12 Repair of Pectus Excavatum

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Pectus excavatum is a congenital deformity of the anterior chest wall. It consists of two primary elements. The first component is posterior depression of the body of the sternum, generally beginning at the level of the insertion of the second or third costal cartilages. The second component is posterior depression of the attached costal cartilages. This depression generally involves ribs 3 through 7 and sometimes will extend to the level of the second costal cartilage. In older teenagers, the posterior depression of the ribs will involve part of the osseous component as well as the cartilage component. This congenital deformity will be apparent within the first year of life in more than 90% of affected children. It occurs most often in families with a history of chest wall deformity, and has been estimated to have an incidence of 1 in 300 to 1 in 400 births.

The physiologic implications of pectus excavatum have been evaluated for the past four decades. It has been demonstrated that a "restrictive" pulmonary defect occurs in individuals with pectus excavatum. The total lung capacity and the vital capacity are below normative values. The values for an individual often do not fall out of the "normal range," but taken as a group, individuals with pectus excavatum do have decreased pulmonary volume compared with normals. The extent of this impairment varies depending upon the severity of the depression and the depth of the chest. Recent results from a multicenter study of patients with pectus excavatum demonstrated a relatively small decrease in their lung function preoperatively; the improvement after surgical correction was approximately 6–10% [1]. The second physiologic impairment that has been demonstrated is a decrease in the filling capacity of the heart (especially the right ventricle) produced by anterior compression from the depressed sternum. Studies dating back to those of Beiser et al. [2] have shown a decreased stroke volume, particularly in the upright position, associated with significant chest wall deformity. Though subsequent studies have shown variable results when using radioisotope techniques, this impairment is clearly one of the components of decreased cardiopulmonary function in patients with severe pectus excavatum. Workload studies have demonstrated that individuals with pectus excavatum develop symptoms of fatigue earlier than normal in gaited exercise protocols. Studies by Cahill in 1984 [3] and Peterson in 1985 [4] demonstrated the level of exercise tolerance increased after repair of the chest wall deformity.

Several considerations determine the patient's appropriateness for repair. These include the degree of psychologic distress created by the deformity, the extent to which cardiopulmonary symptoms impair physical activity, and the results of pulmonary function and physiologic exercise studies.

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12.1 Techniques for Repair

Techniques for repair of pectus excavatum have evolved significantly since it was first repaired in 1911. Modern approaches date to 1949, when Ravitch [5] first reported a technique that involved excision of all deformed costal cartilages with the perichondrium, and division of the xiphoid and the intercostal bundles from the sternum. A sternal osteotomy was created and the sternum was secured anteriorly with Kirschner wire fixation. This approach was modified in the 1950s by Baronofsky [6] and Welch [7], who stressed the need to preserve the perichondrial sheaths to allow optimal cartilage regeneration for durability of the repair. At about the same time, fixation with metallic struts anterior to the sternum was developed by Rehbein and Wernicke [8]. Retrosternal strut fixation was described by Adkins and Blades in 1961 [9]. Recent innovations for strut fixation have included the use of such materials as bioabsorbable struts, Marlex mesh, or Dacron vascular graft, but no evidence demonstrates that these are better than traditional metallic struts.

In 1998, Donald Nuss et al. [10] first described a method for repair of pectus excavatum utilizing a heavy metal strut to displace anteriorly the sternum and depressed costal cartilages without resection or remodeling of any of the costal cartilages. This technique is also known as the minimally invasive repair of pectus excavatum (MIRPE). The Nuss technique has been shown to be quite durable and results in excellent correction of the posterior depression of the sternum and costal cartilages. In 2002, Croitorou et al. [11] reported the use of this method in a larger and older cohort of 303 patients. The primary complication encountered was late bar displacement, requiring bar repositioning in 8.6% of cases, including 50% of those in whom a stabilizer was not used. Allergic reactions to the metal strut were also recognized, often with rash and erythema overlying the bar or with pleural effusions. This study also identified the importance of placing the bars and stabilizers in a subcutaneous position, not submuscularly, to avoid extra osseous bone formation around the strut. The occurrence of “over-correction” of the deformity was seen infrequently, primarily in children with connective tissue disorders (Marfan’s and Ehler-Danlos syndromes). Kelly et al. [12] recently summarized a large experience with the MIRPE technique in 1215 patients and reviewed the changes made to the procedure. One bar was placed in 69% of their patients, and two bars in 30%. Good or excellent surgical outcome at the time of bar removal was seen in 95.8% of the patients. Complications with bar displacement decreased from 12% in the first decade to 1% in the second. Allergy to nickel was identified in 2.8% of patients, the vast majority prior to surgery. Wound infection occurred in 1.4% (17 patients), four of whom required surgical drainage. During the interval of this study, the median age at surgery went from 6 to 14 years. Modifications of the technique have included the routine use of unilateral or bilateral thoracoscopy; techniques to minimize the risk of dissection between the sternum and heart in patients with severe depressions, including elevation of the sternum manually through an infraxiphoid incision or first placing a more superior, transmediastinal tunnel and leaving the introducer in place to elevate the sternum while dissecting the lower tunnel; the use of titanium bars when a metal allergy is identified; using a bar 1 in. shorter than the measurement from right to left midaxillary line; more frequent use of two bars in patients with severe depressions or in older patients; and use of a metal stabilizer to decrease the risk of rotation of the bar.

