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Ten years of clinical experience in the open surgical treatment of chest wall deformities

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Abstract

Background: This study aimed to present a 10-year single-center experience and evaluate perioperative and mid-term outcomes of open and combined surgical treatment for chest wall deformities.

Methods: A total of 45 patients treated between January 2011 and December 2021 were retrospectively analyzed for age, sex, deformity type, surgical procedure, complications, hospital stay, and patient satisfaction. Statistical analyses were performed.

Results: The cohort included 32 males and 13 females with a mean age of 14.14 years (median: 15, range: 12-20). Pectus carinatum was the most common deformity. Open surgery alone was performed in 31 patients (68.9%), combined with the Nuss procedure in 13 (28.9%), and with the Abramson procedure in 1 (2.2%). A significant association was found between deformity type and surgical method. The mean hospital stay was 4.22 days (median: 4, range: 2-10). Early complications occurred in 6.7% of patients, while recurrence was observed in 4.4%. Postoperative satisfaction scores were significantly higher than preoperative scores.

Conclusion: Open surgery is an effective and reliable option for chest wall deformities, particularly in complex cases. Although minimally invasive techniques have advantages, surgical choice should be individualized based on patient age, deformity type, and surgical history.

Keywords: Pectus carinatum, Ravitch procedure, deformity, chest wall.

Chest wall deformities are characterized by abnormal development of the sternum and ribs. Pectus excavatum (PE), occurring in approximately 1 in 300-400 births, and pectus carinatum (PC), seen in 1 in 1.000-10.000 births, are the most common types.[1,2] Beyond cosmetic concerns, these deformities may impair respiratory and cardiac function, requiring surgical correction.

Pectus surgery was first described by Meyer[3] and later refined by Ravitch[4] with subperichondrial resection of costal cartilages and sternal osteotomy, a technique that remains the standard open approach. Minimally invasive techniques were subsequently introduced, including the Nuss et al.[5] procedure for PE and the Abramson et al.[6] procedure for PC. However, not all patients are suitable for minimally invasive methods, and open surgery remains necessary, particularly in complex or mixed deformities. Combined approaches have further improved outcomes.

This study aimed to present our experience with open surgical treatment of chest wall deformities.

Methods

Between January 2011 and December 2021, 45 patients who underwent open surgery for PC, pectus excavatum, or mixed-type deformities at Dokuz Eylül University were included. Mixed-type deformities were defined as the simultaneous presence of PE and PC components within the same chest wall, as confirmed by clinical evaluation and thoracic computed tomography. Patients under 12 years were excluded, as non-surgical treatments (vacuum bell or orthotic therapy) are preferred in this group due to chest wall flexibility. Combined surgical procedures were preferred in patients with complex deformities characterized by marked asymmetry, mixed-type morphology or increased chest wall rigidity; in these cases, open correction was combined with bar-supported methods (Nuss or Abramson) to optimize structural and cosmetic outcomes.

All patients were preoperatively evaluated with physical examination, laboratory tests, pulmonary function tests, electrocardiography, and three-dimensional thoracic CT; echocardiography was performed when indicated.

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Open surgery was performed under general anesthesia in the supine position. A vertical incision was made over the deformity, and pectoral muscles were elevated. Deformed costal cartilages were resected subperichondrially, and sternal wedge osteotomy was performed when necessary. Chest wall stabilization was achieved using sternal and/or costal titanium plates.

In selected cases, combined procedures were performed in the same session using additional bilateral anterior axillary incisions for Nuss or Abramson techniques. After stabilization, the perichondrium was closed, and a hemovac drain was placed. Intrathoracic air evacuation or thoracic drainage was applied when required. Following hemostasis, tissues were closed anatomically.

Patients were retrospectively analyzed for demographic and clinical variables, including deformity type, surgical procedure, number of incisions and resected ribs, instrumentation use, hospital stay, satisfaction, and recurrence.

