A Quantitative Study of the Effect of Wedge Deformity on Thoracic Volume by Virtual Scheuermann’s Models

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Introduction: Scheuermann’s kyphosis (SK) is a sagittal deformity that happens in adolescents. This disease is diagnosed based on the thoracic kyphosis angle (KA) larger than 50 degrees (measured from superior endplate of T1 vertebra to inferior endplate of T12 vertebra) with anterior wedge equal to or larger than 5 degrees in least three consecutive vertebrae. The progressive wedging vertebrae (Fig. 1a) may increase KA and cause shortened thoracic length. Thoracic volume (TV) includes the space inside the rib cage and is bounded by the inner surface of the vertebrae, ribs, costal cartilages and sternum. Severe deformity in SK patients often leads to restrictive lung disease due to smaller TV for lung expansion. Judging from the severity, doctors will determine the treatments: bracing or surgery. Here, we present a process for building five virtual SK patients to show the effect of the wedge deformity (WD) on TV. In future clinical settings, the process can be reproduced to predict the TV changes in SK patients and help doctors decide the timing of intervention.

Materials and Methods: CT-scan data of the rib-cage of a healthy male adult was segmented creating a standard template via Mimics 17.0. This template was used to reconstruct the thorax of five adolescents (three boys and two girls, mean 14 years) with different KA baselines (mean 40.2 degrees) via frontal and lateral X-rays and the reconstruction was implemented in Blender 2.74 with customized add-ons. Also, some assumptions were made based on clinical features of SK disease: 1. At least three consecutive wedging vertebrae possessed wedging angle equal to or larger than 5 degrees. 2. WD above T5 vertebra was not considered. 3. The Apex along the thorax was located at T9 (Fig. 1b). Other assumptions were proposed to simplify the models: 1. Global and local rib cage deformities only occur in sagittal plane. 2. Sternum and ribs do not locally deform when WD progressively bends the thoracic spine. 3. All consecutive endplates remained parallel to each other while WD happens. 4. KA for virtual SK models started with 60 degrees with three WDs and every 10 degrees more of progression would add one more wedging vertebra and so on. Finally, each rib-cage was morphed to simulate SK models with different KAs in five virtual patients and our developed program was capable of creating and measuring the TV in Blender.

Results and Discussion: In Fig. 1c, an average of reduction from 60-degree KA to 110-degree KA was 18.5% in five virtual SK patients. With the increased wedging angle and increased number of wedged vertebrae, the thoracic KA progressively increased, and the TV decreased in an approximate linear fashion by a mean of 3.5% for every 10 degrees more of progression in the five virtual SK patients. The virtual SK patients showed that increased wedging number and wedging angle not only affected the local and global spine deformity but also reduced the TV for lung expansion in adolescent SK patients if no intervention was made.

Translational Impact: TV can be a vital parameter to judge the pulmonary function in spine patients. Five virtual SK patients with different KAs were used to investigate the effect of the WD on the spine deformity and the TV variations. The process of constructing the virtual SK patients can be utilized in future clinical settings to predict and track the TV decrease based on the WD along the thoracic spine. Doctors can decide about timing for intervention for SK patients based on KA with TV variations as a guide.

Disclosure Statement: All authors have no conflicts of interest to declare.