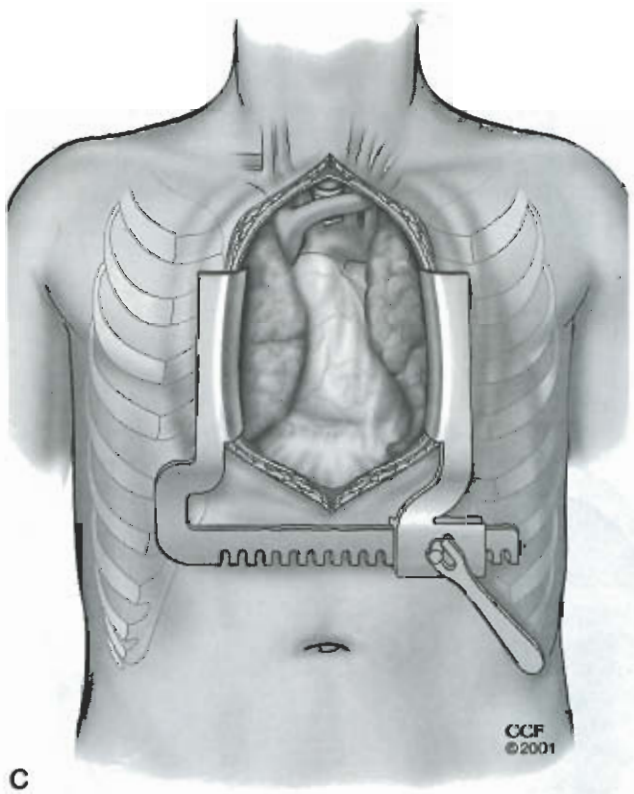

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FIGURE 8–11 ■ *A,* Location of incision for median sternotomy. *B,* A sternal saw can be applied either superiorly or inferiorly. It is critical to ensure a midline division of the bone. *C,* The sternal spreader should be applied at the inferior aspect of the incision to reduce the incidence of brachial plexus injury. (© Cleveland Clinic Foundation, 2001.)

Intralesional triamcinolone injection seems effective in these cases (Martinez-Sanz et al, 1990). Decreased areolar sensitivity is reported in 30% of patients (Deutinger and Domanig, 1992). No long-term interference with breast-feeding is reported (Deutinger and Deutinger, 1993).

Regardless of skin incision, rigid reapproximation of the sternum is the single most important factor in preventing sternal dehiscence and deep-seated infection (DiMarco et al, 1989). A variety of strategies have been devised to oppose the sternal edges after sternotomy (DiMarco et al, 1989; Kalush and Bonchek, 1976; Robicsek et al, 1977; Sirivella et al, 1987; Zieren et al, 1993). For uncomplicated cases, a standard stainless steel wire reapproximation is appropriate (Fig. 8–13*A*). Six to seven #6 stainless steel wires should be used. Depending on the patient's size, 2 or 3 wires are placed in the body of the manubrium. The remaining wires are placed parasternally from interspaces 2 through 5. If an osteoporotic or fractured sternum is encountered, the wire-reinforced closure suggested by Robicsek and associates (1977) should be used (see Fig. 8–13*B*). This technique is also useful to help salvage a paramedian sternal split. Mersilene tape, steel bands, and heavy absorbable suture have all been successfully used to close sternotomy incisions.

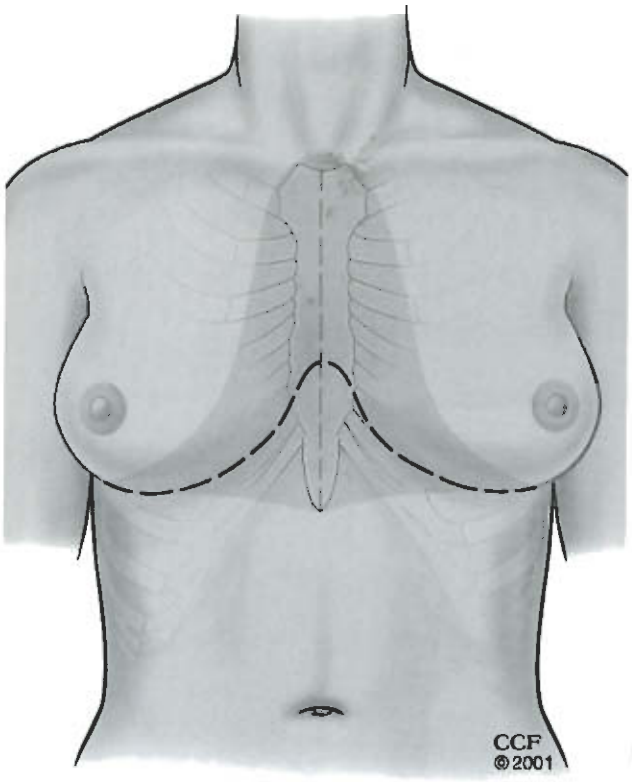

FIGURE 8–12 ■ Submammary incision for sternotomy. Subcutaneous tissue flaps should be raised as depicted by the *shaded areas* in the diagram. The lateral extent of the soft tissue dissection should not be beyond the midclavicular line. (Adapted from Laks H, Hammond GL: A cosmetically acceptable incision for the median sternotomy. J Cardiovasc Surg 79: 146, 1980; © Cleveland Clinic Foundation, 2001.)

