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The minimally invasive Nuss technique for recurrent or failed pectus excavatum repair in 50 patients

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Abstract

Purpose: The aim of this study was to demonstrate the efficacy of the minimally invasive technique for recurrent pectus excavatum.

Methods: Fifty patients with recurrent pectus excavatum underwent a secondary repair using the minimally invasive technique. Data were reviewed for preoperative symptomatology, surgical data, and postoperative results.

Results: Prior repairs included 27 open Ravitch procedures, 23 minimally invasive (Nuss) procedures, and 2 Leonard procedures. The prior Leonard patients were also prior Ravitches and are therefore counted only once in the analyses. The median age was 16.0 years (range, 3-25 years). The median computed tomography index was 5.3 (range, 2.9-20). Presenting symptoms included shortness of breath (80%), chest pain (70%), asthma or asthma symptoms (26%), and frequent upper respiratory tract infections (14%). Both computed tomography scan and physical exam confirmed cardiac compression and cardiac displacement. Cardiology evaluations confirmed cardiac compression (62%), cardiac displacement (72%), mitral valve prolapse (22%), murmurs (24%), and other cardiac abnormalities (30%). Preoperative pulmonary function tests demonstrated values below 80% normal in more than 50% of patients. Pectus repair was done using a single pectus bar (66%), 2 bars (32%), or 3 bars (2%). Stabilizers were used in 88% of the patients. Median length of surgical time did not significantly differ from that of primary surgeries. Complications were slightly higher than those in primary repairs and included pneumothorax requiring chest tube (14%), hemothorax (8%), pleural effusion requiring drainage (8%), pericarditis (4%), pneumonia (4%), and wound infection (2%). There were no deaths or cardiac perforations. Initial postoperative results were excellent in 70%, good in 28%, and fair in 2%. Late complications of bar shift requiring revision occurred in 8%. Seventeen patients have had bar removals with 9 patients being more than 1 year postremoval. For the 17 patients who are postremoval, excellent results have been maintained in 8 (47%), good in 7 (41%), fair in 1 (6%), and failed in 1 (6%). There have been no recurrences postremoval.

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Conclusions: Although failed or recurrent pectus excavatum repairs are technically more challenging, reoperative correction by the Nuss procedure has met with excellent success.

Recurrence rates after repair of pectus excavatum are reported to be anywhere from 2% to 37% [1]. There are patients whose deformity recurs for any number of reasons. For example, recurrence has been noted to be higher in patients with Marfan's syndrome [1]. Other causes that have been attributed to recurrence include age at time of surgery [1], either too early an operation or too late, either too extensive or too little dissection with open techniques, removing the bar too early in minimally invasive techniques [2,3], local infections [4], and unsatisfactory result. We have evaluated 85 patients who had either a prior Ravitch or a prior Nuss procedure but who have had a recurrence; we have performed a secondary Nuss procedure on 50 of these patients. These patients sought evaluation because they continued to experience some of the same symptoms they experienced before their initial repair. They reported shortness of breath, chest pain, and other similar symptoms that affect their activity level. Associated cardiac findings such as cardiac displacement and cardiac compression were often still present. In addition, these patients continued to perform poorly on pulmonary function tests (PFTs). Therefore, in such cases where the recurrent deformity causes the patient to continue to experience symptoms, a second repair seems warranted. The Nuss procedure has been successfully used to repair recurrences in patients who had previously undergone a Ravitch procedure [5]. We have also had excellent success in using the Nuss procedure to repair recurrent pectus excavatum after operation by a variety of techniques. The purpose of our study was to demonstrate the efficacy of using the minimally invasive technique for correction of recurrent or failed repair of pectus excavatum.

1. Methods

All of our patients or their parents, if patients are minors, who seek evaluation for pectus excavatum give informed institutional review board consent to have their data included in our pectus database. Eighty-five patients have been evaluated for recurrent pectus excavatum; 35 have not yet undergone a secondary surgery. For our study, we reviewed the preoperative symptomatology, surgical data, and postoperative results for our 50 patients who underwent repeat procedures for recurrent pectus excavatum. The surgical technique for repair of recurrent pectus excavatum is similar to the technique described for primary repairs with the addition of thoracoscopic pneumonolysis when required. Three members of the pectus team, 2 physicians and our pectus nurse, reached consensus regarding postoperative results using the following criteria: excellent if preoperative symptoms were resolved and chest appearance was normal; good if preoperative symptoms were resolved and chest appearance was improved; fair if preoperative symptoms were improved but appearance not completely normal; and failed if symptoms were worse and chest appearance was not improved or if the deformity reoccurred.

