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Osteonecrosis of the Femoral Head Associated With Slipped Capital Femoral Epiphysis

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Study conducted at Children's Hospital and Harvard Medical School, Boston, Massachusetts, U.S.A.

Summary: We performed a retrospective analysis of 212 patients (299 hips) with slipped capital femoral epiphysis (SCFE) over a 9-year period to assess the incidence of osteonecrosis of the femoral head. Risk factors for the occurrence of osteonecrosis and the influence of treatment on the development of osteonecrosis were determined. Osteonecrosis occurred in 4 hips with unstable SCFE (4/27) and did not occur in hips with stable SCFE (0/272). The proportion of hips in which osteonecrosis developed was significantly higher among the unstable hips (4/27 vs. 0/272, $p < 0.0001$). Among those with an unstable hip, younger age at presentation was a predictor of a poorer outcome. Magnitude of the slip, magnitude of reduction, and chronicity of the slip were not predictive of a poorer outcome in the unstable group. In situ fixation of the minimally or moderately displaced "unstable" SCFE demonstrated a favorable outcome. We have identified the hip at risk as an unstable SCFE. The classification of hips as unstable if the epiphysis is displaced from the metaphysis or if the patient is unable to walk is most useful in predicting a hip at risk for osteonecrosis. **Key Words:** Osteonecrosis—Slipped epiphysis—Unstable.

Long-term studies of patients with severe slipped capital femoral epiphysis (SCFE) have shown that excellent function can be expected until the fifth decade if the hip can be stabilized without the occurrence of osteonecrosis (5,6,13,23). The occurrence of osteonecrosis associated with SCFE, however, leads to a poor functional outcome, with many patients requiring subsequent surgery (5,6,14, 24). Therefore, osteonecrosis must be avoided to obtain a good outcome in the treatment of patients with SCFE.

It has been reported that the rate of osteonecrosis in SCFE may depend on the chronicity of the condition (10), the severity of slip (24), or the method of treatment (1,3,12,20). The concept of the "unstable" SCFE, defined as an inability to bear weight even with crutches at the time of presentation, was presented by Loder et al. (19). This classification emphasized the biomechanical stability of the affected hip and reported a 47% incidence of osteonecrosis (14 of 30 patients) in unstable SCFE. No series to date has demonstrated the superiority of any one treatment method with regard to the rate of occurrence of osteonecrosis after unstable SCFE.

The purpose of this study was to evaluate the frequency of osteonecrosis after SCFE, identify possible risk factors for osteonecrosis, and assess the influence of treatment on the development of osteonecrosis.

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MATERIALS AND METHODS

From January 1985 to December 1993, 336 hips were treated for SCFE at Children's Hospital (Boston, MA) as identified by discharge diagnosis from the hospital database. Patients were excluded if they received their primary treatment for SCFE outside our hospital. A total of 299 hips in 212 patients were identified by retrospective analysis to meet the entry criteria of a complete record and minimum 2-year follow-up radiographs. None of the 37 hips excluded from the study had evidence of osteonecrosis based on the incomplete records.

The terms *acute, acute on chronic,* or *chronic* were used to classify an SCFE during the years of this study (10). We reviewed the clinical and radiographic data at the time of presentation to assess the stability of the hip. An SCFE was considered to have "clinical instability" if at the time of presentation the patient was unable to bear weight even with crutches (19). "Radiographic instability" was suspected when the preoperative radiograph showed a clear separation of the epiphysis and the femoral neck, as evidenced by a gross widened or angulated physis in the absence of metaphyseal remodeling, and was confirmed by fluoroscopic examination or by the occurrence of a reduction (Fig. 1). Evidence of reduction,

FIG. 1. A. Anteroposterior radiograph of the pelvis showing unstable slipped capital femoral epiphysis. **B.** Lateral view of hip.

either intentional or inadvertent, was determined by subtracting the slip angle of the preoperative film from the immediate postoperative film. A change of >10° was considered a reduction (10).

Radiographic data were used to determine the severity of the slip, the degree of reduction, position of pins, and evidence of osteonecrosis. The degree of displacement of the femoral epiphysis was determined from anteroposterior and lateral films using the head-shaft angle of Southwick (24) (Fig. 1). The degree of slip was calculated by subtracting the value on the normal side from the value of affected side or, in the case of simultaneous bilateral SCFE, a standard norm of 11° was used (2). The severity of the SCFE was determined using the Boyer (4) method; "mild" SCFE had a difference in the angle on the lateral radiograph of <30°, "moderate" between 30° and 60°, and "severe" a difference >60°.

