

## Early Experience with the Nuss Minimally Invasive Correction of Pectus Excavatum in Adults

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### Abstract

Nuss described a minimally invasive technique for correcting pectus excavatum in children. A curved stainless-steel bar is inserted behind the sternum through the chest cavity with the convex surface face down, then rotated 180 degrees to elevate the sternum and correct the deformity. The procedure gained wide acceptance in children. The purpose of this study was to determine if the procedure is effective in adults. Only patients with symptoms limiting lifestyle, chest wall indices higher than 3.25, and demonstrable cardiac compression on echocardiography were accepted. Between April 1998 and January 2001, 14 adults aged 19 to 46 underwent assessment for the Nuss minimally invasive technique for correction of pectus excavatum. Eight patients, 19 to 32 years of age, met the stated criteria for acceptance. The comorbidities were 2 asymmetrical deformities, 2 scolioses, 1 previous pectus repair, and 1 previous breast augmentation. The patients were informed of the benefits and disadvantages of both the Ravitch and the Nuss procedures. All patients except the first had talked to one or more adults who previously had the procedure. Follow-up was 7 to 37 months (mean 22.1 months). Four patients have had their bars removed and maintained correction. Success of the operation was based on relief of cardiac compression, alleviation of symptoms, and adequate pain control. Operating time was 1 to 2:05 hours (mean 1:32 hours). Complications were pneumothorax in one patient, urinary retention in 2, and left lower lobe atelectasis in 5. Complications did not prolong hospitalization. Postoperative epidural analgesia was discontinued after 2 to 4 days (mean 2.8 days). Average daily pain scores were between 1.6 and 3.7 on a scale of 0 to 10. Hospital stay was 3 to 5 days (mean 4 days). Relief of symptoms and increase in activity were obtained in all patients. Relief of cardiac compression was demonstrated in the 6 patients who have had postoperative echocardiograms. Patients returned to normal activity 2 to 4 weeks postoperatively (mean 2.3 weeks). Duration of pain medicine was 2 to 4 weeks in 6 patients and 2 and 4 months for the other 2 (mean 5.5 weeks). There were 2 late complications related to the bar, but without loss of correction. The early experience with the Nuss minimally invasive pectus excavatum repair in adults is encouraging. The procedure is effective for correcting pectus excavatum in selected patients. Early results are dependent upon adequate bar stabilization and pain control. The long-term results in adults are unknown.

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In 1998 Nuss described an innovative procedure for repair of pectus excavatum in prepubertal patients. The procedure employs a stainless-steel bar contoured to the patient's chest. The bar is passed retrosternally through the chest with the convex surface positioned posteriorly and then rotated 180 degrees to elevate the sternum. Nuss's results were good to excellent in 86% of patients. The procedure gained wide acceptance for correction of pectus excavatum in prepubertal and early pubertal patients [1 2], whose chests are compliant and who have residual growth necessary for remodeling. Its utility in adults, whose chests are less compliant, is unknown. The purpose of this study was to determine if the procedure could be performed successfully in adults. Only symptomatic patients with significant deformities causing cardiac compression demonstrated on echocardiography were accepted. It was our intent to determine if the pectus bar could be adequately stabilized to maintain correction and if sufficient pain control could be achieved to make the procedure acceptable.

## Materials and Methods

Between April 1998 and January 2001, fourteen patients 19 to 46 years of age, were seen for pectus excavatum. All came seeking the minimally invasive Nuss repair. There were nine men and five women. The Nuss procedure was offered to 8 patients who had symptoms limiting lifestyle, a chest wall index greater than 3.25, and cardiac abnormality on echocardiography. Chest wall index was determined from a computed tomography (CT) scan image of the chest comparing the anterior-posterior dimension to the transverse dimension of the chest. A chest wall index greater than 3.25 was determined at the Johns Hopkins Hospital to be an indication for surgery [3]. Echocardiography was performed at rest, and with exercise, if necessary, to document cardiac compression causing structural or hemodynamic changes in the heart. Five men and 3 women, ages 19 to 32 years (mean 24 years), whose chest wall indices were 3.57 to 8.5 (mean 4.71) had the procedure. Cardiac abnormalities were present on echocardiography in all patients (Table 1). Before surgery each patient was advised of the risks and benefits of the Ravitch costochondrectomy with sternal osteotomy and the Nuss minimally invasive procedure. With the exception of the first patient, all patients had talked to one or more adults who had undergone the Nuss procedure. Follow-up is 7 to 37 months (mean 22.1 months).

