Minimally invasive repair of pectus excavatum (MIRPE) in adults: is it a proper choice?

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Abstract

Introduction: *The Nuss procedure is suitable for prepubertal and early pubertal patients but can also be used in adult patients.*
Aim: *To determine whether the minimally invasive technique (MIRPE) can also be performed successfully in adults.*
Material and methods: *Between July 2006 and January 2016, 836 patients (744 male, 92 female) underwent correction of pectus excavatum with the MIRPE technique at our institution. The mean age was 16.8 years (2–45 years). There were 236 adult patients (28.2%) (> 18 years) – 20 female, 216 male. The mean age among the adult patients was 23.2 years (18–45 years). The recorded data included length of hospital stay, postoperative complications, number of bars used, duration of the surgical procedure and signs of pneumothorax on the postoperative chest X-ray.*
Results: *The MIRPE was performed in 236 adult patients. The average operative time was 44.4 min (25–90 min). The median postoperative stay was 4.92 ±2.81 days (3–21 days) in adults and 4.64 ±1.58 (2–13) in younger patients. The difference was not statistically significant (p = 0.637). Two or more bars were used in 36 (15.8%) adult patients and in 44 (7.5%) younger patients. The difference was not statistically significant either (p = 0.068). Regarding the overall complications, complication rates among the adult patients and younger patients were 26.2% and 11.8% respectively. The difference was statistically significant (p = 0.007).*
Conclusions: *MIRPE is a feasible procedure that produces good long-term results in the treatment of pectus excavatum in adults.*

Key words: *adult, pectus, excavatum, minimally invasive, Nuss.*

Introduction

Pectus excavatum (PE), also known as "funnel chest", is the most common congenital chest wall anomaly associated with anterior chest wall deformity and depression, which affects approximately 1 : 400 live births [1].

Meyer was the first surgeon to try to repair the deformity, in 1911 [2]. He was followed by Sauerbruch, who performed the first pectus repair using bilateral costal cartilage resection and sternal osteotomy [3].

In 1949, Ravitch published his first paper, "The operative treatment of pectus excavatum," and de-

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scribed 8 patients who were treated surgically with his technique [4].

Since then, several papers have been published regarding the modifications to Ravitch's technique, although it maintained its prevalence as the standard technique for the correction of PE. Yet, Ravitch's technique also has some difficulties, as indicated by several reports which have highlighted its morbidities and difficulties [5].

In 1998, a new era began, when Nuss *et al.* reported their experience with 42 patients using a minimally invasive technique to correct the depression of PE [6].

Their technique was based on the use of a stainless steel brace below the sternum, while there was no need for costal cartilage resection or sternal osteotomy.

Since then, the Nuss technique has been used extensively by many surgeons, who focused on the surgical repair of the chest wall deformities. Several modifications in the Nuss technique have also been published. Some of them are currently in use (such as the modified Nuss technique described by Pilegaard *et al.*, which is applied routinely in our clinic for the correction of PE) [7].

However, there are also non-surgical interventions such as the vacuum bell and cosmetic interventions such as the silicon implants and polyethylene implants, which are manipulated in order to fix the deformity cosmetically. The vacuum bell can also be used intraoperatively to facilitate the retrosternal dissection and the insertion of the pectus bar [8, 9].

The Nuss technique is perfectly suitable for prepubertal and early pubertal patients because of their chest wall compliance. While the technique can also be applied in adult patients due to the matured and rigid chest cavity, there are a number of problems including the prolonged operative time, increased rates of complications, bar displacement, higher pain rates and poor surgical outcome [10].

There is a tendency among surgeons not to operate on adult patients unless they have severe deformity that causes pulmonary and cardiac problems.

Aim

The aim of our study was to determine whether the minimally invasive technique (MIRPE) could be performed routinely and successfully not only in pediatric patients, but also in adults. In addition, we evaluated asymptomatic adult patients with symmetric and asymmetric deformities.

