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Original article

Surgical Repair of Congenital Chest Wall Deformity (Pectus Excavatum): A 20-Year Multicenter Experience

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Abstract
Pectus excavatum (PE), the most common congenital chest wall deformity, often worsens during adolescence and can lead to significant cardiopulmonary dysfunction in severe cases. This prospective, multicenter study evaluated the long-term outcomes of the modified Ravitch procedure over 20 years (2003–2023) at three tertiary care hospitals. A total of 100 patients with a Haller Index >3.2, symptomatic PE, or failed non-surgical management underwent the procedure, which included resection of deformed costal cartilages, sternal osteotomy, and selective bar insertion for additional support. Patient demographics, clinical symptoms, surgical outcomes, and complications were analyzed. The cohort consisted predominantly of males (79%), with an average age of 15.9 years. Symptoms included dyspnea (59%), chest tightness (11%), palpitations (4%), and chest pain (6%), while 26% were asymptomatic. Postoperative hospitalization averaged two days, with no significant differences in hospital stay or complication rates between bar-inserted (30 cases) and non-bar-inserted (70 cases) patients. Complications were minimal, including wound fluid accumulation (7%), infection (6%), pneumothorax (3%), and bar displacement (6.6% of bar-inserted cases). All patients demonstrated improvement in the Haller Index, and satisfaction rates were high, with no mortality reported. The study reaffirms the Ravitch procedure as a safe, effective, and durable solution for PE correction, offering both functional and cosmetic benefits. Its adaptability, low complication rates, and positive impact on quality of life make it a reliable option for patients with severe PE. Long-term follow-up supports its role as a gold standard in surgical management, with outcomes remaining stable over decades.
Keywords: *Pectus Excavatum, Chest Wall Deformities, Ravitch Procedure.*

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Introduction

Pectus excavatum (PE) is a congenital anomaly of the anterior chest wall, representing 90% of all chest wall deformities. It typically becomes more pronounced during the adolescent growth spurt, though severe cases are evident at birth. While often considered a cosmetic issue, severe PE can lead to cardiopulmonary dysfunction due to compression of the heart and lungs [1]. The Haller Index (HI), calculated from computed tomography (CT) measurements, is the gold standard for assessing PE severity. A normal HI is ≤2.5, whereas values >3.2 indicate a severe deformity requiring surgical correction. The decision for surgery is influenced by symptom severity, psychological impact, and failure of non-surgical interventions such as bracing or physical therapy [2].

The two main surgical approaches are: The Ravitch procedure, an open technique involving the resection of deformed costal cartilage, and sternal osteotomy. The Nuss procedure, is a minimally invasive approach using a retrosternal bar for correction. This study focuses on the Ravitch procedure and its modifications, evaluating outcomes over two decades in a multicenter setting.

Methods

Study Design and Setting

This is a prospective, multicenter study conducted over 20 years (January 2003 – December 2023) at: Abusetta Pulmonary Hospital, Abusaleem Trauma Hospital, and Sobrata Oncology Hospital.

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Patient Selection

A total of 100 patients diagnosed with PE were selected for the modified Ravitch procedure based on predefined inclusion and exclusion criteria.

Inclusion criteria

We have included patients diagnosed with PE and confirmed by clinical examination and imaging. Symptomatic patients (dyspnea, chest tightness, palpitations, or chest pain). Haller Index >3.2 on CT scan. Failure of non-surgical management (e.g., physical therapy, bracing). Patient and family motivation for surgical correction.

Exclusion criteria

Patients were excluded if they had the following; Severe comorbidities contraindicating surgery (e.g., cardiovascular or respiratory disease, bleeding disorders, uncontrolled pulmonary hypertension). 2). Active infections (respiratory or cutaneous at the surgical site). 3). Lack of patient or family motivation for surgery. Surgical Technique.

The Ravitch procedure was performed using a transverse incision over the most depressed area of the chest. The steps included: Resection of deformed costal cartilages (3rd–7th ribs bilaterally). Sternal osteotomy to reposition the sternum anteriorly. In selected cases, a metal bar was inserted for additional support.

Postoperative management

Patients were monitored for pain control, respiratory function, and early mobilization. The length of hospital stays and postoperative complications were recorded.

Results

A total of 100 cases were submitted to Ravitch procedure for Pectus Excavatum correction, 30 cases with indicated bar insertion, and 70 cases without bar insertion. Age was from 10 to 30 years (Table 1).

Table 1. Age distribution of the studied patients

Age (years)	Male	Female
10 - 15	16	4
16 -20	48	15
21-25	10	2
26 - 30	5	0
Percentage	79%	21%

The average age was 15.9 years. The male gender was predominating (79 cases) while the female gender was (21 cases). The age of diagnosis is varied, from birth (10 cases) to puberty (32 cases). Clinical symptoms were varied. 59 cases had shortness of breath after exercising. 11 cases had chest tightness, 4 cases had palpitation, and 26 cases were asymptomatic. Average of the postoperative hospitalization was 2 days. Each case had an improvement in the Haller index (Table 2).

Bar- inserted patients do not differ from non-bar-inserted patients in the length of hospital stay and rate of complications. The complication, within the first 3 months were, mild incision fluid accumulation (7 cases) wound infection (6 cases), pneumothorax (3 cases), Pleural fluid/Pleural bleeding (2 cases), pneumonia/atelectasis (2 cases), prolonged pain (1 case) and 2 cases with bar displacement (Figure 1). There were no deaths in the observation period. All patients or their parents were satisfied with the appearance of the chest wall after the procedure.

