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ORIGINAL ARTICLE

L. Billing
H.G. Bogren
J. Wallin

Reliable X-ray diagnosis of slipped capital femoral epiphysis by combining the conventional and a new simplified geometrical method

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L. Billing · J. Wallin
Department of Radiology, Östra Hospital, University of Gothenburg, Sweden

H.G. Bogren (✉)
Department of Radiology, University of California, Davis Medical Center, Ambulatory Care Center, 1460 Y Street, Suite 3100, Sacramento, CA 95817, USA
E-mail: hugo.bogren@ucdmc.ucdavis.ed

Abstract *Background:* The diagnosis of subtle slipped capital femoral epiphysis (SCFE), for example in the contralateral asymptomatic hip, may require use of an exactly defined and reproducible lateral view where the slipping angle can be measured. *Objective:* To test a simplified geometrical method and compare it to the conventional method (AP and frogleg views). *Materials and methods:* The two methods were compared in 95 normal children 9–14 years old and 100 children 9–20 years old with SCFE. *Results:* The slipping angle (SA) measurements had very high reproducibility, and the new method was diagnostically superior to the conventional method ($P < 0.05$). *Conclusion:* An exactly defined and reproducible lateral view is recommended for the X-ray diagnosis of SCFE. Nontraumatic SCFE appears to be bilateral in all cases.

Keywords Slipped capital femoral epiphysis · True lateral view · Slipping angle · Bilaterality of SCFE · Frogleg view

Introduction

Slipped capital femoral epiphysis (SCFE) is a rather uncommon disease in children 8–16 years old. The incidence varies with race and gender, being higher in boys than in girls and more common in black children than in white [1,2]. The diagnosis in advanced cases is easy clinically and radiographically and can be made on standard AP and frogleg views of the pelvis and hips, a method used worldwide. The diagnosis in subtle cases, when the slip is small, particularly in the contralateral asymptomatic hip, is difficult and requires exactly defined and reproducible AP and lateral views of the proximal femur.

The etiology is multifactorial, intrinsic or extrinsic [3]. Traumatic and post-traumatic cases are rare and not discussed here. The intrinsic factors may be endocrine, vascular, hereditary or toxic [4], but the etiology is still obscure in most individual cases.

Bilaterality is to be expected in all cases except traumatic where the force may act on one hip only. In all others the cause is unknown, but is assumed to be an agent that has systemic effects. It can therefore be expected to act on both hips equally much, although one hip may be more sensitive and therefore slip more than the other.

SCFE begins with fissures through the growth plate [5]. The epiphysis is then displaced by a rotational slip and tilt most often strictly posteriorly causing an angulation between the epiphysis and the femur [6,7]. The slip causes anatomical alterations in the femoral head and neck that may be seen as 1) radiographical signs on AP and frogleg views – the conventional method, or 2) measured as the slipping angle SA in *an exactly defined lateral view* (*view C – the geometical method*).

Materials and methods

Ninety-five hips in 9- to 14-year-old *normal* subjects were examined using the geometrical method. Of 100 SCFE children, 33 were examined using the frogleg view while view C was used in 67. There were 67 boys and 33 girls, mean age 13.6 ± 2 years (range 9–20).

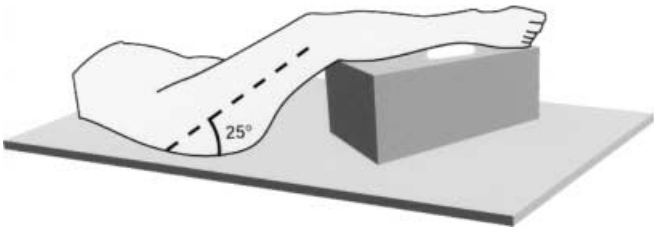

Fig. 1. Positioning of the femur for the lateral view. The knee is flexed 90°. The femur is rotated outwards 90° by placing the lower leg horizontal on a box of such a height that the angle between the femur and the tabletop is 25° (*e*)

The average age at follow-up was 46.3 ± 3.8 years [3]. All measurements were made by two observers.

X-ray positioning and measurements

An absolute prerequisite for measuring an anatomical angle as its X-ray projection is that the object be positioned correctly. This requires that the two anatomical structures (the anatomical 'lines of the slipping angle') are parallel to the X-ray film. If not, the true slipping angle cannot be measured correctly.

The X-ray view – i.e.. the projection of the proximal femoral end – changes in appearance with changes in positioning of the femur. Therefore, an exactly defined positioning of the femur on the X-ray tabletop is a prerequisite for an exact measurement and advantageous also for evaluating the 'signs' of SCFE. If the positioning has been changed between two examinations, it may be difficult to compare and interpret the films.