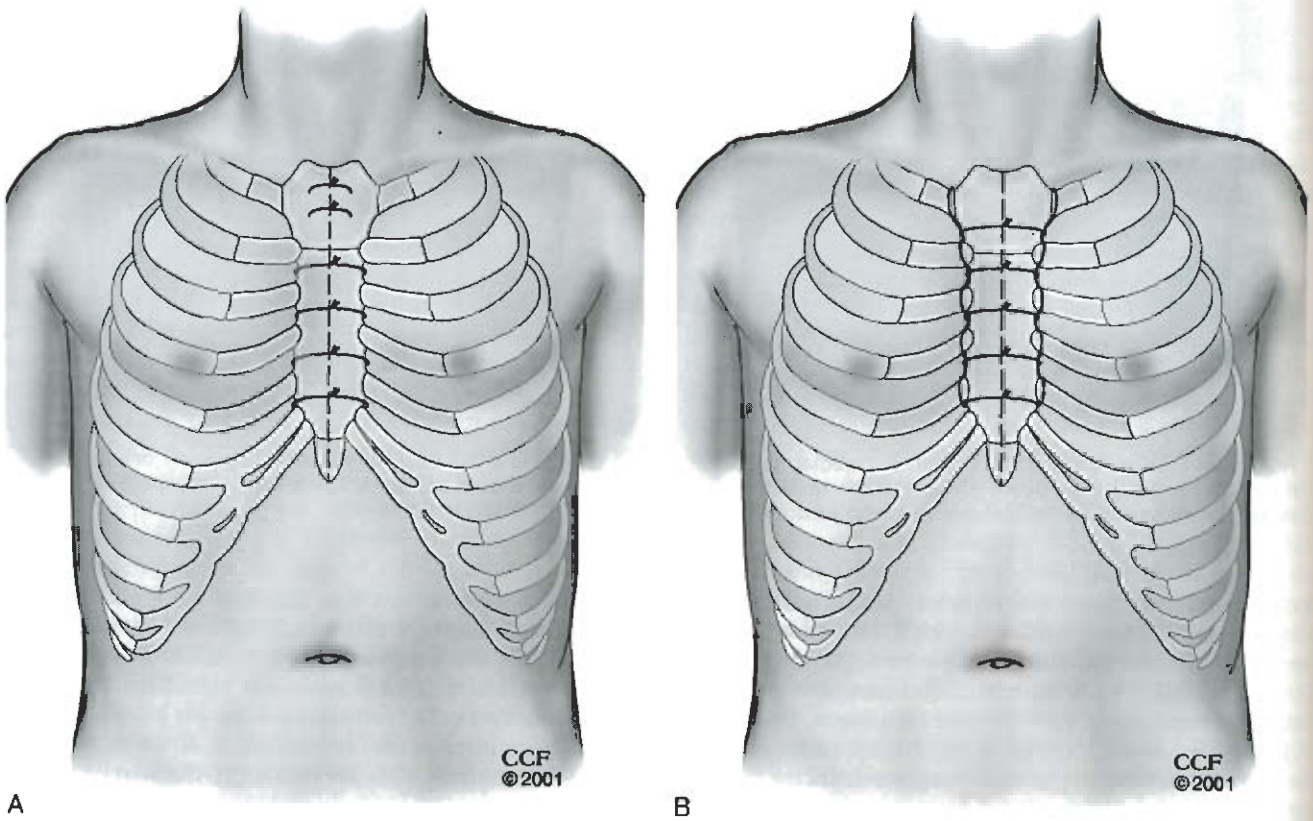

FIGURE 8–13 ■ *A*, Conventional sternal reapproximation with #6 stainless steel. *B*, Sternal closure as proposed by Robicsek. The transverse wires must be placed outside the parasternal weave. (Adapted from Robicsek F, Daugherty HK, Cook JW: The prevention and treatment of sternum separation following open-heart surgery. J Thorac Cardiovasc Surg 73:267, 1977; © Cleveland Clinic Foundation, 2001.)

For patients with preoperative and operative risk factors for sternal wound complications (Demmy et al, 1990; Zacharias and Habib, 1996), the interlocking figure-of-eight closure reported by DiMarco and associates (1989) should be considered.

Although the incidence of mediastinitis following sternotomy is 1% to 2%, the data have been largely derived from cardiac surgical cases. Nonetheless, sternal wound complications do predict a slight long-term survival disadvantage in this population (Stahle et al, 1997). In addition to preoperative patient selection, intraoperative hemostasis and proper sternal closure, early extubation is important in preventing mediastinitis (Demmy et al, 1990). Delayed chest wall complications of median sternotomy include costochondral separation, occult rib fracture, chronic osteomyelitis of the sternum or rib cartilage, sternal non-union, and sternal wire erosion (Weber and Peters, 1986).

PARTIAL STERNOTOMY

Partial sternotomy is a useful adjunct to extend a variety of incisions for additional exposure. It has been combined with a low, collar incision to facilitate tracheal reconstruction (Grillo, 1979), with an oblique cervical incision for upper esophageal (Orringer, 1984) and great vessel exposure, with anterior thoracotomy ("hemi-clamshell"), or with parallel supraclavicular and infraclavicular incisions ("open book incision"). Moreover, when extended in an intercostal space, partial (hemi-) sternotomy can serve as the primary incision for resection of mediastinal malignancy, thymectomy, substernal goiter, or ectopic parathyroid adenoma.

