ORIGINAL ARTICLE

Frequency of radiographic signs of slipped capital femoral epiphysiodesis sequelae in hip arthroplasty candidates for coxarthrosis

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KEYWORDS
Slipped capital femoral epiphysis; Lateral view head-neck index; Osteoarthritis of the hip; Hip X-ray; Femoroacetabular impingement

Summary
Introduction: The rate of osteoarthritis of the hip secondary to slipped capital femoral epiphysis (SCFE) is a subject of debate, and its frequency is underestimated in particular because of subclinical forms that may not be diagnosed during childhood.
Hypothesis: The frequency of radiographic anomalies subsequent to SCFE in adults requiring hip arthroplasty is higher than that reported in recent studies (6% to 15%).
Materials and methods: A prospective single-center epidemiological radiography study was performed by one observer. Hip X-rays of patients who were being treated by arthroplasty for advanced hip osteoarthritis between January 2010 and May 2012 were analyzed. The etiology of osteoarthritis was classified in each patient according to the data obtained (primary, SCFE, dysplasia, protrusio acetabuli, other). The lateral view head-neck index (LVHNI) was used to quantify posterior translation of the femoral head, and identify SCFE sequelae.
Results: One hundred and eighty-six hips were included. Osteoarthritis was considered primary in 51 patients (27.4%), secondary to dysplasia in 42 (22.5%), protrusio acetabuli in 38 (20.5%) or another disease in nine (4.9%) while 46 hips (24.7%) presented a radiographic image suggesting SCFE past history. SCFE type deformities were the primary etiology of osteoarthritis in patients less than 60 years old (30/84 or 35.7%). The mean age of patients in the SCFE group was 56.2 years old (26–80) compared to 66 (54–91) for the primary osteoarthritis group (P < 0.0001). The mean LVHNI was 13% (9–24%) in the SFCE group, the mean body mass index was 27.1 kg/m² (±3.5; 18.2–35.4) in the SFCE group and the male to female ratio was 7.3/1.
Conclusion: Our study identified a population with a morphological SCFE type anomaly of the coxofemoral joint (LVHNI > 9%), which results in the development of earlier osteoarthritis than that found in the rest of the population. SCFE is more common than reported in the literature because it is the first etiology of osteoarthritis of the hip in subjects less than 60 years old.
Level of evidence: Level III. Diagnostic prospective study with a control group.
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Introduction

Slipped capital femoral epiphysis (SCFE) which corresponds to a downwards but especially posterior tilt of the femoral head relative to the neck axis [1–3] is the cause of early osteoarthritis of the hip in adults at rates ranging from 6–15% in the literature [4–10]. The diagnosis of chronic stable forms may be difficult, which is why certain authors have suggested [6,11–16] that there may be a minor form of subclinical SCFE which may remain undiagnosed during childhood and be responsible for certain cases of so-called primary hip osteoarthritis [11]. Nevertheless, these results are debated in the literature because certain authors feel that radiographic signs that are interpreted as SCFE sequelae are the result of arthritis and others, the cause [12–17]. Goodman et al. [12] have confirmed the latter hypothesis by proving that the prevalence of these deformities was stable with age, excluding the presence of degenerative disease. However, very few studies have been performed to evaluate the proportion of osteoarthritis of the hip secondary to SCFE and there are no studies using lateral view hip X-rays to identify this entity.

The hypothesis of this study was that the frequency of radiographic anomalies of SCFE sequelae in adults with end-stage osteoarthritis requiring arthroplasty would be higher than the recent results reported in the literature (between 6% [18–20] and 15% [21]). To evaluate this hypothesis, we used the lateral view head-neck index (LVHNI) [22] which detects and quantifies posterior translation of the femoral head in relation to the neck with good reproducibility based on a specific lateral view of the hip in 45° flexion, 45° abduction and 30° lateral rotation [23]. Posterior translation is considered to be SCFE sequelae when it is greater than 9% [22]. The goal of this study was to provide updated epidemiological results on the frequency of radiographic images suggesting SCFE sequelae in adults presenting with end-stage osteoarthritis of the hip requiring total hip arthroplasty (THA).

