

## The treatment of recurrent pectus excavatum following open surgery through the Nuss procedure

*Açık cerrahi sonrası nüks eden pektus ekskavatumun Nuss işlemi ile tedavisi*

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### ABSTRACT

**Background:** In this study, we report our experience with the redo minimally invasive recurrent pectus excavatum repair through the Nuss procedure.

**Methods:** We retrospectively reviewed 130 patients (98 males, 32 females; mean age 14.6 years; range 1 to 37 years) who underwent minimally invasive repair of pectus excavatum at Erciyes University, Medical Faculty, and Antalya Training and Research Hospital between June 2006 and January 2016. The patients were divided into two groups. Group 1 included 119 patients who underwent primary Nuss repair, whereas group 2 included 11 patients who underwent the Nuss repair for recurrence following an unsuccessful modified Ravitch operation. Demographic characteristics, length of hospital stay, and complications in both groups were compared.

**Results:** The median age was 14 years (range 1 to 36 years) in group 1 and 18 years (range 9 to 31 years) in group 2. Overall complication rates were 8.4% and 27.3% in group 1 and group 2, respectively. There was no statistically significant difference in the length of hospital stay, number of bars placed, and complications between the two groups.

**Conclusion:** Nuss repair is a safe operation in selected recurrent pectus excavatum patients with a previously failed open repair.

**Keywords:** Complication; minimally invasive technique; Nuss procedure; pectus excavatum.

### ÖZ

**Amaç:** Bu yazıda Nuss işlemi ile yeniden minimal invaziv nüks eden pektus ekskavatum tamirine ilişkin deneyimimiz sunuldu.

**Çalışma planı:** Haziran 2006 - Ocak 2016 tarihleri arasında Erciyes Üniversitesi Tıp Fakültesi ve Antalya Eğitim ve Araştırma Hastanesi'nde minimal invaziv pektus ekskavatum tamiri yapılan 130 hasta (98 erkek, 32 kadın; ort. yaş 14.6 yıl; dağılım 1-37 yıl) retrospektif olarak incelendi. Hastalar iki gruba ayrıldı. Grup 1'e primer Nuss tamiri yapılan 119 hasta alınır iken, grup 2'ye daha önce modifiye Ravitch ameliyatı başarısız olan ve nüks nedeni ile Nuss tamiri yapılan 11 hasta dahil edildi. Her iki grup arasında demografik özellikler, hastanede yatış süresi ve komplikasyonlar karşılaştırıldı.

**Bulgular:** Medyan yaş grup 1'de 14 yıl (dağılım 1-36 yıl) ve grup 2'de 18 yıl (dağılım 9-31 yıl) idi. Toplam komplikasyon oranları grup 1 ve grup 2 için sırası ile %8.4 ve %27.3 idi. Hastanede kalış süreleri, yerleştirilen bar sayıları ve komplikasyonlar açısından iki grup arasında istatistiksel açıdan anlamlı bir fark bulunamadı.

**Sonuç:** Nuss tamiri, öncesinde açık cerrahinin başarısız olduğu nüks eden pektus ekskavatumlu belirli hastalarda güvenli bir ameliyattır.

**Anahtar sözcükler:** Komplikasyon; minimal invaziv teknik; Nuss işlemi; pektus ekskavatum.



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Pectus excavatum is a relatively common deformity of the chest wall with an incidence between 0.1 and 0.8/100 persons<sup>[1]</sup> and constitutes more than 87% of all the chest wall deformities.<sup>[2]</sup> Surgical correction remains the definitive management of pectus excavatum, and multiple techniques for repair have been described.<sup>[3-5]</sup>

Before the introduction of the Nuss procedure,<sup>[5]</sup> the repair of pectus excavatum was mostly performed by using the Ravitch procedure,<sup>[3]</sup> with a large inframammary incision, mobilization of pectoralis muscle and resection of costal cartilages with or without placement of a stabilizing bar. Over the last 15 years, the minimally invasive repair of pectus excavatum (MIRPE) has become a standard of care and several centers worldwide have now reported large experiences with the operation, showing that the procedure can be performed safely and effectively.<sup>[6]</sup> The introduction of this radically different technique changed the landscape of pectus excavatum surgery, which was previously dominated by the open approach. The number of patients presenting for surgical correction has increased in part owing to self-referral by patients who are familiar with related information using the internet.

However, the most recent topic nowadays is the application of the MIRPE in recurrent pectus excavatum patients. After a failed open repair, secondary repair becomes more challenging, due to both pleural and pericardial adhesions. In addition, abnormal ossification of the chest wall results in decreased chest compliance which makes secondary repair prone to complications. Reports on secondary repair of a failed open surgery through the MIRPE are few and demonstrates high complication rates.<sup>[7,8]</sup>

In the present study, we report our clinical experience in the management of patients who underwent MIRPE for recurrent pectus deformity following a failed open surgery.

