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Adolescent spine patients have an increased incidence of acetabular overcoverage

Ena Nielsen and Rachel Y. Goldstein*

Children's Orthopaedic Center, Children's Hospital Los Angeles, 4650 Sunset Blvd, MS#69, Los Angeles, CA 90027, USA
*Correspondence to: R. Y. Goldstein. E-mail: rgoldstein@chla.usc.edu
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ABSTRACT

Changes in spino-pelvic alignment can lead to changes in acetabular coverage and predispose those with spinal pathologies to hip pathologies. The purpose of this study was to define the incidence of acetabular overcoverage in pediatric spine patients. Retrospective review of charts and EOS radiographs was conducted for patients ≤21 years old with adolescent idiopathic scoliosis (AIS) or Scheuermann's Kyphosis (SK) who were treated with posterior spinal fusion (PSF) between 12/01/2015–7/26/2016. Radiographs were measured for lateral center edge angles (LCEA), anterior center edge angle (ACEA), and lumbar lordosis pre- and postoperatively. 32 patients met inclusion criteria. Preoperatively, mean LCEA was 44.1 degrees (range: 32–55, SD: 5.1) on the right and 42.8 degrees (range: 33–52, SD: 4.4) on the left. Mean preoperative ACEA was 56.0 degrees (range: 35–90, SD: 10.4). Mean preoperative lordosis was 56.0 degrees (range: −22–105, SD: 19.1) Preoperative LCEA was not associated with lordosis (right: $r = 0.002$, $p = 0.78$, left: $r = 0.006$, $p = 0.66$). Preoperative ACEA was no associated with lordosis ($r = 0.02$, $p = 0.49$). Overall, the mean percent change in LCEA was −3.4% (range: −19.6–21.9, SD: 10.3) on the right and −3.5% (range: −31.0–27.9, SD: 13.3) on the left. Mean percent change in ACEA was 9.1% (range: −20.6–35.7, SD: 15.1). Mean percent change in lordosis was −12.2% (range: −150–33.3, SD: 33.3. The incidence of acetabular overcoverage may be significantly higher in a pediatric spinal population than the general population. Careful monitoring of these patients for signs and symptoms of hip pathology may be warranted.

INTRODUCTION

Spine and hip alignment are inextricably linked by the nature of the pelvic attachment at the lumbosacral junction. Sagittal spine balance affects pelvic tilt at this point of attachment and thus pelvic tilt is able to function as a compensatory mechanism for sagittal malalignment. Due to the nature of the pelvic bone, this change in tilt can lead to hip morbidities co-existing with spinal deformities [1, 2]. In an adult cadaveric study, changes in pelvic tilt were directly correlated with changes in measures of acetabular coverage, including lateral center-edge angle (LCEA), percentage of acetabular crossover and Tonnis angle [3]. Recent studies have shown a relationship between increased hip pathology, most notably acetabular anteversion, following decreases in spinal lordosis [1, 4].

Correction of these spinal conditions has been shown to improve acetabular coverage in the adult population. Watanabe *et al.* showed a correlation between decreased lordosis and decreased acetabular coverage of the femoral head [4]. Expanding on this finding, Buckland *et al.* demonstrated that changes in acetabular version had a strong negative relationship with changes in lumbar lordosis; that is, increasing lordosis resulted in increased acetabular retroversion [1]. Similarly, Hu *et al.* found that changes in acetabular anteversion were significantly positively correlated with changes in pelvic tilt after performing lumbar pedicle subtraction for treatment of thoracolumbar kyphosis [5].

While this phenomenon has been well documented in adults, little is known about the incidence of hip morbidities associated with spinal deformity in the pediatric population. One study of healthy adolescents by Pytiak *et al.* showed a correlation between lumbar lordosis and pelvic tilt, but no correlation between pelvic tilt and measures of acetabular coverage [6]. Clinically, surgeons at our institution have observed that patients with adolescent idiopathic scoliosis (AIS) and Scheuermann's kyphosis (SK) seem to have an unusually high incidence of acetabular overcoverage but actual rates are unknown. Their overcoverage may resolve upon decrease of lordosis with correction of their scoliosis through bracing or surgery [7–14].

