Efficacy and safety of modified bilateral thoracoscopy-assisted Nuss procedure in adult patients with pectus excavatum

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Abstract

Objective: Several modifications for increasing the efficacy and safety of the minimally invasive surgery (Nuss procedure) for repair of pectus excavatum in pediatric patients were presented. In this study, we apply a modified bilateral thoroscopic approach to adapt the Nuss procedure to adult patients. Methods: We prospectively included all adult patients with pectus excavatum corrected by modified bilateral thoracoscopy-assisted Nuss repair from July 2005 to December 2007. Technical modifications included patient positioning, surgical wounds designing, and routine use of the bilateral thoracoscopy viewing before and during mediastinal dissection. The endoscopic appearances and early complications were recorded. Results: Ninety-six adult patients (80 men, 16 women) with a mean age of 24.5 years (18—42 years) were included. Six patients were repaired due to previous failed Ravitch procedure. Pleural, mediastinal adhesions or small aberrant vessels in the mediastinal pleura were found in 19 patients. Two pectus bars were inserted in 22 patients (22.9%). The median operative time is 80 min (range from 50 to 185 min). The blood loss was mostly less than 10 cc (83 in 96 patients). In early complications, pneumothorax occurred in one (1%) patient. There was no mediastinal injury, bleeding complications, or requirement of chest tube insertion postoperatively. The mean length of hospital stay was 7.2 days (range 5—13 days). Conclusions: The modified bilateral thoracoscopy-assisted Nuss repair for adult patients could eliminate the risk of cardiopulmonary injuries. It could allow direct inspections in mediastinum and facilitate mediastinal dissection, especially in patients with recurrence, history of previous thoracic procedure or double-bar insertion. Other methods for ensuring safety such as substernal dissection or elevation may be unnecessary.

Keywords: Pectus excavatum; Nuss procedure; Adult; Thoracoscopy

1. Introduction

Pectus excavatum is the most frequent congenital chest wall deformity mostly presenting since neonate and might be sunken after adolescence [1]. In 1998 Nuss and associates documented a minimally invasive method for correction of pectus excavatum with good results [1,2]. The procedure introduced a curved, stainless-steel bar behind the sternum for correcting the depressed chest wall without resection of costal cartilages. A series of literature demonstrated the experience of Nuss procedure mostly in the pediatric patients, but it was relatively rare in adults [3—5].

Despite this, the procedure was accepted near-universally; the complications and learning curve were discussed in the recent issue [6—8]. The postoperative complications with a wide range were also reported [6,9—12]. The early complications (within 1 month), including pneumothorax (range 6.9—52%), pleural effusion or hemothorax (1.5—38%) and cardiac injury (0.4%), have been presented. A number of modifications for increasing the efficacy and safety for Nuss procedure in pediatric patients were published [13—15]. However, several reports demonstrated that adult patients were at high risk for complication [5,6]. Kim et al. documented the analysis of Nuss procedure for pectus excavatum in pediatric, adolescent and adult patients, and the results showed that the postoperative complications were significantly higher in adolescent and adult than the pediatric group (58.3% vs 11.1%) [5].

The purpose of our study was to describe the further modification of thoracoscopy-assisted Nuss procedure that improves the safety and efficacy in adult patients. The method needs neither more surgical wounds for optic device nor CO2 insufflation device, allows clear visualization before and during mediastinal dissection, and prevents complicated or potentially lethal complications.

