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Preventing Distal Junctional Kyphosis by Applying the Stable Sagittal Vertebra Concept to Selective Thoracic Fusion in Adolescent Idiopathic Scoliosis

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Abstract

Study Design: Multicenter retrospective review.
Objective: To assess the effectiveness of using the stable sagittal vertebra (SSV) for selecting the lowest instrumented vertebrae (LIV) to prevent distal junctional kyphosis (DJK) in selective thoracic fusions.
Summary of Background Data: Cho et al. reported that including the SSV in a fusion decreased the rate of DJK in thoracic hyperkyphosis.
Methods: A retrospective review was performed of patients from two pediatric hospitals with adolescent idiopathic scoliosis who underwent selective posterior thoracic fusion with the LIV at L2 or above from 2000 to 2012. Patients with less than 2 years' follow-up were excluded. The primary outcome measure was DJK, defined radiographically as $\geqslant 10^{\circ}$ between the superior end plate of the LIV and the inferior end plate of the vertebra below on a standing lateral radiograph. We investigated the SSV, which was defined as the vertebral level at which 50% of the vertebral body was in front of the posterior sacral vertical line (PSVL) on a standing lateral radiograph. This particular definition was referred to as SSV.
Results: A total of 113 patients met the inclusion criteria. Mean age was 14.4 years. Mean Cobb angle was 58°. The overall rate of DJK was 7% (8/113). When the LIV was superior to SSV, the rate of DJK was 17% (8/46) versus 0% (0/67) when the LIV was at or inferior to SSV ($p=.01$). The rates of DJK for patients with the LIV one, two, and three levels above SSV were 17% (4/24), 7% (1/14), and 43% (3/7), respectively. There was no significant association between preoperative or postoperative maximum kyphosis, thoracic kyphosis, thoracolumbar kyphosis, pelvic incidence, sagittal balance or coronal balance, and development of DJK.
Conclusion: Although LIV selection is complex, choosing the LIV at or below the SSV is a simple rule that minimizes the risk of DJK.
Level of Evidence: Level IV.

Keywords: Scoliosis; Distal junctional kyphosis; Adolescent idiopathic scoliosis; Stable sagittal vertebra

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Introduction

In the operative management of adolescent idiopathic scoliosis (AIS), selective thoracic fusion allows preservation of motion through the lower lumbar spine [1]. This has been demonstrated to correlate with greater postoperative mobility than posterior fusion involving the lower lumbar segments [2,3]. The benefit of preserved motion is weighed against the potential risk of developing imbalance below the lowest instrumented vertebrae (LIV) in either the coronal or sagittal plane, such as distal junctional kyphosis (DJK). Although much debate on selection of the LIV has focused on coronal plane measurements [4-9]. There has been less discussion of using sagittal factors in choosing the LIV.

The concept of using the stable sagittal vertebrae (SSV) in the sagittal plane for selecting the LIV in patients with thoracic hyperkyphosis was introduced in 2009, and showed that those patients whose fusion did not include the stable sagittal vertebra had significantly higher distal junctional problems, including DJK [10]. The purpose of this study was to assess the effectiveness of using the SSV for selecting the lowest instrumented vertebrae to prevent distal junctional kyphosis in selective thoracic fusions.

Methods

After institutional review board approval, a retrospective, multicenter review of charts and radiographs was performed at two large scoliosis centers that identified 1,531 patients by CPT code for posterior spinal fusion from 2000 to 2012. Excluded patients were those who were younger than 10 or older than 21 years at the time of surgery (n = 16); those with a diagnosis other than AIS (n = 406); and those who were not treated with a posterior thoracic fusion with an LIV at L2 or above (n = 543). Patients with less than 2 years of follow-up, without adequate radiographs, or who did not have a pedicle screw at the base of the construct were excluded (n = 453). All patients included were Lenke type 1 to 3, with either a B or C lumbar modifier. The 113 patients remaining were included in this analysis.