The following data were collected: operating time, duration of epidural infusion, postoperative pain scores, length of hospital stay, alleviation of symptoms, relief of cardiac abnormality on postoperative echocardiography, time to return to normal activity, duration of pain medication post-hospitalization, and complications. Success of the operation was based on relief of cardiac compression resulting in relief of symptoms and increased energy levels, adequate pain management as assessed by post-operative pain scores, length of hospital stay, time to return to normal activity and duration of daily medication.

## Operative Procedure and Perioperative Care

Surgery was performed using general anesthesia and infusion of bupivacaine/fentanyl through a thoracic epidural catheter preoperatively placed with assistance of radiologic imaging. The procedure was performed as described by Nuss with bilateral chest wall incisions, creation of subcutaneous pockets, and entry into the chest lateral to the deepest point of the deformity. Instrumentation and passage of the pectus bar (Walter Lorenz Surgical, Jacksonville, FL) was from the left side. A lateral stabilizing crossbar was routinely placed on the non-dominant hand side and on the contralateral side if deemed necessary to improve stabilization. Chest x-rays were obtained in the operating room and the morning following surgery. Antibiotics were given for 48 hours. Pain control with epidural

bupivacaine/fentanyl infusion was supplemented with parenteral narcotic patient-controlled analgesic (PCA). Transition from the epidural and intravenous narcotic was accomplished with the administration of parenteral ketorolac and oral hydrocodone/acetaminophen. Postoperative care included frequent incentive spirometry, assistance getting in and out of bed, prevention of twisting, turning, lying on either side, or raising elbows above the level of the shoulders. Pain control was assessed every 4 hours with a pain scale of 0 to 10. Patients were discharged from the hospital when pain was adequately controlled with oral medications.

## Results

Operating time was 1 to 2:05 hours (mean 1:32 hours). Results and complications are listed in Table 2. Daily average postoperative pain scores on a scale of 0 to 10 were 1.6 to 3.7, the highest being on the day following surgery. Lowest and highest individual pain scores by day were: 0 to 7 on day one, 1 to 8 on day two, 0 to 7 on day three, 0 to 4 on day four, and 2 to 4 on day five. Average daily pain scores for hospitalized patients are given in Figure 1.

Epidural catheter administration of medication for pain control was continued for 2 to 4 days (mean 2.8 days). Hospital stay was 3 to 5 days (mean 4 days). All patients had relief of symptoms and increase in activity levels. Six of eight patients had postoperative echocardiograms that showed relief of cardiac compression, and one patient who preoperatively had severe mitral valve prolapse had minimal residual mitral valve prolapse.

All patients returned to work or normal activity between 2 and 4 weeks (mean 2.3 weeks) and to unrestricted activity by 6 weeks. Six patients stopped daily oral pain medication between 2 and 4 weeks. Pain medication was continued by 2 patients for 2 and 4 months, respectively. Early complications were pneumothorax in one patient, urinary retention in two, and left lower lobe atelectasis in five. Two late complications occurred related to the pectus bar. The lateral stabilizing bar separated from the pectus bar in one patient who was playing basketball 7 months after surgery. The stabilizing bar was reattached with wire as a day surgery procedure. The patient subsequently developed skin irritation over this site with athletic activity (Table 2). In another patient, cephalad shifting of the convex surface of the bar occurred, causing a popping sensation without loss of correction. The shifting of the bar was detected 3 months after placement. It was stabilized with sutures and left in place. The patient was able to work full-time, but required occasional oral hydrocodone/acetaminophen until the bar was removed 19 months after its insertion. Three patients had transient episodes of mild chest pain with activity or while sleeping on their sides. A 32-year-old woman with an asymmetrical defect, a chest wall index of 8.5, and a small right breast no longer needs a padded bra. Four patients have had uncomplicated bar removal as a day surgery procedure under general anesthesia. There has been no loss of correction in a short follow-up of 1 to 14 months, (mean 9.7 months).

