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Postoperative outcomes after minimally invasive repair of pectus excavatum in children

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Pectus excavatum is the most common chest wall deformity due to the depression of the sternum. It is more common in males, and its incidence is approximately 1 in 300 to 400 live births.[1] In 1998, Nuss et al.[2] introduced a minimal invasive method performed by placing a substernal bar under guidance through thoracic incisions made from both sides without resection of the cartilage and sternum for pectus excavatum repair. Since then, the Nuss procedure has undergone various modifications by surgeons. Minimally invasive repair of pectus excavatum (MIRPE) is a safe and effective procedure with physical and psychosocial benefits.[3] This study aimed to evaluate the complication rates and surgical results with follow-up data after 18 years of clinical experience in MIRPE.

PATIENTS AND METHODS

Patients who underwent MIRPE at the Department of Pediatric Surgery of the

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Abstract

Objectives: This study aims to evaluate the postoperative outcomes of 18 years of clinical experience in minimally invasive repair of pectus excavatum (MIRPE).

Patients and methods: Ninety-four patients (73 males, 21 females; mean age: 12.6±3.7 years; range, 3 to 18 years) who underwent MIRPE between June 2006 and January 2024 and whose metal bars were removed after the treatment period were included in the study. The patient files were retrospectively reviewed in terms of demographic characteristics, clinical findings, radiological findings, and postoperative complications.

Results: Preoperative cardiac anomalies were present in 61% of the patients. Two patients had ventricular compression due to deformity. The mean preoperative Haller index was 4.06±1.46. Except for one patient who was placed double metal bars, all patients received a single bar and bilateral stabilizers. The mean operation time was 85±23.5 min. Postoperative complications were observed in 18 (19%) patients. These complications were bar dislocation (n=11, 11.7%), pneumothorax (n=4, 4.3%), wound infection (n=4, 4.3%), postoperative persistent pain (n=4, 4.3%), wound hematoma (n=3, 3.2%), stabilizer dislocation (n=2, 2.1%), intraoperative chest wall bleeding (n=1, 1.1%), allergy (n=1, 1.1%), pericarditis (n=1, 1.1%), bar infection (n=1, 1.1%), and pleural effusion (n=1, 1.1%). Patients with complications had higher Haller index or higher cardiac anomalies compared to patients without complications ($p<0.05$). The mean time for removal of the metal bar was 26±5.3 months. In two cases, the bar was not replaced after removal due to complications. Seven patients had recurrence after bar removal, six of whom were followed conservatively, and one underwent reoperation. Half of the patients with depression of sternum were among those who had developed complications. The mean follow-up time after bar removal was 50.7±43.4 months.

Conclusion: In children, MIRPE can be safely performed with better surgical outcomes and fewer complications.

Keywords: Chest wall deformity, minimally invasive repair, pectus excavatum.

Bursa Uludağ University Faculty of Medicine between June 2006 and January 2024 and whose metal bars were removed after the treatment period were included in the study. Thirty patients whose metal bar removal was not completed between this period were excluded from the study. Ninety-four patients (73 males, 21 females; mean age: 12.6±3.7 years; range, 3 to 18 years) were retrospectively evaluated in terms of demographic characteristics, clinical findings, radiological findings, and postoperative complications. All patients applying due to pectus excavatum were evaluated by physical examination, pulmonary function test (PFT), echocardiography, and computed tomography (CT). A decision for surgery was made in cases where one or more of the following conditions were present: a Haller index of ≥3.25 on CT, dissatisfaction with the cosmetic appearance due to pectus excavatum, dyspnea, or cardiac compression. Written informed consent was obtained from the parents and/or legal guardians of the patients. The study was approved by the Bursa Uludağ University Health Research Ethics Committee (Date: 03.04.2024, No: 2024/5-6). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Figure 1. Measuring of chest deformity and selecting appropriate metal bar length.

Surgical technique

All patients underwent pectus excavatum repair with a minimally invasive method. Patients were placed in supine position. The bar was shaped according to each patient's chest wall deformity (Figures 1, 2). Skin incisions 3.5- to 4-cm in length were performed on both sides of the thoracic wall, at the level of middle axillary lines (Figure 3). After bilateral incisions were made, a subcutaneous tunnel was created up to the entry point of the bar into the thorax and for the area where the

Figure 2. Shaping of metal bar.