This study aims to determine the incidence of acetabular overcoverage among AIS and SK patients, and to assess the improvement of this condition following spinal fusion for the correction of spinal curvature.

MATERIALS AND METHODS

Institutional review board approval was granted for this study.

Patient population

Patients ≤21 years old with AIS or SK who were treated with PSF between 1 December 2015 and 26 July 2016 at the participating institution were eligible for this study. CPT and ICD-9 codes were used to identify the patient population. Patients were excluded from the study if they did not receive EOS imaging pre- and postoperatively or if their radiographs were inadequate for anterior and lateral measurements.

Radiographs

EOS imaging was used to evaluate the LCEA, anterior center edge angle (ACEA) and degree of lumbar lordosis in all patients preoperatively and immediately postoperatively. Pelvic tilt and rotation was assessed in all radiographs to ensure measurement accuracy. This imaging modality was chosen due to its ability to visualize the vertebral column and hips simultaneously. EOS imaging has been shown to be comparable to traditional radiography in the assessment of hip parameters used in acetabular overcoverage assessment [15].

Data collection

This study was conducted as a retrospective chart review. Patient charts were reviewed for demographic information (age, sex, BMI) and diagnosis. Preoperative and first postoperative radiographs were analyzed to determine the LCEA of each hip and the degree of lumbar lordosis. Lateral acetabular overcoverage was defined as a LCEA ≥40 degrees. Anterior acetabular overcoverage was defined as an ACEA ≥50 degrees. Normal lumbar lordosis was defined as lordosis between 40 and 60 degrees.

LCEA was defined as the angle formed by the intersection of a vertical line drawn through the center of the femoral head and a line drawn from the center of the femoral head to the lateral edge of the acetabulum (Figs 1 and 2).

ACEA was defined as the angle formed by the intersection of a vertical line drawn through the center of the femoral head and a line drawn from the center of the femoral head to the anterior edge on the acetabulum (Figs 3 and 4).

Fig. 1. Measurement of LCEA, bilateral. Reproduced with permission from the Children's Orthopaedic Center, Los Angeles.

The primary study endpoint was the incidence of lateral and anterior acetabular overcoverage pre- and postoperatively. A secondary endpoint was the association between changes in lordosis and changes in LCEA and ACEA.

Statistical analysis

Descriptive data were summarized using mean, range and standard deviation. Significance of perioperative differences in LCEA, ACEA and lumbar lordosis were calculated using a paired t-test. Linear regression was used to determine the correlation between lumbar lordosis and LCEA or ACEA, both preoperatively and perioperatively.

RESULTS

A total of 32 patients met inclusion criteria: 34.4% (n = 11/32) were male and 65.6% (n = 21/32) were

Fig. 2. Measurement of LCEA, detailed. Reproduced with permission from the Children's Orthopaedic Center, Los Angeles.

Fig. 3. Measurement of ACEA, bilateral. Reproduced with permission from the Children's Orthopaedic Center, Los Angeles.

female. Mean patient age was 14.5 years (range: 11–20, SD: 2.2). Mean BMI was 23.6 (range: 15.7–31.8, SD: 4.7). About 81.3% ($n = 26/32$) of patients were diagnosed with AIS and 18.7% ($n = 6/32$) were diagnosed with SK (Table I).