Patient satisfaction was assessed using a 1-5 Likert scale during preoperative evaluation and postoperative follow-up visits. All cases were seen on postoperative day 10, month 1, and year 1. Surveys were administered face-to-face when patients came for follow-up. Cases that underwent concurrent Nuss or Abramson surgery were re-evaluated one year after bar removal. Patients who completed their one-year follow-up and were discharged were contacted, invited to the clinic, and interviewed in person. For cases unable to reach the clinic, the survey was administered via telephone calls and through a thoracic surgeon. A single survey was administered during the postoperative period. This survey included questions related to both preoperative and postoperative periods. And apart from routine postoperative check-ups, the follow-up period averaged 3 years (2-7 years).

Statistical Analysis

Statistical analyses were performed using IBM SPSS v29.0. Data distribution was assessed with the Shapiro-Wilk test. Continuous variables were expressed as mean ± SD or median (min-max), and categorical variables as number and percentage. Student's t-test or Mann-Whitney U test was used for group comparisons, while chi-square or Fisher's exact test was applied for categorical variables. Pearson or Spearman correlation analyses were performed as appropriate. A p-value <0.05 was considered statistically significant.

Ethical approval was obtained from the Dokuz Eylül University Non-Interventional Research Ethics Committee (approval number: 2024/16-12; date: 08.05.2024). Due to the retrospective nature of the study, informed consent from the patients was not required.

Results

Of the 45 cases included in the study, 32 were male and 13 were female. When the deformity types were examined, 22 patients had PC, 13 patients had mixed-type deformity, and 10 patients had pectus excavatum. The mean age was 14.14 years, and the median age was 15 (12-20).

Open surgery alone was performed in 31 patients (68.9%), open surgery + Nuss procedure in 13 patients (28.9%), and open surgery + Abramson procedure in one patient (2.2%) (Figure 1).

Among patients undergoing open surgery alone, three (9.7%) had a prior Nuss procedure, with revision needed due to over-correction. One patient required additional rib resection during follow-up (Figure 2). In the open + Nuss group, no prior surgeries were reported, while in the open + Abramson case, a second rib resection was performed due to recurrence.

The number of incisions ranged from 1 to 3, depending on the procedure. In all 14 patients undergoing combined open + bar surgery, a single bar was used, with an average length of 271.8 mm (median: 280, range: 260-300 mm).

Surgical procedure distribution by deformity type is shown in Table 1. A significant association was found between deformity type and the choice of open versus combined surgery (p=0.002), with combined interventions more common in mixed-type deformities.

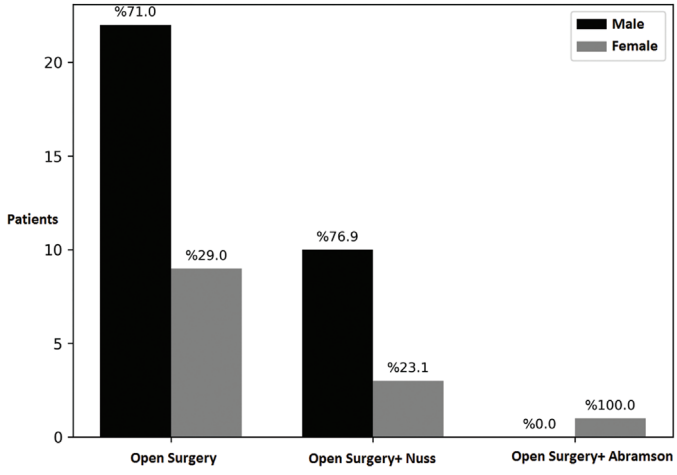


Figure 1. Distribution of the surgical procedures performed according to sex.

(Open surgery: 22 males, 9 females; Open + Nuss: 10 males, 3 females; Open + Abramson: 0 males, 1 female. Percentages indicate the distribution within each surgical method).

