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A novel measure for pectus excavatum: the correction index

Shawn D. St. Peter*, David Juang, Carissa L. Garey, Carey A. Laituri, Daniel J. Ostlie, Ronald J. Sharp, Charles L. Snyder

The Children's Mercy Hospital, Kansas City, MO 64108, USA

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Abstract

Objective: The Haller Index (HI), the standard metric for the severity of pectus excavatum, is dependent on width and does not assess the depth of the defect. Therefore, we performed a diagnostic analysis to assess the ability of HI to separate patients with pectus excavatum from healthy controls compared to a novel index.

Methods: After institutional review board approval, computed tomography scans were evaluated from patients who have undergone pectus excavatum repair and controls. The correction index (CI) used the minimum distance between posterior sternum and anterior spine and the maximum distance between anterior spine most anterior portion of the chest. The difference between the two is divided by the latter (×100) to give the percentage of chest depth the defect represents.

Results: There were 220 controls and 252 patients with pectus. Mean HI was 2.35, and the mean CI was 0.92 for the controls. The mean HI was 4.06, and the mean CI was 31.75 in the patients with pectus. In the patients with pectus, HI demonstrated a 47.8% overlap with the controls, while there was no overlap for CI.

Conclusions: The Haller index demonstrates 48% overlap between normal patients and those with pectus excavatum. However, the proposed correction index perfectly separates the normal and diseased populations.

The standard metric to evaluate patients with pectus excavatum was proposed over 2 decades ago. This metric, the Haller index (HI), was defined as the ratio of the distance between the anterior spine and posterior sternum to the widest transverse diameter of the chest. This index remains the standard preoperative measurement used to quantify the severity of a pectus excavatum deformity, with a value of 3.25 or greater being the generally accepted threshold for consideration of surgical correction [1-3]. There have been little data subsequently generated to validate the accuracy of the HI in separating those patients with a pectus deformity from patients with normal chest contour. Therefore, we calculated the HI in patients who underwent bar repair and compared them to controls to define the diagnostic accuracy of this ratio. In addition, we developed a new metric to more precisely define patients with disease and compared it to the HI.

1. Methods

After institutional review board approval, we evaluated thoracic computed tomography (CT) scans from patients

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* Corresponding author. Center for Prospective Clinical Trials, Department of Surgery, Children's Mercy Hospital, Kansas City, MO 64108, USA. Tel.: +1 816 983 3575; fax: +1 816 983 6885.
E-mail address: sspeter@cmh.edu (S.D. St. Peter).

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who had undergone pectus excavatum repair and a cohort of healthy controls. Pectus patients underwent repair upon the agreement of the operating surgeon and the family that the defect and symptoms were severe enough to mandate repair. The control group of 220 children was composed of 10 males and 10 females from each year of age between 8 and 18 years who had undergone a thoracic CT scan for an indication other than pectus excavatum. Patients with documented pectus defects were excluded from the control group. Each CT scan was reviewed, and both correction and Haller indices were calculated using the Synapse Radiographic Information System (Fujifilm Medical Systems, Stamford, Conn). The ruler tool was used by drawing lines in the appropriate positions, which generates the length of the line in millimeters. The most inferior image of the sternum was used to calculate the indices. The Haller index was calculated in a standard fashion (Fig. 1A). The correction index (CI) requires drawing a horizontal line across the anterior spine. Then two distances are measured: the minimum distance between the posterior sternum and the anterior spine as is used for the HI and the maximum distance between the line placed on the anterior spine and the inner margin of the most anterior portion of the chest. The difference between the two lines is simply the amount of defect the patient has

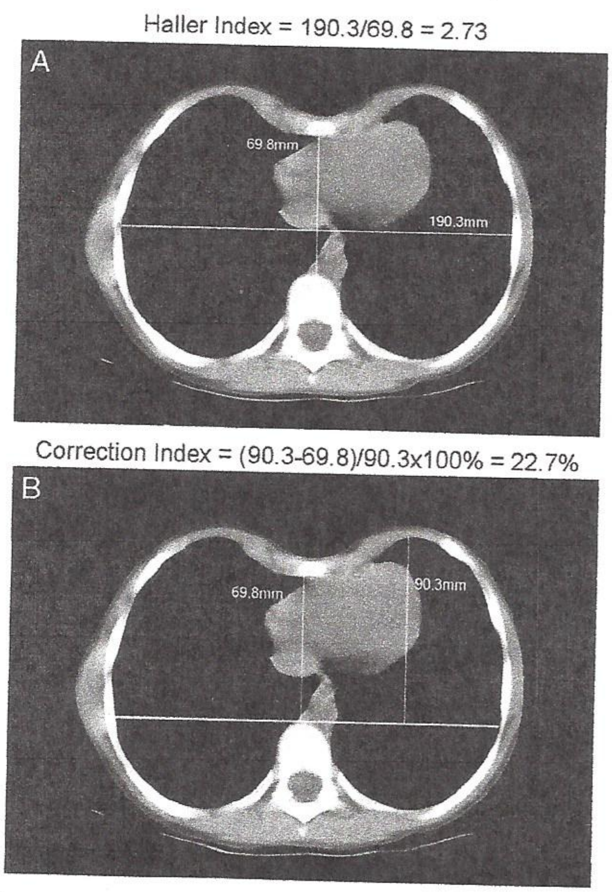

Fig. 1 A and B, Demonstration of the calculation for the HI and CI respectively.

in their chest. If this difference between the measurements is then divided by the maximum prominence of the chest (the longer measurement) and multiplied by 100, it generates the percentage of chest depth the patient is missing centrally (Fig. 1B). Conversely, it represents the percentage of chest depth to be corrected by bar placement, or the correction index.

