Nuss Procedure for Pectus Excavatum

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Ronald F. Lützenberg

Introduction

Pectus excavatum is among the most common congenital deformities of the anterior chest wall and generally one of the most widely seen congenital anomalies. Its etiology is unknown. Since the introduction of the Nuss procedure, this minimally invasive surgical method has gained acceptance among doctors and surgeons worldwide as one the methods, if not the preferred method, to treat pectus excavatum. Many reports have confirmed that patients with pectus excavatum experience considerable physical and mental problems, most of which disappear after surgical repair, thus leading to a high degree of patient relief and satisfaction.

Deformities may be seen in many different configurations of the anterior chest wall. The primary aim of surgical repair is the improvement of anatomic abnormalities, including reduced thoracic volume as well as any type of anterior chest wall deformity.

Several classifications of pectus excavatum categorize and distinguish between localized and more wide-ranging anterior chest wall depressions, particularly those with an asymmetric and rotated sternum and further affected by a deformation of the costal arches. The latter's degree of deformity has a major impact on the feasibility and likely success of surgical repair.

The objective of surgical repair is not only to normalize anatomic abnormalities and pulmonary functions, but also to assist cardiac decompression to relieve the patient's physiologic constraints and improve strength and endurance. When successful, the procedure allows patients a normal life without chest wall deformity. However, patients also expose themselves to numerous potential minor and major complications. A precise understanding of these is important to adequately deal with them.

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The search for superior and more suitable surgical corrective procedures has been ongoing for more than a century. During this period, a variety of procedures have been developed, modified, aborted, and partially resurrected.

The well-established procedure by Ravitch has been modified several times. This evolutionary process reflects the profession's search for perfection in the procedures chosen as each one's respective shortcomings become apparent. However, to date there is still no consensus among the relevant medical authorities regarding which constitutes the most efficacious surgical procedure. Repair of the anterior chest wall entails more than restoration of the funnel. Conventional methods frequently result in a flat-shaped chest.

The Nuss method makes use of the flexibility of the costal cartilages and derotation of the sternum and obviates the need for cartilage resection and osteotomies. The procedure is considered simple but requires great surgical skill and has been associated with various pitfalls. Also, the categorization of the procedure as "minimally invasive" appears debatable, given the extensive use of surgical aids and devices that remain inside the patient post procedure, contributing to frequent reports of a painful and difficult recovery.

Criteria for surgical referral include the following:

- Haller severity index greater than 3.2, taking into account the patient's original chest shape, gender, and particular circumstances of the CT images in the inspiratory/expiratory position
- Pulmonary function testing
- Cardiac compression
- Progression of the deformity
- Symptoms during exercise
- Psychosocial impact

Treatment for pectus excavatum may occur from childhood to adulthood, preferably before the patient has reached 45 years of age. The best age at which to carry it out is 14 years. In doing so, it is important to account for differences between male and female patients in the degree of repair that that is possible. To aid in planning, CT scans of the entire chest section are necessary.

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Figure 45.1

Positioning. The patient is placed in the supine position with both arms abducted at a 10° angle to minimize tension in the cervicothoracic crossing and brachial plexus. The contours of the pectoral muscle are clearly visible and allow free movement of the camera and introducer. The draping extends from the patient's neck to below the navel line to expose the entire chest contour. To avoid an unnatural body shape, no back support is provided

Figure 45.2

Funnel chest analysis and implant position. The exact incision points through which to insert the pectus bar (Biomet Inc., Jacksonville, FL) into the chest are marked. Assessment of the strength and elasticity of the chest is recommended. The lower outer pectus point and inferior edge of the sternum are identified. With the sternal angle used as a reference, the second intercostal space (ICS) is identified as the highest possible pectus bar entry point. Excessive elevation of the upper chest segment may result in thoracic outlet syndrome. In female patients, it is essential to monitor for continued elevation post surgery, which may be caused by the strength of the pectus bar. Over- or undercorrection resulting from the method, as well as its optimal result, lies within a close range. Crucial factors are the implant length, the measurement from midaxillary line to midaxillary line using the template as a model minus 1 in., and shaping, that is, bending and molding of the pectus bar

