Thirty-Year Experience With Repair of Pectus Deformities in Adults

Kamal A. Mansour, MD, Vinod H. Thourani, MD, Eric A. Odessey, BS, Megan M. Durham, MD, Joseph I. Miller, Jr, MD, and Daniel L. Miller, MD

Joseph B. Whitehead Department of Surgery, Section of General Thoracic Surgery, Division of Cardiothoracic Surgery, Emory University School of Medicine, Atlanta, Georgia

Background. **A plethora of studies have described repair of pectus deformities in children, but only few reports have described this repair in adults. The purpose of this study was to review our 30-year experience with surgical repair of pectus deformities in adults.**

Methods. **A retrospective review of all adult patients (> 16 years old) who underwent repair of congenital pectus deformities from 1971 through 2001.**

Results. **There were 77 patients, 64 men and 13 women. Sixty-eight patients underwent surgery for pectus excavatum and 9 for pectus carinatum; median age was 22 years old (range, 16 to 68 years old). Indication for repair was medical concerns in all patients. Preoperative symptoms were dyspnea on exertion in 43 patients, shortness of breath at rest in 22 patients, chest pain in 8 patients, and palpitations in 8 patients. Preoperative electrocardiogram findings included right bundle branch block in 9 patients, sinus bradycardia in 8 patients, left atrial enlargement in 6 patients, and right atrial dilatation in 5 patients. Patterns of the pectus defect were symmetric and localized in 29 patients, symmetric and diffuse in 21, asymmetric and localized in 18, and asymmetric and diffuse in 9 patients. Intraoperative classifications were severe in 38 patients, moderate in 33 patients, and mild in 6 patients. There were no operative deaths. Complications occurred in 11 patients (14.3%). Mean hospital stay was 4 days (range, 2 to 8 days). Mean follow-up was 12 ± 7 years (range, 4 months old to 24 years old); 1 patient (1.3%) required reoperation for recurrent pectus excavatum. Patient satisfaction and relief of medical symptoms was excellent in 70 patients (90.9%), good in 6 patients, and fair in 1 patient.**

Conclusions. **Repair of congenital defects of the sternum in adults can be performed safely with low morbidity and no mortality. Long-term results are excellent with requirement for reoperation rare.**

(Ann Thorac Surg 2003;76:391–5)

Pectus excavatum and pectus carinatum are the two most common congenital chest deformities, occurring in approximately 1:1000 and 1:5000 births, respectively. While pectus excavatum tends to present at an earlier age, both deformities will worsen with aging. Most will manifest before or during adolescence with some degree of aesthetic or functional impairment.

The etiology of pectus deformities has not been clearly elucidated, genetic predisposition may be possibly seen. Surgical correction is often necessary for moderate or severe deformities, because spontaneous regression is rare. Although a myriad of literature has been published on the outcomes following repair of pectus deformities in the pediatric population [1–4], little data have been published in adults requiring pectus repair [5–7]. Therefore, we retrospectively reviewed our experience with repair of pectus deformities in adults.

Material and Methods

A retrospective review was performed of 77 consecutive patients who underwent pectus excavatum or carinatum surgical repair in the Emory Healthcare System between 1971 and 2001 by a single thoracic surgeon [K.A.M.]. There were 64 men (83.2%) and 13 women. Median age was 22 years old (range, 16 to 68 years old). Sternal deformity was a pectus excavatum in 68 patients (88.3%) and pectus carinatum in 9 patients.

Evaluation before surgical repair included conventional chest roentgenography in all patients and electrocardiogram and pulmonary function tests on a per needed basis. Computed tomography (CT) scan of the chest was performed to evaluate the extent and nature of the deformity (Fig 1). More recently, several insurance carriers have required calculation of the pectus index (calculated by a chest CT) and pulmonary function tests with and without exercise. In those patients with associated chest pain, noninvasive cardiac evaluation was performed to rule out significant coronary artery disease. Patient's medical records were reviewed for patient age, gender, surgical history, symptoms, electrocardiographic changes, anatomic defect identified at the time of the surgical repair, the type of surgical reconstruction, and

Presented at the Forty-ninth Annual Meeting of the Southern Thoracic Surgical Association, Miami Beach, FL, Nov 7–9, 2002.

