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ORIGINAL STUDY

A comparison of ultrasonography and radiography in the management of infants with suspected developmental dysplasia of the hip

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The aim of this study was to determine the sensitivity and specificity of plain radiography in the detection of developmental dysplasia of the hip, using hip ultrasonography as a reference standard. A retrospective review was made in 44 infants ranging in age from 4 weeks to 50 weeks (mean age : 21.7 weeks). Both radiographic and ultrasonographic images were obtained for 86 hips. Radiography and ultrasonography were found to be significantly correlated in terms of classification of developmental dysplasia of the hip presence or absence ($p < 0.0001$, Fisher's exact test). With ultrasonography accepted as the standard for the diagnosis of developmental dysplasia of the hip, radiography had a sensitivity of 61% and a specificity of 87%. The results of this study suggest that the two imaging methods give similar overall results, but that low grade dysplasia detected on ultrasonography may go undetected on radiography.

Keywords : hip dislocation ; congenital ; diagnosis ; radiography ; ultrasonography.

INTRODUCTION

Developmental dysplasia of the hip (DDH) is a disorder that is generally present at birth, and may lead to serious disability later in life (*2*). Early treatment is very important to prevent disability due to DDH (*13*). Early diagnosis is an important step toward early treatment. In some countries, newborns are screened for DDH, and the currently used screening methods include clinical examination, hip ultrasonography or a combination of both (*4,8,11,17, 18*). These methods are likewise used in diagnosis and in follow-up during treatment. Hip radiography, although not recommend as a screening method, is also used in diagnosis and in follow-up. Another

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imaging method is magnetic resonance imaging, which shows the developing anatomy of the hip clearly but is used only in selected patients because it requires sedation.

Advantages of ultrasonography are that it is non-invasive, does not involve radiation, and can show the cartilaginous structures of the hip joint. Hip ultrasonography by the Graf method uses alpha and beta angles which are measured via coronal imaging of the hip joint. The Graf method for diagnosing DDH is widely used because it is easy to apply and has been found to have low intra- and interobserver variability (*9*).

Radiography is likewise an easy method, but in young infants it does not show the cartilaginous hip structures as well as ultrasonography does. For the evaluation of suspected DDH, the most useful radiographic features include high acetabular index, defects of the lateral acetabular rim, lateral and/or proximal displacement of the femoral head, and disruption of the Shenton-Menard arch continuity (*14*).

In our clinic we use ultrasonography as the primary imaging method in the diagnosis and follow-up of DDH. We use hip radiography generally in the follow-up of patients whose anatomical landmarks become difficult to see on ultrasonography due to bone development, and in checking for avascular necrosis of the femoral head. However, we frequently encounter patients who are suspected of having DDH and undergo hip radiography before being referred to our clinic. We routinely perform ultrasonography on these patients. These parallel uses of ultrasonography and radiography provide an opportunity to compare the two imaging methods. The purpose of this study was to use hip ultrasonography as a reference standard to determine the sensitivity and specificity of hip radiography in the detection of DDH.

PATIENTS AND METHODS

The study included infants who were referred to our center for DDH evaluation and had undergone hip radiography before referral. A total of 44 infants (35 female, 9 male) from 4 weeks to 50 weeks in age (mean age 21.7 weeks) were included in the study. Upon referral, hip ultrasonography was performed in all patients. Ultrasonography was performed within 10 days after the radiograph. Also included in the study were 4 patients who were older than 5 months of age, who had undergone hip ultrasonography for DDH screening at our center and had undergone radiography in addition to this. Hip radiographs and ultrasonography images of the hip were thus available for analysis for every patient in the study. Infants whose radiographs did not meet the Tönnis criterion for unrotated positioning during radiography (*16*), were not included in the study. In patients in whom gonadal protectors were used the obturator foramina were not visible in some radiographs, and positioning was evaluated according to the symmetry of the iliac crests.

Radiographs were evaluated for defects or flattening of the lateral acetabular rim, lateral and /or proximal displacement of the femoral head, disruption of the Shenton-Menard arch, and for high acetabular index according to age group as defined by Tönnis (*16*). According to these radiologic criteria, each hip was classified as either showing or not showing DDH.