12.2 Surgical Technique

This chapter presents both the current open technique with its modifications (which I use) and the innovative Nuss technique (MIRPE).

12.2.1 Open Repair

Figures 12.1, 12.2, 12.3, 12.4, 12.5, 12.6, 12.7 and 12.8 illustrate the operative procedure for the current open technique.

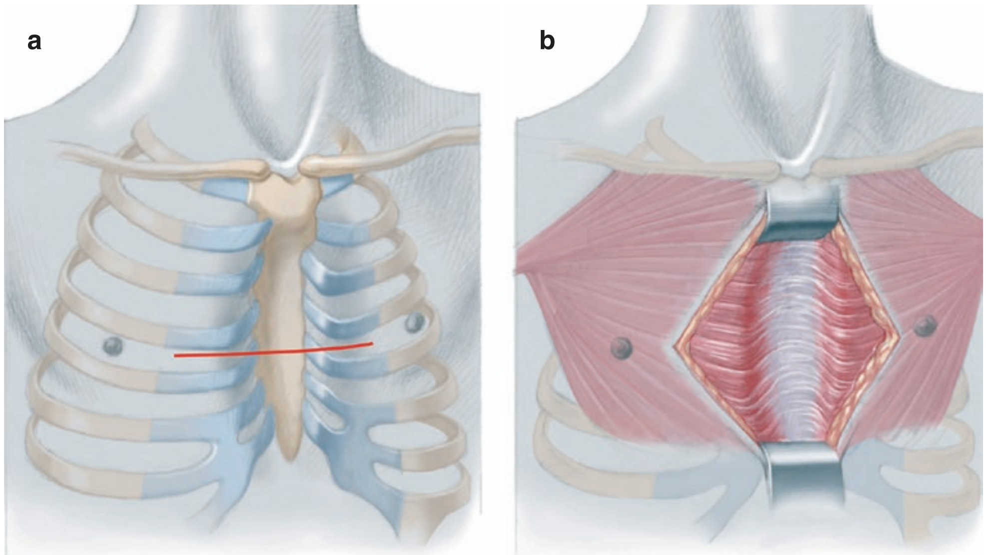

Fig. 12.1 A transverse skin crease incision is placed below and within the nipple lines. In females, it is of particular importance to see that this is placed in the future inframammary crease to avoid unsightly tethering of a scar between the two breasts. The skin flaps are then elevated superiorly to the level of the apex of the deformity and inferiorly to the tip of the xiphoid. The flaps are developed just anterior to the pectoral fascia to keep them well vascularized. The pectoral muscles are then elevated off the sternum, being cautious to keep intact all of the muscle and overlying fascia