The "geometrical method"

The position of the femur on the X-ray tabletop is defined in two dimensions: (1) the angle of elevation, *e*, between the diaphysis and the tabletop as illustrated in Fig. 1. If *e* is 0°, the femur is horizontal. (2) The angle of rotation, *r*, which may be described as follows: with the knee flexed 90°, the lower leg may be used as an hour hand of a clock. If it is in a vertical plane, e.g., the lower leg is hanging over the distal end of the tabletop, the angle *r* is defined to be 0°. If the femur is rotated outwards 90°, the lower leg is horizontal and $r = 90°$ (see Fig. 1). A femur positioned with $e = 0°$, $r = -20°$ is horizontal and somewhat rotated inwards. The neck of the femur is then almost horizontal (the angle of anteversion is compensated). This position of the femur gives the *AP-view A*, which is ideal for study of the 'geometrical anatomy' of the femoral end (Fig. 2, view A).

The following lines may be drawn on view A:

- Axis 1 = the midline of the diaphysis
- Axis 2 = the midline of the femoral neck
- Axis 3 = prolongation of the central straight part of the physis
- Axis P_1 = a line perpendicular to axis 1
- Angle *s* = the angle between axis 3 and P_1. It is normally 25° [6]
- Angle *cd* = angle between axes 1 and 2. Normally about 50°
- Axis B = bisector of angle cd and thus perpendicular to axis 3 (see Fig. 2)

Axis 3, which represents the base of the epiphysis, is perpendicular to axis B.

An AP view positioned ($e = 0°$, $r = 0°$) is also suitable, as this view gives almost the same measure of *s*. In routine work the AP view from the conventional method (the angle *r* may be between 0 and - 20°) is satisfactory.

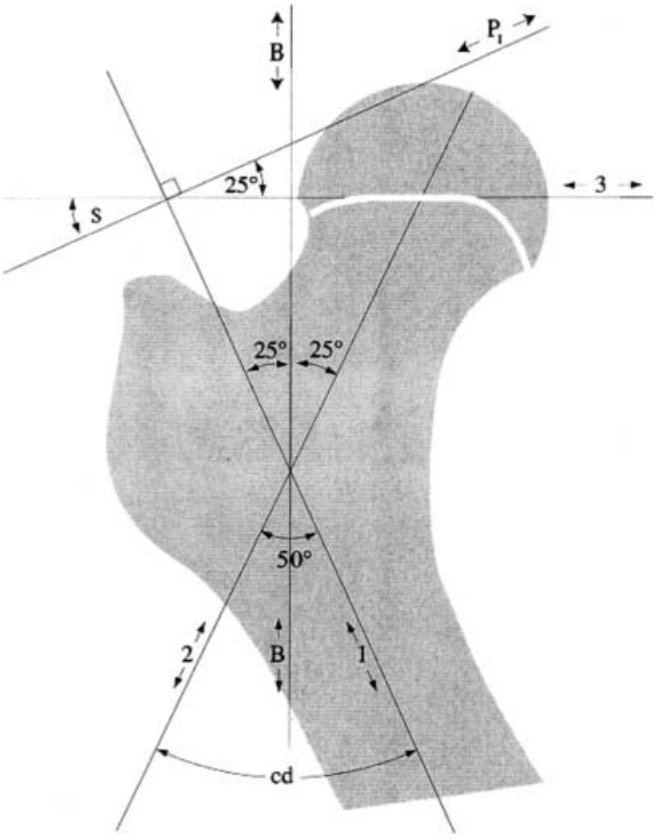

Fig. 2. Drawing of view A. The axes 1, 2, 3 and P_1, described in the text are drawn as well as the angle *s*, normally 25°, and *cd*, normally 50°. The bisector *B* of the angle *cd* is marked and perpendicular to axis 3

The mobility of the hip joint may be restricted by an outwards contracture, which makes it difficult to position for the conventional AP view correctly. Even if such is the case, one may assume that the angle s is 25° and go on with the lateral view, which most often gives the diagnosis.

However, if an exact view A is desired, one may turn the patient prone and flex the knee 90°. The lower leg may then deviate medially owing to the contracture. In the prone position one may place a pillow under the contralateral hip so that the pelvis is turned and the lower leg deviates 0° up to 20° laterally. If the epiphysis has slipped, it will be projected more or less axially instead of in profile. The growth plate may look indistinct or may not be seen. Either way, the angle *cd* may be measured and as $e = cd/2$, this *e*-measure is used for an exact positioning for the lateral view C (Fig. 3).

