Spine Deformity
www.spine-deformity.org

Spine Deformity 5 (2017) 172−180

# Evaluating the Change in Axial Vertebral Rotation Following Thoracoscopic Anterior Scoliosis Surgery Using Low-Dose Computed Tomography

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Received 4 August 2016; revised 3 November 2016; accepted 15 December 2016

## Abstract

**Background Context:** In recent years, there has been increasing appreciation of the need to treat scoliosis as a three-dimensional deformity.

**Purpose:** Assessment of surgical strategies and outcomes should consider not only the coronal plane correction but also derotation of the transverse plane deformity that can affect trunk appearance.

**Study Design:** This study included a cohort of 29 female adolescent idiopathic scoliosis patients who received thoracoscopic single rod anterior fusion (TASF) surgery. This study used pre- and postoperative low-dose computed tomographic (CT) scans to accurately measure apical axial vertebral rotation (AVR).

**Methods:** The pre- and postoperative values for clinically measured coronal Cobb correction and rib hump correction as well as AVR were compared to determine whether these values improved postoperatively. There are no conflicts of interest to report for authors of this investigation.

**Results:** As expected, statistically significant reductions in coronal Cobb angle (mean preoperative Cobb 51°, reducing to 24° at the two-year follow-up) and rib hump (mean preoperative rib hump 15°, reducing to 7° at two-year follow-up) were achieved. The mean reduction in apical AVR measured using CT was only 3° (mean preoperative AVR 16°, reducing to 13° at two-year follow-up), which was statistically but not clinically significant. Significant correlations were found between Cobb angle and rib hump, between Cobb angle and AVR, and between AVR and rib hump, suggesting that patients with greater coronal Cobb correction also achieve better derotation with this surgical procedure.

**Conclusions:** The historical low-dose CT data set permitted detailed three-dimensional assessment of the deformity correction that is achieved using thoracoscopic anterior spinal fusion for progressive adolescent idiopathic scoliosis.



*Keywords:* Adolescent idiopathic scoliosis; Axial spinal deformity; Rib hump; Computed tomography; Axial vertebral rotation; Thoracoscopic anterior scoliosis surgery

Author disclosures: JPL (support for trips/travel from NuVasive; research support from Medtronic and Synthes; grants from Medical Advances without Animals); MTI (institutional support for trips/travel from NuVasive, institutional support for research from Medtronic); CJA (support for trips/travel from NuVasive; researcher support salaries and materials from Synthes and Medtronic; and a European Union Fellowship FP7-PEOPLE-2010-IIF-274964 salary 2012-13); OL (none); AS (none); RDL (support for speaking and/or teaching arrangements from Medtronic; researcher support salaries from Medtronic and Synthes; and fellowship support from DePuy Synthes), GNA (support for speaking and/or teaching arrangements from Medtronic; researcher support salaries from Medtronic and Synthes).

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http://dx.doi.org/10.1016/j.jspd.2016.12.003

## Introduction

Adolescent idiopathic scoliosis (AIS) is the most prevalent paediatric spinal deformity, affecting 2.5% of the population [1,2] and manifesting as a complex three-dimensional (3D) deformity of the spine [3]. Several parameters are used to provide the surgeon with an indication of the severity of the spinal deformity, including the coronal Cobb angle and axial vertebral rotation, which is generally assessed in the clinical setting by measuring rib hump. The degree of coronal deformity is measured from standing radiographs using the Cobb method [4] to quantify the lateral angular deviation of the vertebral column [5]. Axial vertebral rotation (AVR) provides a measure of the axial misalignment of each vertebra relative to the midline of the spine, thus taking into consideration the 3D nature of the deformity. Rib hump (RH) provides an indication of the posterior rotational deformity of the rib cage and is measured noninvasively using a scoliometer [6,7] or smartphone [8], with the patient in the forward bending position.

Although methods have been proposed to measure AVR using plain radiographs [9,10] and magnetic resonance imaging [11], the most accurate methods [12,13] rely on the use of computed tomography (CT) imaging in order to identify key anatomic bony landmarks [14]. Skalli et al. [15] quantified the potential difference in vertebral rotation measurements when measured from either 3D anatomic planes or from reformatted projections aligned with the orientation of the deformed vertebra. These authors found increasing errors in axial rotation with increasing inclination of the vertebra in the sagittal and coronal planes. This implies that AVR measurements obtained from views other than transverse plane images of the spine may be misleading.

The clinical measurements of Cobb angle, RH, and AVR assist in preoperative planning, providing the surgeon with an advanced knowledge of the 3D nature of the deformity. Furthermore, comparison of pre- and postoperative measurements may lead to a more holistic understanding of the deformity and an indication of the surgical success in correcting the deformity and improving patient cosmesis [14]. Previous studies have investigated the relationship between pre- and postoperative measurements of both the spinal (ie, Cobb angle, vertebral rotation) and torso deformity (eg, rib hump, rib hump prominence, rib-vertebra angles, apical rib spread), finding varying degrees of correlation depending on the time-point of comparison, patient demographics, surgical procedure and measurement method [14-17].

Regardless of the technique used, reductions in AVR and RH following surgery are an important determinant of success because torso rotation is often the most noticeable aspect of a deformity. Even so, the surgical procedure of particular interest in this study is thoracoscopic single rod anterior spinal fusion (TASF). The thoracoscopic approach results in reduced scarring and postoperative recovery time; however, the use of a single anterior rod may provide less AVR correction potential than other techniques such as dual posterior rod constructs.

The current study investigated the relationship between pre- and postoperative Cobb angle, RH, and AVR for a series of AIS patients who underwent scoliosis correction surgery via the aforementioned TASF approach. The study aims were twofold: first, to measure the change in Cobb angle, RH, and AVR at the apical vertebra for a series of AIS patients, by comparing these parameters prior to and following surgery using low-dose CT imaging, and second, to identify whether the changes in these parameters were significantly correlated with either their pre- or postoperative values.

## Material and Methods

This study included 29 AIS patients who underwent TASF surgery at the Mater Health Services, Brisbane, Australia, between 2002 and 2009. Inclusion criteria were (1) female; (2) AIS; (3) right thoracic scoliosis, that is, Lenke Type 1; (4) both the cephalic and caudal limits of the major curve in the thoracic spine; and (5) pre- and postoperative clinical imaging data which included the sacroiliac joint anatomy.

The study cohort is some of the earlier cases from a larger TASF patient series at our center (225 cases to date) (Fig. 1A, B). At that time, the standard preoperative management to ensure optimum screw sizing and placement during the TASF procedure required all patients to undergo a low-dose supine CT scan in addition to standing spine radiographs. Standing posteroanterior (PA) and sagittal radiographs were also taken routinely at postoperative clinical review appointments. With hospital and university ethical approvals, low-dose CT scans were additionally performed on a subset of patients from the larger series (with patient consent) at a minimum of two years after surgery. Additional ethical approval has since been granted to use the historical clinical data set of preoperative low-dose CT scans for research purposes.

The TASF procedure involves removal of the intervertebral discs between the vertebral limits of the coronal deformity [18,19]. This is achieved with the use of pituitary rongeurs to remove the annulus fibrosus and the bulk of the nucleus pulposus. A Cobb elevator is used to separate the cartilaginous end plate from the subchondral bone and pituitary rongeurs to remove the endplate material. If necessary, the remaining disc material is cleaned from the space using curettes. Bone graft material is introduced to the disc space followed by correction of the curve, which occurs when the single pure titanium rod is connected to the vertebral body screws inserted at each vertebra involved in the fusion. The spinal levels fused were selected to include the end vertebrae in the major scoliotic curve [20],