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Slipped Capital Femoral Epiphysis: Prevalence, Pathogenesis, and Natural History

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Abstract

Background Obesity is a risk factor for developing slipped capital femoral epiphysis (SCFE). The long-term outcome after SCFE treatment depends on the severity of residual hip deformity and the occurrence of complications, mainly avascular necrosis (AVN). Femoroacetabular impingement (FAI) is associated with SCFE-related deformity and dysfunction in both short and long term.

Questions/Purposes We examined obesity prevention, early diagnosis, reducing AVN and hip deformity as strategies to reduce SCFE prevalence, and the long-term outcomes after treatment.

Methods A search of the literature using the PubMed database for the key concepts SCFE and treatment, natural history, obesity, and prevalence identified 218, 15, 26, and 49 abstracts, respectively.

Where Are We Now? A correlation between rising childhood obesity and increasing incidence of SCFE has been recently reported. Residual abnormal morphology of the proximal femur is currently believed to be the mechanical cause of FAI and early articular cartilage damage in SCFE.

Where Do We Need to Go? Reducing the increasing prevalence rate of SCFE is important. Treatment of SCFE should aim to reduce AVN rates and residual deformities that lead to FAI to improve the long-term functional and clinical outcomes.

How Do We Get There? Implementing public health policies to reduce childhood obesity should allow for SCFE prevalence to drop. Clinical trials will evaluate whether restoring the femoral head-neck offset to avoid FAI along with SCFE fixation allows for cartilage damage prevention and lower rates of osteoarthritis. The recently described surgical hip dislocation approach is a promising technique that allows anatomic reduction with potential lower AVN rates in the treatment of SCFE.

Introduction

Slipped capital femoral epiphysis (SCFE) is a disorder of the immature hip in which anatomic disruption occurs through the proximal femoral physis. SCFE is associated with a highly variable degree of posterior translation of the epiphysis and simultaneous anterior displacement of the metaphysis. In SCFE, there is a spectrum of each of the following elements: temporal acuity [18]; physical stability of the slipping physis [50]; degree of displacement between the proximal femoral neck and the epiphysis [10, 78]; and the amount of deformity that the protruding anterior metaphyseal prominence presents to the anterior acetabular rim with hip flexion [69].

Prevalence of SCFE varies widely among ethnic groups [46], geographic locations, and different seasons [47, 48]. Pathogenesis includes factors that either reduce the

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resistance to shear or that increase the stresses across the proximal femoral physis [20, 45, 68]; for example, endocrine disorders [52, 83], obesity [9, 14, 34, 61, 63, 67, 71, 82], femoral [28] or acetabular retroversion [17], and coxa profunda [72]. The natural history is largely dependent on both the degree of deformity [11] and the occurrence of complications of treatment, mainly avascular necrosis of the femoral head (AVN) and chondrolysis [37, 39, 50, 53]. Most long-term studies demonstrate some loss of function over time with all degrees of deformity [16, 31, 62, 74, 78]. Contemporary analysis suggests femoroacetabular impingement (FAI) as the major pathomechanical element in SCFE-related dysfunction in both short and long term [21, 22, 41, 42, 58, 69].

In this article, we review the current knowledge on SCFE prevalence, pathophysiology, and natural history ("Where are we now?"). We explore the increase in the prevalence of SCFE over the last decades and its direct pathophysiological association with the childhood obesity pandemic. We further discuss the goals of reducing the occurrence of SCFE and improving its long-term results ("Where do we need to go?"). Finally, we examine obesity prevention, early diagnosis, reducing the rate of AVN, articular cartilage damage, and hip deformity as potential strategies to achieve the aforementioned goals ("How do we get there?").

Search Strategies and Criteria

We searched the PubMed database with terms including "SCFE" combined with "treatment", "natural history", "obesity" and "prevalence". A total of 218, 15, 26, and 49 abstracts were respectively identified for each search. After review of the abstracts by one of the authors (EN), we included peer-reviewed studies in English. For the treatment and natural history search we included studies with a minimum of 2 years followup and radiographic and clinical outcomes. We excluded abstracts of case reports and if they did not specifically investigate one of the searched terms. References of included articles were further searched for additional studies. A total of 80 articles were included in this analysis.

