Ultrasound measurements in hips of children above 2 years of age

Normal variations in 232 hips

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In order to find the limits of normal variation of ultrasound measurements in children over 2 years of age, we examined 116 children and adolescents with normal hip joints. The children had been referred for various complaints from their lower extremities. Longitudinal ultrasound scanning from the lateral and anterior aspects was performed by the orthopedic surgeon as an integral part of the clinical examination. The most relevant parameters regarding hip dysplasia are those assessing the coverage of the femoral head: the lateral head distance (LHD, the distance from the lateral tangent of the bony epiphysis to the lateral bony acetabular rim) and the anterior head distance (AHD, measured as LHD, but from the anterior scan).

The LHD increased with age; the upper normal limit (mean + 2 SD) increased from 4 mm at age 2–3 years to 7 mm at age 12–16 years. The AHD was larger in adolescents 12–16 years of age than in younger patients. The upper normal limit was 1 mm in the youngest and 2 mm in the oldest children. The mean (SD) differences (right minus left) in LHD and AHD were 0.3 (1.1) mm and 0.2 (1.0) mm, respectively.

Radiographs were available in 15 of the patients and confirmed the ultrasound findings regarding femoral head coverage. Our findings should be of value in interpreting ultrasound measurements in older children.

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The benefit of ultrasound in evaluating congenital hip dysplasia (HD) in newborns and infants has become well established during the past decade (Graf 1984, Clarke et al. 1985, Terjesen et al. 1989). In older children, most of the acetabulum cannot be seen because of the large ossification center of the femoral head, but other bony and soft structures of the hip joint are visible, allowing assessment of the extent of femoral head coverage by the acetabulum (Terjesen et al. 1991).

Although most patients referred by clinicans on suspicion of HD are under 2 years of age, there are also many children above this age with symptoms indicating possible HD. We examined the limits of normal variation for the ultrasound measurements in children aged 2 years or more.

Patients and methods

During the period 1988 through 1992, we examined at the outpatient clinic the hips of 116 children and adolescents aged 2 years or more. There were 60 boys and 56 girls, with a mean age of 5 (2–16) years. Most of the children had been referred for suspicion of HD or other hip diseases. The reasons for referral were in-toeing gait (60), pain in the hip or knee (29), click or crepitation in the hip (17), limping (6), and out-toeing gait (4). The criteria for including patients in the study were: no previous hip disorder, normal range of motion of both hips, normal anatomic structures of the hip by ultrasound assessment, and ultrasound measurements within the range of normal hips in our previous study (Terjesen et al. 1991). Thus, patients with HD, transient synovitis, Perthes' disease, slipped capital femoral epiphysis, and neuromuscular disease were not included.

We examined all children with ultrasound from the lateral and anterior aspects of the hip joint, according to the method of Terjesen et al. (1991). Real-time ultrasound with a 5 MHz linear transducer was used. The patient was supine and the lower limb was in neutral position. During the lateral longitudinal scan, the baseline of the transducer was kept parallel to the long axis of the patient. The anatomic structures on the ultrasound image are depicted 90° rotated in relation to those on a radiograph (Figure 1). The distance from the lateral tangent of the ossification center of

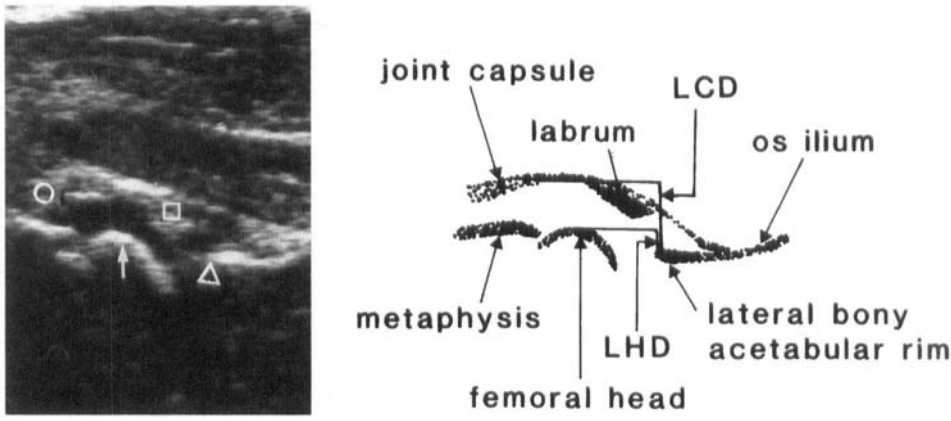

Figure 1. Longitudinal lateral ultrasound image and schematic drawing of a normal right hip in a 6-year-old girl, showing the lateral outline of the ossified epiphysis (arrow), lateral bony acetabular rim (triangle), joint capsule (circle), and labrum (square). Lateral head distance (LHD) and lateral cartilage distance (LCD) are indicated on the schematic drawing.

