Leg-length discrepancy measured by ultrasonography

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Leg-length discrepancy was determined by real-time ultrasonography (ultrasound) in 45 patients, and the measurements were compared with those of erect-posture radiography. A special device for holding and moving the ultrasound transducer was constructed, and the leg length was measured as the highest level of the femoral head in the standing position. The correlation coefficient *r* between ultrasound and radiography was 0.94, the mean difference was –1.9 mm, and the limits of agreement (mean ± 2 SD) were –9.1 to 5.3 mm. The mean difference between examiners 1 and 2 was 1.7 mm, and the 95 percent confidence interval was ± 7 mm.

We conclude that leg-length discrepancy can be reliably determined by ultrasound, although the accuracy is less than that obtained by radiographic methods. Because ultrasound is not limited by radiation hazards, our technique can be used for clinical screening.

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Leg-length discrepancy can be determined with sufficient accuracy by various radiographic techniques and by CT scanning. However, because exposure to radiation is potentially hazardous, radiographic techniques are especially less desirable for screening children and adolescents.

We have evaluated whether or not ultrasonography (ultrasound) is sufficiently accurate to be used for leg-length measurements.

Patients and methods

Forty-five consecutive patients referred because of a leg-length discrepancy were examined by ultrasonography (ultrasound) and radiography. There were 31 men and 14 women, with a mean age of 20 (10–47) years. The etiology of the condition was idiopathic in 19 cases, a previous femoral shaft fracture in 10 cases, a previous tibial fracture in 4 cases, a congenital clubfoot in 5 cases, and other causes in 7 cases.

Ultrasonography

For the ultrasound examination, a real-time apparatus with a 5-MHz linear transducer was used (Sonoline SL-1, Siemens AG, Erlangen, Germany). The patients were examined in the standing position with the knees straight and with equal weight on both legs. A special rack for holding and moving the transducer was constructed (Figure 1). The transducer was fixed horizontally in a holding device on the rack, and was moved vertically up and down with a crank handle. The level of the transducer was measured with a millimeter scale on the rack.

The ultrasound transducer was aimed at the anterolateral aspect of the proximal femur (Figure 2). The femoral head was identified (Figure 3). The most proximal level where the femoral head was seen clearly was assumed to represent the leg length, and this level was read to the nearest millimeter on the scale. Each leg was measured twice by the same examiner, and the average value was used. To evaluate the interobserver variation, the leg-length discrepancy was determined independently by 2 examiners in 14 patients.

Radiography

To assess the accuracy of the ultrasound measurements, radiography was carried out with the patient standing with the legs parallel and both knees fully extended, with both feet placed firmly on the floor, and with the patient's back against the film carrier. The tube-film distance was 180 cm. With the x-ray tube at the level of the middle of the lumbar spine, a

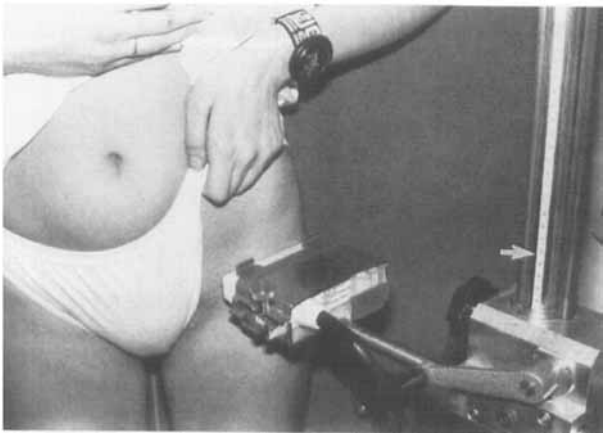

Figure 1. The rack with the holding device for the transducer. The transducer is moved vertically up and down with the crank, and the level is read on the millimeter scale (arrow).

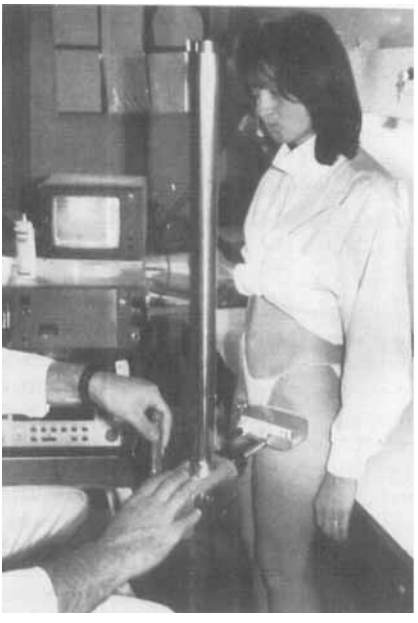

Figure 2. With the patient in the erect position, ultrasound scanning from the anterolateral aspect is performed. The transducer is moved vertically to locate the most proximal part of the femoral head, which represents the leg length.

