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Minimally invasive repair after inefficient open surgery for pectus excavatum☆

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Abstract

Objective: Pectus excavatum is the most common chest wall deformity, and both open surgery and minimally invasive repair have been proposed for primary correction. The aim of this study was to show the feasibility of minimally invasive repair of recurrent pectus excavatum in patients with inefficient previous open surgery. **Methods:** A total of 135 patients underwent minimally invasive repair of pectus excavatum between June 2006 and February 2010. Ten patients had a previous unsatisfactory open surgical repair of the deformity. Operation duration, length of hospital stay, complications and the need for a revision operation were compared between the primary Nuss (N) and the Nuss after Ravitch (RN) groups. **Results:** The N group consisted of 125 patients, requiring 133 operations, whereas 10 patients in the RN group underwent 11 minimally invasive correction operations. For the N and RN groups, medians of operation duration and length of hospital stay were 60 (20–180) and 60 (30–120) min, and 5 (2–15) and 5 (3–10) days, respectively. The differences between the two values were found to be statistically insignificant ($p > 0.05$). Development of perioperative or postoperative complications in both groups was found not to be associated with primary or redo minimally invasive surgery ($p > 0.05$). **Conclusions:** Minimally invasive repair is a safe and easy operation for the correction of pectus excavatum. Previous open surgical repair is not a contraindication for the redo minimally invasive surgery, and it can be performed with acceptable morbidity and length of hospital stay.

Keywords: Pectus excavatum; Minimally invasive; Reoperative surgery

1. Introduction

Pectus excavatum (PE) is the most common chest wall deformity occurring with an incidence of 1 in 300–400 live births [1,2]. The standard repair for PE has been an open procedure described by Ravitch [3] in 1949. Through the years, minor modifications have been applied, but the main idea of the method remained the same and the Ravitch repair was the treatment of choice until the mid-1990s. Since its introduction by Nuss et al. [4] in 1997, the minimally invasive repair of pectus excavatum (MIRPE) has been gaining acceptance worldwide among surgeons and patients [5–12].

Recurrence rates after Ravitch repair of PE are reported to be between 2% and 37% [13]. Reoperative open surgery for these patients has been associated with extensive dissection and substantial blood loss due to pericardial and pleural adhesions [14]; hence, MIRPE can be a good alternative as a redo procedure for this technically challenging correction.

This study evaluates our experience in patients, who have undergone minimally invasive repair using pectus bar, after inefficient open surgery for the correction of PE.

2. Patients and methods

Retrospective review of all patients who had undergone MIRPE was performed. Written consent was obtained from all patients or from their parents if the patient's age was under 18 years to have their data included in this study. Operation duration, length of hospital stay, perioperative and postoperative complications, and the need for a revision operation were compared between the primary Nuss (N) group and the Nuss after Ravitch (RN) group.

The N group consisted of patients, who had their deformities corrected for the first time with MIRPE. Patients in the RN group had a previous unsuccessful correction with open surgery and experienced recurrence of their deformities in the following years.

The indication for surgery depended on the patients' desires; those who had not been content with the appearance

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Fig. 1. (a) Unsuccessful Ravitch repair on a 9-year-old patient, (b) the same patient 6 months after the MIRPE operation.

of their anterior chest wall were candidates for surgery. No indices were calculated. The surgical team evaluated the deformities as mild, moderate, and severe, according to the physical appearance of the anterior chest wall and X-rays. Postero-anterior and lateral chest X-rays, pulmonary function tests, electrocardiography, and echocardiography examinations were done preoperatively to assess the cardiopulmonary status of the patients. Patient satisfaction was evaluated with the answers given on questionnaires done preoperatively and in the postoperative 6th month. In addition, photographs of all patients were taken before and after surgery for comparison.

MIRPE was performed routinely for all patients, by the same surgeon. The surgical technique for the repair of recurrent PE is similar to the technique described for primary MIRPE with the addition of thoracoscopic pneumonolysis when required. Short bars and single stabilizer in one side were preferred whenever possible (Figs. 1 and 2).