Preoperatively, mean LCEA was 44.1 degrees (range: 32–55, SD: 5.1) on the right and 42.8 degrees (range: 33–52, SD: 4.4) on the left. Mean preoperative ACEA was 56.0 degrees (range: 35–90, SD: 10.4). Mean preoperative lordosis was 56.0 degrees (range: −22 to 105, SD: 19.1) (Table II). About 96.9% ($n = 31/32$) of patients had lateral acetabular overcoverage on at least one hip. About 75.0% ($n = 24/32$) of patients had anterior acetabular overcoverage. About 28.1% ($n = 9/32$) of patients were hyperlordotic, 56.2% ($n = 18/32$) had normal lordosis, and 15.6% ($n = 5/32$) were hypolordotic. Preoperative LCEA was not associated with lordosis (right: $r = 0.002$, $P = 0.78$, left: $r = 0.006$, $P = 0.66$). Preoperative ACEA was not associated with lordosis ($r = 0.02$, $P = 0.49$) (Table III).

Postoperatively, mean LCEA was 42.4 degrees (range: 35–59, SD: 5.3) on the right and 41.1 degrees (range: 29–55, SD: 5.7) on the left. Mean postoperative ACEA was 59.1 degrees (range: 40–78, SD: 7.6). Mean postoperative lordosis was 52.2 degrees (range: 11–102, SD: 16.7).

Overall, the mean percent change in LCEA was −3.4% (range: −19.6 to 21.9, SD: 10.3) on the right and −3.5% (range: −31.0 to 27.9, SD: 13.3) on the left. Mean percent change in ACEA was 9.1% (range: −20.6 to 35.7, SD: 15.1). Mean percent change in lordosis was −12.2% (range: −150 to 33.3, SD: 33.3) (Table II). The change in LCEA after PSF was significant on the right, but not on the left (right: $P = 0.04$, left: $P = 0.09$). ACEA significantly decreased after PSF was ($P = 0.03$). The change in lordosis after PSF was not significant ($P = 0.11$). There was no association between the change in lordosis and the change in LCEA (right: $P = 0.52$; left: $P = 0.24$) or ACEA ($P = 0.65$) (Table III).

DISCUSSION

Hip and spine pathology can be linked as a consequence of pelvic attachment at the lumbosacral junction. Previous studies have demonstrated that changes in spino-pelvic alignment can lead to changes in acetabular coverage and, as a consequence, predispose those with spinal pathologies to hip pathologies such as FAI or dysplasia. The purpose of this study was to define the incidence of acetabular overcoverage in pediatric AIS and SK patients. Secondarily, we hoped to determine if a correction of the spinal deformity through PSF would also affect hip morphology.

In a meta-analysis of 2114 asymptomatic hips across 26 studies, the incidence of pincer-type FAI (characterized by

Fig. 4. Measurement of ACEA, detailed. Reproduced with permission from the Children's Orthopaedic Center, Los Angeles.

Table I. Patient demographics

	Mean (range, SD)
Age (years)	14.5 (11–20, 2.2)
BMI	23.6 (15.7–31.8, 4.7)
	% (*N*)
Sex	
Male	34.4% (11/32)
Female	65.6% (21/32)
Diagnosis	
AIS	81.3% (26/32)
SK	18.7% (6/32)

acetabular overcoverage) was 67%; however, the average LCEA was only 31.2 degrees, below the threshold for overcoverage used in the current study. This discrepancy may be due to varying parameters used to diagnose and define pincer deformity across studies, and actual incidence in the general population may be lower [16]. A separate study of 99 asymptomatic adolescents found a 14% incidence of abnormal LCEA [6]. Despite this discrepancy, the incidence of acetabular overcoverage in the AIS and SK populations in the current study was still higher than in the general population. Preoperatively, 93.9% ($n = 46/49$) of patients met criteria for acetabular overcoverage on at least one hip. To our knowledge this is the first study demonstrating this high incidence of acetabular overcoverage associated with AIS and SK.

Acetabular overcoverage predisposes to femoro-acetabular impingement (FAI), a hip pathology which is questionably correlated with an increase in osteoarthritis [17, 18]. If indeed pediatric spine patients have high rates of acetabular overcoverage, they may be at risk for worsening hip pathology later in life. While radiographic findings alone are not enough for a diagnosis of FAI, it may be worthwhile to monitor AIS and SK patients for development of characteristic symptomatology. This can include the gradual onset of hip pain, clicking or popping on the affected side, pain with flexion and internal rotation and a positive impingement test [18–20].