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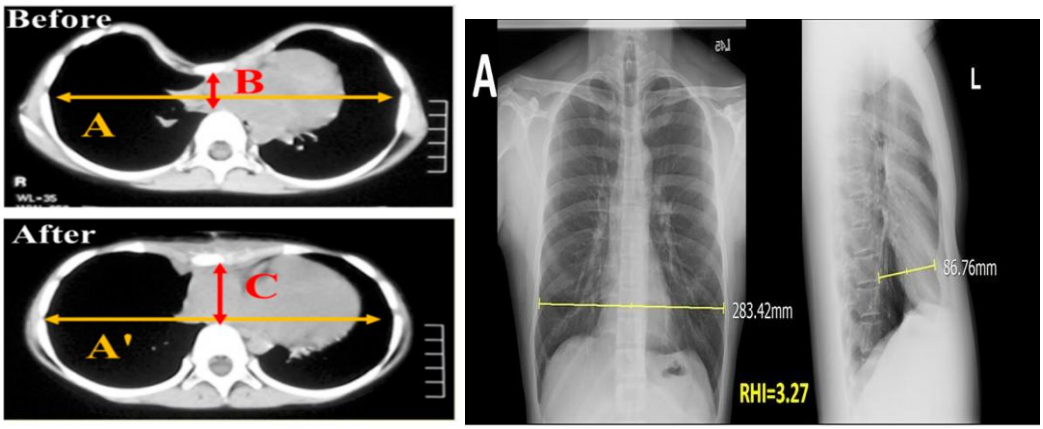

Figure 1. Respiratory complication

Table 2. Time Of P.E diagnosis of the studied patients

Time of P.E detection	Number of cases	percent
AT BIRTH	10	10%
Childhood	58	58%
Puberty	32	32%
Total	100	100%

Table 3. History of previous surgery of pectus excavatum among studied patients

Previous P.E Surgery	Number of paients	Percentage
Previous surgery	8	8%
No previous surgery	92	92%

Table 4. Symptom of the studied patients.

Symptom	Frequency	Percent
Asymptomatic	26	26%
Shortness of breath	59	59%
palpitation	4	4%
chest tightness	5	5%
Chest pain	6	6%
Total	100	100%

Table 5. Length of postoperative hospitalization

Duration	Number of Patients	percentage
2 day	70	70%
3days	25	25%
4 days	5	5%
Total	100	100%

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Table 6. Post operative complications among studied patients

Complication	Number Of Patients	Percentage
Pneumothorax	3	3%
Hemothorax	1	1%
Wound - fluid Collection	7	7%
Wound Infection	6	6%
Pneumonia or Atelectasis	2	2%
Prolonged Pain	1	1%
Bar Displacement	2	2 out of 30 6%

Table 7. Time of Bar Removal Among 30 Studied Patients

Time (months)	Number of patients	Percentage
6	1	3.3%
12	8	26.6%
18	12	40%
24	5	16.6%
Lost patient	4	13.3%

Discussion

The Ravitch procedure has demonstrated excellent long-term outcomes for PE correction. The procedure provides a reliable and permanent correction of the deformity while alleviating associated symptoms. The inclusion of bar insertion in select cases did not significantly alter hospital stay or complication rates. Despite a low but acceptable complication rate, outcomes were overwhelmingly positive, with high patient satisfaction and improved self-esteem. The study's long-term follow-up further supports the procedure's efficacy and durability.

The Ravitch procedure has indeed established itself as a highly effective surgical intervention for the correction of pectus excavatum (PE), with extensive evidence supporting its long-term success. The procedure, which involves the resection of abnormal costal cartilages and sternal osteotomy, provides a robust structural correction that is both reliable and permanent. This not only addresses the physical deformity but also significantly alleviates associated symptoms such as chest pain, respiratory limitations, and cardiac compression, which are often observed in severe cases of PE. The durability of the correction is particularly noteworthy, as the procedure has been shown to maintain its effectiveness over decades, with minimal risk of recurrence.

The inclusion of bar insertion in select cases, particularly for patients with more severe deformities or those requiring additional stabilization, has been a topic of interest. Interestingly, studies have shown that the addition of bar insertion does not significantly impact hospital stay duration or complication rates. This suggests that the procedure can be tailored to individual patient needs without compromising safety or recovery timelines. The ability to customize the surgical approach based on the severity of the deformity and patient-specific factors further enhances the versatility of the Ravitch procedure.

Complication rates associated with the Ravitch procedure are generally low, with the most common issues including pneumothorax, wound infections, and seroma formation. These complications are typically manageable and do not detract from the overall success of the procedure. Importantly, the overwhelming majority of patients report high levels of satisfaction post-surgery, with significant improvements in both physical function and psychological well-being. The correction of the chest deformity often leads to enhanced self-esteem and body image, which can have a profound impact on the patient's quality of life, particularly in adolescents and young adults who may have experienced social stigmatization or psychological distress due to their condition.

Long-term follow-up studies have further solidified the Ravitch procedure's reputation as a durable and effective treatment for PE. These studies have demonstrated that the structural corrections achieved through the procedure remain stable over time, with no significant deterioration in outcomes. Additionally, the procedure has been shown to have a positive impact on cardiopulmonary function in patients who presented with pre-operative impairments, further underscoring its comprehensive benefits.

In summary, the Ravitch procedure stands out as a gold standard for PE correction, offering a permanent solution with excellent long-term outcomes. Its ability to address both the physical and psychological aspects of the deformity, coupled with its low complication rates and high patient satisfaction, makes it a highly reliable option for patients seeking correction of pectus excavatum. The procedure's adaptability, including the selective use of bar insertion, ensures that it can be tailored to meet the unique needs of each patient, further enhancing its efficacy and appeal.

Conclusion

The Ravitch procedure remains a highly effective surgical option for PE correction, providing both functional and cosmetic benefits. Our 20-year multicenter experience confirms its safety, favorable outcomes, and positive impact on quality of life.

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