2. Patients and methods

We prospectively included all adult patients with pectus excavatum corrected by modified bilateral thoracoscopic-
assisted Nuss repairs at the Division of Thoracic Surgery, Tri-
Service General Hospital, Taipei, Taiwan, from July 2005 to
December 2007. Evaluation by complete history, physical
examination, chest radiographs, electrocardiogram, pul-
monary function test, echocardiogram, and computerized
tomography of the chest were performed. The indications for
surgical repair were two or more of the following criteria
demonstrated by Dr Nuss: (1) progression of the deformity;
(2) exercise intolerance; (3) progressive chest pain or
dyspnea; (4) restrictive ventilatory impairment; (5) Haller
index > 3.25; (6) previous failed Ravitch procedure (7)
cardiac compression (8) mitral valve prolapse [13]. The
demographic data, surgical data (blood loss, number of bars,
surgical time), thoracoscopic findings, early complications,
length of hospital stay, and surgical outcome were collected.
All procedures were done with modifications of the Nuss
procedure, which included bilateral thoracoscopic observa-
tion, right-to-left dissection of the mediastinum under the
direct vision through left thoracoscopy during the period
when patients were under hypoinflation status.

2.1. Surgical preparation and technique

All patients had a thoracic epidural for intraoperative
anesthesia and postoperative pain control. The patient was
placed in the supine position after general anesthesia. The
arms of the patient were kept abducted about 70—80° in
relation to the body. One small vertical skin incision was
made in the midaxillary line each side. After subcutaneous or
submuscular dissections were performed, the pleural cavities
were entered at the highest point of the funnel. A decreased
ventilated volume (about 70% of the expected volume) was
achieved by the anesthesiologist. A right thoracoscopy with a
10 mm, 0° scope entering the pleural cavity via the right
surgical wound for direct inspection of the mediastinal
structures was done first. A left thoracoscopy was performed
via the left surgical wound later. A right-to-left mediastinal
dissection by the introducer under direct left thoracoscopic
visualization was undergone (Fig. 1A). After the substernal
tunnel was achieved, a 28 Fr chest tube was connected on the
introducer and retained in the thorax after the introducer
was pulled back. A pre-bent Lorenz pectus bar (Lorenz
Surgical, Inc., Jacksonville, FL) was connected to the chest
tube and advanced across the mediastinum. After the pectus
bar was rotated and anchored into the position, the bar was
fixed with either a 1.0-mm stainless wire or heavy
nonabsorbing sutures at the end holes of the pectus bar
and the right hinge point [7]. In patients with very long and
severe form of pectus excavatum, an additional substernal
tunnel was made under the direct left thoracoscopic viewing
and another pectus bar was introduced and fixed. In patients
with recurrence previously repaired by modified Ravitch
procedure, an additional parasternal incision was made for
mediastinal dissection under the bilateral thoracoscopic
inspection. Two small-caliber (1/8 in. in diameter) close
drainage tubes were inserted into both pleural cavities for
drainage of air and fluid, and then the lung was returned to
normal volume ventilation. After extubation, patients were
sent to the intensive care unit for a postoperative radiograph
and were monitored for 24 h.

Postoperative pain was controlled by epidural patient-
controlled analgesics with administration of fentanyl.
Nonsteroidal anti-inflammatory drugs (NSAIDs) were pro-
vided in patients with severe pain episodes. The patients

Fig. 1. (A) A right-to-left mediastinal dissection by the introducer under direct left thoracoscopic visualization on a 25-year-old man with pectus excavatum (arrow
head). (B) Under the thoracoscopy, mediastinal adhesion (arrow head) was detected (B: bar; C: heart; L: lung; P: pectus). (C) Aberrant vessels were detected in
mediastinal pleura (arrow) and evaded under the direct visual during mediastinal dissection using an introducer (arrow head).
were discharged from the hospital when pain control was possible by oral analgesics. Our patients were followed-up at 2 weeks, 1 month, 3 months after operation, and then twice annually.

2.2. Statistical analysis

Descriptive data are expressed as mean and range. Student’s t-test was used for continuous variables. The chi-square test was used for comparison of categoric variables between groups. A p value of less than 0.05 was considered statistically significant. SPSS 11.0 software (SPSS, Inc., Chicago, IL, USA) was employed for all analyses.

