How I do it

Ultrasonography for evaluation of hip dysplasia

Methods and policy in neonates, infants, and older children

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Ultrasound (US) was introduced in the diagnosis of congenital and developmental hip dislocation and dysplasia (HD) more than 15 years ago (Graf 1980, 1984) and has become generally accepted as an important diagnostic tool (Morin et al. 1985, Terjesen et al. 1989a, Castelein et al. 1992, Millis and Share 1992). However, there is no consensus with regard to ultrasound methods or to policy concerning screening and treatment.

In this article I present the various ultrasound techniques I have developed and evaluate their application in clinical practice. On the basis of more than 10 years' experience with sonography and extensive comparison between US and radiography, I have found these techniques appropriate in routine clinical work.

Newborns (< 1 month of age)

Ultrasound method

US for hip assessment in the neonate has been exactly described previously (Terjesen et al. 1989a, 1996). We use a 5 Mhz (or 7.5 Mhz) linear transducer. The technique is a combination of static and dynamic assessment mainly based on measurement of femoral head coverage (FHC, the cover of the cartilaginous femoral head by the bony acetabular roof). My reason for using this method is that I consider the coverage of the femoral head to be the most important parameter in HD, whatever the age of the patient.

The baby is lying supine and manually supported by the mother, in order to avoid rotation of the child. The examiner holds the transducer with one hand and the leg of the baby with the other (Figure 1). With the leg in neutral position regarding ab/adduction and rotation, but with slight flexion of the hip, a longitudinal scan through the center of the hip joint is obtained. In relation to a radiograph, the anatomic structures are seen 90° rotated on the US image (Figure 2). Two distances are measured from the acetabular floor: to the lateral bony acetabular rim (distance a) and to the lateral hip joint capsule (distance b). Both measurements are taken perpendicular to the baseline of the US image and thus perpendicular to the long axis of the baby. The percentage a/b × 100 represents the FHC. The measurements are rapidly taken on the frozen US image using the software on the monitor. We have found that the mean FHC in newborn girls is 54% and in boys 56% (Terjesen et al. 1989a, Holen et al. 1994). The lower limit of normal range (mean –2 SD) is approximately 45% (44% in girls and 47% in boys). In hips with subluxation, the distances a and b are measured from the medial tangent of the femoral head rather than from the acetabular floor.

Femoral head coverage was also measured by Morin et al. (1985), but they applied a slightly different approach. Whereas we use a linear transducer, keep the hip slightly flexed, and take a parallel to the baseline of the image as our reference line, they employed

Figure 1. The neonate is lying supine, with slight, physiological flexion but otherwise neutral position of the hips. The baby is supported by the mother. The examiner uses one hand to hold the transducer and the other to hold the infant's leg. The linear transducer is applied longitudinally at the lateral aspect of the hip. Thus, a coronal section of the hip joint is obtained.

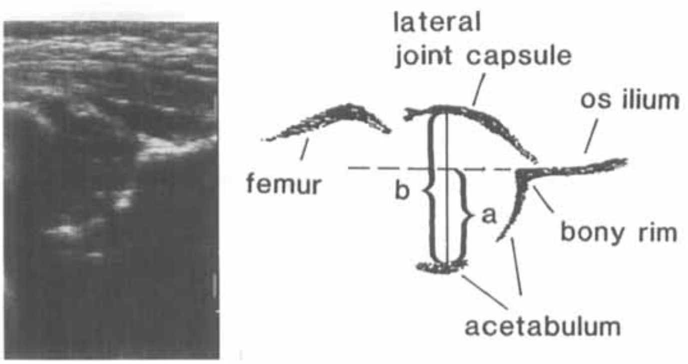

Figure 2. Longitudinal ultrasonogram and schematic drawing of a normal hip in a newborn. The anatomic structures are depicted 90° rotated in relation to those on a radiograph. The distances a and b, measured perpendicular to the baseline of the image, are used for calculation of femoral head coverage (FHC).