Materials and methods

Patients

We performed an epidemiological radiographic, prospective, continuous, single-center study in patients who underwent hip arthroplasty between January 2010 and May 2012 (or 368 arthroplasties). We excluded non-arthritic etiologies (traumatology, osteonecrosis, septic arthritis, inflammatory or tumoral) or 154 hips. Thus, 201 patients (214 hips) whose file was complete and who underwent hip arthroplasty (THA or resurfacing) for osteoarthritis were included. A series of X-rays of the pelvis were performed the day before surgery in the same radiology department including: full weight-bearing, abduction-adduction, neutral and 15° internal rotation of the lower limbs (to correct natural anteversion of the femoral neck); as well as a specific frog leg lateral view in the decubitus-dorsal position in 45° flexion, 45° abduction and 30° lateral rotation. This view, which has been experimentally [23] and clinically [24] validated, exposes the anterior and posterior sides of the femoral neck to identify the real axis of the neck as well as its precise position in relation to the center of the femoral head (Fig. 1). The X-ray tube was placed 120 cm from the patient and the anterior-posterior beam was centered on the pubic symphysis.

Patients were excluded when the severity or type of hip disease made it impossible to obtain high quality AP or lateral X-rays (severely advanced osteoarthritis) (28 hips). Besides the obvious symmetry of the obturator holes and the iliac wings [25,26], we searched for objective criteria on AP X-rays to ensure neutral pelvic rotation (end of coccyx and symphysis pubis aligned within 1 cm) and pelvic version (end of coccyx and symphysis pubis within 1–3 cm of each other) [27–29]. Fifteen degrees of internal femoral rotation was validated if the base of the lesser trochanter was not visible because it was obscured by the internal femoral cortex [30]. These criteria were carefully assessed because a slight modification in rotation can result in significant measurement differences [31]. A total of 186/214 hips (or 178 patients) were included in the study (155 THA and 31 resurfacing) and 28 were excluded or 13%.

Method of evaluation

An automatic, digital AP and lateral X-rays analysis (analysis of hip values) was performed in each hip with the Pictin™ imaging module (Aria, Houdain, France) which we adapted by integrating various specific measurements. This module makes it possible to gather 32 hip measurements (28 on the frontal plane and 4 lateral) with the help of 20 points on AP X-rays, 7 on lateral X-rays. These were then saved along with personal preoperative data (age, gender, body mass index [BMI], medico-surgical history), in a patient file on OrthoWave™ Software (www.orthowave.net, Aria, Houdain, France). The analysis was performed by one examiner (M. J.).

To define SCFE sequelae we used the lateral view head-neck index (LVHNI) which is defined as the ratio between the perpendicular line of the real axis of the femoral neck which passes through the center of the femoral head (d) divided by the diameter of the femoral head (D’) in centimeters (Fig. 2) [22].

\[ \text{LVHNI} = \frac{d}{D'} \times 100 \]
This ratio is expressed as a percentage to prevent metric measurement errors that occur because of inter-individual magnification differences related to a patient's size. SCFE sequelae were considered to be present when the LVHNI was 9% or more [22]. We also looked for the presence of a pistol grip deformity on AP views of the pelvis and measured the alpha angle [32] on lateral views. The LVHNI was the only criteria that identified the SCFE patient group.

This complete hip X-ray analysis diagnosed other architectural anomalies: hip dysplasia was diagnosed by measuring the fundamental angles (CE angle 25–45°, Acetabular Roof Inclination < 13° and CC'D 125–135°) [33,34] and a broken or unbroken Shenton line [29]. Protrusio acetabuli included the diagnosis of coxa profunda if the floor of the fossa acetabuli touched the ilio-ischial line and acetabular over cover if the head went beyond the ilio-ischial line [17]. More rare diagnoses were grouped into the same category (Paget's disease, labral disease, osteopetrosis...). Finally, the diagnosis of primary arthritis was made when none of these other etiologies was confirmed (Table 1).

