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Surgical Treatment for Pectus Excavatum

The aim of this study was to compare clinical outcomes in pectus excavatum patients undergoing a Ravitch operation with those undergoing a Nuss procedure. Retrospective study was conducted on one hundred and twenty three patients who underwent Ravitch operation (n=16) and Nuss procedure (n=107) between 1995 and 2002. Mean age of the patients was 7.9 ±6.2 yr. In the Ravitch group, operation time was 196.9 ±61.0 min, and required 10.2 ±2.6 chondral bone resections. Average hospital stay time was 15.9 days. In the Nuss group, operation time was 67.2 ±33.1 min, and bar removal was required two years after the bar insertion. The length of hospital stay was averagely 8.0 days, and postoperative reoperations were performed in five patients due to bar displacements, while early bar removal was required in one patient. The patient interviews for operation results were conducted and revealed that 92.3% of the patients in the Ravitch group showed good to excellent, while 93.3% of Nuss bar removed patients replied good to excellent. Though Nuss procedure has many advantages, it also has some disadvantages. So, the method of the operation should be selected according to the characteristics of the patient.

Key Words : *Funnel Chest; Pectus Excavatum; Surgical Procedures, Minimally Invasive*

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INTRODUCTION

Chest wall deformity is not an uncommon disease in infants and children, and it is often combined with organic problems as well as cosmetic problems. Pectus excavatum is the most common chest wall abnormality, and a number of patients with the deformity require surgical corrections (1).

At Guro Hospital of Korea University, we have analyzed pectus excavatum patients who underwent Ravitch operation (invasive procedure) and Nuss procedure (minimally invasive procedure) based on preoperative evaluation, operating time, ICU stay time, hospital stay, complications, etc. The aim of this study was to compare clinical outcomes of the two groups, evaluate the degree of patients' satisfaction, and confirm the effectiveness of both surgical methods for correction of pectus excavatum.

MATERIALS AND METHODS

One hundred and twenty three patients with pectus excavatum who underwent repair from December 1995 to May 2002 at Guro Hospital were reviewed retrospectively. The male to female ratio of the patients was 94:29. Average age at the time of operation was 7.86 ±6.21 yr. All patients were checked for history taking and received preoperative physical examination, chest CT, and cardiologic evaluation. If possible, pulmonologic evaluations were performed as well.

Sixteen patients underwent Ravitch operation from December 1995 to May 2002. The male to female ratio was 14:2. The patients averaged 8.8 ±7.4 yr of age with a range of 1.2 to 27 yr. The average height and weight were 131.6 ±28.0 cm and 28.7 ±17.8 kg, respectively. Average Haller index of the Ravitch group was 4.0 ±3.3.

Nuss procedure was performed on 107 pectus excavatum patients from August 1999 to May 2002. There were more male patients than female patients with the ratio of 79:28. The patients in the Nuss group averaged 7.9 ±5.0 yr of age with a range of 2 to 25 yr. Average height and weight were 123.4 ±26.3 cm and 26.2 ±14.0 kg, respectively. Average Haller index was 4.3 ±1.1 (Table 1).

The patients in both groups had associated diseases including gynecomastia, pneumonia, undeveloped breast, etc. One patient who was transferred from a different hospital after the failure of Nuss procedure underwent Ravitch operation, and another patient who had received Ravitch operation underwent Nuss procedure three years later due to an unexpected trauma (Table 2).

In terms of age, height, and weight, the differences between the two groups were not statistically significant. The preoperative and postoperative data of the two groups were com-

pared and evaluated using the Student t-test.

RESULTS

In the Ravitch group, preoperative cardiologic evaluations showed trivial TR, trivial AR, sinus bradycardia, and RBBB in five patients, but there was no need for treatment. All patients in the Ravitch group received submammary incision. The mean operation time was 196.9 ±61.0 min, and the length of hospital stay averaged 15.9 ±2.3 days. On average, 10.2 ±2.6 chondral bone resections per patient were performed. Nine patients underwent sternal wedge resection and five patients received insertion of Kirshner wires for sternal fixation.

In the Nuss group, preoperative cardiologic evaluations showed small ASD, MR, trivial TR, trivial PR, pulmonary hypertension, RBBB, AV block, RVH and sinus bradycardia in nine patients, but medical or surgical treatment was not needed at that time. Steel bars (Walter Lorenz Surgical, Jacksonville, FL, U.S.A.) were placed in all the patients, and stabilizers were used in 8 patients (fixed to the right edge of the steel bar in one patient and fixed to the left edge of the bar in seven patients). The mean operating time for the Nuss group was 67.2 ±33.1 min and the length of hospital stay averaged 8.0 ±1.6 days, which was shorter than that of the Ravitch group (p<0.01) (Table 3).