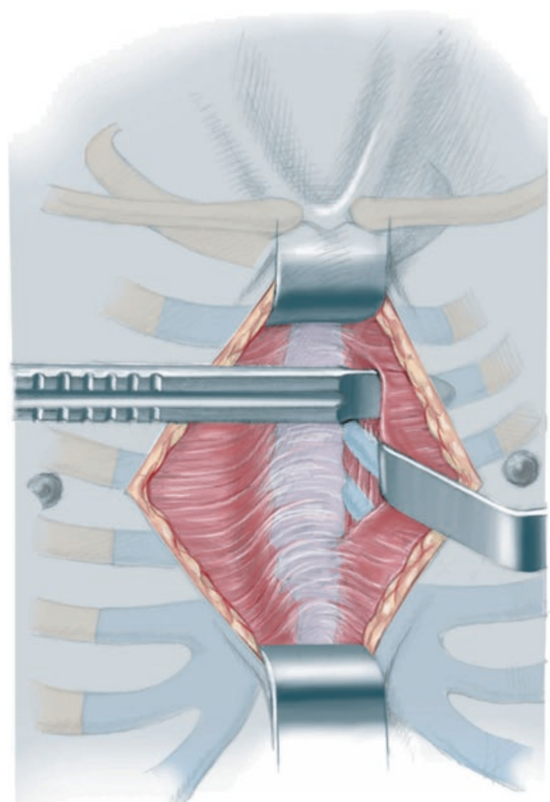

Fig. 12.2 To facilitate identification of the appropriate plane of dissection, the muscle is first elevated just anterior to one of the costal cartilages. When this plane is defined, an empty knife handle is then inserted anterior to the costal cartilage and passed laterally. It is then replaced with a right angle retractor to elevate the muscle anteriorly. This step is then repeated anterior to the next costal cartilage just above or below the first rib defined. Elevation of the muscle flap between the two right angle retractors facilitates identification of the correct plane of dissection. The origin of the salmon-colored pectoral muscles is divided with electrocautery, making certain to stay out of the intercostal bundles, which are covered with a glistening white fascia. Injury of the intercostal bundles can result in significant bleeding. The muscle flaps are mobilized laterally to the costochondral junction or to the lateral extent of the deformity. Generally, cartilages 3 through 7 are involved, but sometimes the second cartilage is also included

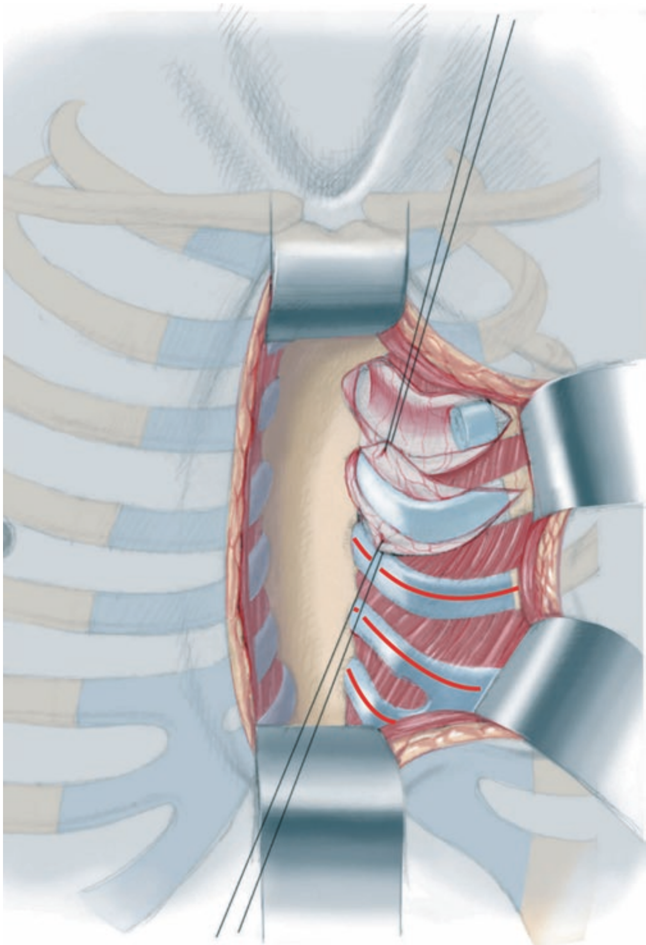

Fig. 12.3 Incisions are then placed through the perichondrial sheaths parallel with the axis of the cartilage. It is helpful to keep the incision on the flat anterior aspect of the rib. The perichondrial sheaths are dissected off the costal cartilage utilizing Welch perichondrial elevators (Codman and Shurtleff; Raynham, MA). Freeing the edge of the perichondrium from the medial aspect of the rib facilitates this process by providing better visualization of the posterior aspect of the cartilage. The cross-sectional shape of the ribs must be remembered. Ribs 2 and 3 are fairly flat, ribs 4 and 5 are round, and ribs 6 and 7 have a narrow width and greater depth