Lateral view

When positioning for the *lateral view C*, $e = 25°$, and $r = 90°$. The base of the epiphysis is then vertical. See Figs. 1 and 3. On this view C, the slipping angle *SA* may be measured. The following axes and angles may be drawn on Fig. 3C and 4C, which represent a normal hip and SCFE, respectively.

- Axis 1 = a line parallel to the anterior, proximally straight outline of the diaphysis
- Axis 2 = a line parallel to the anterior, distally straight outline of the femoral neck disregarding a possible resorption of the proximal part

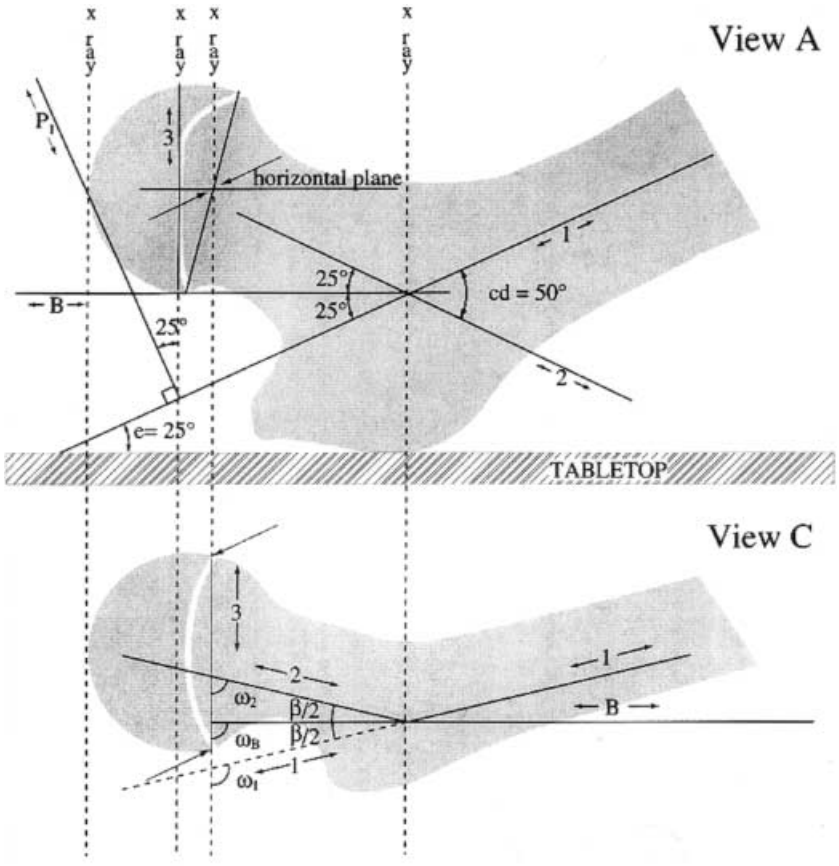

Fig. 3. Here view A (Fig. 2) is rotated 90° around axis B to a vertical position and is viewed horizontally. The drawing illustrates the image of the femur positioned for view C (as in Fig. 1). Axis B is horizontal and thus a perfect side or leg of angle. (An angle is formed by two rays, sides, or legs of angle, which extend from a common point, the vertex of the angle.) Using a vertical X-ray beam, drawing C is obtained. The angles between axis 3 and axes 1, B and 2, respectively, are marked ω_1, ω_B and ω_2. The angle w_B is normally 90° and is always $= \omega_2 + \beta/2$. The *arrows* are explained in the legend to Fig. 4. SA = 0° (angle between P_B and axis 3)

- Axis 3 = the base of the epiphysis – a line between the anterior and posterior margin of the epiphysis and thus a chord in the arc representing the physis
- Angle β = the angle between axes 1 and 2 and thus a projection of the real angle *cd* on Fig. 3A
- Axis B = bisector of the β-angle, Figs. 3C and 4C

A prerequisite to view C is that axis 3 (Fig. 3A) is vertical. Since axis 3 is vertical, axis B is horizontal.

Axis B is horizontal in reality in Figs. 3A and 4 and projected as B in Figs. 3C and 4C. Thus B is the ideal 'line of an angle' representing the femur when we measure the slipping angle (SA) in Figs. 3 and 4. In the film plane the perpendicular P_B to B (Fig. 4C) is as good as B as a 'line of angle.' The anatomical basis for the other 'line of an angle' representing the epiphysis is described and shown in Fig. 4A and projected as axis 3 in Figs. 4C and in 3C. *SA* is the angle between P_B and axis 3, which is 0 in Fig. 3 where P_B and axis 3 are parallel. When the rotational slip and tilting of the epiphysis increases, the slipping angle (SA) increases (Fig. 4C).

