

The Nuss Procedure: Our Experience from the First Fifty

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ABSTRACT

Purpose: The Nuss procedure for pectus excavatum has rapidly gained acceptance among pediatric surgeons. We present the results and lessons learned from our initial 50 patients undergoing the minimally invasive pectus repair.

Patients and methods: After obtaining Internal Review Board approval, we retrospectively reviewed patients undergoing the Nuss procedure from April 1998 to September 2002. Data, including age, operative time, length of hospital stay, and complications, were recorded.

Results: Fifty patients whose average age was 13 years underwent the procedure. The mean operative time was 90 minutes, and the average length of stay was 6 days. Eleven immediate postoperative pneumothoraces were detected, none of which required tube thoracostomy or aspiration. One displaced bar was replaced at 6 weeks, and infection necessitated the removal of that bar at 11 months. A second displaced bar lacking a stabilizer was removed at 15 months with a good cosmetic result. Three bar stabilizer complications occurred. One was replaced at 5 weeks because of displacement, and broken stabilizers were replaced and removed in two other cases. A 16-gauge rib wire has replaced the bar stabilizer in the last eight patients. One internal mammary artery injury occurred during bar insertion. To date, 22 bars have been removed, with overall good cosmetic results.

Conclusion: Advantages of the Nuss procedure in comparison with the open approach are decreased operative times, minimal blood loss, and improved cosmesis. Unique complications included an infected bar, broken bar stabilizers, and an internal mammary artery injury. Initial results demonstrate that the Nuss procedure is a safe and effective method of pectus excavatum repair.

INTRODUCTION

SINCE THE FIRST DESCRIPTION BY NUSS ET AL. in 1998,¹ the minimally invasive approach to pectus excavatum repair has become widely accepted. Initial results from many centers are now being reported. The attractions of the technique, which include decreased operative time, less blood loss, improved cosmesis, and decreased tissue disruption, have driven the surge in the number of cases performed today. The Nuss

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procedure is indeed an entirely different approach to pectus excavatum in comparison with the traditional Ravitch repair. Therefore, safety and efficacy must be evaluated by a collective experience before this approach becomes the new standard of care. This report presents the findings from the first 50 Nuss procedures performed at our institutions.

MATERIALS AND METHODS

After Internal Review Board approval had been obtained, a retrospective chart review was conducted at two institutions. Fifty patients underwent the Nuss procedure for repair of pectus excavatum from April 1998 to September 2002. The first bar removal in this series was performed in July 2000, and the most recent in November 2002. The patients included 43 boys and seven girls whose average age was 13.1 years (range, 4–18 years). The presenting symptoms are listed in Table 1. All children admitted to some degree of emotional disturbance related to their body image. The computed tomographic (CT) scan index, an objective measure of pectus severity described by Haller et al.² as the ratio of the chest width to the antero-posterior dimension on CT scan, was available for 35 patients, with a mean value of 4.27 (range, 2.64–6.25). This ratio is considered significant when above 3.25.

All patients underwent the Nuss procedure as originally described, with the modification of placing the lateral aspects of the bar and stabilizers within a muscular pocket.¹ However, due to the significant degree of bony ingrowth noted at bar removal, we have returned to using the subcutaneous pocket, as described in the original article of Nuss et al.¹ Preoperative prophylactic antibiotics were administered to all patients. In the first eight cases, we did not use the thoracoscope; however, it has been used in all subsequent procedures. In the last eight cases in this series, a 16-gauge rib wire, instead of the bar stabilizers, was used to secure the bar to the underlying adjacent rib. In these cases, the placement of the bar is superficial to the chest wall musculature. Postoperative plain chest radiographs were taken in the operating room to evaluate bar position and possible complications. Bar removal has routinely been performed at 24 months.

RESULTS

In all but one patient, a single bar was inserted. In one 18-year-old, it was necessary to place two bars for proper sternal elevation. The mean operative time was 90 minutes, and all patients but one received an epidural catheter for pain control. An indwelling urinary catheter was used only if the patient experienced urinary retention. The only intraoperative complication was a right internal mammary artery injury that occurred during passage of the bar through the anterior mediastinum. The bleeding was successfully controlled thoroscopically with a harmonic scalpel (Ethicon, Somerville, New Jersey). In 11 patients, small pneumothoraces were detected on the immediate postoperative chest radiographs. All pneumothoraces resolved without the need for a tube thoracostomy. One patient experienced a transient episode of asymptomatic bradycardia, and in another, a cerebrospinal fluid leak developed after removal of the epidural catheter. This was successfully treated with an epidural blood patch.