Address reprint requests to Dr Mansour, 1365 Clifton Road, The Emory Clinic, Atlanta, GA 30322; e-mail: kamal_mansour@emory.org.

Published by Elsevier Inc

0003-4975/03/$30.00
PII S0003-4975(03)00441-7

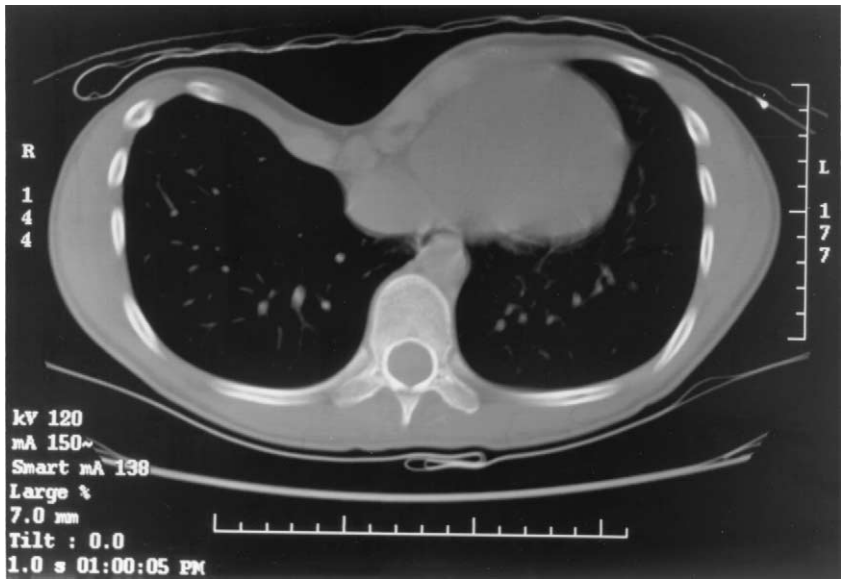

Fig 1. Computed tomography scan of the chest of an 18-year-old patient with pectus excavatum.

hospital course. Patients were contacted for satisfaction of repair and presence of postoperative symptoms.

Surgical technique for repair of the pectus defect was based on the modified Ravitch repairs [8, 9]. A vertical midline incision is made from the third rib to midxiphoid. Bilaterally, the pectoralis major muscles are dissected free from the chest wall using electorcautery for the extent of the defect, allowing visualization of the pericostal surfaces of the involved ribs (generally, ribs three through seven). Bilateral deformed costal cartilages are carefully removed subperichondrially for facilitation of future rib regeneration. Elevation of the sternum is performed using two maneuvers. The first is separation of the sternum from the xiphoid, which remains attached to rectus muscles. The sternum is then freed by dividing the attachments from the beds of the removed cartilages bilaterally. The second sternal elevation maneuver is an anterior wedge osteotomy for correction of the sternal defect (Fig 2). Placement of two #1 Prolene sutures (Ethicon, Sommerville, NJ) is carried through the right and left sides of the xiphoid (at the rectus abdominus attachments) and around the right and left portions of rib number two. Care is taken not to injure the internal mammary artery when placing the Prolene sutures around the second rib. Once these two sutures are tied, this allows the xiphoid/rectus complex to relocate under the sternum as a buttress to prevent posterior sternal collapse. The beds of the removed costal cartilages are reattached to the corrected sternum on both sides. In pectus carinatum, additional reefing or resection of excess beds of the costal cartilages is performed to take up the slack in the redundant perichondrium. Coverage of the sternum includes reapproximation of the pectoralis major muscles and subcutaneous tissues, followed by a subcuticular skin closure (Fig 3). We routinely open the right pleural space and insert a straight 28 to 32 F chest tube within that space. Moreover, we place two 10-mm Jackson-Pratt drains anterior and posterior to the pectoralis muscles. In the majority of patients, all drains are removed between postoperative days 2 to 3. If the J-P drainage is excessive, the patient is discharged and is monitored until the drainage is minimal ($<$ 50 mL/day) and the drains are then removed on an outpatient basis. The majority of the patients were weaned from the patient-controlled analgesic pump on postoperative day 1 or 2 and were discharged with postoperative analgesics without any complications. In our experience, pectus repair patients have minimal pain and were walking by postoperative day 1 and were discharged by postoperative day 3 or 4. This technique was performed in the majority of patients. Our routine surgical method was altered in 2 patients. One of the patients was a 68-year-old man who had undergone coronary artery bypass grafting 10 years earlier at an outside institution and now required aortic valve replacement. Because of fear that redo-sternotomy was too dangerous to open conventionally, because the sternal wires in the pectus deformity were in close proximity to the aortic arch, an entire sternectomy with bilateral pectoralis flaps and an omental flap with Prolene mesh repair was performed [10]. Another 37-year-old man failed initial repair of pectus excavatum 30 years earlier at an outside institution and presented with palpitations and dyspnea on exertion. The chest wall was markedly deformed with "hills and vales" appearance. He underwent complete sternectomy, with pectoralis flaps and methylmethacrylate sandwich Prolene mesh repair. Eight-months later the patient required removal of the methylmethacrylate mesh prosthesis due to pain and limitation of motion with excellent cosmetic results. In 3 patients (3.9%) substernal bar placement was performed.

