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Original Article

A comparison study of radiographic and computerized tomographic angles in slipped capital femoral epiphysis☆

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ABSTRACT

Objective: To compare proximal femur radiologic angles in patients with slipped capital femoral epiphysis and to analyze whether computerized tomography may modify the treatment.

Methods: Cross-sectional study comparing and analyzing the similarity between angles and radiologic classification of interest in slipped capital femoral epiphysis (SCFE).

Results: It was observed that the therapeutic management in slipped capital femoral epiphysis might be modified depending on the classification and radiologic acquisition method adopted.

Conclusion: Multiplanar assessment of proximal femoral deformity in patients with slipped capital femoral epiphysis is a viable option, with the potential to modify the disease classification and, consequently, the therapeutic management.

Estudo comparativo dos ângulos radiográficos e tomográficos na epifisiolistese do fêmur proximal

Palavras-chave:
Escorregamento das epífises proximais do fêmur/radiografia
Tomografia computadorizada por raios X
Articulação do quadril/radiografia

RESUMO

Objetivo: Comparar ângulos radiológicos do fêmur proximal em pacientes com escorregamento proximal da cabeça do fêmur (EPCF) e analisar se a avaliação por tomografia computadorizada pode modificar a conduta.

Método: Estudo transversal que comparou e analisou a concordância entre ângulos e classificações radiológicas de interesse no escorregamento proximal da cabeça do fêmur (EPCF).

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Resultado: Observou-se que a conduta terapêutica na EPCF pode ser modificada a depender da classificação adotada e do método de aquisição de imagens radiológicas.
Conclusão: A avaliação multiplanar da deformidade do fêmur proximal em pacientes com escorregamento proximal da cabeça do fêmur é uma opção viável e com potencial de modificar a classificação da doença nos pacientes e, por conseguinte, a modalidade terapêutica.

Introduction

Slipped capital femoral epiphyses (SCFE) is the most prevalent hip disease in adolescence.[1] It is characterized by a disturbance in the physis, causing anterior slipping and external rotation of the femoral neck in relation to the femoral head, which remains in the acetabulum.[2] The etiology is multifactorial, with obesity being considered the main etiological factor.[1,3]

Early diagnosis and appropriate treatment may reduce the incidence of complications and functional loss.[4–11] Imaging tests are indispensable to confirm the diagnosis and classify the disease. Anteroposterior hip X-ray and Lauenstein-type profile X-ray are usually sufficient for diagnostic confirmation and classification. Computed tomography (CT) and magnetic resonance imaging (MRI) are useful in severe cases to determine physis closure, angular and torsional deviations, and indication of osteotomies.[12,13]

Mild cases are treated by the *in situ* percutaneous fixation technique with a cannulated screw.[14] However, recent literature has favored more aggressive treatment measures. Moderate and severe slipping can be treated with several techniques, such as slipping reduction followed by fixation, or corrective osteotomies in the proximal femur.[15–19]

The therapeutic management depends on the radiological classification of the severity of the disease. Important radiological ratings include the Southwick[16] slip angle and the head–neck angle described by Cohen et al.[20] Cooper et al.[21] recently demonstrated that the three-dimensional deformity caused by SCFE can be better determined with the evaluation of the deformity in the oblique plane. An optional method, which considers the slip percentage between the femur head and neck, was proposed by Wilson,[22] more indicated for small deviations.

The authors' clinical experience is in accordance with the findings by Monazzam et al.[13] and Tins et al.,[12] who described that biplanar radiographs underestimate the severity of SCFE when compared to CT. Richolt et al.[23] suggest that the radiographic evaluation overestimates angular deviations and underestimates torsional deviations. The hypothesis of the present study is that the evaluation of SCFE through CT may alter the slip classification and interfere with therapy. Our objective was to compare the angles obtained by the plain X-ray and CT, and to evaluate whether CT would alter the therapeutic management in SCFE.

