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Femoral anteversion in children measured by ultrasound

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The femoral anteversion was measured by ultrasound and biplanar radiography in 57 children, most of whom had clinical signs of increased anteversion. A modification of previously reported ultrasound techniques was introduced, as the transducer was tilted instead of being kept horizontally. Four different modes of ultrasound examination were evaluated. The most appropriate technique involved only one ultrasound scan at the hip level.

The correlation between the results of ultrasound and radiography was good with less than 10° discrepancy in the majority. Ultrasound is suitable for screening children with rotational disorders of the femur. The main advantage of the method is that exposure to radiation is avoided.

The femoral anteversion (AV) angle can be determined by various conventional radiographic techniques, of which the biplanar technique appears to be the most useful one (LaGasse & Staheli 1972, Ruby et al. 1979). Accurate measurement of the AV angle can be obtained by computed tomography (CT) (Weiner et al. 1978, Peterson et al. 1981). However, exposure to radiation is a disadvantage associated with all radiographic methods, including CT. Thus, nonionizing techniques for determining femoral anteversion are desirable, and ultrasound has recently been introduced for this purpose (Moulton & Upadhyay 1982). So far, no patient series with increased anteversion examined by ultrasound has been reported.

We have studied the following problems: 1) Is ultrasound suitable for determining femoral anteversion in children? 2) What is the correlation between the AV angles measured by ultrasound and radiography? 3) What modification of various ultrasound techniques is the most appropriate for clinical use?

Patients and methods

The material comprised 47 girls and 10 boys, 7 (3–14) years of age, and most of them were admitted because of clinical signs of increased femoral anteversion.

The radiographic examination was carried out according to the biplanar method of Dunlap, modified by Rippstein (1955). The apparent angles of AV and inclination were measured by the same radiologist (S.A.). The true AV angles were determined with the aid of a standard conversion table.

When measuring the AV angles by ultrasound, the patients were supine. A real-time ultrasound apparatus with a 5 MHz linear transducer was used (Sonoline SL-2, Siemens). Four different modes of measurements were tested.

Group A. The children had their knees flexed 90° over the edge of the table, and the lower legs were strapped in the vertical position (Figure 1). Thus, it was assumed that the posterior tangent of the femoral condyles was in the horizontal plane. An ultrasound scan along the axis of the femoral neck was performed, showing the anterior contours of the femoral head and neck, as well as the intertrochanteric region. The correct scanning level was easily recognized after a search with the ultrasound transducer. Because the femoral neck in children is short, a double-size enlargement on the monitor-screen image was used. The transducer was tilted until the outline of the femoral neck appeared as a horizontal line on the monitor screen (Figure 2). The degree of tilt of the transducer was assessed with a clinometer, which was held along the transducer. The AV angle was equal to the angle of tilt.

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Figure 1. The position of the legs used in Groups A and D; the knees flexed 90° over the edge of the table and the lower legs strapped in the vertical position. The angle of tilt of the transducer was read on the scale of the clinometer.

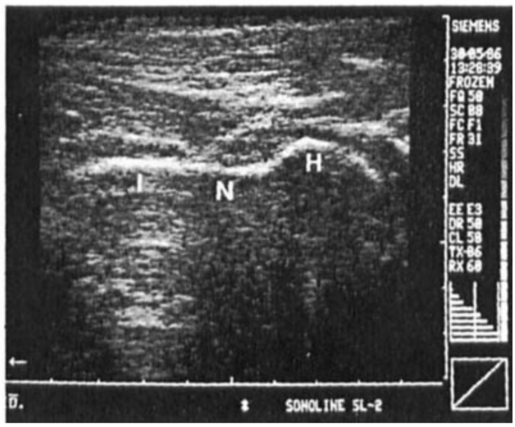

Figure 2. Ultrasound image showing the anterior contour of the femoral head (H) and neck (N) and the intertrochanteric region (I). The femoral neck is seen as a horizontal line.

