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Operative Correction of Pectus Deformities: A Prospective Cohort Study

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Abstract

Background: Pectus deformities represent the most common congenital chest wall abnormalities, significantly impacting both physiological function and psychological well-being of affected patients. While multiple surgical approaches exist, the outcomes of surgical repair remain a subject of ongoing investigation. The objectives of this study were to evaluate the psychological impacts of pectus deformities with assessment of psychological satisfaction of the patient and his family post operative and assess improvements of physiological impacts of these deformities post operative

Methods: This prospective cohort study was conducted at Banha University Hospitals from 2022 to 2025. Fifty patients with pectus deformities underwent surgical correction using either the Modified Ravitch procedure (n=28, 56%) or the Nuss procedure (n=22, 44%). Outcomes included postoperative assessment scores (poor, fair, good, excellent), hospital stay duration, complications, and patient satisfaction.

Results: The study population consisted of 38 males (76%) and 12 females (24%) with a mean age of 14.8 ± 1.9 years. Pectus excavatum was the predominant deformity (86%, n=43), with pectus carinatum comprising 14% (n=7). Severity distribution showed 26% severe cases, with the remainder classified as moderate or mild. The overall excellent outcome rate was 42% (21/50), with 50% achieving good outcomes. Median hospital stay was 9 (8- 10) days, showing positive correlation with Haller index (r=0.33, p=0.026). The recurrence rate was low at 4% (2/50), and psychological satisfaction was achieved in 94% of patients.

Conclusions: Surgical techniques for pectus repair demonstrated high success rates with low morbidity. The Nuss procedure and Modified Ravitch procedure remains a reliable option with good to excellent outcomes in most cases.

KEYWORDS

Pectus deformity; Pectus excavatum, Pectus carinatum; Modified Ravitch procedure; Nuss procedure; Chest wall reconstruction; Surgical outcomes

Introduction

Pectus deformities represent the most prevalent congenital chest wall abnormalities, there is no specific statistics for the rate of pectus deformities in Egypt, but the global prevalence suggests it would be around 1 in 300–400 births for pectus excavatum and 1 in 1,500 for pectus carinatum, with a marked male predominance of 4:1. These structural anomalies primarily encompass two distinct phenotypes: pectus excavatum and carinatum. The clinical significance of these deformities extends far beyond cosmetic

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concerns, encompassing substantial physiological and psychological implications that profoundly impact patient quality of life [1].

In pectus excavatum, excessive posterior angulation of the costal cartilages results in sternal depression, potentially compromising cardiopulmonary function through mechanical compression of underlying structures [2]. The severity of functional impairment correlates with the degree of deformity, typically quantified using the Haller index, which represents the ratio of the transverse chest diameter to the anteroposterior distance at the point of maximum deformity on axial chest computed tomography imaging [3].

The physiological consequences of severe pectus deformities are multifaceted and clinically significant. This includes cardiac and pulmonary dysfunction [4]. The psychological impact of pectus deformities cannot be understated, particularly during adolescence when body image concerns are paramount. Studies have consistently demonstrated increased rates of depression, anxiety, and social withdrawal among affected individuals, with many patients reporting significant limitations in social activities, and sports participation [5].

Surgical correction of pectus deformities has evolved significantly over the past century, with multiple techniques developed to address the diverse presentations and severity levels encountered in clinical practice. The Modified Ravitch procedure represents the traditional open approach involving subperichondrial resection of abnormal costal cartilages, and sternal osteotomy when necessary [6]. In contrast, the Nuss procedure represents a minimally invasive approach that avoids extensive cartilage resection and sternal manipulation [7].

Patient selection criteria for surgical intervention have evolved to encompass both objective physiological parameters and subjective quality of life measures. Traditional indications have included severe deformities with Haller indices exceeding 3.25, documented cardiopulmonary compromise, and significant psychological distress impacting daily functioning [8]. However, contemporary approaches increasingly recognize the importance of patient-reported outcomes and quality of life measures in determining the appropriateness of surgical intervention.