Material and methods

After approval by the ethics council, a retrospective survey was performed of patients who were diagnosed as having high SCFE (ICD M93) between January 2011 and May 2014. During this period, it became routine to order at our medical facility preoperative CT and X-ray for patients admitted with the diagnostic hypothesis of SCFE, candidates for Dunn osteotomy. Next, the radiological images stored in the hospital image system were surveyed. Patients who did not have a CT or X-ray available in the system were excluded. Measurements of the angles of interest were taken by an orthopedic hip specialist, blinded to the patient's identification and clinical data. Radiographic and tomographic measurements were taken separately.

Southwick angle (femoral head-diaphysis angle – HDA)

The Southwick angle is measured between a perpendicular line of the line tangent to the proximal femoral physis superiorly and inferiorly and the anatomical axis of the femoral diaphysis[16] (Fig. 1). For measuring the FHDA in the tomographic images we adopted the method proposed by Southwick that has as standard the coronal and sagittal sections, perpendicular to each other. To evaluate the coronal plane, the section with the largest subtrochanteric diameter was taken as the reference image, and two sections of the CT were superimposed to evaluate the sagittal plane, one with the largest physis diameter and the other with the largest subtrochanteric diameter (Fig. 2). After obtaining the angles in both planes, the three-dimensional deviation of the femoral diaphysis in relation to the femoral head was estimated by trigonometry[24] (Fig. 3).

Cooper's oblique plane (femoral head–neck angle – FHNA)

FHNA is the angle between the femoral neck axis and the epiphyseal axis.[20] The femoral neck axis is determined by a line connecting three equidistant points between the lower and upper femoral neck surfaces.[25] The epiphyseal axis is determined by the perpendicular bisecting line between a point at the anterior end of the femoral epiphysis and a point at the posterior end of the femoral epiphysis.[20] We chose to compare the model proposed by Cooper et al.,[21] in which the coronal plane is determined by the AP X-ray, and the axial plane by CT, with the modification by using the coronal (Fig. 4) and axial (Fig. 5) planes of the CT. The section chosen for the

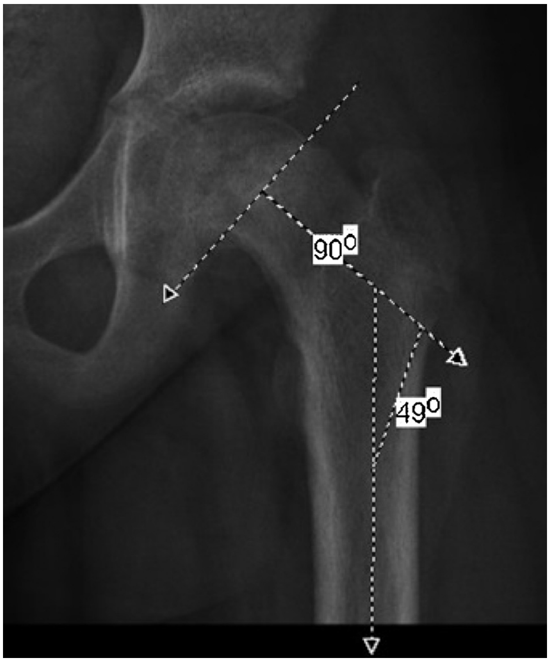

Fig. 1 – Southwick angle on AP X-ray.