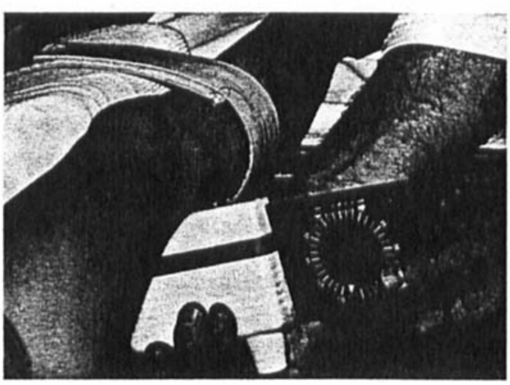

Figure 3. The position of the legs used in Groups B and C permitting transverse scanning of the posterior femoral condyles.

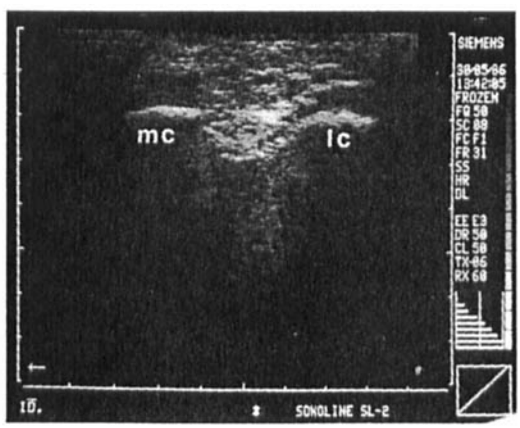

Figure 4. Ultrasound image showing the transverse outline of the posterior femoral condyles (mc – medial, lc – lateral). The tangent of the condyles appears to be horizontal.

Group B. The children had their knees extended, and the lower legs were resting on an additional table and strapped (Figure 3), permitting transverse scanning of the posterior femoral condyles. The angle between the posterior tangent of the femoral condyles and the horizontal plane was measured by tilting the transducer until the tangent appeared horizontal on the monitor (Figure 4). In this position the tilt angle was measured as previously described. The angle between the femoral neck and the horizontal plane was measured as described for Group A. The AV angle was calculated by adding or subtracting the tilt angles of the two scans. When the leg was in internal rotation, the angles were added; if the leg was externally rotated, the angle of the femoral condyles was subtracted from that of the femoral neck.

Group C. A similar procedure as described for Group B was used. However, because the transducer was kept in a somewhat more transversal position, the anterior outline of the greater trochanter was included (Figure 5) instead of the intertrochanteric region used in Groups A and B. The transducer was tilted until the tangent of the greater trochanter and the center of the femoral head appeared horizontal on the monitor. The AV angle was obtained by combining the angles of the knee and the hip scan, as previously described.

Group D. The legs were flexed 90° over the edge of the table, as was done in Group A. Only one ultrasound scan of the hip region was needed. The AV angle was determined according to the angle of tilt when the anterior tangent of the femoral head and the greater trochanter appeared horizontal on the monitor.

All the ultrasound measurements were performed by the same examiner (T.T.). The ultrasound measurements, as well as the radiographic angles, were determined without the examiner knowing the results of the other method. Sixteen children were examined by the methods used in the C and D groups to assess the correlation between the two modifications. Two children were examined by the methods of both Groups A and B. In 46 out of 75 ultrasound examinations, the AV angles were measured twice to find the variation between two consecutive measurements.

Differences between ultrasound and radiographic measurements determined with the t test were considered significant at P values < 0.05. The coefficient of correlation of the two methods was calculated.

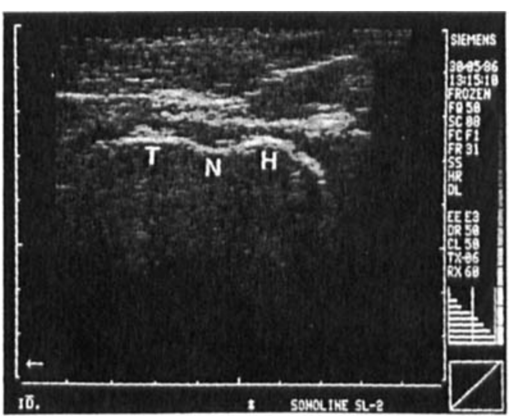

Figure 5. Ultrasound scan used in Groups C and D. The anterior contour of the femoral head (H) and neck (N), as well as the greater trochanter (T), is clearly seen. The tangent of the femoral head and great trochanter appears to be horizontal.

