Osteonecrosis of the Femoral Head Associated With Slipped Capital Femoral Epiphysis


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.

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,
either intentional or inadvertent, was determined by subtracting the slip angle of the preoperative film from the immediate postoperative film. A change of $>10^\circ$ 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 $11^\circ$ 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 $<30^\circ$, "moderate" between $30^\circ$ and $60^\circ$, and "severe" a difference $>60^\circ$.

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

**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.

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 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>
<thead>
<tr>
<th>TABLE 2. Method of treatment of 27 unstable capital femoral epiphysis with occurrence of osteonecrosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
</tr>
<tr>
<td>------------------------------------------------</td>
</tr>
<tr>
<td>Reduction technique</td>
</tr>
<tr>
<td>Closed manipulation</td>
</tr>
<tr>
<td>Open without osteotomy</td>
</tr>
<tr>
<td>Traction</td>
</tr>
<tr>
<td>Inadvertent</td>
</tr>
<tr>
<td>Subcapital cervical resection osteotomy</td>
</tr>
<tr>
<td>In situ fixation</td>
</tr>
<tr>
<td>Bone graft epiphysiodesis</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>
duction/internal fixation (n = 3), bone graft epiphysiod-

esis (n = 5) showed no evidence of osteonecrosis at a

minimum 2-year follow up. The mean degree of reduc-

tion 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 os-
tonecrosis were significantly younger than those with-

out osteonecrosis (mean ± SD = 9.5 ± 1.3 years vs. 11.6

± 1.8 years, p < 0.05, Student’s t test). Use of preopera-
tive traction, time in traction, traction followed by reduc-
tion, 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 osteo-
necrosis. Implants were safely placed under fluoroscopic

guidance to enter the anterolateral femoral neck and cross perpendicular to the physis in the femoral head. In the unstable SCFE, we found that severity of the slip was not a significant factor in determining risk for os-
tonecrosis. 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 respon-
sible for this poor outcome in their series.

Manipulative reduction has been considered a risk fac-
tor for osteonecrosis (6,7,15,25). In our series, manipu-
larive 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 con-
trolled 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. re-

viewed 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 occur-

rence of osteonecrosis, whereas 5 cases of osteonecrosis

occurred in 12 patients who had a formal manipulation

without preoperative traction. Dietz favored traction re-
duction followed by internal fixation, although only 5 of

the 13 acute SCFEs were reduced by this method; osteo-
necrosis 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 vascu-
lature (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 manipu-
lative reduction (22). In our series, only 3 of 18 hips

were reduced while in traction, whereas osteonecrosis de-
veloped in 2 of the remaining 15 hips after a subsequent

manipulative reduction. Given that the degree of reduc-
tion achieved with preoperative skin traction was limited,

we are not convinced of the benefits of traction treatment

to 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 oste-
totomy 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 expe-

rience 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-

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

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

AO, Arbeitsgemeinschaft fur Osteosynthesefragen.
revealed 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 re-
garding whether reduction of unstable SCFE may be ac-
complished 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 classifi-
cations of SCFE with regard to chronicity and severity
have a limited impact in determining outcome. Although
controversy remains regarding the causes of osteonecro-
sis 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 be-
fore initiation of treatment for the patient with an un-
stable 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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