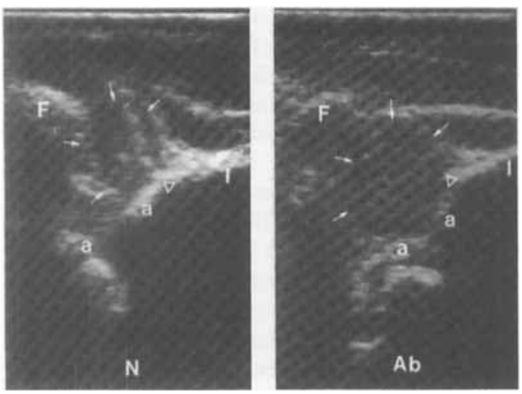

Figure 3. Longitudinal ultrasonograms of a markedly unstable hip (positive Ortolani) in a newborn. In such cases the distances used for assessment of FHC are measured from the medial tangent of the femoral head rather than from the acetabular floor. The outline of the femoral head is indicated by arrows and the lateral acetabular rim by a triangle. The femoral head is severely subluxated when the leg is in neutral position (N) and is reduced to normal position in the acetabulum when the hip is abducted and flexed (Ab). I os ilium; F femur; a acetabulum. Reprinted with permission from J Bone Joint Surg (Br).

a sector transducer, kept the hip in 90° flexion, and used the lateral outline of the iliac bone proximal to the acetabulum as their reference line. Because this outline is not always straight but slightly curved, our reference line is more easily defined.

In newborns with neonatal hip instability (NHI), i.e., positive Ortolani or Barlow test, the coverage is reduced to a mean of 36–37% (Terjesen et al. 1989a, Holen et al. 1994), which means that most neonatally unstable hips are subluxated rather than dislocated. In these cases an additional US scan with the hip in abduction and flexion can be obtained (Figure 3), to simulate treatment with an abduction pillow or splint. A normal FHC in abduction means that the hip has been reduced and that the anatomy of the acetabulum is normal. I find this way of performing dynamic sonography more effective than the commoner technique of using a stress maneuver by pushing the femur proximally and laterally to detect instability. That maneuver is difficult to interpret because there is physiologic laxity of the newborn hip, with mobility of the femoral head up to 4–6 mm (Keller et al. 1988, Saies et al. 1988). Thus, the assessment of whether mobility of a hip represents normal movement or abnormal instability is difficult and potentially unreliable.

An additional transverse scan is taken with the hip flexed to 90° (Figure 4). No measurement is performed on this scan, but any instability is subjectively assessed. Since NHI usually is posteriorly and laterally directed, the stability can be further assessed by a stress maneuver, pushing the thigh posteriorly. Reduction of a subluxated or dislocated hip can be visualized by abduction of the flexed hip. The advantage of the transverse scan, in addition to the longitudinal one, is that a 3-dimensional evaluation of the hip is obtained. Proximal and lateral displacements are seen on the longitudinal scan, and lateral, anterior, and posterior displacements are seen on the transverse scan.

General or selective ultrasound screening?

No consensus has yet been obtained with regard to screening policy in newborns. Whereas general screening of newborns has been practised for several

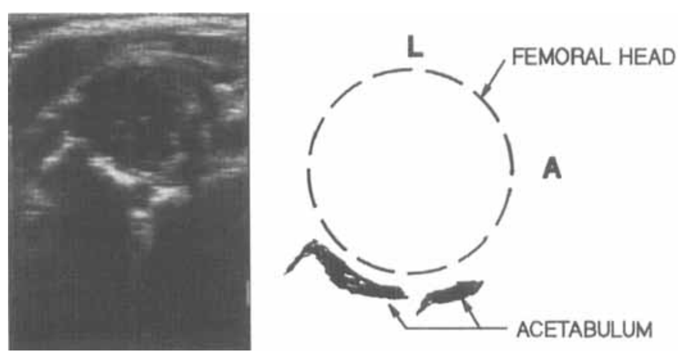

Figure 4. Transverse sonogram and schematic drawing of a normal hip in a newborn. L is lateral, A is anterior.

years in Germany and Austria (Tönnis et al. 1990, Ganger et al. 1992, Tschauner et al. 1993), others have recommended selective screening of risk groups only (Millis and Share 1992, Walter et al. 1992, Catterall 1994). This question can be adequately evaluated only by randomized prospective studies where the incidence of late-detected cases of HD after different screening methods are compared. We have performed such a study at the University Hospital in Trondheim, including 15,529 newborns during the 5-year period 1988–1992 (Holen et al. 1998). Half of the newborns were randomized to clinical screening performed by experienced pediatricians and the other half were examined by ultrasound in addition. The rates of late-detected HD, including dislocation, subluxation and acetabular dysplasia only, were 0.14 per 1000 in the ultrasound group and 0.67 per 1000 in the clinical screening group. Although there was a trend towards better results in the US group, the difference was not statistically significant. The same experience was reported in another prospective, randomized study including 11,925 newborns in Bergen, Norway (Rosendahl et al. 1994).

