Comparison of the Nuss and sternal turnover procedures for primary repair of pectus excavatum

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Summary

Background: Pectus excavatum (PE) is a common chest wall deformity. There are several surgical alternatives for the repair of PE. In our practice, the sternal turnover (STO) procedure had been performed for decades. In 2008, we started treating PE patients with the Nuss procedure. Our objective of this study is to compare these two procedures.

Methods: A retrospective chart review was conducted on 50 patients undergoing pectus excavatum repairs from March 2005 to January 2013, including 20 patients with the STO procedure and 30 patients with the Nuss procedure. Patients were evaluated for type of repair performed, operating time, drainage after operation, length of postoperative stay, complications, and cosmetic results.

Results: The mean age of the STO group was 11.0 years and that of the Nuss group was 15.0 years ($p = 0.353$). The Nuss procedure had a much shorter mean operating time, a less mean drainage after operation, and a shorter mean time to drainage tube removal than those of the STO procedure. The rate of complication was 40.0% (8/20) in the STO group and 33.3% (10/30) in the Nuss group. Follow-up data indicated that 90% (18/20) of patients in the STO group and 96.7% (29/30) of patients in the Nuss group regarded the results as good or excellent ($p = 0.965$).

Conclusion: Our data suggests that both the STO and Nuss procedures are equally safe and effective correction methods. However, less trauma, faster recovery, and better cosmetic results are the benefits of the Nuss procedure.

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Conflicts of interest: The authors declare that they have no financial or non-financial conflicts of interest related to the subject matter or materials discussed in this article.

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1. Introduction

Pectus excavatum (PE) is a common chest wall deformity occurring in 8 per 1000 live births. It is characterized by the posterior depression of the sternum and lower costal cartilages, and is four times more common in boys than in girls.

Most patients are asymptomatic, and they only suffer from a cosmetic point of view. Patients with severe deformities suffer from physical ailments such as frequent respiratory infections, decreased endurance, shortness of breath with exercise, and chest pain. Patients are often susceptible to restrictive lung disease, mitral valve prolapse, and significant problems with self-image, especially when they enter adolescence.

The only way for correction is surgery. Several surgical approaches have been designed for the repair of PE. Two traditional surgical methods widely used are: sternal turnover (STO) operation (mostly in Asian countries such as Japan and China) and Ravitch operation (in Europe and the United States). With the development of endoscopic techniques, Nuss introduced thoracoscopy-assisted minimally invasive repair for PE (Nuss operation) in 1998. Owing to its simplicity, fewer complications, less pain, and satisfactory results, the Nuss operation has been well accepted by both surgeons and patients. Our study compares the Nuss procedure to the STO procedure in order to define their respective benefits, limitations, and case selection.

2. Materials and methods

When PE patients had a Haller index $>3.2$, it was seen as criteria for surgical indication and included in both of the groups. Fifty consecutive patients with PE, who underwent primary repair from 2005 to 2013 in the First Hospital of the China Medical University, were retrospectively reviewed. Twenty patients from March 2005 to April 2010 underwent repair by STO procedure, and 30 patients from September 2008 to January 2013 underwent the Nuss procedure.

As described elsewhere, the STO repair, wherein the deformed sternum is cut at the second or third intercostal space and turned and restored, is an alternative surgical approach. We adopted STO with the pedicle of abdominal rectus muscle. The Nuss repair requires bilateral maxillary transverse incisions and placement of a substernal concave stainless steel bar, which is bent to conform to the patient’s anterior chest wall. At the end of the surgery, chest tubes are inserted, and will be removed postoperatively, whereas the chest roentgenogram shows no obvious pneumothorax or pleural effusion, and the drainage is under 100 mL in 1 day.

A retrospective chart review was performed to document the method of repair and clinical data, including patient characteristics, surgical data, complications, and cosmetic outcome. Patients were photographed prior to and after surgery and graded immediately by themselves after the operation as excellent, normal chest; good, mild residual pectus; fair, moderate residual pectus; and poor, severe recurrence requiring further treatment. Statistical analysis was performed using SPSS 16.0 software (SPSS Inc., Chicago, IL, USA; Student t test and Chi-square test). A $p$ value $<0.05$ was taken to be statistically significant.