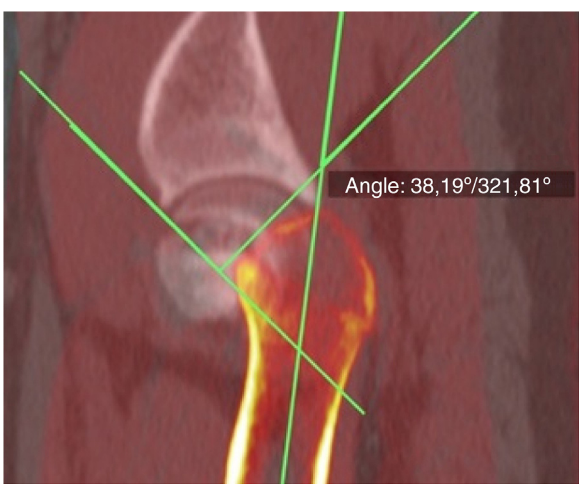

Fig. 2 – Southwick angle (femoral head-shaft angle – FHSA) through the CT sagittal plane.

a) *FHSA - 3D = tan-1 Ö tan2 FHSA coronal plane + tan2 FHSA sagital plane*

b) *FHNA - 3D = tan-1 Ö tan2 FHNA coronal plane + tan2 FHNA axial plane*

c) *WHNS = 1 - (WHNS axial plane x WHNS coronal plane)*

Fig. 3 – (a) Trigonometric formula to determine three-dimensional femoral head–shaft angle; (b) trigonometric formula to determine three-dimensional femoral head–neck angle; (c) trigonometric formula to determine three-dimensional Wilson's head–neck slip.

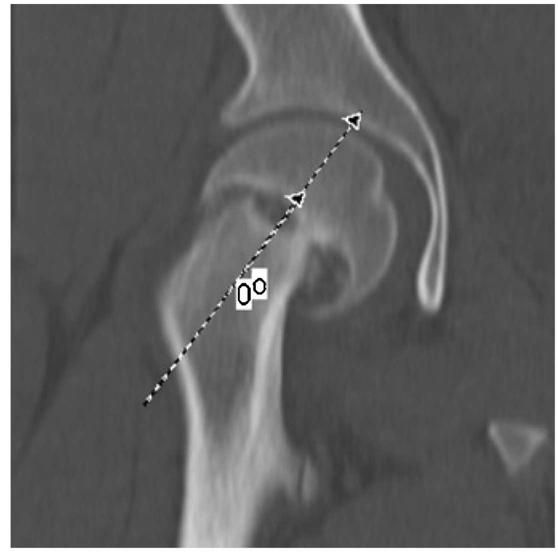

Fig. 4 – Femoral head–neck angle (FHNA) through a CT coronal section.

measurement in the coronal section is the one with the largest femoral neck area. After obtaining the uniplanar measurements, the three-dimensional deviation was determined by trigonometric means (Fig. 3b).

Wilson's head–neck slip (WHNS)

The slip gradation proposed by Wilson consists of the relation between the distance from the upper margin of the femoral neck to the upper margin of the femoral head and the diameter of the femoral neck. The slip was determined in a three-dimensional manner. The percentage of head-to-neck contact in the axial (Fig. 6A) and coronal planes (Fig. 6B) was estimated, and the section with the largest femoral neck area was taken as standard. After obtaining these data, the result between them was obtained to determine the three-dimensional contact. The three-dimensional slip is the complementary number needed to reach 1 (100%) (Fig. 3c and 7).

Imaging assessment and statistical analysis

Data were analyzed with statistical software STATA 11 (Stata Corporation, College Station, USA). The concordance between the categorical variables was made with the Kappa test. The continuous variables were evaluated with paired *t*-test, after confirming normality with the Kolmogorov–Smirnov test. The limit of statistical significance used was 0.05.

