Original Clinical Article

JOURNAL OF CHILDREN'S ORTHOPAEDICS

Correlation between ultrasonic and radiographic imaging of developmental dysplasia of the hip

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Abstract

Purpose The correlation between the degree of developmental hip dysplasia (DDH) measured on ultrasound images compared with that measured on radiographs is not clear. Most studies have compared ultrasonography (US) and radiographic images made at different times of follow-up. In this study the correlation between US images and radiographs of the hip made on the same day was evaluated.

Methods US images and radiographs of both hips of 74 infants, who were treated for stable DDH, were reviewed in a retrospective study. Only infants who had an US examination and a radiograph on the same day were included.

Results The correlation between α-angle of Graf and femoral head coverage on US was strong ($p \leq 0.0001$). Weak correlations were found between the acetabular index of Tönnis on radiographs and α-angle of Graf on US ($p = 0.049$) and between acetabular index of Tönnis on radiographs and femoral head coverage of Morin on US ($p = 0.100$).

Conclusion This study reports on the correlation between US and radiographic imaging outcomes, both made on the same day in patients for treatment and follow-up of DDH.

Level of Evidence IV

Cite this article: Spaans AJ, Beek FJA, Uiterwaal CSPM, Pruijs JEH, Sakkers RJ. Correlation between ultrasonic and radiographic imaging of developmental dysplasia of the hip. *J Child Orthop* 2019;13:155-160. DOI: 10.1302/1863-2548.13.180165

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Keywords: ultrasound; radiograph; developmental hip dysplasia; hip dysplasia; correlation

Introduction

Developmental dysplasia of the hip (DDH) is due to an abnormal relation between the femoral head and the acetabulum and can include acetabular dysplasia with or without instability of the femoral head, subluxation and dislocation.[1,2] In the first months of life, a distinction can often be made between stable and unstable DDH through clinical examination using the Ortolani and Barlow manoeuvres.[1,3] Imaging of the hip is used to confirm and determine the degree of DDH more accurately.[2,4]

The most used and well-known classification for DDH on radiographs is the classification by Tönnis from 1976.[5] He based the diagnosis of DDH on anteroposterior radiographs of the hip by measuring the acetabular index (AI) on more than 1000 radiographs. The AI is defined as the angle between the acetabular roofline and Hilgenreiner's line, a transverse line that links the top of the two triradiate cartilages.[5] Below the age of six months important parts of the pelvis and hip are still cartilaginous, making the Tönnis classification below this age more variable in stable well-centred hips with DDH with regard to the real anatomy of the hip.

In 1980 Graf[6] introduced the real-time ultrasonography (US) for the diagnosis of DDH. With the US method, visualizing the cartilaginous anatomy of the femoral head and acetabulum was possible. The imaging with this method is considered more in accordance with the real anatomy of the hip below the age of six months.[6,7] Next to Graf's method of quantification other methods and techniques have been published, however, there is no consensus about the most adequate method for quantification and classification of DDH.[4,8] The most commonly used methods for evaluation and quantification are the methods according to Graf and Morin and Terjesen.[7-10] Graf's method focuses on acetabular morphology, measuring the angle of acetabular inclination (α-angle) and the acetabular roof angle (β-angle).[7,9] Morin introduced the d/D ratio, which determines the percentage of the femoral head lying medial to the lateral iliac border, also known as the femoral head coverage (FHC) which gives an indication of the depth of the acetabulum.[4,10] Both methods use a lateral coronal view with the hip slightly flexed, this view is equivalent to anteroposterior radiographs of the hip.

As the start of the ossification of the femoral head of the normal hip occurs between the ages of two to eight months, the value and reliability of US is believed to decrease with increasing size of the ossification centre, however, Tegnander and Terjesen[11] showed that reliable US of hips for DDH is possible until a much older age. In dysplastic hips, the ossification of the femoral head is often delayed making the use of US for follow-up of value at higher ages. Radiographs generally start being reliable for evaluating stable, well-centred hips with DDH with increasing ossification of the pelvis and hips from the age of six months.[3,12]

In our institution children who were treated for DDH were followed with US until at least six months of age. With the next examination, usually between eight and nine months, US images and a radiograph were made on the same day. The US examination is used to compare the image with the previous examinations at earlier ages and the radiograph is used as the new starting point for follow-up from that date. This protocol was followed from 2009, resulting in a unique series of US images and radiographs of dysplastic hips made on the same day. The objective of this study was to determine the correlation between US images and radiographs of the hip on the same day in the follow-up of DDH in infants at the age of nine months.