3. Results

3.1. Patient characteristics

Among patients with concomitant flat chest in each group, there were 3 (15%) in the STO group and 8 (26.7%) in the Nuss group ($p = 0.095$). The STO group had higher rates of decreased exercise endurance than the Nuss group (26.7% vs. 75%).

The median Haller index in the Nuss group was 4.0, ranging from 2.6 to 6.2. In the STO group, the median Haller index was 4.3, ranging from 2.8 to 6.5 (Table 1).

3.2. Hospital course

The clinical courses for the two groups were dramatically different. Table 2 provides clinical information for both groups. In 30 patients undergoing Nuss repairs, a single bar was inserted in 23 (76.7%) patients and two bars were inserted in seven (23.3%) patients (Table 2).

3.3. Complications

Table 3 summarizes the complications that occurred during the initial hospital stay. There were no deaths or any cardiac perforations during the 50 repairs. The overall complication rate was 36.0% (18/50), which was not significantly different between the groups. In the STO group, the rate of complications was 40.0% (8/20). Among the patients undergoing the Nuss repair, 10 (33.3%) experienced postoperative complications, containing one (3.3%) delayed brachial nerve temporary paralysis. This rare complication appeared 15 days postoperatively and the patient returned to normal after a short period of physical rehabilitation and oral antibiotics (Table 3).

3.4. Cosmetic results

Data were available for all patients (Table 4). There was no statistical significance between the two groups ($p = 0.965$).

### Table 1 Patient characteristics.

<table>
<thead>
<tr>
<th></th>
<th>Nuss</th>
<th>STO</th>
<th>$\chi^2$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (M/F)</td>
<td>29/1</td>
<td>18/2</td>
<td>0.0002</td>
<td>0.965</td>
</tr>
<tr>
<td>Mean age at operation (range)</td>
<td>15 (6–23)</td>
<td>11 (3–36)</td>
<td>17.519</td>
<td>0.353</td>
</tr>
<tr>
<td>Older than 18 y</td>
<td>2 (6.7%)</td>
<td>3 (15.0%)</td>
<td>0.592</td>
<td>0.296</td>
</tr>
<tr>
<td>Decreased exercise endurance</td>
<td>8 (26.7%)</td>
<td>15 (75.0%)</td>
<td>7.077</td>
<td>0.008</td>
</tr>
<tr>
<td>The median Haller index</td>
<td>4.0</td>
<td>4.3</td>
<td>0.795</td>
<td>0.463</td>
</tr>
</tbody>
</table>

M/F = male/female; STO = sternal turnover.
Surgical treatment of PE began with the report of Ludwig Meyer in 1911. Several surgical methods have been developed for correction of this deformity. STO is an alternative surgical approach that has been described by Ochsner and DeBakey, Nissen, and Wada et al. The biggest challenge of the turnover procedure was its greater invasiveness to the young patients, which was one of the main reasons that most surgeons from America and Europe were reluctant to use it. However, it was the dominant procedure in our clinical practice until 2010. In 1998, Nuss introduced a minimally invasive technique as an alternative surgical approach by placing the sternum with a retrosternal metallic bar that is placed under thoracoscopic control. This procedure has gained popularity and is performed worldwide for PE repair.

Although the number of cases we compared is small, and time is short, to the best of our knowledge, no other study to date has compared the results and complications of these two procedures. The vast majority (94.0%) of our patients were male. This is consistent with the male-to-female ratio for PE repairs reported in the literature. The gender, age at operation, and Haller index combined with flat chest in both groups did not have a statistical difference, which indicated the patients in these two groups were generally comparable. The STO patients had higher rates of decreased exercise endurance. However, it did not mean that the severity of PE is higher in the STO group than in the Nuss group. Decreased exercise endurance is a subjective evaluation, whereas the Haller index is an objective evaluation and the criteria for measuring the severity of PE.