The evaluation of the Southwick angles was done through: 1. Categorical classification in three groups according to the difference between the angle found and the normal pattern: mild slip (0–30°), moderate slip (30–50°), severe slip (greater than 50°)[13,26]; 2. Continuous classification according to the measured angle. The values considered normal are 145° in the AP X-ray and 10° in the Profile X-ray.[27]

The evaluation of Cooper's oblique plane was made through: 1. Categorical classification in two groups according

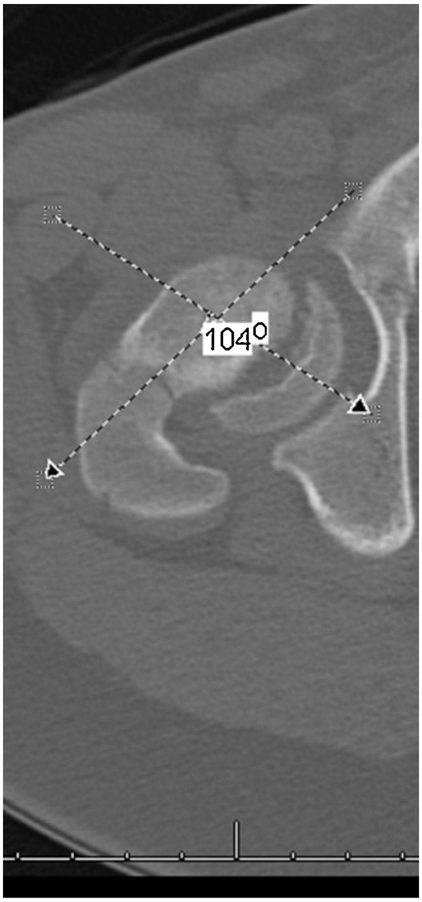

Fig. 5 – Femoral head–neck angle (FHNA) through a CT axial section.

to the angle found: mild slip (less than 50°), severe slip (greater than 50°).[21]

The differences obtained for the WHNS were continuously and categorically classified. The categorical classification as proposed by Wilson et al.[28]: mild (0–33%), moderate (33–50%) and severe (greater than 50%) slip.

WHNS = 1 – (WHNS axial plane x WHNS coronal plane)

WHNS= 1 – [(4.6/21.4) × [(26.9/29)]

WHNS = 1 – [0.21 × 0.92]

WHNS= 1 – 0.19

WHNS= 0.81 = 81%

Fig. 7 – Mathematical method to three-dimensionally determine Wilson's slip.

Results

Twenty-six hips were evaluated in 21 patients (Tables 1–6).

Cooper's oblique plane

There was no significant difference between the two compared methods ($p = 0.59$) and both showed good correlation ($r = 0.93$) and good concordance (kappa = 0.81). Only one case of the 26 evaluated had the classification changed from severe to mild when the CT coronal plane was chosen as measuring method.

Wilson's slip

The slips obtained in the three-dimensional evaluation [85 (71.2–98.8) %] are significantly higher ($p < 0.001$) than those found in the AP X-rays [31.3 (20.2–42.4) %] and Profile X-ray [44.2 (34.1–54.3) %]. The concordance between the classification by CT and X-ray was weak (kappa = 0.216). In the cases considered mild or moderate in the uniplanar evaluation, 80% were classified as severe by the biplanar evaluation.

Southwick angle

The angles found in the AP X-ray [19.5 (9.7–29.3)°] are significantly ($p < 0.001$) lower than those found in the Profile

