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● *Original Contribution*

VALIDITY STUDY OF VERTEBRAL ROTATION MEASUREMENT USING 3-D ULTRASOUND IN ADOLESCENT IDIOPATHIC SCOLIOSIS

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Abstract—This study aimed to assess the validity of 3-D ultrasound measurements on the vertebral rotation of adolescent idiopathic scoliosis (AIS) under clinical settings. Thirty curves (mean Cobb angle: 21.7° ± 15.9°) from 16 patients with AIS were recruited. 3-D ultrasound and magnetic resonance imaging scans were performed at the supine position. Each of the two raters measured the apical vertebral rotation using the center of laminae (COL) method in the 3-D ultrasound images and the Aaro-Dahlborn method in the magnetic resonance images. The intra- and inter-reliability of the COL method was demonstrated by the intra-class correlation coefficient (ICC) (both [2, K] >0.9, $p < 0.05$). The COL method showed no significant difference ($p < 0.05$) compared with the Aaro-Dahlborn method. Furthermore, the agreement between these two methods was demonstrated by the Bland-Altman method, and high correlation was found ($r > 0.9, p < 0.05$). These results validated the proposed 3-D ultrasound method in the measurements of vertebral rotation in the patients with AIS. (E-mail: m.s.wong@polyu.edu.hk) © **2016 World Federation for Ultrasound in Medicine & Biology.**

Key Words: **Adolescent idiopathic scoliosis, 3-D ultrasound, Vertebral rotation, Validity, reliability, Measurement.**

INTRODUCTION

Adolescent idiopathic scoliosis (AIS) presents with a lateral and rotational deformity of the spine (Hresko 2013; Weinstein et al. 2008). The vertebral rotation is an important parameter of the deformity in AIS, which can be used to assess the severity of scoliotic spine, monitor the risk of curve progression and evaluate treatment outcomes (Lam et al. 2008). It is also associated with lateral curvature and ribcage asymmetry, leading to reduced respiratory capacity and cosmetically disfiguring the rib hump (Adam et al. 2008; Cui et al. 2012; Di Silvestre et al. 2013). Thus, an accurate and reliable assessment of vertebral rotation is of paramount importance in the diagnosis and treatment decision of scoliosis.

Several methods have been proposed to assess the vertebral rotation using radiographic images, based on the position of the projected landmarks in relation to the vertebral body (Lam et al. 2008; Vrtovec et al. 2009). However, the measurements taken from radiographic images only represent a projected rotation, which is not directly measured in the transverse plane. Furthermore, the frequent exposure to radiation has been of primary concern for scoliotic patients (Knott et al. 2014). Compared with radiographic assessment, computed tomography (CT) and magnetic resonance imaging (MRI) both can enable visualization of the transverse plane of the vertebra for the measurement of the vertebral rotation (Kotwicki 2008; Lam et al. 2008). The CT/MRI scans and measurements can provide the 3-D information of the spinal structure, thus they are clinically applicable for both pre-operative and post-operative assessments of vertebral rotation (Hong et al. 2011; Lee et al. 2013). However, CT exposes the patients to more radiation than the standard

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radiographs, and MRI examinations are often time-consuming and expensive. Therefore, it is not feasible to use CT/MRI in mass screening and frequent monitoring for scoliosis, such as the measurements of lateral curvature and vertebral rotation.

Currently, ultrasound has gained considerable attention in the assessment of scoliosis (Cheung et al. 2015a, 2015b; Li et al. 2012; Wang et al. 2015; Zheng et al. 2015). Ultrasound imaging is a non-radiation and cost-effective method that is accessible in the majority of medical institutes. The posterior structure of vertebrae could be displayed by ultrasound imaging in the transverse plane. Similar to CT/MRI images, ultrasound images can visualize and measure the vertebral rotation in the transverse plane of scoliotic spine (Burwell et al. 2002; Suzuki et al. 1989). The possibility of using ultrasound to assess vertebral rotation was first studied by Suzuki et al. (1989), who identified the spinous processes and laminae in the transverse plane of ultrasound images of each vertebra and assessed the vertebral rotation directly based on the inclination of the transducer.