In our study, the mean age of patients undergoing the Nuss operation was 15. Performing the procedure in younger patients may be an advantage because of the increased pliability of the thorax. Nuss et al. found the ideal age is just prior to puberty because at that age, the chest is still very malleable. However, if a young patient has significant cardiac and/or pulmonary compression, an early repair is justified. The anamnesis section has a statement of decreased exercise endurance which is significantly different between both groups, may be due to the early diagnosis now.

When the lengths of postoperative stay and the drainage after operation are compared, the Nuss procedure had statistical significance compared to the STO procedure. In terms of operating time and the time of drainage tube removal, the Nuss procedure was superior to the STO procedure. Even though there was no statistical significance owing to our small sample size, clinical significance still exists.

In the STO group, 35% (7/20) of patients needed respiratory assistance by a ventilator after operation for less than 1 day, and 20% (4/20) of patients received a blood transfusion after the operation. None of the patients who underwent the Nuss procedure needed a blood transfusion or ventilator assistance. Minimal surgical trauma, immediate postoperative extubation, and rapid recovery are advantages of the Nuss method.

The complication rate in the Nuss group was lower than that in the STO group. We did not encounter severe complications such as death, cardiac perforation, or thoracic outlet syndrome, as reported in other case series. In the Nuss group, one patient had bar displacement that required reoperation. In his second operation we preferred the technical modification of the Nuss operation, which contained multiple pericostal sutures around the bar, and the short-term result was good. Our rate of bar displacement was a little higher than that of 2.46% by Kelly et al.

One rare complication in the Nuss group merits further discussion. A 15-year-old boy began to suffer delayed injury of the right brachial plexus on the Day 15 postoperatively, which was confirmed by electromyography. A physical check-up revealed a painful and enlarged subaxillary lymph node. After physical therapy and use of oral antibiotics for 1 week, the patient returned to his normal

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Hospital course.</th>
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<tbody>
<tr>
<td></td>
<td>Nuss (N = 30)</td>
</tr>
<tr>
<td>Operating time (min)</td>
<td>89.5 ± 37</td>
</tr>
<tr>
<td>Drainage after operation (mL)</td>
<td>238.6 ± 311</td>
</tr>
<tr>
<td>Tube removal after operation (d)</td>
<td>2.2 ± 1.9</td>
</tr>
<tr>
<td>Length of postoperative stay (d)</td>
<td>6.9 ± 1.4</td>
</tr>
<tr>
<td>Ventilator required</td>
<td>0</td>
</tr>
<tr>
<td>Blood transfusion</td>
<td>0</td>
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</table>

Data are presented as mean ± SD or n (%).

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Complications.</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Nuss (N = 30)</td>
</tr>
<tr>
<td>Pericardial perforation</td>
<td>1 (3.3)</td>
</tr>
<tr>
<td>Pneumothorax requiring treatment</td>
<td>5 (14.3)</td>
</tr>
<tr>
<td>Pleural effusion requiring treatment</td>
<td>2 (6.6)</td>
</tr>
<tr>
<td>Bar shift needing reoperation</td>
<td>1 (3.3)</td>
</tr>
<tr>
<td>Reoperation</td>
<td>1 (3.3)</td>
</tr>
<tr>
<td>Brachial plexus injury</td>
<td>1 (3.3)</td>
</tr>
</tbody>
</table>

Data are presented as n (%).

<table>
<thead>
<tr>
<th>Table 4</th>
<th>Cosmetic results.</th>
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<tbody>
<tr>
<td>Result</td>
<td>Nuss (N = 20)</td>
</tr>
<tr>
<td>Total primary patients</td>
<td>30</td>
</tr>
<tr>
<td>Excellent</td>
<td>20 (66.7)</td>
</tr>
<tr>
<td>Good</td>
<td>9 (30.3)</td>
</tr>
<tr>
<td>Fair</td>
<td>0</td>
</tr>
<tr>
<td>Poor</td>
<td>1 (3.3)</td>
</tr>
<tr>
<td>Excellent + good</td>
<td>20 (66.7)</td>
</tr>
</tbody>
</table>