2.1. Surgical technique

All patients were operated on in the supine position with the abduction of the right arm to ease the right-sided thoracoscopy, under single-lumen tube anesthesia and with CO_2 insufflation through the port to keep the lung out of the operative field. An epidural catheter was placed in all patients prior to surgery. To choose the location for the incisions, a horizontal line was drawn through the region with the deepest point of the deformity on the anterior chest wall. Two transverse incisions were made on both sides, approximately 2 cm each, at the anterior axillary line. Subcutaneous tunnels were created on both sides by blunt dissection reaching the highest points of the deformity to become the entrance and exit points of the bar. Meanwhile, the chosen template was shaped on the chest, and the bar itself was bent to match the template. A separate 1-cm incision was made at the right midaxillary line to place the thoracoscope. A 5- or 10-mm blunt-tip trocar was introduced into the right pleural space and the 30° videothoracoscope was inserted to explore the pleural cavity for the deepest point of the deformity and for any pleural adhesions. If no adhesions were detected, the introducer was inserted through the right incision and forwarded to the deepest point of the deformity to create a tunnel between the sternum and the pericardium by blunt dissection. If any pleural adhesions were detected, thoracoscopic pneumonolysis was performed first, using the introducer for blunt dissection of mild adhesions or using electrocautery, which was introduced through the right incision for strong adhesions. Meticulous blunt dissection with the tip of the introducer was also performed when carrying out a redo surgery to avoid any harm at the pericardium, which may have strong adhesions to the sternum. When the retrosternal tunnel was created, the introducer was pushed throughout the left incision. A tape was tied to the eyelet of the introducer and pulled back, guiding the tape through the right thoracic cavity, and then out of the right incision. The bent bar was tied with the tape and pulled through the tunnel from right to left with the convex side facing down. The bar was rotated 180° pushing the sternum upward. One stabilizer was placed on the left side as close as possible to the exit point from the thoracic cavity to avoid rotation, as Pilegaard and Licht [11] described. The bar and the stabilizer were secured on the muscles by three or four 0 polydioxane sutures. If an acceptable cosmetic result was not obtained with a single bar, one or two additional bars were placed in the same manner. If the deformity was asymmetric, the bar was bent asymmetrically, as Park et al. described [15]. The air in the right pleural space was drained through a suction catheter, and the incisions were closed in layers with absorbable sutures. No drains were placed unless pneumonolysis had been performed.

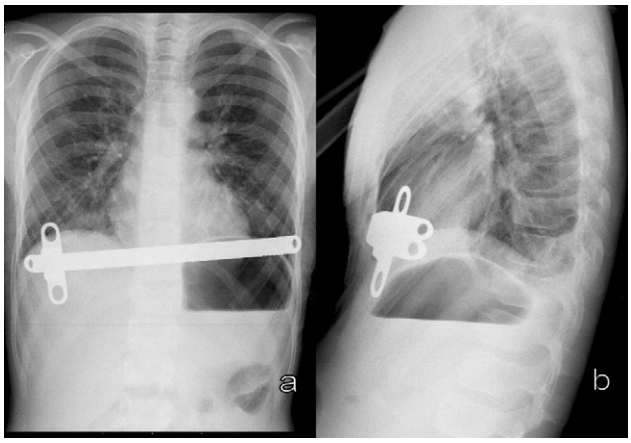

Fig. 2. (a) and (b) Postoperative posteroanterior and lateral chest X-rays of the patient.

A postoperative chest X-ray was obtained to see the bar in place and to look for pneumothorax. No intervention was done for pneumothorax less than 10%, and the patients were followed up with X-rays for an increase in the pneumothorax rate needing a tube thoracostomy. Pain control was maintained with patient-controlled analgesia (PCA) using epidural fentanyl and bupivacaine in the postoperative 48 h, followed by oral tramadol and etodolac.

All pectus bars were left for at least 3 years before they were removed under general anesthesia.

Perioperative complications were the ones that occurred during the surgical procedure or during the hospital stay,

while postoperative complications were the morbidities that occurred after the patients were discharged.

2.2. Statistical analysis

Analyses of all collected data were done with Statistical Package for Social Sciences (SPSS) version 15.0 software (SPSS, Chicago, IL, USA), and p values less than 0.05 were considered as statistically significant. Fisher's exact test was used for the analyses of categorical type of data, whereas the Mann–Whitney U test was used for the analyses of continuous variables.