On the basis of these 2 prospective, randomized studies, it is reasonable to conclude that it is not necessary to examine all newborns with ultrasound, provided that the clinical screening is performed by experienced, skilled examiners, which implies that the rate of late-detected HD is low. If the rate of late-detected cases of dislocation or subluxation is unacceptably high—that is, more than 0.5 per 1000—the quality of the screening should be improved, either by improving the clinical screening or by the use of ultrasound or both. Thus, if the clinical screening is of high quality, I recommend a selective sonographic policy, including newborns with clinical instability or uncertain findings and those belonging to the high-risk groups: family history of HD, breech position, and congenital foot deformities.

Treatment policy

We have evaluated some important questions with regard to treatment policy in newborns: what is the natural history of hips with normal clinical findings and US abnormalities and vice versa? Do these hips need treatment from birth?

Of 9,952 consecutively born babies, we detected 306 newborns with normal clinical findings, but abnormalities shown by US (Terjesen et al. 1996). To assess the natural history, these hips were not treated from birth, but were closely followed up. By 4–5 months of age, 291 infants had normal hips, whereas the remaining 15 babies had persistently abnormal findings (subluxation or acetabular dysplasia only) using both US and radiography. There were no cases of complete dislocation. Treatment with an abduction splint was initiated and the hips thereafter developed normally. Thus, treatment was necessary in only 5% of the 306 potentially abnormal hips. This trend towards spontaneous resolution of ultrasound abnormalities has also been reported by others using the Graf method of measurement (Clarke 1986, Castelein et al. 1992).

In conclusion, newborns with abnormal or suspicious US findings, who are normal on clinical examination (performed by experienced pediatricians or orthopedic surgeons), do not need treatment from birth because most will recover spontaneously. Treatment can be postponed until the age of 4–5 months, unless clinical instability develops or US shows deterioration towards dislocation or severe subluxation. In the few cases where this occurs, treatment should be started without delay. Otherwise, the criteria for treatment should be based on measurements by both US and radiography at age 4–5 months and both should be abnormal before intervention is considered necessary. If the opposite policy is followed and all sonographically abnormal hips are treated from birth, treatment rates of no less than 6–9% of all newborns have been published (Tönnis et al. 1990, Ganger et al. 1992), which obviously mean considerable overtreatment.

Likewise, hips with clinical NHI and normal US findings should also be followed without treatment from birth. Such hips could represent false positive Ortolani or Barlow tests, in which case no real hip pathology exists. Alternatively, they can mean real instability, which may or may not spontaneously resolve. We showed that all, except 2 of 94 infants, with unstable hips or uncertain clinical findings but normal sonography at birth, spontaneously normalized (Holen et al. 1997). Two girls developed moderate subluxation and their hips developed normally after treatment with an abduction splint from the age of 4–5 months. We concluded that US improved the reliability of the neonatal evaluation and effected a marked reduction in the rate of treated newborns.

What about hips with both clinical NHI and US abnormalities? Although most authors have recommended that all cases of true NHI should be treated from birth (Ortolani 1976, Kepley and Weiner 1981, Palmén 1984, Coleman 1993), this policy will result in considerable overtreatment, entailing an increased risk of iatrogenic avascular necrosis. Although a trend towards spontaneous resolution of unstable hips has been reported (Barlow 1962, Dunn 1976), the problem is that it is difficult to decide, on the basis of the primary neonatal examination, which hips will normalize and which will not. There are 2 ways to reduce overtreatment: delayed decision-making concerning treatment and improved diagnostic methods. To attempt to reduce the treatment rate, we followed the spontaneous development of 99 newborns with clinical NHI and reduced FHC by ultrasound (Terjesen et al. 1998). They were not treated from birth, but were reexamined at 1–2 weeks of age. At the second examination, 31 babies had persistent hip instability and reduced FHC, and treatment with a Frejka pillow was started. The hips of the remaining 68 infants were clinically stable (or slightly unstable in a few cases) and their FHC had increased to within the normal range; treatment was therefore withheld. Further follow-up showed normal development in all except 5 of the 68 untreated infants. Because spontaneous resolution occurred in more than 90% of the untreated infants, we concluded that US was very useful in the decision as to which hips needed treatment. However, a strict follow-up regime is essential to initiate treatment without undue delay in the few cases that develop manifest HD during the first months.