2. Results

Of the 50 patients who have had a secondary procedure as of October 31, 2003, 27 of these patients had undergone a prior Ravitch procedure, 23 had undergone a prior Nuss procedure, and 2 of the prior Ravitch patients had also undergone a prior Leonard procedure. Therefore, these 2 patients were only counted once in our analyses. All of the prior Ravitch patients and 20 of the prior Nuss patients had had their initial repair done elsewhere. The male to female ratio in patients requiring a repeat procedure was 9:1. There was a family history of pectus excavatum in 32% of these patients. The median age at initial repair was 9.0 (range, 1-19 years.). The median age at the time of repeat surgery was 16.0 (range, 3-25 years). The median computed tomography (CT) index at the time of repeat surgery was 5.3 (range, 2.9-20). These results are presented in Table 1.

Patients who had had a Nuss procedure and who presented for a second Nuss procedure reported having experienced pain and recurrence shortly after their primary surgery. On chest x-ray, the bar was displaced in most cases. For the Ravitch patients, recurrences were noted anywhere immediately to 7 years postoperatively (Table 2). Those patients who noted recurrence further out from their primary surgery had had the Ravitch before their pubertal growth spurt. These patients reported that their deformity had never been completely corrected and had become much more severe when they underwent their growth spurt. Although

Table 1 Demographics of 50 patients who underwent redo pectus repair

Previous Nuss procedure	23
Previous Ravitch procedure	27
Previous Leonard procedure	2*
Male to female ratio	9:1
Family history	16 (32%)
Median age at initial surgery (y)	9.0 (range, 1-19)
Open Ravitch	8.0 (range, 4-16)
Nuss	14.0 (range, 1-19)
Median age at redo	16.0 (range, 3-25)
Media CT index	5.3 (range, 2.9-20)
Diagnosed Marfan's syndrome [n (%)]	1 (2)
Marfanoid [n (%)]	14 (28)

* Both Leonard patients were also prior Ravitches and are therefore counted once in analysis.

Table 2 Length of time between primary repair and recurrence

Recurrence in Ravitch patients	
Immediately	12
1-2 y postoperatively	2
3-5 y postoperatively	5
7 y postoperatively	4
Unknown	4
	27
Recurrence in Nuss patients	
Immediately	20
1 y	2
14 mo	1
	23

these patients were symptomatic with their recurrence, they were reluctant to undergo another open procedure.

The presenting symptoms (see Table 3) included shortness of breath in 80% of these patients. Seventy percent of these patients experienced chest pain, with or without exercise. Asthma or asthmalike symptoms were still present in 28% of these patients and 14% had frequent upper respiratory infections.

Computed tomography scan and physical examination confirmed cardiac compression in 62% of our patients and cardiac displacement in 72% of our patients. Twenty-two percent of these patients had mitral valve prolapse as confirmed by cardiology evaluation, 24% had cardiac murmurs, and 30% had other cardiac abnormalities.

Pulmonary function tests to assess pulmonary functioning are required as a part of our evaluation process, whether for redo patients or for primary surgical candidates. Research has indicated that pectus patients experience a decrease in pulmonary functioning as compared with the normal population [6]. The cut point for normality was 80%. Of the 50 patients who underwent a repeat procedure, 56.5% had a forced vital capacity (FVC) value below 80%, 54% had a forced expiratory volume in 1 second (FEV_1) value below 80%, and 53.4% had a forced expiratory flow ($FEF_{25\%-75\%}$) below 80%.

Table 3 Presenting symptoms of 50 redo pectus patients

Shortness of breath, lack of endurance, exercise intolerance	40 (80%)
Chest pain, with or without exercise	35 (70%)
Asthma/asthmalike symptoms	13 (26%)
Frequent upper respiratory infections	7 (14%)
Cardiac compression by CT	31 (62%)
Cardiac displacement by CT/exam	36 (72%)
Mitral valve prolapse	11 (22%)
Other anomalies (BBB, aortic insufficiency, regurgitation, hypertrophy, malformations)	15 (30%)
Murmur on exam	12 (24%)
Pulmonary indications	
FVC% below 80%	56.5%
FEV_1% below 80%	54.0%
$FEF_{25\%-75\%}$ below 80%	53.4%

BBB indicates bundle branch block.

