CHAPTER 11

Repair of Pectus Excavatum

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INTRODUCTION

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 3–7 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 as well as the cartilage component. This is a congenital deformity and in greater than 90% of children it will be apparent within the first year of life. It has an increased frequency of occurrence 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 last four decades. It has been demonstrated that a "restrictive" defect occurs in individuals with pectus excavatum. The total lung capacity and the vital capacity are decreased relative to 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 is variable and it depends upon the severity of the depression and the depth of the chest. The second physiologic impairment which has been demonstrated is a decrease in the filling capacity of the heart, in particular the right ventricle. This is produced by anterior compression from the depressed sternum. Studies dating back to those of Beiser have shown a decreased stroke volume, particularly in the upright position, associated with significant chest wall deformity. While 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 in gaited exercise protocols than do normal probands. Two studies by Cahill in 1984 and Peterson in 1985 have also demonstrated that following repair of the chest wall deformity, the level of the exercise tolerance has increased.

Determination of the subject's appropriateness for repair is dependent upon multiple considerations. These include the degree of psychologic distress created by the deformity, the extent of impairment of physical activity by cardiopulmonary symptoms, and results of the pulmonary function and physiologic exercise studies.

Techniques for repair of pectus excavatum have evolved significantly since it was first repaired in 1911. Modern approaches date to 1949 when Ravitch 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 by Baronofsky (1957) and Welch (1958) when they stressed the need for preservation of the perichondrial sheaths to allow optimal cartilage regeneration for durability of the repair. Fixation with metallic struts anterior to the sternum was the next modification developed by Rehbein and Wernicke in 1957. Retrosternal strut fixation was described by Adkins and Blades in 1971. While recent innovations for strut fixation have included the use of such materials as bioabsorbable struts, Marlex mesh or Dacron vascular graft, no evidence demonstrates that these are better than traditional metallic struts.

In 1998 Donald Nuss first described a method for repair of pectus excavatum utilizing a heavy metal strut to displace anteriorly the sternum and depressed costal cartilages. It did not require resection or remodelling of any of the costal cartilages. In this chapter, I will present both the current open technique with its modifications that I utilize, as well as the innovative Nuss technique, which is also known as the minimally invasive repair of pectus excavatum (MIRPE). The latter technique is still awaiting outcome analysis. The first report by Nuss of 42 patients utilized a fairly young cohort in which the median age was 5 years. A subsequent report by Croitoru in 2002 utilizing this method included a larger and older cohort of 303 patients. In that group only 23.4% of the patients had the bars removed.

Figure 11.1a,b

A transverse skin crease incision is placed below and within the nipple lines (**a**). 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 (**b**). 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 preserve all of the muscle and overlying fascia intact.

Figure 11.2

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 in between the two right angle retractors facilitates identification of the correct plane of dissection. The origin of the salmon-coloured pectoral muscles are 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 3–7 are involved, but sometimes the second cartilage is as well.

Figure 11.3

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 perichondrial elevators. Freeing the edge of the perichondrium from the medial aspect of the rib provides better visualization of the posterior aspect of the cartilage facilitating this process. 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.

