The Most Important Risk Factors for Avascular Necrosis and Chondrolysis in Patients with Slipped Capital Femoral Epiphysis

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Objective: *To study the most important risk factors for avascular necrosis (AVN) and chondrolysis in children with slipped capital femoral epiphysis (SCFE).*

Material and Method: *Thirty patients with SCFE, who were surgically treated by single-screw fixation with good positioning from 1998 to 2012, were reviewed (22 male and 8 female patients, 35 hips; bilateral involvement in 1 male and 4 female patients). The following clinical and radiographic data were analyzed: age, sex, weight, height, onset, grading, stability, severity, history of trauma, anterior physeal separation (APS), and major complications such as AVN and chondrolysis. The results were reported according to the Heyman and Herndon criteria as excellent, good, fair, poor, or failure. Multiple logistic regression was used to identify multivariate predictors of osteonecrosis and chondrolysis.*

Results: *The mean patient age was 11.9 years. The right and left sides were affected in 45.7% and 54.3% of patients, respectively. There were 2 acute (5.7%), 26 chronic (74.3%), 5 acute-on-chronic (14.3%), and 2 preslips (5.7%). Five hips were unstable (14.3%), and 30 were stable (85.7%). There were 14 mild slips (40%), 6 moderate slips (17.1%), and 15 severe slips (42.9%). Thirteen hips (37.1%) had a history of trauma. APS was present in 12 hips (34.3%). Nine hips had AVN (25.7%), 7 had chondrolysis (20.0%), and 10 had both AVN and chondrolysis (28.6%). Clinical results were excellent, good, fair, poor, and failure in 13 (37.1%), 12 (34.3%), 6 (17.1%), 2 (5.7%), and 2 hips (5.7%), respectively. Univariate analysis revealed that the statistically significant risk factors ($p<0.05$) for AVN and chondrolysis were the presence of APS ($p = 0.000$), acute and acute-on-chronic onset ($p = 0.001$), moderate and severe grades ($p = 0.002$), instability ($p = 0.17$), and a history of trauma ($p = 0.02$). Multivariate analysis revealed that the presence of APS was the only risk factor for AVN and chondrolysis with the highest statistical significance ($p = 0.000$).*

Conclusion: *Single-screw fixation gave good and reliable outcomes in most cases. APS is the most important risk factor for AVN and chondrolysis in patients with SCFE. The optimal alternative treatment to reduce this major complication should be further studied, especially in patients with acute or acute-on-chronic slips, unstable hips, a history of trauma, or APS.*

Keywords: *SCFE, AVN, Chondrolysis, Risk factors, APS*

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The slipped capital femoral epiphysis (SCFE) is one of the most common adolescent hip disorders[1]. The incidence of surgical repair of SCFE in the Netherlands from 1998 to 2010 was 11.6 per 100,000 children aged 5 to 19 years[2]. The overall incidence of SCFE in the United States from 1997 to 2000 was 10.80 cases for every 100,000 children[3]. SCFE is usually treated operatively with in situ pinning that aims to achieve premature physeal fusion of the capital femoral epiphysis, preventing further slippage and minimizing the risk of subsequent osteoarthritis of the hip[4-7]. The most serious complications of SCFE are avascular necrosis (AVN) and chondrolysis of the hip. The reported prevalence of AVN and chondrolysis is 14.8% and 3.6%, respectively[8], and the overall rate of AVN is 21%[9], which is not rare. Many factors are reportedly associated with the development of AVN, including instability of the SCFE[10], the degree of slippage, the severity of the slip[8], intentional intra-operative reduction of the slip[11], a history of trauma, and the presence of anterior physeal separation (APS)[12]. The most common reported cause of chondrolysis is pin penetration into the joint[13]. The purposes of this study were to identify the most important risk factors for AVN and chondrolysis in SCFE treated with a single well-

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positioned screw without reduction or pin penetration.

