Notable Grand Rounds
of the
Michael & Marian Ilitch
Department of Surgery

Wayne State University
School of Medicine

Detroit, Michigan, USA

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CHEST WALL REPAIR

November 20, 2024

About Notable Grand Rounds

These assembled papers are edited transcripts of didactic lectures given by mainly senior residents, but also some distinguished attending and guests, at the Grand Rounds of the Michael and Marian Ilitch Department of Surgery at the Wayne State University School of Medicine.

Every week, approximately 50 faculty attending surgeons and surgical residents meet to conduct postmortems on cases that did not go well. That “Mortality and Morbidity” conference is followed immediately by Grand Rounds.

This collection is not intended as a scholarly journal, but in a significant way it is a peer reviewed publication by virtue of the fact that every presentation is examined in great detail by those 50 or so surgeons.

It serves to honor the presenters for their effort, to potentially serve as first draft for an article for submission to a medical journal, to let residents and potential residents see the high standard achieved by their peers and expected of them, and by no means least, to contribute to better patient care.

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Chest Wall Repair

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Grand Rounds presentation

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November 20, 2024

Introduction

Chest wall deformities are a diverse group of structural anomalies that can significantly affect patients both physiologically and psychosocially. This paper explores the history and evolution of surgical approaches to chest wall deformities, focusing primarily on pectus excavatum (funnel chest), the most common deformity encountered. It discusses the transition from the Ravitch procedure to the minimally invasive Nuss procedure, outlines other less common deformities and syndromes, and examines their pathophysiology, diagnosis, and indications for surgical intervention.

Evolution of Surgical Techniques

The Ravitch procedure, a traditional approach for correcting chest wall deformities, is well-known among senior surgeons. This labor-intensive method involves reflecting the pectoralis muscles, addressing significant blood loss, and performing extensive subperichondrial cartilage resections. The sternum is mobilized and repositioned, sometimes flipped upside down to improve alignment. However, without structural support, such as a strut, the sternum often regressed to its original position over time. Surgical times frequently extended to four to five hours, with notable challenges in managing hemostasis and postoperative recovery.

Dr. Donald Nuss introduced a paradigm shift in managing pectus excavatum with a minimally invasive approach. Originating in Virginia, the **Nuss procedure** involves placing a curved metal bar under the sternum without removing cartilage. This technique reduced operative time and blood loss significantly while simplifying postoperative recovery. Early adoption by surgeons, including collaborations with Dr. Rogers, marked a turning point, reducing the need for the extensive resections characteristic of the Ravitch procedure.

Types of Chest Wall Deformities

*Common and Rare Deformities (see **Fig. 1**)*

While **pectus excavatum** accounts for 90% of cases seen in clinical practice, other chest wall deformities present occasionally:

Pectus carinatum: An outward protrusion of the sternum, often treated with external bracing rather than surgical intervention.

Poland syndrome: Characterized by underdevelopment or absence of the chest wall muscles, occasionally associated with limb anomalies.

Sternal cleft: A rare congenital defect caused by incomplete fusion of the sternal plates during embryogenesis.

Jeune syndrome: A skeletal dysplasia that rarely presents in clinical practice, involving a narrowed chest cavity and respiratory issues.

Currarino–Silverman syndrome: A combination of upper sternum prominence and lower sternum depression, seldom encountered in surgical cases.

These deformities often result from abnormal cartilage growth, with the most prominent physiological impact seen in pectus excavatum.

Pathophysiology and Clinical Presentation

Embryology and Development: Chest wall deformities originate during embryological development when lateral chest wall growth and midline fusion occur. Disruption in this process can lead to structural anomalies such as sternal clefts. Pectus deformities arise from differential cartilage growth rates —faster growth on the external side pushes the sternum inward, while faster internal growth results in outward bowing. Histological studies have identified increased cellularity in cartilage specimens from affected individuals, although the precise etiology remains unclear.

Physiological Impacts: Pectus excavatum, while often perceived as cosmetic, has significant physiological implications. The inward displacement of the sternum can compress the heart, limiting its ability to increase stroke volume during exertion. This compression impacts cardiac output and contributes to exercise intolerance, shortness of breath, and delayed recovery times after physical activity.