Figure 11.1a,b

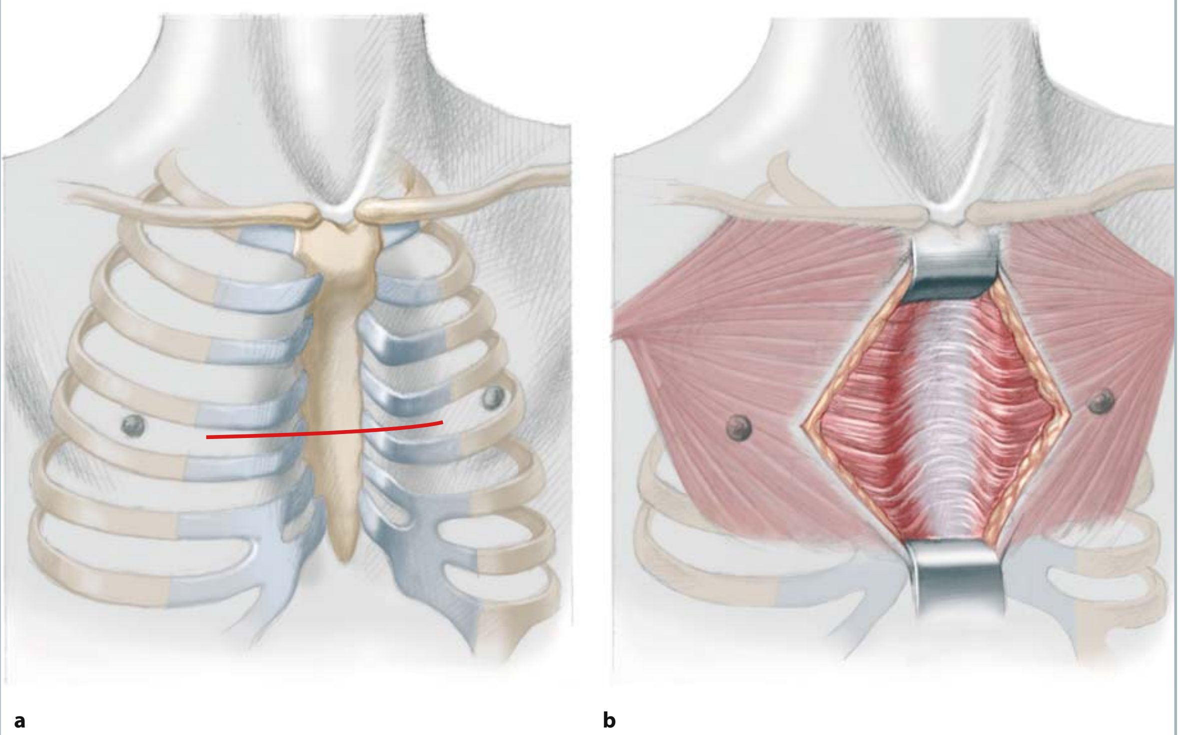


Figure 11.2

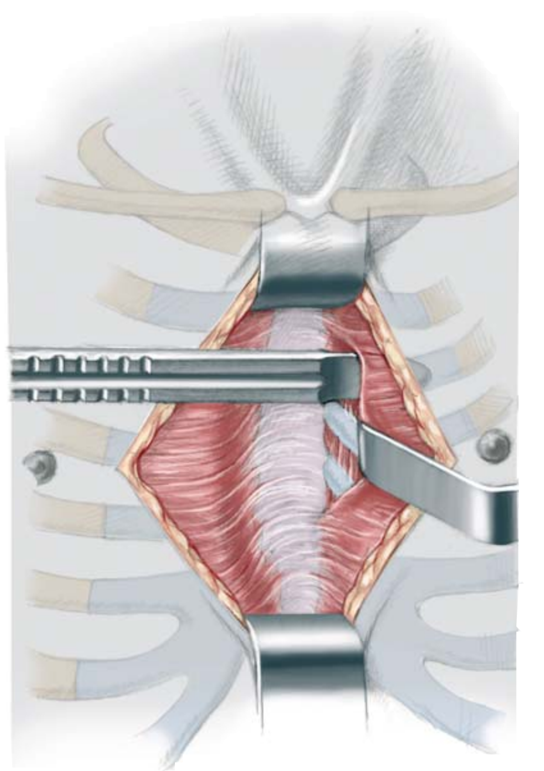


Figure 11.3

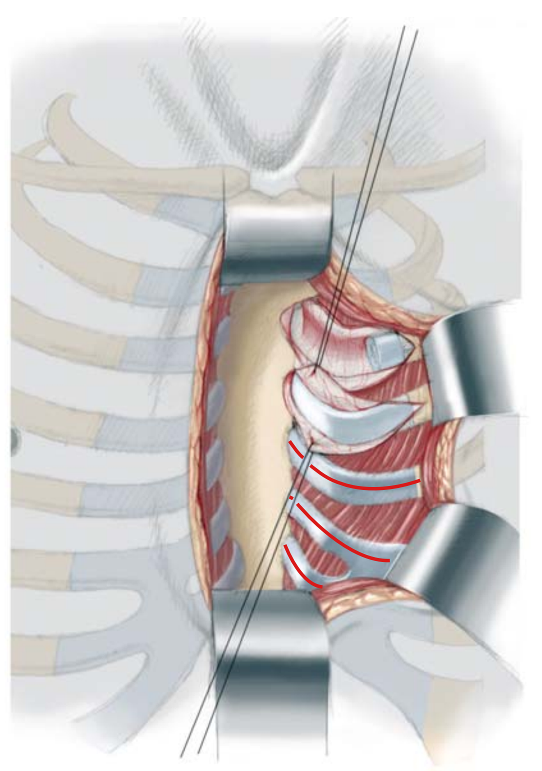


Figure 11.4

The medial aspect of the cartilage is then incised from the sternum (see *insert*) with the posterior aspect protected by the 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 to 1.5 cm lateral to the margin of the sternum. To minimize any impairment of subsequent growth of the ribs, 1 to 1.5 cm of the costal cartilage is preserved with the costochondral junction.

Figure 11.5

The wedge osteotomy is then created on the anterior surface of the sternum at the apex of the deformity. 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 more rapid healing of the fracture.

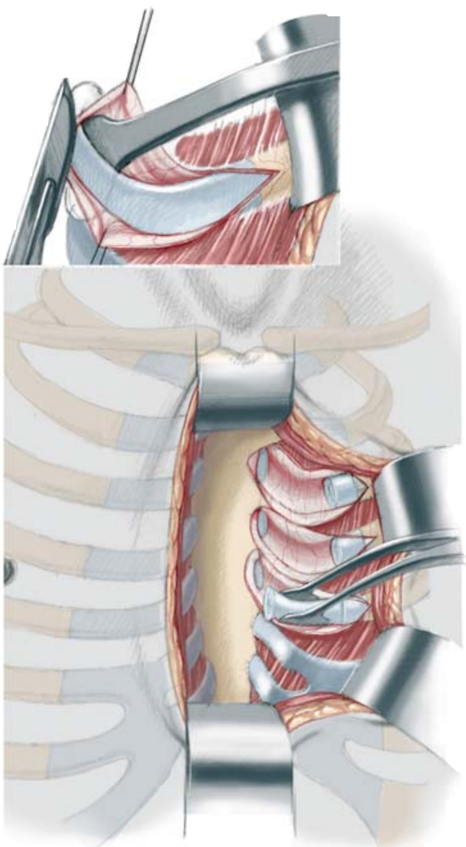
Figure 11.6