Clinical Findings

The most common preoperative symptoms included dyspnea on exertion in 43 patients (55.8%), shortness of breath at rest in 22 patients, chest pain in 8 patients, and palpitations in 8 patients. Additional reasons for correction were esthetics in 28 patients (36.4%) and psychologic

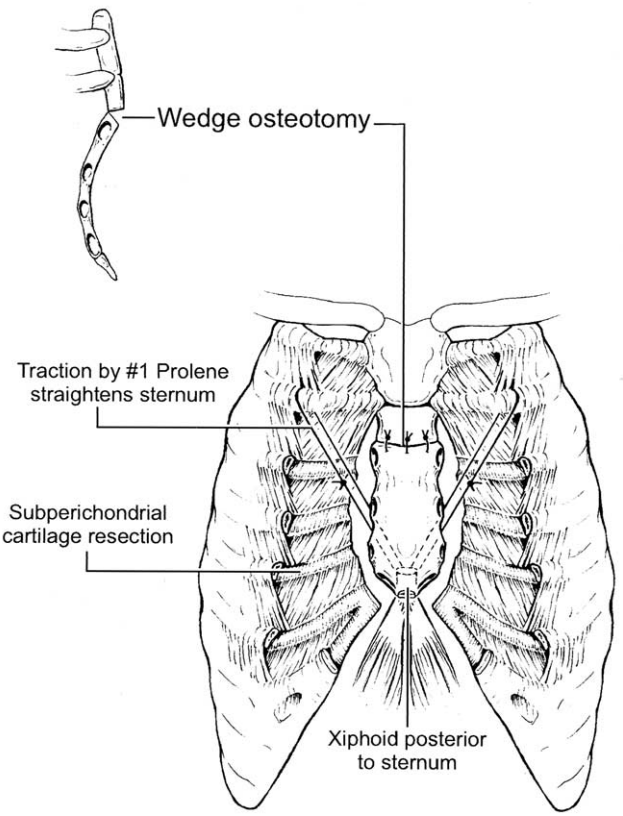

Fig 2. Surgical technique for our repair of the pectus defect based on the modified Ravitch and Robicsek repairs. Illustrated is the separation of the sternum from the beds of the removed cartilages, followed by a wedge osteotomy for correction of the sternal defect, and buttress of the xiphoid/rectus complex to relocate under the sternum.

reasons in 4 patients (5.2%). Preoperative electrocardiographic findings were right bundle branch block in 9 patients (11.7%), sinus bradycardia in 8 patients, left atrial enlargement in 6 patients, and right atrial dilation in 5 patients.