The patient is positioned supine as for a standard sternotomy. The neck should be included in the drape if needed. Flexion and extension of the neck should be possible for tracheal cases. When used as the only incision, an 8 to 10 cm incision can be made beginning at the angle of Louis (Fig. 8–14*A*). Soft tissue flaps are raised as previously described, and the sternum is exposed. A reciprocating saw divides the sternum to the chosen interspace (usually 3 or 4). Given the location of the mass, the saw is used to "T" one side of the sternum towards the mass. A small sternal spreader is used to open the incision. The internal mammary pedicle may need to be divided to improve exposure. Separate lung ventilation is preferable.

After the planned resection is completed, stainless steel wire is used to reapproximate the sternum. An anchoring wire is used to firmly fix the divided bone to the main body of the sternum at the base of the incision (see Fig. 8–14*B*). Suction drains are placed under large subcutaneous flaps.

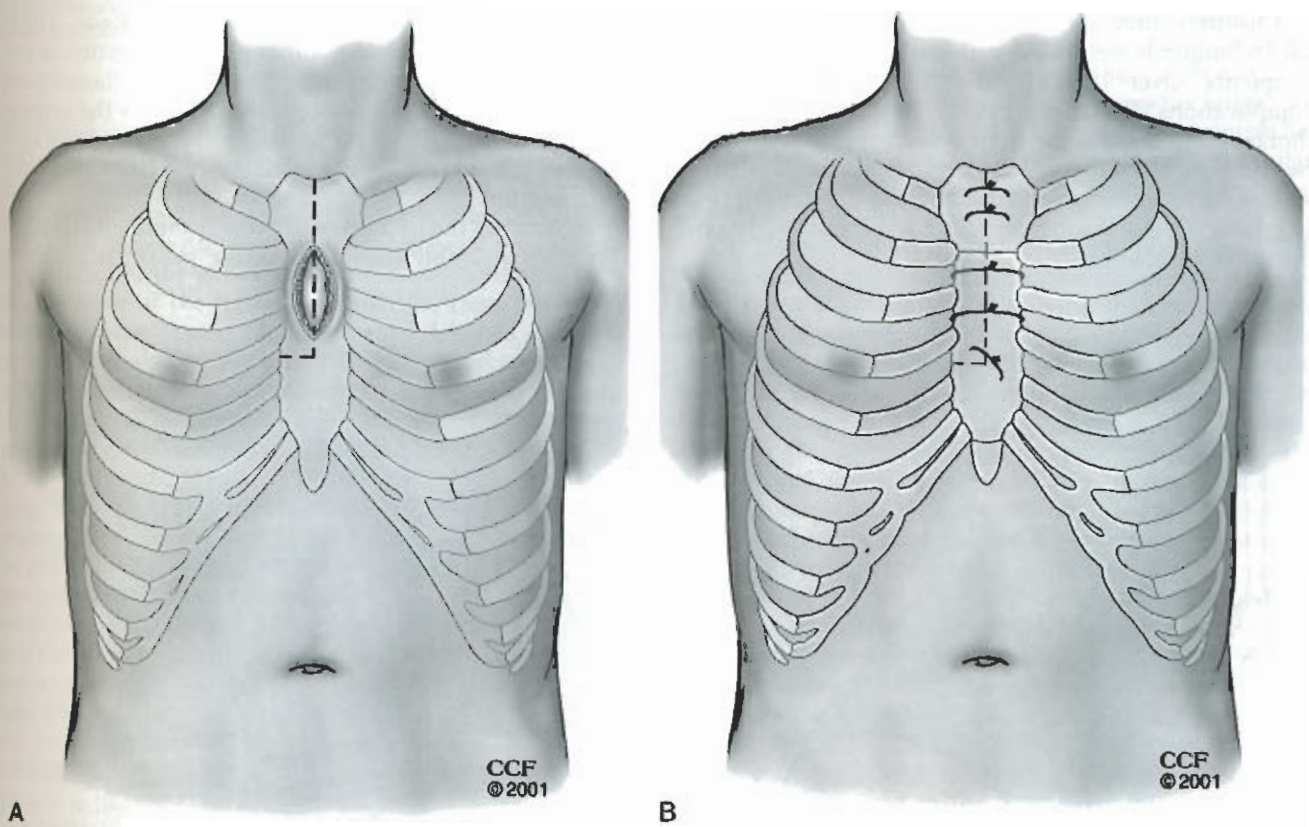

FIGURE 8–14 ■ *A*, Skin incision and position of sternal division for a hemisternotomy. Soft tissue flaps are elevated to expose the upper sternum. The sternum is "T'd" off to the appropriate side. *B*, Wire closure for the partial sternal split is similar to the standard closure with the exception of an inferior anchoring wire placed through the body of the undivided sternum. (© Cleveland Clinic Foundation, 2001.)

THORACOSTERNOTOMY (CLAMSHELL) INCISION

The clamshell incision offers superior exposure of the heart, great vessels, mediastinum, and pulmonary hilum. It has applications in the management of life-threatening traumatic injury, pulmonary metastastectomy (Shimizu et al, 1992) and bilateral sequential double lung transplantation (Kaiser et al, 1991). Rarely, the incision has been used for coronary surgery (Marshall et al, 1988).

After a double lumen endotracheal tube is placed, the patient is positioned supine on the operating table with both arms flexed at the elbows and extended over the face (Fig. 8–15*A*). The patient may be elevated from the table by placement of a roll along the spine and parallel rolls across the scapulae and pelvis. This allows for better exposure should the incision need to be carried more posteriorly. The skin incision is identical to that used for the submammary exposure of the sternum (see Fig. 8–12). Bilateral anterior thoracotomies are performed as previously described; however, rib cartilage is not divided. Interspace 4 is chosen for entrance into the thorax for most cases. Internal mammary pedicles are divided, and suture is ligated. The sternum conjoining the two interspaces is divided with the Gigli saw after the retrosternal space has been dissected bluntly. Bone wax may be applied to the cut ends of the sternum. Rib spreaders are placed bilaterally to open the incision (see Fig. 8–15*B*).