Bar movement occurred in two patients (4.0%), neither of whom had a bar stabilizer. These were the sixth and eighth cases in our series of 50. In one case, the patient sustained a fall from a horse 15 months after the operation. The bar was removed, and the cosmetic result was good. In the other case, the bar was replaced due to displacement 6 weeks postoperatively. A *Staphylococcus epidermidis* infection eventually

TABLE 1. PRESENTING SYMPTOMS

<i>Symptom</i>	<i>No. patients (%)</i>
Concern about body image	50 (100)
Exercise intolerance/shortness of breath	18 (36)
Chest pain	10 (20)
Asthma	8 (16)

NUSS PROCEDURE

developed in this patient at 11 months, necessitating bar removal. Nevertheless, the cosmetic outcome was good.

Bar stabilizer complications required operative intervention in three cases. One displaced stabilizer was replaced at 5 weeks, a second was replaced after it had been found to be cracked and bent at 8 months, and a third stabilizer was removed after 10 months because of breakage. Two of these children went on to have their bars removed at the standard 2 years, with good appearances. The third child died as a result of a motor vehicle accident 2 months before his scheduled bar removal.

To date, 22 bars have been removed. All but two of these procedures were performed on an outpatient basis at 24 months. In two patients admitted for pain control, significant bony ingrowth required the use of a rongeur at the time of removal.

Good to excellent cosmetic results have been seen in all but two patients. In one child, a single bar was placed beneath the lowest aspect of the sternum, although his defect was deepest at a point below the xiphoid. He thus had a persistent pectus defect below the level of the bar. This patient has to date refused placement of another bar. In cases such as this, we have begun to place the bar at the level of maximal deformity, even if this is inferior to the sternum. The second patient was a young girl with a significantly tilted sternum in whom a mild carinatum deformity developed after correction. Another patient was referred for consultation when a marked carinatum developed after a Nuss procedure performed at another institution (Fig. 1). He, too, had had a significantly tilted sternum preoperatively. We have now decided not to perform the Nuss procedure in patients with a severely tilted sternum.

DISCUSSION

There is little question that the development of the minimally invasive repair for pectus excavatum has had a major impact on the management of this deformity. However, less than 6 years have passed since this method was first presented at the 1997 meeting of the American Pediatric Surgery Association,¹ and thus the burden of proof lies with those duplicating Nuss's innovation. The traditional open technique described by Ravitch in 1949³ has been extensively performed and refined during the past 50 years, with very good results. Fonkalsrud et al.⁴ recently summarized their 30-year experience with 375 patients, noting an average length of stay of 3.1 days, improvement in almost all patients with preoperative symptoms, and a low complication rate. In a large, 29-year series of 704 patients, Shamberger and Welch⁵ reported a 4.4% complication rate and a 2.7% major recurrence rate.



FIG. 1. Carinatum defect following a Nuss procedure, performed at another institution, in a patient with a severely tilted sternum.

When groups retrospectively compare the open and minimally invasive techniques, several differences are found. First, the Nuss procedure causes more pain, and patients are thus required to stay in the hospital longer for the epidural or intravenous administration of narcotics. Also, these patients require more repeated operations, particularly for bar displacement. However, the open procedure takes longer to perform, involves more blood loss, and leaves a larger, more prominent scar.^{6,7} Furthermore, the Nuss procedure eliminates the risk for the rare complication of asphyxiating thoracic dystrophy.⁸

Our results with the Nuss procedure are similar to those reported by other authors. Our 90-minute operative time, 6-day length of stay, and 4% bar displacement rate are comparable with the reported ranges of 45 minutes to 2.1 hours, 4.3 to 6.5 days, and 0 to 11%, respectively.^{6,7,9-13}

Patients presenting with severe, asymmetric pectus deformities, typically a markedly tilted sternum, are no longer offered the Nuss procedure. This decision was made based on the difficulties other surgeons have encountered when managing such cases and our own experience.^{12,14}