The timing of surgical intervention remains a critical consideration, with most experts recommending repair during adolescence when chest wall growth is nearing completion but before the cartilages become calcified and less malleable. Early intervention may be associated with higher recurrence rates due to continued growth, while delayed repair in adulthood may result in increased technical difficulty and potentially suboptimal outcomes due to decreased chest wall flexibility [9,10].

Despite the extensive literature on pectus deformity correction, significant gaps remain in our understanding of optimal surgical techniques, patient selection criteria, and long-term outcomes. Additionally, the relative rarity of these conditions and the concentration of expertise in specialized centers contribute to the limited availability of high-quality comparative data. The objectives of this study were to evaluate the outcomes of surgical correction of pectus deformities and to assess patient satisfaction with surgical outcomes.

Interpretation of Haller index:

- normal chest: <2.0
- mild excavatum: 2.0-3.2
- moderate excavatum: 3.2-3.5
- severe excavatum: >3.5

Age: Young age also reduces the values, with 0 to 2-year-olds having smaller Haller indices than older children.

Sex: Females have a greater Haller index than males in early childhood (from 0-6 years of age) and in teenage years (12-18 years of age) [3]

Patients and Methods

Study Design and Setting

This prospective observational study was conducted at Banha University Hospitals from 2022 to 2025. The study population comprised of

50 patients with pectus deformities who underwent surgical correction during the study period.

Inclusion Criteria:

- Patients of both sexes presenting with pectus deformities (pectus excavatum or pectus carinatum)
- Age range suitable for surgical intervention (typically adolescent and young adult patients, 12 – 18 years)
- Candidates deemed appropriate for surgical correction based on clinical assessment

Exclusion Criteria:

Combined vertebral column deformities including kyphosis and scoliosis which were diagnosed by:

Physical examination:

Looking for visual signs like uneven shoulders, hips, or waist, ask the patient to bend over to check for prominent shoulder blades or a shifted waist. assess posture, spinal movements, reflexes, and muscle strength

Imaging tests

X-rays: The most common diagnostic tools to confirm the diagnosis and determine the severity.
Cobb's angle: X-rays are used to measure the curve in degrees, often using Cobb's angle for scoliosis, to help determine the extent of the curvature [11].
Kyphosis angle: For kyphosis, the kyphosis angle is measured from a side-view X-ray.

CT scans: A CT scan may be used to get more detailed images of the bone structure of the spine

Further evaluation by Specialized spine surgeons may be needed in patients with suspected combined vertebral deformities.

- Patients with significant comorbidities precluding safe surgical intervention
- Previous chest wall surgery or trauma
- Patients who refuse to participate in the study
- Patients candidate for non-invasive treatment approaches as: observation and conservative management in some mild cases, Vacuum bell in pectus excavatum and brace in pectus carinatum

Table 1: Preoperative data of patients with chest wall deformity who underwent surgical correction

Variables	(n= 50)
Age, years (mean± SD)	14.78± 1.91
Male	38 (76%)
Deformity	
Pectus excavatum	43 (86%)
Pectus carinatum	7 (14%)
Deformity severity	
Mild	19 (38%)
Moderate	18 (36%)
Severe	13 (26%)
Preoperative psychological disturbance	48 (96%)
Associated symptoms	
None	40 (80%)
Asthma-like	4 (8%)
Dyspnea	6 (12%)
Heller's index [Median (IQR)]	3.4 (3.2- 3.6)

Preoperative Evaluation Protocol

All patients underwent comprehensive preoperative evaluation following a standardized protocol designed to assess the severity of deformity, evaluate functional impairment, and identify potential risk factors for surgical complications.

Clinical assessment included complete history taking focused on symptoms related to the chest wall deformity, including exercise intolerance, dyspnea, chest pain, and psychological distress. The family history of chest wall deformities was documented, as was the presence of associated conditions such as asthma-like symptoms. Physical examination included a detailed assessment of the chest wall deformity, measurement of anthropometric parameters, and evaluation of overall physical development.

