Controversies in the Management of Unstable Slipped Capital Femoral Epiphysis

Shaunette Davey, DO[a,*], Tuesday Fisher, MD[b], Tim Schrader, MD[a]

KEYWORDS

• Slipped capital femoral epiphysis • SCFE • Unstable SCFE • Pediatric hip disorders
• Avascular necrosis • Modified dunn osteotomy

KEY POINTS

- Slipped capital femoral epiphysis is the most common hip disorder in children.
- The primary treatment goal includes the prevention of slip progression by stabilizing the epiphysis while avoiding complications.
- There remains controversy about the optimal management of unstable slips as it relates to technique, timing, capsulotomy with rates of avascular necrosis up to 60% in the literature.

INTRODUCTION

First described by the French surgeon Ambroise Pare in the sixteenth century, slipped capital femoral epiphysis (SCFE) remains a disease that both intrigues and divides the orthopedic community.[1] SCFE is defined as anterior superior displacement of the metaphysis of the proximal femur whereas the epiphysis remains within the acetabulum. It is the most common hip disorder affecting the pediatric and adolescent populations, with a variable reported incidence of 0.71 to 10.8 per 100,000.[2,3] The incidence of SCFE in Polynesian, Black, and Hispanic children is 5.6, 3.94, and 2.53 times higher, respectively, when compared with Caucasian children.[3,4] SCFE more commonly affects boys with a male-to-female ratio of 1.5. The age of onset of SCFE is 12.7 to 13.5 years for boys and 11.2 to 12 years for girls.[4,5] There is also seasonal and geographic variability with higher incidence in the north and western parts of the United States than rates in the Midwest and South.

DIAGNOSIS

The diagnosis of SCFE is largely based on the physical examination supported by radiographic imaging. However, careful history also plays an important diagnostic role. Specifically, the duration of symptoms provides pertinent information as to the acuity or chronicity of the slip. A retrospective analysis of 82 unstable SCFEs found that greater than 85% of patients had symptoms before the onset of the slip, with an average duration of symptoms up to 6 weeks before SCFE.[6] Pain location is relevant as SCFE can also manifest as knee pain. The diagnosis can often be missed or delayed especially in patients who present with knee rather than hip pain and those who do not report severe pain. The history should also include changes in gait or weight-bearing status.

The classification system as described by Loder and colleagues is based on physeal stability to predict prognosis. A stable slip is defined as having the ability to bear weight with or

[a] Children's Healthcare of Atlanta, 5445 Meridian Mark Road, Suite 250, Atlanta, GA 30342, USA; [b] Department of Surgery, Uniformed Services University of the Health Sciences, Bethesda, *MD* 20814, USA
* Corresponding author.
E-mail address: sdavey14@gmail.com

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without crutches, whereas unstable slips are ones whereby walking is not possible even with crutch assistance.[7] The Loder classification has come under scrutiny in that it lacks mechanical implications for stability. Stability can be defined as whether the metaphysis moves in unison with the epiphysis. Unstable slips are present when there is independent movement between the metaphysis and epiphysis at the time of surgery.[8]

Physical examination findings suggestive of SCFE include limping, limited hip flexion, and internal rotation, and pain with internal rotation.[9,10] Drehmann's sign, which refers to abduction and external rotation of the hip with passive flexion, is a diagnostic finding. Bilateral lower extremity motion and rotational profiles should be documented and compared with identify motion restrictions that can occur in multiple planes.

Radiographic workup for SCFE includes anteroposterior (AP) pelvis and frog-leg lateral radiographs. Klein's line is the most widely known radiographic measure of SCFE. This is determined by a line drawn along the femoral neck that should intersect the epiphysis. Loss of this intersection correlates with a slip. However, early slips may show more subtle findings such as widening or irregularity of the physis, sharpening of the metaphyseal border of the femoral head, periosteal elevation, loss of anterior concavity to head–neck junction, and metaphyseal blanch sign of Steel which is a double density seen on AP radiographs due to the posterior slip of the epiphysis.[11] Fig. 1.

TREATMENT

The primary goal of treatment of SCFE is to stabilize the physis thereby preventing slip progression and avoiding complications such as chondrolysis and avascular necrosis. In situ screw fixation is the gold standard in the management of SCFE as it is a utilitarian technique that can be performed by all orthopedic surgeons. Despite its widespread use, the application and adjunctive procedures used with in situ screw fixation remain controversial. Utilization of this technique for surgical treatment of unstable slips, and current controversies, will be further discussed in this section.

Fig. 1. Anteroposterior radiograph of the pelvis demonstrating SCFE of left hip.

In Situ Pinning

The widespread use of in situ fixation in SCFE is based on the work of Boyer and colleagues who reported on the satisfactory outcome of 121 patients followed for up to 47 years. In their study, patients with more severe slips fared better with in situ pinning than those in whom reduction was attempted.[12] This study highlighted the role of proximal femoral physeal remodeling after SCFE. The remodeling that occurs with time has also been supported in additional studies. Proponents of this theory believe that the residual deformity poses no clinically significant long-term sequelae and as such, in situ fixation is useful in the management of unstable slips.[13–15] In contrast, others argue that the potential deformity may be significant and initial management should involve more aggressive primary procedures.