For a more detailed description of the radiographic method and the geometry and projection theory behind the measurements see Billing [6], Wesstein [8] and legends to Figs. 3 and 4.

Results

Accuracy and clinical correlations

The *reliability* of the SA-measurement that is the mean difference in the SA measured by two observers was found to be 0.85° ($P < 0.001$) (95 confidence limits 0.60, 1.11°) [6,9]. These numbers are the same for the original [6] and the present simplified method.

SA measurements – clinical correlations

In the 95 hips in normal subjects ages 9–14, the mean SA (M_{SA}) was found to be $-0.8° \pm 3.7°$. In 23 patients with unilateral SCFE (the first 23 consecutive patients of the 42 patients in Table 1), the asymptomatic hip had an M_{SA} of $6.6° \pm 3.2°$. The difference between the two groups equals $7.4° \pm 0.8°$, which is statistically significant ($P = 0.001$) [9]. See Fig. 5.

If SA $< 7°$, all patients were clinically normal and were found to be normal at follow-up to closure of the growth plate. If SA $> 12°$, all patients had SCFE.

In 100 hips with asymptomatic contralateral slip, the frogleg view was used exclusively in 33 and view C in 67, as described by Jerre et al. [9]. Table 1 shows data taken from Jerre et al. [9] where the two methods are compared, no. 1 at the primary admission, no. 2 at follow-up study during adolescence, and no. 3 at follow-up studies as adults, including review of the old radiographs. Eight out of 33 were diagnosed before closure of the physis with the frogleg view, while 33 out of 67 were

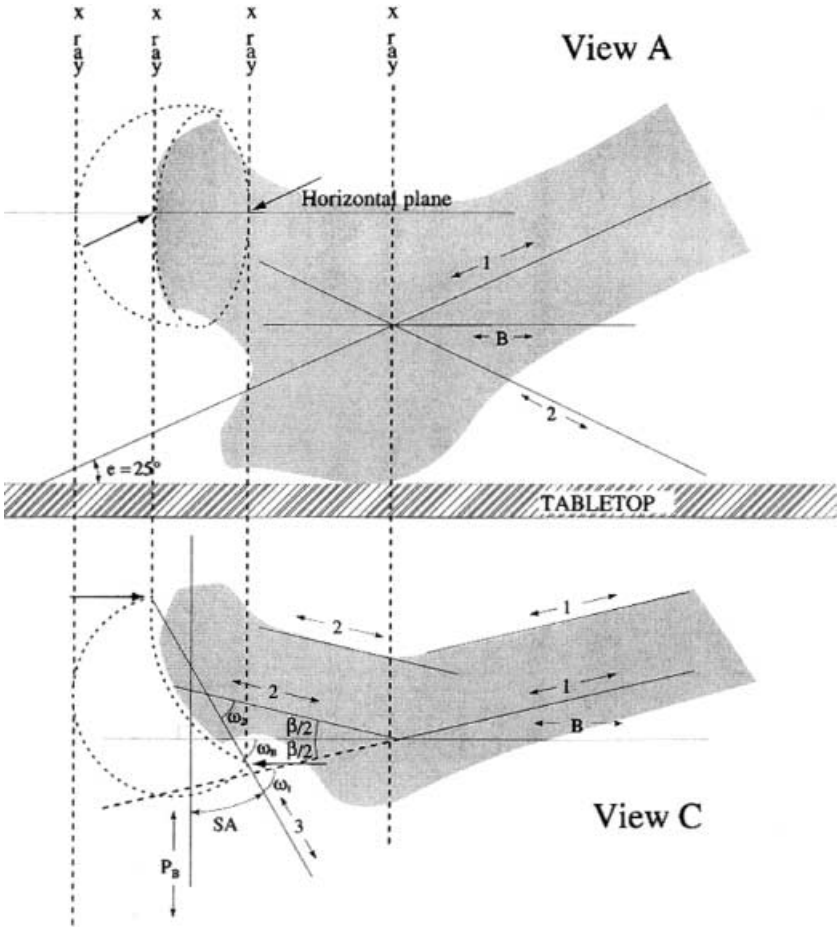

Fig. 4. Drawing of AP view of a slipped epiphysis positioned for view C, i.e., fundamentally as in Fig. 3. In view A the vertical X-ray is a tangent to the epiphysis at the two points marked with *arrows*, both in a horizontal plane, and are therefore the other perfect side or leg of angle. The projection of these points is marked similarly on view C, and defines axis 3. This projection of the horizontal diameter of the base of the epiphysis is a perfect side or leg of angle. This figure is a description of $SA = 90° - \omega_B = 90 - (\omega_2 + \beta/2)$