Closure is time consuming. Attention to proper surgical technique is warranted, especially for lung transplant recipients. Over 10% of patients will develop wound complications (Kaiser et al, 1991). In addition to a sturdy thoracotomy closure, the sternum is reapproximated with two interrupted #6 stainless steel wires. Suction drains should be used if large subcutaneous dissections were necessary. Epidural analgesia usually permits early postoperative extubation.

LATERAL CHEST INCISIONS

It is difficult to define the lateral aspect of the chest, yet much is written about anterolateral, posterolateral, and lateral thoracotomies. For the purposes of this discussion, the boundaries of the *lateral* chest stretch from the nipple anteriorly to the scapular tip posteriorly. Incisions contained within these arbitrary boundaries are classified as lateral chest incisions. Because there is a relative paucity of large muscles that span this area (pectoralis major lies anterior and latissimus dorsi lies posterior), most exposures in this location can be done using a muscle-sparing technique. The serratus anterior, the only muscle in the space, runs in a similar direction as the rib interspaces and can be split without difficulty for low thoracotomy approaches. The two most common lateral chest incisions are the "axillary thoracotomy" and the lateral "muscle-sparing" thoracotomy.

AXILLARY THORACOTOMY

Because of the limited exposure of axillary thoracotomy and the widespread use of video-assisted thoracic surgery (VATS), no longer can sympathectomy (Atkins, 1954), apical bullous disease (Becker and Munro, 1976), or cosmetic concerns (Baeza and Foster, 1976) be considered indications for the approach. The incision has now largely been relegated to a utility incision applicable if problems are encountered in VATS procedures. The transaxillary approach to first rib resection (Roos, 1971) shares the same incision, although the dissection is carried much more superiorly. The axillary thoracotomy provides an approach through the axilla. As the serratus anterior is not part of the axilla, incisions requiring division of this muscle are considered in the lateral thoracotomy section.

Following the induction of general anesthesia (preferably with a double lumen tube), the patient is placed in

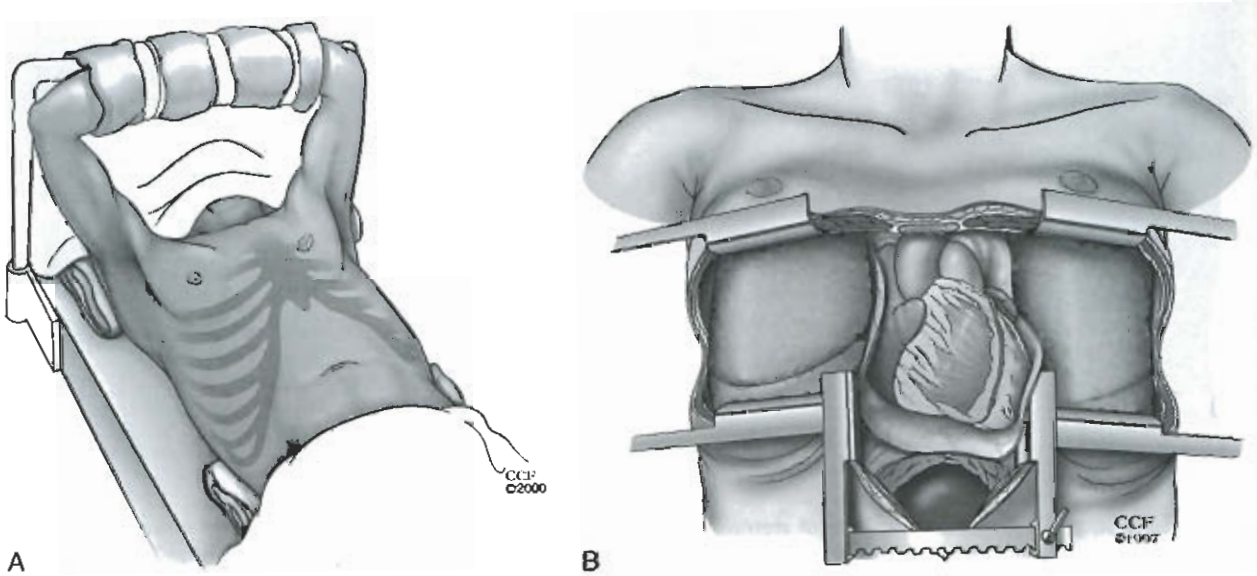

FIGURE 8–15 ■ *A*, Patient position for thoracosternotomy (clamshell) incision. *B*, Excellent exposure is obtained of anterior and middle mediastinal structures. (© Cleveland Clinic Foundation, 2001.)

