Evaluation of the treatment of pectus carinatum with compressive orthotic bracing using three dimensional body scans

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ABSTRACT

Purpose: The purpose of this study is to measure the effectiveness of compressive orthotic brace therapy for the treatment of pectus carinatum using an adjusted Haller Index (HI) measurement calculated from 3D body scan (BS) images.

Methods: Pediatric patients with pectus carinatum were treated with either compressive orthotic bracing or observation. An adjusted BS Haller index (HI) was calculated from serial 3D BS images obtained on all patients. Medical records were evaluated to determine treatment with bracing and brace compliance more than 12 hours daily. Compliant patient measurements were compared to non-compliant and non-brace groups.

Results: Forty patients underwent compressive orthotic bracing, while ten were observed. Twenty-three patients were compliant with bracing, and seventeen patients were non-compliant. Compliant patients exhibited an 8.2% increase, non-compliant patients had a 1.5% increase, and non-brace patients exhibited a 2.5% increase in BS HI. The change in BS HI of compliant patients was significantly different compared to non-brace patients (p = 0.004) and non-compliant patients (p < 0.001).

Conclusions: Three dimensional BS is an effective, radiation free, and objective means to evaluate patients treated with compressive orthotic bracing.

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Pectus carinatum is a congenital anterior chest wall deformity in which abnormal growth of the sternum and costal cartilage result in an outward protrusion [1]. The deformity often worsens during puberty [2,3]. Approximately 0.3% of the population is affected with this disorder and it is more common in males than females [4]. Symptoms most commonly associated with this disorder include social awkwardness, body image concerns, chest pain or shortness of breath [2,3,5,6].

Patients with pectus carinatum were previously treated with operative correction, but compressive orthotic bracing has been shown to be a successful, non-invasive method to treat patients with pectus carinatum [2–7]. Patients are measured and fitted for a brace that is worn throughout the day. This treatment method is effective because the adolescent chest wall remains compliant and can be molded with pressure applied by the brace [2,7].

The Haller Index (HI) is a standard measurement used to evaluate the severity of pectus excavatum deformities [8]. Methods to objectively evaluate patients with pectus carinatum remain limited and often require X-ray or CT scan imaging [2,3,6]. Physician assessment and medical photography are typically employed while radiographic imaging is often reserved for severe deformities [3–5]. Currently there is no reliable objective radiation-free method to objectively evaluate patients with pectus carinatum.

We sought to evaluate whether an adjusted HI measurement obtained from 3D BS images could be used to objectively evaluate patients with pectus carinatum treated with compressive orthotic bracing.

1. Material and methods

Following IRB approval (IRB# 132232–11) and with informed consent, pediatric patients under 18 years of age with pectus carinatum underwent serial full body 3D body scans. Initiation of brace therapy was based on the clinical examination of the pediatric surgeon and discussions with the family regarding expectations and the importance of compliance with therapy. Patients treated with bracing were provided with a custom fit orthotic brace at no cost to the patient. Medical records and body scan images were evaluated retrospectively.

A Vitus Smart 3D Body Scanner (Vitronic GmbH, Wiesbaden, Germany) was used to obtain 3D body scan images. This image scanner utilizes eight cameras and four eye-safe lasers which are used to obtain a whole body image. Images were analyzed using ScanWorx v2.9. (Human Solutions Inc, Troy, MI). An adjusted HI (Fig. 1), was calculated by dividing the transverse distance by the total anterior-
posterior distance at the level of maximum deformity in transverse image slices in body scan images.

Patients were divided into three groups. Non-brace patients were patients who underwent serial body scan images and compressive orthotic brace therapy was not initiated. Brace compliant patients were patients who were treated with compressive orthotic brace therapy and wore the brace more than 12 hours a day as reported by the patient. Brace non-compliant patients wore the brace less than 12 hours a day and were not compliant with physician recommendations for brace use at the time of final evaluation. Statistical analysis was performed using Prism Graph Pad Software (Prism Corp, San Francisco, CA). Paired T-test analysis was performed to evaluate the difference between initial and follow-up BS adjusted HI calculations. A one-way ANOVA was used to determine if the percent change between initial and final adjusted BS HI was different in non-brace, brace compliant, and brace non-compliant groups. Logistic regression analysis was used in patients treated with bracing to compare length of time the brace was worn daily and the percent change in subsequent BS adjusted HI measurements.

2. Results

A total of 50 patients were evaluated including 45 males and 5 females. The average age at time of initial evaluation was 12 (±0.52) years. Patients underwent a median of two BS and approximately 17 (±1.6) months passed between initial and final body scans. The average initial BS HI of all patients evaluated was 1.34 (±0.019). Ten patients were observed without compressive orthotic bracing. Compressive orthotic bracing was initiated in the remaining 40 patients. Of these 40 patients, 23 were compliant with brace use, and 17 were non-compliant (Table 1).