3. Results

From June 2006 to February 2010, 135 patients (116 male and 19 female) with PE underwent a total number of 144 MIRPE operations at our institute. The N group consisted of 125 patients, requiring 133 operations, whereas 10 patients in the RN group who had had a previous unsatisfactory open surgical correction for their deformities underwent 11 redo minimally invasive correction operations. All patients requiring redo operations were classified with moderate or severe recurrent PE.

Median age for groups N and RN was 17 years (range: 6–34 years) and 19 years (range: 7–29 years), respectively. Demographic and surgical data of the patients are shown in Table 1.

Retrospective data scanning revealed 19 patients (14.1%) having at least one family member with a chest wall deformity. As for the additional disorders of 135 patients, scoliosis was the most common disorder being seen in 25 patients (18.5%).

Duration between the primary open surgery and redo MIRPE was between 2 and 11 years in the RN group (Table 2).

The groups showed no statistically significant difference in terms of age distribution in the two groups ($p > 0.05$). There were 17 female patients in the N group and two in the RN group. Forty-four patients in the N group and two in the RN group had asymmetric deformity. The gender distribution and morphology of malformation in both groups were found not to be associated with primary or redo minimally invasive surgery ($p > 0.05$). For the N and RN groups, medians of operating time and length of hospital stay were 60 (20–180) and 60 (30–120) min and 5 (2–15) and 5 (3–10) days, respectively. These results showed that the two groups had no statistically significant difference in terms of operating time and length of hospital stay ($p > 0.05$). Medians of numbers of bars placed in patients were 1 (range: 1–3) in the N group and 1.5 (range: 1–2) in the RN group, showing no statistically significant difference ($p > 0.05$). Eight patients in group N and one patient in group RN had re-operations following MIRPE for insufficient correction, and additional bars were placed (one each) in these patients. The percentage of re-operations in both groups was found not to be associated with primary or redo MIRPE following open surgery ($p > 0.05$).

The complications encountered in the perioperative period and the morbidities seen in the postoperative course are listed in Table 3. In the perioperative period of 133 operations in group N, rib fracture, parenchymal laceration, pericardial laceration, intercostal bundle hemorrhage, pneumothorax, and pleural effusion requiring drainage were seen as major complications, resulting in a total complication rate of 8.3%. In the RN group, pulmonary parenchymal laceration and pleural effusion were seen in one patient each. In another patient in this group, not only the pericardium but also the myocardium was lacerated and primary repair using sutures with Teflon pledgets was performed via an anterior thoracotomy. The perioperative complication rate in the RN group was calculated as 36.33%.

As for the postoperative morbidities, insufficient correction with or without the dislocation of the bar was the most common. Eight additional bars in group N and one in group RN were implanted and three bars were relocated. Wound infection was the second most common morbidity, and, in six

Table 1. Comparison of demographics and surgical data of patients.

	Group N (n:125)	Group RN (n:10)
Average age[a] (years)	17 (6–34)	19 (7–29)
Gender[b]		
Male	108 (86.3%)	8 (80%)
Female	17 (13.7%)	2 (20%)
Morphology[b]		
Symmetric	81 (64.5%)	8 (80%)
Asymmetric	44 (35.5%)	2 (20%)
Operating time[a] (min)	60 (20–180)	60 (30–120)
Number of bars per patient[a]	1 (1–3)	1.5 (1–2)
Hospital stay[a] (days)	5 (2–15)	5 (3–10)
Reoperations[b]	8 (6.5%)	1 (10%)

[a] Medians and range of these parameters in each group were calculated.
[b] Percentage of these parameters in each group were calculated.

Table 2. Length of time between primary open surgery and MIRPE in group RN.

Number of patients	Length of time (years)
5	2
3	5
1	9
1	11

Table 3. Complications seen at the perioperative and postoperative periods.