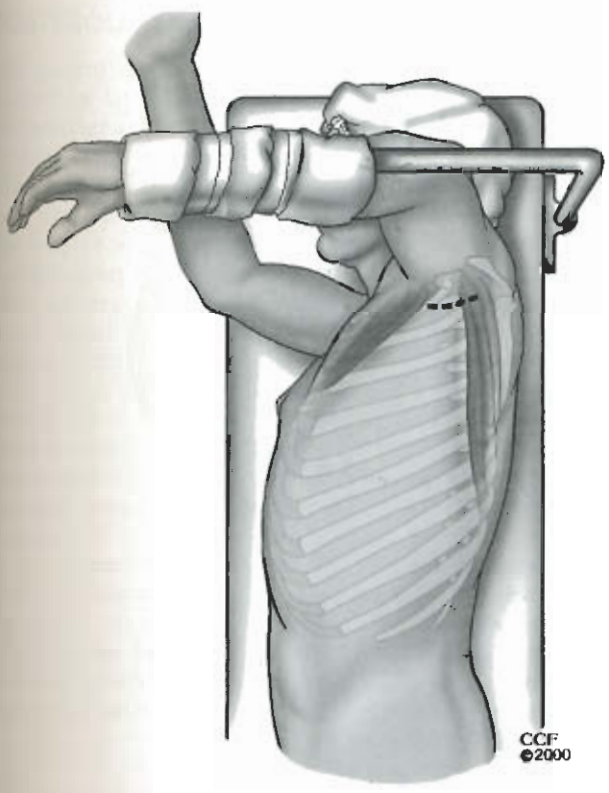

FIGURE 8–16 ■ Patient position and location of the axillary thoracotomy incision. This approach serves as a useful adjunct to video-associated thoracic surgery procedures. (© Cleveland Clinic Foundation, 2001.)

the lateral position on the operating table with the ipsilateral arm flexed and abducted to 90 degrees (Fig. 8–16). A contralateral subaxillary roll is also placed. The entire hemithorax should be included in the sterile field. If the indication is first rib resection, the ipsilateral arm should be included in the sterile preparation. A curvilinear incision is made at the base of the hairline from pectoralis major to latissimus dorsi. After subcutaneous fascia is divided, the axillary fat pad is bluntly dissected superiorly. With the pectoralis major retracted anteriorly and the latissimus dorsi posteriorly, the second intercostal interspace is identified by locating the intercostal brachial nerve. The third interspace is entered anteriorly to the long thoracic nerve by dividing intercostal muscle or resecting the third rib. The long thoracic nerve should be gently mobilized to allow the ribs to be distracted and prevent nerve injury (Massimiano et al, 1988). Intercostal muscles can be divided under both the pectoralis major and the latissimus dorsi muscles to extend the intercostal incision. Superior slips of the serratus anterior muscle may be encountered if the interspace is opened beneath the pectoralis major muscle. These slips can be divided with cautery. Exposure of the first rib through this approach is presented in detail in Chapter 58.

Closure entails rib reapproximation with heavy absorbable suture and repositioning of the axillary fat pad. The superficial fascia should be closed over a suction drain in obese individuals. The skin is closed in the standard fashion.

LATERAL (MUSCLE-SPARING) THORACOTOMY

Muscle-sparing entry of the chest was initially greeted with enthusiasm. There were improvements in postoperative forced expiratory volume in 1 second (FEV_1) and forced vital capacity (FVC) (Lemmer et al, 1990), better shoulder function (Landreneau et al, 1996), and decreased pain (Hazelrigg et al, 1991) compared with the standard muscle-dividing, posterolateral thoracotomy. In addition, involuntary muscular spasm was reported as a late complication of latissimus dorsi division during posterolateral thoracotomy (Kuwabara et al, 1995). These reports have led some to recommend muscle-sparing lateral thoracotomy be used for routine anatomic pulmonary resection (Ginsberg, 1993; Kittle, 1988; Mitchell, 1990). Unfortunately, no controlled studies have documented faster recovery, or better long-term function, when comparing muscle-sparing and muscle-dividing techniques. In fact, Landreneau and colleagues (1996) concluded that the only advantage of muscle-sparing thoracotomy is the preservation of chest wall musculature in the event that rotational muscle flaps would be needed (e.g., bronchopleural fistula closure).

Several variations of the lateral thoracotomy exist. Cosmetically, they differ only in the location of the skin incision (Fig. 8–17). Technically, all involve posterior mobilization of the latissimus dorsi and preservation of the muscle. Serratus anterior is split in the direction of its fibers for more cephalad and anterior chest entry or mobilized anteriorly for lower and more posterior approaches. Functionally, there are slight differences in mediastinal exposure afforded by the various lateral approaches. Some argue that the more anterior approaches should be avoided if extensive chest wall, posterior hilar, or posterior mediastinal involvement exists (Heitmiller and Mathisen, 1989).

The "French" incision (Heitmiller and Mathisen, 1989) is a cosmetic, muscle-sparing anterolateral thoracotomy. The patient is positioned laterally on the operating table and rotated posteriorly 30 to 45 degrees. A deflatable bean bag or cloth rolls are used to fix the patient's position. The axilla is opened as the arm is flexed and abducted 90 degrees. The sterile drape should extend posteriorly to the spine to allow prompt extension of the thoracotomy if needed. The incision is made from the submammary crease (below the nipple) toward a point 1 to 2 cm below the scapular tip. Alternatively, the incision can be carried up toward the axilla in a "lazy-S" manner (Claeys et al, 1995); however, this incision is difficult to extend. The latissimus dorsi is carefully dissected off the serratus anterior and mobilized posteriorly. The long thoracic neurovascular bundle is exposed on the serratus muscle as the latissimus dorsi is dissected. The serratus anterior is divided along its fibers over the chosen interspace (4th or 5th) well anterior to the nerve. The interspace is entered in the standard fashion, and intercostal muscles beyond the operative field are divided to allow maximal spreading of ribs. The interspace can be opened posteriorly down to the costotransverse process articulation, which helps to prevent inadvertent rib fracture when the ribs are separated. A second retractor,

placed perpendicular to the rib spreader, is used to distract the latissimus dorsi posteriorly. For closure, ribs are coapted with interrupted heavy (#2) absorbable sutures placed 2 to 3 cm apart. The serratus muscle is repaired with absorbable monofilament or braided suture. The latissimus is restored in its anatomical position with running sutures; the subcutaneous tissue and skin are closed with absorbable running sutures.