The patients who had undergone bar placement and the healthy controls were plotted together on histograms for both the HI and CI.

Data are expressed as mean ± SD.

2. Results

The pectus population consisted of 252 patients who underwent pectus bar repair for pectus excavatum and who also had a pre-operative CT scan available for review. The mean age at repair was 14.0 ± 3.0 years and the mean HI was 4.06 ± 1.10. In the controls, the mean age was 13.5 ± 3.5 years, and the mean HI was 2.35 ± 0.33 years. The CI was 0.92 ± 1.35 for the controls and 31.75 ± 10.66 in the patients with pectus. The operative and outcome details in the patients with pectus have been previously reported [4].

In the patients with pectus, HI demonstrated a 47.8% overlap with the controls, whereas there was no overlap for CI (Fig. 2). Of the patients with pectus, 49 (19%) possessed an HI of 3.25 or lower.

To visually portray the extremes of each group, the healthy control patient with highest HI and the pectus patient with lowest HI and are depicted in Figs. 3 and 4 respectively.

3. Discussion

The HI was initially described in 1987 as an objective measure to quantify the severity of a pectus excavatum deformity [1]. This description documented a height to width ratio of 3.25 as a discriminator to define the patient as having a significant pectus excavatum defect, making the patient a potential candidate for repair. The number was established by using a group of healthy controls compared to pectus excavatum patients who underwent repair, as was done in this study. The authors found that the control patients had an index of below 3.25 as opposed to the patients with pectus. However, there were only 19 controls, of whom 4 were under 6 years of age and 33 patients who underwent correction. In our study, by utilizing much larger cohorts with age-defined groups for controls, we found this discrimination no longer holds true.

The overlap demonstrated in Fig. 2 between patients with pectus and controls defines the HI as an inadequate measure of disease. Abnormal physiologic parameters for any disease process are normally determined by establishing a normal distribution and using 2 SDs above or below the mean which

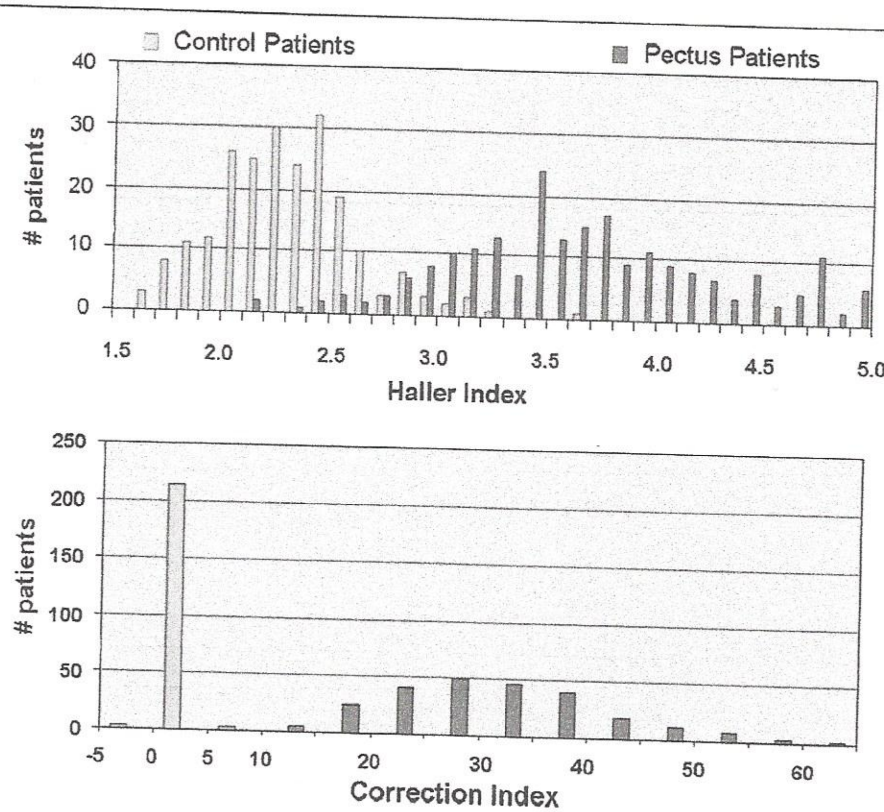

Fig. 2 Histogram for the distribution of HI and CI plotting patients with pectus with healthy controls. In order to demonstrate both curves for pectus and control patients for HI, those with an HI over 5.5 are not displayed as this end of the curve is long tail of sporadic outliers.

leaves 2.5% of the assumed normal population who may meet abnormal criteria by chance in either direction. The 48% overlap seen here between diseased patients and normal patients is clearly unacceptable as a diagnostic test. Using the CI, the normal distribution is created more clearly for both controls and patients with pectus, with no overlap between them. In fact, the gap is large enough that we can possess a high degree of confidence in defining disease. This is logical because if a patient has a CI greater than 10, it means more than 10% of the chest depth between anterior chest and anterior spine is centrally depressed, which is, by definition, pectus excavatum. The possibility of a high index and no defect or a deep defect and low index is removed.