Statistical methods

The measurement of statistical differences was performed with a Student t-test or Wilcoxon test according to distribution normality (Shapiro-Wilk test). $P < 0.05$ was considered to be significant. Excel software (Microsoft, Redmond, Washington, USA) as well as XLSTAT 2012 software (Addinsoft, Paris, France) were used to perform statistical analyses.

Results

The mean age of the series (186 hips) was 61.53 ± 14.38 years old (26–91) with a slightly larger ratio of men (1.27/1). The mean BMI was 25.91 ± 4.22 kg/m² (17.3–50.15) and 21 subjects were classified as obese (BMI > 30 kg/m²). The pistol grip deformity was found in 43 patients (or 23% of the series). The mean LVHNI was 7.8% (0–24%). Finally, the mean alpha angle was 59.6 ± 14.7° (33–111°). Fifty-one patients (27.4%) had primary osteoarthritis, 42 (22.5%) hip dysplasia, 38 (20.5%) protrusio acetabuli and nine (4.9%) another disease. There were 46 patients (24.7%) who presented with images suggesting SCFE sequelae (or a LVHNI > 9%) (Fig. 3). SCFE represented the first etiology of osteoarthritis of the hip in patients under the age of 60 (30/84 or 35.7%) (Fig. 4). Analysis by age group showed that SCFE was also the first cause of osteoarthritis in patients between 40 and 50 years.

Figure 2  Position of points to calculate the HVFNI: a: 4 points are positioned along the axis of the neck forming two line segments. The line joining the middle of these two segments represents the real axis of the femoral neck; b: P1, P2 and P3 are placed on the circumference of the femoral head and used to determine its center (c); c: d is the distance between the center of the femoral head and the perpendicular line where the real axis of the neck that passes through the center of the head.
Table 1  Table summarizing the comparison of radiological and clinical data for the primary osteoarthritis group and osteoarthritis from different etiologies. The statistical comparison is in relation to the primary osteoarthritis group.

<table>
<thead>
<tr>
<th></th>
<th>Primary osteoarthritis group (51 hips)</th>
<th>SCFE group (46 hips)</th>
<th>Hip dysplasia group (42 hips)</th>
<th>Protrusio acetabuli group (38 hips)</th>
<th>Other causes group (9 hips)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age (years)</td>
<td>66.60 ± 12.66 (54–91)</td>
<td>56.23 ± 12.46 (26–80)*</td>
<td>52.8 ± 14.23 (26–87)*</td>
<td>70.1 ± 10.04 (26–87)*</td>
<td>64.3 ± 14.51 (26–80)*</td>
</tr>
<tr>
<td>Gender ratio</td>
<td>1.13 M/1 W</td>
<td>7.3 M/1 W*</td>
<td>0.72 M/1 W (NS)</td>
<td>0.74 M/1 W (NS)</td>
<td>0.5 M/1 W*</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>25.81 ± 4.55 (19.28–35.4)</td>
<td>27.1 ± 3.5 (18.25–35.4)</td>
<td>24.83 ± 3.84 (17.3–31) (NS)</td>
<td>25.8 ± 4.2 (19.26–50.15) (NS)</td>
<td>26.3 ± 3.3 (23–33.1) (NS)</td>
</tr>
<tr>
<td>Pistol grip (%)</td>
<td>6</td>
<td>78*</td>
<td>2 (NS)</td>
<td>8 (NS)</td>
<td>0*</td>
</tr>
<tr>
<td>LVHNI (%)</td>
<td>4.3 (0–8)</td>
<td>13 (9–24)*</td>
<td>6.3 (0–11) (NS)</td>
<td>7.7 (0–14) (NS)</td>
<td>5.5 (0–8) (NS)</td>
</tr>
<tr>
<td>Alpha angle (°)</td>
<td>56.7 ± 14.31 (36–89)</td>
<td>76.7 ± 11.92 (44–111)*</td>
<td>51.7 ± 8.9 (NS)</td>
<td>53.9 ± 9.7 (NS)</td>
<td>50.2 ± 12.6 (NS)</td>
</tr>
</tbody>
</table>

*: significant difference; NS: non-significant difference; SCFE: slipped capital femoral epiphysis; LVHNI: lateral view head-neck index.