Laboratory investigations included routine preoperative laboratory studies performed for all patients, including complete blood count (CBC), liver function tests (LFT), renal function tests (RFT), and international normalized ratio (INR).

Imaging studies included plain chest radiography performed in all patients. Electrocardiography (ECG) was obtained to evaluate cardiac rhythm and identify any baseline

abnormalities. Computed tomography (CT) of the chest was performed with detailed assessment focusing on several key parameters. The degree of severity of pectus deformity was quantified using the Haller index, calculated as the ratio of the transverse diameter of the chest to the anteroposterior distance on the axial slice showing maximum deformity. Displacement of mediastinal structures, when present, was documented and quantified.

Functional assessment included pulmonary function tests performed to assess baseline respiratory function and identify any restrictive or obstructive patterns that might influence surgical planning or postoperative expectations. Echocardiography was conducted to evaluate cardiac function and identify any compression effects on cardiac chambers, particularly the right ventricle.

Surgical Techniques

Two primary surgical approaches were employed in this study

Modified Ravitch Procedure: The Modified Ravitch procedure was performed in 28 patients having pectus excavatum or pectus carinatum deformities (56% of the study population). This technique consists of an 8–12cm transverse incision, with removal of lower cartilages attached to the rib cage in a fashion that would allow their re-growth over the next few months, followed by reconstruction of the sternum to straighten it out, with no metal bar insertion. The sternal support is achieved through adherent non-biological material (a Gore-Tex patch) that is incorporated into human tissue over time, with no need for a second surgical procedure to remove it.

Nuss Procedure: The Nuss procedure was performed in 22 patients having pectus excavatum deformities (44% of the study population). This minimally invasive approach involved the placement of a curved metal bar beneath the sternum through small bilateral thoracic incisions with thoracoscopic guidance, The scope may be inserted on the right side, left side, or both sides, The 5-mm trocar is inserted into the right chest in the midclavicular line, approximately 2 intercostal spaces inferior to the proposed incision site, Bilateral thoracic skin incisions are made from the anterior-axillary to the midaxillary lines and carried down through the subcutaneous tissues onto the surface of the rib cage. A subcutaneous tunnel is then created from the incision site up to the “X” marked on the anterior chest wall. The “X” should be just inside or “medial to the point where the deformity starts to cave inward.” If the tunnel is superior to the origin of the pectoralis muscles, then the tunnel should proceed under the pectoralis muscles. In mature female patients, the inframammary crease incision is used instead. The metal bar was initially inserted in a convex orientation and subsequently flipped to elevate the depressed sternum and adjacent chest wall structures, to achieve an excellent result, the bar should be under the deepest point of the depression. However, if the deepest point of the depression is below or inferior to the sternum, then 2 bars need to be placed—one under the deepest point of the depression and the other one under the lower sternum. If only one bar is used and it is placed inferior to the sternum, it will not correct the deformity, as only the soft tissues will be elevated. It is therefore crucial to always elevate the sternum with at least 1 bar. Usually, 2 bars give better correction than 1 bar and should always be considered in older patients, asymmetric patients, wide deformities, and severe deformities, The bar should fit loosely on each side. If it is too tight it will cause rib erosion, pain, and calcification.

Bar stabilization is essential. If the bar is not properly stabilized, it will become displaced and the deformity will recur, to adequately stabilize the bar, a stabilizer is applied on the left side and attached to the bar with sternal wire or with FiberWire in a figure of 8 fashion. The more medial the stabilizer, the more support it provides. In addition to the stabilizer on the left, multiple “0” PDS “polydioxanone” ligatures are applied around the bar and underlying rib on the right side. The PDS sutures are placed under thoracoscopic guidance using either a laparoscopic “Endo Close” needle, Doyen suture passer, or a thoracoscopic grasper. The PDS sutures need to be placed exactly at the point where the bar crosses the underlying rib. If the sutures are placed in the wrong site, they

will help to displace the bar rather than stabilize it. Sutures should be placed in more than one site, if possible, including the left side. The sutures need to be snug but not tied so tightly that they strangulate the underlying intercostal nerves and blood vessels. The metal bar was planned to remain in place for two to three years to allow permanent remodeling of the chest wall before removal.