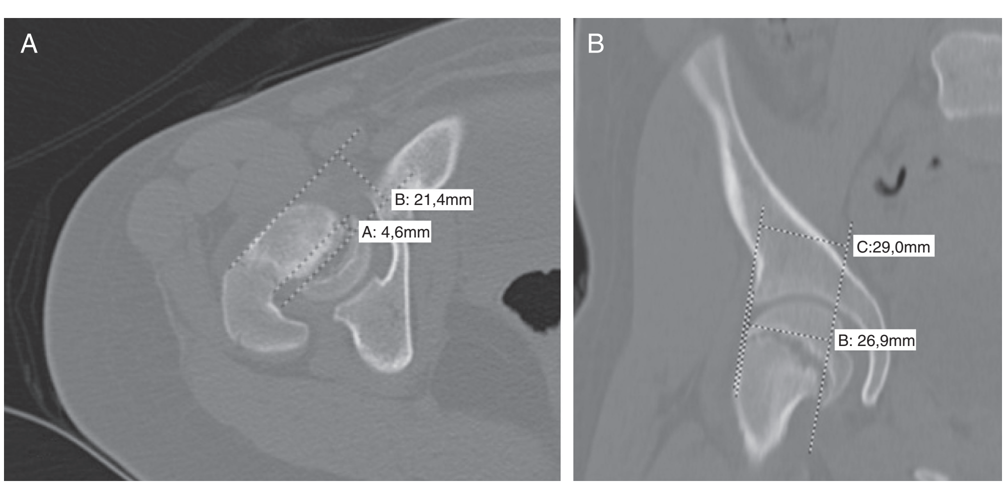

Fig. 6 – (A) Wilson's head–neck slip on a CT axial plane; (B) Wilson's head–neck slip on a CT coronal plane.

Table 1 – Descriptive analysis.

Gender	
Male	14
Female	7
Laterality	
Right	14 (53.8%)
Left	12 (42.2%)
Bilateral involvement	5
Boys	4 (28.57%)
Girls	1 (14.28%)
Age	13.7 (12.9–14.5) years
Boys	13.9 (13.1–14.8) years
Girls	13.2 (11.1–15.3) years
Cooper's oblique plane	
AP X-ray/axial CT	70.3 (62.5–78.0)°
Coronal CT/axial CT	71.0 (64.3–77.7)°
Wilson's neck-head slip	
CT (3D)	85.0 (71.2–98.8)%
AP X-ray	31.3 (20.2–42.4)%
Profile X-ray	44.2 (34.1–54.3)%
Southwick angle	
CT (3D)	47.9 (38.0–57.8)°
AP X-ray	19.5 (9.7–29.3)°
Profile X-ray	51.5 (43.8–59.2)°

Table 2 – Descriptive analysis.

	Mild	Moderate	Severe
Classification through Cooper's oblique plane	–		
AP X-ray/axial CT	3	–	23
Coronal CT/axial CT	4	–	22
Wilson's classification			
CT (3D)	1	2	23
X-ray	5	10	11
Southwick classification			
CT (3D)	8	6	12
X-ray	3	6	17

X-ray [51.5 (43.8–59.2)°] and by tomographic evaluation in three dimensions [47.9 (38.0–57.8)°]. There was no significant difference ($p = 0.28$) between measurements taken in the profile X-ray and 3D CT. However, there was a tendency to classify cases as having lower severity by the three-dimensional CT method when confronted with the radiographic method. The concordance between the three-dimensional CT and the biplanar X-ray evaluation was weak (kappa = 0.306).

Table 3 – Cooper's oblique plane concordance.

		Classification of Cooper's oblique plane with coronal CT		
		Mild	Severe	Total
Cooper's Oblique Plane *Classification using AP X-ray*	Mild	3	0	3
	Severe	1	22	23
	Total	4	22	26

Kappa = 0.83; $p < 0.001$.

Table 4 – Concordance of Wilson's classification through CT (3D) and X-ray.

		Wilson's Classification through CT (3D)			
		Mild	Moderate	Severe	Total
Wilson's classification through X-ray	Mild	1	0	4	5
	Moderate	0	2	8	10
	Severe	0	0	11	11
	Total	1	2	23	26

Kappa = 0.216; $p = 0.018$.

Table 5 – Concordance of Southwick classification through CT (3D) and X-ray.

		Southwick classification through CT (3 D)			
		Mild	Moderate	Severe	Total
Southwick classification through X-ray	Leve	3	0	0	3
	Moderate	4	1	1	6
	Severe	1	5	11	17
	Total	8	6	12	26

Kappa = 0.306; $p = 0.020$.

Concordance between the different classifications

The concordance between the classically used classifications, Southwick-X-ray, Wilson-X-ray, and Cooper, was weak, with kappa of 0.05–0.15.

