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Morphometric Analysis of the Thoracic Intervertebral Foramen Osseous Anatomy in Adolescent Idiopathic Scoliosis Using Low-Dose Computed Tomography

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Abstract

Purpose: The dimensions of the thoracic intervertebral foramen in adolescent idiopathic scoliosis (AIS) have not previously been quantified. Better understanding of the dimensions of the foramen may be useful in surgical planning. This study describes a reproducible method for measurement of the thoracic foramen in AIS using computed tomography (CT).

Methods: In 23 preoperative female patients with Lenke 1 type AIS with right-side convexity major curves confined to the thoracic spine the foraminal height (FH), foraminal width (FW), pedicle to superior articular process distance (P-SAP), and cross-sectional foraminal area (FA) were measured using multiplanar reconstructed CT. Measurements were made at entrance, midpoint, and exit of the thoracic foramina from T1−T2 to T11−T12. Results were also correlated with dependent variables of major curve Cobb angle measured on X-ray and CT, age, weight, Lenke classification subtype, Risser grade, and number of spinal levels in the major curve.

Results: The FH, FW, P-SAP, and FA dimensions and ratios are all significantly larger on the convexity of the major curve and maximal at or close to the apex. Mean thoracic foraminal dimensions change in a predictable manner relative to position on the major thoracic curve. There was no statistically significant correlation with the measured foraminal dimensions or ratios and the individual dependent variables. The average ratio of convexity to concavity dimensions at the apex foramina for entrance, midpoint, and exit, respectively, are FH (1.50, 1.38, 1.25), FW (1.28, 1.30, 0.98), FA (2.06, 1.84, 1.32), and P-SAP (1.61, 1.47, 1.30).

Conclusion: Foraminal dimensions of the thoracic spine are significantly affected by AIS. Foraminal dimensions have a predictable convexity-to-concavity ratio relative to the proximity to the major curve apex. Surgeons should be aware of these anatomical differences during scoliosis correction surgery.

Keywords: Adolescent idiopathic scoliosis; AIS; Morphometric; Intervertebral foramen; Computed tomography

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Introduction

Deformation of the posterior elements and asymmetrical growth of the posterior elements relative to the vertebral body are an important morphological aspect of adolescent idiopathic scoliosis (AIS) [1] and have been described in other anatomical studies [2-4]; however, the quantitative effects of this deformity on the thoracic intervertebral foramen in AIS have not previously been described. Accurate and reproducible study of the intervertebral foramen in scoliosis is difficult because of the three-dimensional nature of the deformity. The foramen also is a complex three-dimensional space that is affected by the deformity of the individual vertebral elements that form its boundaries. The clinical relevance of the dimensions of the thoracic intervertebral foramen at this stage are uncertain; however, an improved understanding of the differences in convexity and concavity intervertebral foramina may be of benefit to surgeons or other clinicians in assessing the local anatomy in individual patients with AIS, or in future advances in implant development.

Some controversy exists in the precise definition of the intervertebral foramen; however, it is usually considered to be bounded by vertebral body and posterior element osseous structures, including the pedicle superiorly and inferiorly, the pars and zygapophysial joints and ligamentum flavum posteriorly, and the vertebral body and disc anteriorly [5]. The foramen is a complex three-dimensional shape with an entry and exit bounded by the medial and lateral borders of the pedicles. Although anatomical studies have been performed of the vertebrae and specific parts of the posterior elements in normal [6-9] and deformed spines [3,10-12], only a limited number of studies have included the intervertebral foramen and are more numerous for the cervical [13,14] and lumbar regions [5,15-20]. A literature search by the authors found no quantitative studies of the thoracic spine intervertebral foramen in normal or AIS patients. Studies of the intervertebral foramen of the cervical and lumbar spine describe or depict in example pictures different anatomical landmarks and methods of measurement that make comparison and reproduction difficult. Deformity measurements such as axial rotation or coronal tilt that are relevant to morphometric spine studies such as this are also heterogeneous and have inherent problems in reproducibility of measurement [21,22]. This study, therefore, was undertaken to better understand the dimensions of the thoracic intervertebral foramen in AIS as a contribution to the anatomical literature and as a potential aid to surgical planning.

Materials and Methods

Twenty-three CT scans with the highest image quality were selected from an existing historical databank of low-dose CT scans of preoperative patients with AIS who subsequently underwent thoracoscopic scoliosis correction surgery. The databank contained scans collected between the years 2002 and 2009; however, the selected scans for the current study were those most recently taken between 2007 and 2009. All scans in the Preop CT Databank are from an Australian surgical practice of two experienced spinal orthopaedic surgeons (RDL and GNA) in Brisbane, Queensland. Low-dose CT spine scans covering C7 to S1 had been collected as part of a routine preoperative protocol for surgical planning purposes during those years, though they are no longer performed as part of current practice. The compilation and use of the databank for future research projects has ethics approval from our institution's Human Research Ethics Committee. Scans were performed in the supine position on Brilliance 64 and Lightspeed VCT machines with X-ray source voltage and current of 80—100 kVp and 29—119 mA, respectively, and a slice thickness of 2.5—3 mm with 1—1.25 mm overlap between slices, giving voxel dimensions ranging between 0.49 × 0.49 × 1 mm and 0.78 × 0.78 × 1.25 mm. The scans from the databank used in this study had an average estimated

Table 1
Demographic data of patients.

Characteristics of Study Group (n = 23)	Mean
Age (years)	15.7 (11.6—22.0)
Weight (kg)	55.2 (37.5—84.7)
Race	55.2 (37.5—84.7)
Major Cobb angle—X-ray measured (degrees)	53.7 (42—63)
Major Cobb angle—CT measured (degrees)	43.5 (34.5—53)
	Number of patients
Race	
Caucasian	22 (96%)
Polynesian	1 (4%)
Lenke classification	
1A	13
1B	4
1C	6
Risser grade	
0	3
1	0
2	1
3	3
4	8
5	8
Apex level	
T7	2
T7—T8	4
T8	2
T8—9	7
T9	3
T9—T10	5
No. of spinal levels in major curve	
5	1
6	3
7	13
8	5
9	1
Mean	7.08

Note: Means are given with (ranges).