

The use of nonthoracoscopic Nuss procedure for the correction of pectus excavatum by trans-esophageal echocardiography monitoring

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Abstract

This study was aimed to review the current experience regarding the correction of pectus excavatum by Nuss procedure with nonthoracoscopic assistance using trans-esophageal echocardiography monitoring.

A total of 172 patients with pectus excavatum were surgically treated from August 2011 to August 2016. The sample size comprised 131 boys and 41 girls and the average age was 13 years and 2 months. A total of 144 cases were initially operated on, whereas 13 subjects exhibited postoperative recurrence following Ravitch repair of a pectus excavatum deformity and 15 cases experienced a history of median sternotomy. The intraoperative Haller index ranged from 3.6 to 14.2 (mean 4.1). The intraoperative TEE monitoring was conducted with middle-esophageal 4-chamber view and middle-esophageal Aortic short axis view to detect the injury of heart and of the large vessels by the introducer and Nuss steel bars.

The operation conducted in all patients was successful in the absence of severe complications. The time of operation ranged from 38 to 80 minutes (mean 50 minutes). The bleeding volume during the procedure was between 10 and 40 mL (mean 15 mL). The time from operation to discharge was from 5 to 7 days (mean 6 days). Pneumothorax occurred in 25 cases following the termination of the operation, including 9 cases of needle puncture aspiration and 6 cases of closed drainage. Pleural effusion occurred in 4 cases. No patients suffered from wound infection. Effusion occurred in 9 cases following 6 to 23 months, whereas dressing changes and surgical debridement were evident in 2 and 7 cases, respectively. The bars were removed in 82 of the 172 patients within 3 years. The progression of the thoracic wall was assessed for the period of 8 to 68 months following the surgery, during the follow-up period. The average time period of follow-up was 32 months.

Nuss procedure with nonthoracoscopic assistance with trans-esophageal echocardiography monitoring for the correction of pectus excavatum was safe for all of the cases investigated. It exhibited lesser trauma and required a shorter time period.

Abbreviations: HI = Haller index, TEE = trans-esophageal echocardiography.

Keywords: Nuss procedure, pectus excavatum, trans-esophageal echocardiography

1. Introduction

Pectus excavatum is the most frequently encountered chest wall deformity. The worldwide prevalence ranges from 2.5 to 12 cases per 1000.^[1–3] The Nuss procedure is used to correct this

deformity, since it was first reported by Donald Nuss in 1998.^[4] Although this technique is considered to be minimally invasive, minor to life-threatening complications have been described previously in the literature.^[5–11] Certain methods were developed to prevent these serious complications associated with the Nuss procedure.^[12–17] However, effective and noninvasive monitoring improvement procedures have not yet been reported. In the present study, trans-esophageal echocardiography (TEE) was carried out in patients undergoing Nuss procedure.

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Written informed consent was obtained from the patient.

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2. Materials and methods

From August 2010 to August 2016, 172 patients with pectus excavatum were operated on by the Nuss method. The operation was conducted in patients with a Haller index (HI) range of 3.6 to 14.2. The study consisted of 131 males and 41 females with an average age of 13 years and 2 months and a range of 7 years and 8 months to 22 years and 5 months. A total of 144 cases presented with no operation history, whereas 13 cases had received Ravitch repair of a pectus excavatum deformity and 15 cases exhibited a history of median sternotomy. Prior to the surgery, a series of clinical examinations including a chest X-ray, a chest computed tomography (CT) scan, and an echocardiography, were conducted. An electrocardiogram and a pulmonary function test were essential in all children prior to surgery.