Charts were reviewed and radiographic measures as defined by the Spinal Deformity Study Group were recorded at preoperative, postoperative, and final follow-up radiographs [11]. These included major Cobb angle, degree of maximum kyphosis (largest single kyphotic measurement irrespective of level), degrees of thoracic kyphosis (T5–T12), degrees of thoracolumbar kyphosis (T10–L2), degrees of lumbar lordosis (T12–S1), sagittal balance, pelvic incidence, coronal balance, and distal junctional kyphosis. DJK was defined as $\geqslant 10^{\circ}$ measured from the superior endplate of the LIV to the inferior endplate of the vertebra one level below. We investigated the SSV on a standing lateral radiograph, which was defined as the vertebral level at which 50% of the vertebral body was in front of the posterior sacral vertical line (PSVL). Statistical analysis was performed using Stata 12 (Stat Corp., College Station, TX). Descriptive statistical analysis was used for patient characteristics, as well as univariate analysis to identify potential predictive factors leading to distal junctional kyphosis.

Results

Of the 113 patients who met inclusion criteria, 95 were female and 18 were male. Mean follow-up after index selective thoracic fusion was 3 years (range 2–6 years). The mean age at time of surgery was 14.4 years (range 10.6–18.8 years), and the mean major Cobb at time of surgery was 58° (range 42°–95°) (Table 1). The mean number of levels fused was 10 vertebrae (range 7–13 vertebrae).

The overall rate of DJK was 7% (8/113). When the construct did not include the SSV, that is, the LIV was above the SSV, the rate of DJK was 17% (8/46) (Figure 1). The rates of DJK for patients with the LIV one, two, or three levels above the SSV were as follows: 1 level = 17% (4/24); 2 levels = 7% (1/14); 3 levels = 43% (3/7). There was no DJK (0/67) when the LIV was chosen at or below the SSV (Table 2). The rate of DJK was significantly higher for patients with an LIV above the SSV (p = .001).

The overall rate of revision surgery performed in this series for DJK was 1% (1/113). The overall revision rate was 4% (5/113): 1 for infection, 1 for a broken screw after patient hit by ski lift, 1 implant removal in hopes of relieving medial scapula pain, 1 for inclusion of lumbar curve after coronal decompensation, 1 for DJK. One case was revised for DJK in a 12-year old female with preoperative major Cobb of 63o and maximum kyphosis of 34°. The patient initially received instrumentation from T2 to L1 with an SSV at L2 (Figure 2 B-D). The revised construct was lengthened to L4 to restore coronal and sagittal balance.

We also investigated other radiographic parameters as potential risk factors for development of distal junctional kyphosis. There was no significant association between preoperative maximum kyphosis, thoracic kyphosis, thoracolumbar kyphosis or lordosis, and development of DJK. Nor was there significant correlation (p > .05) between preoperative pelvic incidence, sagittal balance or coronal balance, and development of DJK (Table 1).

Table 1
Preoperative measures versus overall DJK by univariate analysis (n = 113).

	Mean ± SD	Odds ratio	p value	95% confidence interval
Major Cobb	58.1°± 8.6°	1.01	.86	0.929, 1.09
Maximum kyphosis	35.0°± 12.7°	1.01	.81	0.948, 1.07
Thoracic kyphosis	24.7°± 13.6°	1.04	.18	0.978, 1.11
Thoracolumbar kyphosis	−1.4°± 11.9°	1.02	.58	0.957, 1.08
Lordosis	62.3°± 11.7°	0.984	.60	0.925, 1.04
Pelvic incidence	55.7°± 14.4°	0.946	.13	0.878, 1.02
Sagittal balance	−24.2°± 35.8°	0.983	.13	0.959, 1.01
Coronal balance	−1.9°± 18.2°	1.01	.60	0.969, 1.06

DJK, distal junctional kyphosis.