3. Results

Ninety-six adult patients (80 men, 16 women) with a mean age of 24.5 years (range 18—42 years) who successfully underwent modified bilateral thoracoscopic-assisted Nuss repair were included. The demographic features of Nuss repair in our patients are shown in Table 1. Six patients were repaired due to recurrence of pectus excavatum after a modified Ravitch procedure. Two patients received thoracoscopic procedure with resection of blebs and pleurodesis for spontaneous pneumothorax, two patients had history of pneumonia, and one patient had history of thoracic trauma with pulmonary contusion. Under the bilateral thoracoscopic evaluations, 19 patients were found having pleural, mediastinal adhesions or small aberrant vessels in the mediastinal pleura. In these patients, six patients were present due to a previous modified Ravitch procedure, two patients to previous thoracoscopic procedures, and three patients to pneumonia or pulmonary contusion previously. Eight patients without previous surgical or traumatic history (8/85 patients; 9.4%) were found to have pleural adhesion (Fig. 1B) or aberrant vessels (Fig. 1C). The pleural or mediastinal adhesions were dissected under thoracoscopic visualization. The aberrant vessels detected by thoracoscopy were evaded to injury during the mediastinal dissection and attachment of the bar. Eighty-four patients were corrected by single pectus bar, and 22 patients by double bars (22.9%).

Six patients who received a modified Ravitch procedure with recurrence were repaired by Nuss procedure. Posterior support with a strut after cartilage resections was performed in five patients. The strut was removed 1—2 years after the modified Ravitch procedure in four patients, and the other one was removed during Nuss repair.

The surgical time ranged from 50 to 185 min. Mean surgical time for first repair with single bar was 65 min (range 50—100 min), but for redo patients or correction with double bars the time was 120 min (range 100—185 min). The blood loss was all less than 30 cc, and mostly less than 10 cc (83 in 96 patients; 86.4%). No blood transfusion was needed in any patients during and after operation. The pleural drainage tubes were removed 1.4 days (1—6 days) after operation if no persistent air leakage.

4. Early complications

No mortality, mediastinal injury, active bleeding and life-threatening complication occurred after operation. Only one patient with pneumothorax (1%) was identified after operation, but did not require chest tube insertion. One patient with double-bar insertion had atelectasis with pleural effusion (1%) 3 weeks after repair requiring needle thoracocentesis.

5. Late complications

Pericardial effusion occurred 2 months after 1 (1%) repair for previous failed Ravitch procedure requiring pericardio-centesis and administration of steroid. There were two (2.6%) bar displacements requiring surgical revision.

6. Follow-up

The mean length of hospital stay was 7.2 days (range 5—13 days). The patients had been followed for a mean time of 22 months (from 3 to 35 months) after operation. Subjectively, 88 patients (91.6%) have been satisfied with their surgical correction (excellent: 73%; good: 18.6%). Seven patients (eight bars) were removed. There was no complication. These patients were followed up for 2—8 months and no

Table 1 Demographic and clinical characteristics of 96 patients with pectus excavatum corrected by modified bilateral thoracoscopy-assisted Nuss procedure