Material and methods

Between July 2006 and January 2016, 836 patients (744 male and 92 female) underwent correction of pectus excavatum with the MIRPE technique at our institution. The mean patient age was 16.8 years (range: 2 to 45 years). All patients obtained an excellent cosmetic result (Photo 1). There were 236 adult patients (28.2%) (> 18 years) – 20 female, 216 male. The mean age among the adult patients was 23.2 years (range: 18–45 years). Patient demographics and preoperative characteristics are summarized in Table I. In all cases, a preoperative computed tomography (CT) scan was performed in order to evaluate the intrathoracic cavity for surgical planning. Echocardiography and pulmonary function tests were also performed in order to evaluate the cardiac and pulmonary performance. In addition, a preoperative nickel allergy test was performed. Indications were psychosocial complaints due to cosmetic appearance, reduced exercise tolerance, dyspnea on exertion and chest pain. The Haller index (HI) was also used as an indication for surgery. HI greater than 3 was classified as severe deformity. The HI was calculated with CT. The HI of the patients ranged from 3.30 to 11 (mean: 4.4). All patients were operated on by the same surgeon. The data were retrospectively collected and analyzed. The recorded data included the length of hospital stay, postoperative complications, number of bars used, duration of the surgical procedure and signs of pneumothorax on the routine postoperative chest roentgenogram.

Surgical technique

All patients were positioned in the supine position with both arms abducted. An epidural catheter was placed for postoperative pain management before the general anesthesia. Double-lumen intubation was used routinely except for patients younger than 10 years of age. In this group of patients, the operation was carried out using apnea intervals.

The deepest point of the deformity, xiphoid and entry and exit points of the bar were marked on the skin. The incision for the scope was made from the right lateral side at the mid-axillary line and just below the level of the nipple to visualize the chest cavity cranially and caudally. A 5-mm trocar was in-

Photo 1. Pre- and postoperative images of a 45-year-old patient who underwent MIRPE

troduced into the thorax and the deepest point of the deformity was defined using a 30° scope.

A template (Zimmer Biomet Inc., Warsaw, Indiana, USA) was formed in order to make a model of how the chest was intended to look after the correction. Following this, a Pectus Support Bar (Zimmer Biomet Inc., Warsaw, Indiana, USA) was bent to match this template. Having employed the modified Nuss technique as described by Pilegaard *et al.* [7, 11], we used bars that were shorter than the bars described by Nuss. Using a shorter bar, the stabilizer could be placed closer to the exit of the pectus bar from the thoracic cavity. This modification is believed to decrease the occurrence of bar displacement.

Table I. Demographic variables and preoperative characteristics of adults patients (n = 236) undergoing MIRPE

Characteristic	Results
Age, mean [years]	23.2 (18–45)
Gender, *n* (%):	
Male	216 (91.5)
Female	20 (8.4)
Depth of defect (Haller index)	4.4 (3.3–11)
Preoperative symptoms (patients), *n* (%):	
Cosmetic concern	126 (53)
Dyspnea on exertion	16 (6)
Shortness of breath at rest	0
Cardiac arrhythmia, palpitations	0
Chest pain	38 (16)
Fatigue, decreased energy	27 (11)
Electrocardiogram changes	8 (3)
Mitral valve prolapse	21 (8)

Lateral incisions for introducing the bar were approximately 2 cm on the right side and 3 cm on the left side. We stabilized all bars on the left side.

With lateral incisions, a subcutaneous tunnel was created with blunt dissection, through the entry and exit points of the bar. A steel introducer (Zimmer Biomet Inc., Warsaw, Indiana, USA) was inserted into the thoracic cavity at the level of the entry point. It was pushed below the sternum and just above the pericardium securely using videothoracoscopy. An umbilical tape was secured to the tip of the introducer, while the introducer was withdrawn with its convex side facing down. This resulted in the tunneling of the umbilical tape from left to right. The tape was tied to the tip of the bar. With the guidance of the umbilical tape, the bar was passed through the

thorax from the right to the left incision in a concave-up position. The bar was flipped 180° in order to buttress the sternum and correct the deformity.