The development of the 3-D ultrasound system can enable the 3-D reconstruction of vertebral images and facilitate the measurement of scoliotic spine in various anatomic planes that could not be accomplished previously (Cheung et al. 2013, 2015a, 2015b Nguyen et al. 2014; Purnama et al., 2010; Wang et al. 2015). Spinous, laminae and transverse processes can be visualized and used as landmarks to measure the lateral curvature and vertebral rotation in the coronal and transverse planes of the ultrasound images (Cheung et al. 2015a, 2015b; Li et al. 2012; Ungi et al. 2014; Wang et al. 2015). Recently, the center of laminae (COL) method has been proposed to measure the vertebral rotation in the transverse plane of 3-D ultrasound images (Chen et al. 2015; Vo et al. 2015). The reliability and validity of this proposed method have been demonstrated. However, the evidence is limited to phantom studies. Thus, the objective of this study was to explore the possibility of using the proposed 3-D ultrasound method (*i.e.*, COL) to measure the vertebral rotation in the patients with AIS in the clinical setting and to evaluate its reliability and validity with the concurrent MRI method.

MATERIALS AND METHODS

Clinical patients

The patient inclusion criteria of this validity study were the following (i) female adolescents; (ii) diagnosis of AIS; (iii) Cobb angle of 10°–80°; (iv) no prior surgical treatment; and (v) out-of-brace MRI examination of the whole spine. Ethics approval was obtained from the local health research ethics board. All examination procedures were explained to the patients, and written informed consent was obtained.

Sixteen female patients with AIS (aged 15.4 ± 2.6 y) were recruited from a scoliosis clinic. Of the patients, three had a single thoracic curve, one a single lumbar curve, 10 a double curve and two a triple curve, producing a total of 30 curves for analysis in this study. The distribution of apical vertebra of these curves was 19 thoracic, three thoracolumbar and eight lumbar levels. The Cobb angles of these curves measured from MRI coronal images ranged from 10.2° to 68.2° and the average value was 21.7° ± 15.9°.

Equipment

To evaluate the validity of the 3-D ultrasound method, 3-D ultrasound and MRI scans of the full spine were arranged on the same d (within 3 h) and performed in the same supine position so as to match the observations.

The 3-D ultrasound scans were performed with a 3-D SonixTABLET ultrasound unit (Analogic Corporation, Peabody, MA, USA), coupled with a C5-2/60 convex transducer, SonixGPS and 3-D guidance device (driveBAY; Ascension Ltd., Milton, Florida, USA) (Fig. 1a). A purpose-design couch with a central rectangular slot (size: 12 cm [width] × 60 cm [length]) was used to facilitate ultrasound scanning at the supine position (Fig. 1a). The MRI scans were conducted using a

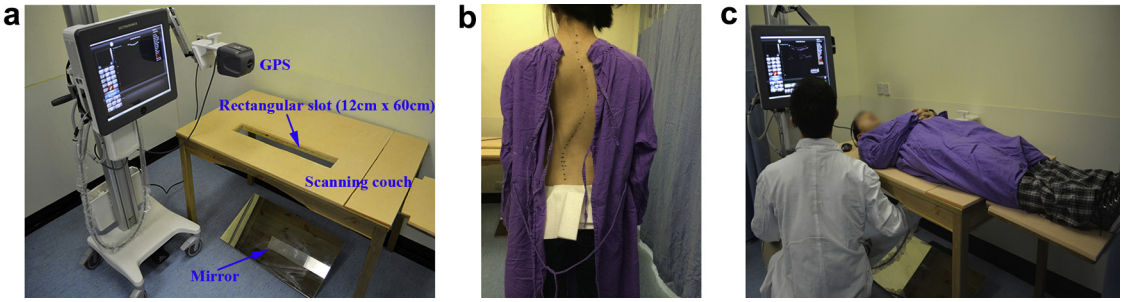

Fig. 1. 3-D ultrasound system and ultrasound scan; (a) 3-D SonixTABLET ultrasound unit with a SonixGPS System; (b) a patient with AIS; (c) ultrasound scanning was performed in the supine position. AIS = adolescent idiopathic scoliosis.