The choice of surgical technique was based on surgeon preference and patient characteristics. Patients selected for the Nuss procedure may have had more favorable anatomical features or less complex deformities and because this procedure is less invasive and better cosmetically [12].

The idea of choosing modified Ravitch procedure was that no metal bar was inserted with no need for second operation to remove as in Nuss procedure.

Outcome Assessment Measures

The primary outcome assessment measures were designed to evaluate both immediate surgical results and follow-up functional and cosmetic outcomes. A comprehensive grading system was employed to standardize outcome assessment across all patients.

Postoperative Assessment Grading:

- Excellent: Anterior chest wall restored to normal or near-normal configuration, surgical scar was good, and expectations of the patient and family were fully fulfilled
- Good: Some residual sternal depression present, scar was good, and family were satisfied with the overall result
- Fair: Mild degrees of deformity remained, but overall improvement was achieved
- Poor: Significant residual deformity requiring consideration of secondary surgical intervention [13]

Considerations for psychological assessment:

Subjective experience: The psychological impact of a pectus deformity is highly personal. Some patients with mild deformities can experience significant distress, while others with more severe cases may have a more positive self-image.

Informed expectations: Realistic expectations are crucial for patient satisfaction. Some dissatisfaction post-surgery can be linked to factors like surgical scars or residual pain, highlighting the need for thorough preoperative counseling.

Age of surgery: While psychological benefits are seen at all ages, the adolescent years are a key period for identity and self-esteem formation, making surgical correction during this time particularly impactful [14].

Psychological assessment Measures:

Increased self-esteem: Improved body image leads to a strong increase in self-esteem. This positive shift is often noticed early in the postoperative period.

Less social anxiety: Many patients with pectus deformities avoid social activities where their chest may be visible. After surgery, patients report reduced social self-consciousness and greater engagement in social activities

Reduced depression and anxiety: While severe mental illness is not common, patients often report feelings of depression, anxiety, and insecurity related to their deformity. Surgical correction leads to a significant improvement in these psychosocial indicators.

Improved quality of life (QoL): High patient satisfaction with the cosmetic results, alongside psychological and physical improvements, contributes to a higher overall quality of life [14].

Early Postoperative Assessment: All patients were assessed for immediate postoperative parameters including need for intensive care unit (ICU) admission, requirement for mechanical ventilation and duration if needed, total hospital stay duration, and early complications such as bleeding or wound infection.

Follow-up Protocol: Patients were followed systematically at predetermined intervals to assess short-term outcomes. Outpatient follow-up visits were scheduled for two weeks, three months, and six months postoperatively. At each

follow-up visit, patients were assessed for degree of correction maintenance, evidence of recurrence of deformity, and overall satisfaction with the surgical result. Plain chest radiography was performed at follow-up visits to document radiographic improvement and identify any complications.

Statistical analysis

Descriptive statistics were calculated for all variables, with continuous variables presented as means ± standard deviations or median (interquartile range) and categorical variables presented as frequencies and percentages. Correlation analysis was performed to assess relationships between continuous variables, with Spearman's rank correlation coefficient used for non-parametric data.

Univariable ordinal logistic regression was used to model the relationship between preoperative data and postoperative assessment outcomes. However, the Haldane correction was used due to perfect separation in the data. Univariable negative binomial regression was used to assess the association between preoperative data and hospital stay. All statistical analyses were performed using Stata 18 (Stata Corp, College Station, TX).

Ethical Considerations

The study was conducted in accordance with the principles of the Declaration of Helsinki and local institutional guidelines for clinical research [15]. Institutional review board approval was obtained prior to study initiation. Patient confidentiality was maintained throughout the study period, with all data collected and stored in accordance with applicable privacy regulations.

