Compressive Orthotics in the Treatment of Asymmetric Pectus Carinatum: A Preliminary Report With an Objective Radiographic Marker

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Background/Purpose: Pectus carinatum (PC) traditionally has been managed with surgical reconstruction. Compressive orthosis also has resulted in subjective improvement in this defect. The goal of the authors was to develop an alternative brace and an objective radiographic marker to monitor the effects of chest wall compression on sternal protrusion.

Methods: Baseline chest computed tomography (CT) scans were obtained for 5 teenage boys with chondrogladiolar type of PC. The angle at the point of greatest sternal rotation was measured as the baseline deformity. Compressive orthosis was initiated using a custom-fitted brace. Follow-up chest CT scans were obtained to document change in sternal rotation.

Results: One patient was lost to follow-up after 6 months with subjective improvement. Another opted for surgical correction after 3 months, having shown a 16% decrease in sternal rotation preoperatively. Two patients showed subjective improvement corroborated by 33% and 44% decreases in sternal rotation. The fifth patient, who discontinued bracing after 1 month, showed a 25% increase 6 months later.

Conclusions: Preliminary results indicate a potential role for compressive orthosis in the management of pectus carinatum. The objective radiographic marker described may be used to monitor the effects of growth or treatment with compressive orthosis.
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INDEX WORDS: Pectus carinatum, compressive orthosis, chest wall deformity.

PECTUS CARINATUM (PC) is a chest wall deformity caused by relative overgrowth of the costal cartilages resulting in protrusion of the sternum. PC defects are characterized by the most prominent aspect of sternal deformity. Chondrogladiolar (CG), the most common variety, is the symmetric or asymmetric protrusion of the gladiolus and inferior costal cartilages. Chondromanubrial (CM) is the protrusion of the manubrium and superior costal cartilages. With asymmetric CG type, unilateral overgrowth of the costal cartilages results in a rotational deformity of the sternum and a keellike appearance of that side of the chest. The deformity appears to increase in magnitude during the active linear growth of puberty. Hence, most patients present for correction as teenagers.[1] Unlike pectus excavatum, PC rarely is associated with significant physiological derangements in cardiopulmonary functions.[2] Nonetheless, the cosmetically significant deformities of PC have long been managed with surgical reconstruction.

Drawing on accepted orthopedic tenants of molding growing bone and cartilage with orthotics, Haje and Bowen[3] developed a custom-fitted compressive orthotic that places greatest external forces on the point of the most prominent sternal protrusion of CG-type deformity. Improvement in the deformity was rated on a subjective scale according to appearance. According to this scale, all patients treated showed improvement, whereas all untreated patients showed no change or worsening of their deformity.[3,4]

We developed a similar nonoperative modality for mild to moderate defects based on compressive orthosis. To objectively quantify the effects of this brace, we developed a radiographic marker to measure initial sternal rotation and subsequent changes with growth or treatment.

MATERIALS AND METHODS

Five boys, between the ages of 13 and 15 years, with asymmetric CG type of PC, denied symptoms indicative of cardiopulmonary impairment. Before initiating orthosis, a baseline computed tomography (CT) scan was obtained at 1-cm increments from the sternal notch through the xiphoid. Measurements of the angle of sternal rotation (ASR), at the point of greatest rotation, offered a quantitative marker to assess chest wall deformity before orthosis was initiated (Fig 1).

The clamshell brace was then custom designed from Kidex thermo-

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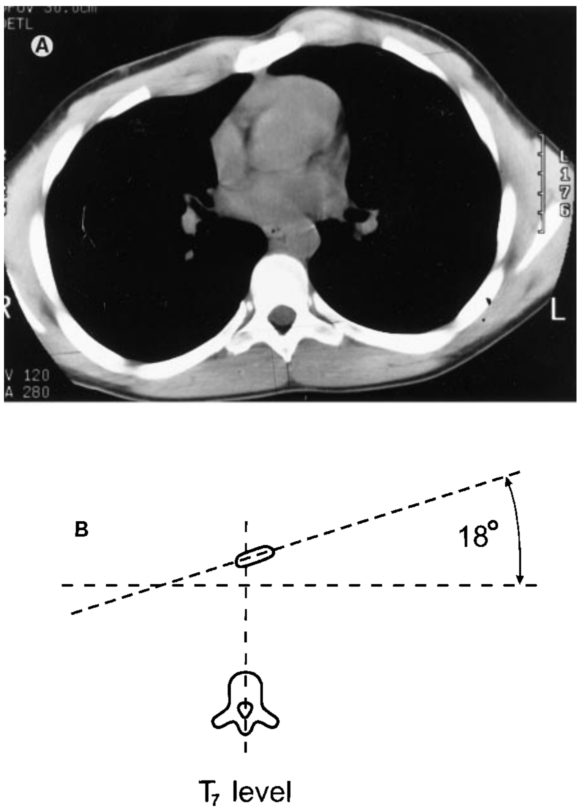

Fig 1. Patient 1 before bracing. CT scan at point of greatest sternal rotation (A) and measurement of baseline sternal angle (B).

plastic (Rohm & Haas, Russelheim, Germany), lined with Beta Pile (Velcro Brand, Smalley & Bates, Inc, Cedar Grove, NJ), and custom fitted to place maximal pressure over the point of greatest protrusion (Fig 2). The patient was instructed to wear the brace a minimum of 12 hours per day during the first 6 months. Thereafter, the brace could be limited to bedtime wear. Follow-up CT scans were obtained at 3, 6, and 12 months when possible, and the ASR was measured at the same thoracic level at which the initial prebracing angle had been measured (Fig 3) to document chest wall remodeling.