Patients in both groups experienced similar early complications such as skin wound dehiscence, pneumothorax, hemothorax, etc.

Three patients (18.8%) in the Ravitch group experienced early operative complications such as hemothorax (n=1), flail chest (n=1), and skin wound dehiscence (n=1). All patients with complications were treated successfully. There were not any cases of long-term complications.

In the Nuss group, early operative complications reached 8.4% requiring reoperation in 3 patients. Long-term postoperative complications occurred in 3.7% of the patients, which included bar displacement requiring reoperation (n=5), and uncontrolled wound infection requiring early bar removal (n=1) (Table 4).

Postoperative intravenous antibiotics were administered for 14.8 ±2.8 days, 7 ±1.6 days in the Ravitch and the Nuss group, respectively. The difference between the two groups had statistical significance (p<0.01). Preoperative and postoperative laboratory data including hemoglobin, cardiac enzyme, liver function test, and so forth showed no statistical differences, and blood transfusion was not needed in both groups.

Mean ICU stay time for the Ravitch group was 3.9 ±2.1 days, and ventilator was applied for an average of 3.0 ±2.0 days. Immediate postoperative pain was controlled by full sedation under ventilatory support, and intermittent NSAIDS were used to control postoperative pain after weaning of the ventilator. On average, sitting position was possible in 11.3 ±3.4 days and ambulation was permitted in 12.1 ±3.6 days after operation (Table 3).

In the Nuss group, patients were admitted to the ICU for one day not requiring ventilator support and patients-controlled analgesia (PCA) pump was utilized to control post-

Table 1. Patient's profile (M ±SD*)

	Ravitch Operation	Nuss Procedure	Nuss Bar Removal
Number (M:F†)	16 (14:2)	107 (79:28)	15 (10:5)
Operation Period (yr)	1995-2002	1999-2002	2001-2002
Age (yr) (Range of ages)	8.8 ±7.4 (1.2-27)	7.9 ±5.0 (2-25)	6.0 ± 1.0 (2.3-15)
Height (cm)	131.6 ±28.0	123.4 ±26.3	119.8 ±25.2
Weight (kg)	28.7 ±17.8	26.2 ±14.0	24.0 ± 13.2
Haller Index	4.0 ±3.3	4.3 ±1.1	4.5 ± 1.2

M ±SD*= Mean ±Standard Deviation. M:F†= Male:Female.

Table 2. Combined disease with pectus excavatum

Combined disease	No. (age, yr)*	Operation
Gynecomastia	1 (18)	Ravitch
Undeveloped Breast	1 (24)	Nuss
Pneumonia, Left†	1 (6)	Nuss
Inguinal hernia	1 (6)	Nuss
Failed Nuss Procedure	1 (8)	Ravitch
Trauma after Ravitch Operation	1 (14)	Nuss

Pneumonia, Left†: Autopneumonectomy status.

Table 3. Results of operations

	Ravitch Operation	Nuss Procedure	Bar Removal
Incision	Submammary incision	Transverse incision, each lateral (2 cm)	Previous incision
Operation time (min)	196.9 ±61.0	67.2 ±33.1	41 ±23 (35.6 ± 11*)
ICU stay time (days)	3.9 ±2.1	1	None
Ventilator applying time (days)	3.0 ± 2.0	Not apply	None
Sitting position (days)	11.3 ± 3.4	4.0 ±0.6	2
Ambulation (days)	12.9 ± 3.6	6.3 ±0.9	3
Hospital day (days)	15.9 ± 2.3	8.0 ± 1.6	5.6 ±3.1 (4.5 ±0.9*)
Pain control	NSAIDS	PCA pump†	NSAIDS
Others	Chondral bone resection (M ±SD%) =10.2 ±2.6	Stabilizer :Right-1 case Left-7 cases	

*: except one case who had pneumonia and wound infection.
PCA pump†: Patient-controlled analgesia pump.
M ±SD%: Mean ±Standard Deviation.

Table 4. Complications after Nuss procedures

Early				Late		Profile		
Complications (8.41%)	Number	Treatment	Others	Complications (3.74%)	Number	Age (yr)	Onset	Treatment
Atelectasis	2	Tracheal suction	Left total/ Left upper lobe	Wound infection	1	6	POD* 2nd months	Bar removal (POD* 5th Months)
Hemothorax	3	Catheter insertion		Rotated Bar	2	2	POD* 6th months	Reoperation
Pneumothorax	5	Catheter insertion				4.7	POD* 7th months	Reoperation
Pneumonia	1	Antibiotics	Preoperative pneumonia under autopneumonectomy status	Hemothorax (by Trauma)	1	2.5	POD* 13th months	Catheter insertion
Rotated Bar	3	Reoperation						

POD*: Postoperative days.

operative pain (Table 3). The size of the bar used in Nuss procedure varies from 7 to 14 inches. Nine inch bar was most commonly used (n=36) and average size of the bars used is 9.7 ±1.6 inches. 30° and 90° sitting position were possible on postoperative 4.0 ±0.6 days, and 5.0 ±0.7 days, respectively. And ambulation was permitted in 6.3 ±0.9 days.