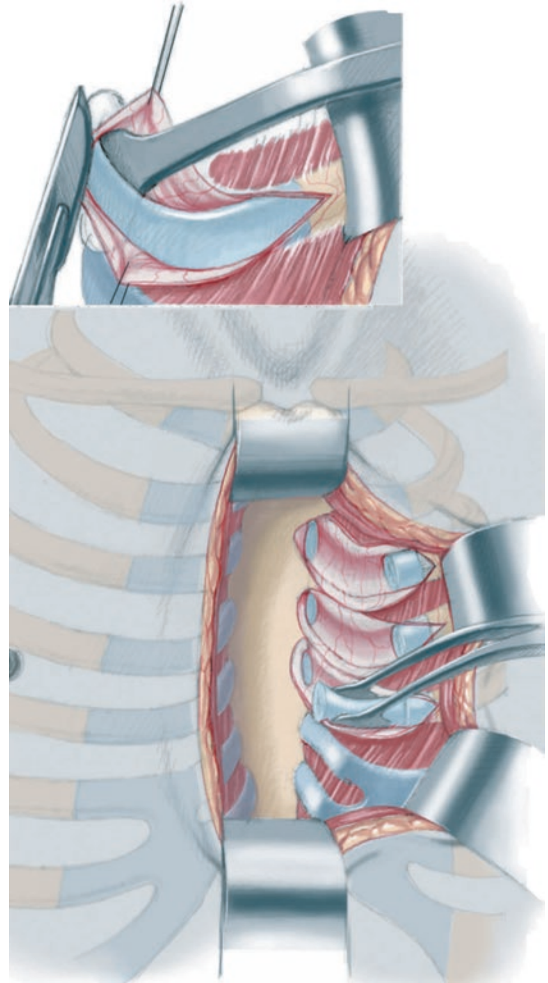

Fig. 12.4 The medial aspect of the cartilage is then incised from the sternum (*Inset*), with the posterior aspect protected by the Welch perichondrial elevator. Incising the cartilage directly adjacent to the sternum will also minimize the risk of injury to the internal mammary vessels, which are generally 1–1.5 cm lateral to the margin of the sternum. To minimize any impairment of subsequent growth of the ribs, 1–1.5 cm of the costal cartilage is preserved with the costochondral junction

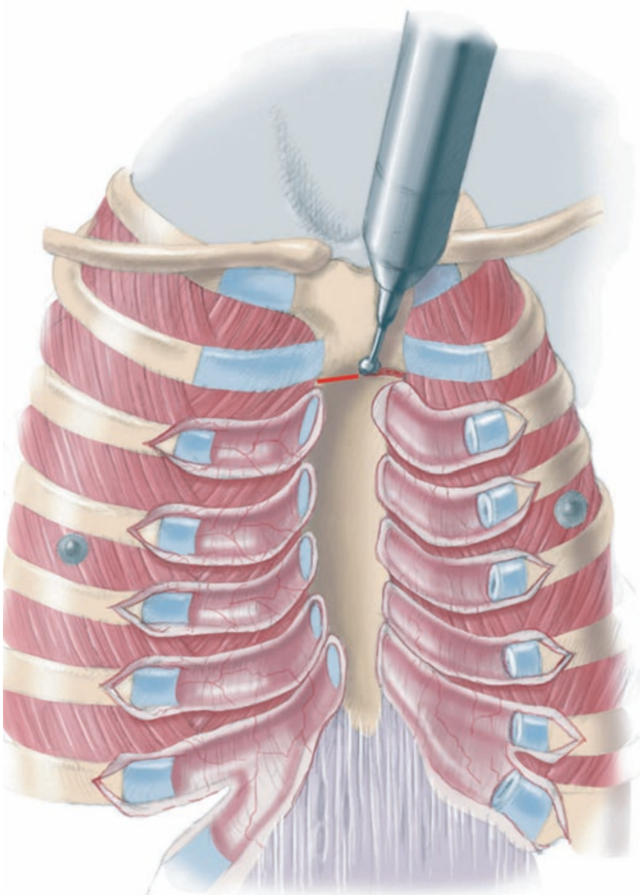

Fig. 12.5 The wedge osteotomy is then created on the anterior surface of the sternum at the apex of the deformity. I use a Hall air drill (Zimmer, Inc.; Warsaw, IN). The segment of bone is then mobilized using one of the wings of the perichondrial elevators, but without entirely dislodging it from the sternum. Leaving it partially in place will facilitate rapid healing of the fracture

