SLIPPED CAPITAL FEMORAL EPIPHYSIS

INCIDENCE AND CLINICAL ASSESSMENT OF PHYSEAL INSTABILITY

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In an unselected series of 55 cases of slipped capital femoral epiphysis (SCFE) we observed an incidence of 25% of epiphysial reduction, mostly unintentional. Reduction indicated phyeal instability and was associated with an effusion, detected by sonography on admission, and inability to bear weight.

The true prevalence of instability may be higher since an effusion was noted in 33 cases (60%) on the initial sonographic assessment. Serial radiographs showed reduction in 12 (22%), with an average change of 15.1° in the head-neck angle. Serial sonography showed reduction in 7 out of 20 cases (35%), with an average change of 3.7 mm in displacement. In two cases reduction was seen on sonography but not on radiography.

Of the slips which showed subsequent reduction, 12 had had a bone scan on admission; three showed initial epiphysial avascularity but only one progressed to symptomatic avascular necrosis. All stable hips had normal epiphysial vascularity on the initial bone scan. This indicates the importance of injury from the initial displacement in causing avascular necrosis, rather than effusion, vascular compromise or iatrogenic injury from gentle repositioning.

Phyeal instability in SCFE is common and should be assessed clinically on admission. It is indicated by joint effusion or inability to bear weight. A slip is very unlikely to be unstable in a child able to bear weight and with no sonographic effusion.

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Traditionally, the classification of slipped capital femoral epiphysis (SCFE) has been based primarily on the duration of the symptoms and the history (Fahey and O’Brien 1965), but these are often vague. Attempts have been made to arrive at more objective clinical findings based on the stability of the slip. The lesion was not considered acute if there was an adherent physis at open reduction (Fahey and O’Brien 1965), if no improvement was produced after conventional traction in extension (Wiberg 1966), or if gentle manipulation under anaesthesia was not successful (Aadalen et al 1974).

It has recently been noted that a significant proportion of patients who were unable to bear weight on admission (Loder et al 1993) or in whom an effusion in the joint was detected sonographically (Kallio et al 1993) had improvement in the position of the epiphysis during treatment.

We have assessed, retrospectively, an unselected series of children with SCFE, to determine the incidence of phyeal instability, the presence of an effusion on initial sonography of the hip, and the patients’ ability to bear weight on admission to see if these factors have any predictive value in the classification of phyeal stability and prognosis.

PATIENTS AND METHODS

Between 1989 and 1993, 60 consecutive patients with 74 episodes of SCFE were admitted to the Women’s and Children’s Hospital, Adelaide, Australia. Six episodes had to be excluded due to missing or inadequate radiographs and 13 because of missing sonographs showing assessment of effusion. Thus, 55 episodes in 45 patients were available for study, including two bilateral slips and two with implant failure and consequent redisplacement. There were 34 boys and 11 girls with a mean age of 13.3 ± 2.0 years. Their mean weight was 61.3 ± 14 kg and the mean duration of symptoms was 12.3 weeks.

The hospital records were reviewed and the duration of symptoms, traditional classification and the ability to bear weight on admission were noted. The operation notes gave information as to the use of preoperative traction, a fracture table in the operating theatre, closed reduction, and the mode of fixation.

The pre- and postoperative radiographs were reviewed to assess the severity of the slip by measuring both the head-shaft angle (Southwick 1967; Boyer, Mickelson and Ponse-
ti 1981) and the percentage of slip on the frog-lateral projection (Wilson, Jacobs and Schecter 1965), changes after management, and the pin position at operation. An attempt was made to find objective radiological criteria to measure the reduction of the slip. We found all the current methods unreliable. The head-shaft angle varied greatly, even in stable hips (tst of the difference between two examinations was 6° (−16 to 15)) and in contralateral normal hips with apparently identical radiographic projections. The variability increased with larger initial displacement. Criteria for reduction could not be based on an exact amount of change in the head-shaft angle or in the percentage slip. We therefore used the opinion of two independent observers, based on careful comparative visual analysis of the serial radiographs.