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Young adult (18—25 years; n = 63)</th>
<th>Old adult (26—42 years; n = 33)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Male 55 (87.3%)</td>
<td>Female 28 (84.8%)</td>
</tr>
<tr>
<td></td>
<td>Female 8 (12.7%)</td>
<td></td>
</tr>
<tr>
<td>Mean BMI (SD)</td>
<td>19.2 (2.3)</td>
<td>18.6 (1.8)</td>
</tr>
<tr>
<td>Family history</td>
<td>23 (36.5%)</td>
<td>11 (33.3%)</td>
</tr>
<tr>
<td>Symptoms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Progressive deformity</td>
<td>22 (34.9%)</td>
<td>10 (30.3%)</td>
</tr>
<tr>
<td>Exercise intolerance</td>
<td>40 (63.5%)</td>
<td>25 (75.8%)</td>
</tr>
<tr>
<td>Progressive chest discomfort</td>
<td>43 (68.3%)</td>
<td>28 (84.8%)</td>
</tr>
<tr>
<td>Palpitation</td>
<td>8 (12.7%)</td>
<td>5 (15.2%)</td>
</tr>
<tr>
<td>Comorbidities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scoliosis</td>
<td>15 (23.8%)</td>
<td>6 (18.2%)</td>
</tr>
<tr>
<td>Social withdrawal</td>
<td>11 (17.5%)</td>
<td>6 (18.2%)</td>
</tr>
<tr>
<td>Haller index</td>
<td>5.1 (3.0—13)</td>
<td>4.8 (2.9—10)</td>
</tr>
<tr>
<td>Cardiac compression on CT scan</td>
<td>57 (90.5%)</td>
<td>29 (87.8%)</td>
</tr>
<tr>
<td>Restrictive pulmonary function</td>
<td>20 (31.7%)</td>
<td>11 (33.3%)</td>
</tr>
<tr>
<td>Mitral valve prolapse</td>
<td>8 (12.7%)</td>
<td>4 (12.1%)</td>
</tr>
<tr>
<td>Previous failed Ravitch procedure</td>
<td>4 (6.3%)</td>
<td>2 (6.1%)</td>
</tr>
<tr>
<td>Mean hospital stay (SD)</td>
<td>6.8 (4—13)</td>
<td>7.3 (4—14)</td>
</tr>
<tr>
<td>Complications</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pneumothorax</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Pleural effusion</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Bar displacement</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Pericardial effusion</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Satisfaction (cosmetic)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excellent</td>
<td>47 (75.3%)</td>
<td>23 (69.7%)</td>
</tr>
<tr>
<td>Good</td>
<td>11 (17.4%)</td>
<td>7 (21.2%)</td>
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<tr>
<td>Fair</td>
<td>4 (6.3%)</td>
<td>2 (6.1%)</td>
</tr>
<tr>
<td>Failed</td>
<td>1 (1.6%)</td>
<td>1 (3%)</td>
</tr>
</tbody>
</table>
The device of CO2 might be not necessary. In the patients with hypoinflation of lung during mediastinal dissection, it could allow excellent visualization over each pleural cavity. Under the bilateral thoracoscopy via the wound due to bar insertion, there were no other cardiopulmonary complications in pediatric patients [15]. Palmer et al. demonstrated a bilateral thoracoscopy with left-to-right mediastinal dissection in pediatric pectus excavatum that could provide good visualization of mediastinum and eliminate the complications in pediatric patients [15].

The adult chest is considered less flexible and compliant than the child chest due to increasing maturity of ossification [3,19—21]. A majority of surgeons indicated a high risk for complications with Nuss procedure in adult patients [5,13]. The accumulation of clinical experience and modifications of this new technique were encouraged for decreasing complications in adults. Nuss et al. demonstrated thoracoscopy applied to the minimally invasive repair of pectus excavatum using right thoracoscopy via an additional small incision for thorascopic observation in the right pleural cavity under insufflation of CO2 [10]. In our modifications, we applied bilateral thoracoscopy via the wound due to bar insertion without other incisions for the thorascopic. The device of CO2 might be not necessary. In the patients with double-bar insertion or repair for the recurrent pectus excavatum, bilateral thoracoscopy could provide a safe and efficient achievement of mediastinal dissection. The modified bilateral thorascopy with right-to-left mediastinal dissection for Nuss procedure in adults with pectus excavatum was applied without additional port incisions compared to prior reports [15] and resulted in better cosmetic results. A small-caliber tube was inserted to pleural cavities for drainage of pleural air and fluid for 1—2 days. Only one patient had short-term air leakage, and tubes were removed 6 days after operation. Only one patient with pneumothorax (1%) was identified, but this was not linked to chest tube insertion. There were no other cardiopulmonary complications.