As a rule, inserted bars are removed two years after Nuss procedure, and we performed bar removal on fourteen patients two years after repair from August 2001 through May 2002. One patient had premature bar removal due to pneumonia and uncontrolled wound infection five months after repair.

Mean age of patients who underwent bar removal was 6.0 ±1.0 yr, and mean operating time was 41 ±23 min. Excluding one exceptional case of premature bar removal, the mean operating time decreased to 35.6 ±11 min. Postoperative antibiotics were administered for 3 days and pain was controlled by intermittent NSAIDS. Sitting position and ambulation were possible on postoperative 2 and 3 days, respectively.

The preoperative mean Haller index was 4.5 ±1.2 in bar removed 15 patients. After bar removal, mean Haller index decreased to 3.0 ±1.0.

Postoperative complications did not occur after bar removal, and mean hospital stay was 5.6 ±3.1 days. Excluding one case of patient who required premature bar removal, the mean hospital stay was reduced to 4.5 ±1.0 days.

Interviews were conducted to measure the degree of postoperative satisfaction of the patients. Thirteen patients who underwent Ravitch operation and fifteen patients who received bar removal after Nuss procedure were interviewed. The patients were classified into four groups: excellent indicates satisfaction in cosmetic and functional outcome, good is considered satisfaction with mild discomfort but no interference in regular activities, fair shows intermittent interference and difficulty in regular activities, and poor means dissatisfaction in both cosmetic and functional outcome. 92.3% of patients in the Ravitch group and 93.3% in the Nuss group were classified as good to excellent results, and no patient from either group was classified as poor (Table 5). Statistical comparison between the two groups was not possible but these interviews indicated that patients were generally satisfied with the cosmetic results and had no functional difficulties as well.

Table 5. Patient's satisfaction

	Ravitch Operation (n=13)	Nuss Bar removal (n=15)
Follow-up period (month) (M ±SD*)	23.3 ±18.5 (2-70)	2.4 ±2.8 (2-11)
Excellent	10 (76.9%)	12 (80%)
Good	2 (15.4%)	2 (13.3%)
Fair	1 (7.7%)	1 (6.7%)
Poor	0 (0%)	0 (0%)

M ±SD*: Mean ±Standard Deviation.

DISCUSSION

Pectus excavatum, produced by posterior depression of the sternum and the lowest costal cartilage produced by posterior depression of the sternum, is the most common congenital chest wall deformity (1). It occurs approximately one in every one thousand births. It was seen more frequently in boys than in girls with a ratio of 4:1. About 90% of patients are diagnosed before one year of age, but the exact cause is not known (2). The possible theories of pectus excavatum were reported as increased intrauterine pressure, rickets, abnormality of the diaphragm that result in posterior traction on the sternum (3, 4).

Clinical manifestations show chest pain, mitral valve prolapse, palpitations, and respiratory disease. Udoshi and associates (5) reported that 18% of pectus excavatum patients manifested mitral valve prolapse. Whereas Saint-Mezard and associates (6) reported that 65% of pectus excavatum patients manifested mitral valve prolapse and 0.17% of patients were associated with congenital heart disease (7). Therefore, Nuss et al. (8) insisted that the indication of the Nuss procedure should not be restricted to cosmetic problems, but Actis Dato et al. (9) reported that 95% of patients among operated patients were operated due to only cosmetic and cosmesis-related psy-

chologic problems. In our cases, all the causes of operation were cosmetic and cosmesis-related problems.

Diagnostic techniques for pectus excavatum should include chest CT, cardiologic evaluation, and pulmonary evaluation as well as history taking and physical examination, because preoperative evaluation of cardiac or vascular abnormality and musculoskelatal or connective tissue disease will provide chances of lowering operative risks. Pulmonary evaluation is, however, limited to teenagers and adults who are able to cooperate.

Severities of deformity are evaluated with chest CT scan, and chest CT scan also enables to examine the presence of cardiac compression or displacement and secondary lung compression. Willital (10), Welch (11), Haller et al. (12) and others have proposed various methods to measure severity of chest wall deformity. In recent time, Haller index, the ratio of the transverse diameter to the anteroposterior diameter obtained by chest CT, is most widely used for scaling the severity of pectus excavatum (13). All the patients in the Ravitch group were rescaled using Haller index for more exact comparisons.