The pattern of sternal defect was symmetric and localized in 29 patients (37.7%), symmetric and diffuse in 21 patients, asymmetric and localized in 18 patients, and asymmetric and diffuse in 9 patients. Intraoperatively, the severity of the pectus deformity was classified as severe in 38 patients (50.6%), moderate in 33 patients, and mild in 6 patients. In those patients with mild or moderate pectus deformities, coexisting esthetics and psychologic reasons played a larger part in the decision to proceed with surgery.

Results

Seventy-seven patients underwent surgery to correct a pectus deformity, pectus excavatum in 68 patients, and pectus carinatum in 9 patients. Six patients (7.8%) had prior pectus excavatum repair during childhood. There were no operative deaths. Complications occurred in 11 patients (14.3%), pleural effusion in 5 patients, pneumonia in 4 patients, and wound seroma in 2 patients. Mean hospital stay was 4 days (range, 2 to 8 days), whereas mean intensive care unit stay was 0.6 days (range, 0 to 2 days).

Sixty-one patients (79%) underwent long-term follow-up with telephone calls (mean 12 ± 6 years; range, 4 months to 24 years), the remaining 16 patients (21%) had follow-up as performed by clinic chart reviews during visits at our institution (mean 10 ± 6 years; range, 2 to 23 years). One patient (1.3%) required reoperation for recurrent pectus excavatum 3-years after the initial operation, reconstruction was performed using methylmethacrylate sandwich Prolene mesh repair. The 3 patients who underwent simultaneous bar placement required bar removal at 6, 12, and 13 months for pain or bar protrusion, respectively. Relief of symptoms and patient satisfaction was excellent in 70 patients (90.9%), good in 6 patients, and fair in 1 patient. No patient experienced worse symptoms after repair.

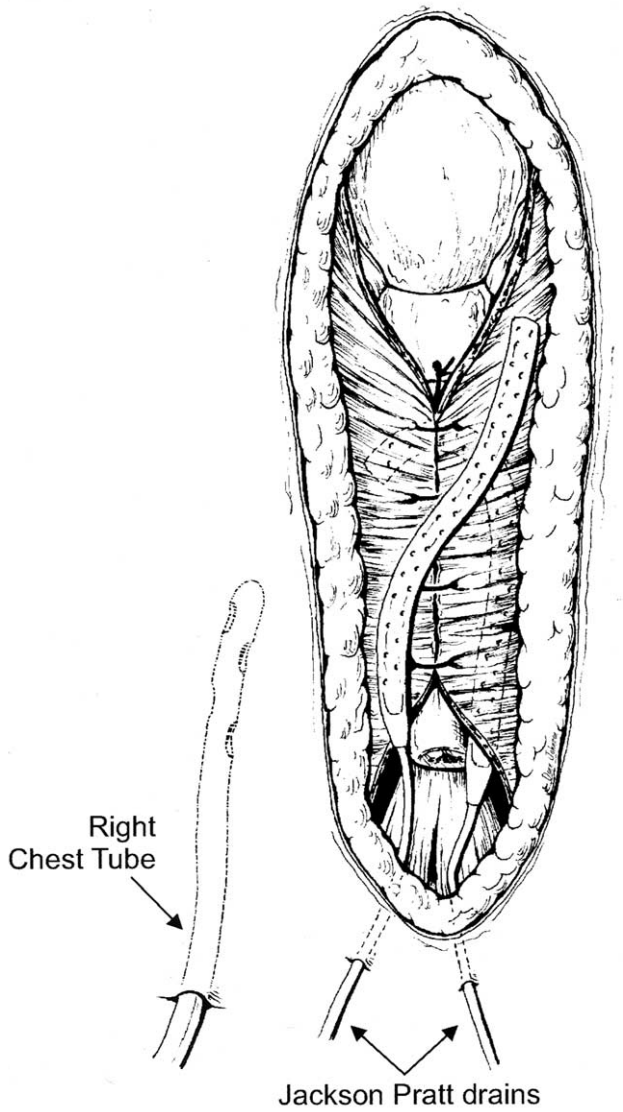

Fig 3. Coverage of the repaired sternum includes reapproximation of the pectoralis major muscles and subcutaneous tissue, followed by a subcuticular skin closure.