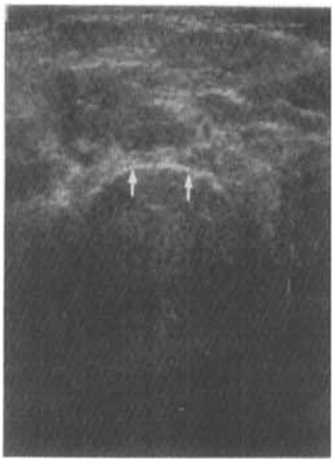

Figure 3. Ultrasound image showing the anterolateral contour of the proximal part of the femoral head (arrows).

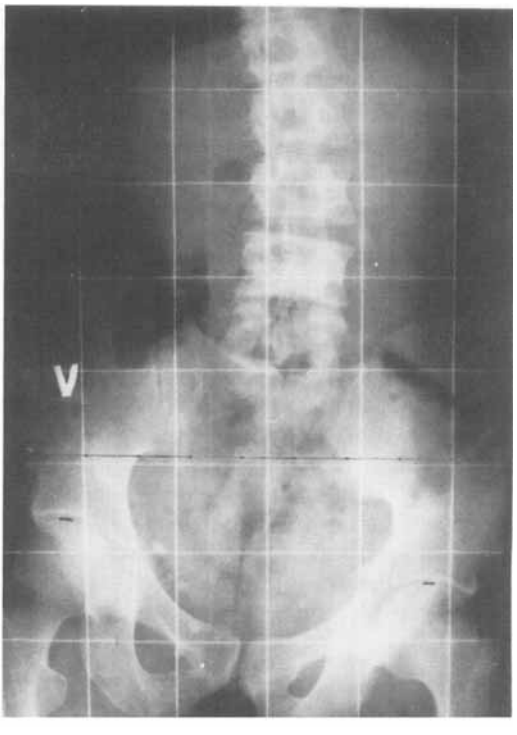

Figure 4. Radiograph obtained in the erect posture showing the hip joints and the lumbar spine. The proximal level of the femoral head on both sides is indicated.

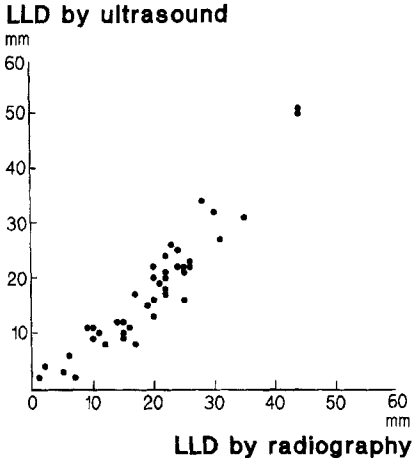

Figure 5. Scatter diagram showing the leg-length discrepancies of all the patients determined by ultrasound and radiography.

radiograph of the spine and pelvis, including both hip joints, was obtained (Figure 4). A scale on the bucky, with horizontal lines made of accurately aligned steel wires with 5-cm increments, was included in the radiographs. The vertical distance from the proximal tangent of the femoral head to the nearest reference line was measured in millimeters; the difference between the two sides represented the length discrepancy.

In 22 patients, a second radiograph was obtained after wooden boards had been placed under the shortest leg to equalize the lengths. Thus, the precision of the radiographic technique could be assessed by calculating the difference between the two measurements.

Statistics

The agreement between ultrasound and radiographic measurements was assessed by the correlation coefficient r and by the limits of agreement (mean difference between the methods ± 2 SD) according to Bland and Altman (1986). The precision of repeated radiographic measurements was calculated as the repeatability coefficient, i.e., ± 2 SD of the differences between the first and the second measurement (Bland and Altman 1986). The paired samples t-test (two-tailed) was used for the differences between ultrasound and radiographic measurements, for the repeated radiographic measurements, and for the interobserver variation by ultrasound. The significance level was set at 0.05.

Results

The mean leg-length discrepancy measured by ultrasound was 17.9 (2–51) mm and by radiography 19.6 (1–44) mm (Figure 5). The correlation coefficient was 0.94. There was no trend towards a greater difference between the methods with increasing leg-length discrepancy. The mean difference between ultrasound and radiographic measurements was –1.9 mm (range –9 to 7 mm, SD 3.6). The limits of 95 percent probability of agreement (mean ± 2 SD) were –9.1 to 5.3 mm. The agreement between the methods was good, as the difference in measurements using the two methods was 5 mm or less in 38 patients (84 percent).

The mean difference between repeated measurements by radiography (measurement 1 minus measurement 2) was –0.8 mm (range –8 to 5 mm, SD 2.5). Thus, the repeatability coefficient (± 2 SD) was ± 5.0 mm.

The mean interobserver variation by ultrasound (examiner 1 minus examiner 2) was 1.7 mm (range –3 to 11 mm, SD 3.6). The difference between the 2 examiners was not significant; thus, the 95 percent confidence interval of interobserver variation (± 2 SD) was ± 7 mm. The interobserver variation was 6 mm or less in all the patients except 1. This was a 35-year-old man with a previous pertrochanteric fracture. The top of the femoral head of the fracture side was difficult to define exactly, and the interobserver variation was 11 mm.