Where Are We Now?

Slipped capital femoral epiphysis is the most common hip disorder affecting adolescents. The overall prevalence varies from 0.71 to 10.8 per 100,000 children [33, 40, 46]. It is known to affect boys more often that girls with a male-to-female ratio of approximately 1.5 [40, 46], although unstable slips seem to be at least as common in females as in males. The prevalence of bilateral SCFE has been reported from 20% to 80% and in bilateral cases, the second SCFE usually occurs during the first year after the first slip [49]. There is a racial variability with a higher prevalence rate in blacks, Hispanics, Polynesians, and Native Americans when compared with whites [8, 40, 46]. There is also seasonal and geographic variability with higher rates in the north and western parts of the United States [40]. The age of onset of SCFE is approximately 12.7 to 13.5 years for boys and 11.2 to 12 years for girls [40, 46]. There is a trend toward onset of SCFE at a younger age compared with previous reports [30, 40, 61]. It has been postulated that this phenomenon correlates with earlier children maturation [64]. Of concern is the fact that the incidence of SCFE has been rising over the past decades [8, 61, 63, 77].

Although different theories [12, 15, 70] have been proposed in the past, the pathogenesis of SCFE remains unclear. Ultrastructural analysis shows slippage of the physis occurs secondary to weakness of the supporting fibrous network caused by collagen disturbance [2, 19, 57]. Mechanical [4, 20, 45, 68], endocrine [52, 85, 86], and metabolic disorders of puberty [60] have been postulated to cause the pathological disturbance in the growth plate that ultimately fail mechanically and slip. Despite previous reports on the association of human leukocyte antigen in identical twins with SCFE [3], a genetic basis has not been established.

The pathogenesis of SCFE is most likely multifactorial. However, mechanical factors, mainly obesity and abnormal morphology of the proximal femur and acetabulum, seem to play a determinant role [85].

The high prevalence of obesity among patients with SCFE is widely recognized [9, 14, 34, 61, 63, 67, 71, 82]. More than 80% of the children diagnosed with SCFE are reportedly obese (body mass index greater than the 95th percentile) [55]. Obesity may increase the risk of SCFE as a result of both higher mechanical loads across the femoral physis and a metabolic disorder. Obese children have decreased femoral anteversion [24] and a more vertical-oriented proximal femoral physis [59]. Increased prevalence of childhood obesity is a worrisome phenomenon. Obesity should be seen as a chronic disease with deleterious health consequences that can potentially constitute a metabolic disorder. Previous reports in the United States have shown the prevalence of obesity has doubled in the past two decades [38]. Three recent reports on American [8], Scottish [61, 63], and Australian children [63] have revealed a close correlation between rising childhood obesity and an increase in the incidence of SCFE worldwide.

Certain abnormal morphologies of the proximal femur have been associated with SCFE. Reduced femoral

anteversion and absolute femoral retroversion may predispose the proximal femoral physis to slip, particularly if the AP shear forces are increased secondary to abnormally high patient weight [28, 81]. The increased obliquity of the proximal femoral physis is reportedly a mechanical factor in the development of SCFE [59, 68]. In the past, axial (version) orientation of the acetabulum was reportedly not found to play a role in the pathogenesis of SCFE [80]. However, recently both acetabular retroversion and increased coverage of the femoral head (coxa profunda) were described in the involved and the uninvolved contralateral hip in patients with SCFE [35, 72].

Traditionally, the natural history of SCFE has been directly related to the degree of the slip and the complications of treatment. The main predictive factors for degree of stable SCFE are age at diagnosis and symptom duration [36, 51]. The most worrisome complication of treatment is AVN of the femoral head, which is strongly associated with SCFE instability [50, 65, 66, 84]. AVN is recognized as a risk factor for early development of severe osteoarthritis of the hip [6, 37, 39]. In the past, two classic studies defined the role of in situ fixation in the treatment of SCFE as a safe and reliable method [10, 11]. The Iowa hip rating score after in situ fixation of moderate and severe chronic SCFE was reportedly 85 out of a possible 100 points at an average of 41 years of followup [11]. However, residual deformities associated with mild SCFE have been reported to play a role in development of hip osteoarthritis (OA) [83]. In addition, an investigation in cadaveric human femora reported approximately 70% incidence of a severe degree of OA in hips with minimum postslip morphology [29].