## PATIENTS AND METHODS

A retrospective review was performed of 130 patients (98 males, 32 females; mean age 14.6 years; range 1 to 37 years) who underwent MIRPE by the Nuss technique at Erciyes University, Medical Faculty and Antalya Training and Research Hospital between June 2006 and January 2016. The patients were divided into two groups. Group 1 included 119 patients who underwent primary Nuss repair, whereas group 2 included 11 patients who underwent Nuss repair after a failed open surgery. The deformities were evaluated by the surgical team as mild, moderate, and severe, according to the physical appearance of the anterior chest wall and X-rays. The evaluation before surgical repair included plain chest radiographs, electrocardiogram, and echocardiogram in all patients. No computed tomography was obtained and also no indices were calculated, unless the deformity was severe. In addition, MIRPE was performed routinely in each patient by a single surgeon.

A written consent was obtained for the Nuss procedure from each patient or from each parent for those who were under 18 years. The study was conducted in accordance with the principles of the Declaration of Helsinki.

The surgical technique was the same as described by Nuss<sup>[9]</sup> with only one exception that we never used CO<sub>2</sub> insufflation. A chest X-ray was obtained immediately in the postoperative period to reassess the bar placement and to confirm the absence of a pneumothorax. Pneumothoraces less than 10% were followed with X-rays, while more than 10% required tube thoracostomy. Pain control was maintained with patient-controlled analgesia (PCA) using intravenous tramadol and tenoxicam in the postoperative 48 h, followed by oral diclofenac. Physical activity was restricted for 12 weeks. Bars were removed on about two years after placement. No problem was observed during the removal of the bars, although it was particularly

**Table 1. Comparison of demographics of patients**

Variables	Group 1 (n=119)				Group 2 (n=11)			
	n	%	Median	Range	n	%	Median	Range
Age* (year)			14	1-36			18	9-31
Gender‡								
Male	88	73.9			10	90.9		
Female	31	26			1	9.09		
Hospital stay* (days)			4	2-8			5	3-6

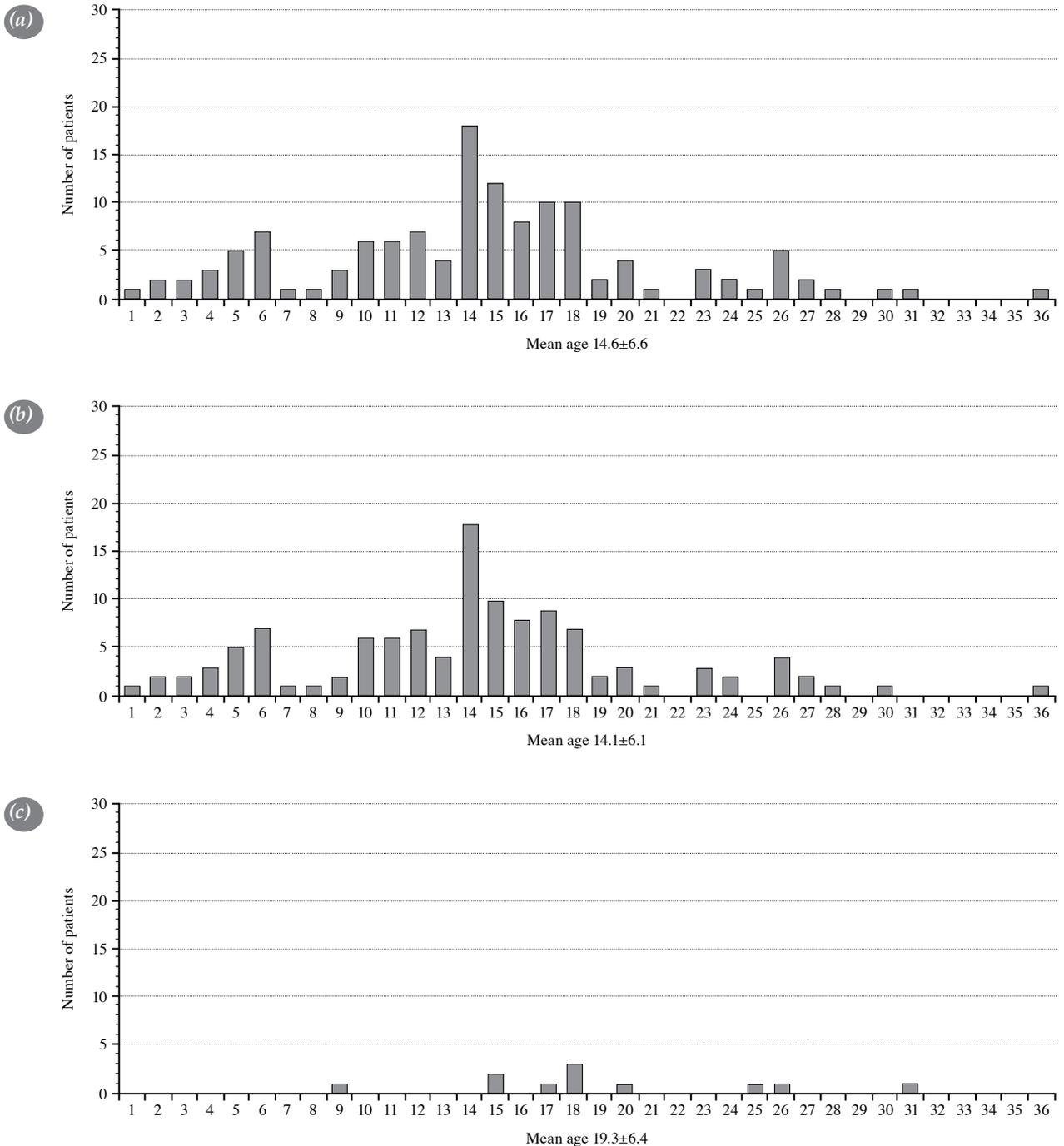
\* Medians and range of these parameters in each group were calculated; ‡ Percentage of these parameters in each group were calculated.

