

Nonoperative Correction of Pectus Carinatum with Orthotic Bracing

GREGORY T. BANEVER, MD, STANLEY H. KONEFAL, JR., MD, FACS,
KIM GETTENS, CO, and KEVIN P. MORIARTY, MD, FACS, FAAP

ABSTRACT

Background: This study sought to evaluate the efficacy of nonoperative compression in correcting pectus carinatum in children.

Materials and Methods: Children presenting with pectus carinatum between August 1999 and January 2004 were prospectively enrolled in this study. The management protocol included custom compressive bracing, strengthening exercises, and frequent clinical follow-up.

Results: There were 30 children seen for evaluation. Their mean age was 13 years (range, 3–16 years) and there were 26 boys and 4 girls. Of the 30 original patients, 6 never returned to obtain the brace, leaving 24 patients in the study. Another 4 subjects were lost to follow-up. For the remaining 20 patients who have either completed treatment or continue in the study, the mean duration of bracing was 16 months, involving an average of 3 follow-up visits and 2 brace adjustments. Five of these patients had little or no improvement due to either too short a follow-up or noncompliance with the bracing. The other 15 patients (75%) had a significant to complete correction. There were no complications encountered during the study period.

Conclusion: Compressive orthotic bracing is a safe and effective alternative to both invasive surgical correction and no treatment for pectus carinatum in children. Compliance is critical to the success of this management strategy.

INTRODUCTION

PECTUS CARINATUM IS AN UNCOMMON DEFORMITY of the chest wall characterized by anterior protrusion of the sternum and costal structures, with an approximate prevalence of 1 in 1700.¹ Its pathogenesis has been proposed to be congenital in most cases, possibly involving sternal growth plate damage or overgrowth of ribs.^{2,3} Acquired etiologies have also been encountered, including drug-induced and poststernotomy.^{4,5} The current correction of this condition is surgical, often involving resection of costal cartilages and sternal osteotomy.^{6–16} The majority of these operations are variations of the proce-

dures first described in 1949 by Ravitch.¹⁷ In 1979, Haje and Raymundo reported their experience with nonoperative bracing for the correction of this pectus deformity, yet there are few reports describing this technique.^{1,18–21} We sought to prospectively investigate this modality in children and adolescents presenting with pectus carinatum.

MATERIALS AND METHODS

The study design was approved by the Institutional Review Board. From August 1999 to January 2004, 30 pa-

Division of Pediatric Surgery, Shriners Hospital for Children, Baystate Medical Center, Tufts University School of Medicine, Springfield, Massachusetts.

Presented at the American Academy of Pediatrics National Conference and Exhibition, San Francisco, California, October 2004.

TABLE 1. PRESENTING SYMPTOMS

	(N = 30)
Social concerns	11 (37%)
Chest pain	8 (27%)
Exertional dyspnea	2 (7%)
None	9 (30%)

tients presenting to the Shriners Clinic with pectus carinatum were prospectively enrolled in the study after appropriate informed consent was obtained. Although surgical correction was described to the parents, our group did not offer this option. After a complete history and physical examination, each patient participated in a structured protocol of initial pulmonary function testing, compressive orthotic bracing, specific strengthening exercises, and follow-up visits. Each patient was measured for the brace, which was custom-fitted and provided at the next patient visit. The fitting involved creating a cast of the patient's chest wall with fiberglass, which was then used to custom-mold a modified polyethylene bivalve brace, costing approximately \$300. The brace was further modified in our orthotics department by cutting out the area of greatest sternal protrusion, adding padding, and then reapplying this with Velcro straps.

The brace was to be worn up to 23 hours per day, with removal permitted for swimming and certain sports activities. Chest wall muscle strengthening exercises were taught to each child to maximize the rate of correction. These exercises focus on strengthening the pectoralis and sacrospinalis muscles as well as expanding the chest through deep breathing.

The initial follow-up visit was scheduled after 1–3 months to assess patient compliance and fit of the orthosis, followed by visits every 3–6 months until the treatment was deemed successful. For those patients who had a full correction, brace use was discontinued, and they were seen every 6–12 months to monitor for recurrence. The overall frequency of the visits was determined by patient compliance and the need for brace adjustments. Compliance was categorized into bracing performed daily, frequently, seldom, and never. Progression of the

defect was determined using photographs taken at every patient examination.