Figure 3. Skin insicions.

stabilizers would be fixed. Bilateral 5-mm trocars were placed. A videothoracoscope was inserted into the thorax with carbon dioxide insufflation from the left thorax. With the help of a 5-mm curved laparoscopic dissector, a tunnel was created between the sternum and the pericardium, with the tip of the dissector in contact with the sternum (Figures 4a, b). Tunneloscopy was performed and the laparoscopic dissector was passed to the opposite thorax under thoracoscopic vision. For guidance, the vascular tape was passed from the insertion point of the bar on the right side to the thorax with a dissector and was taken out of the thorax from the insertion point of the bar on the left side under thoracoscopic vision. The bar was guided using vascular tape through the appropriate intercostal spaces, passing them through the thoracic cavity along a previously created retrosternal tunnel. The bars were then rotated to push up the depressed chest wall (Figure 5a). The bar was fixed with a double stabilizers with 2/0 nonabsorbable suture passing on the chest wall muscles (Figure 5b).

Patients were provided with perioperative serratus block and patient-controlled analgesia (peripheral continuous morphine infusion) for postoperative pain management. If the pain continued after the first postoperative month, it was considered persistent pain. The patients were immobilized for three to five days postoperatively. Exercise was prohibited until the removal of the bar. On average, the bar remained in the patient for approximately two years, then removed under general anesthesia during an outpatient procedure.

Statistical analysis

Statistical analyses were performed with IBM SPSS version 28.0 software (IBM Corp., Armonk, NY, USA). Results were presented as median (min-max) or frequency and percentage. The Mann-Whitney U test was used for nonnormally distributed data. Results between categorical variables were compared using the chi-square test and Fisher exact test. A p-value of <0.05 was considered statistically significant.

RESULTS

The most common complaint at the presentation was depression of sternum (n=60). Other complaints included dissatisfaction with the cosmetic appearance due to pectus excavatum (n=51), dyspnea (n=17), and chest pain (n=2). Twenty-nine patients were incidentally detected in other departments and referred to our department. The patients were diagnosed with pectus excavatum by physical examination and CT. The mean preoperatively measured Haller index was 4.06±1.46.