Comment

Although the majority of pectus operations are performed in children by pediatric general or cardiothoracic surgeons, a minority of patients who do not undergo prepubertal repair present as adults to adult thoracic surgeons with physiologic symptomology. Although pectus abnormalities are the most common congenital sternal deformities, presentation of these patients during adulthood is uncommon and consequently a paucity of literature exists on the long-term efficacy of surgical repair in adults. Due to the pliability of the chest cavity of infants and children, most prepubescent patients present asymptomatically. In contrast, adults more commonly present with easy fatiguability, low energy levels, tachycardia, irregular heart rate, dyspnea on exertion, or chest pain.

A variety of techniques have been described for repair of pectus defects, including the classic and the consequently modified repairs by Ravitch [8, 9], the sternal turnover technique, the unilateral costoplasty technique, the reconstruction with silicone implants, and the minimally invasive (Nuss) procedure [11]. In the current series, the majority of patients were repaired using modifications outlined by Ravitch, based on subperichondrial resection of deformed costal cartilages, sternal osteotomy, xiphoid detachment and translocation underneath the sternum, and anterior fixation of the sternum without a prosthesis [8, 9]. In contrast to Fonkalsrud and associates [6], we do not routinely place a sternal support bar, except in reoperative patients or those with connective tissue disorders. The use of Kirschner wires for substernal support to accelerate primary osseous healing in the short-term and in the long-term, to stabilize the results of early healing [12], has largely been abandoned secondary to migration of the wires.

Popularization of the Nuss procedure (minimally invasive pectus excavatum repair) has revolutionized the care of children with congenital sternal defects [13]. This repair avoids cartilage resection and sternal osteotomy, with the tenets of repair relying on a steel bar placement under the sternum to elevate the aberrant sternum and costal cartilages. In an eloquent series from Nuss and colleagues [11] in more than 300 patients, 257 patients (84.5%) had excellent initial results with minimal morbidity and no mortality; mean age of these patients was 12.4 years. In 71 patients with long-term follow-up, 71.8% had excellent results, 19.7% good results, and 8.5% failed correction. When comparing the results in younger patients with older patients, the authors noted that in the latter group, recovery time was longer, frequently required two bars for complete correction, and bar displacement was more common.

In a comparative study, Fonkalsrud and colleagues [14] noted that patients undergoing minimally invasive pectus excavatum repair (MIPER; average age 12 years old) or modified Ravitch repair (MRR; average age 17 years old) had excellent clinical results. Patients undergoing MRR had longer operating times, but decreased hospital stay, complication rates, and use of pain medications. Because measurement of the amount of force in pounds required to correct a sternal deformity has been demonstrated to be predictive of surgical success, Fonkalsrud and coworkers [6] noted that children less than 11 years old required a mean of 15.3 pounds for correction of the sternal defect, whereas adults 19 years old and older required a mean of 41.2 pounds. Patients undergoing a modified Ravitch procedure required only 1.5 pounds of force, regardless of pectus severity.

To date, only Coln and colleagues [7] have specifically addressed implementation of the Nuss minimally invasive correction of pectus excavatum in 8 symptomatic adults with cardiac compression. They noted relief of symptoms, increase in energy levels, improvement in appearance, and demonstrable relief of cardiac compression at a mean follow-up of 22 months in all patients. Although these results are encouraging, a larger cohort of patients with longer follow-up is necessary for widespread use of minimally invasive repair of pectus deficits in adults. In the current series, we did not utilize the minimally invasive technology.