Materials and methods

We reviewed US images and radiographs of both hips of 76 infants who were diagnosed with stable DDH between the age of three and four months. Inclusion criteria for this study were infants between 34 and 48 weeks (mean 40 weeks) of age who had a follow-up US and a radiograph on the same day according to protocol. Two patients were excluded; one with a luxation of the hip and one with proximal femoral focal deficiency, leaving 74 patients (seven male, 67 female) with 148 hips for evaluation. Our institutional review board approved a waiver of informed consent for this study (18-666).

All US images where made with a 12.5 MHz linear transducer (model IU22; Philips, Markham, Ontario, Canada) using the lateral coronal view. All radiographs were made in supine anteroposterior position according to Tönnis.[5] The parameters measured on US where the α- and β-angles according to Graf[4,9] ($\alpha > 60°$ normal) and FHC percentage according to Morin (> 58% normal, 33% to 58% intermediate and < 33% abnormal).[4,13] AI was classified according to Tönnis on radiographs (normal values depend on age).[5] The degree of rotation and tilt in the radiographs was analyzed according to van der Bom et al.[14]

All US images and radiographs where assessed by a medical student, trained by a paediatric radiologist in order to avoid bias as much as possible. An experienced radiologist was considered to have a bias due to his experience as compared with a medical student that strictly applies the rules of Graf, Morin and Tönnis. The medical student was checked for accuracy during the training period.

Statistical analysis

This was performed using IBM SPSS Statistics 20 for Windows (IBM Corp., Armonk, N.Y., USA). All p-values < 0.05 were considered significant. Correlation analysis between the AI in radiographs and α-angle and FHC percentage in US images was done in two ways. Correlation between the continuous outcomes of all measurements was done using the Pearson's correlation. After classification of all hips according to the three methods, the degree of correlation was measured between two categorical variables using the Pearson's contingency coefficient (values between 0 and 1). Analysis of the degree of correlation was repeated after exclusion of patients with an excessive degree of rotation or tilt in the radiograph.[13] Methods and normal values were measured according to Tönnis[5] and Boniforti et al.[15]

Results

All 148 hips were classified according to Graf's method: 67.6% were Graf type I (normal); 29.7% were type IIb; 2.7% were type IIc.

According to Morin's classification 68.2% of all hips were normal and 31.8% were intermediate (between 33% and 58% FHC). No hips had FHC percentages below 33% indicating definite dysplasia. The mean FHC was 61.6% (SD 7.8).

On radiographs, classification of the 148 hips according to Tönnis was: 78.4% normal, 16.2% light dysplasia and 5.4% severe dysplasia.

First, the correlation between the clinical diagnoses was calculated. There was agreement between the classifications of Morin and Graf in 97 of 148 patients (66%), between Tönnis and Graf in 98 of 148 patients (66%) and between Morin and Tönnis in 97 of 148 patients (66%). Figure 1 shows an example of normalized ultrasound but abnormal radiography.

Second, the correlation between α-angle and FHC percentage in US was calculated. A Pearson correlation of 0.619 ($p < 0.0001$) was found, indicating strong correlation (Fig. 2).

Third, the correlation between AI in radiographs and α-angle in US and the AI in radiographs and the FHC percentage in US was calculated. The Pearson correlation between AI and α-angle and between AI and FHC percentage showed significant values of -0.336 ($p < 0.0001$) and

-0.278 (p = 0.001), respectively (Figs 3 and 4). Because AI values increase while the α-angle and FHC percentage values decrease as the degree of dysplasia gets more severe, these negative correlations can be seen as positive. Nevertheless, these values are too low to be clinically relevant.

Calculating the contingency coefficients, there were weak correlations between Tönnis and Graf and between Tönnis and Morin. Because the distribution of pelvic alignment in all radiographs was normal in only 54.1% (40 patients; in the other patients tilt, rotation or a combina-

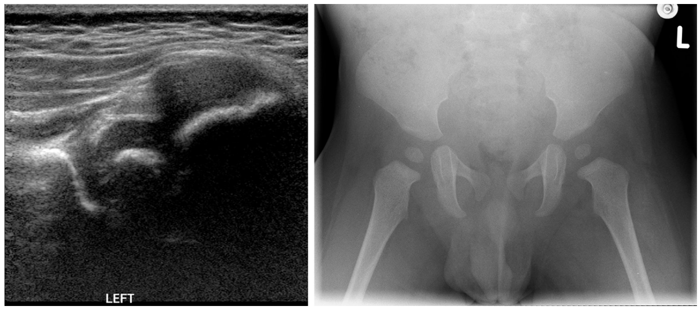

Fig. 1 Ultrasound (**a**) and radiograph (**b**) made on the same day in an eight-month-old patient.