A poignant example involves an Olympic swimmer with pectus excavatum who experienced prolonged recovery times despite competing at an elite level. This case underscores the impact of chest wall deformities on physical performance, even among highly conditioned athletes.

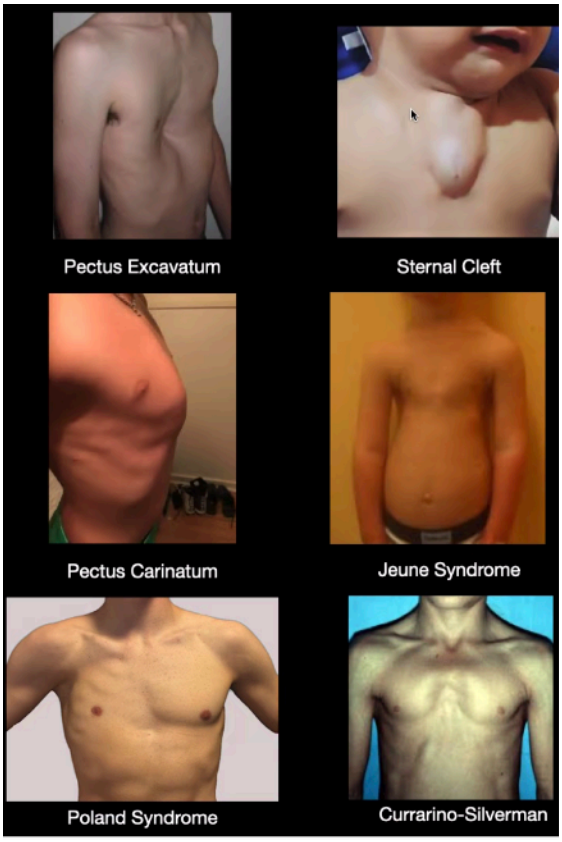

Figure 1. Common and Rare Deformities

Diagnostic Considerations and Patient Evaluation

Patients with chest wall deformities are typically diagnosed during childhood or early adolescence, with pectus excavatum becoming most apparent during the rapid growth phase of puberty. The male-to-female ratio is approximately 4:1, with an incidence of 1 in 400. A familial predisposition is noted in about one-third of cases, often manifesting as subtle rib anomalies or chest wall irregularities in relatives.

Evaluation involves assessing the depth of the sternal depression, chest wall symmetry, and the impact on the patient's quality of life. Functional limitations, particularly during physical exertion, are explored through clinical history and direct patient inquiry. However, a growing concern is the sedentary lifestyle of many adolescents, with video gaming replacing sports participation, complicating the assessment of functional impairment.

When evaluating patients with chest wall deformities, a thorough physical examination is essential. Many children with pectus excavatum present with a prominent costal margin. Surgeons must inform families that correcting the sternum may make the costal margin appear more pronounced. Additionally, scoliosis is more prevalent in these patients, necessitating examination of the back. Although most cases of scoliosis do not require surgery, there are occasional instances where patients undergo both pectus and scoliosis correction.

For diagnostic quantification, the Haller index is a widely used metric. It measures the ratio of the transverse chest diameter to the anteroposterior distance between the spine and sternum. A Haller index greater than 3.2 is often required for insurance coverage of surgical correction. While computed tomography (CT) scans can provide precise measurements, their routine use is discouraged due to unnecessary radiation exposure. In many cases, the Haller index can be reasonably estimated through physical examination or plain radiographs.

Pulmonary function tests (PFTs) are generally not necessary, as most pectus patients do not exhibit significant lung function abnormalities. Symptoms like exercise-induced shortness of breath are often mistaken for asthma, although they may be related to cardiac compression caused by the chest wall deformity. Cardiac evaluation may include echocardiography, as studies have demonstrated that up to 27% of patients have mitral valve prolapse, which often resolves after surgical correction.

For pectus carinatum, external bracing has proven highly effective, provided the patient is compliant. Braces, which are now available through more affordable sources such as Amazon, have significantly reduced costs compared to earlier proprietary models. Treatment typically spans about two years, mirroring orthodontic treatments, with initial intensive use followed by nighttime-only wear.