	Group N (n:133)[a]	Group RN (n:11)[a]
Perioperative[b]		
Pulmonary parenchymal laceration	1	1
Pericardial laceration	2	1
Myocardial laceraton		1
Pleural effusion requiring drainage	4	1
Pneumothorax requiring drainage	1	
Intercostal hemorrhage	2	
Rib fracture	1	
Total	11 (8.3%)	4 (36.3%)
Postoperative[b]		
Wound infection	9	1
Insufficient correction/dislocation	11	1
Intolerable pain	1	1
Metal allergy		1
Dressler's syndrome		1
Total	21 (15.8%)	5 (45.4%)

[a] n: Number of MIRPE procedures.
[b] More than one complication were seen in some patients.

patients, incision revision was required while the rest regressed under antibiotherapy. Intolerable pain in the postoperative course was observed in three patients: two in the N group and one in the RN group. The bars of these patients were removed 15 days, 80 days, and 10 months after surgery, respectively. One patient in the RN group had prolonged bilateral swelling and pain with sterile serous wound discharge. Although his preoperative skin test was negative, dermatological examination revealed type 4 hypersensitivity (nickel allergy); hence, the bar was removed after 6 weeks. The patient, who had experienced the myocardial laceration, developed Dressler's syndrome on the postoperative 3rd month that was treated with non-steroidal anti-inflammatory drugs. Complication rates in the postoperative course in the N and RN groups were thus calculated as 15.8% and 45.4%, respectively.

As seen above, more than one complication was seen in some patients in both the perioperative and postoperative periods. In the perioperative period, 10 patients (8%) in the N group and three patients (30%) in the RN group had complications, while in the postoperative period, 18 patients (14.4%) in the N group and two patients (20%) in the RN group had complications. Development of perioperative or postoperative complications in both groups was found out not to be associated with primary or redo MIRPE ($p > 0.05$).

There were no mortalities in both groups. Over 94% of all patients, who had undergone MIRPE, reported satisfaction with their postoperative results. Seven patients in the N group had their bars removed at the end of the planned period with no recurrence. None of the bars have been removed yet in the RN group.

4. Discussion

Since the 1940s, open surgical procedures, generally known as the Ravitch repair and its modifications, have been applied for the correction of pectus deformities. Open surgery for PE consists of an incision for at least 10 cm long, costal cartilage resections, and sternal osteotomies for remodeling the anterior chest wall. MIRPE, initially described by Nuss et al. [4], was founded on the ability of the chest wall to reconfigure and remodel [16]. In this technique, through two small incisions on both sides of the chest, an introducer is pushed along posterior to the sternum and ribs, and anterior to the heart and lungs; then, a bent stainless steel bar is slipped under the sternum, through these incisions, with the guidance of a thoracoscope, to push the sternum outward.

Since the mid 1990s, MIRPE has gained worldwide recognition with its feasibility, short operating time, good cosmetic results, and low morbidity. Despite the fact that better – or at least similar – outcome can be achieved with this much quicker and less invasive method, some surgeons still preserve their belief in open surgery [17].

The use of MIRPE for initial repair of PE has been reported by many centers from around the world, but there is a group of patients who have undergone an open surgery for the correction of PE and experience a recurrence of their deformity; and there has been very little research on the use of MIRPE and the postoperative outcomes after redo correction, for those patients who would benefit from another repair [16,18–20]. This retrospective study attempts to evaluate the usage of MIRPE for patients who have undergone previous open correction.

MIRPE has similar limitations as with any video-assisted thoracoscopic surgery (VATS) approach. Some factors such as decreased flexibility of the chest wall with advanced age (>15 years) or the asymmetric morphology of the deformity are thought to lead to unsatisfactory results [15,21]. Because of general aspects of VATS, our hypothesis was that a previous surgical procedure concerning the chest wall, mediastinum, and the pleural space, like an unsuccessful open surgery for PE, could complicate redo MIRPE with pleural and pericardial adhesions. To assess this possibility, we compared our surgical outcomes between patients undergoing MIRPE with or without a previous open surgery for correction.

In literature, complication rates after MIRPE vary greatly among different series, such as: hemothorax 1–5%, pleural effusions requiring chest tube 2–9%, wound infections 3–9%, and redo operations 4–19%. Total complication rate varies between 15% and 27% [6,7,9,15,21]. Complication rates are higher in the redo MIRPE groups in different series due to pleural and pericardial adhesions [18,20,22]. Nuss [20] reported high complication rates in this group of patients as 44% required chest tubes, 8% had hemothorax, 8% had pleural effusion, 9% had bar displacement, and two patients experienced temporary arrhythmic cardiac arrest. Miller [16] included subxiphoid incision to his procedure for substernal management, while Schaarschmidt et al. [22] placed additional ports for pneumonolysis. We did not make any extra incisions but used the main incision made for the entrance of the bar as a port for the electrocautery for pneumonolysis when needed. Our complication rates are higher in the relatively small RN group as these cases are challenging for the pleural and pericardial adhesions, yet our complication rates both for primary and redo MIRPE are consistent with the published literature data by many researchers and by the inventor of this method himself [20].