Material and Method

Forty-two patients with SCFE were retrospectively reviewed from 1998 to 2012. Seven patients who were lost to follow-up immediately after the postoperative period were excluded from the study. One patient with an endocrine abnormality was also excluded from the study. Four patients who had undergone two-screw fixation were also excluded from the study. The remaining 30 patients (35 involved hips) were included. All hips had good, stable screw positioning without screw penetration. After approval from the institutional review board, the following clinical data and radiographic measurements were reviewed and analyzed: age, sex, affected side, height, weight, body mass index, duration of symptoms, grade, severity, stability, and history of trauma. Slip onset was defined as acute, acute-on-chronic, chronic, or preslip[14]. The angle of the slip was measured by the Southwick method[15]. The SCFE could then be graded as mild, moderate, or severe[16]. The stability of the slip was classified as unstable if the patient had severe pain and could not walk even with crutches[9]. The slip was classified as stable if walking and weight bearing were possible. APS was measured on the lateral view as shown in Fig. 1. It was defined as the distance between the anterior lip of the femoral head epiphysis and the closest point of the adjacent metaphysis. In normal hips, the width of the physis is less than 1 mm[12]. All patients were treated by in situ single cannulated screw fixation without intentional reduction. The screw direction was perpendicular to femoral epiphysis, and the screw depth was about 5 mm from the subchondral bone across the physeal plate of the femoral head. The results of treatment were classified according to the Heyman and Herndon criteria as excellent, good, fair, poor, or failure[17]. The outcome was excellent if the patient had a normal range of motion of the hip without pain or limping; good if the patient had limitation of internal rotation; fair if the patient had limitation of abduction and internal rotation; poor if the patient had a mild limp and pain; and failure if the patient had a limp and pain with marked limitation of motion that led to the need for reconstructive surgery.

Statistical methods

The primary outcome was the presence of osteonecrosis and chondrolysis. Patients' demographic and clinical characteristics were evaluated and are presented as mean and standard deviation or as percentage. Logistic regression was used to identify statistically significant risk factors for osteonecrosis and chondrolysis. Multiple logistic regression was used to identify the multivariate predictors of osteonecrosis using a stepwise criterion of $p<0.05$ for inclusion in the final model. Statistical analysis was performed using SPSS software (PASW Statistics for Windows, version 18.0; SPSS, Inc., Chicago, IL).

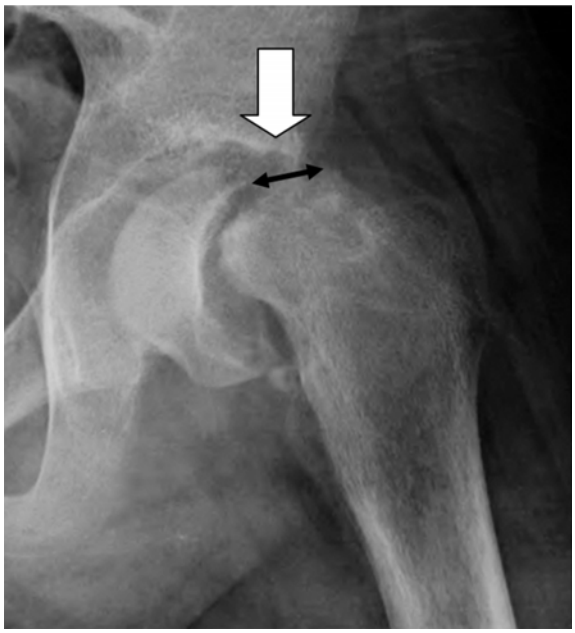

Fig. 1 Frog-leg radiograph of left hip showing the presence of anterior physeal separation (black line). The white arrow indicates that the black line starts from the superior part of the epiphysis of the femoral head and extends directly toward the superior part of the metaphysis of the femoral head. Normally the black line should be ≤1 mm, but in slipped capital femoral epiphysis with the presence of anterior physeal separation, this distance has increased to 10 mm in this picture[12].

Results

Thirty patients (35 involved hips) were evaluated. The mean patient age was 11.9 years (range, 9-16 years). Table 1 shows the patients' demographic and clinical characteristics. There were 22 male patients (1 with bilateral hip involvement) and 8 female patients (4 with bilateral hip involvement). The right side was affected in 45.7% of patients, and the left side was affected in 54.3%.There were 2 acute (5.7%), 26 chronic (74.3%), 5 acute-on-chronic (14.3%), and 2 preslips (5.7%). The mean symptom duration was 3.63 months

Table 1. Patient characteristics

Demographic characteristics (total = 30 patients)	
Age (years)	
Mean (SD)	11.9 (1.61)
Sex (%)	
Boys	22 (73.3)
Girls	8 (26.7)
Duration of follow-up (years)	
Mean (SD)	3.3 (2.1)
Height (cm)	
Mean (SD)	151.8 (8.9)
Weight (Kg)	
Mean (SD)	59.1 (11.8)
Body mass index	
Mean (SD)	25.7 (4.5)
Clinical characteristics (n = 35 hips including 1 boy and 4 girls with bilaterality)	
Side (%)	
Right	16 (45.7)
Left	19 (54.3)
Onset (%)	
Acute	2 (5.7)
Acute-on-chronic	5 (14.3)
Chronic	26 (74.3
Preslip	2 (5.7)
Severity of slip (%)	
Mild	14 (40)
Moderate	6 (17.1)
Severe	15 (42.9)
Stability	
Stable	30 (85.7)
Unstable	5 (14.3)
Trauma	
Present	13 (37.1)
Absent	22 (62.9)
APS	
Present	12 (34.3)
Absent	23 (65.7)
Complications	
AVN	9 (25.7)
Chondrolysis	7 (20)
Combined	10 (28.6)