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. While in the past the xiphoid was divided along with the rectus muscle from the tip of the sternum, I currently avoid this step. This minimizes 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 avoids taking down the rectus attachment.

Figure 11.7

A retrosternal strut is tunnelled posterior to the sternum. This 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 to avoid injury to the internal mammary vessels on the contralateral side. Prior to passing the strut behind the sternum, it is preformed so that there is a slight indentation 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°. 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 periosteum laterally with two heavy no. 0 absorbable sutures. This will secure the strut in position.

Figure 11.4



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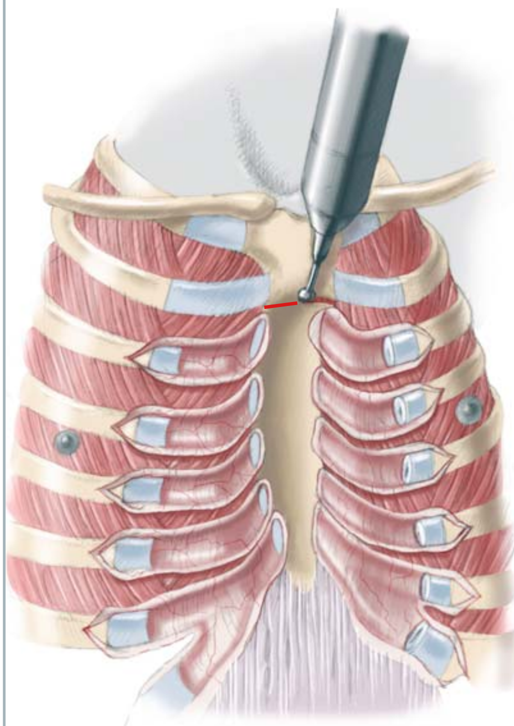