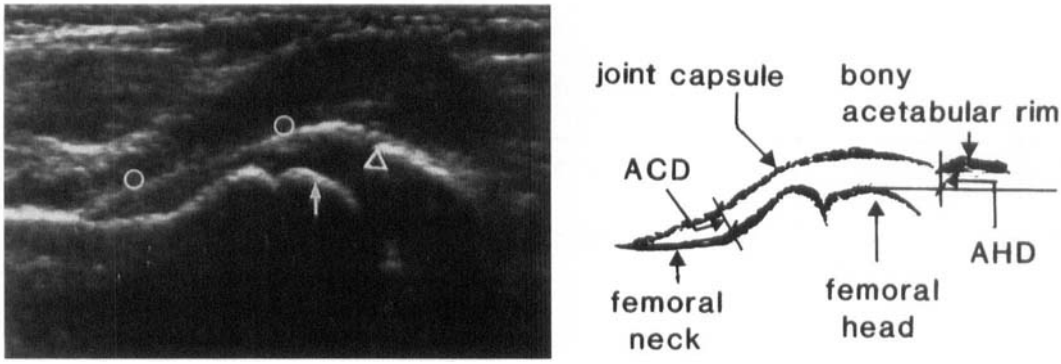

Figure 2. Anterior ultrasound image and schematic drawing of a normal left hip in a 5-year-old girl, showing anterior outline of the femoral head (arrow) and neck, anterior bony acetabular rim (triangle), and joint capsule (circle). Anterior head distance (AHD) and anterior capsule distance (ACD) are indicated on the schematic drawing.

the femoral head to the lateral bony acetabular rim (lateral head distance, LHD) was measured. When the entire ossification center was medial to the acetabular rim, the LHD was given a negative sign. During the last 2 years of the study, including 39 patients under 12 years of age, the distance from the lateral tangent of the cartilaginous femoral head to the lateral bony acetabular rim, was also measured (lateral cartilage distance, LCD) (Terjesen 1993). LHD and LCD express the lateral position of the femoral head relative to the acetabulum and represent the uncovered part of the epiphysis. Based on the measurements of LHD and LCD the thickness of the lateral femoral head cartilage was calculated (LCD minus LHD).

During the anterior scan the transducer was kept over the central part of the femoral head and the long axis of the femoral neck, also depicting the anterior acetabular rim and the anterior joint capsule (Figure 2). Two distances were measured: from the anterior tangent of the bony epiphysis to the anterior bony acetabular rim (anterior head distance, AHD) and from the midportion of the femoral neck to the anterior joint capsule (anterior capsule distance, ACD). The AHD expresses the anterior covering of the bony femoral head and was given a minus sign when the entire bony epiphysis was posterior to the acetabular rim.

Conventional anteroposterior radiographs, which had been ordered beforehand by the referring general practitioner, were available in 15 of the children with a mean age of 5 (2–14) years. The ultrasound examiner did not see the radiographs until after the sonography. The distance from the lateral tangent of the femoral head to the lateral acetabular rim (lateral head distance by radiography, LHDR) was measured. The measurement was made parallel to Hilgenreiner's line. The LHDR corresponds to LHD by ultrasound and expresses the coverage of the femoral head.

Table 1. Ultrasound findings in 116 patients with normal hip joints

Age years	Number of hips	LHD		AHD		ACD	
		Mean	Mean +2SD	Mean	Mean +2SD	Mean	Mean +2SD
2–3	126	0.8	3.5	–1.5	1.1	3.7	5.1
4–7	58	1.5	4.3	–1.8	0.7	4.4	5.9
8–11	30	2.6	5.7	–1.9	0.6	4.4	6.3
12–16	18	3.1	6.7	–0.7	1.5	5.1	7.3

LHD lateral head distance, mm, AHD anterior head distance, mm, ACD anterior capsule distance, mm

We used analysis of variance (ANOVA) and Scheffe's F-test to compare group means. The significance level was set at $p < 0.05$. The correlation between various parameters was expressed as Pearson's correlation coefficient (r).

Results

The mean LHD was 0.8 mm in the youngest children and 3.1 mm (p 0.0001) in the oldest (Table 1). The upper normal limit (mean + 2 SD) increased from 3.5 mm at age 2–3 years to 6.7 mm at age 12–16 years. The mean side difference (right minus left) was 0.3 mm (SD 1.1).

The mean LCD in patients under 12 years of age was 5.2 mm and no difference with age occurred (Table 2). There was a high correlation between LHD and LCD (r 0.69). The thickness of the lateral femoral cartilage was 3–4 mm in most hips and was smaller in the age group 8–11 years than in younger children (p 0.001).

The mean AHD had a minus sign in all the age groups, showing that the whole ossification center was posterior to the anterior acetabular rim in most hips (Table 1). The AHD was larger in adolescents 12–16 years of age than in younger patients (p 0.009), whereas there were no differences between the 3 youngest groups. The mean (SD) side difference (right minus left) was 0.2 (1.0) mm.

The ACD was 4–5 mm in most hips and increased with age (p 0.0001, Table 1). The upper normal limit increased from 5 mm at age 2–3 years to 7 mm in the oldest group. The mean difference between the right and left side was 0.3 (SD 1.0) mm.