The key to successful bracing is patient compliance. Motivating children to wear the brace consistently can be challenging, especially with resistance from parents and discomfort during use. Bracing works more effectively in younger patients whose cartilage remains flexible, while older patients experience greater discomfort due to stiffer cartilage.

Pain Management and Postoperative Challenges

Postoperative pain is a significant concern for both patients and caregivers, particularly with procedures such as the Nuss repair. Older patients often experience increased pain due to the stiffness of their cartilage. Effective pain management requires a coordinated approach involving nurse practitioners and residents to address both acute and long-term discomfort.

Rare Syndromes

Poland Syndrome is characterized by the unilateral absence of the pectoralis major muscle, is an extremely rare condition. It may also involve anomalies such as syndactyly and other hand deformities. The etiology is unclear, with theories ranging from sporadic genetic mutations to in utero injuries affecting embryonic muscle migration.

Surgical correction typically involves reconstructive procedures, such as latissimus dorsi flaps, to improve cosmetic appearance. While effective, these procedures are rarely performed, even by specialists, due to the rarity of the condition.

Jeune Syndrome is a skeletal dysplasia resulting in a rigid, non-expanding chest wall, which can severely restrict respiratory function. Treatment options include rib expansion techniques, such as dividing and lengthening ribs or employing rib plating. However, the need for growth in pediatric patients complicates management, as repeated surgeries may be required. This condition remains a challenging and infrequently encountered anomaly.

Surgical Technique and Patient Management

Decision to Operate: The decision to proceed with surgical correction of pectus excavatum is primarily patient-driven. It is essential to inform patients and their families about the nature of the procedure, expected outcomes, and the potential for significant postoperative pain. Emphasis is placed on the fact that surgical intervention is not mandatory for all individuals. Patients are advised that they can lead active lives and even achieve high levels of athletic performance without correction, as evidenced by athletes who have competed successfully despite the deformity.

Approximately 80–90% of patients elect to undergo surgery after comprehensive counseling. Some may initially defer the procedure due to concerns about pain or other factors but often return later when they feel ready. For instance, adolescents might choose to wait until they are older, with some opting for surgery during college years.

Preoperative Planning: Preoperative assessment involves meticulous planning to determine the optimal placement and size of the corrective bar. In the operating room, with the patient's arms extended, the surgeon uses malleable template bars provided by the Biomet pectus repair system to select the appropriate bar length, typically ranging from 11 to 20 inches. (**Fig. 2**) Most teenagers require a 14- or 15-inch bar. Key anatomical landmarks are marked, including:

- *Intercostal spaces*: Identified on each side where the bar will be inserted and exited.
- *Deepest point of sternal depression*: Often at the level of the xiphoid process, although placing the bar directly at the xiphoid may not provide optimal elevation.

These markings guide incision placement and ensure precise correction of the deformity.

Surgical Procedure: The Nuss procedure employs a minimally invasive approach to correct pectus excavatum:

Incisions: Small lateral incisions are made in each axillary region.

Subcutaneous Tunnels: Tunnels are created up to the marked intercostal spaces.

Thoracoscopic Guidance: A thoracoscope is inserted to provide visual assistance, enhancing safety during the procedure.

Figure 2. Before and After

Bar Passage: The introducer is advanced across the mediastinum, carefully dissecting between the heart and sternum while avoiding injury to vital structures.

Bar Placement: The steel bar is guided into position and rotated to elevate the sternum, effectively correcting the deformity.

Initially, the procedure was performed without thoracoscopic assistance. However, following reports of serious intraoperative complications, including a case where the right atrium was perforated during a teaching demonstration, thoracoscopy has become standard practice. It not only improves safety but also allows for intraoperative imaging that can be shared with patients and families.

Pain Management Strategies: Postoperative pain is a significant concern, particularly due to the pressure exerted by the corrective bar on the ribs and intercostal nerves. Effective pain management is crucial for recovery:

Avoidance of Epidurals: Epidural anesthesia is generally avoided as it may prolong operative time and delay postoperative mobilization without providing superior pain control.

Local Nerve Blocks: Multilevel intercostal nerve blocks with agents like bupivacaine are administered around the operative site to manage pain.

Caution with Cryoablation: While some surgeons use cryoablation of intercostal nerves to reduce pain, concerns about potential long-term nerve damage and neuroma formation have limited its adoption in this practice.