A stabilizer was placed on the left side of the bar as closely as possible to the entry into the thoracic cavity to avoid rotation. A no. 5 sternal wire was used to fix the stabilizer to the bar on the left side. The bar was also secured on the right side using one no. 1 polydioxanone (PDS) (No. 1 Pedesente Doğsan, Trabzon, Turkey) suture around the ribs. Using additional absorbable 2-0 vicryl sutures, the bar was fixed to the adjacent tissue.

Additional bars were implanted as a single bar did not provide satisfactory cosmetic correction and the HI was greater than 5. We also placed the bars asymmetrically in patients with asymmetric deformity.

Later, a slim 14 Fr silicone tube was inserted into the pleural cavity through the trocar site. The proximal end of the silicone tube was placed in a small cup of saline solution in order to form a modified underwater seal device. The lung was reinflated, intrathoracic air was evacuated and lung re-expansion was controlled with the videothoracoscope at the end of the procedure. The tube was withdrawn, while the anesthesiologist applied positive end-expiratory pressure.

A chest X-ray was taken on the same day of the surgery in order to evaluate the presence of pneumothorax. All patients took antibiotics intravenously for 3 days.

Pain management was the most important issue following the surgery. It was managed with an epidural catheter for the first 2 days. On the third day, the catheter was removed and nonsteroidal anti-inflammatory drugs (NSAID) and myorelaxant drugs were administered orally for 5 weeks postoperatively. The patient was monitored in the outpatient clinic 1 week after surgery for clinical evaluation with an X-ray and 1 month after surgery for general evaluation. After 2.5–3 years, we called the patients back for removal of the implanted system.

For the first 6 weeks, we did not allow the patient to carry a heavy weight (more than 2 kg in front of the body or more than 5 kg on the shoulders). Cycling and rotation of the upper body of more than 15° were also prohibited. The patient was also requested to sleep in the supine position without turning to either side. In addition, heavy contact sports (e.g. boxing, hockey, and self-defense sports such as karate and judo) were all forbidden until the removal of the bar.

Statistical analysis

Statistical analysis was performed using Pearson's χ^2 test for bivariate analysis. All statistical analyses were performed using IBM SPSS Statistics, version 20.0 (IBM Corp., Armonk, N.Y.). Values of $p < 0.05$ were considered statistically significant.

Results

The modified Nuss operation was performed in all 236 adult patients. The median length of the bars was 11 inches (range: 9–14 inches) for adults and 10 inches (range: 7–14 inches) for younger patients. The average operative time was 44.4 min (range: 25–90 min).

The median postoperative stay was 4.92 ±2.81 days (range: 3–21 days) in adults and 4.64 ±1.58 (2–13) in younger patients. The difference was not statistically significant (p = 0.637). Two or more bars were used in 36 (15.8%) adult patients and 44 (7.5%) younger patients. These figures were not statistically significant either (p = 0.068). Intraoperative variables and characteristics of hospital stay are summarized in Table II.

There were no perioperative deaths. Cardiac injury developed in one case where a small ventricular defect was repaired rapidly with anterior thoracotomy. One patient developed aspiration pneumonia which was treated with antibiotics. Seven (2%) patients had asymptomatic residual pneumothorax

Table II. Intraoperative variables and characteristics of hospital stay (adult patients, n = 236)