The mean age of the group with SCFE was 56.23 ± 12.46 years old (26–80), they were mostly men (sex-ratio: 7.3/1) and slightly overweight with a mean BMI of 27.1 ± 3.5 kg/m² (18.25–35.4). The mean LVHNI was 13% (9–24%) and a pistol grip deformity was found in 36/46 cases (78%). Finally, the mean alpha angle was 76.7 ± 11.92° (44–111°) (P < 0.01).

There were several differences between this group and the group with primary osteoarthritis:

- the mean age of patients in the SCFE group was approximately 10 years younger than in the primary arthrosis group which was 66.6 ± 12.66 years old (54–91) (P < 0.0001);
- the higher proportion of men was not as marked in the primary osteoarthritis group (sex-ratio: 1.13/1) (Table 1);
- the mean BMI (27.1 kg/m² vs 25.81 kg/m²; P = 0.11) and the mean alpha angle (76.7° vs 56.7°; P < 0.001) was higher in the SCFE group;
- 91% of the alpha angle measurements were above 55° in the SCFE group compared to 43% in the primary arthrosis group;
- the pistol grip deformity was more frequent in the SCFE group (78% vs 6%). However, 22% of the hips presenting with SFCE did not have this deformity (Table 1).

Discussion

The goal of this study was to identify the frequency of SFCE using a new diagnostic tool in adults with end-stage osteoarthritis of the hip requiring hip arthroplasty. This study made it possible to determine that the real number of SFCE is more important than described in literature because this etiology was the first cause of osteoarthritis in young subjects (≤60 years old, 35.7%) and the second cause if all age groups were included (24.7%).

There are several limits to this study. First, the results of this epidemiological study cannot be extended to the general population because it was a single-center study. On the other hand with this design, the test bias was reduced.
Frequency of radiographic signs of epiphysiolysis in coxarthrosis

Figure 5  Distribution of the etiologies of osteoarthritis of the hip by age group. Hip dysplasia was the first cause of osteoarthritis of the hip in young subjects under the age of 40, SCFE type sequelae was the first cause in subjects whose mean age was between 40 and 60, protrusio acetabuli was the first cause in subjects over 60.

...all X-rays were performed in the same unit, using the same protocol and were interpreted by the same operator with computer software. Also the number of excluded patients was high compared to the total number of patients (28/214 or 13%). However, this percentage was still acceptable and necessary to allow us to optimize the measurements and results by excluding X-rays that did not meet our strict criteria of quality. Finally, the single observer analysis creates a subjective bias, but reduces the interpretation bias. The role of SFCE in the progression of osteoarthritis of the hip has been suggested by several authors [4,17,35]. It causes local cam-effect lesions (labral or cartilaginous), resulting in medium term osteoarthritis [6,8,18,36]. The development of anterior femoracetabular impingement due to head-neck deformity has been contested [13,14] but Goodman et al. [17] showed that the prevalence of SFCE was identical in all age groups suggesting that this anomaly is not the consequence of osteoarthritis, but the cause.

The frequency of deformities from SFCE sequelae varies greatly depending on the diagnostic criteria: the Norwegian register only identified SFCE in 6% of patients under 60 based on APX-rays [19]. Lequesne et al. [37] noted that 15% of 200 patients with osteoarthritis of the hip presented with a morphological anomaly secondary to SFCE (caput varum) based on AP X-rays. Solomon [38] (anatomical study) showed that 59/188 (35.4%) patients with osteoarthritis of the hip presented with SFCE sequelae, Murray [6] found that 39.5% had a “tilt deformity” based on analysis of AP X-rays. Our figure of 24.7% is lower than that in previous series.