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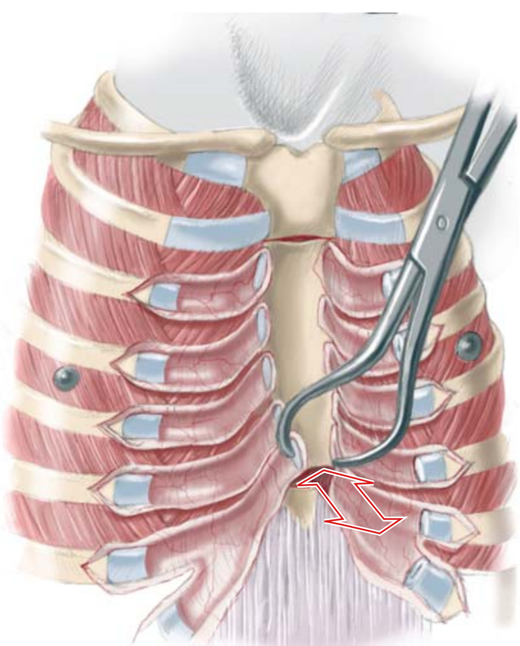

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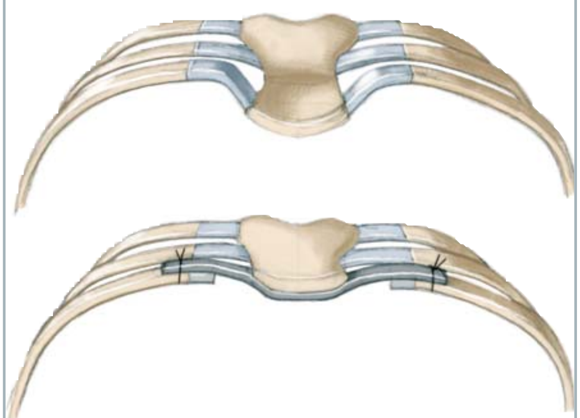


Figure 11.8

This 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. This allows it to be covered with soft tissue. At the inferior aspect the flap is attached to the rectus muscle with interrupted absorbable sutures.

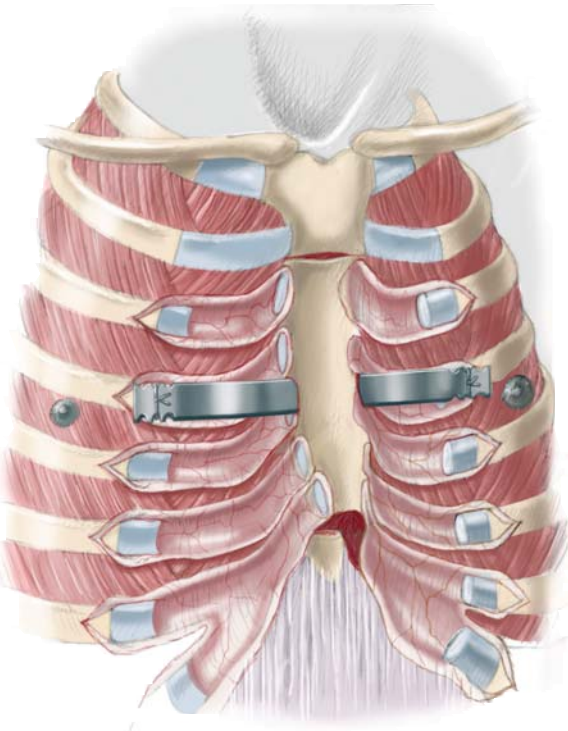
Figure 11.9

For the Nuss procedure two incisions are made at the mid-axillary line at the level of maximal sternal depression. A Lorenz tunneller 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 tunnelled behind the sternum and anterior to the pericardium and it 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 Lorenz tunneller 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 manoeuvre. The first adaptation now widely utilized involves a thoracoscope to monitor the passage of the tunneller 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 as the clamp is passed across the chest to broaden the retrosternal space.