According to our experience from these studies on natural history, there is a marked trend towards normal development, not only of clinically unstable hips with normal US findings and vice versa, but also of hips that are abnormal on both clinical examination and US at the primary neonatal evaluation. If delayed decision-making is practised and ultrasound is used in the evaluation, only hips with persistent, real abnormalities will be treated. The prerequisite for such a policy is expert clinical and ultrasound examinations, performed by doctors with great experience. If these requirements are not met, conventional treatment from birth of all babies with unstable hips is a simpler and probably a safer policy.

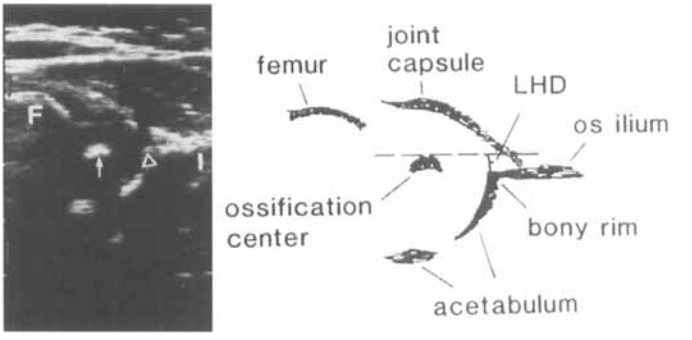

Figure 5. Longitudinal ultrasonogram and schematic drawing of a normal hip in a 4-month-old infant with the ossification center of the femoral head. The lateral head distance (LHD), from the lateral tangent of the ossification center to the lateral bony rim of the acetabulum, is measured perpendicular to the baseline of the image. I is os ilium and F is femur. The ossification center is marked by an arrow and the lateral acetabular rim by a triangle. Reprinted with permission from J Bone Joint Surg (Br).

Infants (1 month to 2 years)

Ultrasound method

The sonographic FHC measurement, as described for newborns, is also used in infants with or without a small ossification center of the femoral head (Figure 5). Above 12 months of age, FHC is not appropriate, because the acetabular floor is prevented from being visualized by the rather large ossification center.

When the ossification center of the femoral head becomes visible, usually between 2 and 6 months of age, an indirect method is used to assess the coverage of the femoral head (Terjesen et al. 1989b). On the longitudinal lateral scan, the distance from the lateral tangent of the ossification center to the lateral bony acetabular rim is measured (Figure 5). The measurement is taken perpendicular to the baseline of the US image. This distance, which is called the lateral head distance (LHD), represents the uncovered part of the bony femoral head. When the whole ossification center is medial to the lateral acetabular rim, the LHD is given a minus sign. A similar distance can be measured by radiography and is called LHDR, lateral head distance by radiography (Figure 6). Comparison

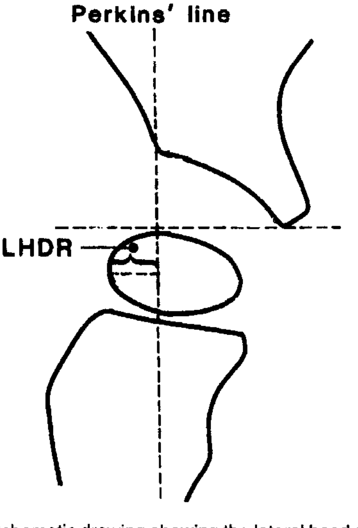

Figure 6. Schematic drawing showing the lateral head distance by radiography (LHDR) which is measured parallel to Hilgenreiner's line.

Lateral head distance (LHD) according to age

Age (years)	LHD (mm)	
	Mean	Upper normal limit [a]
< 1	0	3
1–3	1	4
4–7	2	5
8–11	3	6
> 12	4	7

[a] mean +2 SD

between the sonographic LHD and the radiographic LHDR has shown good agreement, which means that LHD is a reliable parameter for assessment of femoral head coverage (Terjesen 1996, Terjesen et al. 1989b).

The LHD increases with age (Table). The mean LHD is 0 mm below 1 year of age and the upper normal limit (mean +2 SD) is 3 mm. Between 1 and 2 years of age, the mean LHD is 1 mm and the upper normal limit is 4 mm. The LHD is higher in pathologic hips and it increases with the severity of HD. Below 2 years of age, the mean LHD is 4 mm in acetabular dysplasia, 7 mm in subluxation and 12 mm in dislocation (Terjesen 1996, Terjesen et al. 1989b).