Patient Education: Patients are counseled preoperatively about expected pain levels. An analogy is used wherein patients press firmly on a rib to understand the sensitivity of the periosteum, helping set realistic expectations.

Older patients often experience more significant pain due to stiffer cartilage and increased force required for correction. Tailored pain management plans are essential for this group.

Challenges in Adult Patients: Performing the Nuss procedure in adult patients presents unique challenges:

- *Case Example*: A 37-year-old woman sought correction for her pectus excavatum. Due to the rigidity of her sternum and its proximity to the spine, standard techniques were insufficient.
- *Modified Approach*: Bilateral thoracoscopic assistance was necessary to safely navigate the introducer across the mediastinum.
- *Increased Pain*: The patient experienced considerable postoperative pain, more so than typically observed in younger patients, underscoring the increased difficulty and recovery considerations in adult populations.

Patient Experiences and Outcomes: Patients' decisions to undergo surgery are influenced by various factors, including cosmetic concerns, physiological symptoms, and lifestyle considerations:

- *Timing of Surgery*: Some patients choose to have the procedure during adolescence, while others wait until adulthood. Delayed decisions are often due to initial apprehension about pain or the impact on daily activities.
- *Postoperative Recovery*: Effective pain management and patient education contribute to better recovery experiences. Emphasizing mobilization and avoiding prolonged bed rest can aid in reducing complications.
- *Long-Term Outcomes*: Most patients report significant improvement in symptoms and satisfaction with cosmetic results. Continuous follow-up ensures any complications are promptly addressed.

Procedural Details and Postoperative Management

Surgical Technique: Bar Placement and Adjustment: The Nuss procedure involves a precise sequence of steps to ensure effective correction of pectus excavatum while minimizing risks:

- **Bar Passage and Placement**: After creating subcutaneous tunnels beneath the sternum, the corrective bar is bent using a malleable template to match the patient's anatomy. The bar is passed beneath the sternum in an inverted position and then rotated to elevate the sternum into its corrected position. The ends of the bar rest on the ribs and overlying muscles, providing stability and support.
- **Multiple Bars for Severe Deformities**: For patients with severe or extensive deformities, a second bar may be placed. Using the same incisions, a separate tract is tunneled, and the additional bar is inserted to address residual depression. Approximately 10–15% of patients require a second bar to achieve optimal correction.
- **Intraoperative Visualization**: Thoracoscopic guidance is essential for safe dissection, particularly in cases where the sternum is close to the spine or other vital structures. This ensures that the bar can be passed without damaging the heart or lungs.

- **Bar Stabilization**: To prevent bar rotation, stabilizers are attached to both ends of the bar and sutured to the chest wall. This creates a stable construct that resists movement during recovery.

Postoperative Care and Recovery

Hospital Stay and Pain Management: Postoperative pain is a significant concern due to the pressure exerted by the bar on the ribs and intercostal nerves. Management strategies include:

- **Patient-Controlled Analgesia (PCA)**: Patients self-administer pain relief for the first day postoperatively. Continuous dosing (basil) is avoided to encourage controlled, as-needed use.
- **Anxiolytics**: Medications like diazepam (Valium) are prescribed for anxiety and muscle relaxation. The need for parental reassurance and coaching is also emphasized.

Hospital stays typically range from 1 to 3 days, depending on the patient's pain tolerance and mobility. Early mobilization with physical therapy helps improve outcomes and reduce complications.

Activity Restrictions: Patients are advised to avoid twisting motions for the first four weeks to prevent bar displacement. After this period, restrictions are lifted, and patients can resume normal activities. However, high-impact sports or activities, such as martial arts, may pose risks to the bar and sternum.

Bar Removal: The corrective bar is left in place for 2 to 3 years to allow the chest wall to stabilize. Older patients may require longer durations due to stiffer cartilage. Removal is performed as an outpatient procedure by reopening the original incisions, detaching the stabilizers, and sliding the bar out.

Complications During Removal: Heterotopic ossification can complicate removal. In rare cases, such as with patients involved in high-impact sports, extensive bone formation around the bar may require chiseling and fluoroscopic guidance for extraction.