There exist conflicting reports as to the physiologic deficits associated with carinatum deformities. Some have described that cardiopulmonary compromise and postoperative improvement are nearly equivalent to that in pectus excavatum, suggesting underlying pathology in both conditions [15]. Others report no correlation of pectus carinatum with any functional deficits, and propose that the only indication for surgical correction is cosmetic [16]. The operative technique, similar to that of pectus excavatum, consists of removal of deformed costal cartilages and correction of the sternal angle with anterior transverse osteotomies [6, 16, 17]. In the current series, we have accumulated 9 patients who required surgical intervention for pectus carinatum. All patients exhibited marked clinical improvement, with associated low morbidity. All patients underwent correction for medical reasons.

Thus far, no consensus regarding the constellation of physiologic impairments required for pectus repair has been ascertained. The compression of thoracic contents results in either reduction in right ventricular volume [18] or mild restrictive lung disease [19]. Patients with pectus most often complain of reduced exercise tolerance, though the clinical importance of this symptom remains a source of controversy. Some believe that functional impairment is so minimal that psychologic problems are the only indication for surgical repair. In the surgical repair of pectus defects in adults, we have found that patient symptomology is the most important preoperative decision factor.

More important is the debate as to whether surgery is an effective means of improving exercise tolerance in patients with pectus excavatum. One study concluded that although patients anecdotally reported symptomatic improvement postoperatively, there was no objective correlation between right ventricular function and the degree of sternocostal elevation [20]. Another study, however, revealed evidence of marked improvement in postoperative exercise tolerance at 6 months [6]. These conclusions

suggest underlying cardiopulmonary dysfunction that is likely additive to a compression-related deficit.

Although repair of pectus deformities is most commonly performed in children, in those adult patients with symptomatic pectus defects, we have indicated in the current series that effective repair utilizing the modified Ravitch techniques can be performed with low morbidity, no mortality, and marked long-term improvement in symptomatic limitations.

References

1. Robicsek F. Surgical treatment of pectus excavatum. Chest Surg Clin N Am 2000;10:277–96.
2. Robicsek F, Fokin A. Surgical correction of pectus excavatum and carinatum. J Cardiovasc Surg 1999;40:725–31.
3. Shamberger RC, Welch KJ. Surgical repair of pectus excavatum. J Pediatr Surg 1988;23:615–22.
4. Shamberger RC, Welch KJ. Surgical correction of pectus carinatum. J Pediatr Surg 1987;22:48–53.
5. Fonkalsrud EW, Bustorff-Silva J. Repair of pectus excavatum and carinatum in adults. Am J Surg 1999;177:121–4.
6. Fonkalsrud EW, DeUgarte D, Choi E. Repair of pectus excavatum and carinatum deformities in 116 adults. Ann Surg 2002;236:304–14.
7. Coln D, Gunning T, Ramsay M, Swygert T, Vera R. Early experience with the Nuss minimally invasive correction of pectus excavatum in adults. World J Surg 2002;26:1217–218.
8. Ravitch MM. Operative treatment of congenital deformities of the chest. Am J Surg 1961;101:588–96.
9. Ravitch MM. The operative treatment of pectus excavatum. Ann Surg 1949;129:429–44.
10. Gould WL, Jett GK, Bostwick J, Jones EL, Mansour KA. Simultaneous repair of severe pectus excavatum and aortic valve replacement following previous open-heart surgery. Ann Thorac Surg 1988;45:82–4.
11. Croitoru DP, Kelley RE Jr, Goretsky MJ, Lawson ML, Swoveland B, Nuss D. Experience and modification update for the minimally invasive Nuss technique for pectus excavatum repair in 303 patients. J Pediatr Surg 2002;37:437–45.
12. Erdoğan A, Ayten A, Öz N, Demircan A. Early and long-term results of surgical repair of pectus excavatum. Asian Cardiovasc Thorac Ann 2002;10:39–42.
13. Nuss D, Kelly RE, Croitoru DP, et al. A 10-year review of a minimally invasive technique for the correction of pectus excavatum. J Pediatr Surg 1998;33:545–52.
14. Fonkalsrud EW, Beanes S, Hebra A, Adamson W, Tagge E. Comparison of minimally invasive and modified Ravitch pectus excavatum repair. J Pediatr Surg 2002;37:413–7.
15. Peña A, Pérez L, Nurko S, Dorenbaum D. Pectus carinatum and pectus excavatum: are they the same disease? Am Surg 1981;47:215–8.
16. Pickard LR, Tepas JJ, Shermeta DW, Haller JA. Pectus carinatum: results of surgical therapy. J Pediatr Surg 1979; 14:228–30.
17. Fonkalsrud EW, Beanes S. Surgical management of pectus carinatum: 30 years' experience. World J Surg 2001;25:898–903.
18. Zhao L, Feinberg MS, Gaides M, Ben-Dov I. Why is exercise capacity reduced in patients with pectus excavatum? J Pediatr 2000;136:163–7.
19. Quigley PM, Haller JA, Jelus KL, Laughlin GM, Marcus CL. Cardiorespiratory function before and after corrective surgery in pectus excavatum. J Pediatr 1996;128:638–43.
20. Kowalewski J, Brocki M, Dryjanski T, Zolynski K, Koktysz R. Pectus excavatum: increase of right ventricular systolic, diastolic, and stroke volumes after surgical repair. J Thorac Cardiovasc Surg 1999;118:87–92.