Results

In most cases there was good agreement between the ultrasound and radiographic measurements of the AV angles (Table 1); the coefficients of correlation in Groups A-D ranged from 0.57 to 0.88. The mean difference between the two methods was 1° in both Groups A and B. However, in Groups C and D, the AV angles determined by ultrasound were on an average 4° greater than those obtained by radiography. The difference between ultrasound and radiography was less than 5° in more than half of the measurements and more than 10° in only one tenth (Table 2). There was no asymmetry between the right and left hips in any of the groups.

In patients where the AV angles were measured twice by the same ultrasound examination, the mean difference between two consecutive

Table 1. Femoral anteversion angles determined by ultrasound and radiography. Values are mean (range)

	Group A n 36	Group B n 28	Group C n 46	Group D n 40
Ultrasound	33 (12–47)	39 (16–51)	39 (14–56)	40 (24–50)
Radiography	32 (3–51)	40 (20–58)	36 (14–47)	36 (18–47)

Table 2. The differences in femoral anteversion angles between ultrasound and radiography, expressed as the number of hips according to the magnitude of the difference

Difference	Group A n 36	Group B n 28	Group C n 46	Group D n 40
0–5°	24	17	24	20
6–10°	6	9	16	15
>10°	6	2	6	5

measurements was 3° (0–10°). The difference was < 8° in 95 per cent of the measurements. Two patients were measured twice with an interval of some months, and the differences ranged from 3° to 7°.

The correlation of the AV angles determined by ultrasound and radiography in Groups C and D are shown in Figure 6. Only 2 of the 40 AV angles in Group D and 5 of the 46 angles in Group C were outside the range of the mean difference of 4° ± 10°.

The difference between the AV angles determined by the ultrasound techniques of Groups C and D in 16 patients examined by both methods was on an average 3° (0–9°).

Discussion

The AV angle is usually defined as the angle between the posterior tangent of the femoral condyles and the line connecting the midpoints of the femoral head and neck, projected on a plane perpendicular to the long axis of the femur. By ultrasound, the anterior outline of the proximal femur is scanned and AV is measured as the angle between the condylar plane and the anterior tangent of the femoral neck or the tangent of the femoral head and greater trochanter. Thus, AV determined by ultrasound and radiography does not represent the same anatomic angle. Studies on dry femora have shown a very good agreement between ultrasound and direct measurements (Moulton & Upadhyay 1982, Zarate et al. 1983), and also between ultrasound and CT (Clarac et al. 1985). In the latter study, a series of patients was also examined; the difference between the values determined by ultrasound and CT was less than 5° in 90 out of 93 hips. Our investigation confirms that ultrasound is reliable for measuring femoral AV, although the agreement with radiography was not as good as that reported by Clarac et al. (1985).