If posterior mediastinal exposure is desired, the French incision may be inadequate. A more posterior incision, however, centers the latissimus dorsi in the operative field (see Fig. 8–17). Consequently, more lateral muscle-sparing approaches require that the latissimus be mobilized more completely. As expected, postoperative seroma complicates these approaches.

For the lateral thoracotomy, the patient is placed in a lateral position and the ipsilateral arm positioned in front of the patient (see Fig. 8–17). The patient may be slightly elevated off the operating table, which widens the ipsilateral interspaces. The dependent leg is slightly flexed at the hip and knee; a pillow is placed between legs. A skin incision is extended from the anterior axillary (or midaxillary) line to below the scapular tip. Soft tissue flaps are raised with cautery, and the latissimus muscle is fully mobilized. Like the "French" incision, serratus anterior is usually divided in the direction of its fibers, although the muscle is elevated anteriorly without division to provide exposure through a lower interspace such as the 6th. A closed-suction drain should be tunneled subcutaneously at the conclusion of the procedure.

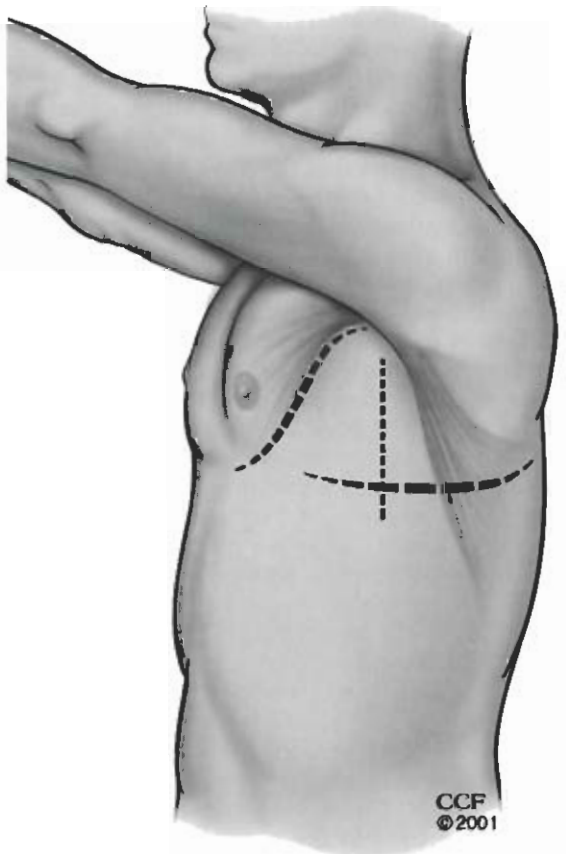

FIGURE 8–17 ■ Common locations of incisions used for lateral thoracotomy. Most of each incision is anterior to the latissimus dorsi allowing for easy posterior mobilization of the muscle. As incisions are placed more posteriorly, muscle-sparing approaches require greater mobilization of the latissimus muscle. (© Cleveland Clinic Foundation, 2001.)

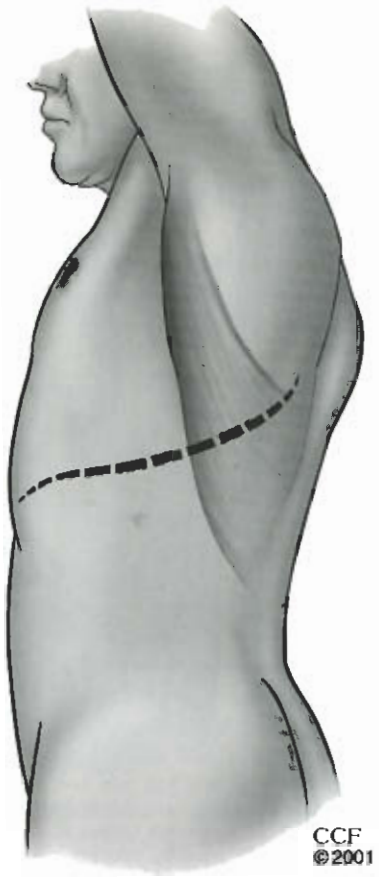

FIGURE 8–18 ■ Standard location of the posterolateral thoracotomy. The incision can be extended posteriorly (and superiorly) to the base of the neck and anteriorly (and inferiorly) to the costal margin. (© Cleveland Clinic Foundation, 2001.)

POSTERIOR INCISIONS

Although some consider the *classic* posterolateral thoracotomy (Sweet, 1950) a relic of the past, the utility of this incision cannot be underscored. One might argue that this incision has experienced a renaissance as larger, more complicated pulmonary and esophageal resections have become more common. Current indications include extrapleural pneumonectomy, superior sulcus tumors, tracheal surgery, and resection of advanced malignancy following induction therapy. Often, the serratus anterior can be spared during the thoracotomy, limiting postoperative disability. We routinely employ this approach for single lung transplantation. The posterolateral thoracotomy can also be performed in a muscle-sparing manner (Ashour, 1990). Because the latissimus dorsi is mobilized anteriorly, unlike lateral approaches, the muscle is not stretched against the maximum convexity of the chest. This may result in less muscle stress and quicker recovery (Ashour, 1990).

