

Nuss operation for pectus excavatum: a single-institution experience

Yong-Zhong Mao, Shao-Tao Tang, Yong Wang, Qiang-Song Tong, Qing-Lan Ruan

Wuhan, China

Background: The Nuss procedure for repair of pectus excavatum (PE) has been accepted worldwide because of minimal invasiveness and excellent cosmetic results. We summarized our experience with the treatment of 115 patients aged 2.7-18 years.

Methods: All the 115 patients underwent the Nuss procedure successfully from July 2003 to February 2008. They were divided into two groups: children group (below 12 years) and adolescents group (aged 12-18 years).

Results: The rate of complications was 14.7% and 37.5% in the children and adolescents groups, respectively ($P < 0.05$). There was significant difference in operation time, length of hospital stay, and analgesic time between the two groups ($P < 0.05$). The initial results of Nuss procedure were excellent.

Conclusions: The Nuss procedure can be performed with excellent early results in children. We suggest that children with PE should accept the Nuss procedure as early as possible when they are over 5 years old.

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Key words: adolescents;
children;
complication;
Nuss procedure;
pectus excavatum

Introduction

Pectus excavatum (PE) is one of the most common congenital chest wall anomalies in children. It is characterized by depression of the anterior chest

wall and sternum. Children with PE often suffer from limited cardiac and respiratory function. The deformity can also cause social psychologic stress because of the appearance of the chest. Therefore, correction of PE in children is necessary in order to prevent and relieve aggravating symptoms.^[1]

The traditional open Ravitch method and its variations have been the procedure of choice for nearly 50 years.^[2] The Nuss procedure, introduced by Nuss in 1998, has become an alternative to the traditional Ravitch procedure. Avoidance of cartilage resection, osteotomy and extensive dissection has made the Nuss procedure an attractive option for repair of PE. The Nuss procedure has been increasingly accepted worldwide.^[3] In China, more and more pediatric centers are adding the Nuss procedure to their surgical armamentarium. This technique has been used in our center since 2003. The present study was to summarize our early experience with this procedure and the initial outcomes. The methods for preventing complications were also discussed.

Methods

General data

From July 2003 to February 2008, 115 patients (72 male and 43 female) with PE underwent the Nuss procedure at the Pediatric Center of Union Hospital. The age of the patients ranged from 2.7 to 18 years, with an average of 7.85 ± 5.14 years (median, 6.5 years), and the mean Haller CT index was 4.51 ± 1.32 (range, 2.6-6.83). All the operations were performed by the same team. Hospital records were retrieved and the recorded data included complaints, postoperative complications, length of hospital stay, duration of the surgical procedure, and signs of pneumothorax on the routine postoperative chest X-ray. The 115 patients were divided into two groups: children group (below 12 years old) and adolescents group (aged 12-18 years). Their results of the Nuss procedure were compared.

Patient selection for correction repair was based on symptoms, physical examination, chest X-ray, and computed tomography (CT). The Haller CT index

Author Affiliations: Department of Pediatric Surgery, Union Hospital of Tongji Medical College, Huazhong University of Science and Technology, Wuhan 430022, China (Mao YZ, Tang ST, Wang Y, Tong QS, Ruan QL)

Corresponding Author: Yong-Zhong Mao, MD, Department of Pediatric Surgery, Union Hospital of Tongji Medical College, Huazhong University of Science and Technology, Wuhan 430022, China (Email: maoyz68@yahoo.com.cn)

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was calculated by dividing the width of the chest wall at the widest point by the distance between the posterior surface of the sternum and the anterior surface of the vertebral body. Patients of more than 2.5 years old, with a Haller CT index greater than 3.0 or unsatisfied appearance of the chest, were included for surgery. Patients of less than 2.5 years old or with a severe asymmetrical funnel chest were excluded. The scheduled time for removal of the metal bar was two and half years after the Nuss procedure.

Operative procedure

The patient was placed in supine position under general anesthesia. After draping the patient, the selected metal bar (Nuss bar, Lorenz Surgical, Inc., Jacksonville, Florida, USA) was bent into its final convex shape to conform to the desired anterior chest wall curvature. The procedure was performed as described previously.^[3-5] A stabilizer was placed on the lateral side of the bar to avoid rotation. The bar was secured with Nylon 1-0 sutures to the lateral chest wall muscles and to the stabilizer.

If an acceptable cosmetic result could not be achieved with a single metal bar, an additional bar was inserted at one intercostal space above or below the original bar. If the patient presented with asymmetric PE, the bar was shaped asymmetrically according to the method described by Park.^[6] Before closing the incision, positive end expiratory pressure (PEEP) was added to prevent pleural air trapping.