In our series, both primary MIRPE (N) and redo MIRPE after open surgery (RN) groups showed similar operation durations and length of hospital stay, which suggests MIRPE following open repair is a feasible procedure. When the complication rates are assessed together with the similar operation durations in both groups, we can say that we were too fast and may be less careful than needed in the redo group, leading to higher complication rates. This shows that extra care is needed in every step of the procedure to reduce the complication rates, and if not, it is possible to cause serious complications even in experienced hands.

We conclude that the pleural and pericardial adhesions formed following a thoracic operation such as the open repair of PE can be surmounted by meticulous dissection under thoracoscopic guidance, and a previous procedure is not a contraindication for MIRPE. To identify the 'ideal candidate selection', referred by many authors, larger and prospectively designed studies are needed. With increasing experience, the complication rates are thought to be decreased in time.

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Appendix A. Conference discussion

Dr J.-M. Wihlm (*Strasbourg, France*): My first question is about wound infection. You mentioned 9 in one group and 1 in the second group. Were they early, mid-term, or long-term infections?

Dr Yüksel: This was early infection at the end of the hospital stay. We usually saw early infection, not long-term infection. In most of the patients we didn't find any specific agent.

Dr Wihlm: In some series there are also mid-term or long-term infections observed, and, strangely enough, in our experience we had infections appearing 14 months and 21 months after Nuss bar placement. It's almost like pacemakers, where you can have a very delayed infection with mild germs which need months and years to come out. I have an additional question: What was your treatment for that?

Dr Yüksel: We just gave antibiotics.

Dr Wihlm: You didn't take out any bars for this reason?

Dr Yüksel: No, not due to the infection, but due to nickel allergy, we took out the bar in one patient.

Dr Wihlm: The next question is about recurrence after a Ravitch procedure. It has been assumed that it is generally related to extensive cartilage resection, and this gives a kind of anterior flail chest associated with the recurrence. So in your 10 cases, but now there are 18 cases of redo with the Nuss procedure after a first Ravitch operation, aren't you afraid that there will be another recurrence again after bar removal? Your bar insertion doesn't bring more cartilage than before.

Dr Yüksel: Yes, you are right.

Dr Wihlm: What is your experience of this? Have you already taken out the bars in the group of 10 redos with a Nuss procedure? Dr Yüksel: Not this group. In just one patient we took out the bar after one year, but we don't know now what's going on with the thoracic shape; with the other 17 patients, the bar has stayed. Personally I am afraid with this group of patients, because, and you said, the thoracic wall inside and the cartilage have deformed the sternum also. I don't know. But now these patients are happy about the thoracic shape, and I want to state that as long as the patient is happy, I am happy.

Dr Wihlm: So they are temporarily happy!

Dr F. Robicsek (*Charlotte, North Carolina, USA*): Mr Chairman, I would like to suggest not using the term 'Ravitch procedure' anymore because there is simply no such thing. Mark died about 20 years ago. The original Ravitch procedure in 1949 was grossly ineffective, with a large number of recurrences. However, the modern varieties of open repair could be done minimally-invasively through a small incision with no mortality and very low morbidity. The principal modification is to support the sternum one way or another, permanently or temporarily. The term 'Ravitch procedure', however, is still used as a 'straw man' to fight. So I would suggest replacing it with the words 'open repair', with the added identification of exactly what type of open repair.

Dr J. Kozak (*Lodz, Poland*): I have two brief questions. Did you elevate the sternum while placing the bar between the heart and the sternum? Second, did you stabilize at the middle of the bar? Rotation of the bar is usually anteriorly and we have to stabilize at the middle of the bar.

Dr Yüksel: Can you repeat the first question?

Dr Kozak: During placement of the bar under the sternum, we usually elevate the sternum and then you have a big space to place the bar.

Dr Yüksel: Yes.

Dr Kozak: We don't need the procedure we saw here.

Dr Yüksel: Yes, you can, but there is more intervention and more complications. That is why. It's up to you.