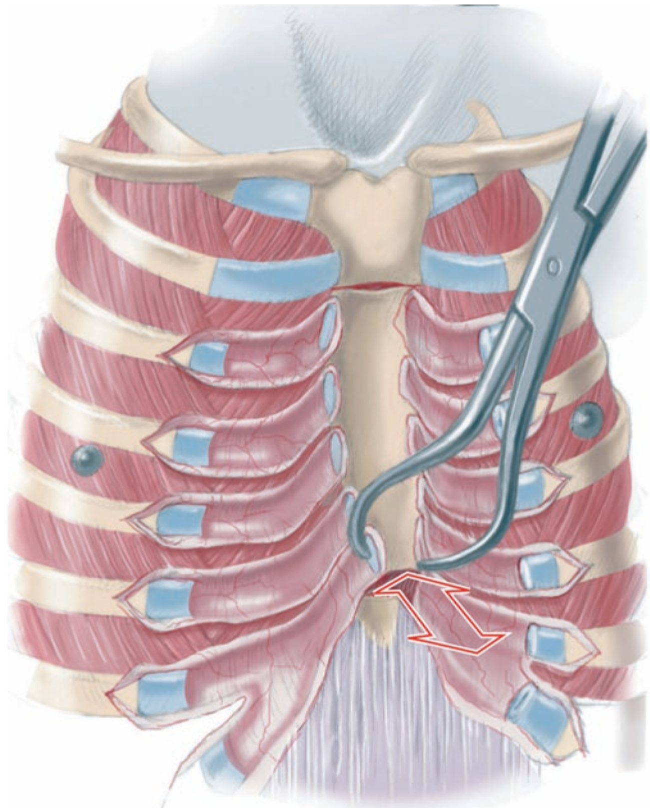

Fig. 12.6 The sternum is then elevated with a towel clip, and posterior pressure is applied to the upper portion of the sternum to fracture the posterior sternal plate. In the past, the xiphoid was divided along with the rectus muscle from the tip of the sternum, but I currently avoid this step to minimize the occurrence of an unsightly depression at the base of the sternum. Using a posterior sternal strut, it is also unnecessary to divide the lower perichondrial sheaths, as was done in the past. (This division of the lower perichondrial sheaths also contributed to the depression below the sternum.) If the xiphoid produces an unsightly protrusion when the sternum is in its corrected position, it can be divided from the sternum using a lateral approach with cautery. This technique avoids taking down the rectus attachment

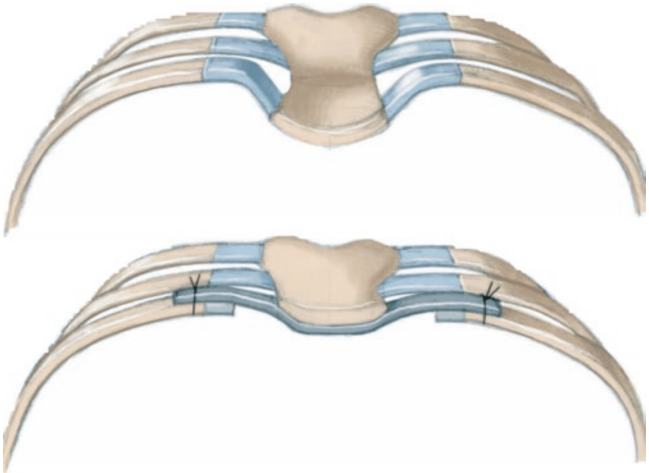

Fig. 12.7 This figure depicts the retrosternal strut, which is tunneled posterior to the sternum. The retrosternal tunnel is made by partially dividing one of the perichondrial sheaths directly adjacent to the sternum. A tunnel is then created posterior to the sternum with a Schnidt clamp, which is brought out directly adjacent to the sternum on the contralateral side to avoid injury to the internal mammary vessels. Before passing the strut behind the sternum, it is preformed so that there is a slight depression in which the sternum will sit, and the strut is curved somewhat posteriorly on each end to allow it to conform to the shape of the ribs and avoid any unsightly protrusions into the skin and the muscle. The Schnidt clamp is then used to draw the strut behind the sternum with the concave portion of the strut anterior. Once it is behind the sternum and in an appropriate position just anterior to the ribs on each side, it is rotated 180 degrees. It is important in this step to make certain that the strut is deep to the pectoral muscle flap to provide adequate soft tissue coverage over the strut. The strut is then secured to the anterior periosteum of the rib laterally with two heavy #0 absorbable sutures, which will secure the strut in position