We had three unusual complications. First, an injury to the internal mammary artery occurred as a bar was passed through the anterior mediastinum, and the use of a harmonic scalpel was required for control. To our knowledge, this complication has not been reported in the literature, although a pseudoaneurysm of the internal mammary artery has been described.¹¹ Second, one of the bars became infected on a delayed basis, and removal was required. This patient presented with an abscess beneath his healed scar that involved the hardware. Nuss et al.¹⁵ reported that bar infection occurred in 3 of their 329 patients, and two of these bars had to be removed. Third, breakage of two bar stabilizers required either replacement or removal, which has not been reported in the literature.

Based on our experiences, we have developed several technical modifications for special circumstances. During the right-to-left mediastinal dissection with the Crawford clamp in older patients with a significantly large CT scan index, the thoracoscope is used bilaterally to visualize the appropriate exit of the clamp from the anterior mediastinum. We believe that this technique helps to prevent cardiac injury in these extreme cases. At times, the deformity is so severe that the tip of the clamp cannot exit the left side of the chest, so the umbilical tapes are passed to the clamp intrathoracically under direct visualization with the thoracoscope in the left side of the thorax.

In one patient presenting with a deformity with a maximal depth at a level inferior to the xiphoid, placement of the bar at the lowest margin of the sternum resulted in a residual pectus deformity below the level of the bar. There appear to be several options in such cases; the bar can be placed at the area of maximal depth, or two bars can be inserted. We have found that placement of one bar at the deepest point is adequate. Although only the anterior ribs and costal cartilages are forced forward, this arrangement has resulted in full correction of the defect.

The bar stabilizers have presented several problems, including bulkiness, bone overgrowth, and the need for a more extensive operation for removal, dislodgement, or breakage. In fact, broken stabilizers appear unique to the literature. These issues led us to search for an alternative method of securing the bar. At the meeting of the American Pediatric Surgical Association in May 2002, Coran et al.¹⁶ described a method of bar fixation in which a 16-gauge wire was placed around the bar and rib. Following their presentation, we began to use a wire without the stabilizer as our preferred method of fixation. We performed eight cases before September 2002, which are included in this study. It is expected that this approach will further min-

TABLE 2. LESSONS LEARNED

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1. The ideal patient age is 8 to 12 years because the chest wall is more pliable.
 2. The Nuss procedure is not offered to patients with severe, asymmetric pectus deformities because of the risk for creating a pectus carinatum deformity.
 3. For a deformity with a maximal depth inferior to the sternum, bars are placed at that level rather than at a higher level under the sternum. This practice better corrects the deformity, particularly if only one bar is used.
 4. When severe deformities are corrected, the thoracoscope is moved to the left side of the chest during the mediastinal dissection to improve visibility. In severe cases, the umbilical tapes are grasped intrathoracically when the mediastinal dissector is unable to exit the left side of the thorax.
 5. A 16-gauge rib wire has replaced the bar stabilizers to avoid the complications associated with the stabilizers.
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imize the rate of bar displacements because the bar is attached to the bony thorax as opposed to only the muscle and fascia. Furthermore, ease of removal may be an added benefit. The wire simply has to be cut and pulled, whereas dissection is required to free the stabilizer, which occasionally includes bony overgrowth or fibrous reaction. Another method that has been described involves placement of a nonabsorbable suture as a third fixation point around the bar and rib anteriorly.¹⁷ This is another promising idea, although the long-term results have yet to be reported.

The minimally invasive pectus excavatum repair appears to be a sufficiently safe procedure, particularly with the use of adequate bar stabilization. Although our results are early, no evidence of major recurrence after bar removal has been noted in any of our patients.

The lessons learned from our first 50 cases are listed in Table 2.

CONCLUSION

We are encouraged by the results of our initial 50 patients undergoing the minimally invasive repair of pectus excavatum. This is a less burdensome operation for both patient and surgeon, with the caveat that length of stay and pain medication requirements are greater. Unique complications also occur, but cautious modification of the technique may help to minimize these. Finally, long-term follow-up data will be needed to evaluate the true efficacy and complication rates.

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