No differences in LHD, AHD and ACD between the different groups of complaints and correlated to age were found. Nor were there any differences in these parameters between affected and contralateral hips in children with unilateral complaints.

All 15 radiographs showed normal hips, confirming the ultrasound findings. The correlation coefficient between lateral head distance measured by ultrasound and radiography was 0.59. The mean difference between LHD and LHDR (LHD–LHDR) was –0.3 (-4.0–2.4) mm, and the difference was 3.0 mm or less in 28 of the 30 hips.

Table 2. Lateral cartilage distance (LCD, mm) and thickness of the lateral femoral head cartilage (mm) by ultrasound

Age years	Number of hips	LCD		Cartilage thickness	
		mean	SD	mean	SD
2–3	50	5.2	1.3	4.4	0.9
4–7	18	5.2	1.3	4.0	0.8
8–11	6	5.4	0.9	2.6	0.4

Discussion

Our study showed that all relevant lateral and anterior anatomic structures of the hip joints in older children can be reliably visualized by ultrasound. With regard to hip dysplasia, a decreased coverage of the femoral head is considered to be the most important parameter, irrespective of the age of the patient. Thus, it is essential to establish the limits of normal variation of LHD in the various age groups. The present results showed somewhat smaller values for the upper normal limit of LHD in the two youngest age groups than did our previous study (Terjesen et al. 1991). Based on both these studies, the following upper normal limits are suggested: 4 mm at age 2–3 years, 5 mm at 4–7 years, 6 mm at 8–11 years, and 7 mm in adolescents above 11 years of age. In patients with LHD lower than these limits, hip dysplasia can be excluded. When LHD is higher, radiography should also be used for the evaluation. The same policy can be used in the follow-up of patients previously treated for hip dysplasia (Figure 3).

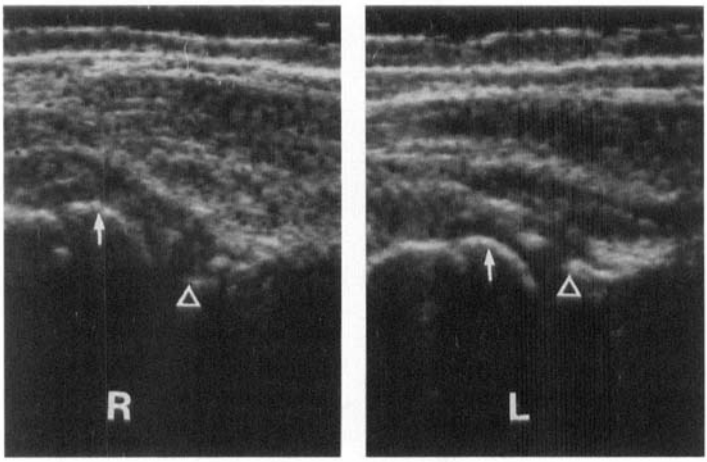

Figure 3. Longitudinal lateral ultrasonograms (labels as in Figure 1) of both hips in a 6-year-old girl (not included in the present material) during follow-up of previously treated hip dislocation. The femoral head is laterally displaced in the right hip (R), indicating slight subluxation, whereas the left hip (L) is normal. Radiography confirmed the ultrasound findings.

A comparison between ultrasound and radiography was performed in 15 children.The results confirmed our experience of a good accordance regarding extent of femoral head coverage (LHD and LHDR), indicating that the ultrasound evaluation is reliable (Terjesen and Østhus 1991, Terjesen et al. 1991). Although ultrasound (like radiography) entails potential measurement errors due to patient positioning, transducer position, and identification of anatomic landmarks on images, the moderate interobserver variation of ± 1 mm (Terjesen et al. 1991) confirms our experience that the technique is appropriate in clinical practice.

In addition to LHD, the exposed lateral part of the femoral head was also measured as the lateral cartilage distance (LCD) in patients under 12 years of age. Little useful additional information was gained by determining this parameter which is in accordance with experience based on arthrography (Gallagher et al. 1983). Moreover, the outline of the bony femoral head is more easily identified than that of the cartilaginous part. We therefore recommend LHD as the main parameter regarding femoral head coverage.

The anterior head distance showed that the whole bony femoral head was totally covered by the acetabulum in most hips. If a hip with HD has anterior protrusion or subluxation, this will be detected by an increased AHD.

The anterior capsule distance (ACD) is of little importance in hip dysplasia. However, all conditions with effusion or blood in the hip joint increase the ACD. This is therefore the main ultrasound parameter in transient synovitis (Kallio et al. 1985, Wingstrand 1986, Terjesen and Østhus 1991). The side difference was less than 2 mm in all normal hips, and the ACD increased somewhat with age, in keeping with our previous results (Terjesen et al. 1991).

We have adopted sonography as the primary imaging technique in all patients, regardless of age, referred for possible hip dysplasia. If that sonography is performed by an experienced examiner, the evaluation takes no more than about 5 min in most patients. If performed by the orthopedic surgeon as an integral part of the clinical examination, as was done in our study, we think ultrasound examination is time-saving and probably less expensive than separate radiographic and clinical examinations.

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