## Discussion

Reports of pectus excavatum repair in adults are rare. Despite well-documented reports to the contrary, the longstanding misconception persists that pectus excavatum is a cosmetic defect with no physiologic consequences [4 5 6]. This misconception results in patients' reaching adulthood with uncorrected defects, some developing cardiopulmonary symptoms for the first time and others experience worsening of symptoms they have endured for years. Frequently young children with pectus excavatum are asymptomatic because of the flexibility of their chests and limited physical exertion. Cardiac abnormalities have not been commonly reported in patients under 11 years of age [1

2]. Pulmonary function can be abnormal in patients with pectus excavatum, but it is improved by surgery only if the defect is severe [6]. Pulmonary function was not part of the study in our patients [7].

At puberty, symptoms develop because of increased physical activity, worsening of the pectus during increased linear growth, and decreasing chest elasticity. In adults the loss of elasticity and flexibility of the chest leads to cardiac symptoms with only moderate exertion. Symptoms include easy fatigue, low energy level, shortness of breath, tachycardia, irregular heartbeat, fainting, and exercise-induced wheezing. Surgeons are often reluctant to perform pectus repair in adults, and adult patients are reluctant to accept costochondrectomy because it is regarded as a formidable procedure with potentially significant blood loss. In an 11-year period, Fonkalsrud [7] successfully repaired pectus excavatum in 23 adults, using costochondrectomy, sternal osteotomy, and strut stabilization according to the principles described by Ravitch [8 9] and Adkins [10]. The average duration of operation was 3.1 hours. Hospital stay averaged 3.6 days, and blood loss was negligible. All patients resumed full physical activity within 8 weeks and their chests were stable at 10 weeks. There was a marked improvement in stamina 4 months after surgery. The mean follow-up was 4.8 years (range 4 months to 11 years). Patients were improved after surgery in this benchmark study, but documentation of physiologic assessment was not available for most patients.

The bracing technique described by Nuss offers an alternative treatment for pectus excavatum. The simplicity of the operation, the short operating time, subsequent remodeling of the chest, preservation of chest wall growth, and avoidance of a cosmetically displeasing scar have resulted in surgical treatment being sought for a deformity that has significant physiologic consequences. Nuss's original report demonstrated conclusively that pectus excavatum in pre-pubertal patients could be remolded without costochondrectomy or sternal osteotomy. The improved appearance was good to excellent in 86% of the patients, but no physiologic assessment was done. Nuss's operative time is 45 to 90 minutes (mean 60 minutes), hospital stay is 4 to 7 days (mean 5.6 days), and blood loss is negligible. Normal activity is permitted at 4 weeks. He reports a 7% incidence of bar displacement rarely needing reoperation and few other complications. Less favorable results have been reported by others [11].

Extending the minimally invasive operation into the adolescent age group has accounted for most of complications. These patients require more intensive pain management and better stabilization of the pectus bar. Forcing the sternum anteriorly causes considerable pain in the chest and back in the skeletally mature patient. The increased pressure on the bar by the less flexible chest increases the likelihood of bar displacement. With adequate pain control and secure stabilization of the bar, the operation can be successful in teenagers.