The controversy surrounding the treatment of SCFE has been fostered by the paucity of literature regarding the outcome of in situ fixation for unstable slips. In a comparative study, the outcomes of stable versus unstable SCFE after in situ fixation were reported by Lang and colleagues who found 11.1% AVN of femoral head in unstable slips whereas a 1.2% incidence was found in stable slips.[16] This study evaluated 184 SCFEs, 9.8% of which were unstable; however, the mean follow time was only 3.2 months which may not have provided adequate follow-up time to obtain a true incidence of AVN for these unstable slips. Wenger and Bowmar provided a review of the literature which included their experience with unstable slips and recommended that in situ fixation alone may not be sufficient given the rates of AVN reported in these cases. They also noted residual cam deformity should also be considered as it can lead to premature arthritis from articular cartilage injury.[17]

The literature available leaves several unanswered questions regarding the necessity of reduction, timing of surgery, number of screws, and whether to perform capsulotomy.

Reduction Technique

Whether or not an intentional reduction should be performed at the time of in situ fixation is an area of controversy. Some authors argue that reduction has the potential to restore blood flow to the femoral head in the case of twisted or kinked vessels whereas others have concerns regarding the potential for iatrogenic injury to the retinacular vessels leading to the development of osteonecrosis.[18,19] Kitano and colleagues investigated risk factors for the development of AVN after SCFE and found that 7 of 21 unstable SCFE's developed AVN. The only factor that influenced AVN was closed reduction.[19] Interestingly, this was the case with deliberate reductions and "serendipitous reductions" (obtained with patient positioning). Based on these findings, they recommend not performing a reduction in unstable, acute slips. In contrast, Loder and Dietz provided recommendations in their 2012 systematic review of the literature which found that the best treatment of unstable SCFEs is gentle reduction, decompression, and internal fixation.[20] The senior author's practice is to assess physeal stability in the operating room and if unstable, a formal reduction using flexion, abduction, internal rotation followed by extension and adduction is performed, the joint is then reassessed and if deemed acceptable, we then proceed with in situ pinning.

Timing of Surgery

The optimal timing of reduction and operative stabilization in the management of unstable SCFE remains elusive. Unstable slips carry a significant risk of AVN with rates up to 60% in studies.[7,19,21,22] Timely reduction may lead to the restoration of blood flow to the femoral head thus decreasing the risk of AVN. In Loder's classic paper, the definition of "early" as it pertains to surgical timing, was not clearly defined.[7] A retrospective study by Kalogrianitis and colleagues sought to establish a recommended timing for reduction of unstable slips. They found that unstable slips are best stabilized within 24 hours of the slip, if possible, or to delay until 5–7 days to avoid the higher rate of AVN.[23] This study introduced the idea of an unsafe window for the timing of surgical management in unstable SCFE. This has been reviewed more recently in a multicenter study by Kohno and colleagues who evaluated 60 patients with an unstable SCFE treated with closed reduction and pinning or in situ pinning and found AVN developed in 16 of the 60 patients. The rate of AVN was significantly higher in patients with closed reduction and pinning who had surgical intervention between 24 hours and 7 days than those treated before or after this time (10 of 13 patients, $P = .002$).[24] There is inconsistency in the literature on how timing is reported. Some studies report time from presentation to the hospital while others report time from symptoms to surgical intervention. This heterogenicity makes it difficult to precisely draw conclusions on optimal surgical timing to avoid AVN or the concept of an "unsafe window."

Fixation with 1 Versus 2 Screws

One versus 2 screws in situ fixation has been another topic of debate in unstable slips. In his poll of North American surgeons, Sucato found near unanimous agreement that 2 screws are necessary for the management of unstable slips.[25] The rationale for 2 screw fixation has been stronger biomechanical construct with multiple points of fixation. This has been demonstrated in previous biomechanical models, whereby it has been found that 2 screws construct increases stiffness by 33% than a single screw fixation leading to a potential mechanical advantage.[26,27] This, however, may be technically difficult to achieve for some high-grade slips. In high-grade slips as the epiphysis displaces from the metaphysis, the safe zone to place a second screw across the physis narrows. This poses a risk for improperly placed screws and joint penetration. There are also concerns that multiple screws may increase the risk of osteonecrosis. This was reported by Tokmakova and colleagues who found a higher incidence of osteonecrosis in unstable slips treated with multiple pins.[22] Other authors have found no difference in the rate of osteonecrosis between single and multiple screw fixations. The senior author's preferred fixation is with one screw.

Capsulotomy

It has been theorized that hematoma and subsequent vascular compression could be a possible mechanism in the etiology of AVN in unstable SCFE.[28,29] There remains inadequate data in the literature to determine the best treatment method for or against capsulotomy. Herrera-Soto and colleagues reported the mean intracapsular pressure of unstable SCFEs in 13 patients during reduction and subsequent capsulotomy. The intracapsular pressure increased after manipulative reduction but dropped after capsulotomy and decompression.[30] In a meta-analysis reporting of pooled data of 17 articles with 302 unstable SCFE, Ibrahim and colleagues found no association between hip decompression and lower rates

of AVN.[31] In contrast, Parsch and colleagues reported a 4.7% AVN rate in their study of operative management of 64 unstable SCFEs.[32] They attribute to this low rate of AVN to emergent timing of surgery, evacuation of the hematoma by performing capsulotomy, and gentle controlled reduction of the slip.

