Gender Dependent Differences in Growth and Vertebral Dimension of the Pediatric Thoracic Spine

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Disclosures:

Introduction: Quantitative morphological studies of the human thoracic spine have been used to inform the design and placement of orthopedic devices such as corrective braces, growing rods, and fusion instrumentation [1-3]. Three-dimensional (3D) geometric measurements of the thoracic vertebrae have been widely reported for the adult population [4-6] and few studies have reported comparable measurements for several pediatric age groups [7-8]. However, the current pediatric literature does not encompass the entire pediatric age range, which is important to understand the significant changes in spine morphology that occur with growth from infancy to pubescence to early adulthood. The objective of this study was to assess the morphology of the thoracic spine in skeletally normal pediatric males and females, and to compare these vertebral dimensions and their respective growth rates across vertebral levels as a function of age and gender.

Methods: Chest CT scans of 94 pediatric subjects (44 Males, age range: 1.1 - 18.62 years, mean age 10 ± 5.84 years; 50 Females, age range: 1.09 - 18.11 years, mean age 10.04 ± 6.06 years) between the 5th and 95th percentiles in height, weight and body mass index were digitally reconstructed using a medical imaging software, Mimics (Materialise Inc., Belgium). A custom MATLAB (The MathWorks Inc, Natick, MA) code was used to quantify 26 geometric measurements from the reconstructed surface geometry of each thoracic vertebra (T1-T12) including anterior and posterior vertebral body heights; superior and inferior endplate widths and depths; bilateral pedicle widths, heights, areas and angles; spinal canal width, depth and area; spinous process length and angle; transverse process width; superior and inferior inter-facet widths, and bilateral inter-facet heights and angles. Non-parametric statistics, namely Levene’s tests of parameter ranks were used to determine equality of variance and Wilcoxon Ranked-Sign tests were used to assess symmetry (right versus left, superior versus inferior and anterior versus posterior) within genders. Mann-Whitney-U and Median tests were conducted to compare measured parameters between genders. Linear regression models were created using age as the independent variable to estimate parameter growth rates, and multiple regression ANOVAs were used to evaluate the significance of differences in growth rates across vertebral levels and between genders. All statistics were calculated using SPSS (IBM Corp, Armonk, New York) with significance assessed at p<0.05.

Results: Within Gender Differences
Symmetry assessments were consistent in both males and females, with overall symmetry of left / right and superior / inferior dimensions of the pedicles and facets. Anterior / posterior vertebral body and superior / inferior endplate measurements displayed significant asymmetry (p<0.05) in males and females with the exception of endplate depths which were symmetric below T7. Multiple regression ANOVAs showed significant growth rate differences across all thoracic vertebral levels for all parameters except spinal canal width, depth and area which displayed similar growth rates in both males and females.

Between Genders Differences
There were significant differences in pedicle widths and pedicle areas between males and females at all thoracic vertebral levels (p<0.05). For all levels, pedicle heights showed no difference between genders. Additionally no differences between males and females were observed for geometric dimensions of the facets, vertebral bodies, endplates, processes or spinal canal. Growth rate regression analyses revealed significant gender-based differences in pedicle widths, pedicle areas and endplate widths (Figure 1). No differences in growth rate between males and females were detected for pedicle heights. All other vertebral dimensions showed similar growth rates between genders except for transverse process width, which displayed significant differences (p<0.05) below T7. No significant correlations were found between angular measurements and age; hence these parameters were not included in the regression analysis.

Discussion: In conclusion, this is the first comprehensive study to quantify the morphology and growth rates of the thoracic vertebrae in pediatric male and female subjects. Overall symmetry was observed within each gender for pedicle and facet dimensions, while the vertebral bodies and endplates were asymmetric. Between genders, differences were noted in pedicle widths and pedicle areas, but not pedicle heights. Within the male and female groups, multiple regression analyses showed differences in growth rates across thoracic vertebral levels for all vertebral dimensions except spinal canal width, depth and area. Between genders, analyses showed significant differences in growth rates of pedicle widths and areas, as well as endplate widths. Consistent age- and gender-based differences in pedicle widths and areas may have implications for pedicle screw design and spinal fusion techniques. While the current study provides a comprehensive understanding of thoracic vertebral growth in the pediatric population, shape changes resulting from asymmetric growth of vertebral structures have yet to be
Significance: Previous studies have approached quantitative analysis of the pediatric thoracic spine by comparing geometric parameters across arbitrarily determined age groups which may skew the results of any age-dependent morphological evaluations. The current study is the first comprehensive assessment of vertebral geometric parameters and growth as a function of age and gender, and such information could be valuable in making clinical decisions and in the design of pediatric-specific spine instrumentation.

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