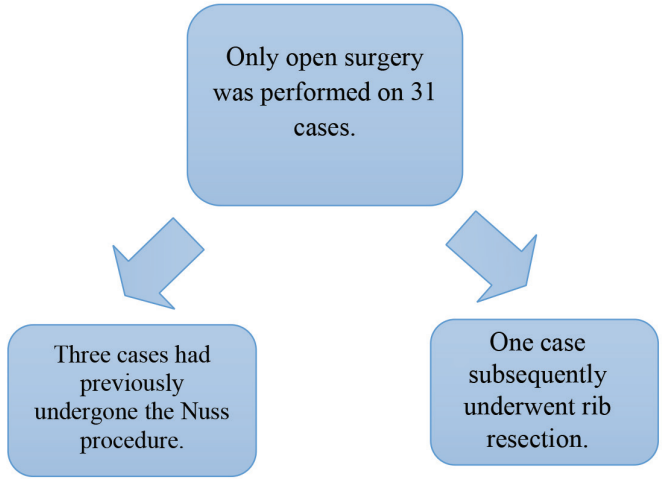


Figure 2. Additional surgical requirements in patients who underwent isolated open surgery.

In the open surgery group, sternal wedge osteotomy was performed in 25 patients, and partial rib resection in 40, with an average of 3.44 ribs removed (median: 3, range: 1-8). No significant relationship was observed between deformity type and the use of sternal osteotomy (p=0.81) or rib resection (p=0.351) (Table 1).

Titanium plates were used in all patients for chest wall stabilization. A total of 91 plates were placed; the average number of plates per patient was 2.28 (median: 2; range: 1-6). No plate-related complications such as migration, exposure, or need for removal were observed during the follow-up period. Furthermore, no bar-related complications, including bar migration or the need for bar removal, were observed in either the early or late postoperative period.

The mean hospital stay was 4.22 days (median: 4; range: 2-10). In patients who underwent isolated open surgery, the average hospital stay was 5.18 days (median: 5; range: 3-8), whereas in patients who underwent combined procedures, it was 3.96 days (median: 4; range: 2-10). A statistically significant difference in hospital stay was observed between the groups (p=0.025).

All cases except one were monitored postoperatively without drains. The patient who required a drain had a mixed deformity and underwent open surgery + Nuss. Early complications (in the first postoperative month) occurred in three patients (6.7%) as pneumothorax, which resolved with nasal oxygen therapy without requiring invasive intervention. No significant relationship was found between early complication development and deformity type or the surgical procedure applied (p=0.558; p=0.870; p=0.682) (Table 2).

Late complications occurred in two patients (4.4%) as recurrence. Recurrence developed in one patient who underwent isolated open surgery at the 22nd postoperative month, and in one patient who underwent open surgery + Abramson at the 26th postoperative month. Revision rib resection was performed in both patients. No significant relationship was found between late complications and deformity type or the surgical method applied (p=0.682) (Table 3).

Patient satisfaction was evaluated using a 1-5 point scale. The mean preoperative satisfaction score was 2.20 (median: 2; range: 1-3), and the mean postoperative satisfaction score was 4.70 (median: 5; range: 3-5). There was a statistically significant difference between preoperative and postoperative scores (p<0.001). The mean postoperative score was 4.69 in the isolated open surgery group and 4.72 in the combined surgery group, with no significant difference between the groups (p=0.860).

Table 1. Distribution of surgical methods and resections according to deformity type

Surgery	Deformity	Procedure	n
Open	PC	Wedge + RR	9
Open	PC	RR	10
Open	PE	Wedge + RR	2
Open	PE	RR	8
Open	Mixed	Wedge + RR	2
Open+N	PC	Wedge + RR	2
Open+N	PE	Wedge + RR	1
Open+N	PE	Wedge	2
Open+N	PE	RR	2
Open+N	Mixed	Wedge + RR	3
Open+N	Mixed	Wedge	3
Open+A	PC	Wedge + RR	1

p=0.002 (Fisher's exact test); PC: Pectus carinatum; PE: Pectus excavatum; RR: Rib resection; N: Nuss; A: Abramson.