Closed reduction guided by dynamic ultrasonography

Most subluxated and dislocated hips in patients below 2 years of age can be successfully treated by closed reduction and plaster immobilization (Tönnis et al. 1984, DeRosa and Feller 1987). I have found US useful in deciding which hips can be reduced and in guiding the maneuver of closed reduction (Terjesen 1992a). First, the hip is examined in the neutral position and the LHD and/or FHC (depending on the age of the patient) are measured. Subluxation and dislocation are clearly seen (Figure 7) and the severity of the pathology is expressed by the US measurements.

Closed reduction is attempted by first flexing the hip to more than 90°, then abduction is applied, and sometimes internal rotation is also needed (when there is a large femoral anteversion). The reduction maneuver is visualized and guided by US and the LHD is measured again when the best possible coverage of the femoral head has been obtained (Figure 7). The effects of positioning are assessed, noting the positions where the hip tends to redislocate and the position of optimal stability. This evaluation is useful during application of the hip spica, which is applied in the most stable position that can be achieved without undue degrees of abduction.

Sonography for guiding closed reduction is useful in children below 2 years of age, but it is not appropriate in older children with frank dislocation (Terjesen 1992a). If ultrasound shows that abduction of more than 60° or pronounced internal rotation is necessary for obtaining concentric, stable reduction, a primary femoral osteotomy with varization and derotation should be performed. Otherwise, an extreme position in the plaster cast (too much abduction or internal rotation) would be needed to avoid redislocation, but this position markedly increases the risk of avascular necrosis of the femoral head.

The advantages of US are that it does not involve exposure to radiation, that the need for expensive and elaborate radiographic methods like arthrography and computed tomography is eliminated or at least reduced, and that reduction of dislocated hips is more reliably achieved when guided by direct visualization.

Older children (above 2 years of age)

Ultrasound method

There has been a widespread opinion that ultrasound

Figure 7. Longitudinal sonograms of the right hip and pelvic radiograph in a 15-month-old girl. With the leg in neutral position (RN), the hip is dislocated (LHD is 12 mm). Closed reduction, guided by ultrasound, was obtained by flexion and abduction of the hip (RA), reducing the LHD to 0 mm. Other labels as in Figure 5.

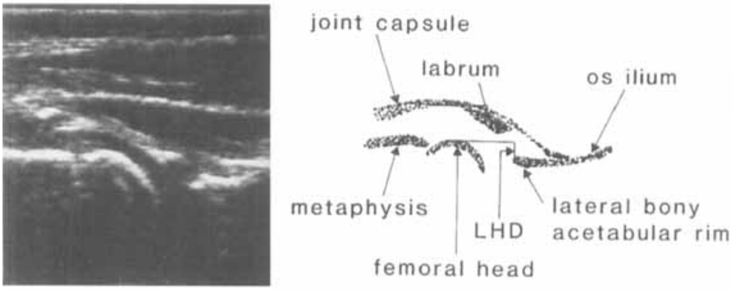

Figure 8. Normal longitudinal scan and schematic drawing of a normal hip in a 5-year-old boy. Although the acetabular floor and roof are not visualized at this age, other important anatomic structures are clearly seen: the femoral head and metaphysis, the lateral outline of os ilium, the lateral acetabular rim, the joint capsule, and the labrum. The LHD is indicated.

is not appropriate for diagnosis of HD in children older than 1–2 years of age (Graf 1984, Clarke et al. 1985, Suzuki et al. 1987, Millis and Share 1992). The reason is that most of the acetabulum cannot be seen behind the large ossification center of the femoral head. However, other important anatomic structures are clearly visualized on the lateral longitudinal scan in older children: the lateral outline of the ossification center, the lateral joint capsule, and the lateral acetabular rim (Figure 8). Thus, the coverage of the femoral head can be assessed by measurement of LHD, exactly as described for infants. We have documented a good accordance between LHD and both the corresponding radiographic distance LHDR and the migration percentage (measured according to Reimers 1980), showing that LHD is an appropriate method in children above 2 years of age and in adolescents as well (Terjesen et al. 1991). It can, indeed, also be used in adults. The measurement is rapidly performed on the frozen monitor image of the longitudinal scan through the center of the femoral head.