Recent studies investigating clinical and radiographic evidence of FAI during the first decade after SCFE treatment revealed a persistent femoral deformity in patients undergoing in situ fixation [13, 21]. Dodds et al. [13] reported pain in 31% of 49 patients with a mean followup of 6.1 years after in situ pinning. Fraitzl et al. [21] reported on 16 patients who underwent in situ pinning for mild SCFE with an average of 14 years of followup. None of the 16 patients had normal proximal femoral morphology assessed by the head-neck offset ratio, although only six of 16 patients had a positive impingement provocation test. The authors however reported a lower level of physical activity in the patients studied. They hypothesized that remodeling of the head-neck junction and following a less physically demanding lifestyle may have allowed the patients to remain asymptomatic.

In the past, a high (75%) probability of remodeling of the femoral head-neck junction an average of 7.1 years after in situ pinning of SCFE has been reported [32]. The remodeling process has been associated with 39% excellent and 50% good results assessed by the Heyman and Herndon criteria in a series of 44 patients followed for an average of 11.4 years [7]. Current investigations however have challenged remodeling as a benign process [42, 54, 69]. Using a three-dimensional modeling study, Rab [69] described two types of mechanical conflict between the femoral metaphysis and the acetabulum in the production of abnormal motion after SCFE. Impaction occurs when the proximal femoral metaphysis comes in contact with the acetabular rim, which limits the ROM of the hip, resulting in damage to the anterior part of the acetabular labrum. Inclusion impingement occurs when the remodeled proximal femoral metaphysis enters the acetabulum, which can lead to articular cartilage damage. More recently, Ganz et al. [27] described the pathomechanics of FAI. FAI is a dynamic phenomenon in which there is abnormal contact between the proximal femoral head-neck junction and the acetabular rim. FAI has been associated with the developmental of OA of the hip [27]. The abnormal morphology of the proximal femur is currently believed to be the mechanical cause of FAI and early articular cartilage damage in SCFE [41, 42, 54, 69, 75].

Different investigators have (recently) reported on early acetabular cartilage damage even after mild SCFE [23, 41, 75]. Labral tear and anterosuperior acetabular cartilage damage was reported on hip arthroscopy in four patients with acute to chronic hip pain with SCFE [23]. Leunig and colleagues [41] reported on early mechanical damage to the acetabular cartilage by the prominent metaphysis in mild, moderate, and severe SCFE. The authors postulated that mechanical jamming was the main factor causing direct and early mechanical acetabular rim and cartilage damage that may lead to hip OA [41]. In a retrospective study, Sink et al. [75] reported acetabular cartilage injury in 33 and labral injury in 34 of 39 hips at the time of surgical dislocation of the hip for the treatment of symptomatic stable SCFE.

Where Do We Need to Go?

The increasing incidence of SCFE over the past few decades [8, 61, 63, 77] suggests interventions should be considered both to reduce SCFE prevalence and to promote early diagnosis and treatment. There is an increasing need for community awareness of the symptoms associated with SCFE, thigh and groin pain, limp, and referred knee pain to allow early diagnosis and implement treatment because delayed diagnosis is associated with increased slip severity that ultimately leads to poorer long-term outcome. The correct radiographic technique is important to identify the slip and to avoid abrupt maneuvers that potentially could cause further displacement of the epiphysis.

The correlation between childhood and adolescent SCFE and hip OA needs to be explored further. Treatment

complications, mainly AVN, have a direct impact on the outcome of disease. Therefore, there is a need to develop a treatment strategy that takes into consideration lower risks of both residual hip deformity and AVN. Ideally this would imply two lines of action: (1) improve the understanding of cartilage damage and implement surgical techniques that would avoid early articular cartilage injury in cases of stable SCFE; and (2) improve the knowledge about the pathogenesis of damage to the femoral head blood supply and implementing safe surgical techniques with low risk of further damaging the blood supply in cases of unstable SCFE.

How Do We Get There?