Discussion

Surgical treatment of PE began with the report of Ludwig Meyer in 1911. Several surgical methods have been developed for correction of this deformity. STO is an alternative surgical approach that has been described by Ochsner and DeBakey, Nissen, and Wada et al. The biggest challenge of the turnover procedure was its greater invasiveness to the young patients, which was one of the main reasons that most surgeons from America and Europe were reluctant to use it. However, it was the dominant procedure in our clinical practice until 2010. In 1998, Nuss et al. introduced a minimally invasive technique as an alternative to the standard open repair, which raises the sternum with a retrosternal metallic bar that is placed under thoracoscopic control. This procedure has gained popularity and is performed worldwide for PE repair.

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baseline. Therefore, we believed that the subaxillary lymphadenopathy caused by the surgery and inflammation resulted in the delayed and temporary brachial nerve palsy.\(^\text{14}\) In order to prevent immediate brachial plexus injury, Nuss\(^\text{15}\) thought the standard position was supine with both arms abducted at the shoulders to approximately 70°, taking care to protect the patient from brachial plexus injury.

Patient satisfaction is an extremely important outcome to consider when evaluating these two procedures. Nuss\(^\text{15}\) reported that the long-term results in 628 primary repair patients after more than 1 year post bar removal are excellent in 540 patients (86.0%), good in 65 patients (10.3%), fair in 15 patients (2.4%), and failed in 8 patients (1.3%). Jo et al\(^\text{16}\) found that greater than 90% of patients reported good to excellent postoperative results. Lam et al\(^\text{17}\) found an advantage to the Nuss procedure for satisfaction and less chest discomfort. In our Nuss group, we had similar results (96.7% patients with either good or excellent results). Both the STO and Nuss procedures are effective correction methods.

In our view, the Nuss procedure will become the treatment of choice for children and adolescents with symmetric and asymmetric PE. Boehm et al\(^\text{18}\) thought older patients and patients with asymmetric defect should be advised to undergo repair by the conventional open method. We had treated eight patients who had asymmetric deformity by means of the Nuss procedure, with cosmetic outcomes that were good to excellent. Felts et al\(^\text{19}\) thought that asymmetrical PE (whatever the etiology) should be treated by placing two implants, which improved the cosmetic results with no postoperative repercussions. Among eight patients with asymmetric chest wall deformities, who underwent our Nuss procedure, only one patient placed two implants; the cosmetic outcome was excellent. Therefore, in our opinion, the asymmetrical forms of the condition, which classically are not a contraindication for the Nuss procedure (because the results have been shown to be sufficiently satisfactory) can be treated effectively and satisfactorily with one or two implants shaped to fit the deformity, with stable results over time.

Some of the limitations of our study include the following:

The study is retrospective. However, prospective comparison is impossible. We started performing the Nuss procedure in 2008 and no patients or their parents have undergone the open procedure after 2010. The sample is small. Comparison of the two types of operation has limitations because the relatively small number of patients reduced the statistical power.

There is a lack of information on long-term follow-up. The bar(s) should remain in the chest for 2–4 years after pectus repair.\(^\text{15}\) To-date, we have only removed one bar by reopening the ipsilateral incision on the side at which the bar was secured, and the cosmetic outcome was excellent. With more patients now approaching the time for elective bar removal, the long-term cosmetic outcome can be followed up and assessed. We anticipate the strength of our findings to improve with further follow-up and as our patient numbers grow.

It is apparent that both techniques are highly safe and effective in correcting PE deformities. Patients who have undergone the Nuss procedure recover more quickly and have a better cosmetic outlook than have patients who underwent STO repair. Our short-term results have encouraged us to offer this procedure to all surgical candidates, with careful consideration given to each case. Long-term follow-up will be necessary to evaluate not only the recurrence rate and cosmetic results, but also patient satisfaction (after removal of the sternal support bar).

Acknowledgments

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References