RESULTS

Between August 1999 and January 2004, 30 patients with pectus carinatum were evaluated for study participation. There were 26 boys and 4 girls, with an average age of 13 years (range, 3–16 years). On examination, 2 patients had upper sternal protrusions, while the remainder had middle and lower sternal defects. The duration of deformity at presentation ranged from 1 to 12 years, with a mean of 2.7 years. Four of the patients additionally had scoliosis and one had previously undergone Nuss repair for pectus excavatum at another institution. Presenting symptoms are listed in Table 1.

Six patients never returned to obtain the brace, so only 24 patients entered the study. Another four patients were lost to follow-up. Of the 20 remaining patients, the progress of treatment at the last follow-up visit is illustrated in Table 2. The mean duration of bracing in this group was 16 months. Improvement was seen at the first follow-up examination in 12/20 patients (60%), and by the second visit in 15/20 (75%). There did not appear to be a correlation between age and outcome.

Compliance was characterized as daily use in 12/20 (60%) children, and frequent use in another 4/20 patients (20%), while one patient used the brace seldom, and one never. The remaining two patients entered the study too close to the analysis date to determine frequency of use. The average patient had 3 follow-up visits and 2 brace adjustments during the study period. The frequent visits helped to ensure the brace fit properly and comfortably, and allowed recruitment of the family in encouraging the patient to participate fully.

The duration of bracing for the three patients who completed the treatment averaged 24 months. Although the true length of brace use per day was difficult to reliably gauge, the compliant patients usually performed 8–12 hours of bracing daily, frequently overnight. A representative case is illustrated in Figs. 1, 2, and 3. Of the four patients who were lost to follow-up, three used the brace infrequently, and one had some improvement with daily

TABLE 2. TREATMENT STATUS AT LAST FOLLOW-UP

<i>Progression of treatment</i>	(N = 20)	<i>Average duration of brace use</i>
Completed successfully	3 (15%)	24.3 months
Continue bracing with near complete correction	5 (25%)	23.6 months
Continue bracing with significant improvement	7 (35%)	13.4 months
Continue bracing but either no improvement or too early	5 (25%)	8.8 months



FIG. 1. Male patient with pectus carinatum, prior to treatment.



FIG. 3. The same patient wearing the brace.

use before leaving the study. There were no complications associated with use of the brace, and no pain medicine was required. As described by Egan et al., many patients find wearing a T-shirt beneath the device to be more comfortable.¹⁹

DISCUSSION

Although pectus carinatum and excavatum deformities occur with a combined frequency of 1 in 400 children, minor malformations of the anterior chest wall have been radiologically detected in up to 33% of children.^{22,23} The management of pectus defects has been predominantly surgical, with a variety of procedures described in the literature.⁶⁻¹⁶ Although success rates are very high for these interventions, they are not without risk. Complications include seroma,^{7,12,13,16} pneumothorax,^{6-8,11-14,16} significant bleeding,^{6,7,11,12} recurrence requiring revision,^{6,7,13-16} excessive scarring,^{7,8,13-16} and acquired Je-



FIG. 2. Appearance of chest after 23 months of treatment.

une's syndrome.²⁴ It should be noted that a significant proportion of these patients present with no symptoms, making the procedure a cosmetic endeavor.

Our experience demonstrated significant to complete correction in 75% of our compliant patients, with no complications. Additionally, none of our patients had surgical correction.

As noted by other authors, compliance is critical to the success of bracing for pectus carinatum.^{19,21} One third of the patients we evaluated either never started the bracing, or were lost to follow-up. Of the three patients who successfully completed the treatment, all wore their braces daily. Frequent outpatient visits, with repeated encouragement of patients and families as well as comparative photographs to illustrate improvement, worked to maximize the patient's participation. The close follow-up was also important because comfort was a contributing factor, and readjustments to the brace were required. Further modifications to our current brace, such as decreasing its overall size, allowing it to be more easily concealed beneath clothing, may help improve the rate of use further.

Early improvement in the pectus deformities was seen in the majority of patients. However, total correction required prolonged use of the device, averaging 24 months in our group. This has also been seen by other authors, and should be explained to patients upon initiation of treatment, to prevent unrealistic expectations.²¹

In conclusion, these initial results demonstrate that nonoperative compressive bracing for the management of pectus carinatum is a safe and effective alternative to invasive surgical repair. The outcome of this therapy is greatly dependant upon patient compliance, and a realistic treatment period of 2 years should be presented to patients upon initiation. Long-term results will elucidate the durability of correction of pectus carinatum using this method.