All patients received general anesthesia. Following tracheal intubation, the trans-esophageal TEE probe (Philips, iE Elite,

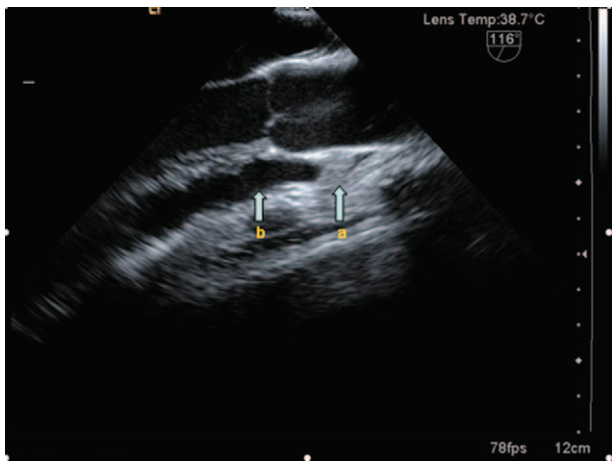


Figure 1. Ultrasonic images before surgery. (a) Sternum. (b) Pericardium.

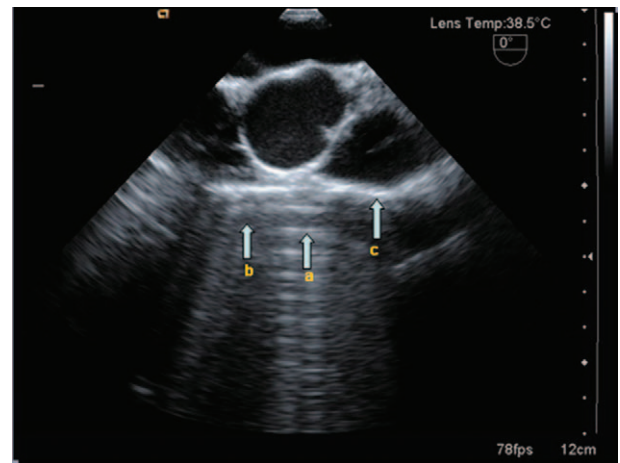


Figure 3. Ultrasonic images of implant bar. (a) Bar. (b) Sternum. (c) Pericardium.

Philips Ultrasound Inc, Bothell, WA) was inserted (Fig. 1). All patients were placed in the supine position prior to the start of the operation. The selected size bar was bent according to the morphology of the pectus. Tiny skin incisions (2–2.5 cm) were made bilaterally in the lateral chest, and hinge points were determined at both crests of the depression. Subcutaneous tunnels were generated bilaterally from the skin incisions toward the hinge points. An introducer was placed into the pleural space through the right hinge point and was passed along the curvature of the depression with the mediastinum dissected toward the opposite hinge point. The introducer bar was finally passed through the hinge to the other skin incision (Fig. 2). The bent bar was then passed along the introducer and placed at a dorsal position. The bar was subsequently turned 180° to face ventrally, which elevated the sternum. These critical procedures (especially inserting the introducer and turning the bar) were completed under the monitoring of TEE in the mid-esophageal right ventricular outflow tract inflow section and in the mid-esophageal 4-chamber view (Fig. 3). The surgeons ensured that no injury of the pericardium occurred and no hemothorax and massive hemorrhage was detected by the TEE (Fig. 4). The incisions were closed by layers. All patients received antibiotics and analgesic following the operation.

3. Results

The operations for all the patients were conducted successfully in the absence of serious complications. The time range of the operations was between 38 and 80 minutes (mean 50 minutes). The blood loss during the procedure ranged from 10 to 40 mL, with an average volume of 15 mL. Pneumothorax occurred in 25 cases when the operation had finished, including 9 cases of needle puncture aspiration and 6 cases of closed drainage. Pleural effusion occurred in 4 cases following the operation. The patients who experienced the aforementioned complications recovered well 1 month postoperatively in the absence of special treatment. No patients suffered from wound infection. The average postoperative inpatient stay was 6 days (standard deviation 6, range 5–7 days). Effusion occurred in 9 cases following 6 to 23 months, whereas dressing changes and surgical debridement were evident in 2 and 7 cases, respectively. No bar was removed in advance due to potential incision infection. The follow-up period was between 8 and 68 months for the total sample size of the 172 patients. The activity increased in the absence of pain and all the patients achieved a satisfying appearance. The fixed plate and