Twenty-seven of the patients had a 99mTc bone scan on admission. Generalised increase of activity around the hip, local activity at the physis and any sign of epiphyseal avascularity were noted.

On admission, a sonographic assessment was made of the effusion, physeal displacement and metaphyseal resorption (Kallio et al 1991, 1992). Twenty patients had postoperative sonographic examination which allowed assessment of the changes in the epiphyseal position during the treatment. We have found that sonography is more reliable in showing minimal epiphyseal reduction (Kallio et al 1993).

For comparison of parametric data, the unpaired Student's t-test and Statview programs (Feldman et al 1988) were used. The mean values were given ±1 standard deviation. The chi-squared test was used for testing the differences in proportions.

RESULTS

According to the traditional classification, three hips were considered to show preslip, 12 an acute slip, 8 an acute-on-chronic slip and 32 a chronic slip (Table I).

An effusion was detected by sonography on admission in 33 hips (60%). Reliable retrospective information on the ability to bear weight on admission was available for only 45 hips. In eight patients (18%), weight-bearing or walking was not possible and of these, seven had an effusion (p = 0.06) and five had a subsequent reduction (p = 0.01).

Preoperative traction was used for 13 hips and a fracture table was used in the theatre in 30. Formal manipulative closed reduction by the Leadbetter manoeuvre was attempted for five hips, with improvement in position in two. Open reduction was performed on one hip.

All patients were treated by fixation; in 32 hips with two Knowles pins and in 23 with one cannulated hip screw. In one hip, there was penetration of a Knowles pin into the joint space. This was not detected initially and mild chondrolysis developed; this resolved after the pins were withdrawn six weeks later. One hip had two Knowles pins positioned in the upper lateral quadrant but there were no clinical sequelae.

Displacement. The mean preoperative head-shaft angle was 144.8 ± 17.5°. The slip was considered to be mild in 37 hips, moderate in 13 and severe in five. The mean angle was 134.6 ± 16.9° for the hips with subsequent reduction and 147.6 ± 18.3° for those without reduction (p = 0.02).

The preoperative sonographic displacement was available for 50 hips: five had to be excluded because of advanced remodelling. The mean was 5.9 ± 3.6 mm. The slip was considered mild in 29, moderate in 15, and severe in six. The mean displacement was 8.5 ± 3.5 mm for the hips with later reduction and 5.1 ± 3.3 mm for the hips without reduction (p = 0.003).

Reduction. Epiphyseal reduction was observed in 12 hips (22%) on serial radiographs and was noted on sonography in 7 out of 20 hips (35%). Combining the data gave a total of 14 epiphyseal reductions (25%). Of these, 11 were unintentional and occurred either during preoperative traction or when positioning the patient on the operating table. Two were successful attempted closed manipulations and one was an open reduction.

There was no apparent relationship between reduction and the age, gender or weight of the patients. The traditional classification was unable to predict reduction (p = 0.5). In 32 patients considered to have chronic slip by the traditional classification, seven (22%) had subsequent reduction. In 23 acute cases including preslip and acute-on-chronic slip there was reduction in seven (31%). There was a poor association between the duration of symptoms and the chance of reduction. The mean duration of symptoms was six weeks for those with reduction and 16 weeks for those without reduction (p = 0.07). Of the 39 patients who had had symptoms for more than three weeks nine (23%) had subsequent reduction (p = 0.5).

Sonographic evidence of effusion on admission significantly predicted subsequent epiphyseal reduction (p = 0.003; Table II). Sonography detected all except one unstable slip (sensitivity 93%). This was in a patient with bilateral moderate slip during the early part of the study. These factors resulted in an incorrect assessment of the effusion.

The inability to bear weight on admission was significantly associated with later reduction (p = 0.01) with a

<table>
<thead>
<tr>
<th>Table I. Classification of the 55 hips with SCFE</th>
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<tr>
<td></td>
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<tr>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>Preslip</td>
</tr>
<tr>
<td>Traditional (Fahey and O’Brien 1965)</td>
</tr>
<tr>
<td>Sonographic (Kallio et al 1993)</td>
</tr>
<tr>
<td>Weight-bearing* (Loder et al 1993)</td>
</tr>
</tbody>
</table>

* reliable retrospective information on patients' ability to bear weight for each hip was available in only 45 cases
high degree of specificity (91%). Only three of the 33 hips without reduction were wrongly considered to be unstable on admission (Table III).