Ultrasonography of the hip was performed according to the Graf method. The ultrasonography device had a 7.5-MHz linear transducer (Toshiba Sonolayer SSA-270A, Japan). Images were classified according to the Graf classification (*6,7*). Graf type 1 hips were categorized as normal, and types 2b, 2c, D, 3 and 4 were categorized as having DDH. Because type 2a hips can later show either normal or abnormal development, type 2a hips were not included in the study (*4*).

Ultrasonography images were evaluated by the first and second authors, who were experienced in hip ultrasonography, and radiographs were evaluated by the fourth and fifth authors, who were experienced in hip radiography. Evaluations of ultrasonography images were made without knowledge of the results obtained from the evaluations of radiographs, and vice versa. Statistical analyses were performed with the use of Fisher's exact test. Significance was defined as $p < 0.05$. Calculations were performed with SPSS for Windows (version 13, SPSS, Chicago, IL, USA).

RESULTS

A total of 86 hips in 44 infants (35 female, 9 male) from 4 weeks to 50 weeks in age (mean age 21.7 weeks) were included in the study. In 2 infants, Graf type 2a hips were present on one side and these two hips were not included in the study. Results of classification by ultrasonography and radiography are summarized in Table I. With ultrasonography accepted as the standard for the diagnosis of DDH,

Table I. — Comparison of ultrasonography and radiography in the evaluation of DDH

Imaging diagnosis	Ultrasound DDH	Ultrasound normal	Total
Radiography DDH	16	8	24
Radiography normal	10	52	62
Total	26	60	86

Table II. — Radiographic classification of Graf type pathologic hips

Pathologic type on ultrasonography (Graf type)	Normal according to radiography	DDH according to radiography	Total
Type 2b	9	6	15
Type 2c	1	5	6
Type D	0	1	1
Type 3a-b	0	4	4
Total	10	16	26

radiography had a sensitivity of 61% and a specificity of 87%.

Hips showing complete displacement on ultrasonography (Graf types 3a, 3b and D) were all identified as pathologic on radiography (Table II). The largest differences between ultrasonography and radiography were seen in the classification of Graf types 2b and 2c hips (Table II).

An example of a difference in classification by ultrasonography and radiography is shown in Fig. 1. The patient, a female infant, was 14 weeks old at the time of the radiograph (Fig. 1a). The radiograph was evaluated as bilateral DDH. However, on ultrasonography one week later, the diagnosis was normal development (Fig. 1b). When the infant was 11 months old, the family requested a follow-up evaluation. Due to ossification, satisfactory ultrasonographic images could not be obtained, but a radiograph was taken at this time and showed normal development (Fig. 1c). In contrast to this Fig. 2a shows the pre-referral hip radiograph of a female infant 23 weeks old ; the radiograph was interpreted as normal, but on ultrasonography performed on referral, DDH was apparent in the right hip (Graf type 2b) although the left hip appeared normal (Fig. 2b). Treatment with abduction orthosis was administered for 3 months. On a follow-up radiograph taken at age 16 months, both hips showed normal development. When the results, shown in Table I, were evaluated with Fisher's exact test, radiographic findings and ultrasonographic findings were found to be significantly associated ($p < 0.0001$).

DISCUSSION

Few studies have directly compared ultrasonography and radiography in the diagnosis of DDH. In a study by Clarke *et al* (*3*), 83 infants who had been referred for hip evaluation underwent clinical examination, radiography and then real time ultrasonography. The authors used a combination of clinical and radiographic findings as a standard and calculated real time ultrasonography to have a specificity of 97% and a sensitivity of 88%. However, the authors suggested that since radiographic studies do not always reveal mild abnormalities, false positive results on ultrasonography might reflect true pathology (*3*).