Figure 11.10

The preformed strut which has been pre-measured and bent to make certain 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.

Figure 11.8



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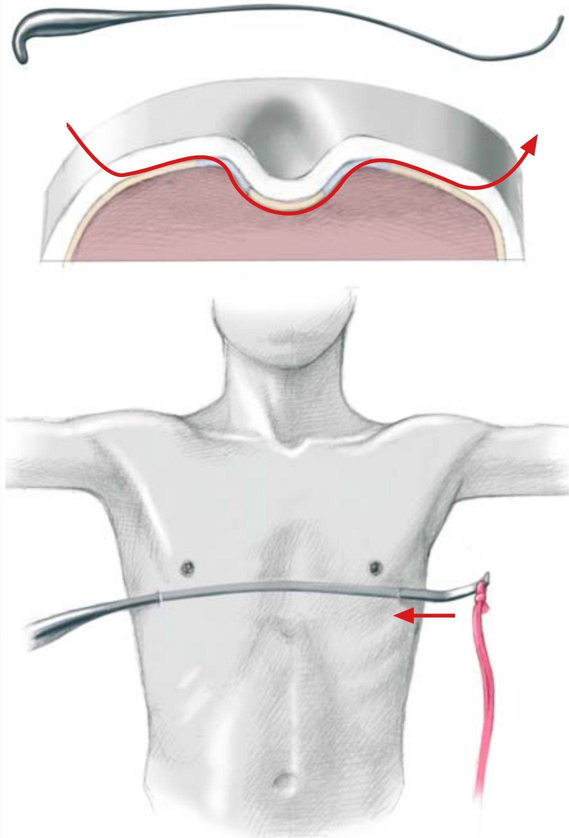


Figure 11.10

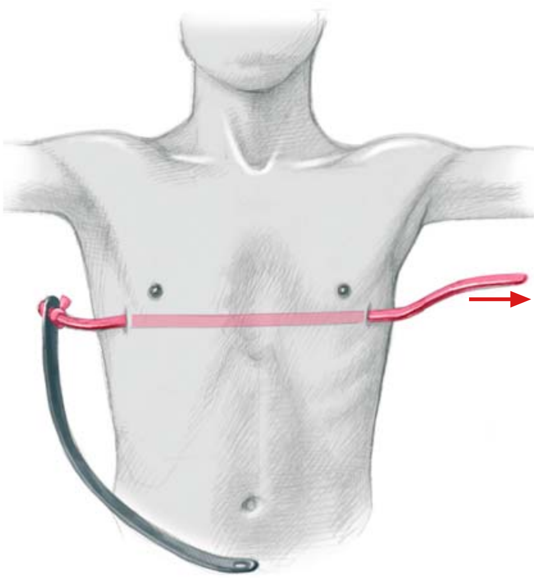


Figure 11.11

Once the bar is in position, it is rotated 180° with a special "Lorenz flipper" to elevate the sternum and costal cartilages. During this manoeuvre the skin and muscle flaps are elevated over the end of the bar so that the bar sits directly along the chest wall.