Table 1. Number of patients with bilateral slips as determined using the frog lateral view and the standardized lateral view according to Billing (complete table from Jerre et al. [9])

	Frog lateral view $n = 33$	Standardized lateral view according to Billing $n = 67$
Diagnosed at primary admission	4	19
Diagnosed later during adolescence	4	14
Diagnosed at follow-up as adults	9	9
Total	17	42

diagnosed using the view C. The difference in detectability is significant with a P value of 0.030, as analyzed by Chi square [10]. When we compared the subjects that were diagnosed as adults, 9 in each group, with those who were diagnosed before closure of the physis, 8 in the frogleg group and 33 in the view C group, the P value equaled 0.038. Nine of 17 were not detected during adolescence using the frogleg view compared to 9 out of 42 with the true lateral view ($P = 0.001$).

Discussion

The use of *view C* was more accurate than use of the *frogleg view* with significantly higher detectability before the closure of the growth plate. In the adult group more bilateral slips had been missed during adolescence with the frogleg view (27%) than with the true lateral view (13%) ($P = 0.001$). It is therefore advantageous to use view C in adolescence to detect all slips, so that they can be pinned immediately, while the growth plate is still open, to prevent further slip. However, mild or borderline cases (SA 7°–12°) were not detected at the first routine measurement even with the true lateral view, only at a second review by an in the diagnosis of SCFE well-trained radiologist. The average radiologist may miss similar cases. However, a follow-up should always be done in the asymptomatic hip since we now know that the slip is always bilateral.

We believe that bilaterality is to be expected in all cases except the rare traumatic cases where the cause of the slip is unknown and it is believed to be metabolic, chemical, endocrinological, or genetic etc. Whatever the provoking factor or agent, the slip must influence both

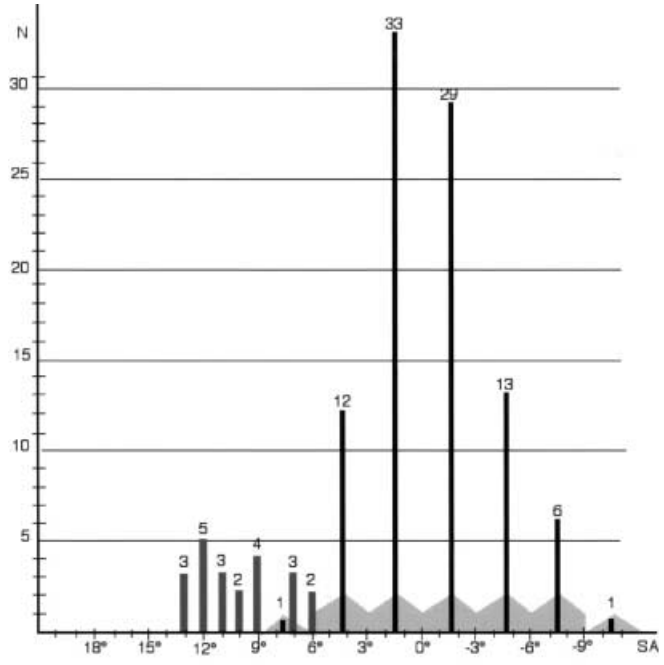

Fig. 5. Histogram and bar diagram showing 95 normal hips (*black*) versus 23 asymptomatic contralateral hips (*gray*). M_{SA} in normal hips equals $-0.8° \pm 3.7°$ in contralateral hips $6.6° \pm 3.2°$ ($P = 0.001$). The difference is $7.4° \pm 0.8°$ ($P = 0.001$). All data from Billing [6], p. 45

hips equally. One hip may be more sensitive than the other so that the slip gets larger in one hip or one hip may have a higher load than the other perhaps habitually in overweight patients.

The difference between normal and contralateral asymptomatic hips was found to be significant ($P = 0.001$, see Fig. 5), which means that SCFE is always bilateral except for rare cases caused by heavy trauma, and such cases were not included in this series [11]. No contralateral SCFE hip had an SA of or around 0°. In only two cases was SA 6°; in all others it was larger. The incidence of bilaterality has been described to vary between 60 and 80% [8, 9,12]. However, the latest data we have shown in Fig. 5 suggests that there is bilaterality in 100% of the cases, although some cases may not progress to be clinically symptomatic. It is also known that the slip can progress rapidly, but also stop at any time (probably in about 40% of the cases). The etiology of nontraumatic SCFE is mostly unknown, and the rate of slipping is unpredictable. There is no known therapy to arrest progression of SCFE except for pinning in situ.