Radiographs were followed for at least 2 years from the date of treatment to record the appearance of osteonecrosis (9,17). Osteonecrosis was determined by serial radiographs showing the presence of increased density in the femoral head with segmental collapse (Fig. 2).

Patients with unstable SCFE were treated with either urgent operative treatment (n = 9) or were placed in traction pending available operative time (n = 18). In general, mild unstable SCFEs were stabilized with internal fixation in situ. Severe unstable SCFE had one of the following: (i) manipulative reduction and internal fixation, or (ii) open reduction with subcapital cervical resection osteotomy of the femoral neck and internal fixation. One patient had an open bone graft epiphysiodesis without reduction. All manipulative reductions were performed under general anesthesia with longitudinal traction and minimal internal rotation under fluoroscopic guidance. No attempt was made to obtain an anatomic reduction. Rather, the surgeon's evaluation of the preoperative radiograph and the amount of metaphyseal remodeling determined optimal reduction position. The choice of open reduction (n = 2) rather than closed reduction (n = 11) was based on the surgeon's judgment. The subcapital cervical resection osteotomy was a modification of the Mueller technique to shorten the femoral neck and reduce the femoral epiphysis (20). The subcapital cervical resection osteotomy was used only when it was clear that a hip was irreducible by manipulation at the time of the hip arthrotomy.

The fixation devices early in this series were Knowles pins and AO epiphyseal screws. In the latter half of the series, cannulated screws predominated. All implants were inserted under image intensifier control to ensure the proper placement and alignment. The implants were

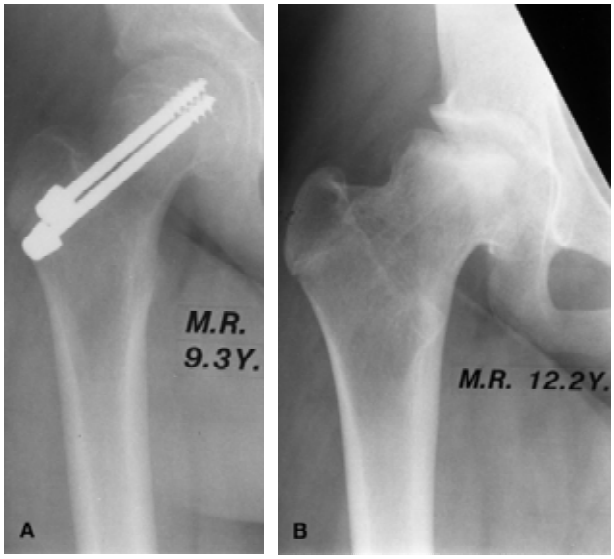

FIG. 2. A. Anteroposterior postoperative radiograph of the right hip, showing reduction after open reduction and AO screw fixation. **B:** Anteroposterior radiograph of the right hip showing osteonecrosis and collapse of the femoral head 2 years after surgery.

placed into the femoral neck and perpendicular to the physis, with the entry site dependent on the degree of epiphyseal displacement.

Statistical Methods

The primary outcome evaluated in this study was the presence or absence of osteonecrosis. Demographic data are expressed in terms of the mean and standard deviation or as percentages. Continuous variables were compared by Student's *t* test and nominal data by the Pearson chi-square test. A two-tailed probability based on Fisher's exact test was used to compare proportions of osteonecrosis between unstable and stable SCFE. Logistic regression was used to confirm whether instability was predictive of osteonecrosis and to identify the risk factors for osteonecrosis in the subgroup of unstable hips. The Wald statistic was used to evaluate the significance of each variable and potential two-way interactions (15). Multiple logistic regression was conducted to identify the multivariate predictors of osteonecrosis using a stepwise criterion of $p < 0.05$ for inclusion in the final model (18). Statistical analysis was performed using SAS (Version 6.12; SAS Institute, Cary, NC) and SPSS (Version 10.0; SPSS, Inc., Chicago, IL) software packages.

RESULTS

There were 299 hips with SCFE reviewed, of which 74 were either acute or acute on chronic. There were 27 unstable SCFEs, 10 of which were acute unstable and 17 acute on chronic unstable. Seven of the 27 hips were unstable by history alone, 2 unstable by radiograph alone, and 18 satisfied both criteria of instability. There were 19 severe slips, 5 moderates, and 3 milds in the unstable group. Demographic characteristics for the stable and unstable groups were similar (Table 1). In the unstable group, one patient had Down syndrome, one had mental retardation with developmental delay, and the remaining patients had no other recognized conditions. Preoperative traction consisting of Buck's traction with 5 lbs. was used on 11 patients, split Russell's traction on 5 patients, and skeletal traction on 2 severe slips. The duration in preoperative traction ranged from <24 hours to 6 days. Osteonecrosis developed in 2 of the 18 patients treated with preoperative traction; both of these had traction for <24 hours. No statistical association was detected between the use of preoperative traction and the development of osteonecrosis.