The LHD increases with age (Table). The upper normal limit (mean +2 SD) increases from 4 mm at age 2-3 years to 7 mm above the age of 12 (Terjesen et al. 1991, Tegnander and Terjesen 1995). In patients with LHD lower than these limits and otherwise normal sonographic findings by subjective evaluation, acetabular dysplasia, subluxation and dislocation can be excluded and radiography is not needed. When LHD is higher, a standard pelvic radiograph should be obtained for a more thorough evaluation of the hip joint. We have followed this policy for many years both in infants and older children referred for clinically suspected HD and in the follow-up of patients previously treated for HD. Because most children in both groups have normal hips, this policy will substantially reduce the exposure to radiation.

In patients with subluxation, the effects of a femoral osteotomy with varization and derotation are simulated by US scans with the hip in varying degrees of abduction and internal rotation, to determine the position where the LHD is lowest (Figure 9). If this position is found, for instance, at 30° of abduction and 40° of internal rotation, the appropriate treatment is femoral osteotomy with 30° of varization and 40° of derotation. If the LHD does not decrease to normal values in the position of best possible reduction, an acetabular osteotomy is also performed to improve femoral head coverage.

In children older than 2 years of age, an additional anterior scan is routinely performed. With the transducer applied anteriorly along the femoral head and

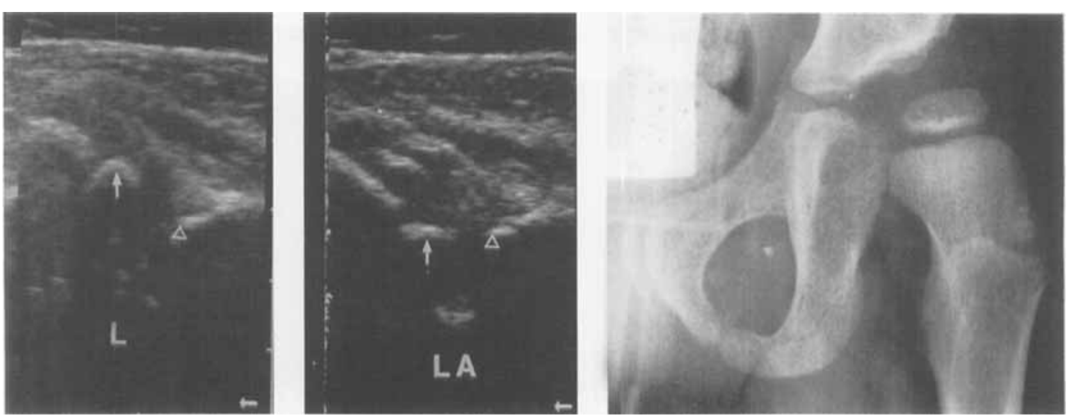

Figure 9. Longitudinal sonograms and radiograph of the left hip in a 3-year-old girl, who previously had been treated with closed reduction and hip spica cast. The hip is subluxated when the leg is in neutral position (L). With 30° abduction and 40° internal rotation (LA), simulating the effect of a varus derotation femoral osteotomy, the femoral head is concentrically reduced and the LHD is reduced to 0.5 mm. Labels as in Figure 5.

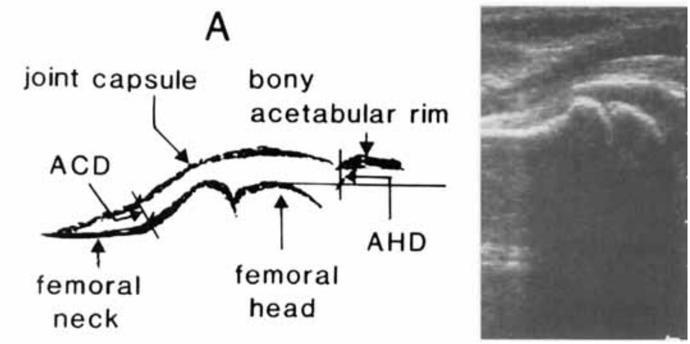

Figure 10. Anterior sonogram and schematic drawing of a normal hip in a 5-year-old boy. The measurements of anterior head distance (AHD) and anterior capsule distance (ACD) are indicated.

neck, the anterior head distance, AHD (Figure 10), is measured in a similar way as described for LHD (Terjesen et al. 1991). Anterior subluxation is diagnosed by an abnormally increased AHD and any posterior subluxation will also be detected. On the anterior scan, the anterior capsule distance, ACD, is also measured as the distance between the femoral neck and the anterior joint capsule (Figure 10). Although the ACD has little significance in the diagnosis of HD, it is the main parameter in transient synovitis and other conditions with increased fluid content in the hip joint (Terjesen and Østhus 1991). The anterior scan is also appropriate in the diagnosis and follow-up of patients with Perthes' disease and slipped capital femoral epiphysis (Terjesen 1992b, 1993).