If SA $> 6°$ and $< 13°$, SCFE is suspected, and we recommend follow-up with re-examination of the hip in 2–4 weeks. If the SA has increased 2° or more, SCFE is present [9,12]. The recommendation is based on the earlier observation that five out of eight cases with an SA between 6 and 13 developed SCFE during the period of observation until closure of the physis.

Billing [6] originally described a somewhat more complicated geometrical method to measure SA and used this in routine work in the Department of Orthopedic Surgery in Gothenburg, Sweden. The results were published in 1959 [7]. The SA measurements were exactly the same using the modified new method compared to the old. The angle originally measured was called "eppa." The measurement of SA has been simplified compared to the original measurements of eppa (which equals 90–SA).

We are aware that measurements of eppa or SA have not had a great following, probably because it has been regarded as difficult and also because there has not been an awareness that SCFE is always bilateral. Because of our new insight about the bilaterality of SCFE, we recommend measurement of SA in all cases of SCFE instead of other proposed supplementary methods. Nonsymptomatic, borderline, or mild cases cannot be diagnosed with any other method be it CT, MR, nuclear medicine or ultrasound. No other method has as much sensitivity in follow-up examinations as our true lateral view.

The literature is full of reports of cases that have escaped recognition or been misinterpreted as Perthes' disease [13, 14,15]. Cohen et al. [16] mentioned the difficulty different investigators had had in obtaining reproducible roentgenograms and introduced computed tomography to measure the head-neck angle similar to the Southwick [17] angle. He examined 12 patients with SCFE and used their asymptomatic contralateral hip as a control plus 5 additional control hips that were undefined. He found the control hips to be $0° \pm 2°$ and the SCFE between 14° and 78°. However, the contralateral hips cannot be used as control hips, as we now know that SCFE is always bilateral. Furthermore, he did not present any P value comparing the two. There was no definition of a so-called early slip and there was no follow-up of the contralateral presumed normal hip in Cohen's series. Umans et al. [18] compared MRI and CT. He also used the asymptomatic hip as the control hip and found the CT head-neck angle in the controls to vary between 0° and 14°, while it was 4°– 57° in symptomatic hips. An overlap between so-called normal and abnormal hips was evidently present, probably because of bilaterality. MRI was used to record bone marrow edema, synovitis, and focal as well as diffuse physial widening. All his patients, including all normal cases, had widened epiphysis on MR. Most of them also had nonspecific synovitis. Umans considered a symptomatic hip with a head-neck angle of 4° as a preslip with metaphyseal sclerosis too subtle to recognize except following a review of the CT studies. There was no reported follow-up of the asymptomatic hips or any measurement of the accuracy and specificity of MR.

Magnano et al. [19] examined 21 patients whom they considered to have an early slipped capital femoral