Results

Patient Demographics and Baseline Characteristics

The study population consisted of 50 patients with pectus deformities who underwent surgical correction during the study period. The demographic characteristics revealed a predominant male population, with 38 males (76%) and 12 females (24%). The mean age at the time of surgery was 14.8 ± 1.9 years (range 12-18 years). The distribution of deformity types showed pectus excavatum as the predominant condition, affecting 43 patients (86% of the study population), while pectus carinatum was present in 7 patients (14%). Two patients (4%) reported a positive family history of chest wall deformities.

Severity assessment based on clinical evaluation and imaging studies revealed that 13 patients (26%) presented with severe deformities, while the remaining 37 patients (74%) were classified as having moderate or mild deformities, Mild cases were operated for psychological issues as they experienced preoperative significant distress with increased self-consciousness and avoidance of social activities. During study, many mild cases preferred noninvasive measures such as vacuum bell, brace or conservative management.
The median Haller index, calculated from chest CT imaging, was 3.4 (3.2- 3.6) (Table 1).

Preoperative Clinical Presentation

Psychological disturbance prior to surgery was documented in 48 patients (96% of the study population). Associated respiratory symptoms were present in 10 patients (20%), with all these cases with associated respiratory symptoms were presented with asthma-like symptoms or dyspnea (Table 1).

Surgical Technique and Operative Characteristics

The Modified Ravitch procedure was performed in 28 patients (56% of the study population), while the Nuss procedure was employed in 22 patients (44%).

In Modified Ravitch procedure an 8–12cm transverse incision, with removal of lower cartilages attached to the rib cage in a fashion that would allow their re-growth over the next few months, followed by reconstruction of the sternum to straighten it out, with no metal bar insertion. This procedure takes about two to three hours.

In Nuss procedure Bilateral thoracic skin incisions are made from the anterior-axillary to the midaxillary lines and carried down through the subcutaneous tissues onto the surface of the rib cage under thoracoscopic guidance, The scope

may be inserted on the right side, left side, or both sides, The 5-mm trocar is inserted into the right chest in the midclavicular line, approximately 2 intercostal spaces inferior to the proposed incision site. This procedure takes around 2 hours

All patients were successfully extubated on the operating table, without significant complications requiring prolonged mechanical ventilation.

The operative procedures were completed without major intraoperative complications, and no patient required conversion from one technique to another during surgery.

Possible complications associated with surgery include:

- Wound Problems include:
  - Infection: All precautions including antibiotics during and immediately after surgery should be taken but wound infection is a risk with all surgeries. If infection occurs, dressings and antibiotics are usually all that is required. Rarely, further surgery to clean the wound is required.
  - Seroma: can occur even several weeks after surgery.
  - Healing: it might have very different aspects: wide, retractile, adhesive, hyper or hypo-pigmented, or keloid.

- Bleeding: is rare to occur in less than 1% of cases and can occur during or after the procedure.
- Pneumothorax: In most cases it can be monitored following surgery with chest x-rays and in less than 2% of cases it requires a chest drain to remove the air.
- Pleural effusion: Despite being rare, it can be monitored with chest x-rays and in less than 1% of cases requires a chest drain to remove the fluid.
- Pericarditis / Pericardial effusion is thought to be caused by inflammation of the lining of the sac of the heart, it is rare but unpredictable and is usually treated with rest and anti-inflammatory medication. The pericardial effusion may need to be monitored and very rarely drained.
- Displacement/movement of the bar: can occur following Nuss procedure, the risk is low at around 2%.
- Unstable sternum can occur if the cartilages are too extensively cut and the sternum can then over time cause discomfort, constant or intermittent clicking or even pain.
- Chronic Pain after surgery has been described and is usually mild, intermittent and can be related to specific movements or activities. It is not common, rarely significant and can be treated with painkillers if needed.