Table 4 Complications for redo patients

Early complications	
Deaths	0
Cardiac perforations	0
Pneumothorax	35 (70%)
Requiring chest tube	9 (18%)
Aspiration	2 (4%)
Chest tube and aspiration	1 (2%)
Hemothorax	4 (8%)
Pleural effusion requiring drainage	3 (6%)
Pericarditis	2 (4%)
Wound infection	1 (2%)
Pneumonia	2 (4%)
Late complications	
Bar shifts	7/50 (14%)
Requiring revision	4 (8%)

The number of bars used in the repeat Nuss procedures differed from the number of bars used in our primary patients in that we placed 3 bars in one of our redo patients. Otherwise, we placed either 1 (66%) or 2 bars (32%). Stabilizers were used in 88% of these patients. Blood loss was minimal and no patient required a transfusion. The median length of surgical time was 2.34 (range, 1-7.1 hours). Although the median length of time was similar to the time required for primary surgeries, we have not had any primary surgeries that required 7 hours.

Early postoperative complications are presented in Table 4. Thirty-five of these patients had a pneumothorax

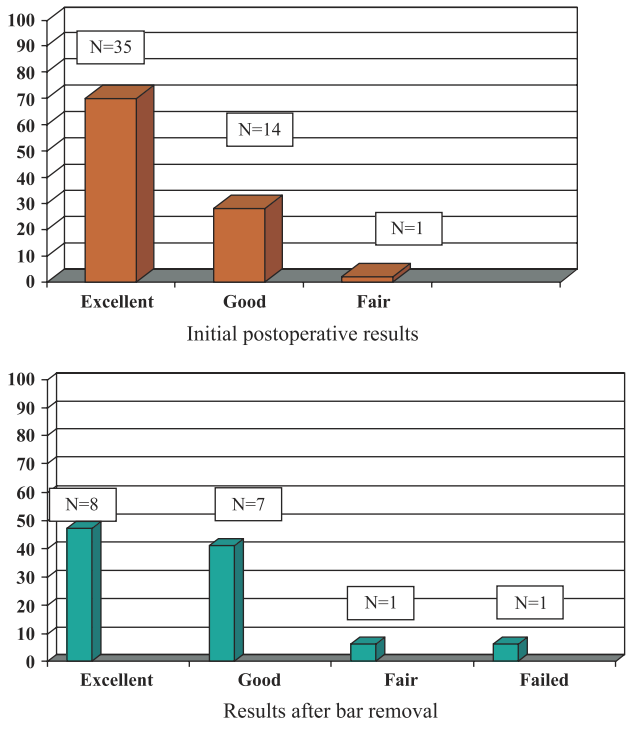

Fig. 1 Initial postoperative results (N = 50) and results postbar removal (N = 17) for patients who underwent redo surgery.