One of the most common complications was bar displacement [6]. According to the literature, the incidence of bar displacement was 3—20% [7,12,13]. Old age and severity of pectus were the risk factors for bar flipping. Insertion of double bars, in old age or complicated patients, and fixation of the bars (using stabilizers or wire fixation) securely were recommended. Pleural effusions were the most common complication in the adult series in 3—17% of the patients [3]. The collection of pleural fluid may need thoracocentesis, chest tube drainage, or administration of oral cortisone. The temporary presence of pleural effusions may be explained by the empty space being created by elevation of the sternum or atelectasis [3]. In the adult, prior thoracic surgery, recurrent pectus excavatum, pulmonary infection or trauma might increase the complication rate. In our series, 11 patients were found having pleural or mediastinal adhesions due to prior thoracic surgery, recurrent pectus excavatum, pulmonary infection or trauma. The aberrant vessels in the mediastinal pleura were found in eight patients (9.4%). These findings could be explained by the presence of pleural effusion, hemothorax or pneumothorax after injuries of these small vessels or lungs by blind dissection. In our patients, the pleural complications were low. No patients developed pleural effusion or mediastinal injuries in our study just after the operation. The modified Nuss procedure using bilateral thorascopy could detect and evade aberrant vessels or adhesions to facilitate the dissection of the mediastinal pleura. In our experience, six adult patients had recurrent pectus excavatum after Ravitch repair and received Nuss procedure. Bilateral thorascopy-assisted technique was applied to these patients, and there were no differences in the complications compared to the first repair. But we found the differences in redo patients were longer operative time, the need of an additional parasternal incision for mediastinal dissection, and more flexibility of pectus. Due to the defect of the thoracic cage after first repair by modified Ravitch procedure, long-term correction is suggested.

The indications of Nuss repair in our patients are shown in Table 1. Before Nuss repair, we explained the surgical indications, complications, predicted results and limitations of Nuss repair in adults to patients and family. After patients signed the informed consent, the surgery was done. Our data, mitral valve prolapse was found in 12.5%. In the literature, mitral valve prolapse in patients with pectus excavatum was 12—20% [13]. Its actual mechanism is unknown, but cardiac abnormalities caused by the depressed chest wall might be considered.

In our experiences, indications for double-bars support were suggested on: (1) depressed area >3 intercostal spaces, (2) after single bar insertion, the deformity is still obvious, and additional bar could correct the deformity significantly. It is also dependent on the experience of surgeons, chest wall elasticity and patients’ decision. It is interesting that all patients having failed Ravitch procedure could be corrected by single bar well. It might be due to a chest wall defect that, after resection of costal cartilages, increased the chest wall plasticity. The differences of the clinical characteristics for single- or double-bars insertion are demonstrated in Table 2. It showed that female patients had higher rate for double-bar correction. Double-bar repair needed longer operation time and had a higher complication rate than single-bar procedures.

The two patients with bar displacement and the chest wall sagging progressively from the initial appearance that needed revision occurred 1—2 months after surgery. The
two patients were 22- and 25-year-old males who had severe central depression of the sternum (Haller index 5.1 and 6.5; depth of depression is 3.2 and 3.8 cm). One patient received revision 2 months after operation, and the other was revised 1 year after first repair. During revision, the bar was removed and after mediastinal dissection the bar was inserted again.

In the literature [13], the pectus bar(s) are suggested to be removed after the chest wall deformity was corrected in 2–4 years. The patient was under general anesthesia, and the ends of the bar were mobilized via the old incision wounds. The wires were cut and removed first, the bar was removed directly after the externalized portion ends of the bar was bent reversely. In our experiences, the patients with fair or failed result had more complicated deformities, including pectus excavatum combined with pectus carinatum, long area deformity, severe bony rigidity, residual deformity or partial recurrence after repair.

In out series, out of 96 patients, 89 still have bars inside. Evaluation of results cannot be considered complete while the metal support is still in place. This was the limitation of this study. We will evaluate the short- and long-term results of their repair.

8. Conclusion

Nuss procedure using the modified bilateral thoracoscopic repair for adult patients with pectus excavatum could eliminate the risk of cardiopulmonary injuries. It could allow direct inspection in mediastinum and facilitate mediastinal dissection, especially in patients with recurrent pectus excavatum, history of previous thoracic procedure or trauma. Other methods for ensuring safety such as substernal dissection or elevation might be unnecessary.