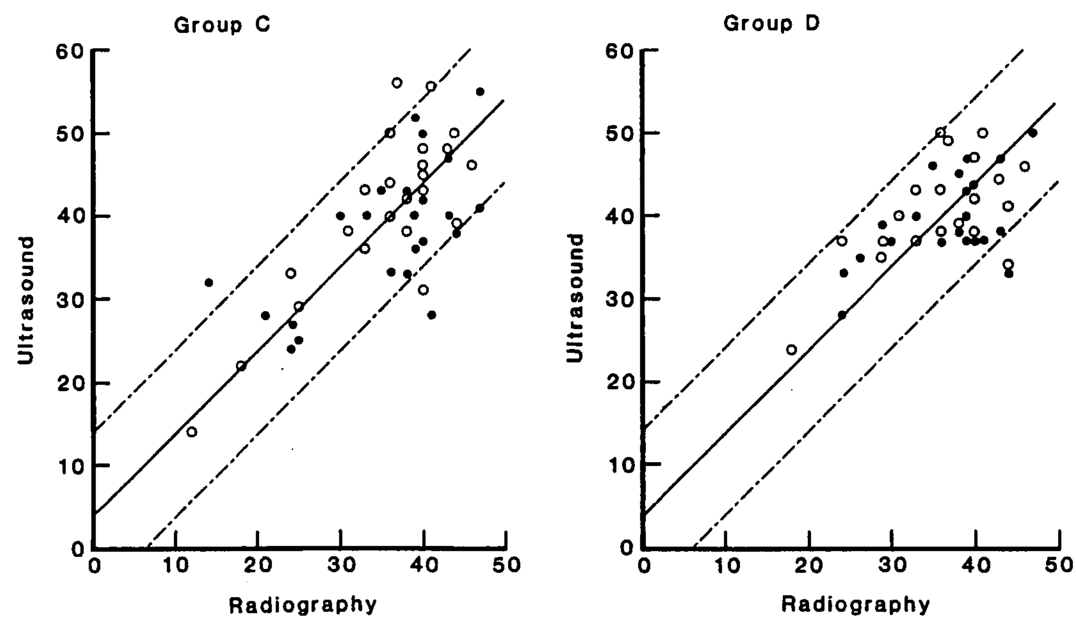

Figure 6. The relationship between the AV angles of all the hips in Groups C and D determined by ultrasound and radiography. The lines indicate the mean difference of 4° ±. 10°, •, right, ○ left hip.

The accuracy of the method of Rippstein (1955) is approximately ± 5° (Ruby et al. 1979, Henriksson 1980). Because the precision of the ultrasound method in our study was approximately ± 7°, a discrepancy less than 10° between ultrasound and radiography appears satisfactory.

The mean AV angles in our subjects were rather high. This was not unexpected, considering that most patients were admitted for disturbances of gait pattern owing to increased femoral anteversion.

In previous reports the ultrasound transducer was kept in the horizontal position, and the AV angle was measured on the monitor-screen image (Moulton & Upadhyay 1982, Zarate et al. 1983, Clarac et al. 1985). This method is satisfactory for measuring AV angles within the normal range. However, in patients with increased anteversion, the horizontal position of the transducer is not appropriate. The transducer tends to lose its contact with the skin over the trochanteric region, and the outline of the lateral part of the femoral neck and the trochanteric region is not adequately depicted. This was the reason why we tilted the transducer until it was parallel with the desired line, which then became horizontal on the monitor screen. Thus, the bony contours are always clearly seen, no matter whether the anteversion is increased or within the normal range.

Moulton & Upadhyay (1982) and Zarate et al. (1983) used two ultrasound scans, one of the knee region and one of the hip. However, only one scan at the hip level was performed by Clarac et al. (1985), assuming that the knee axis was in the correct position when the knees were flexed 90° and the lower legs kept vertical. We evaluated both modifications and found no difference. The use of only one scan is simpler and less time-consuming.

Whereas the tangent of the femoral neck was used by Zarate et al. (1983) and Clarac et al. (1985), the tangent of the femoral head and greater trochanter was used by Moulton & Upadhyay (1982). We found both modifications equally reliable. However, the determination of the proximal and distal limits of the femoral neck is often uncertain, making the tangent of the neck more difficult to define. In children, where the femoral neck is short, this is a greater problem than in adults. This drawback is eliminated by using the head-trochanter tangent, which usually is easy to determine. When using the head-trochanter tangent, the AV angles determined by ultrasound in children should be corrected by subtracting 4° from the measured values.

An important advantage of ultrasound is that exposure to radiation is avoided. The examination is rapid, safe, and painless. Ultrasound scanning is recommended for screening children with rotational disorders of the femur. In patients with obvious discrepancies between clinical findings and AV angles determined by ultrasound, additional radiographic examinations are needed, preferably by CT.

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