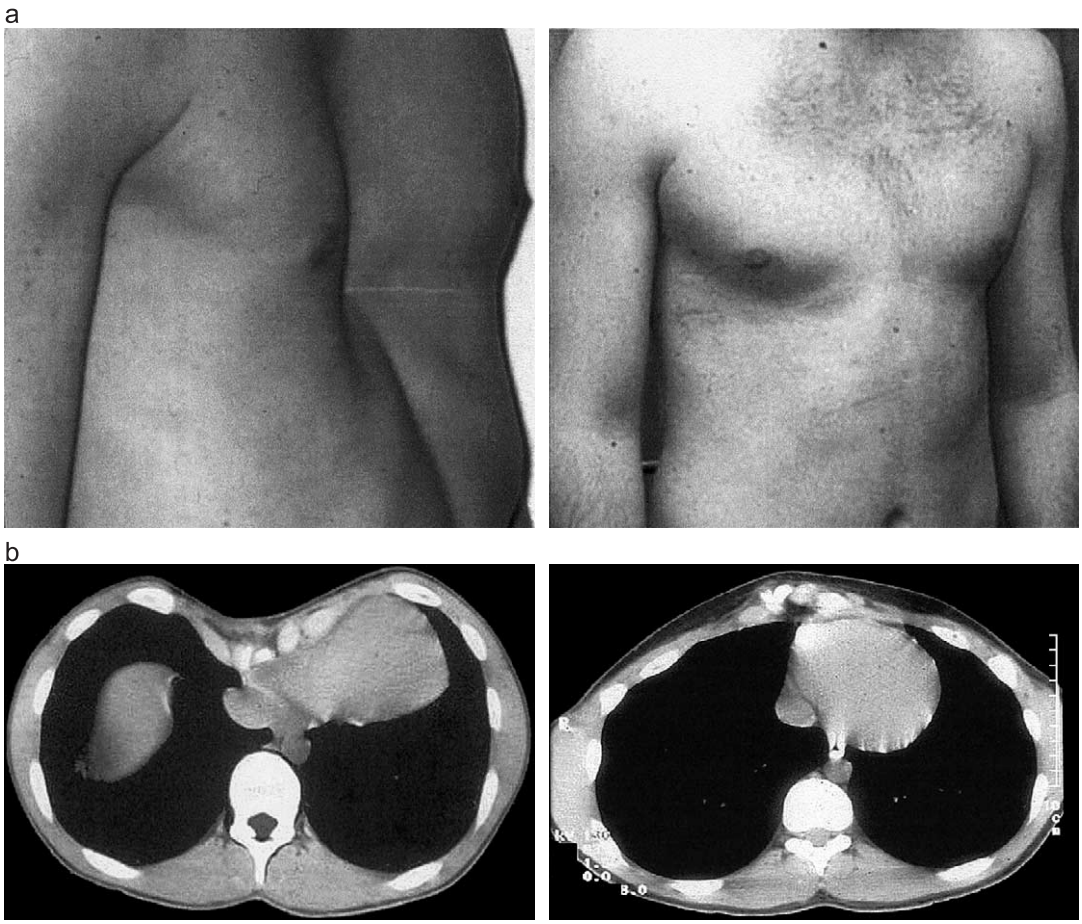

Fig. 2 a, Patient with recurrent pectus after Ravitch procedure with postoperative appearance after redo. b, Computed tomography scan of the patient before and after redo using minimally invasive technique.

with 12 (24%) requiring a chest tube and/or aspiration at the time of the operation. Four (8%) had a hemothorax postoperatively. Three patients (6%) had pleural effusions large enough to require drainage. Two (4%) of our patients had pericarditis postoperatively and one (2%) experienced wound infection. Pneumonia developed in 2 (4%) of our patients. There were no deaths or cardiac perforations.

Late complications have primarily consisted of bar displacements. Seven of the 50 patients (14%) experienced bar shifts. Four of the 7 (8%) required a revision.

Both the initial postoperative results and results after bar removal are presented in Fig. 1.

Seventeen patients have had their bars removed. Results were excellent in 47% (Fig. 2a,b), good in 41%, fair in 6%, and failed in 6%. The one patient with a "failed" result has developed a parasternal carinatum ridge, and although he no longer has an excavatum deformity, we considered this a failure of the Nuss technique. This patient will very likely require a second repeat procedure.

Our patients complete a postoperative questionnaire designed to assess whether they are continuing to experience symptoms and their satisfaction with postoperative results. Patients who have had a secondary minimally invasive procedure after either a Ravitch or a Nuss procedure and who have returned for follow-up have reported resolution of their preoperative symptoms with 85% reporting increased exercise tolerance. On physical exam, the cardiac compression and cardiac displacement had resolved. Most respondents (23/28, 82%) also report being happy to very happy with their results.

Postoperative pulmonary function studies showed slight improvement in half of the patients and no change or a slight decrease in the remaining patients. Eleven out of 19 (58%) patients who had preoperative PFTs and who had had a prior Ravitch showed improvement in their postoperative $FEF_{25\%-75\%}$. Eight out of 14 (57%) patients who had preoperative PFTs and who had had a prior Nuss showed improvement in their postoperative $FEF_{25\%-75\%}$.

3. Discussion

Prior data have supported the use of the minimally invasive Nuss procedure for initial repair of pectus excavatum [7]. However, there are patients who experience a recurrence of their deformity, regardless of which procedure was initially used. For those patients who would benefit from another repair, there has been very little