TABLE 1. *Demographic data on 299 patients with slipped capital femoral epiphysis*

	Stable group	Unstable group
No. of hips	272	27
Mean age, yr (SD)	11.7 (2.0)	11.3 (1.9)
Side of SCFE		
Right	44%	45%
Left	56%	55%
Bilateral	45%	40%
Sex		
Male	61%	63%
Female	39%	37%

SCFE, slipped capital femoral epiphysis; SD, standard deviation.

TABLE 2. *Method of treatment of 27 unstable capital femoral epiphysis with occurrence of osteonecrosis*

Treatment	Ho. of hips	Osteonecrosis
Reduction technique		
Closed manipulation	11	2
Open without osteotomy	2	1
Traction	3	0
Inadvertent	1	0
Subcapital cervical resection osteotomy	6	1
In situ fixation	3	0
Bone graft epiphysiodesis	1	0
Total	27	4

Treatment of the 27 hips with unstable SCFE included 17 reductions, 3 in situ fixations, 6 subcapital cervical resection osteotomies, and 1 bone graft epiphysiodesis (Table 2). Of the 17 reductions, 3 were obtained by traction, 11 were by closed manipulation, 2 were by open reduction, and 1 occurred without manipulation during induction of anesthesia and patient positioning. Three patients with "unstable" SCFE were pinned in situ; two were classified as mild and one as moderate.

In the unstable SCFE group (n = 27), there were 7 patients with single-implant fixation and 19 with double-implant fixations (1 patient had a bone graft without placement of an implant). Central placement of the single or double screws occurred in 26 of the patients. Three of the four patients in whom osteonecrosis developed had a double-screw fixation, and one had single-screw fixation. All of these screws were in the central position with no evidence of protrusion.

There were 272 stable SCFEs, of which 251 slips were treated with in situ fixation. There was no evidence of osteonecrosis in any of these patients. Of the remaining stable SCFEs, four were treated with bone graft epiphysiodesis, eight with an intertrochanteric osteotomy and screw fixation of the SCFE, and nine with subcapital cervical resection osteotomies. There was no evidence of osteonecrosis in this group. However, there was one case of chondrolysis in a severe chronic SCFE that was treated with an intertrochanteric osteotomy. The absence of osteonecrosis in the "stable" SCFE is a significant finding compared with patients with the "unstable" SCFE ($p < 0.0001$, Fisher's exact test).

Osteonecrosis occurred in 4 of the 27 unstable hips; 2 of the patients with osteonecrosis had severe displacement, 1 had moderate displacement, and 1 patient had mild displacement at presentation (Table 3). Osteonecrosis developed in 2 of the 11 patients who had closed manipulative reduction under general anesthesia and in 1 patient of the 2 who had an open manipulative reduction without an osteotomy. One patient with mental retardation/developmental delay, who had a progressive slip after a previous failed in situ fixation of an unstable SCFE, was treated with an open reduction and subcapital cervical resection osteotomy complicated by osteonecrosis. Those unstable slips that were treated with traction re-

TABLE 3. *Data on 4 patients who developed osteonecrosis after treatment for unstable slipped capital femoral epiphysis*

Patient no.	Age (yr)	Severity	Implant	Treatment
1	8	Mild	Knowles pins × 2	Closed reduction
2	9	Severe	AO screw × 2	Open reduction
3	11	Severe	Ace screw × 2	Closed reduction
4	10	Moderate	AO screw × 1	In situ/late osteotomy

AO, Arbeitsgemeinschaft fur Osteosynthesefragen.

duction/internal fixation (n = 3), bone graft epiphysiodesis (n = 1), in situ internal fixation (n = 3), or primary open reduction with subcapital cervical resection osteotomy (n = 5) showed no evidence of osteonecrosis at a minimum 2-year follow up. The mean degree of reduction in SCFEs in which osteonecrosis developed was 21° (15°, 20°, and 28°), and the mean position after reduction to the "chronic position" was 35° (10°, 37°, and 60°). The mean degree of reduction for the unstable group as a whole (excluding the subcapital resection osteotomy patients) was 33° (range, 6°–55°) and the position achieved was 32° degrees (range, 10°–60°).

In the unstable subgroup (n = 27), patients with osteonecrosis were significantly younger than those without osteonecrosis (mean ± SD = 9.5 ± 1.3 years vs. 11.6 ± 1.8 years, $p < 0.05$, Student's t test). Use of preoperative traction, time in traction, traction followed by reduction, initial severity of SCFE, magnitude of reduction, final position, and sex were not found to be significant univariate or multivariate risk factors for osteonecrosis ($p > 0.05$ in each case).

