Cardiac Morphologic Changes After the Nuss Operation for Correction of Pectus Excavatum

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Background. **Pectus excavatum results in compression of the heart and may compromise cardiac function. Several studies have shown that surgical correction improves cardiac function as assessed on echocardiography. However, morphologic changes to support this have not been reported.**

Methods. **Between July and December 2011, 109 patients underwent the Nuss operation. We measured the Haller index and other variables. To identify the location of the heart within the chest cavity, the distances from the middle of the spine to the right and left heart walls and from the anterior border of the spine to the anterior and posterior heart walls were measured. To characterize dimensional changes, the anteroposterior, transverse lateral, and right and left oblique longest lengths were measured.**

Results. **The postoperative Haller index was significantly different from the preoperative one (2.52 ± 0.40 versus 4.50 ± 1.45; $p < 0.001$). The location changes in the anterior, rightward, and leftward directions were 4.97 ± 8.03 mm ($p < 0.01$), 1.66 ± 7.89 mm ($p = 0.027$), and −2.70 ± 11.12 mm ($p = 0.01$), respectively. The dimensional changes in anteroposterior and right oblique lengths were 5.42 ± 6.42 mm and 16.33 ± 7.77 mm ($p < 0.01$), respectively.**

Conclusions. **The heart moved positively in the anterior and rightward directions and negatively in the leftward direction, and the anteroposterior and right oblique dimensions were increased after surgical correction. These data suggest that the heart tends to return to a normal position and shape, and that these changes may contribute to improvement in cardiac function.**

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Pectus excavatum (PE) is characterized by depression of the anterior chest wall including the sternum. This change is often described using a measurement of chest wall deformity such as the Haller index (HI) or the Depression index [1, 2]. Pectus excavatum may result in compression of intrathoracic organs, especially the heart and lungs.

Surgical resection of abnormal costal cartilage and correction of the depressed anterior chest wall increase pulse oximetry, which is an index of a cardiac efficiency [3, 4]. Echocardiography has demonstrated significant increases in right ventricular diastolic and systolic volume indices as well as stroke volume after surgical correction [5–7]. Maagaard and colleagues [8] recently reported preoperatively maximum cardiac index during exercise was lower in patients with PE compared with healthy, age-matched control subjects. One year after operation, this had increased in patients, and 3 years postoperatively cardiac index had normalized.

Although the cardiac deformity index was proposed to assess morphologic changes after the Nuss operation [9], detailed morphologic changes in the heart to support this improvement have not yet been reported. In this study, we compared cardiac morphology before and after the Nuss operation and analyzed the effects of correcting the chest wall deformity.

Patients and Methods

From July through December 2011, 109 patients with PE underwent the Nuss operation. Operation was performed in patients with clinical and psychological symptoms, HI greater than 3.25, or cardiac compression caused by depressed sternum on chest computed tomography. Among them were 30 females and 79 males, with an average age of 8.9 ± 6.8 years (range, 3 to 31 years; Table 1). There were 57 patients in the preschool group (<5 years of age), 14 in the school age group (6 to 11 years of age), 26 in the adolescent group (12 to 18 years of age), and 12 in the young adulthood group (>19 years of age). The HI ranged from 2.44 to 9.87 with a mean of 4.50 ± 1.45. Regarding the morphologic classification [10], 61 patients (56%) presented with symmetric type (type 1) and 48 patients (44%) with asymmetric type (type 2) PE.

Written informed consent was obtained from each patient or parents before the operation. The study protocol

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Table 1. Preoperative and Postoperative Changes in the Haller Index

Variable	Preoperative HI	Postoperative HI	*p* Value
Total (n = 109)	4.50 ± 1.45	2.52 ± 0.40	<0.001
Sex			
Male (n = 79)	4.31 ± 1.92	2.46 ± 0.57	<0.001
Female (n = 30)	4.30 ± 2.41	2.51 ± 0.58	<0.001
Age group			
<5 y (n = 57)	4.69 ± 1.53	2.50 ± 0.34	<0.001
6–11 y (n = 14)	4.19 ± 1.37	2.28 ± 0.37	<0.001
12–18 y (n = 26)	4.34 ± 1.54	2.58 ± 0.53	<0.001
>18 y (n = 12)	4.30 ± 0.80	2.69 ± 0.33	<0.001
Morphologic subtype			
Type 1 (n = 61)	4.49 ± 1.26	2.42 ± 0.35	<0.001
Type 2 (n = 48)	4.51 ± 1.69	2.65 ± 0.44	<0.001

HI = Haller index.

was approved by the Institutional Review Board of the Catholic Medical Center.