Intravenous analgesics, morphine or aspirin-DL-lysine for injection, were routinely given to control postoperative pain in the initial 3 to 5 days. Sport activities were not permitted for six weeks to allow scar tissue to mature and to hold the bar in place. After six weeks, the patients can slowly resume normal activities. Heavy contact sports were not recommended.

Statistical analysis

The data were compared with Students' *t* test and Chi-square test. All statistical analysis were performed using SPSS 10.0 statistical software. *P* values less than 0.05 were considered statistically significant.

Results

The 115 patients underwent the Nuss procedure successfully. In no patient did we convert the procedure to a Ravitch operation. Video-thoracic laparoscopy of 0 or 30 degrees was used. A single bar was inserted in 97 patients, while double bars were inserted in the remaining patients. The duration of surgical procedures, length of hospital stay, and analgesic time

Table 1. The results of the Nuss procedure in the two groups

Group	Rate of complications (%)	Operation time (min)	Length of stay (d)	Analgesic time (d)
Children (n=75)	14.7	55±20	7.2±1.5	4.5±2.1
Adolescents (n=40)	37.5	68±25	10.8±2.0	6.4±3.6
<i>P</i> value	<0.05	<0.05	<0.05	<0.05

Table 2. Complications in the two groups

Complications	Children group (n=75)	Adolescents group (n=40)
Early complications		
Subcutaneous emphysema	3	2
Pneumothorax with spontaneous resolution	2	2
Pneumothorax requiring aspiration	1	1
Pneumothorax requiring chest tube	0	1
Hemopneumothorax	1	1
Atelectasis	1	2
Pericardial effusion	1	1
Late complications		
Bar displacement	1	2
Seroma and infection	1	3
Total	11 (14.7%)	15 (37.5%)

are shown in Table 1.

Early postoperative complications included subcutaneous emphysema, pneumothorax with spontaneous resolution, pneumothorax requiring aspiration, pneumothorax requiring chest tube, hemopneumothorax, atelectasis, and pericardial effusion. Late complications included bar displacement, seroma and infection (Table 2).

Early excellent results (symmetrical chest and no depression of the sternum) were observed in 104 (90.4%) of the patients, and good results (local asymmetrical chest or mild depression of sternum) in 9 (7.8%), except for recurrence occurred in 2 (1.8%). The metal bar was removed from 37 patients after a mean duration of 30 months, of whom, 33 showed excellent results and 4 showed good results.

Discussion

The Ravitch procedure can provide the best long-term results for PE and has been the treatment of choice for decades. However, instability of the chest wall due to extensive dissection of the perichondrium may occur in some children. Even growth retardation of the chest wall takes place with decreased pulmonary function over time.^[7] Thus, minimally invasive methods have been used clinically. Compared to the Ravitch procedure, the Nuss technique has many advantages

such as short operating time, minimal blood loss, early return to full activity, small skin incision, and maintenance of chest wall elasticity.^[8] The results of the procedure have led to its wide use in pediatric surgery.

Currently, the recommended age for PE repair is 5 to 20 years, but the optimal age is 6 to 12 years.^[9,10] In the present study, most (65%) of patients were less than 12 years old. We thought that the costal cartilage and the sternum were more flexible in the children group than in the adolescents group. Because of the better flexibility of the chest wall, postoperative pain in the children group was also slighter than that in the adolescents group, and there was a rare need of analgesics. A recent survey of the Nuss procedure in children showed that the average age was 10.6 years.^[11] Most surgeons preferred to perform the Nuss procedure in children before the early teenage.^[11] The force necessary to elevate the sternum to the desired level in children under 10 years old was reported to be 15 lbs, whereas in adolescents the force was as approximately twice as that.^[12] The more stronger force against the sternum not only causes considerable pain, but also increases the instability of the metal bar as well as the possibility of bar displacement. By comparing the results of the Nuss procedure in different ages, Ohno et al^[13] concluded that patients of more than 13 years old experienced more complications and had poorer cosmetic results than did younger patients. In our study, the rate of complications in the adolescents group was also significantly higher than that in the children group. In children less than 5 years old, the sternum is not completely ossified, and can not bear the elevating force of the bar. Some patients may develop progressive chest wall deformity such as pectus carinatum. Therefore, we suggest that the Nuss procedure should be performed as early as possible once children with PE are more than 5 years old.