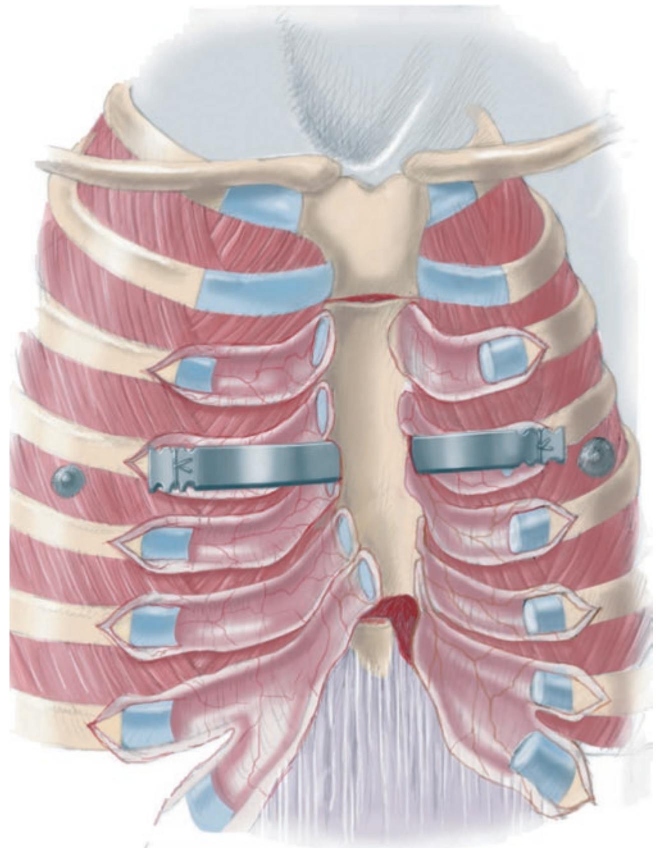

Fig. 12.8 This figure depicts the position of the retrosternal strut from an anterior perspective, with it secured to the ribs on each side. The pectoralis major muscle flaps are then approximated over the sternum. The flaps are advanced inferiorly to compensate for the fairly bare lower portion of the sternum, so that it is covered with soft tissue. At the inferior aspect, the flap is attached to the rectus muscle with interrupted absorbable sutures

12.2.2 The Nuss Minimally Invasive Repair of Pectus Excavatum

The innovative Nuss (MIRPE) technique is shown in Figs. 12.9, 12.10, 12.11, 12.12, 12.13 and 12.14.