Figure 45.1

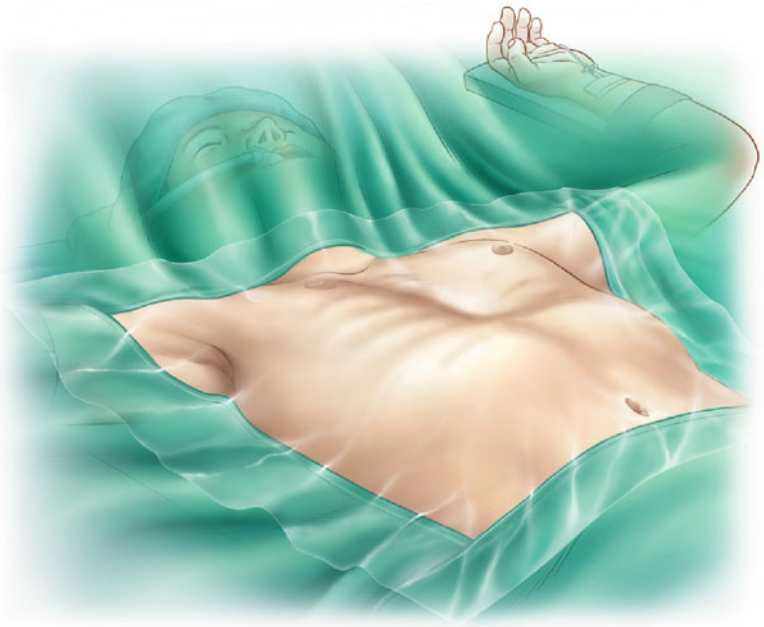
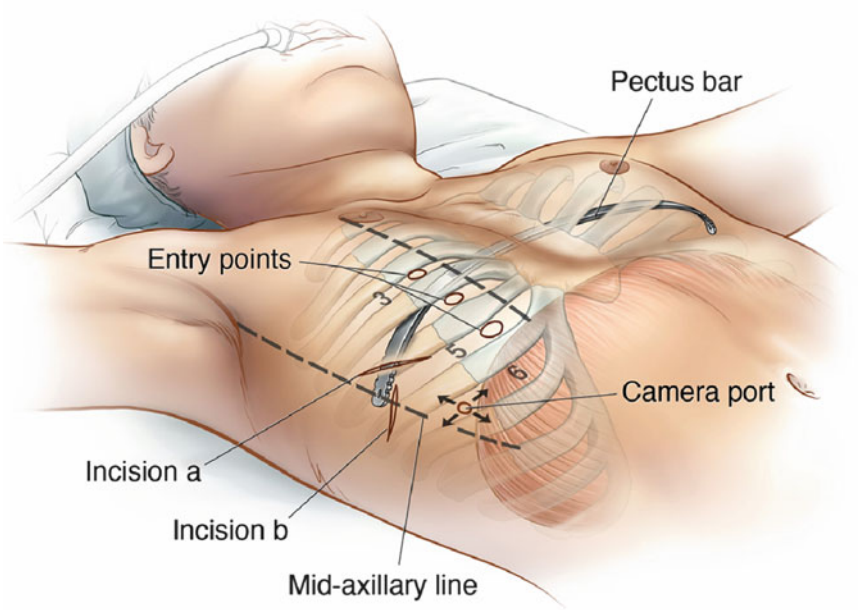


Figure 45.2



Figures 45.3 and 45.4

Input variables for the pectus bar's shape. Input variables for the pectus bar's shape are as follows:

1. Contours of the bar
2. Length of the bar
3. Points of entry and exit from the chest. It is important to analyze the correct biomechanical location, which will afford the greatest self-sustainability of the implant. Further, it is essential to analyze the length and rotation of the sternum, the position of the intercostal spaces, and the angulation of the costosternal connecting zone. The touch point of the pectus bar to the chest wall puts pressure on certain ribs, lowering that section of the chest. Thus, correction of the costal arches is affected and may even become impossible.
4. Number of implants, accounting for the patient's degree of deformity, age, and gender
5. Differences between male and female contours
6. Analysis of the costal arch deformity
7. Incision type and location, taking surgical and aesthetic/cosmetic considerations into account

Figures 45.3 and 45.4

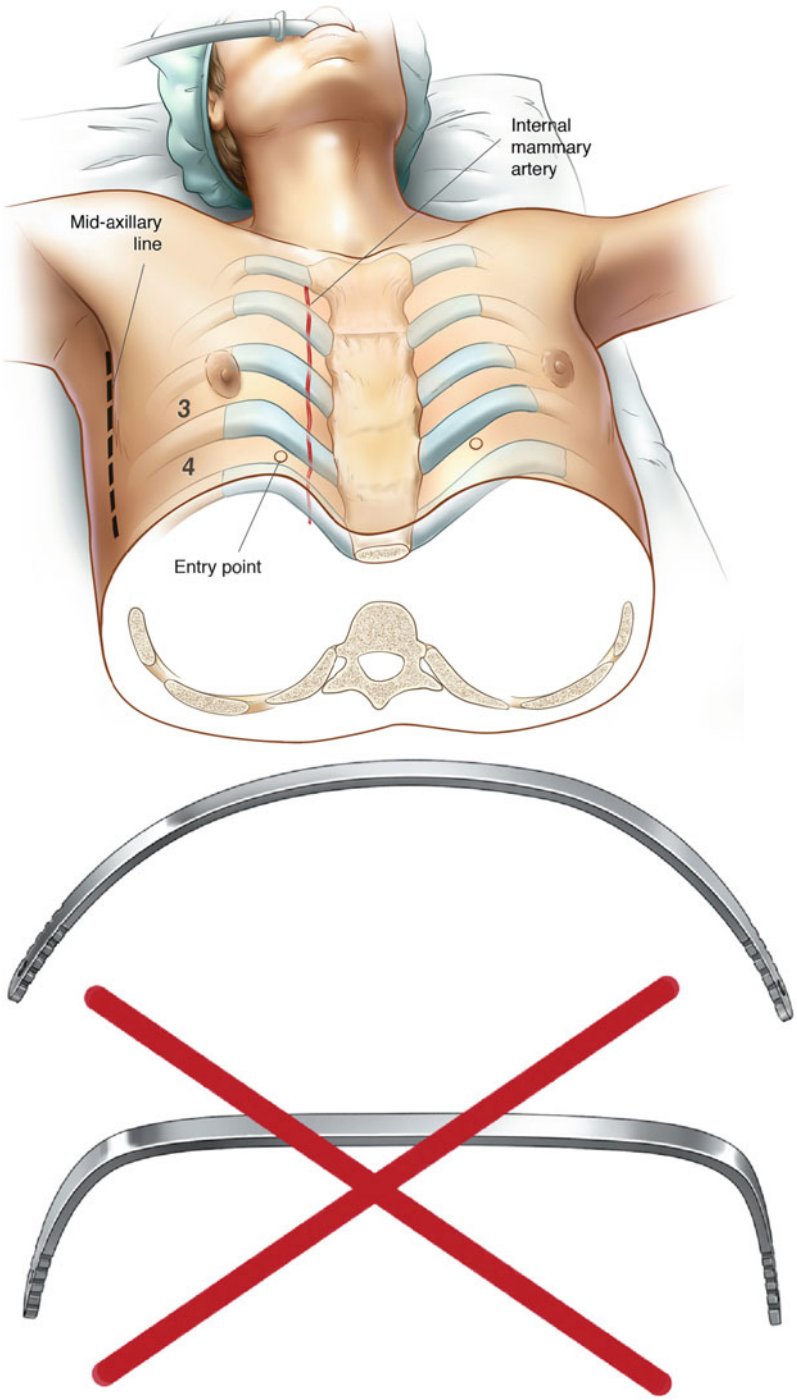
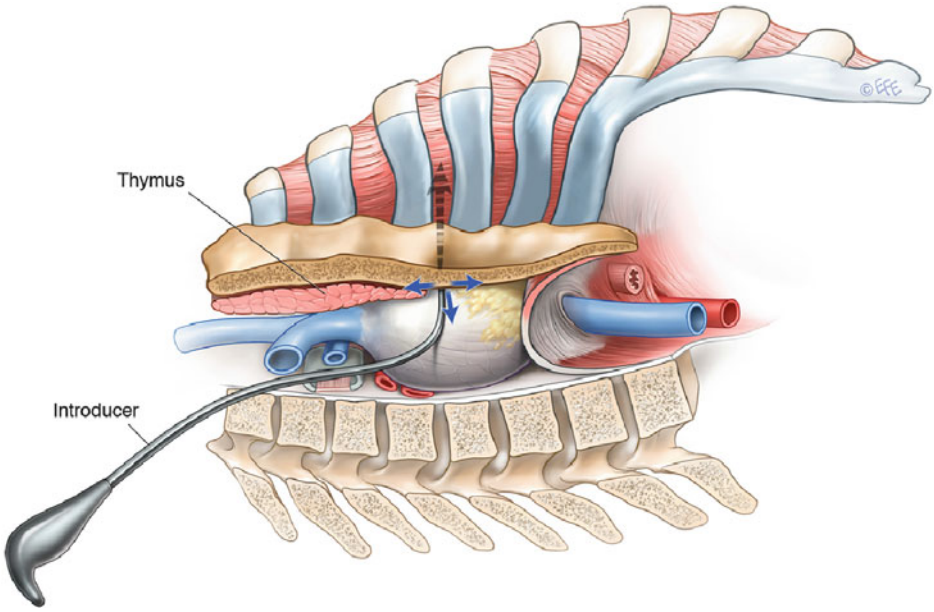