Amongst non-brace patients, 3 were female and 7 were male. Reasons for observation included mild deformity, patient wishes, or mixed deformities. The average age at initial evaluation was 9 (±1.3) years old and patients all underwent a total of two BS. Follow up BS images were obtained 22 (±4.1) months following initial BS. The average initial BS HI was 1.51 (±0.055) and average final BS HI was 1.54 (±0.060). There was an average 2.5% (±1.1%) increase from initial to final BS HI measurements. This was not statistically significant using a paired T-test comparison (p = 0.059).

There were 17 brace non-compliant patients evaluated in which 16 were male and one was female. A median of two body scans were performed and there was an average 14 (±2.9) month span between initial and final BS images. Patients were 13.5 (±0.71) years old at the time of brace initiation and the brace was worn 4.1 (±0.80) hours daily following brace initiation. Four of these patients reported zero hours of brace use daily, while the remaining patients reported daily but reduced brace use. The average initial BS HI was 1.28 (±0.022) and final BS HI was 1.3 (0.026). There was an average 1.6% (±0.99%) increase between the initial and final BS HI measurements. Using a paired T-test, this difference was not significant (p = 0.14).

A total of 23 patients were compliant with compressive orthotic brace therapy. Twenty-two patients were male and one patient was female. Patients were an average of 12.1 (±0.67) years old at the time of brace initiation and they underwent a median of three body scans over an average 16.3 (±2.2) month time span. Two patients exhibited recurrence of deformity necessitating re-initiation of brace therapy. Patients wore the brace an average of 13.7 (±0.82) hours a day following brace initiation. The average initial BS HI was 1.32 (±0.017) and the average final BS HI was 1.42 (0.024). There was an 8.3% (±1.0%) increase in BS HI from the first to the last scan. The change from initial and final BS HI was compared using a paired T-test and was found to be statistically significantly (p < 0.001).

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Comparison of initial and final BS HI measurements in non-brace, brace-compliant, and brace non-compliant groups.</th>
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<tr>
<td></td>
<td>Average initial body scan HI</td>
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<tr>
<td>No brace, n = 10</td>
<td>1.51 ± 0.055</td>
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<tr>
<td>Non-compliant brace, n = 17</td>
<td>1.28 ± 0.022</td>
</tr>
<tr>
<td>Compliant brace, n = 23</td>
<td>1.32 ± 0.017</td>
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Fig. 1. 3D BS images of a single patient with pectus carinatum treated with orthotic compressive brace. Patient was initially non-compliant with brace therapy but with improved compliance, a reduction in the chest wall deformity was observed.

Fig. 2. Graph exhibiting the percent change in BS HI from initial to final measurements amongst non-brace, brace compliant, and brace non-compliant groups. Using one-way ANOVA, a significant difference was observed comparing brace compliant patients to non-brace and brace non-compliant patients.
correlation was observed in modified HI measurements compared to standard CT HI measurements in patients with pectus excavatum and carinatum [11]. In this study, we have shown that the adjusted HI measurements calculated from 3D BS images can be used to successfully monitor the chest wall for changes over time in patients treated with compressive orthotic bracing. A significant change in BS HI from initial to final BS measurements was observed with compliant brace use. Further, a significant difference in the percent change in serial BS adjusted HI measurements was observed in compliant patients compared to non-brace and brace non-compliant patients.

Approximately 55% of the variation in the change observed in serial BS measurements can be attributed to the total time a patient wears the brace daily using linear regression analysis. A dose dependent relationship between the time a patient wore the brace daily and the increase in the adjusted BS HI was observed. With compliant 24 hour daily brace use, an approximate 7–11% increase in subsequent BS HI measurements can be expected. In contrast, a 2–3% increase is expected to be observed in patients that wear the brace less than 6 hours daily. Our data suggest that the greater the number of hours a patient wears the brace daily, the more likely patients with pectus carinatum will achieve successful results.

There were several limitations in this study. Because of the retrospective nature of this study, differences amongst comparison groups were unable to be controlled. The difference in the average age and the time between subsequent images in each group was variable. Non-brace patients were younger and had more mild defects than those treated with brace therapy. In addition, there were more male patients evaluated compared to female patients. Information on patient compliance and the amount of time the brace was worn daily was obtained from the medical record which may lead to bias in reported results. Compliance with bracing was low, in contrast to other studies in which higher compliance rates were observed. Of the 40 patients treated with bracing, approximately 57.5% patients wore the brace for more than 12 hours daily, 10% reported not wearing the brace at all while 32.5% of patients treated with the brace wore it daily for a suboptimal amount of time. Several reasons could be attributed to lower compliance rate observed which includes provision of the brace for free to patients, the type of brace used, or time between interval followup because many patients traveled a long distance for therapy. Finally, while the Vitus Smart Scan body scan system is available for purchase, currently only a few medical centers have access to this imaging system for medical use at this time.

Compressive orthotic bracing is an effective treatment method for pectus carinatum. Using 3D BS image measurements, we have further confirmed that with compliant brace therapy, significant improvements can be observed in patients with pectus carinatum. In addition, we have also shown that 3D body scan imaging can successfully monitor changes in the anterior chest wall using serial body scan images over time with compliant brace therapy. In summary, we have shown that 3D BS imaging is an effective, radiation free, and objective method to evaluate patients treated with compressive orthotic bracing using serial scans over time.

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References