Considering both joint effusion and the ability to bear weight, the prediction of reduction was even more accurate with 100% sensitivity and 46% specificity (Table IV).

Reduction was associated with the use of preoperative traction but the patients who were put on traction had more acute symptoms which were associated with an effusion (p = 0.04) and with inability to bear weight (p = 0.06). There was no correlation between reduction and the intraoperative use of a fracture table.

Avascular necrosis (AVN). Only one hip developed symptomatic AVN. This patient had an acute severe slip with epiphyseal avascularity seen on the $^{99m}$Tc bone scan and had open reduction. Two hips had initial epiphyseal avascularity and a closed reduction, but did not develop AVN. The other nine hips with a normal initial epiphyseal bone scan and later reduction did not develop AVN.

**DISCUSSION**

The traditional classification of SCFE into acute, acute-on-chronic and chronic slip is not based on objective findings and is not accurate enough for scientific evaluation. It is probably better to classify the hips into stable and unstable as proposed by Loder et al (1993), provided that there is a satisfactory method for identifying and measuring the degree of instability.

The term ‘instability’ in SCFE has not yet been satisfactorily defined. A stable slip should imply an adherent physis during weight-bearing, active leg movements, or gentle joint manipulation. Physisal instability implies that the displaced epiphysis can move in relation to the metaphysis. This may happen on every step or on active movement of the affected leg. This intra-articular movement will irritate the synovium which may result in pain and persistent joint effusion (Kallio et al 1993), giving either an antalgic limp or inability to bear weight. The position of the unstable epiphysis may change during the treatment and reduction of the slip may occur during preoperative traction or when positioning the patient in the operating theatre. Gentle manipulation or merely positioning the leg into internal rotation may reduce an acute slip but not a chronic one (Busch and Morrissy 1987). An unstable slip is at a potential risk for further displacement.

Serial changes in the epiphyseal position can be detected by radiography (Fahey and O’Brien 1965) and by ultrasonography (Kallio et al 1993). Assessment from serial radiographs is difficult because of variation in the position of the hip and of the X-ray tube. Similar problems arise with CT (Cohen et al 1986) and MRI. Repeated sonography by an experienced technician will currently give the most accurate judgement (Kallio et al 1993).

Loder et al (1993) reported reduction in 28 of 55 hips with acute slip (51%). Our series included a mixture of acute and chronic cases; there was reduction in 25% overall and 31% of the acute and acute-on-chronic groups. The inaccuracy of radiological assessment leads us to rely on sonography. The incidence of effusion on admission was 60%, suggesting that the true rate of instability is somewhere between this figure and the 25% of observed reduction overall.

Loder et al (1993) found a convincing correlation between the ability to bear weight and achieved reduction in a large group of patients with acute SCFE. In our study weight-bearing was an insensitive clinical indicator of a potential epiphyseal reduction, missing 58% of the hips that later became reduced. It was, however, specific for physisal stability in that 91% of the patients who had no reduction

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**Table II. Relationship of sonographic joint effusion (Kallio et al 1993) to epiphyseal reduction in 55 hips**

<table>
<thead>
<tr>
<th>Effusion</th>
<th>Yes</th>
<th>No</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>13</td>
<td>20</td>
<td>33</td>
</tr>
<tr>
<td>No</td>
<td>1</td>
<td>21</td>
<td>22</td>
</tr>
<tr>
<td>Total</td>
<td>14</td>
<td>41</td>
<td>55</td>
</tr>
</tbody>
</table>