Figure 45.5

Guidance and control of the instruments. The camera is positioned from the right side via the sixth or seventh intercostal space in the anterior axillary line. Focus is on the diaphragm position. Gas pressure of 6- to 8 mm Hg shifts the lung and elevates the anterior chest wall. First, the mediastinal pleura is opened in the upper part at the end of the lower thymus horn directly retrosternally. From there, the incision is extended caudally retrosternally in full view of and protecting the pericardium. In cases of a low funnel and center-of-chest position of the heart, the pericardium may appear to be doubly present, causing the surgeon to pick the wrong incision point, which may lead to severe complications

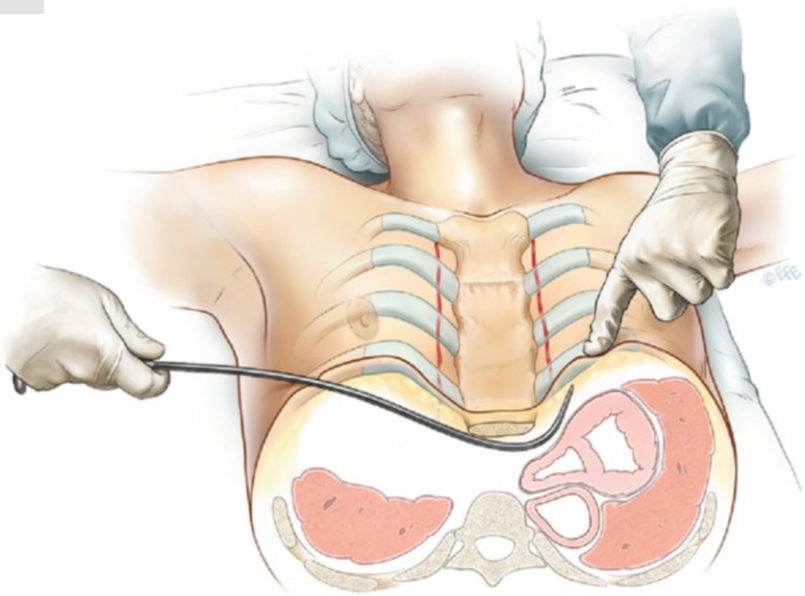
Figure 45.5



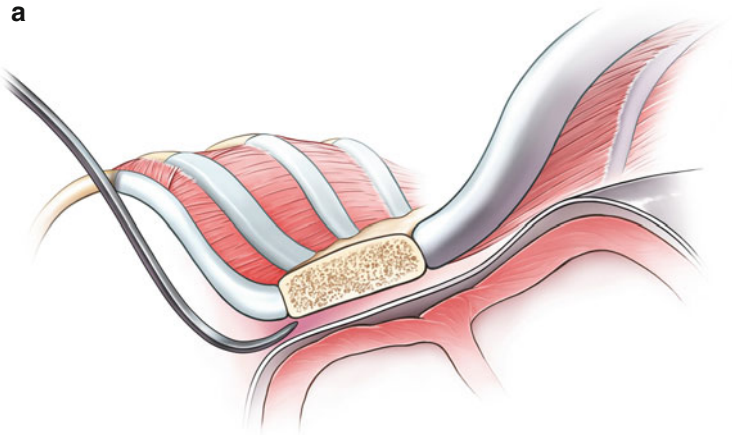
Figures 45.6 and 45.7