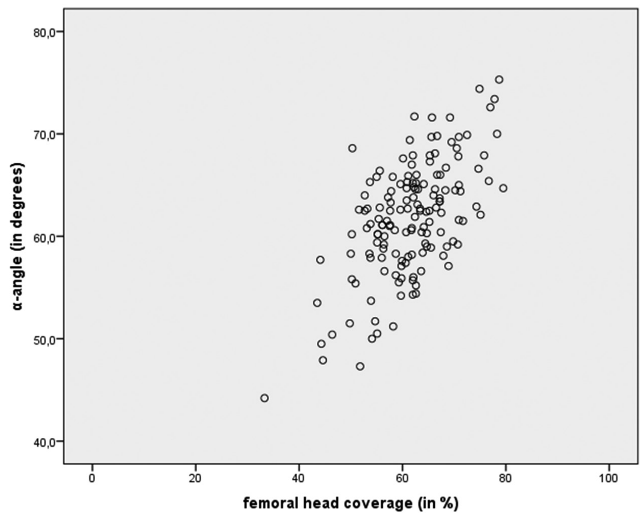

Fig. 2 Correlation between α-angle and femoral head coverage in ultrasounds.

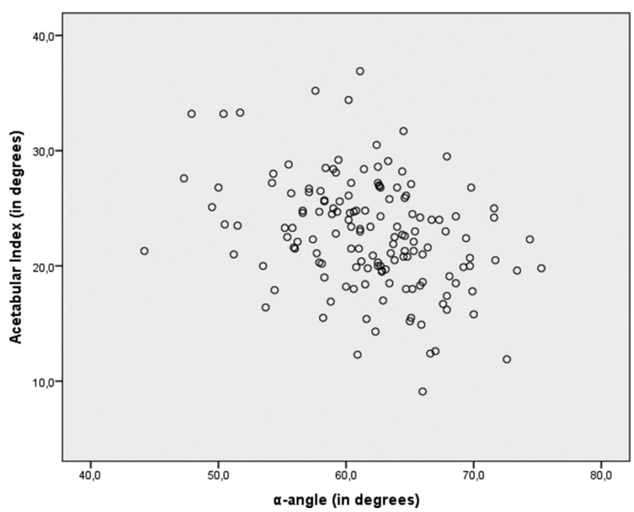

Fig. 3 Correlation between acetabular index in radiographs and α-angle in ultrasounds.

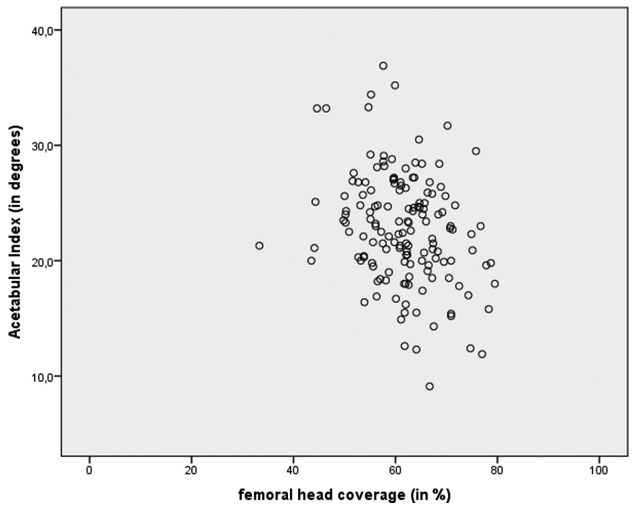

Fig. 4 Correlation between acetabular index in radiographs and femoral head coverage in ultrasounds.

Table 1 Association between radiography (Tönnis) and ultrasonography (Graf and Morin)

		Total group (n = 148)		Group with normal pelvic alignment (n = 80)	
		α-angle of Graf	FHC of Morin	α-angle of Graf	FHC of Morin
AI of Tönnis	Contingency coefficient	0.160	0.134	0.162	0.174
	Significance	0.049	0.100	0.141	0.113

AI, acetabular index; FHC, femoral head coverage

tion was measured), the correlations were also calculated in this subgroup of patients. No significant correlation was found between Tönnis and Graf and a weak correlation between Tönnis and Morin (Table 1).

