Increased Acetabular Depth May Influence Physeal Stability in Slipped Capital Femoral Epiphysis

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Abstract

Background Multiple mechanical factors affecting the hip have been associated with the development of slipped capital femoral epiphysis (SCFE). Whether acetabular depth plays a role in the development of a SCFE has not been elucidated. **Questions/purposes** (1) What is the prevalence of a deep acetabulum in SCFE? (2) Is the presence of a deep acetabulum associated with physeal instability? (3) Is the presence of a deep acetabulum associated with the occurrence of a contralateral SCFE?

Methods We retrospectively reviewed 232 patients (156 males) who presented with a unilateral SCFE. Fifty (22%) subsequently developed a contralateral SCFE. The

involved and uninvolved sides were evaluated for the presence of a deep acetabulum (DA). Preoperative radiographic parameters, slip stability, development of a contralateral SCFE, and demographic factors were then compared between patients with and without DA.

Results DA was present in 120 hips (52%) with a SCFE. DA was more common in females (55 of 76 [72%]) than males (65 of 156 [42%]). Patients with DA presented with a higher lateral center-edge angle (33° versus 31°), slip angle (52° versus 43°), and with a lower body mass index (28.1 versus 30.0 kg/m²). Increased acetabular depth was more common in patients with an unstable SCFE (29 of 41 [71%]) than those with a stable SCFE (91 of 191 [48%]). The presence of DA either on the affected side or the contralateral side did not predict a contralateral SCFE.

Conclusions Despite not predicting a contralateral SCFE, DA may influence physeal stability if a SCFE does develop. Therefore, the contralateral hip with DA should be closely monitored.

Level of Evidence Level II, prognostic study. See Guidelines for Authors for a complete description of levels of evidence.

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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Introduction

The etiology of slipped capital femoral epiphysis (SCFE) has been studied extensively but is still incompletely understood. Abnormal mechanical forces acting across the proximal femoral epiphysis have been identified as a potential contributing factor. Obesity, a common finding in patients with SCFE, increases shear stress across the proximal femoral physis [3, 21, 25]. Relative or absolute femoral neck retroversion and changes in the strength of

the physis and periphyseal tissues have also been implicated as potential causes of SCFE [4, 7, 23, 29].

The association of a deep acetabulum with various conditions such as Marfan syndrome [30, 33], rheumatoid arthritis [11], and femoroacetabular impingement (FAI) [8, 31, 32] has been well documented. The association between a deep acetabulum and SCFE has been hypothesized but a link is still unclear. Kordelle et al. [15] found no association with acetabular height, width, or depth for predisposition to SCFE using three-dimensional CT. They suggested that any acetabular anatomical changes that occur in association with a SCFE are in response to the SCFE. Kitadai et al. [14] and Sankar et al. [27] have suggested that children with SCFE tend to have increased lateral acetabular coverage (an indicator of acetabular depth) of the affected and unaffected hip, respectively. In addition, there is also no known relationship between acetabular depth and physeal stability as defined by Loder et al. [19].

Although an increased lateral center-edge angle (LCEA) of Wiberg ($> 40^\circ$) is considered an indicator of a deep acetabulum [30], this may not be a reliable measurement because of age and sex variation in skeletally immature subjects [9]. Two definitions of a deep acetabulum include coxa profunda, when the medial edge of the acetabulum touches or crosses the ilioischial line [5, 8], and acetabular protrusio, when the medial edge of the acetabulum crosses the ilioischial line (3 mm in males, 6 mm in females) [11, 33]. A commonly used alternative definition of acetabular protrusio is when the medial edge of the femoral head touches or crosses the ilioischial line [2, 5, 8]. No study has specifically evaluated the incidence of a deep acetabulum using the relationship of the medial edge of the acetabulum (coxa profunda) and/or the femoral head to the ilioischial line in patients (acetabular protrusio) with a SCFE.

Our study investigated three questions: (1) What is the prevalence of a deep acetabulum (coxa profunda or acetabular protrusio) in SCFE? (2) Is the presence of a deep acetabulum associated with physeal instability? (3) Is the presence of a deep acetabulum associated with the occurrence of a contralateral SCFE?

Patients and Methods

We retrospectively identified 382 patients treated for a unilateral SCFE at presentation between 1975 and 2003. We excluded patients with insufficient radiographic analysis ($n = 115$) and incomplete clinical/demographic data ($n = 35$). These exclusions left 232 patients (156 males, 76 females) at an average age of 13 years (range, 9–17 years) and an average body mass index (BMI) of 29 kg/m^2 (range, $16\text{--}68 \text{ kg/m}^2$) included in the analysis. The majority of the

patients presented with a stable SCFE as defined by Loder et al. [19] (stable $n = 191$ [82%] versus unstable $n = 41$ [18%]). Patients were treated with in situ pinning ($n = 223$ [96%]), open reduction ($n = 2$ unstable [1%]), or an osteotomy ($n = 7$ [3%]). We had prior institutional review board approval for our study.