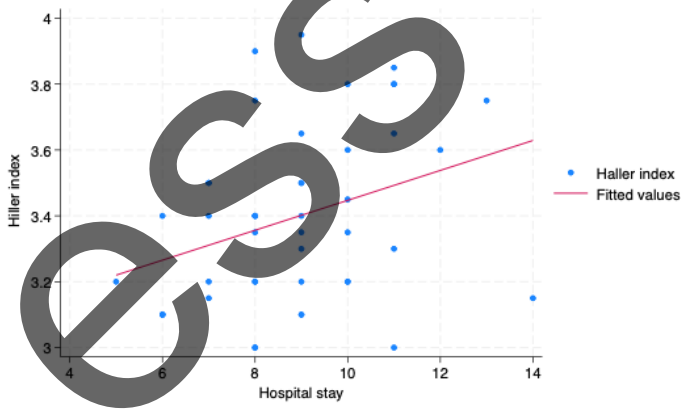

Figure 1: Correlation between Hiller index and hospital stay

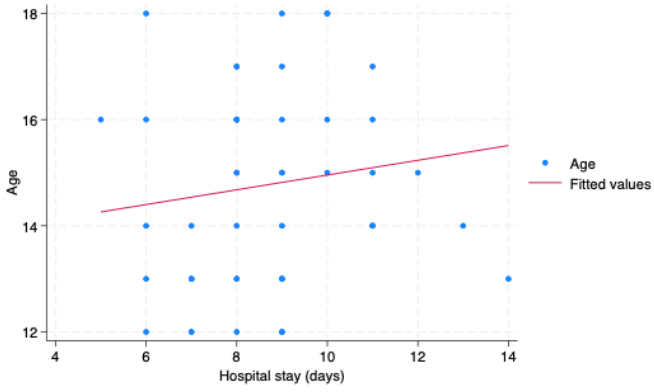

Figure 2: Correlation between age and hospital stay

Postoperative Outcomes and Hospital Course

The immediate postoperative course was generally uncomplicated for the majority of patients. Intermediate care unit admission was required for 48 patients for 1-2 days primarily for pain control, 2 patients post modified Ravitch procedure required ICU admission for one day as they were complaining of respiratory distress that was managed with nebulization and proper medications with no need for mechanical

ventilation. The median hospital stay duration was 9 (8- 10 days) for monitoring Hemodynamics, pain control, wound care and routine investigations "mainly CBC and Chest X ray". Statistical analysis revealed a positive correlation between hospital stay duration and the Haller index (Spearman's rho = 0.33, p = 0.026) (Figure 1). The correlation between age and hospital stay was positive but not statistically significant (Spearman's rho = 0.22, p = 0.124) (Figure 2).

Table 2: Operative and postoperative data of patients with chest wall deformity who underwent surgical correction

Variables	(n= 50)
Surgical technique	
Modified Ravitch	28 (56%)
Nuss procedure	22 (44%)
Postoperative complications	
None	45 (90%)
Pneumothorax	2 (4%)
Wound infection	3 (6%)
Hospital stay, days [Median (IQR)]	9 (8- 10)
Increased effort tolerance postoperative	46 (92%)
Recurrence	2 (4%)
Psychological satisfaction	47 (94%)
Postoperative assessment	
Poor	2 (4%)
Fair	2 (4%)
Good	25 (50%)
Excellent	21 (42%)

Pain management protocol:

In-hospital pain management

- Epidural catheter: Can deliver continuous pain medication, often a combination of a local anesthetic and opioid, during the first few days when pain is most severe.
- Intercostal nerve blocks: used to block pain signals from the nerves that run between the ribs.
- Intravenous pain control medications: Morphine or other IV medications are sometimes used for severe pain.
- Oral pain medication: As the epidural catheter is removed, oral medications and NSAIDs like ibuprofen are used to manage pain.