Vascular flow measurements before and after capsulotomy may provide a means to study the role of reduction and capsulotomy in femoral head perfusion. Schrader and colleagues reviewed 23 hips in which percutaneous intracapsular decompression was performed along with ICP monitoring.[33] (Fig. 2) At 2-year follow-up, there were no AVN cases in patients who had blood flow to the femoral head recorded on ICP monitoring at the time of the study. The best practice evidence has yet to be established as it pertains to capsulotomy. Further studies establishing the role of capsulotomy on femoral head perfusion with mid to long-term follow-up clinical studies are needed.

Modified Dunn

First described in 1964,[34] subcapital realignment osteotomy for SCFE has been modified and popularized over the past 2 decades by Ganz.[35] Advocates of the technique report correction of the head–neck offset and slip angle to near anatomic position due to the restoration of the proximal femoral anatomy.[36,37] However, the procedure is met with numerous potential complications, the most devastating of which is AVN. The most common complications reported in the literature after the modified Dunn procedure include, nonunion of the greater trochanteric osteotomy and implant failure.[37–39] In their report on 40 patients followed for 1 and 3-year minimum after modified Dunn procedure, Ziebarth and colleagues reported 0% osteonecrosis or chondrolysis.[37] Similar excellent outcomes from Ganz' institution in Bern have been reported by Tannast and colleagues, with a 2% AVN rate.[40] In a single surgeon retrospective study, Persinger and colleagues evaluated 31 consecutive hips with a mean follow-up of 27.9 months.[41] They reported an incidence of AVN of 6% after the modified Dunn procedure.

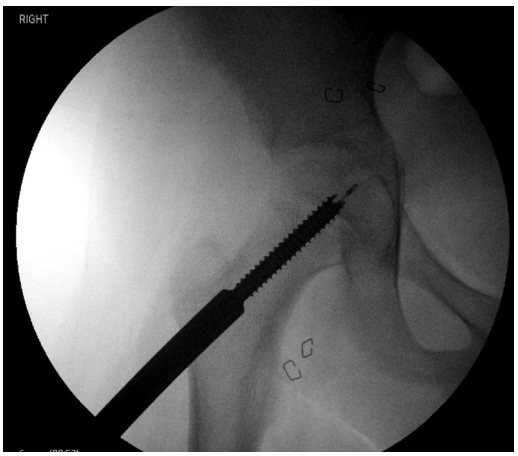

Fig. 2. Anteroposterior radiograph of the Right hip demonstrating in situ screw fixation with ICP probe into the epiphysis through a cannulated screw.

Despite such promising outcomes, these low rates of AVN after modified Dunn have not been replicated uniformly across other institutions. In a multicenter retrospective study, Sankar and colleagues evaluated 27 hips treated via modified Dunn technique and found a 27% rate of osteonecrosis with a relatively short follow-up mean of 22.3 months.[42] In a recent multicenter report of 21 hips followed for a mean of 40 months after modified Dunn, Masquijo and colleagues reported AVN rate of 47% in their series.[39] The modified Dunn is a technically demanding procedure with significant risks for devastating outcomes in the adolescent population. Surgeon and institution volume should be considered before performing this procedure. It is our recommendation that these cases are performed by a high-volume surgeon at tertiary referral centers.

We report the treatment algorithm in our institution used by the senior author for the urgent management of unstable slips. The surgical technique has been previously described by Schrader and colleagues with the use of intraoperative monitoring of perfusion pressure for in situ pinning.[33] Capsulotomy is routinely performed using a Cobb elevator. In situ pinning with one screw is our preference; however, a second screw may be necessary for high-grade slips due to persistent instability. We do not routinely perform arthroscopy or open procedures at the time of presentation of unstable SCFE. We believe that the stabilization of the slip is of utmost importance and that further treatment can be performed at a later time which may necessitate referral to a tertiary center for those not at these institutions. After in situ pinning, the patients are monitored at regular intervals with radiographs and clinical examination correlated with patient-reported symptoms. A modified Dunn is considered in patients with open physis, who report pain with deep flexion/impingement supported by clinical and radiographic findings. Magnetic resonance imaging (MRI) is obtained before surgical intervention. Other advanced imaging such as

computed tomography (CT) scans and bone scintigraphy are not routinely used. The modified Dunn is performed as described by Ganz and colleagues.[35]

In summary, the urgent management of unstable SCFE is met with controversy as to the preferred operative technique for treatment. Further studies with mid–long-term follow-up are needed to best resolve this issue and to provide a clear treatment algorithm for Orthopedic surgeons.

DISCLAIMER

Some authors are employees of the U.S. federal government and the United States Army. The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or reflecting the views of the Department of Defense or US government.

DISCLOSURE

The authors have nothing to disclose.

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