I always use both the lateral and anterior scans in children above 2 years of age, whether the child is referred for suspicion of HD or other hip disorders. First, the child is clinically examined and then the hips are assessed by US. If sonography shows normal hips, radiography is omitted. If, however, sonography shows abnormal or doubtful findings or if the clinical evaluation raises suspicion of intraosseous pathology, additional radiography is performed. The aim is not to abandon radiography, but to reduce its use to the necessary minimum.

Femoral anteversion

During the last few decades, the anteversion (AV) angle of the femur has usually been measured by biplanar radiography (Rippstein 1955) and, in recent years, CT has also been used for this purpose (Murphy et al. 1987). These methods entail radiation hazards for the patients, which is the main reason why US methods have been introduced. We have developed an US technique for measurement of the AV angle (Terjesen et al. 1990, 1993) that will be briefly described.

The patient is lying supine, with hips in the neutral position, and knees flexed 90° over the end of the table. The lower legs are kept parallel and perpendicular by a foam rubber pillow between them, and a strap around the lower legs (Figure 11). In this position, it is assumed that the dorsal tangent of the femoral condyles is horizontal, and an anterior scan only of the proximal femur is needed. We use a linear transducer (5 Mhz) with a length of aproximately 10 cm, in order to visualize the femoral head, the neck, and the anterior aspect of the greater trochanter at the same time. The anterior tangent of the femoral head and the greater trochanter, the head-trochanter (HT) tangent, is used as the reference line (Figure 12). The transducer is tilted until the HT tangent is horizontally depicted on the monitor screen image. The degree of tilt is then read by a clinometer attached to the US transducer (Figure 11). The AV angle measured is the tilt angle of the transducer when the HT tangent is

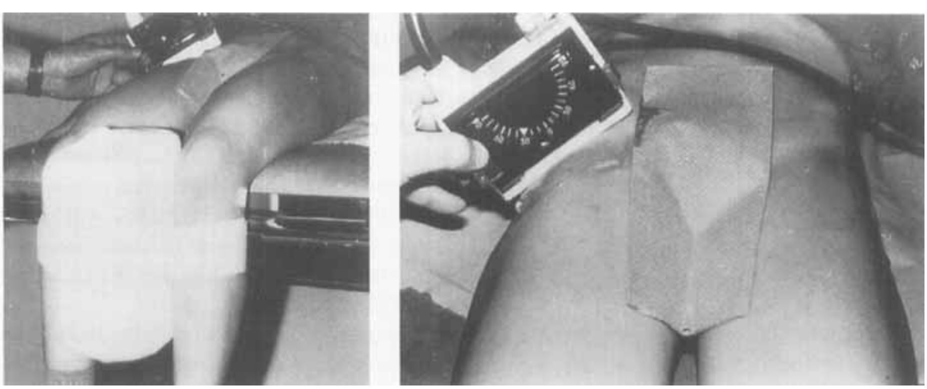

Figure 11. For anteversion measurements, the patient is lying supine with extended hips, knees flexed 90° over the edge of the table, and the lower legs strapped in the vertical position. A clinometer is attached to the transducer, in order to measure the tilt angle.

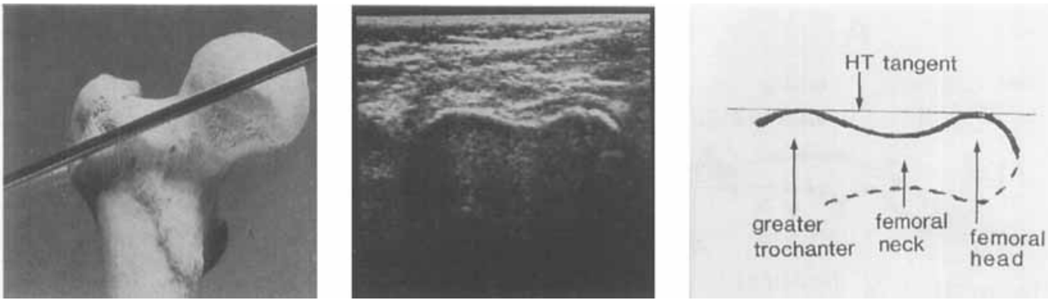

Figure 12. Left, the correct scanning level for measuring the head-trochanter (HT) tangent is shown. On the ultrasonogram and schematic drawing, the femoral head, neck and greater trochanter are seen. The transducer is tilted (Figure 11) until the HT-tangent appears to be horizontal.

horizontal.