APS = anterior physeal separation; AVN = avascular necrosis

before the first visit. Five hips were unstable (14.3%), and 30 were stable (85.7%). There were 14 mild slips (40.0%), 6 moderate slips (17.1%), and 15 severe slips (42.9%). Thirteen hips (37.1%) had a history of trauma. APS was present in 12 hips (34.3%). Nine hips had AVN (25.7%), and seven hips had chondrolysis (20.0%). Ten hips had both AVN and chondrolysis (28.6%).

Clinical results were excellent, good, fair, poor, and failure in 13 (37.1%), 12 (34.3%), 6 (17.1%), 2 (5.7%), and 2 hips (5.7%), respectively.

Univariate analysis revealed that the statistically significant risk factors ($p<0.05$) for AVN and chondrolysis were present with APS ($p = 0.000$), acute and acute-on-chronic onset ($p = 0.001$), moderate and severe grades ($p = 0.002$), instability ($p = 0.17$), and a history of trauma ($p = 0.02$). Multivariate analysis revealed that the presence of APS was the only risk factor for AVN and chondrolysis with the highest statistical significance ($p = 0.000$) (Table 2).

Discussion

The treatment goals for SCFE are to stabilize the epiphysis, prevent further slippage, and promote premature physeal fusion without complications. Single-screw fixation is the most widely accepted method of treatment because of its high success rate and low complication rate. Good and excellent results were obtained in 25 hips (71.4%) in the present study. There were 9 hips with AVN, 7 with chondrolysis, and 10 with both AVN and chondrolysis. All 10 hips with both AVN and chondrolysis had APS. The presence of APS was found in 12 hips with the chance of combined AVN or chondrolysis in 10 hips (83.3%). Hips without APS had no chance of AVN in this study. Among all affected hips, 80.0% were unstable, 53.8% had a history of trauma, 85.7% were acute or acute-on-chronic, and 47.6% had moderate to severe slips with a chance of AVN or chondrolysis (Table 2).

Kinking of the retinacular vessels[18] and increased intracapsular joint pressure have been documented as causes of AVN in patients with unstable SCFE[19]. In the present study, the presence of APS was the most important risk factor for AVN combined with chondrolysis. Instability, severe displacement, and a history of trauma increase damage to the vessels, promoting the development of AVN and leading to chondrolysis. The stability attained by stable single-screw fixation can prevent some patients from developing AVN by preserving the remaining viable vessels.

In the present study, the rate of combined AVN and chondrolysis was 28.6%, even with good single-screw fixation. Further study is required to identify any information that may help to lower the rate of AVN or chondrolysis. Slongo et al reported a 0% AVN rate after the modified Dunn procedure[20]. The modified Dunn procedure using the surgical dislocation approach is another means of achieving reduction,

Table 2. Risk factors for avascular necrosis and chondrolysis (total number of hips = 35)

Titles	No AVN, no chondrolysis		Combined AVN or chondrolysis		*p*-value
	Number hips	%	Number hips	%	
Sex					
Boys	14	60.9	9	39.1	0.113
Girls	11	91.7	1	8.3	
Side					
Right	13	81.3	3	18.8	0.285
Left	12	63.2	7	36.8	
Trauma					
Present	6	46.2	7	53.8	0.02
Absent	19	86.4	3	13.6	
APS					
Present	2	16.7	10	83.3	0.000
Absent	23	100	0	0	
Stability					
Stable	24	80	6	20	0.017
Unstable	1	20	4	80	
Grade					
Mild	14	100	0	0	0.002
Moderate, severe	11	52.4	10	47.6	
Onset					
Acute, acute on chronic	1	14.3	6	85.7	0.001
Chronic, preslip	24	85.7	4	14.3	
Results					
Excellent	13	100	0	0	0.000
Good	11	91.7	1	8.3	
Fair	1	16.7	5	83.3	
Poor	0	0	2	100	
Failure	0	0	2	100	

AVN = avascular necrosis; APS = anterior physeal separation

fixation, and joint decompression with the advantage of obtaining anatomic reduction. However, it is a more technically demanding procedure. The overall rate of AVN by this technique is reportedly 8%[9]; it may be considered in selected patients who have unstable, severe slippage with APS.

The authors conclude that the presence of APS in SCFE is the most important risk factor for AVN and chondrolysis. More appropriate alternative treatments to reduce this major complication should be further studied, especially in patients with acute or acute-on-chronic slips, instability, a history of trauma, or APS.