RESULTS

Table 1 shows the outcome of the 5 patients involved. Patients 1 and 2 wore the brace for the longest periods of time (23 hours a day for 15 months and 12 hours a day for 12 months, respectively) and showed subjective improvement in chest wall appearance corroborated by the greatest objective decrease in the ASR (44% and 33% decreases, respectively). In both these patients, the greatest improvement was seen after the first 6 months of brace wear. Patient 3, whose ASR improved by 16% after 3 months of brace wear for 6 to 8 hours a day, opted for surgical correction at that point because of lifestyle interference from the brace. Patient 4 was lost to follow-up after 6 months of brace wear, but did claim subjective improvement and satisfaction, desiring no further orthosis or surgery. Patient 5, who decided not to wear the brace after 1 month because of interference with athletics, showed a 25% increase in ASR on follow-up CT.

DISCUSSION

Pectus carinatum defects occur less frequently than the more common excavatum defects by a ratio of approximately 1:5[5] and more frequently in boys than girls by a ratio of 4:1.[1] Moreover, many pectus defects share elements of both excavatum and carinatum anomalies. In addition to the psychological impact the presence of a significant chest wall deformity may have on the growing

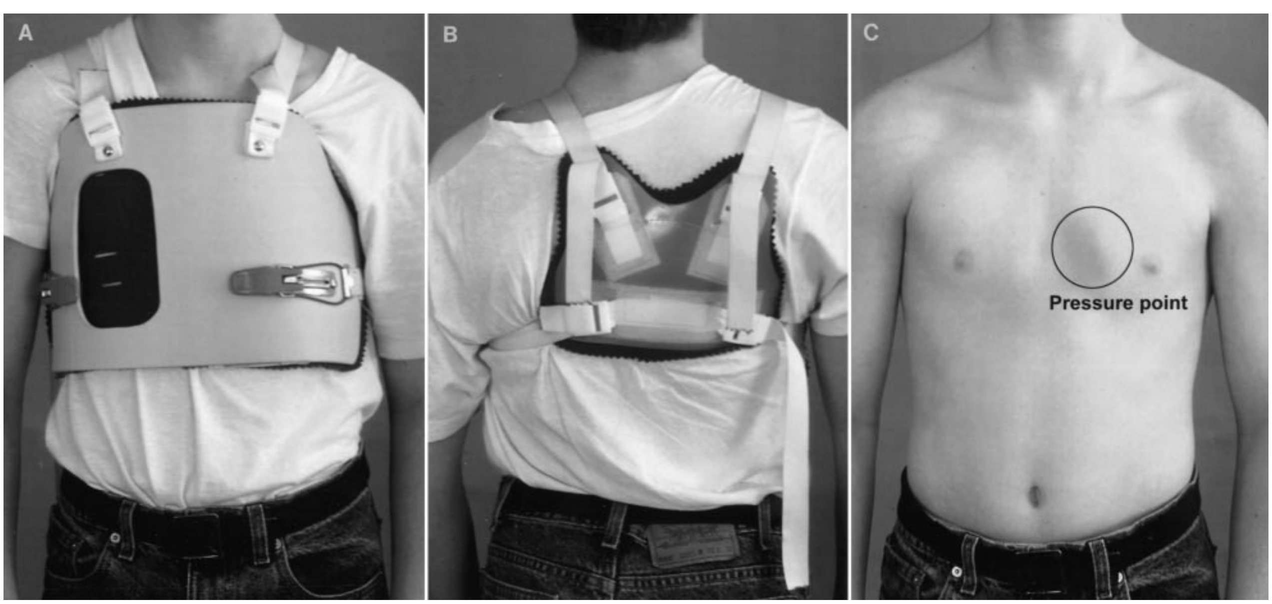

Fig 2. Patient wearing orthotic brace. Anterior view (A), posterior view (B), and point of greatest pressure applied by brace (C).