At-home pain management

- Oral medications: Patients will continue to take oral pain medications as prescribed.
- NSAIDs: These are continued to help manage pain and inflammation.
- Encouraged activities: Patients are encouraged to take deep breaths and walk short distances, as this helps with recovery.
- Restrictions: Patients will need to avoid activities like sleeping on their side or twisting their upper body to protect the healing chest.

Postoperative Assessment Outcomes

The primary outcome measure was the postoperative assessment score, graded on a four-point scale from poor to excellent. The overall distribution of outcomes was highly favorable, with 21 patients (42%) achieving excellent results, 25 patients (50%) achieving good results, 2 patients (4%) achieving fair results, and 2 patients (4%) achieving poor results

In modified Ravitch procedure, 28 patients were operated on with 11 patients achieving excellent results, 13 patients achieving good results, 2 patients achieving fair results, and 2 patients achieving poor results

In Nuss procedure, 22 patients were operated on with 10 patients achieving excellent results and 12 patients achieving good results

Complications and Adverse Events

The overall complications rate was "10% of cases", with most adverse events being minor and self-limited. Postoperative complications were documented in a small number of patients:

- Three patients experienced wound infections "6% of cases" that were successfully managed with antibiotic therapy and local wound care.
- Two patients developed pneumothorax "4% of cases"
  - One patient developed mild pneumothorax that was managed by High flow oxygen, Monitoring Respiratory rate and Oxygen saturation with serial follow up chest X ray with no need for intercostal tube insertion
  - The other patient developed moderate pneumothorax that was managed by intercostal tube insertion

Table 3: Factors associated with postoperative outcomes

Hospital stay	B (95% confidence interval)	P
Age	0.015 (-0.034- 0.064)	0.541
Sex	-0.128 (-0.332- 0.075)	0.215
Deformity	-0.144 (-0.429- -0.141)	0.323
Severity of the deformity	0.099 (-0.018- 0.22)	0.097
Haller index	2.37 (0.272- 4.47)	0.028
Surgical technique	-0.244 (-0.589- 0.102)	0.166
Postoperative assessment	**Odds ratio (95% confidence interval)**	**P**
Age	1.065 (0.793- 1.428)	0.675
Sex	1.42 (0.42- 4.804)	0.572
Deformity	0.931 (0.204- 4.24)	0.926
Severity		
Moderate	0.158 (0.038- 0.659)	0.011
Severe	0.015 (0.001- 0.157)	<0.001
Haller index	0.002 (0.0001- 0.056)	<0.001
Surgical technique	26.48 (1.37-513.01)	<0.001

- No major complications such as cardiac perforation, bar displacement (in Nuss procedure patients), or significant bleeding requiring reoperation were observed in this series (Table 2).

Short-term Outcomes

The recurrence rate was remarkably low, with only 2 patients (4% of the study population) developing recurrence of their deformity post modified Ravitch procedure during the follow-up period (6 months) with consideration of secondary surgical intervention

- Psychological satisfaction with surgical outcomes was achieved in 47 patients (94% of the study population).
- Increased effort tolerance following surgery was reported by 46 patients (92% of the study population).
- Patients with asthma-like symptoms reported improved symptoms after surgery.
- Follow-up period for each patient was 6 months that wasn`t enough for removal of Nuss bar as the bar should be removed after 2- 3 years

Regression Analysis

Regression analysis revealed that the Haller index was associated with prolonged hospital stay. No other preoperative factors had a positive association with the duration of hospital stay. Postoperative assessment was positively associated with disease severity and the Haller index (Table 3).

Discussion

This prospective study of 50 patients undergoing surgical correction of pectus deformities provides valuable insights into the effectiveness of different surgical approaches and highlights several important clinical findings.

The overall excellent outcome rate was 42% (21/50), with 50% achieving good outcomes and only 8% experiencing fair or poor results. This finding is consistent with contemporary literature reporting high success rates for pectus deformity correction and supports the continued use of surgical intervention for appropriately selected patients [16]. The low recurrence rate of 4% and high psychological satisfaction rate of 94% further underscore the effectiveness of surgical correction in this patient population.