The fatal flaw of the HI calculation is the importance of width in the equation. While width serves as a surrogate for comparing the dimensions of the chest, it does not depict the position of the sternum relative to the anterior ribcage. As such, a wide chest increases HI and narrow chest decreases HI regardless of the severity of defect, while the CI is blind to width and precisely defines the distance the sternum is from goal position. Examining outliers from each population in

Haller Index = 233.7/62.8 = 3.72

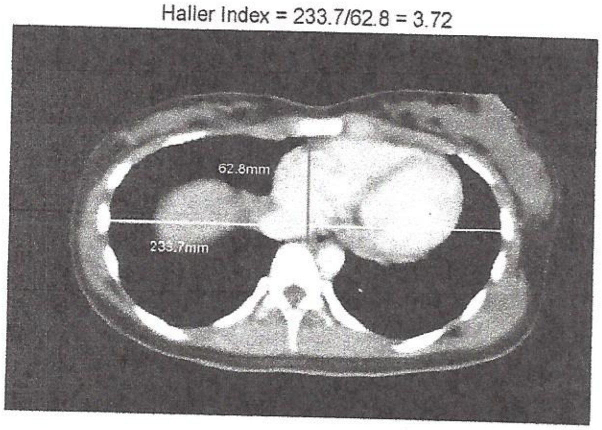

Fig. 3 CT image of the normal patient with the highest HI.

Haller Index = 213.5/99.1 = 2.15

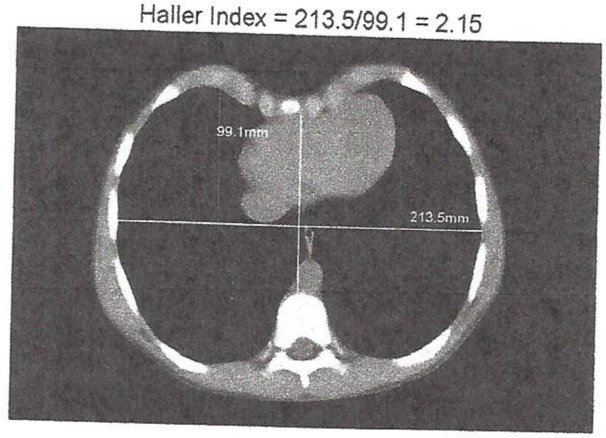

Fig. 4 CT image of the pectus patient with the lowest HI.

this study makes it apparent that a patient with a wide, flat chest such as seen in Fig. 3 can possess an HI well above the threshold for repair. It can be easily seen that this patient's sternum is perfectly even with the ribcage, and therefore, the CI in this patient is effectively zero while the HI is 3.7. Likewise, a patient with a deep, narrow chest and a dominant central concavity may demonstrate an HI well below the surgical threshold as seen in Fig. 4. This patient has a CI of 16.0, which would clearly define the patient has having the disease if a CI threshold of 10.0 were used.

Unfortunately, the HI which was based on a small study population has become a standard for qualifying reimbursement. As surgeons evaluating patients with severe defects that are both symptomatic and distressing to the patients, we often face the frustrating circumstance where the HI does not qualify, as seen in Fig. 2, where 19% of the pectus population lies below the 3.2 line for HI. These data demonstrate that by eliminating the width of the chest from the evaluation of the defect, we can precisely quantify what percentage of their chest depth is lost by the central inversion of the sternum. Conversely, this is the percentage of chest depth to be regained by bar placement, since the bar is held anteriorly by the most anterior portions of the ribcage. Since healthy patients have a CI that should not approach double digits, and all the patients we studied who underwent repair had a CI in the double digits, a CI threshold of 10.0 will allow us to define those patients with significant defects and more accurately select patients who should be considered for repair. The deficit of the CI is in the case of severe asymmetry, where the CI could be reported from the maximum protuberance or listed on each side. However, often with severe asymmetry, the indication for repair is also carinatum, which is a different defect.

An alternative use for the HI would be as a proxy for the severity of the defect, using it to serve as a marker for such variables as increased risk of recurrence, prolonged operative time, or longer hospital stay. Unfortunately, studies to date have shown little if any correlation between the index and a variety of outcome variables [5].

The CI is very simple to measure, easily reproducible, and a very accurate measurement, which clearly differentiates patients with pectus excavatum from those without the disease.

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