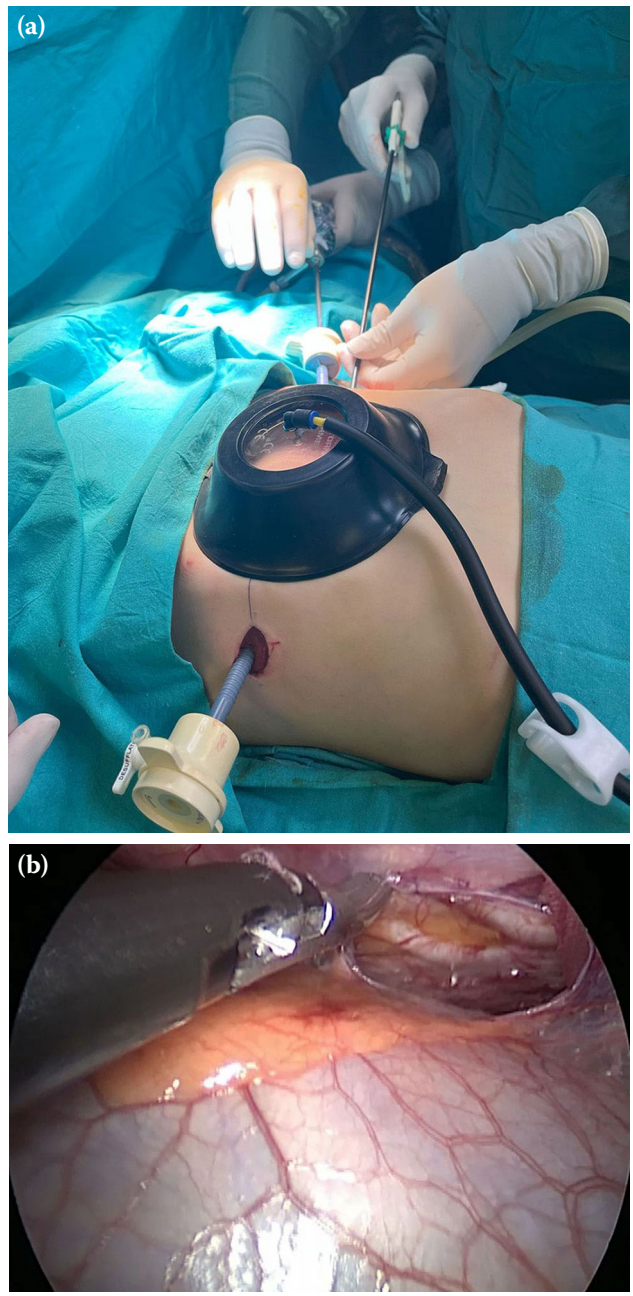

Figure 4. **(a)** Creation of tunnel for metal bar passage under thoracoscopic vision. **(b)** Thoracoscopic view of the tunnel between the sternum and the pericardium while the tip of the dissector was in contact with the sternum.