Discussion

Minimally invasive techniques are often preferred in chest wall deformity surgery; however, treatment should be individualized based on age, deformity type, chest wall rigidity, and anatomical location. In younger patients with mild deformities, conservative methods such as vacuum bell or orthoses are prioritized.[7-9] In contrast, patients over 12 years of age, with rigid chest walls or unsuccessful non-surgical treatment, benefit more from surgical intervention. In our series, the average age was calculated as 14.14, which is consistent with the literature.

The Nuss and Abramson procedures rely on chest wall elasticity, and their effectiveness decreases in rigid thoraxes, highlighting the role of open surgery.[10] Open techniques allow anatomical correction through cartilage resection and sternal repositioning and are preferred in severe, asymmetric, or complex deformities.

Resection extent in open surgery should be tailored to deformity characteristics while preserving chest wall stability.[11] Post-Ravitch instability remains a concern, as cartilage regeneration may be insufficient, leading to complications such as malunion or pseudoarthrosis.[12]

To enhance stability, rigid fixation systems are increasingly used. While Kirschner wires were used previously, titanium plates now provide more reliable stabilization, with favorable outcomes reported in the literature.[13,14] In our practice, titanium plates are preferred in cases requiring sternal osteotomy or extensive resection, applying a rib-sparing approach to preserve chest wall mobility.

A meta-analysis of 1.432 patients from 13 studies reported that open surgery in adults may be more advantageous than minimally invasive methods in terms of early complications and recurrence, likely due to increased chest wall rigidity.[15] Similarly, Buchwald et al.,[16] in a series of 98 cases, demonstrated that the Ravitch procedure can provide durable correction, particularly in mixed-type deformities (Picture 1).

Reported complication rates after open surgery vary in the literature. Recurrence rates of 8.4% in PC and 10.7% in PE have been reported, with postoperative complication rates around 5.3%.[17,18] Pneumothorax, which we also saw in our cases and which can be seen as an early complication, was reported as 3.4% in the pediatric age group and 4.6% in the adult age group in a meta-analysis.[19] In our study, early pneumothorax was observed in 6.7% of patients and late recurrence in 4.4%, consistent with previous reports.

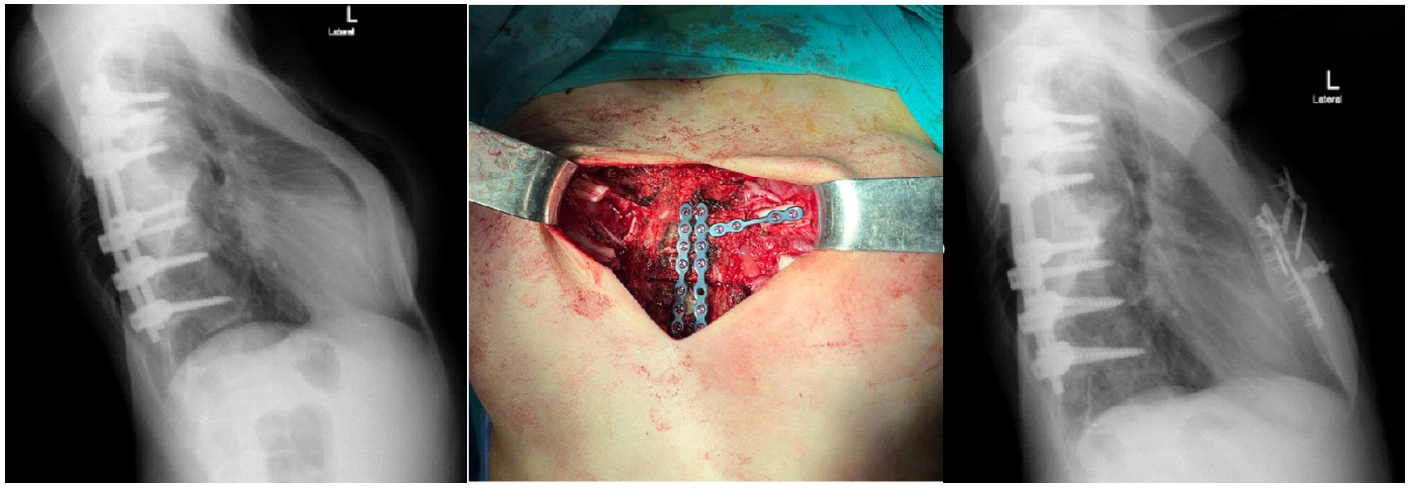
In a study evaluating 68 cases, 25 of which underwent open surgery and 43 of which underwent minimally invasive surgery, the mean hospitalization time was calculated as 4.4 days in the group that underwent open surgery and 2.4 days in the group that underwent minimally invasive surgery, and it was stated that there was no statistically significant difference between the two groups.[15] In our cases, the mean hospitalization time was calculated as 4.2 days, which supports the literature.