Terjesen *et al* (*15*), in a study of both hip joints in 156 children aged between two months and two years, compared ultrasound and radiography in classifying each hip as normal, dysplasia, subluxation, or dislocation. With the two imaging methods, the same classification was arrived at in 303 of the 312 hips. According to radiography, dysplasia was present in 15 hips. Of these, 7 were normal according to ultrasonography and were left untreated. During follow-up of these 7 hips, radiographic normalization was seen in 6 and improvement in 1. The authors recommended that ultrasound be used

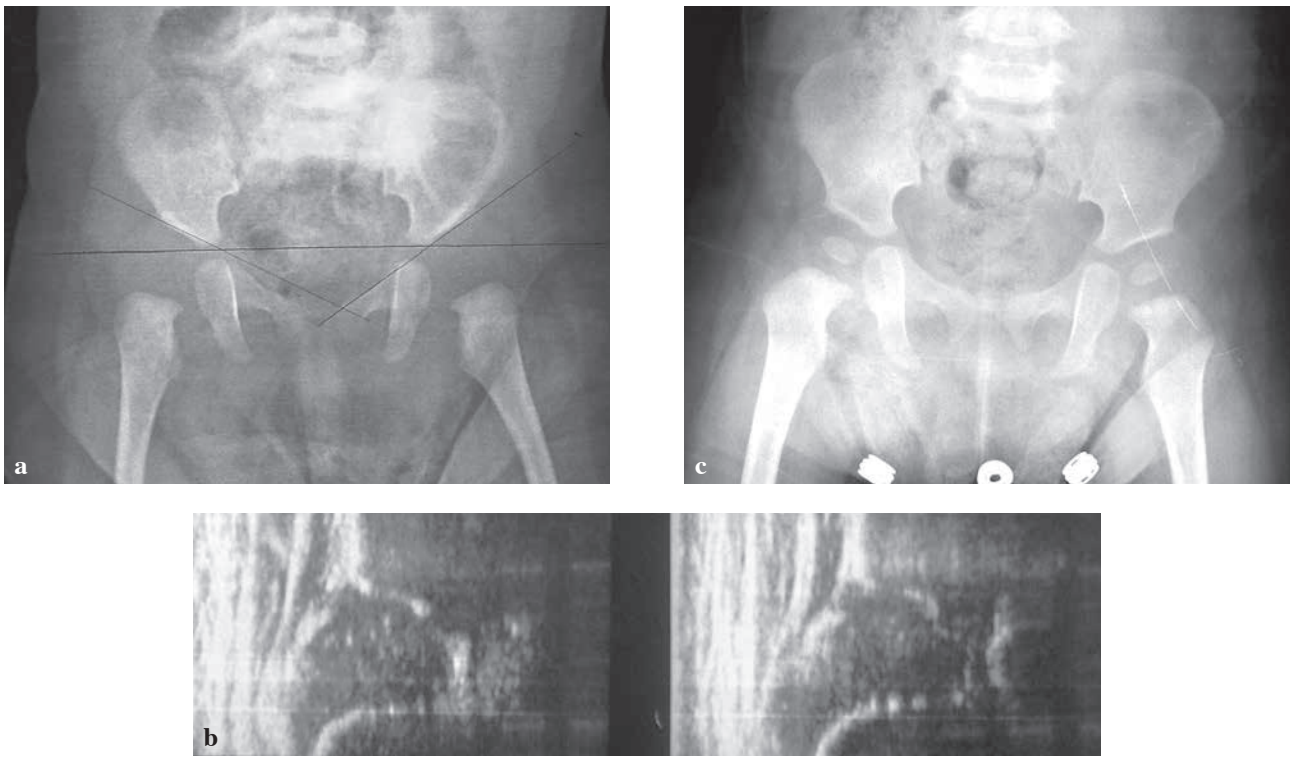

Fig. 1. — Female infant. (a) Radiograph taken at age 14 weeks ; evaluated as bilateral DDH. (b) Ultrasonography performed one week after the radiograph in 1a shows Graf type 1 (normal) development. (c) Follow-up radiograph obtained at age 11 months shows normal development.

as the primary imaging technique for infants in this setting.