Discussion

Only a limited number of studies are published on the correlation between US and radiographic findings of DDH. Whereas most studies compared US images and radiographs made on different times of follow-up, this study is unique in comparing US images and radiographs made on the same day, making a more accurate correlation between the two methods of imaging possible. All patients had stabile well-centred hips ranging between normal and serious acetabular dysplasia with only a weak, non-significant correlation between the US and radiographic findings in respectively the total group, and in the subgroup with a normal distribution of pelvic alignment according to van der Bom et al.[14]

Only one other study performed both imaging modalities on the same day. Terjesen et al[16] examined the hip joints of 156 consecutive children aged two to 23 months. However, of the 312 hips examined, 286 were found normal on US and radiography. With radiography 15 hips were classified having dysplasia, six with subluxation and there were five dislocated hips. With US seven hips were found to be normal, seven had dysplasia, eight had a subluxation and four a dislocation of the hip. They measured the lateral head distance by both methods and found a correlation coefficient of 0.73 in this small group of patients. When excluding the cases with normal hips, subluxation or dislocation with both US and radiography, only 15 cases are left. In seven of the 15 hips with radiographic dysplasia US was normal, which results in an agreement between radiography and US of 47%. All patients with abnormal US also had abnormal radiographic measurements. In our study, in 17 of the 32 hips with radiographic dysplasia US was normal (agreement of 53%). In addition, 33 of 48 patients with US dysplasia had normal radiographs (agreement of 31%).

There are several studies comparing US and radiographic outcomes made at different times of follow-up. A weak correlation between the AI of Tönnis and the α-angle of Graf was reported by Morin et al.[13] In this case there was no correlation in the mid-range group of DDH and the authors could only demonstrate some correlation at the ends of the spectrum.[10,13] Gunay et al[17] had similar upper and lower threshold values of FHC (51% and 39%), with similar results such that all hips having these values or beyond had mature or pathological development, respectively.

Pillai et al[18] compared three US investigations, respectively made at presentation, six weeks and three months of age, with a radiograph done at the age of six months. Dornacher et al[19] correlated the AI of Tönnis and the α-angle of Graf by comparing the initial severity of DDH on the US images with the severity of residual dysplasia according to Tönnis on the radiographs at the time the children started walking. Both studies found no significant correlation between US and radiography at different times of follow-up.[18,19]

Possible causes for the discrepancies between radiographic and US findings have been discussed by Joseph and Meyer.[20] They divided the discrepancies into two categories; apparent and true discrepancies. 'Apparent discrepancies' can be caused by errors in technique or in interpretation either of the US or the radiograph. If no explanation could be found, the term 'true discrepancies' was used. A cause for the discrepancies could be errors made in measuring the AI due to pelvic rotation or tilt in the radiograph. The negative effect of pelvic tilt and rotation on the reliability of measurements of the AI in radiographs was more often described.[5,14,15,21] We found in the present study that only 54.1% of radiographs had normal pelvic alignment. However, after repeating the analysis in this subgroup of our study, we did not find higher correlations. Another factor interfering with US measurement might be the fact that the ossification of the femoral head progresses with age, making the Y-fuge of the acetabulum more difficult to project with US. However, with a large osseous nucleus the possible error would result in a higher α-angle and therefore the possible error would result in more normal hips on the US images. That effect was not seen in the results since more hips were diagnosed as dysplastic with the US imaging compared with the radiographic findings. Also, many dysplastic hips have a delay in the ossification of the femoral head at the age of nine months. Also, the ossification nucleus did not influence the measurement of the depth of the acetabulum for the quantification of the FHC.[11] The difference might also (partly) be explained because US is a slice through the acetabulum whereas radiography is a composite shadow.

The differences in US and radiologic outcomes in the evaluation of DDH remain intriguing. Despite better quality of US and radiology, correlation between these modalities has not improved in the last decades. Harcke and Grissom[12] initially described the examination technique of dynamic echography of the infant hip. Recently, Alamdaran et al[22] found that single view static and dynamic techniques provide a high diagnostic value for the assessment of DDH. A study investigating the correlation between dynamic US and radiographic measurements for DDH may be of value.

In conclusion, this study shows that the image of the hip on the US image cannot be translated one-to-one to the radiographic appearance especially in well-centred hips. Several studies show that only the hips at both ends of the distribution curve (severe dysplasia and hips with relatively high α-angle and low AI indexes) seem to correlate and the diagnosis DDH of many hips will remain doubtful being in the grey middle zone between both modalities.

Received 07 October 2018; accepted after revision 18 February 2019.

COMPLIANCE WITH ETHICAL STANDARDS

FUNDING STATEMENT

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

OA LICENCE TEXT

ETHICAL STATEMENT

Ethical approval: This was a retrospective study with collection of patient data. This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent: Not required for this work.

ICMJE CONFLICT OF INTEREST STATEMENT

None of the authors have any conflict of interest to declare.

AUTHOR CONTRIBUTIONS

AJS: analyzed the data and wrote the manuscript.

FJAB: trained the student, supervised the measurements and wrote parts of the manuscript.

CSPMU: helped with analyzing the data.

JEHP: performed data collection and wrote the manuscript.

RJS: developed the idea for the study, discussed the results and was coordinator of the study.

ACKNOWLEDGEMENTS

The authors thank Ms L. S. M. Derks for data collection.

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