The goal of reducing SCFE incidence might be achieved with interventions on both patient-level and population-level bases. Once SCFE is diagnosed in one hip, prophylactic treatment of the contralateral hip should be considered strongly because of the high prevalence of bilateral SCFE. Although prophylactic pinning of the contralateral hip is still controversial [18, 36, 49], young age at diagnosis, unstable SCFE, endocrine disorders, and unreliable patient followup are relative indications for prophylactic treatment [49]. The increasing incidence of SCFE and childhood obesity [8, 61, 63] reinforces the necessity for promoting population-level health policies to support childhood obesity prevention [56]. Further studies will be required to determine whether reducing the incidence of obesity would have a positive impact on SCFE incidence.

The current recognition of frequent early articular cartilage damage, even in mild SCFE [23, 41, 73], needs to be considered when establishing goals and a strategy of treatment. Traditionally the goal of primary treatment of SCFE has been to stabilize the epiphysis and prevent additional displacement and complications (AVN), thereby restoring reasonable function and delaying or preventing OA [11]. The widely accepted in situ fixation might not be adequate to accomplish these goals [58]. In many hips, in situ fixation serves the purpose of stabilizing the slip and at best allows early symptomatic pain relief. In situ fixation in any but the mildest of slips requires metaphyseal remodeling to allow near-normal ROM of the hip [54, 69]. We now understand that proximal femur remodeling is not necessarily a benign process. Currently, remodeling is believed to be a major factor in articular cartilage damage that occurs as the remodeling metaphysis enters the acetabulum [42, 54, 69]. However, further investigations are essential to identify patients at risk to develop symptomatic FAI after SCFE and to determine whether the abnormal morphology after in situ pinning requires treatment. Concomitant treatment of the slip by screw fixation across the physis and of the abnormal FAI-predisposing morphology of the proximal femur, by a femoral head-neck osteochondroplasty, may be the appropriate treatment for mild SCFE [43]. A prospective randomized clinical trial will be necessary to establish the efficacy of this approach compared with in situ pinning alone to avoid cartilage damage, pain, and development of hip OA after mild SCFE. In moderate to severe SCFE, intertrochanteric osteotomies (ITO) have been indicated to realign the proximal femur [1, 5, 31, 74, 79]. In a previous study, ITO allowed for 90% excellent or good results according to the Southwick criteria after an average of 9 years (range, 2–24 years) [1]. In another series with an average of 24 years of follow-up (range, 20–29 years), 55% of the patients showed no radiographic evidence of OA or clinical pain after an ITO for severe SCFE [74]. However, the role of proximal femur osteotomies to correct healed SCFE deformity and avoid FAI-related cartilage damage and development of OA should also be determined by further studies.

In a recent systematic review of the literature, instability independently predicted AVN: patients with unstable slips had a 9.4-fold greater risk of developing AVN [84]. The rates of AVN of the femoral head after unstable SCFE treatment vary from 5% to 47% [50, 65, 66, 82]. Open reduction seems to play a role in reducing the rates of AVN in unstable SCFE [65, 76, 87]. The recently described surgical hip dislocation (SHD) approach [25] and development of a retinacular flap [26] that protects the blood supply to the femoral head has allowed treatment of unstable SCFE with lower rates of AVN [44, 73, 76, 87]. The SHD approach offers the advantage of providing an anatomic reduction while preserving the soft tissue retinaculum containing the deep branch of the medial circumflex artery, the most important source of blood supply to the femoral head. SHD and subcapital realignment have been reported to have a low complication rate in moderate to severe stable SCFE with wide open physes [76, 87]. However, it is in the unstable SCFE that the SHD approach may theoretically decrease the complication of AVN [87]. Further prospective comparison studies are necessary to determine the role of this cutting-edge technique.

In summary, SCFE is an increasingly common adolescent hip problem with frequent lifelong sequelae. Many opportunities exist for improved understanding of factors determining outcomes and for better decision-making in multiple subgroups. Contemporary treatment strategies that allow anatomic reduction are promising. However, they are technically demanding and should be proven to be safe (low rates of AVN) to become widely implemented. The use of contemporary analytic methods, study designs, and

outcome measures will be essential to determine the role of different surgical strategies in preserving the native hip and avoiding development of hip arthritis requiring future joint arthroplasty.

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