Operative Technique

All patients were placed in the supine position before the start of surgery. The selected sized bar was bent according to the morphology of the pectus. A crane was applied to the depressed sternum at the xiphoid for initial elevation of the sternum in case of severe depression. Tiny skin incisions were made bilaterally in the lateral chest, and hinge points were determined on both crests of the depression. Subcutaneous tunnels were created bilaterally from the skin incisions toward the hinge points. An introducer or the pectus clamp (Biomet Microfixation, Jacksonville, FL) was introduced into the pleural space through the right hinge point, was passed along the curvature of the depression with the mediastinum dissected toward the opposite hinge point, and finally passed through the hinge to the other skin incision. A 20F chest tube was passed as a guide along with the pectus clamp. The bent bar was then passed along the guide and positioned facing dorsally. The bar was subsequently turned 180 degrees to face ventrally, which elevated the sternum. The convexity of the bar was adjusted to achieve an optimal result. The bar was fixed to the bilateral reciprocal ribs using multipoint fixation method. After hemostasis and irrigation, the incisions were closed in layers. This surgical technique has been described in detail in a previous publication [11].

We removed the pectus bar after 2 years for patients younger than 12 years, after 2.5 years for patients between 12 and 18 years, and after 3 years for patients older than 18 years [12].

Measurement of Cardiac Morphology

All patients underwent chest computed tomography before and 1 to 2 weeks after the operation. In the mediastinal window, depth of sternal depression, HI, and cardiac location and dimensional changes were measured on transverse chest computed tomographic images at the lowest point of the sternum, near the xiphosternal junction. If the measurements were impeded owing to the position of the bar, the point just below or above the bar was measured.

For the leftward and rightward location changes (Fig 1), a vertical line was drawn from the middle of the vertebral spinous process, and the distances from the line to the right and left side walls of the heart were measured. To assess the anteroposterior (AP) location changes, a horizontal line was drawn at the anterior border of the vertebral body, and the distances from this line to the anterior and posterior walls of the heart were measured. Each location and directional change of the heart was calculated by subtracting the preoperative measurement from the postoperative measurement. For the dimensional changes of the heart (Fig 2), the AP and transverse lateral longest lengths were measured. The longest oblique lengths were also measured at a 45-degree angle from the horizontal. The right oblique measurement is the longest oblique length extending from the back to the anterior rightward direction, and the left oblique measurement extended in the anterior leftward direction.

Statistical Analysis

Data analysis was performed with the SPSS program package (SPSS version 12.0; SPSS, Chicago, IL). Continuous variables were presented as a mean ± standard deviation and were compared with Student's *t* tests or by one-way analysis of variance as appropriate. Correlation among groups was calculated with linear regression analysis. A probability value of less than 0.05 was considered statistically significant.

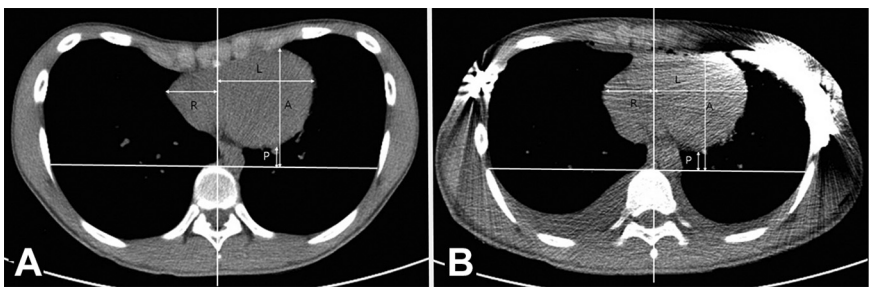

Fig 1. Measurement of changes in cardiac location (A) before and (B) after the Nuss operation.