DISCUSSION

DR DAVID R. JONES (Charlottesville, VA): That was a very nice presentation and I enjoyed it very much. I have one question for you. When I have fixed these defects before, particularly in patients who have Marfan's syndrome or have severe pectus defects, I have used a stabilizing strut underneath the inferior aspect of the repair and then take that out at some point postoperatively. Did you use this technique at all or when would you consider using this? Thank you.

DR THOURANI: Doctor Jones, thank you for those comments and questions. The stabilization bar was used very infrequently in our series; in fact, only three patients had stabilization bars placed. In those patients, the bars were removed at 6 months, 12 months, and 13 months postoperatively.

The bar, popularized by Dr Nuss, has been used primarily in repair of pectus examination in the pediatric population.

In the few adult series of pectus excavatum repair, the bar has been sparingly used. More recently, in the World Journal of Surgery in 2002, Dr Coln has described the use of the bar in repair of pectus deformities in 8 adults. He had excellent outcomes with that, but it is a preliminary study with only eight patients and approximately 12- to 20-month follow-up.

Although we do not use the stabilization bar frequently, some surgeons feel that the bar may be useful in those patients with extremely broad deformities in which unusually long segments of ribs have been resected, in Marfanoid patients in whom the length of the sternum would impose excessive leverage on the repair, and in recurrence pectus patients requiring a major reconstruction.

DR GEOFFREY M. GRAEBER (Morgantown, WV): I very much enjoyed your presentation. It is excellent work. I wanted to ask you one question about one problem that sometimes we face. In doing that extensive a dissection sometimes there is a fair amount of drainage from the wound. What type of drainage system do you use, how do you handle persistent drainage? I notice your incidence of seroma was low, but I would be interested to hear how you handle the drainage and how you minimize it. Thank you.

DR THOURANI: Doctor Graeber, thank you for your eloquent comments and questions. In the majority of patients, we intentionally open the right pleural space and place a chest tube. We also place two 10-mm J-P drains underneath the pectoralis muscle closure over the corrected pectus defect. In the majority of cases, all drains are removed between postoperative days 3 to 5. If the J-P drainage is excessive, the patient is discharged and is monitored until the drainage is minimal ($<$ 50 cc/day), when the drains are removed on an outpatient basis.

DR W. STEVES RING (Dallas, TX): Frequently in adult pectus deformity you have associated rib abnormalities that have developed over time because of the prolonged costal abnormalities. Do you handle these any differently?

DR THOURANI: In addition to subperichondrial removal of the deformed cartilages, we remove the portion of the abnormal rib. We do not remove the entire rib.