POSTEROLATERAL THORACOTOMY

The patient is placed in the same position as that described for lateral thoracotomy. The incision is started at the anterior axillary line and continued posteriorly for 2 to 3 cm below the scapular tip. The incision then follows the contour of the posterior border of the scapula superiorly along a line midway between the medial aspect of the scapula and the spine (Fig. 8–18). The dissection is carried down to the latissimus muscle, which is divided with cautery. Vascular pedicles within the muscle are easily identified by associated fatty tissue. The serratus muscle is similarly divided. Division of the serratus slips close to rib insertions ensures that the majority of the muscle will remain innervated. If additional scapular mobility is necessary (e.g., superior sulcus tumor), trapezius and rhomboid muscles can be divided. Ribs are then counted posteriorly, and the appropriate interspace is entered (4th or 5th).

For extended resections, it is occasionally necessary to resect or "shingle" a rib to enhance exposure. For these rare cases, the periosteum is scored longitudinally along the posterior aspect of the rib. A periosteal elevator is used to reflect the periosteum off the rib. Once the intercostal neurovascular bundle is separated from a portion of the underside of the rib, a Doyen raspatory can be used to separate the remaining periosteum over the desired length. The rib is then resected with shears, and the periosteum and pleura are opened to permit access into the pleural cavity.

When a rib is resected, the closure becomes more complicated. If resected properly, the periosteum with attached intercostal muscle can be sewn closed. Otherwise, simply reapproximating the ribs above and below the resection leaves a defect in the chest wall through which the lung may herniate. This defect can be particularly troubling if a pneumonectomy has been performed, as a subcutaneous seroma may result from extravasated pleural fluid. To prevent this complication, slips of muscle can be used to close the defect.

MUSCLE-SPARING POSTEROLATERAL THORACOTOMY

To spare the latissimus dorsi from a posterolateral approach requires anterior mobilization of the muscle. This is achieved by disconnecting the latissimus muscle posteriorly from the thoracolumbar fascia (Fig. 8–19*A*). This incision is used for the majority of our pulmonary resec-