Arumilli *et al* (*1*), investigated whether radiographs are necessary during the follow-up of infants who have a family history of DDH but who appear normal at initial evaluation. Of 89 infants who had normal findings on clinical examination and ultrasound at age six to eight weeks, all were found to have normal hips on radiographs taken after an interval of 6 to 12 months. In another study that compared ultrasonography performed at various times in infancy to radiography performed at 6 months, Pillai *et al* (*12*), reported specificities for ultrasonography that ranged from 71% to 98% when acetabular index measured radiographically was taken as the standard.

In the diagnosis of DDH, the similarity of findings obtained by ultrasonography and radiography raises the possibility that ultrasonography might be taken as the standard method against which radiography is measured. This would be consistent with the greater capacity of ultrasound to show cartilage, which composes a greater portion of the hip in infants than in adults. In ultrasonographic methods for the diagnosis of DDH, measurements of cartilaginous structures as well as of bone are used (*6*). This is in contrast to radiographic methods, which use only measurements of bony structures. In a recent cross-sectional study, Li *et al* (*10*) used magnetic resonance imaging (MRI) to evaluate osseous and cartilaginous structures in 81 children with DDH and 241 children with normal hip development. The diagnosis of DDH was made according to the acetabular index obtained from radiographs. From the MRI, the authors obtained an osseous acetabular index and a cartilaginous acetabular index, and reported that these showed different trends of development according to age. The authors recommend the use of MRI for the evaluation of cartilaginous components of the acetabulum. Compared to MRI, however, ultrasonography has the advantage of providing images interactively in real time.

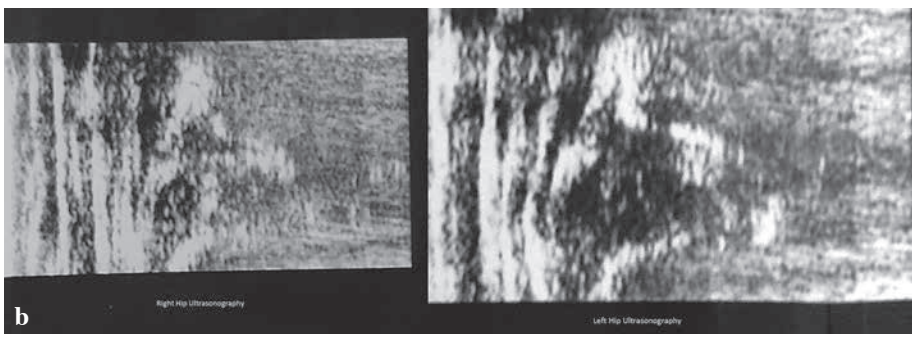

Fig. 2. — Female infant. (a) Pre-referral hip radiograph taken at age 23 weeks ; interpreted as normal. (b) Ultrasonography performed on referral shows DDH in the right hip (Graf type 2b) although the left hip appeared normal.

Our results are consistent with a general similarity of findings between radiography and ultrasonography in the diagnosis of DDH. Of the infants diagnosed as having DDH on ultrasound, a high proportion were also diagnosed as having DDH on radiography ; likewise, of the infants diagnosed as normal on ultrasound, a high proportion also appeared normal on radiography. Of the infants diagnosed as having DDH on ultrasonography, those with decentralised hips (Graf types D and 3) were all likewise diagnosed as having DDH on radiography, so the diagnoses obtained with the two imaging methods did not differ in these infants. However, of the infants whose hips were pathologic without being decentralised (Graf types 2b and 2c), the radiographs were interpreted as normal in approximately half of the cases. This suggests that ultrasonography might be a better method for detecting low grade dysplasia. In Infants who undergo treatment for DDH, radiography does appear to be useful in detecting late acetabular dysplasia (*5*) and femoral head avascular necrosis.

The main strength of this retrospective study is that it is based on contemporaneous radiographic and ultrasonographic images. The limitation of the study, however, is its cross sectional rather than longitudinal design. The results of this study suggest that in infants who undergo radiography and ultrasonography for suspected DDH, the two imaging methods give generally similar results, but that low grade dysplasia detected on ultrasonography may go undetected on radiography.

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