Special Cases and Long-Term Outcomes

Severe Cases and Marfan Syndrome: Patients with Marfan syndrome or unusually severe deformities present unique challenges. One notable case involved a patient who grew significantly taller between surgeries, requiring a second bar to address a new sternal depression. Despite these challenges, long-term stability of the corrected sternum has been maintained in such cases.

Complications: Complications include transverse thoracic growth leading to rib indentation from the bar. However, rib remodeling typically resolves these issues after bar removal.

Functional and Cosmetic Outcomes: Most patients achieve satisfactory functional and cosmetic results. However, occasional complications, such as fractures or ossification, highlight the importance of careful management and follow-up.

Case Reflections and Humor in Practice

The narrative also underscores the variability in patient recovery experiences, ranging from rapid discharges to extended hospital stays due to pain or psychological factors. Lighthearted anecdotes, such as a "wimpy" patient from Midland or the challenges of managing overprotective parents, add a human element to the technical complexities of the procedure.

Postoperative Considerations and Patient Outcomes

Early Bar Removal: While the standard duration for bar retention is 2–3 years, there are cases where earlier removal is necessary due to patient-specific circumstances. These include:

Athletic Activity Interference:

- Gymnast Case: A high-level gymnast specializing in uneven parallel bars experienced discomfort from the bar due to repeated impacts. The bar was removed after one year without any loss of sternal correction.

- Golfer Case: A young golfer believed the bar was affecting his game. Despite early removal at one year, his performance remained unchanged, attributed more to a lack of practice than the bar itself.

Infection and Other Complications: A patient with severe eczema developed a bar infection six months postoperatively. The infection was managed temporarily with antibiotics but recurred upon cessation. Removal of the bar resolved the issue, highlighting the importance of skin health and hygiene in preventing complications.

Patient Satisfaction and Long-Term Outcomes

Postoperative outcomes are overwhelmingly positive, with most patients expressing satisfaction with both functional and cosmetic improvements. Notable cases include:

- *High-Performance Athletes*: A volleyball player with one of the deepest deformities corrected has become a successful Division I athlete. Despite an associated scoliosis correction and the need for rib resections, her outcomes were excellent.
- *Personal and Social Confidence*: A young woman sought surgical correction not only for exertional limitations but also for cosmetic reasons, such as difficulty fitting into wedding dresses. Postoperatively, she reported improved self-confidence and physical well-being, reinforcing the multifaceted benefits of repair.
- *Complex and Severe Deformities*: Severe cases sometimes require additional interventions, such as multiple bars or rib resections, to achieve optimal outcomes. For example, a patient with Marfan syndrome required a second operation due to growth-induced deformity progression. Another patient with a deeply extended thoracic depression necessitated two bars for proper correction.

Challenges and Humor in Patient Management

Managing postoperative expectations and complications often requires creative solutions. For instance:

A cross-country runner, frustrated by the clicking sound of the bar during runs, was humorously advised to use it as a "metronome" to improve his pace.

Overly protective or guilt-ridden parents, particularly in early recovery stages, sometimes require reassurance and encouragement to support their child's recovery effectively.

Pain and Recovery

The procedure is undeniably painful, particularly during the immediate postoperative period. However, the long-term benefits, including improved physical capability, self-image, and overall quality of life, often outweigh the initial discomfort. Patients who undergo the procedure generally adapt well and report lasting satisfaction.

Conclusions

The surgical management of pectus excavatum and related chest wall deformities has evolved significantly with the adoption of the Nuss procedure. This minimally invasive approach offers effective correction with fewer complications compared to traditional methods. Despite the significant postoperative pain, the procedure provides substantial improvements in both functional and psychological outcomes for most patients.

Key insights from this body of work include:

Patient selection and thorough counseling are essential for setting realistic expectations.

The decision to operate is guided by patient motivation, supported by a multidisciplinary approach to care.

Advances in surgical techniques, including the use of thoracoscopy and bar stabilization, have enhanced safety and outcomes.

Individualized pain management and activity modification strategies play critical roles in recovery.

Ultimately, the combination of technical precision, patient-centered care, and ongoing innovation continues to improve the lives of individuals with chest wall deformities, making the challenges of this specialty rewarding for both surgeons and patients.