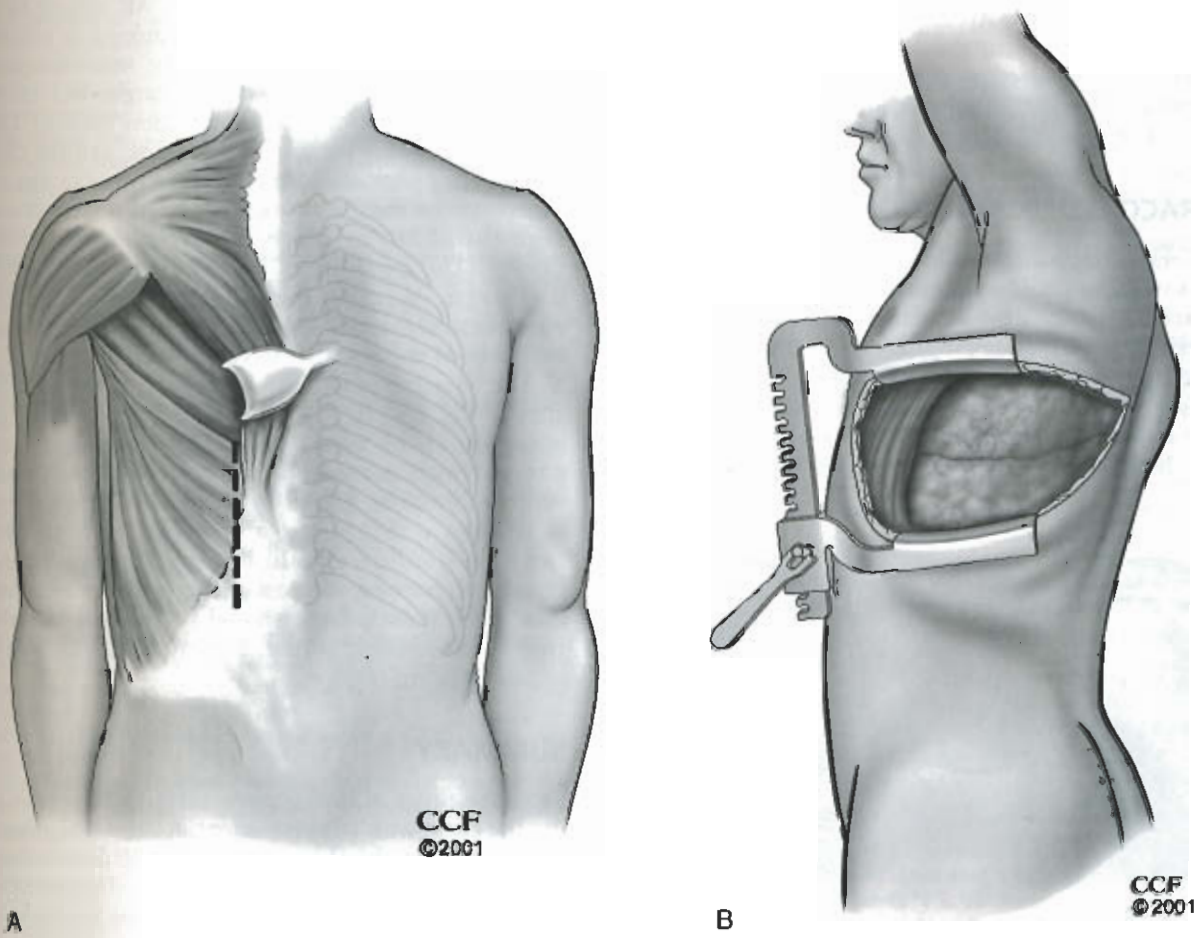

FIGURE 8–19 ■ *A*, For the muscle-sparing posterolateral thoracotomy, the latissimus dorsi is disconnected from the thoracolumbar fascia with cautery *(dashed line)*. *B*, After complete mobilization, both latissimus and serratus muscles can be moved anteriorly and spared. (Adapted from Ashour M: Modified muscle sparing posterolateral thoracotomy. Thorax 45:935, 1990; © Cleveland Clinic Foundation, 2001.)

tions. It offers excellent posterior exposure for complicated hilar dissections and lymphadenectomy. Limited postoperative disability has been encountered with this approach.

After standard posterolateral incision, subcutaneous flaps are raised over the latissimus dorsi superiorly and inferiorly. The plane between the latissimus and trapezius muscles should be developed with cautery. The posterior aspect of the latissimus muscle is then freed from the thoracolumbar fascia with cautery, for 6 to 7 cm. After this maneuver, the latissimus dorsi can easily be reflected anteriorly, exposing the serratus muscle (see Fig. 8–19*B*). After the serratus is moved anteriorly under the latissimus, the interspace is approached and opened.

POSTERIOR THORACOTOMY

Prior to the development of lung isolation, pneumonectomy for suppurative disease was often performed from a posterior approach. This permitted early division of the bronchus and lung collapse. With the bronchus controlled, purulent secretions could not escape from the operated lung and contaminate the contralateral side. Few indications remain for this approach.

The patient is placed in a prone position on a specially designed table that allows anterior access to the chest if necessary (Fig. 8–20). An incision is extended from the anterior axillary line to the base of the neck, midway between the medial edge of the scapula and the spine. Rhomboid, trapezius, latissimus, and serratus muscles are divided. The selected interspace may then be entered.

THORACOABDOMINAL INCISION

The thoracoabdominal incision permits simultaneous dissection in pleural and abdominal cavities. The left-sided approach is particularly attractive to thoracic surgeons. This exposure facilitates esophageal, gastric, splenic, and retroperitoneal surgeries. The closure can be formidable and time consuming. Postoperative recovery has been greatly improved by epidural analgesia.

Left lung isolation is necessary. The patient is placed

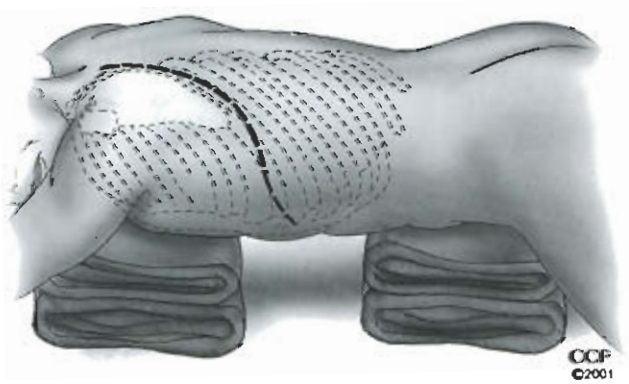

FIGURE 8–20 ■ Location of the posterior thoracotomy incision. With the patient placed prone on the operating table, the posterior thoracotomy incision begins at the base of the neck and is carried inferiorly and anteriorly. The scapula is disconnected from trapezius, rhomboid, and teres muscle groups. (© Cleveland Clinic Foundation, 2001.)

FIGURE 8–21 ■ Incision for thoracoabdominal approach. The patient's hips are rotated back 45 degrees to facilitate the abdominal dissection. (© Cleveland Clinic Foundation, 2001.)

in a lateral position with the hips rotated posteriorly by an additional 45 degrees (Fig. 8–21). The sterile field should include the left arm and neck if a cervical esophagogastric anastomosis is anticipated. In cases of esophageal malignancy, the abdominal portion of the incision is made first to determine operability. An oblique incision from the midline to the left costal margin is utilized. If the exploration is unremarkable, the incision is continued obliquely across the costal margin and extended upward as a posterolateral thoracotomy incision. Latissimus and serratus muscles are divided, and the chest is entered in either the 6th or 7th interspace. The costal margin is cut sharply. We do not routinely resect a short segment of rib cartilage as advocated by Heitmiller (1988). The exposure is completed by division of the diaphragm. Although the diaphragm can be incised circumferentially, a radial incision can be made if anterior branches of the phrenic nerve are carefully avoided.

The closure must not be looked upon casually as simply the end of a long procedure, but as an entire operation on its own. The diaphragm should be reconstructed with nonabsorbable suture, and the paracostal sutures should be spaced by 2 to 3 cm. The costal margin is repaired with a heavy, absorbable, figure-of-eight suture. This suture should be passed through the diaphragm to buttress the costal margin and prevent herniation. Each muscle layer should be carefully closed with running absorbable suture. Superficial tissues are closed in the standard fashion.

SUMMARY

Since the times of Hippocrates, surgeons have been incising the chest with curative intent. As knowledge has been accumulated and techniques refined, the thoracic surgeon is now armed with a vast array of incisions from which to choose. The difficulty lies in choosing the right one.

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