The demographic characteristics of our study population align closely with established epidemiological data, with a male predominance of 76% and a mean age of 14.8 years reflecting typical patterns for surgical intervention. The predominance of pectus excavatum cases (86%) is

consistent with published literature indicating that this variant accounts for approximately 90% of all pectus deformities [17]. The presence of psychological disturbance in 96% of patients preoperatively emphasizes the significant psychosocial impact of these deformities and supports the inclusion of psychological factors in surgical decision-making [18].

The comparison between the Modified Ravitch procedure and the Nuss procedure revealed important differences in outcomes. The choice of surgical technique was based on surgeon preference and patient characteristics, potentially introducing selection bias. Patients selected for the Nuss procedure may have had more favorable anatomical features or less complex deformities [19].

The Modified Ravitch procedure demonstrated reliable results with 85.7% of patients +achieving good to excellent outcomes, consistent with established literature reporting success rates of 85-95% for this technique [20]. The longer operative times and more extensive tissue dissection associated with the Modified Ravitch procedure may contribute to increased postoperative pain and longer recovery times [21], as suggested by the correlation between deformity severity and hospital stay duration.

The high rate of increased effort tolerance (92%) following surgical correction provides important evidence for the functional benefits of pectus deformity repair. This finding supports the concept that these deformities can cause meaningful physiological impairment beyond cosmetic concerns and that surgical correction can provide tangible functional improvements. The correlation between Haller index and hospital stay duration (r=0.33, p=0.026) suggests that patients with more severe deformities experience greater surgical trauma and require longer recovery periods, supporting the use of objective severity measures in surgical planning.

The psychological satisfaction rate of 94% is particularly noteworthy given the significant psychological impact of pectus deformities documented in the literature. Studies have consistently shown that patients with pectus deformities experience higher rates of depression, anxiety, and social withdrawal, with many reporting limitations in social activities and sports participation [22]. The high satisfaction rate observed in our study suggests that surgical correction can effectively address these psychological concerns and improve quality of life.

The improvement in asthma-like symptoms observed in all affected patients provides additional evidence for the functional benefits of surgical correction. While the mechanism underlying this improvement is not fully understood, it may relate to improved chest wall mechanics and reduced airway compression, allowing for more effective ventilation patterns and reduced respiratory distress [23].

The low complication rate observed in our study (6% overall) is consistent with contemporary literature reporting complication rates of 5-15% for pectus deformity correction [24,25]. The absence of major complications such as cardiac perforation or significant bleeding reflects careful patient selection and meticulous surgical technique. The most common complications were wound infections and pneumothorax.

The requirement for Intermediate care unit admission in most patients for 1-2 days primarily for pain control rather than management of complications highlights the importance of effective pain management protocols in the postoperative period. The significant postoperative pain associated with chest wall reconstruction procedures necessitates multimodal pain management approaches and may benefit from enhanced recovery protocols to minimize hospital stay duration and improve patient comfort [26].

Limitations

Several important limitations of this study must be acknowledged. The small sample size, non-randomized design and unequal group sizes limit the ability to draw definitive conclusions about the comparative effectiveness of surgical techniques. The relatively short follow-up period “6 months” may not capture long-term

complications or late recurrences, particularly important for the Nuss procedure where bar-related complications can occur years after implantation or follow up after bar removal. The subjective nature of some outcome measures, particularly the postoperative assessment grading, introduces potential for bias despite attempts at standardization.

Conclusion

This prospective study found that both the Modified Ravitch and Nuss procedures are effective for pectus repair, with high success rates and low recurrence. Functional improvements, including increased effort tolerance along with high psychological satisfaction, highlight the benefits of surgical correction beyond cosmetic results.

The study underscores the importance of individualized surgical choice based on patient factors, surgeon expertise, and institutional resources. It also emphasizes the psychological impact of pectus deformities and the value of quality-of-life considerations in treatment decisions. Overall, both techniques are safe and effective. Surgical intervention remains highly beneficial for appropriately selected patients

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