Two of us (DG, AR), both nontreating pediatric orthopaedic physicians, made radiographic measurements on a standardized supine AP view of the pelvis at the time of presentation, including LCEA of Wiberg [34] and Southwick's angle [28]. If an adequate radiograph from the time of presentation was not available, we used the radiograph from the first postoperative clinic visit (0–2 weeks postoperatively). A deep acetabulum was defined as one in which the medial edge of the acetabulum (coxa profunda) or the medial edge of the femoral head (acetabular protrusio) was touching or crossed the ilioischial line [2]. We then divided patients into one of two groups based on whether they had a deep acetabulum (DA) or no deep acetabulum (NDA) at the time of initial presentation. Those with coxa profunda and those with acetabular protrusio were considered as one group because they are on the same spectrum of a DA and the small number of protrusio patients ($n = 9$) could not be statistically analyzed.

Differences between the DA and the NDA groups with respect to the LCEA, Southwick angle, BMI, and age at presentation were analyzed using the Student's *t*-test and differences between the groups with respect to sex, physeal stability, and development of a contralateral SCFE were analyzed using Fisher's exact test. Statistical analysis was performed using IBM SPSS Statistics 19 software (IBM Corp, Armonk, NY, USA).

Results

A deep acetabulum (Fig. 1) was present in 120 hips with SCFE (DA group, 52%) and absent in 112 hips with a SCFE (NDA group, 48%). The DA group had a higher frequency of females (72% versus 42%, $p < 0.001$), a higher slip angle (52° versus 43° , $p < 0.001$), and higher LCEA (33° versus 31° , $p = 0.024$). Similar findings were also observed on the contralateral, unaffected side with a greater LCEA in the DA group (33° DA versus 31° NDA, $p = 0.038$) but no difference in the Southwick angle between groups. The DA group also had a lower BMI (28.1 kg/m^2 versus 30.0 kg/m^2 , $p = 0.028$) than the NDA group. There was no difference with respect to age at presentation between the two groups (12.7 years versus 12.9 years, $p = 0.255$) (Table 1).

At presentation, 82% ($n = 191$) of the SCFEs were classified as stable, whereas 18% ($n = 41$) were classified as unstable. The presence of a DA was more common

Fig. 1 Preoperative supine AP radiograph of a 13-year-old boy with a left unstable SCFE and a DA. The medial edge of the acetabulum (dashed line) is medial to the ilioischial line (solid line). The maximal distance between the medial edge of the acetabulum and the ilioischial line measured 4.5 mm.

Table 1. Demographics and radiographic findings

Demographic and radiographic findings	Deep acetabulum (n = 120)	Normal acetabulum (n = 112)	p value
Sex			
Male	65	91	< 0.001
Female	55	21	
Age (years)	12.7 ± 1.7	12.9 ± 1.5	0.255
Body mass index (kg/m ²)	28.1 ± 5.5	30.0 ± 7.2	0.028
Slip angle	52° ± 22°	43° ± 19°	< 0.001
	14° ± 9°	15° ± 10°	
CL slip angle			
LCEA	33° ± 7°	31° ± 8°	0.024
CL LCEA	33° ± 7°	30° ± 7°	0.038

CL = contralateral; LCEA = lateral center-edge angle.

($p = 0.009$) in those with an unstable SCFE (71% [29 of 41]) as compared with those with a stable SCFE (48% [91 of 191]).

Of the 50 patients (22% of the cohort) who subsequently required treatment for a contralateral SCFE, 28 (56%) had a DA as compared with 92 of 182 (51%, $p = 0.526$) of the contralateral hips that did not subsequently slip.

Discussion

Renal insufficiency [18], obesity, and endocrine abnormalities such as hypothyroidism and growth hormone deficiency [20] are known risk factors for the development of a SCFE. The etiology of SCFE in most patients, however, is still unclear. Multiple mechanical factors have been identified as contributing to the development of a SCFE. Relative or true femoral neck retroversion [7], the orientation of the femoral epiphysis [23], and changes in the strength of the physis [4] and periphyseal tissues have been implicated as potential causes. Lateral overcoverage, seen as a surrogate measure of a DA, may be a factor in the development of SCFE [14]. However, there is no description of a deep acetabular socket as a mechanical risk factor for the development of a SCFE or influencing the physeal stability. We therefore addressed three questions: (1) What is the prevalence of a DA (coxa profunda or acetabular protrusio) in SCFE? (2) Is the presence of a DA associated with physeal stability? (3) Is the presence of a DA associated with the occurrence of a contralateral SCFE?