In 1911, Meyer first introduced the operation for chest wall deformity (14). The operation methods have evolved to costal cartilage resection and sternal osteotomy with external or internal support during 1920 to 1950s (15, 16).

In 1946, 1952, and 1960, Ravitch established methods of coastal cartilage resection, sternal osteotomy, and perichondral sheath roofing suture for pectus excavatum and pectus carinatum (16, 17).

In 1987 and 1998, Nuss presented minimally invasive operation using steel bars for pectus excavatum. Today, Nuss procedure is used worldwide in pectus excavatum patients (8, 18).

For the Ravitch group, the need of postoperative ventilator support is controversial. But we considered that immediate postoperative iatrogenic flail chest should be corrected because about 10 or more chondral bones were resected per patient. Therefore, we applied the ventilator to all the patients in the Ravitch group during immediate postoperative period. Furthermore, postoperative ventilatory cares under full sedation decrease the need for postoperative pain control and help the fixation of operated wounds. So, postoperative pain management was achieved with intermittent NSAIDS and analgesics.

Generally, many authors and we did not apply the ventilator in Nuss group postoperatively. But some authors insisted that short term ventilatory cares decrease the need for postoperative pain control and prevent early bar displacement after Nuss procedure (19). In our cases, PCA pump was used for postoperative pain control after Nuss procedure.

Many authors proposed that bars used in Nuss procedure should be removed two years after operation, but some reported that bar removed three years after operation also brought good results (20). We also adhered to the principle that the inserted bar should be removed two years after operation to avoid excessive rib abnormality.

After bar removal, we confirmed that the Haller index was decreased successfully, but follow-up chest CT scan was not conducted on many Ravitch group patients. So, the exact comparison of the Haller index in both groups was not possible in our cases.

In both Ravich operation and Nuss procedure, postoperative complications included keloid scarring, wound seroma, atelectasis or pneumonia, pneumothorax, recurrent sternal depression, etc.

Our experiences of postoperative complications were not different from those of other general thoracic surgeries such as pneumothorax, hemothorax, skin wound dehiscence and pneumonia. In the Ravitch group, long-term complications did not occur. In the Nuss group, however, we had one patient with uncontrolled wound infection whose bar was removed five months after operation. In addition, five patients required reoperation due to bar displacement. Relatively higher incidence of reoperations is one of the disadvantages of Nuss procedure. In addition, rare cases of major complications including cardiac perforation, Staphylococcus sepsis, and thoracic outlet syndrome after Nuss procedure have been reported (18, 19). So, we performed intraoperative thoracoscopic evaluation to prevent injuries of chest organs in all patients of the Nuss group. Hebra and associates (20) reviewed the results of the experience of APSA members for Nuss procedure; reoperation rate for bar displacement was 9.2%, infection rate was 2%, cardiac injury rate was 0.4%, and early bar removal rate was 1.2%. And reoperation using the modified Ravitch approach was performed in 0.8%.

Nuss and associates (8) reported that 93% of patients showed good to excellent results. Fonkalsrud and associates (24) reviewed three hundred and seventy five patients during a thirty-year period and reported no major complications occurred, and approximately 3% of the patients showed minor complications including seroma, pleural effusion, atelectasis or pneumonitis, pneumonia, and pericarditis. The report also yielded good to excellent cosmetic results in 97% of the patients.

In our case, fifteen patients of the Nuss group with bar removal were interviewed and 93.3% showed good to excellent results.

As above mentioned, Nuss procedure (a minimally invasive pectus excavatum repair technique) does not require precordial incision, pectoralis muscle flap and rib, or sternal resections. In addition, Nuss procedure is associated with shorter operating time, less intraoperative bleeding, less time required to return to regular activities, good long-term results of chest strength and cosmetic outcomes, expansion flexibility, and elasticity (8). Because of the above advantages of Nuss procedure, many surgeons prefer the procedure to the previous Ravitch operation.

However, Nuss procedure required staged operation for bar removal. And continuous attention was needed to prevent bar displacement. Results indicate disadvantages of the Nuss

procedure including high complications and reoperation rates.

In conclusion, the methods of the operation, operative wound, and immediate postoperative courses varied in both groups. Although the outcome of the patient interviews showed no differences between the two groups, long term follow-up of the Nuss group is needed. Therefore, the application of operation methods should be determined by considering the severity and characteristics of the chest wall deformity. Also, patients and their family members must have sufficient information of the operations.

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