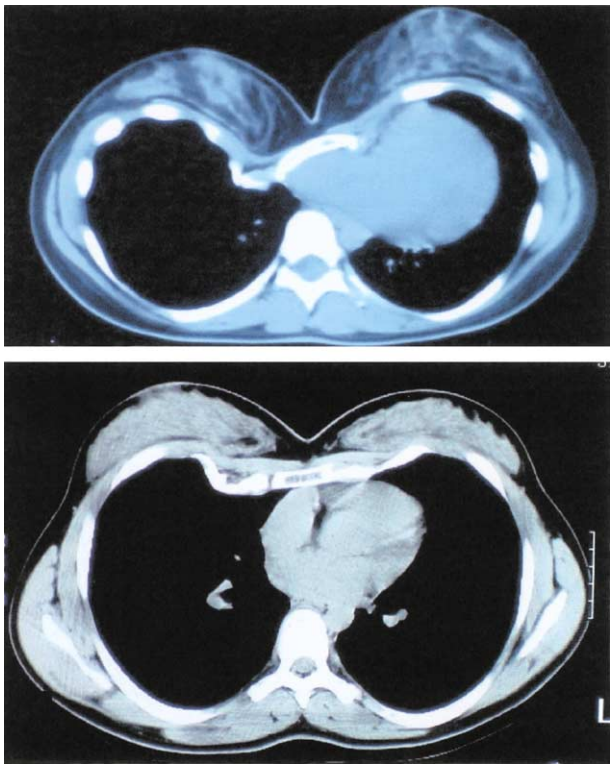

Fig. 3 Computed tomography scans demonstrating abnormal ossification of the costochondral cartilages after Ravitch procedures in 2 patients.

research on the best technique and the postoperative outcomes after repeat procedures [1].

In evaluating patients with a recurrence to determine whether they would benefit from another procedure, we find that it is important to evaluate the presenting symptoms to determine whether the patient is continuing to have the same symptoms that led them to seek surgical correction in the first place. The patients that we evaluated for a secondary procedure were continuing to experience chest pain or respiratory symptoms that interfered with their physical activity. Most of the patients with recurrences after previous Ravitch procedures had their repairs done at a young age (median = 8.0). On preoperative evaluation with CT scan, 16 of the 27 redo patients (59%) had ossifications to varying degrees of the previously resected costochondral cartilages and several had acquired thoracic chondrodystrophy with poor growth of their chest wall (Fig. 3). Of these 16 patients, 8 had undergone primary repair before the age of 7, which is consistent with previous findings that too early and extensive open pectus procedures can result in chest wall constriction [8]. The extensive dissection done during an open procedure, although technically extrapleural, can also produce extensive intrathoracic adhesions. Most patients with a previous Ravitch repair had poor chest wall movement and compliance because of the abnormal ossification of the anterior chest wall. This abnormal calcification that results after each violation of the perichondrium and periosteum is why we have not performed the secondary pectus repairs as open Ravitch-type repairs. This is also why we do not advocate wiring of the pectus bar to the ribs or sternum. After a repeat procedure, the presenting symptoms and appearance are improved but may fail to improve chest wall compliance after previous open repairs.

Abnormal ossification of the costochondral cartilage may also account for the inconsistency in improvement of postoperative PFTs after open procedures with a redo [8]. This may also be true in patients after open procedures without evidence of recurrence, because this finding is often not detected on plain chest x-ray and is best seen by CT scan. Although chest wall compliance may be improved when the costochondral cartilages are not ossified using the Nuss technique, recurrent pulmonary adhesions after a repeat operation requiring pneumolysis may contribute to the inconsistency in postoperative PFT improvements in these patients. Because the PFTs were done as static PFTs and not as exercise PFTs, they may not have been as sensitive to changes in preoperative and postoperative pulmonary functioning.

Patients with a previous Nuss procedure were found to have malpositioned or displaced bars after their initial procedures, which indicates a technical error in applying the minimally invasive technique. Recurrence in these patients occurred within months of the initial procedure. Preoperative CT scans often demonstrated a bar that was too long or that had been placed too lateral to the sternum (Fig. 4). This abnormal positioning allows posterior stripping of the