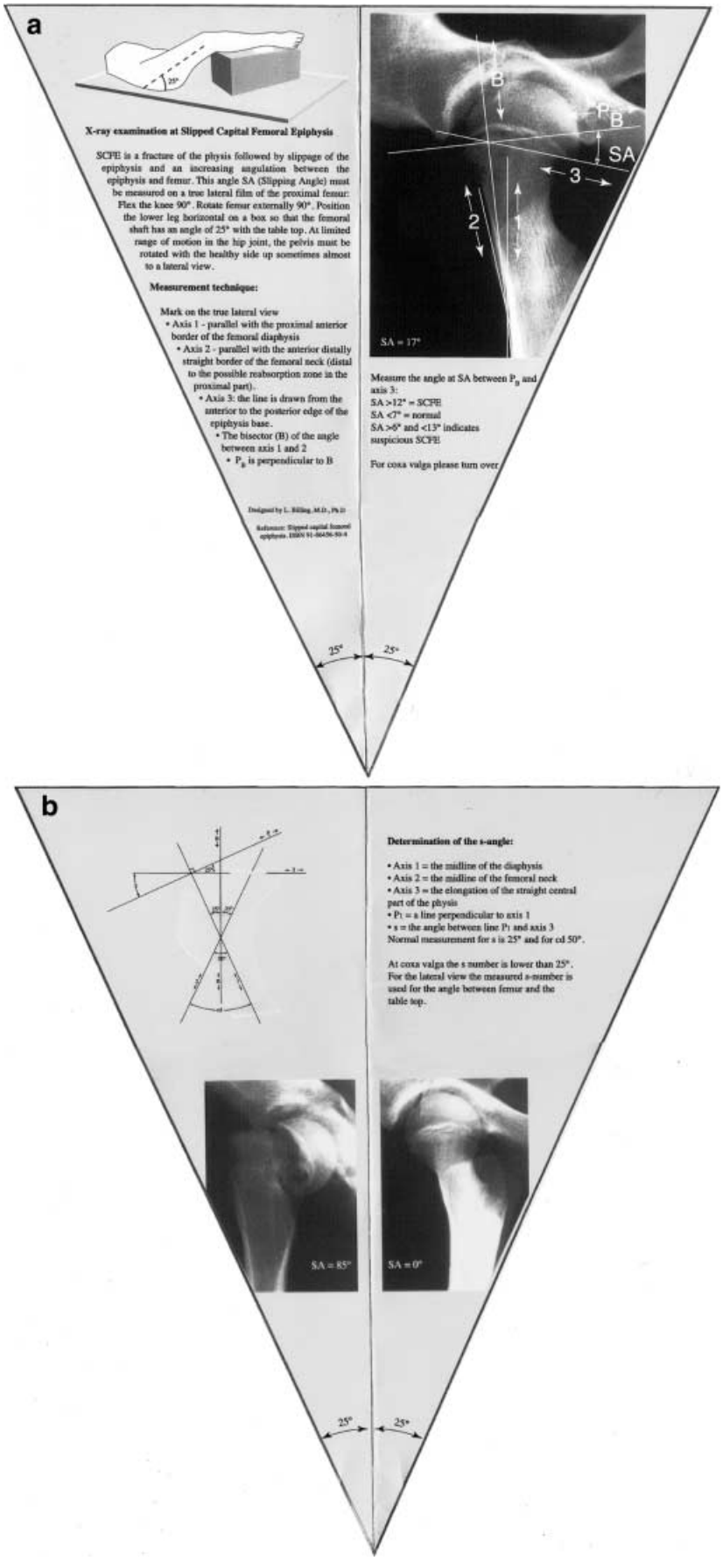

Fig. 6. The youth hip triangle (YHT). The YHT is an equilateral with top angle of 50° and height about 30 cm. Folded around the height it forms two rectangular triangles with one angle = 25° to be used for the position of the femur as seen in Fig. 1. The **a** front and **b** back of the YHT contains figures and a short description of how to position the patient for AP and lateral views and how to measure and evaluate the slip angle

epiphysis with X-ray examination, AP and frogleg views in most patients, MRI (9 cases) and ultrasound. They considered MRI to indicate early SCFE if they found joint effusion and hyperintense physis. These MR findings are nonspecific and can probably be found in, for example, Perthes' disease as well. They considered MR to be false positive where there was no joint effusion and no hyperintense physis. Ultrasound could also detect joint effusion and, in 12 cases, a step. However, all these 12 cases had evidence of SCFE on the radiographs that were limited to AP and frogleg views. The ultrasound joint effusion is also nonspecific. They also claim to have examined the contralateral hip, but no results of the contralateral hip measurements are given. Ultrasound and MRI have not been proven to add much to a definitive diagnosis of SCFE. Hip joint effusions are seen in transient synovitis, Perthes' disease, SCFE, rheumatoid, or septic arthritis and is very nonspecific [20].

There is no study in the literature of the accuracy of CT for the diagnosis of SCFE. Measurements have been made, but there is no true control series of normals and there is no follow-up study of possible so-called preslip cases. The MR and ultrasound findings published are nonspecific, except for where ultrasound can see a step between the metaphysis and epiphysis. However, those published cases had already been diagnosed by simple frogleg views (not even a true lateral view had to be used) [18].

The only method that can diagnose SCFE accurately at all stages is the true lateral view described by us. It has not had a large following in the past, since most radiologists find the geometry and projection theory [8] behind the method somewhat difficult to understand. However, the true lateral view is now very easy to acquire and the measurements have been simplified and can easily be performed in a safe manner. Few radiologists understand the algorithms behind CT and MR, but seem to accept them, trusting that the physics have been properly figured out by others.

CT and MR are potentially useful, but cannot be relied upon until a large series of SCFE has been studied and compared not with the contalateral hip but with hips that are known to be normal. MR images may be useful for measurements, but such do not appear to have been performed.

When view C was introduced, it soon became obvious that it was superior to the frogleg view since it detected bilateral slips in cases where frogleg views were used and the bilaterality was missed. The true lateral view therefore soon replaced the frogleg view totally, and no large series using both methods for comparison was undertaken.

As mentioned earlier, it may be difficult to diagnose SCFE with the conventional method if the proximal femoral end is remolded. We have observed cases undetected with the conventional method with SA $>25°$. Moreover, view C is also superior to other lateral projections for evaluating the conventional 'signs' of SCFE and other hip diseases such as Perthes' disease [6].