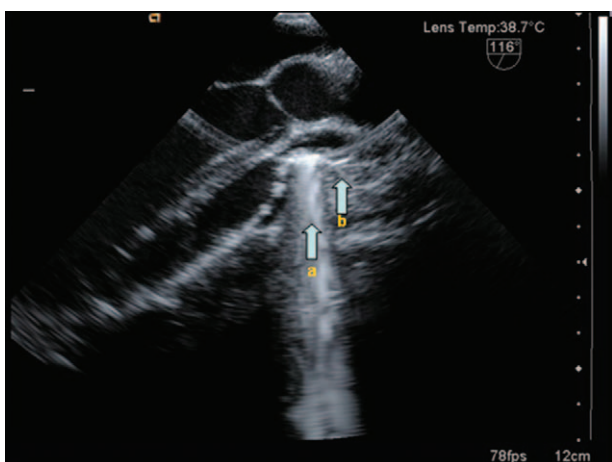


Figure 2. Ultrasonic images of implant introducer. (a) Introducer. (b) Sternum.

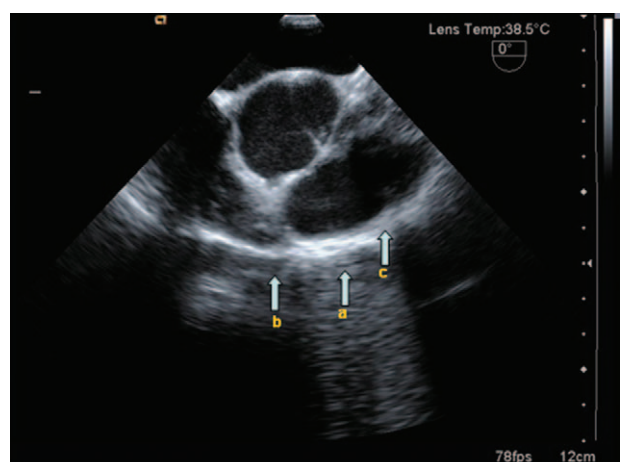


Figure 4. Ultrasonic images after surgery. (a) Bar. (b) Sternum. (c) Pericardium.

support were removed in 82 cases with satisfying appearance within 3 years.

4. Discussion

The Nuss procedure has gained increasing acceptance worldwide due to its minimally invasive application, the reduced bleeding and fast recovery of the tissue. The Nuss procedure requires reduced operating time and hospitalization period compared with the traditional Ravitch method. In addition, it exhibits minimal blood loss and can avoid the surgical manipulation of the cartilages and sternum. The Nuss procedure for pectus excavatum is widely accepted and a vast number of modified approaches have been reported to prevent complications.^[6,18] The medical experience of the surgeon and the careful and gentle conduct of the procedure can avoid serious complications. However, an effective and noninvasive monitoring improvement needs to be developed. In the present study, TEE was carried out in patients who were operated on by the Nuss procedure.

The nonthoracoscopic approach was accepted among the 172 patients. All the patients successfully received the TEE probe following anesthesia. Additional injury was avoided in the absence of invasive procedures in the pleura cavity. A CT scan was conducted preoperatively to evaluate the pitting level of the stern. The TEE was used to check the important structures behind the sternum and aided the identification of the significant adhesions. This process is considerably helpful, notably for the subjects with significant distorted anatomy and those who were previously operated on, in the presence of recurrent disease. Certain patients with significantly distorted anatomy exhibited an inadequate dissection of the pericardium, free from the posterior aspect of the sternum, as demonstrated by preoperative TEE. In the present study, TEE demonstrated that the adhesions were dense and were fused by the sternum, pericardium, and myocardium tissues, in 15 patients who had undergone previous operation of median sternotomy. This aided the construction of a plan prior to the operation regarding these patients. In addition, TEE monitoring always offers an improved visualization during the Nuss procedure, despite the presence of severely distorted anatomy. Under the guidance of TEE, the introducer and the steel bars were visually controlled, which reduced the operation time and blood loss. The thoracoscopic approach of the Nuss procedure has been previously reported in the literature.^[6,10] Using right chest thoracoscopy with blunt dissection of the mediastinum, the passage of the pectus dissector from the right side to the left side has been achieved. However, right-side thoracoscopy does not always offer improved visualization of the mediastinal structure due to the displaced heart in severe deformities. TEE has its advantages in presenting the heart and large blood vessels.^[19-23] TEE provides improved visualization and ensures the safety of the procedure, notably for the surgeon responsible to conduct the operation, compared with thoracoscopic intervention. Furthermore, the noninvasive monitoring nature of the Nuss procedure aids the prevention of severe intraoperative complications.