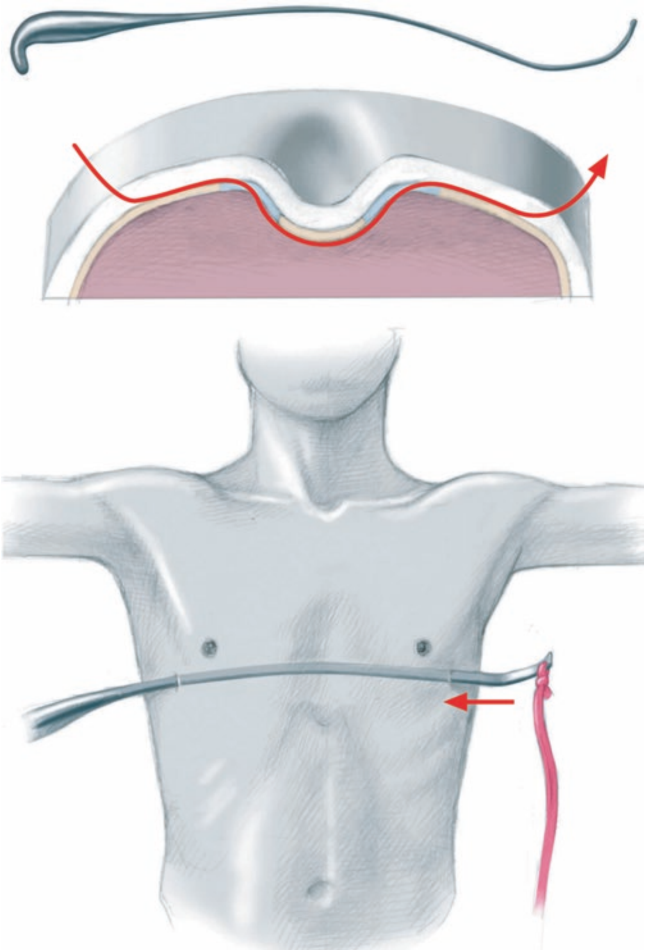

Fig. 12.9 Two incisions are made at the anterior axillary line at the level of maximal sternal depression. A pectus tunneler (Biomet Microfixation; Jacksonville, FL) or long clamp is then passed through one lateral incision along the chest wall and enters into the pleural cavity at the inner aspect of the pectus ridge. It is tunneled behind the sternum and anterior to the pericardium, and is brought out the contralateral side. The point of exit from the thorax is also aimed at the inner aspect of the pectus ridge. Thereafter, it is passed along the outside of the chest wall and out through the skin at the anterior axillary line. An umbilical tape is then grasped by the clamp or pectus tunneler and brought through the tunnel. Two tapes are often used, in case one breaks. Several adaptations have been utilized to minimize the risk of cardiac injury from this maneuver. The first adaptation, now widely used, involves a thoracoscope to monitor the passage of the tunneler behind the sternum. A second adaptation, less frequently used, is to make a small incision at the tip of the sternum, through which a bone hook can be inserted. The sternum is elevated anteriorly to broaden the retrosternal space as the clamp is passed across the chest

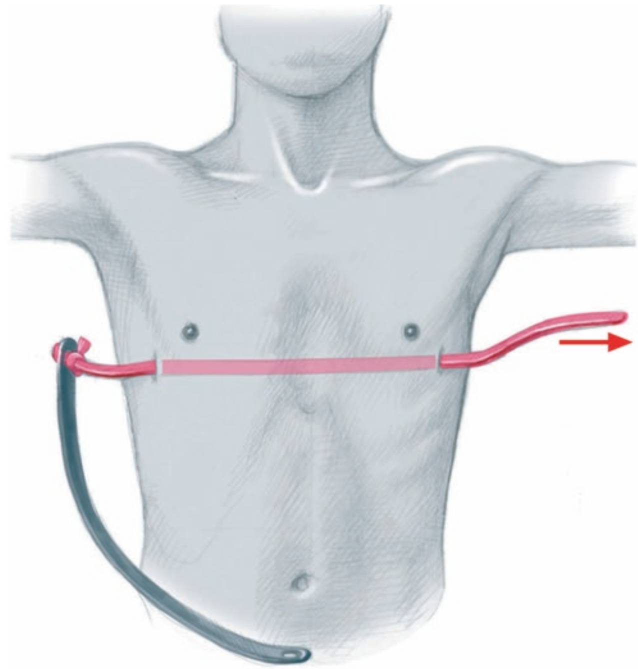

Fig. 12.10 The preformed strut (Biomet Microfixation; Jacksonville, FL), which has been pre-measured and bent to ensure that it fits the breadth of the patient's chest, is then brought through the chest and passed so that the concave surface is anterior

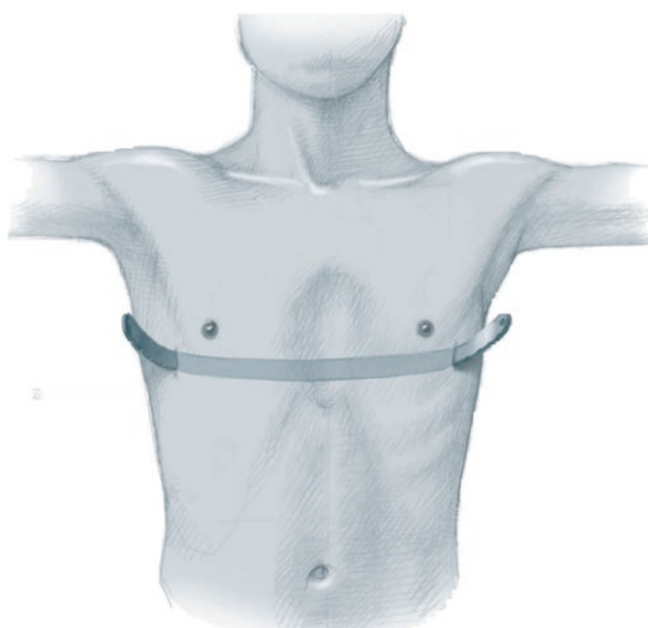

Fig. 12.11 Once the bar is in position, it is rotated 180 degrees with a special "Pectus Flipper" (Biomet Microfixation; Jacksonville, FL) to elevate the sternum and costal cartilages. During this maneuver, the skin and muscle flaps are elevated over the end of the bar so that the bar sits directly along the chest wall