Nevertheless, we should mention the lack of reproducibility and precision of the femoral head ratio of Murray or caput varum of Lequesne [14] and especially that most of those series were limited to AP X-rays.

More recently, Clohisy et al. [18] evaluated the hip X-rays of 337 patients under 50 years old who underwent hip arthroplasty for osteoarthritis and only found SFCE sequelae in 6.2% (however judgment criteria were not described), primary osteoarthritis in 35.9% and hip dysplasia in 48.4%. The proportion of hip dysplasias (42%) was slightly lower in the subjects under 50 in our series while the percentage of SFCE (37%) was higher, which reduced the percentage of subjects with primary osteoarthritis of the hip (14%) showing that the frequency of the latter was underestimated which has been suggested by numerous other authors [6,11,33,38—41]. Over time as the understanding of the physiopathological mechanisms and available diagnostic means have improved, the proportion of patients with so-called primary hip osteoarthritis has decreased. Our series identified 27.4% of patients with primary hip osteoarthritis all ages combined, which is much lower than the range of 36—84% reported in the literature [33,39—42].

All of the studies in the literature evaluating SCFE have reported a large majority of men whatever the judgment criteria (pistol grip deformity, femoral head ratio, cadaveric study) with a male to female sex-ratio from 1.3/1 to 14/1 [5,11,28,35,38,43]. Our series is in the middle of this range with a sex-ratio of 7.3/1, which is higher than the rates reported in pediatric surgical series (1.65/1 [2] and 1.9/1 [44]). Detection of the pistol grip deformity underestimates
SFCE sequelae because only 78% of patients in the SFCE group had this deformity which is much less than the 95% suggested by Gosvig et al. [33].

Nevertheless, the main limitation of the pistol grip deformity is its subjectivity since Tanzer and Noizeux [16] showed that 100% of the subjects with hip osteoarthritis presented with this deformity. The body mass index of the subjects in the SCFC group (27.1 kg/m²) was slightly higher than the hip osteoarthritis group whatever the etiology (25.91 kg/m²) suggesting, like other authors, that SCFE is associated with being overweight which increases the mechanical stress on the cartilaginous growth plate [42]. These stresses can also be due to overtraining in sports [43,45]. It should be noted that the mean BMI of our entire series (178 patients) was fairly low (25.91 kg/m²) while a link between obesity and osteoarthritis of the hip has been shown [44,46].

The Notzli et al. [32] alpha angle can be used to identify cam-effect femoracetabular impingement which may be caused by SCFE [5,35]. This measurement has been validated on axial MRI images and has been used to search for impingement in the hip on standard X-rays [47–50]. This measurement was validated experimentally on a 45°/45°/30° frog leg view [23]. We therefore determined this angle to confirm the relationship between radiographic impingement and SCFE sequelae. The mean alpha angle was 76.7 ± 11.92 (44–111) in the SCFC group which is largely more than the pathological alpha angle (55°). The difference was highly significant compared to the primary hip osteoarthritis group (56.7 ± 14.31 [36–89]) (P < 0.001). These results suggest that there is a relationship between cam-effect anterior femoracetabular impingement and SCFE but this needs to be confirmed in a longitudinal study.

Conclusion

Our study identified a population with a morphological SCFE type anomaly of the coxofemoral joint LHNI > 9% which results in the development of early osteoarthritis of the hip. This population is young, male and slightly overweight compared to the population presenting with primary osteoarthritis. SCFE is more frequent than described in the literature because it is the primary etiology of osteoarthritis of the hip in subjects under the age of 60.

Disclosure of interest

P. Chiron is a consultant for Zimmer, Smith and Nephew and Sanofi and has received royalties from Zimmer and Integra. The other authors declare that they have no conflicts of interest concerning this article.

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