Table 2. Distribution of early complications according to surgical method

Surgery	Complication (+)	Complication (-)	Total
Open	2	29	31
Open+N	1	12	13
Open+A	0	1	1
Overall early complication rate: 6.7% (n=3), p>0.05 (Fisher's exact test); N: Nuss; A: Abramson.			

Table 3. Distribution of late complications (recurrence) according to surgical method

Surgery	Recurrence (+)	Recurrence (-)	Total
Open	2	29	31
Open+N	0	13	13
Open+A	0	1	1
Overall late complication rate: 4.4% (n=2), p=0.682 (Fisher's exact test); N: Nuss; A: Abramson.			



Picture 1. Case of pectus arcuatum treated with Ravitch procedure, sternal wedge osteotomy, and rib resection, with sternal fixation using a titanium plate (preoperative radiograph, intraoperative view, postoperative radiograph).

Comparative studies indicate high patient satisfaction with both open and minimally invasive techniques.[17] In a study in which 69 patients who underwent Ravitch treatment were evaluated in the postoperative period, the mean satisfaction score was reported as 4 on a scale of 1-5 points.[20] In our series, the mean satisfaction score increased significantly from 2.20 preoperatively to 4.70 postoperatively. No significant difference was observed between surgical methods, suggesting that both approaches can achieve favorable aesthetic and functional outcomes with appropriate patient selection.

This study has several limitations. First, its retrospective design may be associated with inherent selection bias. Second, it reflects a single-center experience with a relatively limited sample size, which may affect the generalizability of the findings. However, it also provides a consistent surgical approach and homogeneous patient management. Third, although follow-up duration was sufficient to capture early and mid-term outcomes, longer-term results would further strengthen the conclusions. Finally, the absence of a randomized comparison between surgical techniques limits definitive comparisons, although the study offers valuable real-world clinical insights. Open surgery remains an effective and reliable option for chest wall deformities, particularly in complex cases, with high correction rates and improved patient satisfaction. Complication rates were comparable to the literature. However, larger prospective studies are needed to confirm long-term outcomes.

Ethics

Ethics Committee Approval: Ethical approval was obtained from the Dokuz Eylül University Non-Interventional Research Ethics Committee (approval number: 2024/16-12; date: 08.05.2024).

Informed Consent: Due to the retrospective nature of the study, informed consent from the patients was not required.

Footnotes

Authorship Contributions

Surgical and Medical Practices: V.K., F.M., E.K., İ.K., A.Ş.; Concept: V.K., F.M.; Design: V.K., F.M., A.Ş.; Data Collection or Processing: F.M., E.K.; Analysis or Interpretation: F.M., E.K.; Literature Search: F.M., İ.K.; Writing: F.M., A.Ş., V.K.

Conflict of Interest: No conflict of interest was declared by the authors.

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