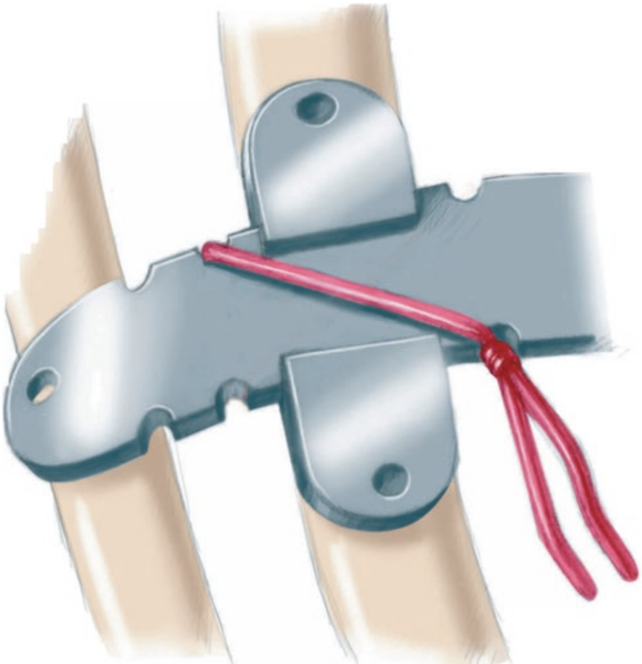

Fig. 12.12 When this procedure was initially performed, the most frequent complication was rotation of the pectus strut. To reduce this risk, a "stabilizer" may be attached to both sides of the strut with heavy #3 wire or suture. Once attached to the strut, it is then sutured to the soft tissues of the chest to provide secure fixation and prevent rotation of the bar and loss of correction of the deformity

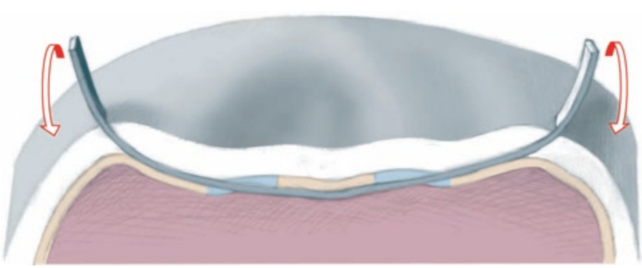

Fig. 12.13 The pectus strut in position prior to rotation

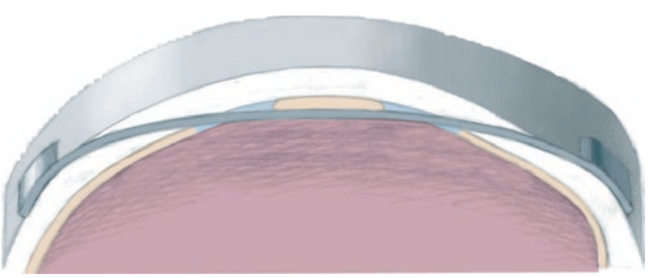

Fig. 12.14 The bar in the final position, displacing the sternum and costal cartilages anteriorly to correct the pectus excavatum deformity. The bar is electively removed in 2 to 3 years

12.3 Results

The overall results of repair of pectus excavatum should be excellent. The perioperative risks must be limited. The most significant complication is a major recurrence, which has been described in large series as occurring in 5–10% of patients. A limited pneumothorax requiring aspiration is infrequent and rarely is a pneumothorax of such magnitude to require a thoracostomy tube. Wound infection should be rare with the use of perioperative antibiotic coverage and protective coverage of the skin during the operative procedure to minimize any contamination by skin flora.

Long-term outcome of the Nuss procedure in teenagers is well documented. The most frequent complication described in early use of the minimally invasive procedure was rotation of the strut. Lateral stabilizers have significantly decreased the incidence of this complication. Other complications described include pneumothorax, pericarditis, and hemothorax. Complications unique to the minimal access procedure that have not occurred with the standard open technique include thoracic outlet syndrome and the rare occurrence of a carinate deformity after repair. An allergic reaction to the metal Lorenz struts has occurred in 1% of patients, who present with rashes along the area of the bar requiring replacement with bars composed of other alloys. Older patients seem to encounter significant pain equivalent to that of the open repair [1].

Conclusions

Both techniques appear to achieve excellent correction of the deformity [13, 14]. Complication rates of each technique were equivalent in a multi-institution study. Repair of pectus excavatum is important for children who are either psychologically distressed or physiologically impaired by their deformity.

Suggested Reading

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