The optimal age for pectus excavatum repair is 6 to 12 years old.^[4-6] The Nuss procedure is notably applicable for young children. In principle, the soft bone and longer cartilago costalis provide optimal reshaping of the tissue in young children. The psychosocial factor contributes significantly to the timing of the operation regardless of the parameter age and the influence of pulmonary and heart functions by the distorted anatomy. The disease is frequently characterized by aggravation that occurs

parallel to the growth of the child during adolescence. In the present study, the age ranged from 7 years and 8 months to 22 years and 5 months, while the TEE increased the safety of the operation.

Despite the minimally invasive surgical access acquired by the Nuss technique, a number of complications are associated with this procedure.^[5,11,24-26] The complications include the following: pneumothorax, bar displacement, pericardium effusion, cardiac perforation, and scoliosis that is caused by persistent pain. Pneumothorax was the most common complication. In the present study, 38 cases (22.09%) of postoperative complications were noted. Pneumothorax occurred in 25 cases, and the associated symptoms were noted in 15 patients, including 9 cases of needle puncture aspiration and 6 cases of closed drainage. A total of 10 cases with minor pneumothorax indicated adequate recovery in the absence of special treatment. Due to the nonthoracoscopic approach of the Nuss procedure, the high risk factors lead to pneumothorax, including parallel bar technique, double bar technique, and severe asymmetry.^[27] Pleural effusion occurred in 4 cases following the operation. The patients who experienced these complications indicated optimal recovery 1 month postoperatively in the absence of special treatment. TEE can find severe pneumothorax and it is difficult to find a slight pneumothorax. Effusion occurred in 9 cases following 6 to 23 months, whereas dressing changes and surgical debridement were evident in 2 and 7 cases, respectively. The development of allergy that is associated with the Nuss bar has been described previously.^[28-30] The nickel element is the main risk factor and is classified as a cause of the pathologic reaction. The majority of the incisions have been reported to heal following anti-allergy treatment and only a small number required immediate removal of the bar.^[28] In the present study, no allergy was recorded but wound reject reaction occurred in 1 case that required immediate removal of the Nuss bar.

The pectus bar is removed between 3 and 4 years following the initial operation. Adults suffering from this disease and severe pectus excavatum cases require bar repositioning. In the present study, 82 cases had the pectus bar removed, whereas 12 cases required immediate pectus bar removal. A total of 10 cases required immediate pectus bar removal due to unexpected growth of the tissue that extended beyond the length of the bar. A total of 2 cases suffered from wood reaction and were willingly subjected to an earlier pectus bar removal. During the follow-up period (8–68 months), no pectus bar dislocation was observed, and all patients were satisfied with the postoperative result.

Based on the present experience of this procedure, serious challenges have been reported and the development of appropriate techniques to overcome the associated problems is imperative. In the present study, 172 patients successfully received the Nuss procedure with no severe intraoperative complications. TEE provided improved visualization of the pectus excavatum and it is considered a noninvasive monitoring option in the conduct of the Nuss procedure that can prevent severe intraoperative complications compared with thoracoscopy.

Author contributions

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