Discussion

Although opinions differ widely with respect to the amount of leg-length discrepancy that is clinically important, accurate methods for determining leg length are essential. Clinical measurements are notoriously inaccurate (Nichols 1960, Clarke 1972, Fisk and Baigent 1975). Thus, radiographic techniques are required for reliable measurements. Scanography in the supine position has been employed by some authors (Amstutz and Sakai 1978, Siffert 1987), whereas others prefer erect radiographic techniques (Rush and Steiner 1946, Clarke 1972, Giles and Taylor 1981).

The reliability of new methods, such as ultrasound, has to be evaluated by comparison with radiography and by assessment of the interobserver variation. One problem is that radiography also involves a certain amount of inaccuracy. The erect radiographic techniques have an inaccuracy of approximately 3 mm (Rush and Steiner 1946, Gofton and Trueman 1971, Clarke 1972, Giles and Taylor 1981). Our radiographic method was the standard method employed in the diagnosis of scoliosis. The central x-ray beam was at the level of the lumbar spine, and was thus at a more proximal level than that recommended for leg-length measurements (Clarke 1972, Giles and Taylor 1981). Moreover, the radiographs were taken by various technicians in a busy routine laboratory. These factors probably contributed to the somewhat greater inaccuracy as compared with studies focusing on leg-length discrepancy. Our accuracy was not better than ± 5 mm using routine radiography aimed at diagnosis of scoliosis with the subject in the erect position. However, this degree of accuracy is adequate for screening purposes.

The ultrasound measurements correlated well with those of radiography, because 85 percent of the differences between the methods were within ± 5 mm, and 95 percent were within ± 7 mm. Because both methods involve errors of measurement, the accuracy of the ultrasound technique was assumed to be ± 5 mm. The rather large interobserver variation as regards 1 patient with a previous pertrochanteric fracture signals caution when making measurements in cases where the proximal femur is abnormal, because the top of the femoral head may be difficult to determine exactly. This anatomic landmark was also subjectively assessed in other patients, because the ultrasound contour of the femoral head gradually changes from sharp to blurred over a difference in height of a few millimeters. Another source of error is that the patient does not stand with perfectly straight knees.

Using ultrasound, the leg-length discrepancy was measured, on an average, as 1.9 mm less than that measured on radiographs. The reason for this systematic difference might be the geometric magnification factor of radiography, which is approximately 1.5 mm when the leg-length discrepancy is 18 mm (Gofton and Trueman 1971).

Only one previous report of leg-length measurement using ultrasound seems to have been published (Holst and Thomas 1988). The leg lengths of 20 cadavers in the supine position were compared with direct measurements of the anatomic preparations. The accuracy was good, because there was complete agreement in the majority and the maximum error was 10 mm. The results of Holst and Thomas (1988) accorded well with ours. However, we feel that leg-length discrepancy should preferably be determined in the erect position.

Compared with radiography, the benefits of ultrasound are that it is less expensive and that it is not associated with radiation hazards. Thus, ultrasound is suitable as a screening method in patients referred because of a clinically suspected leg-length discrepancy. The ultrasound examination should by preference be carried out by the orthopedic surgeon during the clinical evaluation. The length of the lower legs can be determined separately by measuring the level of the proximal margin of the tibial condyles. Although ultrasound is somewhat less accurate than radiographic methods, it could be used for screening purposes. However, in patients undergoing procedures to equalize their leg lengths, erect-posture radiography should be done preoperatively both to measure the leg-length discrepancy by the most accurate method and to assess the lumbar spine for postural scoliosis and the effect on the spine of equalizing the leg length.

References

Amstutz H C, Sakai D N. Equalization of leg length (editorial). *Clin Orthop* 1978; 136: 2–6.

Bland J M, Altman D G. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1986; 1 (8476): 307–10.

Clarke G R. Unequal leg length: an accurate method of detection and some clinical results. *Rheumatol Phys Med* 1972; 11 (8): 385–90.

Fisk J W, Baigent M L. Clinical and radiological assessment of leg length. *N Z Med J* 1975; 81: 477–80.

Giles L G, Taylor J R. Low back pain associated with leg length inequality. *Spine* 1981; 6 (5): 510–21.

Gofton J P, Trueman G E. Studies in osteoarthritis of the hip. II. Osteoarthritis of the hip and leg length disparity. *Can Med Assoc J* 1971; 104 (9): 791–9.

Holst A, Thomas W. Non invasive, reliable and repeatable at any time-ultrasonographic measurement of leg length. *Electromedica* 1988; 56 (3): 105–9.

Nichols P J R. Short leg syndrome. *Brit Med J* 1960; 1: 1863–5.

Rush W A, Steiner H A. A study of lower extremity length inequality. *Am J Roentgenol* 1946; 56: 616–23.

Siffert R S. Lower limb-length discrepancy. *J Bone Joint Surg* (Am) 1987; 69 (7): 1100–6.