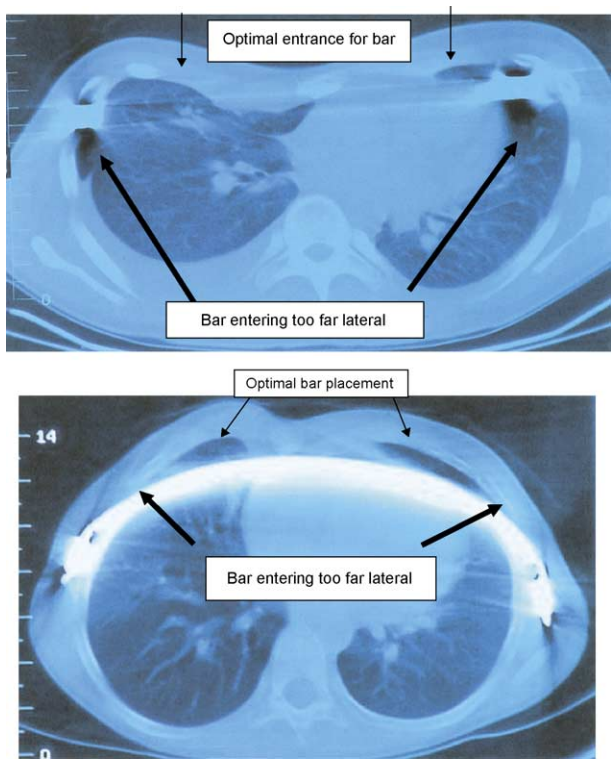

Fig. 4 Computed tomography scans showing malposition of pectus support bar in 2 patients.

intercostal muscles, producing pain for the patient, recurrence of the deformity, and intrathoracic adhesions. In 15 of the 23 (65%) Nuss redo patients, the bars were downsized anywhere from 1 to 4 in, indicating that too lateral a placement of the bar requires a longer bar than would be predicted from preoperative chest measurements.

Our patients do not undergo postoperative cardiology evaluations or repeat CT scans, and we are therefore unable to assess the relief of cardiac symptoms in mitral valve prolapse or other cardiac anomalies. However, on physical exam, symptoms of cardiac compression and displacement are found to be relieved postoperatively.

As in most repeat operations, complications were slightly higher, but in this study, were not significant. This is especially true if placement of a chest tube after dissection of adhesions is viewed as a component of the operation rather than as a complication.

The minimally invasive Nuss technique for reoperative correction of failed or recurrent pectus excavatum is an excellent method of repair.

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Discussion

Unidentified speaker: I have a quick question. When you had marked ossification, did you have to do anything with those cartilages when you placed the bar in? Did you have to break any of those ossified cartilages or modify them at all, or did the bar take care of that?

D. Croitoru (response): We have not modified the cartilages, although there may be some patients that will require some type of modification. They are the patients with a mixed deformity of both pectus excavatum and carinatum deformities that have developed unusual ridges that may need modification of the cartilages. The concern is that every time that you enter the bone or the cartilage, you have the potential for stimulating further ossification. This is the same concern we have with modifications that have been prescribed for bar fixation by putting wires or screws into the ribs. We have seen these when we have done patients who have had Rehbein struts left in place or wires to the ribs. It encourages stimulation of ossification around those prostheses. Therefore we have not endorsed fixation of the bars to the ribs or the sternum and those that are doing this are finding it very difficult to remove the bars at 2 years' time.

Unidentified speaker: How do you know if a patient is developing an acquired throcic dystrophy?

D. Croitoru: You can see whether the chest really has stopped growing and has become completely stiff with no motion. Many of these patients are doing abdominal breathing after they have had previous operations. The chest wall does not move, so I don't know if there is a way that we can quantify that to know who might require some type of secondary procedure to release some of the cartilages and bony ossification.

Unidentified speaker: Is there anyone you wouldn't try a redo Nuss on then, I guess is the question.

D. Croitoru: Well, so far there has only been one patient that has been turned down for a redo secondary to significant ossification of the rib ends that curled markedly inwards. We did not feel that we would be able to approach this with the minimally invasive technique. So the answer to your question is that a few patients will be turned down.

A. Coran (Ann Arbor, MI): I have a question about the technique here. We haven't done as many redos as you have, but if it is a Ravitch that was done before this recurred, one of the things I have found that is helpful in doing it safely with the Nuss procedure is to put a thoracoscope in both chests and then take the little center of the Ravitch incision, open it up a little bit, put your finger in there and begin to dissect the pericardium safely off the substernal area under direct vision. Now, do you have any other tricks for doing these so you don't run the risk of getting into the pericardium or, worse, getting into the heart?

D. Croitoru (response): Dr. Coran you are correct in your concerns and although I do not use your method that is one technique to insure safety. With the Ravitch procedure, you theoretically have never entered the chest, but you may be surprised at the extent of intrathoracic adhesions that can form. We start off all

these procedures prepared with thoracoscopic instruments. What I do is just do thoracoscopic lysis of all those adhesions with instruments, and what I usually do is place my instruments directly through the substernal tunnel, not with trocars, just directly putting them in the intercostal spaces and taking down the adhesions. Sometimes you need to take them down with a harmonic scalpel. I usually do this from the right and have occasionally put in a scope on the left. It just depends on how difficult it is for you to see. Although I have not found that I have to do this very often.