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Non-radiographic severity measurement of pectus excavatum

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ABSTRACT

Background: To avoid the radiation exposure of CT imaging and the expense of CT or MRI studies, we sought to develop a non-radiographic severity measurement of pectus excavatum based on 3D photogrammetric imaging.

Methods: Over 28 mo, ten consecutive patient volunteers with pectus excavatum underwent 3D stereophotogrammetric imaging. The surface width to surface depth ratio (Surface Lengths Pectus Index), the chest deformity's surface area to total chest surface area (Pectus Surface Area Ratio), and the chest deformity's volume to total chest volume (Pectus Volume Ratio) were calculated. Simple linear regression analysis compared the Surface Lengths Pectus Index, Pectus Surface Area Ratio, and Pectus Volume Ratio calculations each to the corresponding known CT pectus index.

Results: The correlation between CT pectus index versus Surface Lengths Pectus Index yielded an R-squared value of 0.7637 and a P value of 0.0013. A CT pectus index of 3.4 or greater (eight patients) corresponded to a Surface Lengths Pectus Index of 1.86 or greater (six patients). The CT pectus index versus Pectus Surface Area Ratio (R-squared = 0.4627, $P = 0.0305$) and the CT pectus index versus the Pectus Volume Ratio (R-squared = 0.3048, $P = 0.0990$) demonstrated less correlation.

Conclusion: Surface Lengths Pectus Index corresponds to the CT pectus index and may be adequate to determine severity of pectus excavatum in some patients.

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Introduction

Indication for surgical correction of pectus excavatum is first and foremost dictated by the severity of the deformity. Haller, *et al.*[1] described the CT pectus index measurement in the late 1980s, which became the clinical standard in objectively measuring pectus excavatum. MRI has been substituted for CT to address concerns of CT radiation.[2] The disadvantages of CT imaging regarding radiation exposure and the expense of either CT or MRI studies prompted us to seek a non-radiographic severity measurement of pectus excavatum using 3D photographs. 3D photographic imaging is a fast, non-ionizing and patient friendly technique that is capable of capturing 3D photorealistic surface images within a few milliseconds. It provides high-resolution 3D photographs that are easily collected, manipulated, and analyzed. In addition, 3D photogrammetry demonstrates comparable accuracy to anthropometry[3-6] (i.e., measurement of the human individual). In this study, we sought to evaluate the severity of chest wall deformity in patients with pectus excavatum using 3D photographic as a possible alternative to the CT pectus index.

Materials and methods

Following Institutional Review Board approval, ten consecutive patient volunteers with pectus excavatum (Table 1) underwent 3D stereophotogrammetric imaging of the torso over a 28-mo period. Informed consent was obtained for all subjects. Prior to the 3D photogrammetric evaluation, each of the study patients had previously undergone CT pectus index measurement as per the author's usual practice in evaluation of patients with pectus excavatum under consideration for surgical treatment at our institution. Surface imaging was performed using the 3dMD torso photography system, which consists of seven camera groups, each of which included a stereo pair of geometry CCD cameras and a color camera for the texture overlay. The images were acquired in a booth that incorporates the prepositioned cameras to obtain photographs from multiple angles of the torso. The participants were asked to stand upright in the booth and maintain a static T-pose position. Positioning compliance by each subject was easily achieved. Images were taken from all the cameras simultaneously and then combined to create a photorealistic 3D static image of the subject. The 3D photographs are obtained within a few milliseconds, similar to a regular 2D camera.

Table 1 – Patient demographics (age, gender, CT pectus index).

Subject number	Age	Gender	CT pectus index
1	19	M	3.4
2	14	M	3.6
3	19	M	4.43
4	17	M	4.1
5	18	M	2.44
6	17	M	3.8
7	18	F	5.6
8	16	M	2.5
9	14	F	3.4
10	13	M	3.4

Data analysis was performed using the 3dMDvultus software with alignment of the 3D photographic data easily calibrated to a perpendicular reference. The 3D photographic surface images were manipulated in cross-section and then evaluated by three separate examiners. Body measurements such as surface lengths, surface areas, and volumes were collected for each patient by each examiner on three separate occasions. The anterior-posterior (AP) length was defined by the deepest point of deformity to a perpendicular point at the posterior midline. The width length was defined by the transverse distance measured at the same cross-section of the deformity. In addition, the surface area and volume were calculated for both the deformity and torso. The deformity was defined by the area below the level of the normal aspect of the anterior chest, whereas the torso was measured from the level of the sternal notch to the xiphoid.

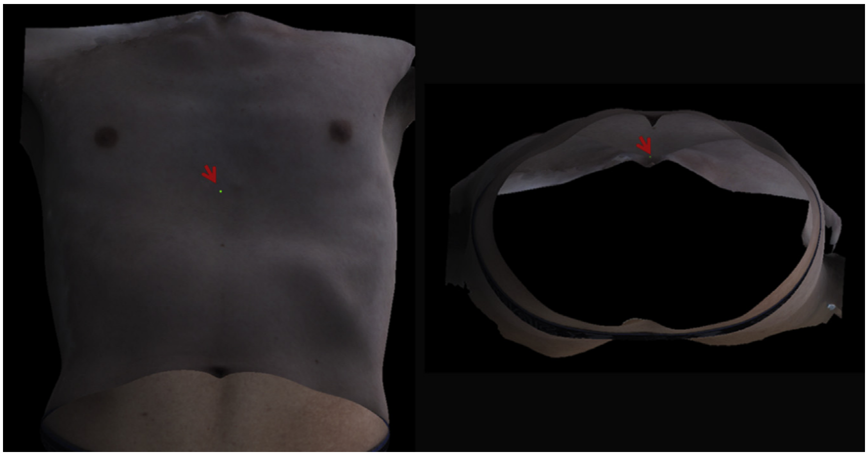

Fig. 1 – 3D photogrammetric imaging of pectus excavatum enables precise physical exam measurements, and therefore, calculations of ratios for surface lengths, pectus surface area, or pectus volume. (Color version of figure is available online.)