Reliability of a Three-Dimensional Scanning Technique and Metrics Quantifying Pectus Deformities

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Summary

Current assessments of pectus deformities use highly subjective, low precision calipers and may require exposure to ionizing radiation. This study demonstrates the high reliability of a low cost commercially available 3D scanning and custom measurement technique for non-invasive assessment of pectus deformities that addresses these current limitations.

Introduction

Pectus excavatum (PE, caving of the chest wall) and pectus carinatum (PC, protrusion of the chest wall) are the most common chest deformities in adolescents [1]. Severity of PE is assessed with computed tomography scans, necessitating radiation exposure. The assessment of PC is limited, as the evaluation of PC severity/correction is based on subjective caliper measurements [2]. The anteroposterior (AP) and mediolateral (ML) dimensions at the protrusion of the apex are frequently reported. A three-dimensional (3D) chest scanning technique may eliminate the need for ionizing radiation and quantify deformity/treatment progress. Towards the overall goal of providing a non-invasive technique for quantifying PC and PE, a low-cost 3D-torso scanning/quantification technique has been developed. This study aimed to evaluate the reliability of the technique in quantifying PC severity.

Methods

3D models of a male thorax mannequin with simulated PC were derived from data acquired using a commercial scanning device (Occipital Inc., USA) in this ethics approved study (REB17-0238). A mannequin was selected to eliminate potential breathing errors during scanning. A torso coordinate system was determined based on nine objectively defined landmarks on the mannequin. Three raters (R1-R3) each scanned the mannequin ten times consecutively within a test session (10 scans by R1, followed by R2, R3). This process was repeated on two additional sessions (n=30/rater). The mannequin position remained fixed for all sessions. A 3D-thorax model was created for each scan using custom software (Matlab [v2018b], MathWorks, USA). Transverse cross-sections were identified at the apex of the PC deformity, and AP/ML dimensions calculated. Measures of AP/ML dimensions at the PC apex of the mannequin were also obtained by R1 using calipers (Fillauer, USA). Intra-rater reliability was calculated for each rater as a coefficient of variation (CV). To compare the 3D-model AP/ML measures to the caliper measures, the mean difference was calculated.

Results and Discussion

The CV ranged from 0.3%-0.7%, 0.3%-0.5%, and 0.2%-0.5% for RI, R2, and R3, respectively (Table 1). The largest intra-rater difference was 2.5 mm (<0.01% error, R3, ML). The scanning technique demonstrated high reliability, showing great promise for assessing PC. The mean differences between the 3D torso model measures and calipers were 6.9 mm and 3.2 mm for the AP and ML directions, respectively. These differences were greater than the differences observed within raters using the scanning technique. Future studies will consist of testing the repeatability and reproducibility of the 3D scanning technique on PC patients in the clinical environment.

Conclusions

The low-cost commercial scanning technique shows promise for repeatable quantification of chest deformity associated with PC, providing improvements on caliper measures of PC.

Acknowledgments

Braceworks Custom Orthotics Ltd. and AITF

References

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Table 1: The means (standard deviations) and calculated CV for the AP and ML measures of PC deformity for each rater.

	Session 1				**Session 2**				**Session 3**			
	AP		**ML**		**AP**		**ML**		**AP**		**ML**	
Rater	**Mean (SD) (mm)**	**CV (%)**	**Mean (SD) (mm)**	**CV (%)**	**Mean (SD) (mm)**	**CV (%)**	**Mean (SD) (mm)**	**CV (%)**	**Mean (SD) (mm)**	**CV (%)**	**Mean (SD) (mm)**	**CV (%)**
1	282.7 (0.8)	0.3	326.4 (2.2)	0.7	285.1 (1.1)	0.4	325.9 (2.1)	0.6	284.6 (1.3)	0.4	324.8 (2.2)	0.7
2	284.3 (1.4)	0.5	327.5 (1.7)	0.5	285.9 (0.8)	0.3	327.6 (1.7)	0.5	285.7 (0.7)	0.3	326.9 (1.5)	0.5
3	283.2 (1.0)	0.3	328.6 (1.8)	0.5	283.6 (0.8)	0.3	326.1 (1.7)	0.5	284.5 (0.7)	0.2	327.1 (1.4)	0.4