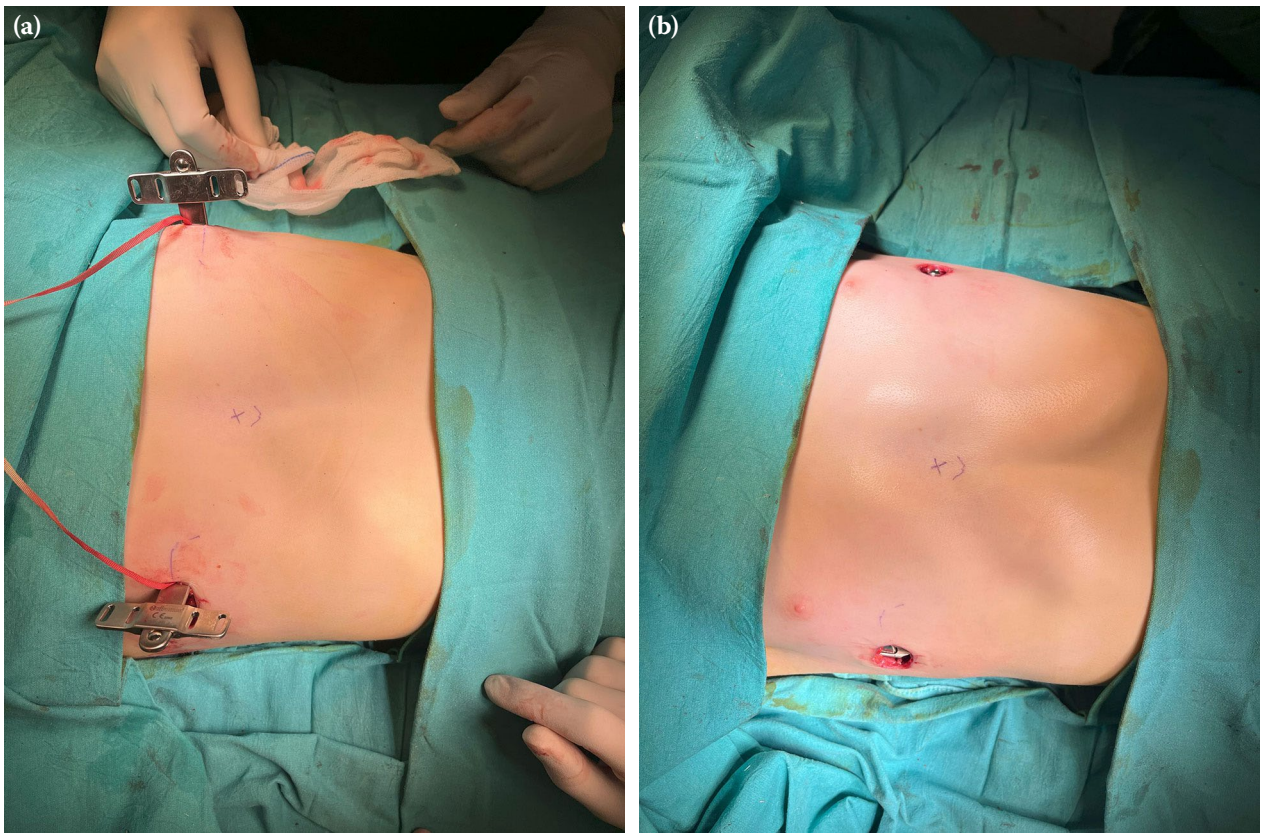

Figure 5. **(a)** Elevation of the sternum by rotating the metal bar. **(b)** Fixation of the stabilizers and final imaging of the chest.

Pulmonary function tests were performed on 49 patients [abnormal PFTs (n=6), normal PFTs (n=41), discordant PFTs (n=2)]. Comorbidities included Marfan syndrome (n=5), scoliosis (n=5), tethered cord (n=1), Poland syndrome (n=1), cerebral palsy (n=2), and anal atresia (n=1).

TABLE 1
Number and percentage of postoperative complications

	n	%
Metal bar dislocation	11	11.7
Pneumothorax	4	4.3
Site infection	4	4.3
Postoperative persistent pain	4	4.3
Wound hematoma	3	3.2
Stabilizer dislocation	2	2.1
Intraoperative chest wall bleeding	1	1.1
Allergy	1	1.1
Pericarditis	1	1.1
Bar infection	1	1.1
Pleural effusion	1	1.1

At least one cardiac anomaly was present in 61% of the patients. Two patients had ventricular compression due to deformity. Anomalies detected on echocardiography included mitral valve prolapse (n=39, 42%), mitral insufficiency (n=21, 22%), tricuspid insufficiency (n=7, 8%), aortic root dilatation (n=5, 5%), atrial septal defect (n=3, 3%), pulmonary insufficiency (n=3, 3%), patent foramen ovale (n=2, 2%), bicuspid aorta (n=2, 2%), pulmonary stenosis (n=2, 2%), aortic stenosis (n=2, 2%), tricuspid stenosis (n=1, 1%), ventricular septal defect (n=1, 1%), and aortic insufficiency (n=1, 1%).

Except for one patient who received double metal bars, all patients received a single bar and a double-sided stabilizer. The mean operation time was 85±23.5 min. Postoperative complications

TABLE 2
Comparison of patients with and without complications

	Patients with complications (n=18)				Patients without complications (n=76)				
	n	%	Median	Min-Max	n	%	Median	Min-Max	*p*
Age at the time of operation (year)			14	5-17			13.5	3-18	0.306
Sex Male Female	 17 1				 56 20				0.059
Haller index			3.9	3.08-8.7			3.47	2.30-11	**0.025**
Cardiac anomaly	15	83			42	55			**0.028**
Operation time median minutes			75	60-130			87.5	45-180	0.729
Length of hospital stay median days			5	4-19			5	3-7	0.130
The median time in month the bar remained inside the patient			25	1-35			25	23-37	0.274
Recurrens after bar removal		3	17		4	5			0.074

were observed in 18 (19%) patients (Table 1). The most common complication was metal bar dislocation (11.7%). Of the 11 patients with metal bar dislocation, six had bar revision, one patient was followed up without revision, one patient had a revision with double bars, one patient had a revision and bar removal after revision, one patient had a revision and subsequent bar removal due to bar infection + pleural effusion, and one patient had bar removal + Rawitch procedure. Two patients had stabilizer dislocation, and revision was performed for refixation.

In the case of intraoperative bleeding at the trocar entry site on the chest wall, the bleeding was controlled by enlarging the incision. In four patients who developed pneumothorax, postoperative needle aspiration was applied, and no chest tube was placed. One patient had skin lesions in the area where the metal bar was located and underwent allergy testing for the content of the bar, but no causative agent was found. The allergic reaction was controlled with steroid and antihistamine treatment.