DISCUSSION

In this study, we have shown that the stable SCFE can be successfully treated without the occurrence of osteonecrosis. Implants were safely placed under fluoroscopic guidance to enter the anterolateral femoral neck and cross perpendicular to the physis into the femoral head. In the unstable SCFE, we found that severity of the slip was not a significant factor in determining risk for osteonecrosis. Our findings differed from those of Rattey et al. (23), who reported 4 cases with osteonecrosis in their review of 26 acute SCFEs (3 were moderate slips, whereas 1 was a mild slip). Severity of slip angle did not appear to be exponentially linked to osteonecrosis, and it may be that stability, which was not assessed, was responsible for this poor outcome in their series.

Manipulative reduction has been considered a risk factor for osteonecrosis (6,7,15,25). In our series, manipulative reduction in the unstable SCFE was not associated with an increased risk of osteonecrosis compared with the entire unstable group. This may be due to the controlled nature of the partial reduction under fluoroscopic guidance to a position short of the anatomic position. The susceptibility to avascularity in the unstable SCFE has been demonstrated by Kallio et al. (16). In their study, stable SCFEs had normal epiphyseal vascularity on bone scan at presentation, whereas the unstable group showed some elements of epiphyseal avascularity, emphasizing stability as a predictor of outcome.

The use of preoperative traction in the treatment of the unstable SCFE remains controversial. Casey et al. reviewed 161 hips with SCFE, of which 18 were treated with traction (7). In that study, 11 patients had traction followed by manipulative reduction without the occurrence of osteonecrosis, whereas 5 cases of osteonecrosis occurred in 12 patients who had a formal manipulation without preoperative traction. Dietz favored traction reduction followed by internal fixation, although only 5 of the 13 acute SCFEs were reduced by this method; osteonecrosis developed 1 of the 5 (8). Hall has stated that traction alone produced little in the way of correction while potentially compromising the femoral head vasculature (12). It is difficult to separate the effect of traction from the effect of time in the outcome of treatment. Peterson et al. found that time to reduction was a risk factor for the development of osteonecrosis with manipulative reduction (22). In our series, only 3 of 18 hips reduced while in traction, whereas osteonecrosis developed in 2 of the remaining 15 hips after a subsequent manipulative reduction. Given that the degree of reduction achieved with preoperative skin traction was limited, we are not convinced of the benefits of traction treatment of the unstable SCFE.

An osteotomy of the femoral neck has been associated with high rates of osteonecrosis in the treatment of SCFE (9,11,12,25). Osteonecrosis occurred in one of the six patients treated with a subcapital cervical resection osteotomy in our at risk group of unstable SCFE hips. This patient initially presented with an unstable SCFE treated with an in situ fixation. Further displacement of the femoral head required a revision procedure of subcapital cervical resection osteotomy. Whether the insult to the femoral head's blood supply occurred at the initial event or from the osteotomy is impossible to determine. We noted no occurrence of osteonecrosis in the five patients in this series with open reduction and subcapital cervical resection osteotomy performed as the initial procedure. The osteotomy effectively shortened the femoral neck to allow repositioning of the femoral head without tension to the posterior capsule and vessels. Although our experience with this procedure is limited, it may be of benefit in severe unstable irreducible SCFE as an alternative to pinning in situ or forced manipulative reduction.

A limitation in our study was the low statistical power for comparing treatment groups. A power analysis re-

vealed that 30 hips would be required in each treatment group to provide 80% power for detecting differences in the proportion of osteonecrosis based on a two-tailed Fisher's exact test. In addition, with only four cases of osteonecrosis, we cannot make a definite statement regarding whether reduction of unstable SCFE may be accomplished without increased risk for osteonecrosis. In view of the fact that no significance was shown and the study's low power, further studies are necessary to evaluate the impact of different treatment algorithms on outcome.

We have demonstrated that previously used classifications of SCFE with regard to chronicity and severity have a limited impact in determining outcome. Although controversy remains regarding the causes of osteonecrosis in the treatment of SCFE, we have found that the instability of an SCFE was the only risk factor associated with the development of osteonecrosis. The possibility of osteonecrosis should be clearly identified to parents before initiation of treatment for the patient with an unstable SCFE. We recommend that the unstable SCFE with minimal or moderate displacement be treated with in situ fixation. Manipulative reduction of the severely displaced unstable SCFE, if performed, should be done only under controlled fluoroscopic guidance to the chronic position.

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