Discussion

The literature on SCFE still lacks standardization to evaluate the severity of the disease and the therapy proposal. In

Table 6 – Concordance between different classifications.

	Classification through Cooper's oblique plane	Classification through Wilson's slip with X-ray
Classification through Wilson's slip – X-ray	Kappa: 0.107 *p*: 0.08	
Classification through Southwick angle – X-ray	Kappa: 0.152 *p*: 0.07	Kappa: 0.058 *p*: 0.33

addition, the few articles aimed at analyzing the intra and interobserver concordances of the uniplanar methods suggest low values,[29] whereas multiplanar evaluations have better concordance.[13,21,23] There are several articles with their own proposals for classification of the disease, but few of them consider the multiplanar nature of the deformity. We believe that the three-dimensional evaluation allows better determination of the actual proximal femur deformity and intra and interobserver agreement. In addition, the three-dimensional evaluation can modify the therapeutic management. However, three-dimensional hip deformities cannot be adequately measured by radiographic means, because it is not possible to guarantee the perpendicularity of rays between the anteroposterior and profile incidences. Therefore, the use of methods that allow three-dimensional evaluation, such as CT and magnetic resonance imaging, is necessary.

As initially expected, there is little difference between evaluating Cooper's oblique plane with CT axial section and AP X-ray, or using the axial and coronal CT sections. Among the most widespread methods, this is one of the few that evaluates the three-dimensional deformity, but there are still studies that support the 50°-limit adopted by Cooper et al.[21] for modifying the therapeutic approach. This author, based on the oblique plane, suggests that deviations smaller than 50° are treated with *in situ* fixation and deviations greater than 50° with dislocation followed by anatomical reduction of the hip.

The three-dimensional evaluation of Wilson's slip showed significantly higher values than the X-ray evaluation. Thus, 80% of mild cases would have its management altered; more complex surgical procedures are adopted when the disease is biplanarly classified. On the other hand, Southwick's classification through CT underestimated the values found by X-ray; 66% of the cases classified as moderate in an X-ray would have the therapy changed to less invasive procedures if the 3D classification was adopted, in agreement with the previously reported findings by Richolt et al.[23]

Another important aspect to consider is the lack of agreement between the different classifications that are commonly used: Southwick-X-ray, Wilson-X-ray, and Cooper. When evaluated simultaneously by the three methods, eight of the 26 hips analyzed (30.79%) could have the therapeutic management changed, depending on the reference classification. None of the cases were classified as mild simultaneously by all methods, while only 33.3% (8/24) of the cases were consistently considered severe by all classifications.

Three-dimensional evaluations may be the best way to guide therapeutic management, since they allow estimating the deformity inherent to the disease in a way that is closer to reality and with better reproducibility. The best three-dimensional evaluation method is a matter that needs to be deepened, but we see the three-dimensional evaluation of Wilson's slip and the Southwick angle as promising options, since they are adaptations of two widely used models with a wide series of cases previously studied in the literature.[10,15–17,22,26,28]

A limitation of the present article is the initial severity of the disease in the individuals studied. Future research may evaluate the difference between radiographic and tomographic findings in patients with milder SCFE. In addition, the lack of a control group (which could be formed, for example, by an asymptomatic population), limits the conclusion of the difference in radiographic and tomographic findings.

The authors believe that improving patient care with SCFE depends on better standardization of deformity gradation and therapeutic management. To do this, we must: 1) define the role of radiological methods that allow a three-dimensional evaluation of the deformity, such as computed tomography and magnetic resonance imaging; 2) to standardize the ideal therapeutic indication according to the deformity, in face of new diagnostic options.

Conclusion

The present study found differences in SCFE angles between measurements taken by radiography and computed tomography. A multiplanar evaluation of the proximal femoral deformity is a viable option with the potential to change the classification of the disease in the patients and, therefore, therapeutic management.

Conflicts of interest

The authors declare no conflicts of interest.

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