The present study has several limitations. First, patients with SCFE typically have prodromal symptoms, which can be present for days to months. Therefore, the radiographs used in this study are not obtained at the start of the SCFE. However, we would not anticipate the morphology of the acetabulum would vary greatly over these relatively short periods and therefore should not affect our measurements. Second, almost one-third of the original cohort was excluded because of missing or poor-quality radiographs. We do not believe this compromises our data because we were still left with a large cohort. Given the prevalence of DA and NDA was nearly identical and the difference in the DA group with an unstable SCFE versus those with a stable SCFE was so dramatic, it is unlikely that the additional patients would change the statistical significance (or lack thereof) of those findings. Third, potential limitations of the LCEA in the SCFE hip include an immature lateral margin of the acetabulum and perceived difficulty in identifying the center of the femoral head. Both of these limitations would lead to underestimation of the lateral coverage. Given that this cohort averages 13 years old, we believe skeletal immaturity had a minimal effect on the lateral measurement. In addition, the LCEA was not the primary method of measuring acetabular depth; it is intended to corroborate the evaluation of the medial edge of the acetabulum and tear-drop. Furthermore, we did not determine the reliability of our measurements of the LCEA and we found no historical data documenting the interobserver variability for the LCEA in the SCFE hip or for Southwick's angle.

We found an incidence of a deep acetabular socket in 52% of the patients who presented with a SCFE based on the medial edge of the acetabulum touching or crossing the

ilioischial line. This is different than what has been demonstrated in a normal population. Gusis et al. evaluated the measurement methods of 150 children with no known hip disease between 2 and 15 years old. They concluded that the line crossing method (the relationship of the medial acetabular edge to the ilioischial line) was more trustworthy than measuring the LCEA [9]. When evaluating the 64 subjects between 9 and 14 years of age (similar age range of our study), the acetabuli of male subjects were an average of approximately 2.5 mm lateral to the ilioischial line, whereas the average female acetabuli were an average < 1 mm lateral to the ilioischial line [9]. The average subject did not demonstrate a DA.

The difference in sex distribution of a DA is similar to what has previously been reported in the literature for adult patients. In a series of 302 adult hips treated for various hip problems using a surgical hip dislocation approach, Beck et al. [1] identified 16 patients with isolated coxa profunda (isolated pincer impingement), 14 of whom were female. Similarly, Leunig et al. [16] reported a higher incidence of females with acetabular protrusio undergoing a joint preservation procedure (83%) and with protrusio secondary to osteoarthritis (89%). The patients in our DA group also had a LCEA that was an average of 2° higher than patients in the NDA group on both the affected and contralateral, uninvolved side (we recognize that, despite being statistically significant, this may be within measurement error). This finding is consistent with data that have been reported in previous studies. Sankar et al. quantified the coverage of the normal hip in patients with unilateral SCFE and compared them with patients who were matched as normal control subjects [27]. The authors found the mean LCEA and Tönnis angle (TA) of the contralateral hip were 33° and 5° compared with the control group with a mean LCEA and TA of 20° and 8°, respectively ($p < 0.001$) [27].

Although the majority of the patients in our study cohort presented with a stable SCFE, patients who presented with an unstable SCFE had a higher frequency of a DA. Acetabular protrusio results in higher load transmission through the medial aspect of the joint. As a consequence, the hips of adults with osteoarthritis secondary to acetabular protrusio have a loss of medial joint space, whereas the superior joint space initially remains unaffected [6, 16, 22]. Thus, increased load transmission through the medial joint, in potential combination with increased obliquity of the femoral physis [23], thinning of the perichondrial ring complex [4], and/or femoral retroversion [7], may make the femoral physis more susceptible to shearing forces resulting in an unstable SCFE. Leunig et al. have demonstrated the arthritic destruction of the protrusio hip begins in the posteroinferior acetabulum as a result of the contra-coup injury associated with pincer impingement [1, 16]. Therefore, pincer FAI (DA) may also add to the stress across the

at-risk proximal femoral physis (retroverted with increased obliquity) and contribute to the development of an unstable SCFE.

Patients who initially present with a unilateral SCFE have a risk of developing a contralateral slip that ranges anywhere from 20% to 60% [10, 17, 24]. Twenty-two percent of our subjects required treatment for a subsequent contralateral SCFE, a rate that is consistent with what has been previously reported. More than 50% of patients with and without a DA on the initial SCFE side had evidence of a DA on the contralateral side. However, there was no difference in the rate of subsequent contralateral SCFE between those with a deep contralateral acetabulum and those without. The presence of a DA on the uninvolved hip at initial presentation does not seem to be a radiographic predictor of developing a contralateral slip. Patients with an unstable SCFE have a higher risk of developing avascular necrosis [12, 13, 26]. Early recognition and treatment of at-risk patients may improve clinical outcomes. Although a DA on the uninvolved contralateral side does not seem to predict a contralateral SCFE, our data suggest the DA may influence physeal stability if a SCFE does develop. Therefore, the presence of a DA on the uninvolved, contralateral side may need to be taken into consideration when considering prophylactic in situ pinning of a hip, because the hip may be at increased risk for an unstable SCFE.

Our observations showed a lower BMI, a higher LCEA, and slip angle were associated with a DA and a DA is more common in patients with an unstable SCFE. Females are more likely than males to have a DA. The presence of a DA of the uninvolved hip in patients presenting with unilateral disease is not a risk factor for developing a contralateral slip but may need to be a factor in a decision algorithm for prophylactic treatment of a contralateral, uninvolved hip.

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