difficult in adult patients due to bar adhesion to bone tissue. Patient demographics, complications, and postoperative surveys were evaluated.

**Statistical analysis**

The IBM-SPSS version 20.0 software (IBM Corp., Armonk, NY, USA) was used for data analysis.

Quantitative data were expressed in median, while categorical or qualitative data were expressed in numbers and percentages. The chi-square test was applied to test for correlation between two independent parameters. The independent-samples t-test was used to compare the mean values. A *p* value of <0.05 was considered statistically significant.



**Figure 1.** (a) Age distribution for all patients. (b) Age distribution for group 1. (c) Age distribution for group 2.

**Table 2. Complications**

Complications	Group 1		Group 2		p
	n	%	n	%	
Pneumothorax	4	3.4	1	9.1	>0.05
Chest tube	1	0.8	1	9.1	>0.05
Spontaneous resolution	3	2.5	0	0	>0.05
Breakage of stabilizer	1	0.8	0	0	>0.05
Intolerable pain	2	1.7	0	0	>0.05
Wound infection	1	0.8	1	9.1	>0.05
Wound seroma	1	0.8	0	0	>0.05
Laceration of the internal thoracic artery	1	0.8	0	0	>0.05
Laceration of the intercostal artery	1	0.8	0	0	>0.05
Pericardial tear	1	0.8	0	0	>0.05
Skin erosion	2	1.7	2	18.2	>0.05
<i>Total</i>	10	8.4	3	27.3	>0.05

## RESULTS

Demographic characteristics of patients are shown in Table 1. Median age for group 1 and group 2 was 14 years (range 1 to 36 years) and 18 years (range 9 to 31 years), respectively. The age distribution for all patients and for both groups separately is illustrated in Figure 1. The youngest patient in group 1 was an 11-month-old hypotonic girl with muscle weakness and severe pectus excavatum. She was intubated and put on a ventilator. Pediatricians were unable to extubate her for 10 days in the pediatric intensive care unit and surgery was planned to be the last choice. We performed MIRPE. The patient was extubated on postoperative Day 10 and was discharged from the hospital on postoperative Day 17. To the best of our knowledge, there are few reports of patients under one year old treated with MIRPE.<sup>[10-12]</sup> The youngest patient with recurrence after open surgery was nine years old and primary operation was performed two years before. There were no statistically significant differences in the age distribution between the two groups ( $p>0.05$ ). The median length of hospital stay was four (range 2 to 8) days for group 1 and five (range 3 to 6) days for group 2. There were no statistically significant differences in the length of hospital stay between the two groups ( $p>0.05$ ).

**Table 3. Surgeon graded early cosmetic outcomes**

Initial results	Group 1		Group 2	
	n	%	n	%
Excellent	108	90.8	8	72.7
Good	8	6.7	3	27.3
Fair	3	2.5	0	0

Seventeen patients in group 1 and only one patient in group 2 had two bars. The median number of bars placed was one (range 1 to 2) in group 1 and one (range 1 to 2) in group 2, showing no statistically significant difference ( $p>0.05$ ).