(**a**, **b**) Guidance and control of the introducer. During retrosternal passage, the surgeon's left index finger maintains contact with the tip of the introducer. The preparation in case a deep funnel exists and the heart is moved to the left requires only a short distance up to the exit. Based on thoracoscopic images, this distance appears longer, and one may be surprised at how quickly the tip of the introducer is felt. If the funnel is more moderate, the heart is not moved aside to the same extent. The setup for the preparation between sternum and heart is longer and more difficult. The device must be guided away from the heart carefully. One must avoid stripping away and damaging the intercostal muscles. Otherwise, the consequences may include bleeding, hematoma, outpouring, and dorsal displacement of the pectus bar

Figures 45.6 and 45.7



a



b

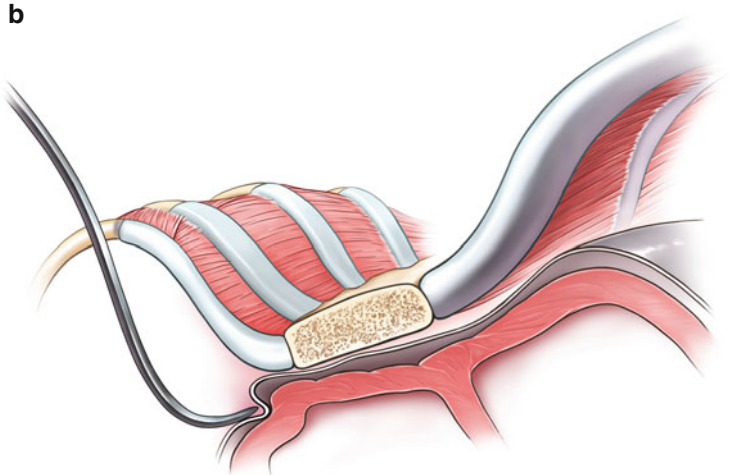
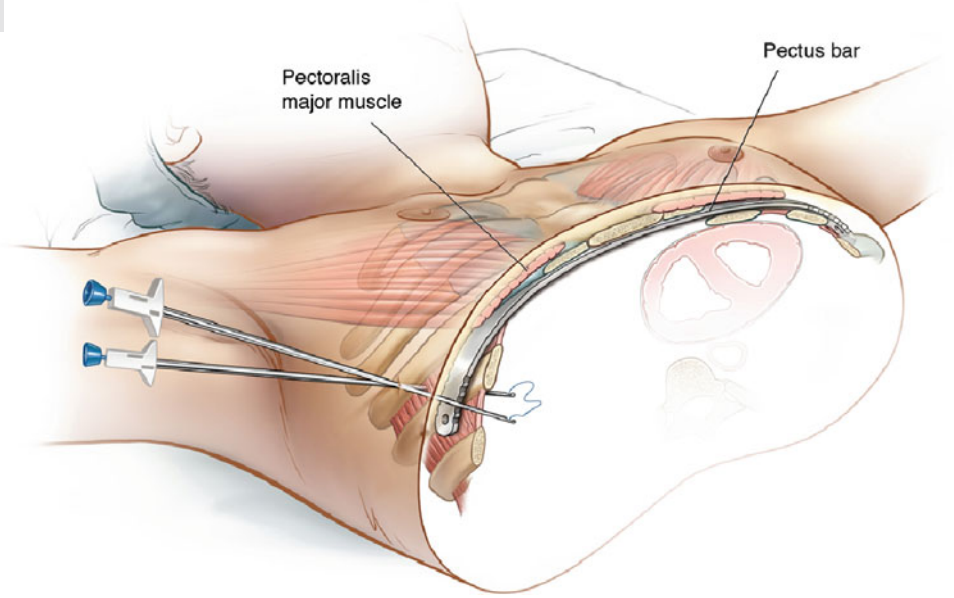