No information has been available regarding the effectiveness of the minimally invasive procedure in adults. The patients in our series were seeking the minimally invasive procedure for correction of the defect. Most had been told their deformities were cosmetic and that surgery should not be done. Half were symptomatic as teenagers, and the others developed symptoms after maturity. A housewife with a high pectus index was unable to climb stairs without resting, and was limited in her ability to care for her children. A college basketball player with a high energy need was unable to get full playing time because of fatigue. The insidious physiologic deterioration with age is demonstrated in two patients, ages 26 and 32 who, despite lower chest wall indices, developed symptoms and had cardiac compression demonstrated on echocardiography (Table 1).

Intraoperative contouring and fixation of the bar is important to maintaining bar stability. The bar is

manipulated as necessary for further contouring with a bar bender. The goal is to have the extrathoracic portion of the bar fit comfortably against the chest wall throughout its entire length. The lateral stabilizing bar is attached on the nondominant hand side, usually near the end of the pectus bar. The attachment is currently done with wire. Approximately 10 heavy polydioxanone sutures on each side are used to secure the bar to the chest wall. No attempt is made to stabilize the intrathoracic portion of the bar. On occasions when contouring of the bar does not provide adequate stabilization, a second stabilizing bar is attached to the pectus bar on the dominant hand side. Reoperation would not have been necessary in the patient whose stabilizing bar came off if wire had been used for fixation.

Instrumentation for inserting the pectus bar is preferably used from the left side, to minimize the unlikely possibility of cardiac injury. Passage from the right side behind a dextrorotated or severely depressed sternum directs the passing instrument toward the displaced heart. In addition, lifting the sternum enough with the instrument to avoid the heart can be difficult. The thoroscope may not be of assistance in this circumstance because the sternum blocks the view of the heart until the instrument has passed behind the sternum. Passage from the left side allows the instrument to be safely passed first in front of and then beyond the heart before encountering the sternum, minimizing the potential for injury. The thoroscope was used in two of our patients. It was helpful in the patient with a recurrent pectus.

Maintaining stabilization of the bar and providing good pain control are important to keeping the bar in place. Pain control was a high priority in our patients. Sufficient intravenous and epidural medication was given at the conclusion of surgery to prevent sudden awakening and uncontrolled movement likely to loosen the bar. Adjustments were made in the epidural rate and intravenous narcotic as needed to relieve pain without overly sedating the patient. Ketrolac was administered intravenously every 6 hours beginning on the first postoperative day to aid in decreasing the epidural and the intravenous narcotic infusions. Conversion to oral ketrolac was made before discharge, with total administration limited to 5 days. The pain-management protocol assessed pain scores, vital signs, oxygen saturation, level of epidural, and leg movement. Pain scores were recorded every 4 hours for patients who were awake. Pain scores were highest on the day following surgery as the patients became more active. The pain scores decreased significantly over the next 2 days for the majority of patients. The length of hospitalization was directly related to the adequacy of pain control. The two patients who stayed 5 days had the highest pain scores during hospitalization and required longer duration of oral pain medication (2 and 4 months). Both had high chest wall indices (5.2 and 8.5). Oral inpatient and outpatient medications include rofecoxib, hydrocodone/acetaminophen, acetaminophen/codeine, and oxycodone hydrochloride. Patients with spasm in the muscles of the back benefited from diazepam. Return to work, college, or light housework occurred in 2 to 4 weeks with good pain control. Perioperative complications did not increase the length of hospitalization. Left lower lobe atelectasis was present on the postoperative chest x-ray in five patients and was thought to be due to chronic compression of the lung by the displaced heart, as was demonstrated on a preoperative full chest CT scan in the fourth patient (Table 1).

The purpose of this study was to determine if the procedure was effective in adults for relief of cardiac compression and alleviation of symptoms. To that end, the operation was beneficial. There is little common ground to compare the results in these selected patients either to the Nuss procedure in children or to adults having the Ravitch procedure. Children, unlike adults, have chests that are flexible, resulting in less pain and a faster recovery. Young children may not have symptoms, and cardiac compression has not been uniformly demonstrated in them [1 2 11]. Our patients were discharged sooner (average 4 days) than reported by Nuss (average 5.6 days), whose longer average hospitalization time is likely influenced by conservatism in developing the procedure.