REFERENCES

1. Mielke CH, Winter RB. Pectus carinatum successfully treated with bracing: a case report. *Int Orthop* 1993;17:350–352.
2. O'Neal ML, Dwornik JJ, Ganey TM, et al. Postnatal development of the human sternum. *J Pediatr Orthop* 1998;18:398–405.
3. Robicsek F. Surgical treatment of pectus carinatum. *Chest Surg Clin N Am* 2000;10:357–376.
4. Steinmann B, Otten A, Gitzelmann R. Skin and bone lesions (dermato-osteolathyrism), possible side effects of D-penicillamine treatment, in a boy with cystinuria. *Helv Paediatr Acta* 1979;34:281–291.
5. Haje SA. Iatrogenic pectus carinatum: a case report. *Int Orthop* 1995;19:370–373.
6. Shamberger RC, Welch KJ. Surgical correction of pectus carinatum. *J Pediatr Surg* 1987;22:48–53.
7. Fonkalsrud EW, Salman T, Guo W, et al. Repair of pectus deformities with sternal support. *J Thorac Cardiovasc Surg* 1994;107:37–42.
8. Kobayashi S, Yoza S, Komuro Y, et al. Correction of pectus excavatum and pectus carinatum assisted by the endoscope. *Plast Reconstr Surg* 1997;99:1037–1045.
9. Lacquet LK, Morshuis WJ, Folgering HT. Long-term results after correction of anterior chest wall deformities. *J Cardiovasc Surg (Torino)* 1998;39:683–688.
10. Robicsek F, Fokin A. Surgical correction of pectus excavatum and carinatum. *J Cardiovasc Surg (Torino)* 1999;40:725–731.
11. Saxena AK, Willital GH. Surgical repair of pectus carinatum. *Int Surg* 1999;84:326–330.
12. Willekes CL, Backer CL, Mavroudis C. A 26-year review of pectus deformity repairs, including simultaneous intracardiac repair. *Ann Thorac Surg* 1999;67:511–518.
13. Fonkalsrud EW, Beanes S. Surgical management of pectus carinatum: 30 years' experience. *World J Surg* 2001;25:898–903.
14. Fonkalsrud EW, DeUgarte D, Choi E. Repair of pectus excavatum and carinatum deformities in 116 adults. *Ann Surg* 2002;236:304–312.
15. Fonkalsrud EW. Management of pectus chest deformities in female patients. *Am J Surg* 2004;187:192–197.
16. Fonkalsrud EW, Anselmo DM. Less extensive techniques for repair of pectus carinatum: the undertreated chest deformity. *J Am Coll Surg* 2004;198:898–905.
17. Ravitch M. The operative treatment of Pectus excavatum. *Ann Surg* 1949;122:429.
18. Haje SA, Raymundo JLP. Chest wall deformities: conservative treatment of the anterior protrusion forms. *Brazilian J Orthop* 1979;14:167–178.
19. Egan JC, DuBois JJ, Morphy M, et al. Compressive orthotics in the treatment of asymmetric pectus carinatum: a preliminary report with an objective radiographic marker. *J Pediatr Surg* 2000;35:1183–1186.
20. Haje SA. Pectus carinatum successfully treated with bracing: a case report. *Int Orthop* 1995;19:332–333.
21. Haje SA, Bowen JR. Preliminary results of orthotic treatment of pectus deformities in children and adolescents. *J Pediatr Orthop* 1992;12:795–800.
22. Lukanich JM, Grondin SC, Sugarbaker DJ. Chest Wall and Pleura. In Townsend CM, Beauchamp RD (eds): *Sabiston Textbook of Surgery*. Philadelphia: W.B. Saunders, 2001, pp. 1167–1170.
23. Donnelly LF, Frush DP, Foss JN, et al. Anterior chest wall: frequency of anatomic variations in children. *Radiology* 1999;212:837–840.
24. Weber TR, Kurkchubasche AG. Operative management of asphyxiating thoracic dystrophy after pectus repair. *J Pediatr Surg* 1998;33:262–265.

Address reprint requests to:
Kevin P. Moriarty, MD
Pediatric Surgical Services
Shriners Hospital for Children
125 Liberty Street
Springfield, MA 01103

E-mail: kpmort@charter.net