Figure 45.8

The cross-section of the pectus bar to the corresponding rib is fixed with polydioxanone 1 sutures by two rib heights. Seams are placed with the Endo Close Trocar Site Closure Device (Covidien Ltd., Hamilton HM, Bermuda) in a single- or double-stitching technique. Via transmediastinal thoracoscopy, the implant is located to the left and positioned the same way as the sutures, by one to two rib heights. The three-point method by Herba offers additional protection through a seam following the midclavicular line on the right via a 2- to 3-mm incision. Use of lateral stabilizers is not necessary; although they add stability, they may cause complications such as seromas, pain, and changes in curvature. Larger incisions are required, and explantation may be complicated

Figure 45.8



Conclusion

With the correct pectus bar length and shape, as well as point of introduction, it is possible to correct virtually any type of deformity, including those distinctly asymmetric. Limitations of treatment may be found in cases of a stiff chest, as may be found in elderly patients, in combination with a high degree of costosternal angulation. Although the angulation may be corrected, protrusion on the parasternal opposite area may occur. Thoracic remodeling may address this during a period of up to 2 years. Understanding the limitations of this method is key to avoiding suboptimal results. The correction affects not only the chondral parts of the chest wall, but also the bone section by changing the costotransverse connection with the vertebrae. In fact, the avoidance of cartilage resections allows the full length to be maintained, which is required to achieve a normal chest shape. This surgical method requires expert training. The most frequently reported complications are related to three types of bar displacement: slippage and dorsal and lateral displacements. Damage to the pericardium, lung, and heart may result when the complexity of the repair is not well understood. Therefore, surgeons who perform the procedure must have the requisite surgical know-how and equipment to respond to potential complications.

The surgical implants are removed 2–4 years after insertion, completing the treatment. Bilateral exposition of the implants is always performed using a special device manufactured by Biomet Inc. (Jacksonville, FL) that slightly diminishes the bend. With its remaining bend, the implant may be removed from the tissue with only a minor pull and counterrotation of the chest.

It is of utmost importance to apply proper safety measures throughout the procedure to perform the entire correction successfully and achieve the desired results. Accordingly, incision size and procedure duration, although important, clearly rank second to safety. Especially in light of the wide range of possible variations in deformity, extensive hands-on surgery is required to achieve the best possible reconstructive results. The benchmark after implant removal and treatment of the incision points is the absence of any sign of a prior pectus excavatum.

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