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Potential conflicts of interest

None.

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ปัจจัยเสี่ยงที่สำคัญที่สุดต่อการเกิดภาวะหัวกระดูกตายขาดเลือดและกระดูกอ่อนสลายในผู้ป่วยโรค slipped capital femoral epiphysis (SCFE)

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วัตถุประสงค์: เพื่อศึกษาปัจจัยเสี่ยงที่สำคัญที่ที่สุดต่อภาวะหัวกระดูกตายขาดเลือดและกระดูกอ่อนสลายในผู้ป่วย slipped capital femoral epiphysis (SCFE)

วัสดุและวิธีการ: ผู้ป่วย SCFE 30 รายที่ได้รับการรักษาการผ่าตัดยึดด้วยสกรู 1 ตัว โดยไม่ดัดดึงในปี พ.ศ. 2541-2555 เป็นชาย 22 ราย โดยเป็นสองข้าง 1 รายและหญิง 8 รายโดยเป็นสองข้าง 4 รายรวมเป็น 35 สะโพกข้อมูลทางคลินิกและภาพรังสีได้นำมาศึกษาเรื่องอายุ เพศ น้ำหนัก ส่วนสูง กลุ่มระยะเวลาที่เกิดโรค ความรุนแรงของโรค ความไม่มั่นคงและดูภาวะแทรกซ้อนหลังการรักษาคือภาวะหัวกระดูกตายขาดเลือด (AVN) ภาวะกระดูกอ่อนสลาย วัดผลการรักษาตามตัวชี้วัดของ Heyman และ Herndon แบ่งเป็นผลดีเลิศ ดี ปานกลาง ไม่ดี และล้มเหลวใช้สถิติ multiple logistic regression วิเคราะห์ปัจจัยต่าง ๆ

ผลการศึกษา: อายุเฉลี่ย 11.9 ปีข้างขวา 45.7% ข้างซ้าย 54.3% กลุ่มอาการเป็นเฉียบพลัน 5.7% เฉียบพลันเรื้อรัง 14.3% เรื้อรัง 74.3% ระยะแรกเริ่ม 5.7% กลุ่มไม่มั่นคง 14.3% มั่นคง 85.7% ในส่วนการเคลื่อนที่ของโรคพบว่าเคลื่อนที่น้อย 40% ปานกลาง 17.1% มาก 42.9% พบว่ามีประวัติอุบัติเหตุ 37.1% และยังพบว่ามีภาพรังสีเกิดขึ้นของภาวะ anterior physeal separation (APS) อยู่ 34.3% ภาวะแทรกซ้อนพบว่ามีภาวะหัวกระดูกตายขาดเลือด 25.7% กระดูกอ่อนสลาย 20% ถ้านับพบภาวะใดก็ได้ในสองภาวะนี้พบ 10 สะโพก (28.6%) ผลการรักษาได้ผลดีเลิศ 37.1% ดี 34.3% ปานกลาง 17.1% ไม่ดี 5.7% ล้มเหลว 5.7% การวิเคราะห์ด้วยสถิติ multiple logistic regression พบว่าปัจจัยเสี่ยงของการเกิดภาวะหัวกระดูกตายจากการขาดเลือดและกระดูกอ่อนสลายมาจากการมีภาวะ APS ($p = 0.000$), ระยะเฉียบพลันกับระยะเฉียบพลันในเรื้อรัง ($p = 0.001$), กลุ่มที่เคลื่อนที่ปานกลางถึงมาก ($p = 0.002$), กลุ่มที่ไม่มั่นคง ($p = 0.17$) กลุ่มที่มีประวัติอุบัติเหตุ ($p = 0.02$) จากการวิเคราะห์ด้วย multivariate analysis พบว่าภาวะการเกิด APS เป็นปัจจัยเสี่ยงที่สำคัญที่สุดที่ทำให้เกิดภาวะหัวกระดูกตายจากการขาดเลือดและกระดูกอ่อนสลาย ($p = 0.000$)

สรุป: การเกิดภาวะ APS เป็นปัจจัยเสี่ยงที่สำคัญที่สุดที่ทำให้เกิดภาวะหัวกระดูกตายจากการขาดเลือดและกระดูกอ่อนสลาย ($p = 0.000$) ในกลุ่มที่มีภาวะ APS ที่ไม่มั่นคง มีประวัติอุบัติเหตุ และกลุ่มเฉียบพลันถึงเฉียบพลันในเรื้อรังที่เคลื่อนที่มากควรมีการพิจารณาการรักษาที่เหมาะสมยิ่งขึ้นในอนาคต