More than one complication was seen in the patients in both groups. Table 2 summarizes the complications of 130 patients with an overall complication rate of 10%. Four patients (3.4%) in group 1 and one patient (9.1%) in group 2 had pneumothorax. Two of these five patients with pneumothorax (one in each group) required the chest tube insertion. Pneumothoraces of three patients (2.5%) in group 1 regressed spontaneously. The absorbable stabilizer of one patient (0.8%) in group 1 was broken at the postoperative one month; therefore, we removed it and inserted a metal stabilizer. One patient in group 1 required a mini-thoracotomy due to intercostal arterial laceration. In another patient, bleeding from internal thoracic artery was managed by the bar itself; in which the bleeding was stopped after positioning the bar. One patient in each group (0.8% vs 9.1%) had wound infection which responded to antibiotics. Pericardial laceration which required no surgical intervention occurred in one patient (0.8%) also in group 1.

In group 2, complications were slightly higher than those in group 1 and included pneumothorax requiring the chest tube insertion (9.1%), skin erosion (18.2%), and wound infection (9.1%). Overall complication rates in group 1 and group 2 were 8.4% and 27.3%, respectively. No statistically significant difference in the incidence of complications was observed between the groups ( $p>0.05$ ). None of the patients required a blood transfusion and there were no perioperative or late deaths.

Early cosmetic outcomes were judged by the operating surgeon during follow-up on postoperative Day 10 and excellent results were obtained in 90.8% of the patients in group 1 and in 72.7% of patients in group 2 (Table 3).

## DISCUSSION

The first pectus repair with bilateral costal cartilage resection and sternal osteotomy was performed by Sauerbruch in 1920.<sup>[13]</sup> Later, this technique was popularized by Ravitch.<sup>[3]</sup> The Ravitch and its modified versions need a long incision either vertical or horizontal in the anterior chest wall and resection of costal cartilages in which most cases a posterior support is needed either a metal bar or a meche.<sup>[3]</sup> The MIRPE introduced by Nuss,<sup>[5]</sup> became a standard of care in the last 15 years.<sup>[6]</sup> Compared to the open surgical techniques such as Ravitch and its modifications, shorter operating times,<sup>[5]</sup> less intraoperative bleeding,<sup>[14]</sup> and good aesthetic results<sup>[15]</sup> are the main advantages of this minimally invasive method.

After the Ravitch repair of pectus excavatum about 3 to 5% of the patients may require a secondary repair due to recurrence. Redo open surgery for these patients requires extensive and meticulous dissection for possible pericardial and pleural adhesions.<sup>[16]</sup> Although reports demonstrating that the patients with failed repair or recurrent pectus excavatum could also safely undergo MIRPE have been published,<sup>[7]</sup> controversy still exists as to the best operative management of recurrent pectus excavatum.<sup>[7,8]</sup> Antonoff et al.<sup>[8]</sup> suggested that those patients who underwent reoperative repair using an alternative approach to the initial procedure seemed to have more successful outcomes than those patients who underwent repetition of the original procedure. However, Redlinger et al.<sup>[7]</sup> published their experience that there was a greater than 95% success rate for a secondary PE repair via the minimally-invasive Nuss technique, regardless of what technique was used at the initial repair. In this aspect, we established this retrospective study to compare our surgical results with the MIRPE in primary and recurrent pectus excavatum patients.

Complications of the MIRPE have been discussed in numerous journals in the literature.<sup>[16-18]</sup> The range of overall MIRPE complications reported in the literature varies from 5 to 46.7%.<sup>[16,18-20]</sup> In our study, 13 (10%) of 130 patients had one or more complication.

In another study, Kelly et al.<sup>[6]</sup> reported one of the largest series on detailed complications with this approach in which pneumothorax was accepted as an integral part of the procedure; therefore, the

ratio of pneumothorax with spontaneous resolution and pneumothorax requiring chest tube was 64.7% and 4.0%, respectively. In our study, five (3.8%) of 130 patients had pneumothorax with three (2.3%) spontaneous resolution and with two (1.5%) requiring a chest tube.

Furthermore, patients with a previous Ravitch repair had poor chest wall compliance due to abnormal ossification of the anterior chest wall. Although technically extrapleural, the extensive dissection during open surgery can produce extensive pericardial and pleural adhesions.<sup>[7]</sup> Redo patients have significantly more frequent complications in the literature.<sup>[6,7,9]</sup> Redlinger et al.<sup>[7]</sup> reported 35 (83%) pneumothoraces in 42 of redo patients with a previous Ravitch procedure. Our complications were also slightly higher in the redo group; however, it did not reach statistical significance. In our study, overall complication rate for redo patients was 27.3% and only one patient (9.1%) had a pneumothorax who also required a chest tube (9.1%).

In conclusion, our study results showed that patients who were previously underwent primary or failed repair of pectus excavatum had similar results in terms of the length of hospital stay, number of bars placed, and complications. Therefore, selected recurrent pectus excavatum patients with a previous failed open repair can safely undergo reoperation by the minimally invasive repair of pectus excavatum.

### Declaration of conflicting interests

The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

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