It is equally difficult to compare this current report of 8 patients to the extensive experience of Fonkelsrud. There were good subjective results with the Ravitch procedure in 23 adults over a longer period of time but no documentation of physiologic improvement [7]. Faster return to activity for adults seems to favor the minimally invasive procedure, but definite proof is lacking. The follow-up in our patients is brief and the number too small to make valid recommendations. It remains a work in progress.

## Conclusions

In eight adult patients with symptoms limiting lifestyle from a pectus excavatum causing cardiac compression, the performance of the Nuss procedure was beneficial. The patients had relief of symptoms, increase in energy levels, improvement in appearance, and demonstrable relief of cardiac compression when studied postoperatively. The hospital stay was comparable for adults and children. Return to normal activity is later than for children, but appears to be sooner than for adults having the Ravitch procedure. The early results are gratifying and are dependent upon adequate stabilization of the bar and adequate pain management.

**Résumé.** Nuss a décrit une technique mini-invasive pour corriger le thorax en entonnoir (pectus excavatum) chez l'enfant. On insère dans la cavité thoracique, derrière le sternum, une tige en acier inox avec sa surface convexe vers le bas, qui ensuite subit une rotation de 180° afin de surélever le sternum et de corriger la déformation. Ce procédé a été largement adopté pour les enfants. Le but de cette étude a été de déterminer si ce procédé était également efficace chez l'adulte. On a inclus dans cette étude seulement les patients avec des symptômes affectant leur style de vie, un indice de paroi thoracique supérieur à 3.25 et des cas de compression cardiaque démontrée sur échographie cardiaque. Entre avril 1998 et janvier 2001, 14 adultes âgés de 19 à 46 ans ont été évalués pour la technique mini-invasive de Nuss pour correction du thorax en entonnoir. Huit patients, de 19 à 32 ans, ont rempli les critères pour ce procédé. Parmi les co-morbidités on a noté deux cas de déformation asymétrique, deux cas de scoliose, une intervention antérieure pour la même pathologie et une intervention antérieure pour augmentation mammaire. Les patients ont été informés des bénéfices et des inconvénients possibles des procédés de Ravitch et de Nuss. Tous les patients sauf le premier ont eu l'occasion de parler avec un ou plusieurs autres adultes ayant eu ce même procédé auparavant. Le suivi a été de 7 à 37 mois (moyenne: 22.1). Par la suite, on a enlevé la tige chez quatre patients sans compromettre le résultat final. Le succès de l'intervention a été basé sur le soulagement de la compression cardiaque, l'amélioration des symptômes et le contrôle de la douleur. La durée de l'intervention a été de 1 à 2 h:05 (moyenne 1:32). On a observé un pneumothorax dans un cas, une rétention urinaire chez deux patients et une atelectasie lobaire inférieure dans cinq cas. Ces complications n'ont pas prolongé la durée de l'hospitalisation. L'analgésie péridurale postopératoire a été arrêtée entre deux et quatre jours (moyenne 2.8) après l'intervention. Les scores quotidiens de la douleur ont été compris entre 1.6–3.7 sur une échelle de 0–10. La durée de l'hospitalisation a été de 3–5 jours (moyenne 4). On a observé un soulagement des symptômes et une augmentation de l'activité chez tous les patients. La décompression cardiaque, confirmée par des échographies postopératoires, a été obtenue chez six patients. Les patients ont pu reprendre une activité normale 2–4 semaines après l'intervention (moyenne 2.3). La durée de l'analgésie a été de 2–4 semaines chez six patients et de 2 à 4 mois pour les deux autres (moyenne 5.5 semaines). Il y a eu deux complications tardives en rapport avec la tige sans compromettre le résultat final. Notre expérience avec la réparation du thorax en entonnoir par la méthode mini-invasive de Nuss chez l'adulte est encourageante. Chez des patients sélectionnés, ce procédé est efficace dans la correction du thorax en entonnoir. Les résultats précoces sont dépendants de la stabilisation de la tige et du contrôle de la

douleur. Les résultats à long terme chez l'adulte sont inconnus.