Because of the difficulty in diagnosing SCFE with the conventional method, we recommend that the true lateral view be used routinely. An alternative method may be to use this view only in uncertain cases, although we know that even large slips can go undetected on routine views. An alternative that has been proposed is that one use CT, MR, or perhaps even nuclear medicine to study the uncertain small slips [20]. This is feasible, but no large series of cases with proper controls has so far been described using any of those methods. Furthermore, CT and nuclear scanning involve harmful radiation, especially CT to the genital organs. All of them, not the least MRI, are expensive. The cost-effective method is to use the true lateral view routinely. The frogleg view was developed in 1901 by Lauenstein [21] and performed in a case of what he thought was SCFE, but which turned out to be Perthes' disease. The true lateral view is easy to obtain and will be an easy routine view if it replaces the somewhat outdated frogleg view.

To use the geometrical method in routine work. a practical approach is to use the youth hip triangle (YHT) (Fig. 6), which, in an abbreviated form, gives all the necessary information for positioning the femur, measuring the SA, and making the diagnosis. The YHT can be displayed on the wall of the X-ray room so that it is clearly visible and available for use (see Fig. 6). The geometrical method is cost effective and can be used in any size X-ray department. The youth hip triangle can easily be copied from Fig. 6. A fancier version imbedded in plastic can be ordered from us.

References

1. Henriksson B (1969) The incidence of slipped capital femoral epiphysis. Acta Orthop Scand 40: 365–372
2. Loder RT, Aronson DD, Greenfield ML (1993) The epidemiology of bilateral slipped capital femoral epiphysis. J Bone Joint Surg Am 75: 1141–1147
3. Jerre R (1995) Physiolysis of the hip. Epidemiology, diagnosis and long-term follow-up. Vasastadens Bokbinderi, Sweden
4. Speer DP (1982) Experimental epiphysiolysis: etiologic models of slipped capital femoral epiphysis in the hip. Proc Hip Soc. Mosby, St Louis
5. Reiland S (1978) Growth and skeletal development of the pig and pathology of so-called leg weakness in the pig. Acta Radiol Scand Suppl 358:15–44
6. Billing L (1954) Roentgen examination of the proximal femur end in children and adolescents. Acta Radiol [Suppl 110]:1–76

7. Billing L, Severin S (1959) Slipping epiphysis of the hip: a roentgenological and clinical study based on a new roentgen technique. Acta Radiol [Suppl 174]:1–80
8. Wesstein EW (1999) CRC concise encyclopedia of mathematics. Chapman and Hall/CRC, Boca Raton
9. Jerre R, Billing L, Hansson G, et al (1996) Bilaterality in slipped capital femoral epihysis. J Pediatr Orthop B 5:80–84
10. Jerrold HZ (1999) Biostatistical analysis. Prentice Hall, New Jersey
11. Jerre R, Karlsson J (1997) Outcome after transphyseal hip fractures – four children followed 34–48 years. Acta Orthop Scand 68:235–238
12. Billing L, Eklöf O (1984) Slip of the capital femoral epiphysis: revival of a method of assessment. Pediatr Radiol 14:413–418
13. Oram V (1953) Epiphysiolysis of the head of the femur. A follow-up examination with special reference to end results and the social prognosis. Acta Orthop Scand 23:100–120
14. Cowell HR (1966) The significance of early diagnosis and treatment of slipping of the capital femoral epiphysis. Clin Orthop Relat Res 48:89–94
15. Reynolds RAK (1998) Diagnosis and treatment of slipped capital femoral epiphysis. Curr Opin Pediatr 11:80–83
16. Cohen MS, Gelberman RH, Griffin PP, et al (1986) Slipped capital femoral epiphysis: assessment of epiphyseal displacement and angulation. J Pediatr Orthop 6:259–264
17. Southwick WO (1967) Osteotomy through the lesser trochanter for slipped capital femoral epiphysis. J Bone Joint Surg Am 49:807–835
18. Umans H, Liebling MS, Moy L, et al (1998) Slipped capital femoral epiphysis: a physeal lesion diagnosed by MRI, with radiographic and CT correlation. Skel Radiol 27:139–144
19. Magnano GM, Lucigrai G, De Filippi C, et al (1998) Diagnostic imaging of the early slipped capital femoral epiphysis. Radiol Med 95:16–20
20. Robben SGF, Meradji M, Diepstraten AFM, et al (1998) US of the painful hip in childhood: diagnostic value of cartilage thickening and muscle atrophy in the detection of Perthes disease. Radiology 208:35–42
21. Lauenstein C (1901) Nachweis der Kocher'schen Verbiegung des Schenkelhalses bei der Coxa Vara durch Röntgen-Strahlen. Beitr Klin Chirurg 28:61–64