Characteristic	Result
Operative time [min]	44.2 (25–90)
Estimated blood loss [ml]	25 (5–500)
Bars placed, *n* (%):	
1	200 (84)
2 or more	36 (15)
Mortality, *n* (%)	
Intraoperative death	0 (0.0)
30-day mortality	0 (0.0)
Length of hospital stay, mean	4.92 ±2.81 (3–21 days)

which was resolved without chest tube placement. Postoperative pleural effusion was detected in 2 patients. The effusions were minimal and they were resolved spontaneously. Wound infection developed in 4 patients. Wound care and antibiotics were sufficient for recovery in this group. One patient developed thoracic outlet syndrome after the correction of the deformity. The first rib caused severe obstruction of the right subclavian artery. The resection of the first rib and the division of the anterior scalene muscle and fibrous bands provided complete relief in this case. Bar displacement developed in 12 (5%) adult patients, while it was observed in 5 (0.8%) younger patients. The difference between the two groups was statistically significant ($p < 0.05$). All complications related to the surgical procedure are provided in Table III.

Regarding the overall complications, the complication rates among the adult patients and younger patients were 26.2% and 11.8% respectively. The difference was statistically significant ($p = 0.007$).

Table III. Complications

Complications	*N* (%)
Bar displacement	12 (5)
Cardiac injury	1 (0.4)
Thoracic outlet syndrome	1 (0.4)
Wound infection	4 (1)
Pneumonia	1 (0.4)
Removal of stabilizer pain	0
Sternotomy/thoracotomy	1 (0.4)
One more bar	2 (0.8)
Removal before time due to pain	0
Pneumothorax	7 (2)
Pneumothorax which needed drainage	0
Pleural effusion	2 (0.8)
Pleural effusion which needed drainage	0
Prolonged pain	4 (1)
Readmission for pain	0
Recurrence	0
Respiratory distress	0
Bleeding requiring transfusion or reoperation	0

Discussion

The surgical treatment of pectus excavatum has changed in the last few decades. Although the Ravitch procedure is still a widely used approach for adult patients with pectus excavatum, there is an increasing trend for using the minimally invasive technique also known as the Nuss procedure. There are sufficient data regarding the use of the Ravitch repair in adult patients [12–16], although the treatment of pectus excavatum with the minimally invasive technique in adults is still controversial. Many surgeons still recommend the use of the Ravitch approach, since there are problems such as the frequent need for multiple bars and higher rate of complications that accompany the minimally invasive approach.

The minimally invasive technique has been used for pectus excavatum repair since 1998 [6], although only a limited number of studies have been published on this topic.

In 2002, Coln *et al.* reported their early experience with the minimally invasive technique in adults. Eight patients (5 male and 3 female), aged between 19 and 32 years, underwent the minimally invasive Nuss repair [17]. They used one bar with one or two stabilizers. The mean operative time was 1.32 h, while the mean hospital stay was 4 days. There were no early complications, although in one case the separation of a stabilizer required reoperation, while in another case bar displacement was reported as a late complication. Although the short time results were encouraging, this was a small series with a short follow-up period.

Kim *et al.* [18] reported their experience with the minimally invasive pectus repair with 51 patients. They assigned the patients to three different age groups. Twelve patients were older than 20 years, and 12 patients were aged between 12 and 20 years. Two bars and lateral stabilizers were used routinely in the adult patients, while two bars were used only in 9 adolescents. The mean operative times were longer in the adult group (127.3 ±44.9 min). The mean hospital stay was 10 ±8.5 days for adult patients. These values are very high compared with our results. In our study, the operative time was 44.4 min and the mean hospital stay was 4.92 ±2.81 days.

The postoperative complication rate in the adolescent and adult groups was 58.3%, and bar rotation was reported in 8.3% of adolescents and 33.3% of adults.

In our study, bar displacement developed in 5% of the adult patients, whereas the complication rate in the same group was 26.2%.