**Resumen.** Nuss describió una técnica mínimamente invasora para la corrección del pectus excavatum en niños: se inserta una barra curva de acero por detrás del esternón, a través de la cavidad torácica, con la superficie convexa hacia abajo, y se rota 180° para elevar el esternón y corregir con ello la deformación. El procedimiento ha ganado amplia aceptación para su empleo en niños. El propósito del presente estudio fue determinar si es aplicable y efectivo en adultos. Sólo fueron incluidos pacientes con sintomatología que afectara su estilo de vida, con índices de pared torácica >3.25 y compresión cardíaca demostrada. Entre abril de 1998 y enero de 2001 se realizó la evaluación para practicar el procedimiento de Nuss en 14 adultos con edades entre 19 y 46 años. Ocho pacientes, con edades entre 19 y 32 años, cumplieron los criterios para ser intervenidos, en los cuales se registró comorbilidad así: deformación asimétrica en 2, escoliosis en 2, reparación previa del pectus excavatum en 1 y mamoplastia de aumento en 1. Los pacientes fueron informados sobre los beneficios y las desventajas respectivas de los procedimientos de Ravitch y de Nuss. Todos, menos uno, habían conversado con uno o más adultos que habían sido sometidos al procedimiento. El seguimiento fue de 7 a 37 meses (promedio 22.1). En cuatro ya se han removido las barras y la corrección se mantiene. El éxito del procedimiento se fundamentó en la corrección de la compresión cardíaca, la mayoría de los síntomas y un buen control del dolor. El tiempo operatorio osciló entre 1 y 2:05 horas (promedio 1:32). Las complicaciones incluyeron neumotórax en 1 caso, retención urinaria en 2 y atelectasis del lóbulo inferior izquierdo en 5; estas complicaciones no prolongaron la hospitalización. La analgesia epidural pudo ser descontinuada entre los 2 y los 4 días (promedio 2.8) postoperatorios. El nivel promedio de dolor osciló entre 1.6 y 3.7 en una escala de 0 a 10. La hospitalización duró entre 3 y 5 días (promedio 4). Se logró mejoría de los síntomas y un incremento en la actividad en la totalidad de los pacientes. La desaparición de la compresión cardíaca pudo ser demostrada en los 6 pacientes en quienes se practicó ecocardiografía postoperatoria. Todos los pacientes pudieron retornar a su actividad normal a las 2–4 semanas (promedio 2.3) luego de la operación. La administración de medicamentos para el dolor se prolongó por 2–4 semanas en 6 pacientes y por 2–4 meses en los otros dos (promedio 5.5 semanas). Se registraron 2 complicaciones tardías relacionadas con la barra, sin que hubiera pérdida de la corrección. La experiencia inicial con la reparación mínimamente invasora de Nuss en adultos es promisoría. El procedimiento es efectivo en la corrección del pectus excavatum en pacientes seleccionados. Los resultados tempranos dependen de la adecuada estabilización de la barra y del control del dolor. No se conocen los resultados a largo plazo en los adultos.

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## Tables

[Table 1.](#) Patient information.

[Table 2.](#) Results and complications.

## Figures

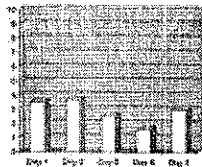


Figure 1  
Figure 1 (large scale)

Fig. 1. Average daily pain scores for 8 patients the first three days, 6 patients the fourth day, and 2 patients the fifth day. Epidural infusion was discontinued on day 2 to 4 (mean 2.8) (pain scored on a scale of 0-10).