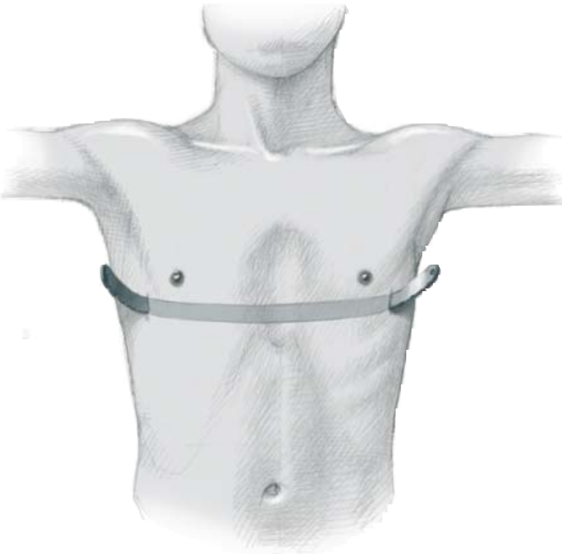
Figure 11.12

The most frequent complication of this procedure when it was initially performed was rotation of the Lorenz strut. To reduce this risk, a "stabilizer" may be attached to both sides of the strut with heavy no. 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.

Figure 11.13, 11.14

This diagram shows the Lorenz strut in position prior and after rotation. The bar in the final position is displacing the sternum anteriorly along with the costal cartilages to correct the pectus excavatum deformity. The bar is electively removed in 2 to 3 years.

Figure 11.11



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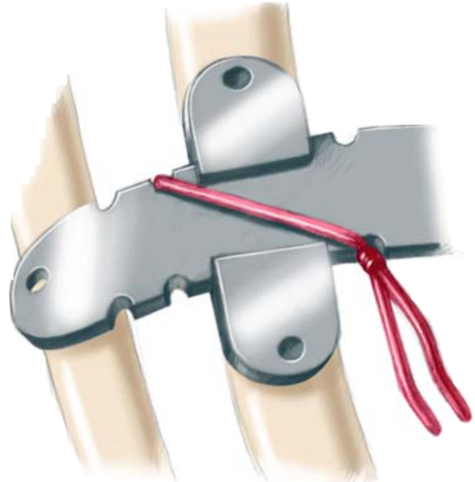

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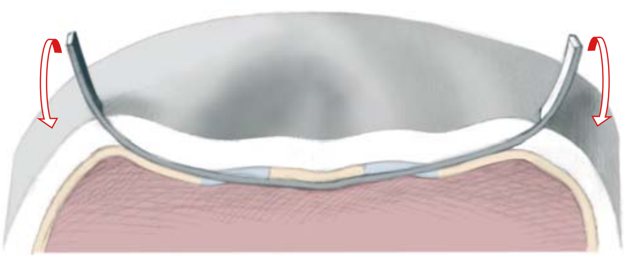

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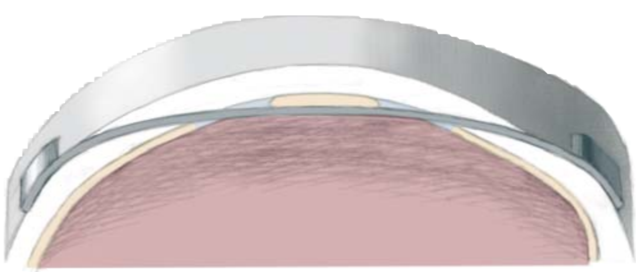

CONCLUSION

The overall results of repair of pectus excavatum should be excellent. The peri-operative risks must be limited. The most significant complication is a major recurrence, which has been described in large series as occurring in 5 to 10% of patients. A limited pneumothorax requiring aspiration is infrequent and rarely requires a thoracostomy tube. Wound infection should be rare with the use of peri-operative 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 not well documented at this time as it has been used for less than a decade in older patients. 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 which have not occurred with the standard open technique include thoracic outlet syndrome and the rare occurrence of a carinate deformity after repair. Occurrence of an allergic reaction to the metal Lorenz struts has also 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 with the minimally invasive procedure, but quantitative comparisons to the standard open operation have not yet been reported.

Both techniques appear to achieve excellent correction of the deformity. Comparison of complication rates of each technique has not yet been accomplished, but hopefully a multi-institutional prospective study of these surgical techniques will define their relative benefits and risks. Repair of pectus excavatum is important for children who are either psychologically distressed or physiologically impaired by their deformity.

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