The AV angles measured by US and radiography are not identical, because different anatomic landmarks are used. With radiography, the central axis of the femoral head and neck is the reference line, whereas the anterior tangent of the femoral head and greater trochanter is used with US. When compared with radiographic measurements, we found that the AV angles were systematically somewhat higher with US. Thus, a correction factor had to be introduced, 5° in children below 12 years of age and 10° in adolescents and adults (Terjesen et al. 1990, Terjesen et al. 1993). To obtain the best possible estimate of the real (radiographic) AV angle, 5° or 10° must be subtracted from the AV angle that is measured with US, when the head-trochanter tangent is used as the reference line.

This method has shown good agreement with radiographic measurements in both children (Terjesen et al. 1993) and adults (Terjesen et al. 1990). Moreover, the interobserver variation (±2 SD) is only 5°, confirming that the method is appropriate (Bråten et al. 1992). The measurement is rapid; it takes less than 5 minutes to measure the AV angles of both legs.

Alternative methods measure the AV angle on the US image when the transducer is kept horizontal (Moulton and Upadhyay 1982, Phillips et al. 1985). Because our modification gives a clearer image of the anatomic landmarks when the AV angles are large, as they usually are in patients with HD, the technique of tilting the transducer is recommended for routine clinical use.

Who should perform ultrasonography?

Although sonography in orthopedic disorders can be performed by ultrasound technicians or radiologists, provided that they have adequate knowledge and experience with the methods, I have always felt that these examinations should be done by orthopedic surgeons. The reason is that not only experience with sonography is necessary; knowledge of and clinical experience with the dynamics of the hip joint are also required. Clinical insight is particularly important when reduction maneuvers and stress evaluations are performed and when assessing the effects of positioning in the decision regarding closed reduction and femoral osteotomy, as previously described.

Orthopedic surgeons, working with hip problems in children, should be trained in US examinations and practice sonography regularly both in referred children and in the follow-up of treated children. The clinical and US examinations should be performed by the same orthopedic surgeon as a combined evaluation. We have followed this policy for many years and have found it rational, because it is time-saving and less expensive than separate clinical and sonographic examinations.

Conclusion

Ultrasound represents a major improvement in the diagnosis of congenital and developmental hip dislocation and dysplasia (Figure 13). Femoral head coverage is the main parameter in abnormal hips and it can be measured by US in all age groups, even in adults. Thus, sonography is recommended as the primary imaging technique, when there is clinical suspicion of HD not only in newborns and infants but also in older children. US also has an important role in the follow-up of treated patients. This policy will substantially reduce patient exposure to radiation because radiography is omitted when hips are shown to be normal with US.

Sonography is also useful in the treatment of subluxation and dislocation, as closed reduction can be directly observed and guided. In older children, measurement of femoral anteversion, as well as scans with the hip in different positions to simulate the ef-

The main principles of ultrasound examination in congenital and developmental hip dysplasia and dislocation			
Age	**Ultrasound scan**	**Ultrasound measurements**	**Dynamic evaluation**
Newborns	Longitudinal, lateral Transverse, lateral	Femoral head coverage	Red. positive Ortolani [a] Assesment of stability (stress maneuver)
Infants	Longitudinal, lateral	Femoral head coverage (<12 months) Lateral head distance	Closed reduction guided by ultrasound
Children (>2 years)	Longitudinal, lateral	Lateral head distance	Simulating femoral osteotomy in hips with reduced head coverage
	Anterior, along the femoral neck	Anterior head distance and anterior capsule distance	
	Anterior, oblique	Femoral anteversion	

[a] reduction by abduction/flexion in hips with positive Ortolani test

Figure 13. Algorithm showing ultrasound measurements and dynamic evaluation according to age of the patient.

fect of femoral osteotomy, are appropriate in the preoperative planning for hips with subluxation. Thorough knowledge of the hip joint is required in dynamic sonography and preoperative planning. Therefore, I recommend that sonography be performed by orthopedic surgeons as an integral part of the clinical examination.

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