Recent reports have demonstrated more promising outcomes in adults [19–21]. Pilegaard published his experience with 52 adult patients who were over 30 years of age [21]. The median age of the patients was 37 (range: 30–53). One bar was used in 15 (29%) patients, while two bars were used in 35 patients, and three bars were used in 2 patients. Two stabilizers were used in 10% of the bars. The median duration of surgery was 60 min and median postoperative hospital stay was 4 days. Although 25 patients had pneumothorax, only 1 of them required a chest tube. There was no bar rotation, while 1 patient with lateral migration of the bar was reoperated. The bars were removed early because reoperation caused infection and the patient refused to take antibiotics for a long time.

In another study, Teh *et al.* evaluated the results of 19 patients aged 17 years or above [22]. The mean operative time was 2.1 ±0.2 h. Twelve patients required two bars, while one bar was used in 7 patients. We used two or more bars in 36 (15.8%) patients in adults. The mean hospital stay was 5.8 days, which was similar to our result. One patient developed pneumonia and 6 patients had residual pneumothorax which resolved without chest tube placement. Pneumothorax rates were quite high in comparison with our study. We believe this is mainly due to our evacuation technique, where we used an underwater seal mechanism.

In 2008, Pilegaard and Licht published a larger study including 180 adult patients [11]. The patients were aged 18 years or above (mean: 22 years). One hyndred and sixty of them were male patients. They used two bars in 57 patients and three bars in 2 patients. They found that more than one bar was used in adults compared with younger patients and reported it as statistically significant. In our study, we also found that more than one bar was used frequently in adults, but we found that this was not statistically significant.

The median duration of the procedure was 41 min, which was very similar to our operative time, since we performed the same modified technique as described by Pilegaard. The median hospital stay – 5 days (3 to 29 days) – was also similar. The hospital stay was not significantly longer compared with the younger patients. The mean hospital stay was 4.92 ±2.81 days in our study, which was not significantly different in comparison with the younger patients, who had a mean hospital stay of 4.64 ±1.58 days.

They detected pneumothorax in 86 (48%) cases, while 4 patients required tube drainage. In our study, there were only 7 (5%) patients with pneumothorax, which resolved spontaneously. Other complications included pneumonia in 4 patients, pleural effusion in 4 patients, empyema in 1 patient, seroma in 1 patient and deep infection in 5 patients. Three (2%) patients underwent reoperation because of the dislocation of the bar.

In 13 (7%) patients, the stabilizer was removed early due to intolerable pain. In our study, we did not remove any bars or stabilizers due to pain. Yet, 12 (5%) patients underwent reoperation for bar displacement.

Absorbable stabilizers were used in 8 patients. We did not experience any displacement or rotation in the last 3 years. The mean duration of bar application was 36 ±4.6 months (30–48 months). One hundred and thirty-six (57%) patients had their bars removed, while there was no recurrence.

Pain appears to be the major problem following the minimally invasive pectus repair. It is believed that there is greater stress in all ribs in adults compared to children after the Nuss procedure [23].

On the other hand, force distribution in adults is more diffuse and often frequently located in the posterior part of the chest wall. Moreover, there are papers which report the increasing use of analgesics and narcotics in older patients [24].

We managed the pain in adult patients with the same amount of analgesics that we used in younger patients. As also reported in the literature [25], we found that patients with more than one bar had less pain in the adult group.

We also experienced a very rare problem in one of the patients. The patient developed vascular thoracic outlet syndrome after the correction of the deformity. The first rib caused severe obstruction of the right subclavian artery. The patient was treated with resection of the first rib and division of the anterior scalene muscle and fibrous bands [26].

Conclusions

Data from our present clinical experience indicate that many adults with pectus deformities can be operated on using the minimally invasive technique.

We can achieve the same good results as the younger patients with the same operative time as well as the same number of bars. Although complications are quite high in comparison with the younger patients, patients do not have to stay longer after the operation compared with the younger patients.

In conclusion, minimally invasive pectus repair for the treatment of pectus excavatum is feasible and provides good long-term results in adult patients. As surgeons become more experienced, complications can be minimized and improved outcomes can be achieved.

Conflicts of interest

The authors declare no conflict of interest.

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