Patients who developed complications had a higher Haller index and a higher incidence of additional cardiac anomalies compared to those who did not develop complications ($p<0.05$) (Table 2). The mean time for removal of the metal bar was 26±5.3 months. The mean follow-up time after removal of the metal bar was 50.7±43.4 months. There were six (6%) patients who had mild depression of the sternum after removal of the metal bar. One patient required reoperation due to recurrence during follow-up, and MIRPE was performed. Following removal of the bar after two years, the patient was satisfied with the cosmetic appearance. The mean time for removal of the bar in patients with recurrence was 29.4±3.6 months. Half of the patients with recurrence were among those who developed complications. Data for three patients could not be reached, and 82 patients were satisfied with their cosmetic appearance.

DISCUSSION

Pectus excavatum is the most common congenital chest wall deformity observed in the pediatric population.[4] It is characterized by a sunken appearance of the anterior chest wall and affects the heart and lungs depending on the severity of compression.[4] The frequency of cardiac anomalies increases in patients with pectus excavatum along with the accompanying syndromes.[5] The incidence of mitral valve prolapses that are observed in 1% of the normal population varies between 17 and 59% in patients with pectus excavatum.[6,7] In our study, 42% of the patients had mitral valve prolapse. However, the relationship between postoperative complications and cardiac anomalies is unknown. In our

study, the frequency of cardiac anomalies was significantly higher in cases with complications.

The Nuss procedure, the first minimally invasive method in patients of all ages, has undergone various modifications by surgeons to prevent any life-threatening complications. These modifications are related to the use of thoracoscopy, incision sites, bar size, placement method, and fixation and passage of the bar.[8] Tunneloscopy aims to prevent cardiac and vascular injuries when placing the metal bar.[9] No intraoperative major injuries were observed in our study. We believe that placing the bar under thoracoscopy, tunneloscopy, and the use of a vascular tape for guidance in all patients reduced major complications. Furthermore, elevating the sternum during surgery can prevent major injuries when creating the tunnel and placing the metal bar.[8]

Although minor and major complication rates related to the MIRPE vary between 5 and 27%, the most common complication is bar dislocation.[9-14] The complication rate in our study was 19%, and bar dislocation was observed in 11% of the patients. In the early period, double bar application to reduce bar dislocation and fixation of stabilizers to the chest muscle wall with nonabsorbable sutures are important in terms of preventing bar migration, but despite many modifications, there is no single perfect method to prevent dislocation.[9] In our study, a double bar was applied to one patient, while revision was made in other patients.

Factors such as the severity of pectus excavatum, surgeon experience, use of thoracoscopy, shape and length of the bar, fixation of the stabilizer, and flexibility of the chest wall affect postoperative complications.[10-12] Studies on the effect of Haller index on postoperative outcomes have not revealed a clear relationship.[13,14] However, Media et al.'s[15] study of 2013 pectus excavatum patients consisting of children, adolescents, and adults revealed that complications increase with increasing age and a Haller index above 5. In our study, the Haller index was significantly higher in patients with complications.

Recurrence after the Nuss procedure is less than 1%.[16,17] To reduce the risk of recurrence, the bar should remain in the patient for at least two years. In our study, the mean bar removal time was 29.4±3.6 months, with 1% reoperation due to recurrence, and 6% mild depression after bar removal.

This study has several limitations, including its retrospective design and the lack of a comparative analysis. Future prospective studies are warranted to compare the MIRPE technique with various surgical modifications and alternative approaches in order to more comprehensively evaluate its efficacy and outcomes.

In conclusion, the use of thoracoscopy is important to prevent complications in the MIRPE, which can be used with satisfactory results in children. It is necessary for the surgical stages to be in accordance with general principles to prevent the development of complications. The Nuss procedure can be safely performed in the pediatric age group, when the chest wall is more flexible, allowing for better surgical results with fewer complications, particularly when considering the modifications that have occurred over time.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Idea/concept, control/supervision, references: A.P., A.N.G.; Design, materials, literature review: A.P., Ş.N.S., F.Ç.; Data collection and/or processing, writing the article, analysis and/or interpretation: A.P., Ş.N.S., H.B., S.Ö.; Critical review: A.N.G.

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