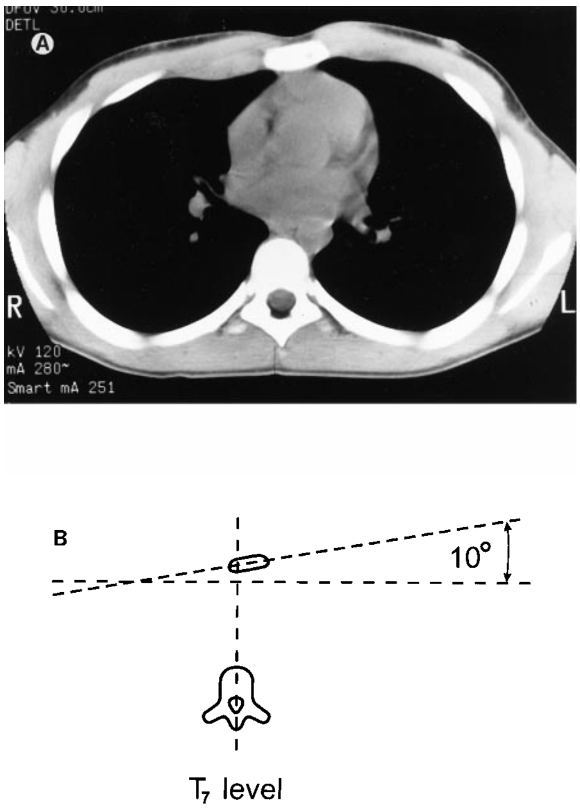

Fig 3. Patient 1 after 6 months of bracing. CT scan at same level as baseline scan (A) and measurement of 6-month sternal angle (B).

child, ongoing sternal dysmorphogenesis may result in decreasing chest wall flexibility with poor inspiratory chest expansion later.[14] Surgical intervention, generally some modification of the Ravitch technique, which utilizes resection of the deformed costal cartilages along with sternal osteotomy, has been the traditional approach to more significant defects.[1,5-13] However, many patients and their families are reluctant to proceed with surgical correction for what they view as a predominantly cosmetic defect.

Recently, a nonoperative approach utilizing compressive orthosis was proposed by Haje and Bowen.[3,4] This orthotic, called the dynamic chest compressor (DCC), was constructed with two U-shaped metal rods placed around the patient's chest, 1 anterior and 1 posterior, with an anterior pressure pad and 2 posterior counter-pressure pads. The 2 metal rods were fixed to one another laterally by screws, which could be used to adjust the pressure applied by the pressure pad. Patients were advised to wear the orthotic 23 hours a day during the first 6 months, to perform deep breathing exercises for 20 minutes 3 times a day while wearing the brace, and to develop their chest muscles with resistance exercises.

We adopted a similar approach with 5 patients, but sought to better quantitate treatment outcomes with objective radiographic criteria. The greatest improvements appear to be directly related to compliance in wearing of the brace. Patient 1, the most compliant participant, reported wearing the brace for up to 24 hours per day and exhibited the greatest improvement in ASR. In contrast, patients 3 and 5 reported poor compliance, secondary to interference with athletics, which resulted in choosing surgical treatment and an increase in ASR, respectively. Both of these patients have resumed their athletics and are satisfied with their respective outcomes.

Because of the limited number of participants in this series to date, the question remains as to the optimal age for initiating orthosis in these patients. We believe, however, that because the costal cartilages are more flexible and the deformity less severe earlier in the patient's pubertal growth spurt, bracing at this stage may result in a greater improvement over a shorter period of time.

Even with earlier orthosis, however, there is the possibility of subsequent worsening of the deformity if follow-up is inadequate. Haje and Bowen[3] had 1 patient who started brace wear at age 10. The patient's parents, satisfied with the result after just 1 month of brace wear, allowed the patient to discontinue its use. On a follow-up visit 4½ years later, the patient's deformity had worsened. Our 2 most compliant patients, 1 and 2, who showed the greatest objective radiographic improvement after the first 6 months, have not shown objective worsening after 15 and 17 months' follow-up, respectively.

There have been no untoward sequelae to the wearing of the brace, even with continuous daily wear. None of the patients required analgesics while wearing the brace. Patients did find it more comfortable to wear a t-shirt under the brace to minimize perspiration. Although mild erythema was noted at the point of greatest pressure applied by the brace (Fig 2C), there was no ecchymosis or skin breakdown.

Table 1. Results of Compressive Orthosis

Patient No.	Age (yr)	Pretreatment Sternal Angle	Posttreatment Sternal Angle	% Change in Angle	Months Worn	Follow-Up (mo)
1	13	18°	10°	−44%	15	15
2	13	15°	10°	−33%	12	17
3	14	13°	11°	−16%	3 (then surgery)	
4	13	9.5°	(Lost to follow-up)	Not available	6	6
5	15	8.0°	10°	+25%	1	12

All 5 of these patients had CG type PC with asymmetric sternal protrusion. This deformity facilitates the measurement of sternal rotation from transverse CT scan images as described above. For patients with symmetrical CG protrusion; those with CM pectus deformity, in which the manubrium symmetrically protrudes with a relative depression of the body of the sternum; or those with mixed-type deformity, sagittal CT reconstructions of the sternum may offer an alternative for initial angle measurement and follow-up.

These preliminary observations from using compressive orthotosis in the management of pectus carinatum indicate a potential role for this approach in the initial, if not definitive, management of moderate forms of this deformity. Application of compressive orthotics early in the teenage growth phase, during a period of maximal flexibility of the sternal and costal structures, may optimize results with this approach. Patient compliance with regular brace wear and diligent follow-up is paramount to the success of this method of treatment.

In addition, we have shown that the objective radiographic marker described herein may be used to monitor the effects of growth or the treatment of asymmetric pectus carinatum defects with compressive orthotics.

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