**Table III. Relationship of weight-bearing (Loder et al 1993) on admission to epiphyseal reduction in 45 hips**

<table>
<thead>
<tr>
<th>Ability to bear weight</th>
<th>Yes</th>
<th>No</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unable</td>
<td>5</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>Able</td>
<td>7</td>
<td>30</td>
<td>37</td>
</tr>
<tr>
<td>Total</td>
<td>12</td>
<td>33</td>
<td>45</td>
</tr>
</tbody>
</table>

**Table IV. Characteristics of 52 hips showing either stable SCFE (no effusion and able to bear weight) or unstable SCFE (joint effusion and unable to bear weight) by number or mean ± so**

<table>
<thead>
<tr>
<th></th>
<th>Stable (n = 18)</th>
<th>Unstable (n = 34)</th>
<th>p value of difference</th>
</tr>
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<tbody>
<tr>
<td>Male:female</td>
<td>12:6</td>
<td>28:6</td>
<td>0.2</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>14 ± 2</td>
<td>13 ± 2</td>
<td>0.24</td>
</tr>
<tr>
<td>Duration of symptoms (wk)</td>
<td>14 ± 2</td>
<td>6 ± 6</td>
<td>0.0001</td>
</tr>
<tr>
<td>Duration of symptoms &lt; 3 wk/&gt;3 wk</td>
<td>2/16</td>
<td>13/21</td>
<td>0.04</td>
</tr>
<tr>
<td>Sonographic remodelling yes:no</td>
<td>13:4</td>
<td>13:20</td>
<td>0.01</td>
</tr>
<tr>
<td>Sonographic severity of the slip (mm)</td>
<td>5 ± 3</td>
<td>7 ± 4</td>
<td>0.07</td>
</tr>
<tr>
<td>Head-shaft angle (degrees)</td>
<td>145 ± 15</td>
<td>143 ± 21</td>
<td>0.72</td>
</tr>
<tr>
<td>Reduction yes:no</td>
<td>0.18</td>
<td>13:21</td>
<td>0.003</td>
</tr>
<tr>
<td>Complications*</td>
<td>0/18</td>
<td>2/32</td>
<td>0.03</td>
</tr>
</tbody>
</table>

* one hip had epiphyseal avascular necrosis and one had chondrolysis

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were able to bear weight.

We observed a strong association between the sono-
graphic detection of joint fluid and eventual reduction with
39% of the hips with an effusion showing improvement of
the epiphyseal position. The relatively low specificity
(51%) may be explained by the inability of present imaging
techniques to detect subtle changes in position. The real
incidence of instability in the group of patients with an
effusion is probably much higher since effusion was 95% sensitive as a predictor of instability in this series.

Manipulative reduction (Fahey and O'Brien 1965), over-
reduction (Casey, Hamilton and Bobechko 1972; Bishop et al
1978), severe displacement, acute or acute-on-chronic
slip, and inappropriate pin placement (Busch and Morrissy
1987) all carry an increased risk of epiphyseal AVN. A
tense synovial effusion (Casey et al 1972), the timing and
magnitude of the reduction and the use of preoperative
traction (Loder et al 1993) may be important but their role
is uncertain.

Injury from the initial displacement rather than iatrogenic
injury from gentle repositioning or vascular com-
promise due to joint effusion is very important in the
pathogenesis of AVN. In our series gentle reduction in
itself, even in association with a joint effusion, did not
result in AVN in hips with a normal epiphyseal bone scan
on admission. The magnitude of reduction, however, may
be important since the reductions in this study were mostly
unintentional and averaged 15° compared with a mean
reduction of 31° in the patients of Loder et al (1993). They
postulated that early timing of the reduction may be
unwise, but because of the low incidence of AVN, we were
unable to show any correlation with the history of symp-
toms, the use of preoperative traction or the timing of
reduction.

Conclusions. Any slip which presents with either inability
to bear weight or a joint effusion detected by sonography
should be considered potentially unstable. The patient
should be admitted as an emergency for bed rest and early
operation. In those with gross displacement the presence
of an effusion indicates the possibility of successful reduction
with preoperative traction or when positioning the patient
on the operating table. The slip is stable if the patient is
able to bear weight and if there is no effusion detected on
initial sonography. The patient may be admitted to have
surgery semielectively.

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