It should be emphasized that even though the Nuss procedure is minimally invasive and simple, there are major complications such as pneumothorax, hemopneumothorax, pericardial effusion and bar displacement. It was reported that the incidence of complications after the Nuss procedure is even higher than that of the Ravitch operation.^[8]

Subcutaneous emphysema and pneumothorax were most frequent at the early postoperative stage, especially in our first 10 patients. The most severe subcutaneous emphysema we had met occurred in a patient, in whom the subcutaneous gas disseminated up to the supraclavicular fossa and down to the right upper quadrant abdomen. Subsequently, before closure of the incision, the anesthetist applied positive pressure ventilation until no more air bubbles escaped from the tubing. This problem was gradually eliminated. Nuss

et al^[14] reported that the incidence of pneumothorax was 54%, in which only 1.7% needed thoracic cavity drainage. Generally, small residual pneumothorax does not require surgical treatment, and it can be absorbed. In severe cases or cases accompanied by hemopneumothorax, aspiration or chest tube is needed.

Pericardial effusion occurred in two patients in our study. The patients presented with fever, dyspnea, and complained of retrosternal pain. On auscultation, a friction rub was heard. Ultrasonography confirmed fluid in the pericardial sac. These patients required pericardial catheterization and had an uneventful recovery. The etiology of pericardial effusion is not clear, but seems to be related to trauma. It is therefore important to minimize the trauma to the pericardium when creating the substernal tunnel.

Patients undergoing the Nuss procedure need adequate pain management to prevent postoperative respiratory complications and ensure an uneventful recovery. Serious chest pain may lead to acquired thoracic scoliosis.^[15] Intravenous infusion of analgesics was used for postoperative pain relief in our study. One child had a hospital stay of 2 weeks because of postoperative pain. Several children complained of abdominal distention and vomiting, which may be related to the use of analgesics. The symptoms disappeared in several days after conservative therapy.

Bar displacement occurred in 5.9% of the patients, and it often happened within the first 30 days after surgery.^[11] A bar stabilizer reduced the rate of bar displacement from 15.7% to 5.4%,^[14] and a three-point fixation technique reduced the incidence to 5%.^[16] A five-point fixation technique, proposed by Park and colleagues,^[6] even reduced the incidence to 3.4%. In our study, the metal bar was secured with Nylon 1-0 sutures to the lateral chest wall muscles and to a stabilizer, with a bar displacement incidence of 2.6%. In two patients, the bar had a slightly lateral sliding, and there was a slight change of the chest wall contour. One had a remarkable flipping of bar rotation, and refixation was needed. Shortening the metal bar by approximately 5 cm, placing the stabilizer much close to the entrance of the bar into the thoracic cavity, and submuscular and pericostal fixation of metal bar are prerequisites for the prevention of bar dislocation.^[4,5] In fact, it is not necessary to use the pericostal fixation technique in all patients undergoing the Nuss procedure. In patients with symmetric PE or young patients with mild symmetric PE, routine bar fixation can result in satisfactory outcomes.

Seroma and infectious complications may lead to bar removal and recurrence of defects. The published rates of postoperative infection range from 1% to 6.8%, and *staphylococcus aureus* is the most common

organism (83%) sensitive to methicillin.^[17] The recent reported rate of wound infection is 2.2%.^[11] In the present study, all infectious complications were seen on the side of the stabilizer as reported in the literature.^[9] We speculate that extensive submuscular dissection during insertion of a stabilizer may result in the formation of a large amount of seroma and increase the risk of wound infections around the bar. Incision seromas were initially aseptic on examination in our 4 patients and became infected in 2 after spontaneous perforation. In an attempt to salvage the bar, infected tissue was resected in 4 children, and intravenous antibiotics were given 2 weeks after the operation. This strategy was successful in retaining the bar in all patients. Our experience indicates that there is no need for immediate removal of an infected bar, and most of these infections can be managed by local wound treatment and antibiotic therapy.

The long-term results of the Nuss procedure were excellent. Nuss et al^[14] reported that the long-term results after the bar removal were excellent in 71% of cases, good in 21%, and recurrence in 7.8%. In our study, 33 of the 37 children who underwent bar removal could keep the original contour. Although four patients had local asymmetry, they were satisfied with the operative results. Further observations are needed to draw a conclusion about the long-time outcomes after bar removal.

In conclusion, our study demonstrates that the Nuss procedure for PE can be performed with excellent early results in children. The complications are preventable and decrease with the accumulation of the operator's experience. Proper use of the operative techniques of the Nuss procedure and attention to details previously described are important in preventing complications. We suggest that children with PE should accept the Nuss procedure as early as possible when they are more than 5 years old.

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