About 34.7% ($n = 17/49$) of patients were hyperlordotic. Of the 24 patients that fell into the normal range for lordosis (40–60 degrees), 41.7% ($n = 10/24$) were in the upper quartile of normal (55–60 degrees). Thus, the overall rate of high-normal lordosis and hyperlordotic curves was 55.1% ($n = 27/49$), which is consistent with previous studies demonstrating increased lordosis in AIS and SK patients [9–11, 13, 14, 21, 22]. Previous studies have postulated a correlation between lumbar lordosis and acetabular coverage [1, 4, 6], but our study failed to find any significant relationship between these measures (right: $r = 0.01$, $P = 0.52$, left: $r = 0.02$, $P = 0.45$).

Despite a significant 9.2% decrease in lordosis ($P = 0.04$), we found no significant change in LCEA after PSF (right: $P = 0.49$, left: $P = 0.08$). Several adult studies of hip-spine pathologies have found significant changes in measures of hip morphology after treatment of spinal conditions [1, 4, 5]; however, two of these studies enrolled only patients whose spinal pathology affected the lumbar region. Treatment of these conditions may have resulted in a greater change in lumbosacral alignment than treatments affecting only the thoracic or cervical vertebrae. The majority of spinal fusions in the current study occurred in the thoracic and high lumbar region, which may explain why we saw minimal change in pelvic parameters after treatment.

This study has several limitations. First, due to the constraints of radiographs available for retrospective review, this study used plain radiographs for measurements, which can be affected by pelvic tilt, rotation and patient distance from the beam source [23]. In addition, we used only standing radiographs, which have been shown to give decreased measures of LCEA relative to standard supine films [15, 24]. It is possible these limitations introduced random error into the measurements and true values may be even higher than those presented in the study.

Finally, our center began using EOS imaging in late 2015 and as a result there are relatively few patients included in this study. This may have contributed to the lack of significant associations between LCEA and lordosis.

Our results suggest that the incidence of acetabular overcoverage may be significantly higher in a pediatric

Table II. Radiographic measurements and percent change

Measure	*Mean*	*Range*	*SD*
Pre-op LCEA, right	44.1 degrees	32–55	5.1
Pre-op LCEA, left	42.8 degrees	33–52	4.4
Pre-op ACEA	56.0 degrees	36–90	10.4
Pre-op lordosis	56.0 degrees	−22 to 105	19.1
Post-op LCEA, right	42.4 degrees	35–59	5.3
Post-op LCEA, left	41.1 degrees	29–55	5.7
Post-op ACEA	59.1 degrees	40–78	7.6
Post-op lordosis	52.2 degrees	11–102	16.7
% Change LCEA, right	−3.4%	−19.6 to 21.9	10.3
% Change LCEA, left	−3.5%	−31.0 to 27.9	13.3
% Change ACEA	9.1%	−20.6 to 35.7	15.1
% Change lordosis	−12.2%	−150 to 33.3	33.3

Table III. Significant of association between radiographic measurements

Measure	P-*value:* *pre-op association with lordosis*	P-*value:* *change pre-op to post-op*	P-*value:* *association with change in lordosis*
LCEA, right	0.78	0.04*	0.52
LCEA, left	0.66	0.09	0.24
ACEA	0.49	0.03*	0.65
Lordosis	—	0.11	—

*Statistically significant.

spinal population than in the general population. Further longitudinal studies examining the incidence of hip morbidity in AIS and SK patients should be done to evaluate the clinical significance of this finding. Careful monitoring of these patients for signs and symptoms of hip pathology may be warranted, especially in patients with additional risk factors for FAI.

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CONFLICT OF INTEREST STATEMENT

None declared.

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