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Pearls and Pitfalls of Hip Ultrasound

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Failure to appreciate key anatomic features and suboptimal sonographic technique lead to incorrect assessment of the key elements of developmental dysplasia of the hip: position, stability, and morphology. In this article, we address common errors, identify sonographic features critical for accurate image interpretation, and address measurement variability.
Semin Ultrasound CT MRI 41:513-517 © 2020 Published by Elsevier Inc.

Introduction

Ultrasound of the hips was first done with an articulated arm scanner in 1980 by Graf.[1] Since then, many investigators have used ultrasound in the diagnosis and management of developmental dysplasia of the hips (DDH), and as technology has advanced, the scanning has become progressively sophisticated and detailed. A variety of techniques has been described, but predominant are the "dynamic" technique popularized by Harcke et al.[2,3] and the "morphologic" technique by Graf et al.[4] The SPR-AIUM-ACR Guideline for DDH[5] recommends 2 orthogonal sonographic views that represent a synthesis of the 2 approaches.[6] We describe anatomic features and optimal technique of DDH sonography that will eliminate common errors and therefore improve the accuracy of hip sonography.

Technical considerations

Dynamic technique

The hips are scanned laterally in physiologic neutral and flexed positions in both transverse (axial) and coronal planes. Ambidextrous scanning is recommended: the right hip is scanned with the probe in the left hand and the leg controlled with the right hand. Conversely, the left hip is scanned with right hand holding the probe and the left hand on the knee.

Pitfall: Grasping the knee tightly upsets the baby and provokes resistance, which makes it difficult to obtain diagnostic images and to perform the stress maneuvers accurately.

Pearl: A relaxed infant is key to a good study. An easy way to guide the knee in coronal flexion is with the palm of the hand gently covering the knee. In this position, the hand is also in position to apply a posterior push or "piston" maneuver to provide stress. Underhand grip of the transducer is recommended to stabilize the hand that rests in part on the exam table (Fig. 1A). In coronal neutral, the hip is in physiologic neutral (mild flexion) (Fig. 1B).

Stress simulating the Barlow maneuver is used in the flexed views. If the hip is malpositioned either at rest or with stress, flexion and abduction are used to attempt to reduce the hip, simulating the Ortolani maneuver. In this technique, the emphasis is on position and stability more so than morphology, but there is also evaluation of the acetabulum and the ossific nucleus. Abnormal findings should be confirmed in all views.[7]

Reporting of a study should contain comment on position, stability, and morphology to meet the standard. Dynamic exam results can be summarized and reported simply as normal, lax with stress, subluxated, dislocatable, dislocated reducible, or dislocated not reducible. The acetabula are described (eg, normal, shallow, angled, and dysplastic). Measurement of the alpha angle is optional but is only one element that can be used to describe acetabular morphology; it does not provide a complete description.[8] Any abnormal finding on one view should be confirmed on other views.

Morphologic technique

With the Graf technique, the patient is placed in the decubitus position. This positioning is facilitated by a padded device, but it is also possible to obtain this view without the device or with the infant supine. The hip is scanned laterally in the coronal plane. The patient is repositioned in the opposite decubitus position, and the other side is scanned. This technique emphasizes the morphology of the acetabulum,

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https://doi.org/10.1053/j.sult.2020.05.015
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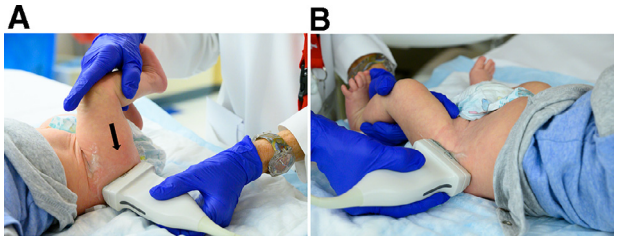

Figure 1 Recommended dynamic scan technique. (A) Coronal flexion, right hip. Note relaxed grasp of knee in position for posterior (piston) stress (arrow). (B) Coronal neutral left hip. Note physiologic femur position.

but observation of hip position and coverage is part of the exam. Once exact landmarks have been obtained, measurements are made, and the hip is classified according to established criteria as normal, borderline, or abnormal. The standard Graf types are based on 2 angles, alpha and beta.[4] Measurement variability is greater for the beta angle,[9,10] and consequently, this is commonly not utilized with classification based on the alpha angle only.

Pitfall: Measurement made on a view that does not clearly contain the true plane of the mid-acetabulum produces false information (Fig. 2A). Often, in emphasizing the bone echoes for the alpha angle, the echogenic tip of the labrum is neglected. This relates to the practice of no longer reporting the beta angle; however, clear labrum tip visibility serves to determine correct position of the image.

Pearl: Accurate measurement of the alpha angle requires exact positioning.[11] Three critical landmarks must be visible: (1) straight iliac line parallel to the probe, (2) inferior tip of the iliac bone in the medial acetabulum, and (3) echogenic tip of the labrum (Fig. 2B).

Coronal views

Alternative methods to assess development of the acetabulum have been proposed to address alpha angle measurement variability[12] and correlation with radiographic measurement of acetabular development. These methods include measurement of acetabular coverage of the femoral head.[13-16]

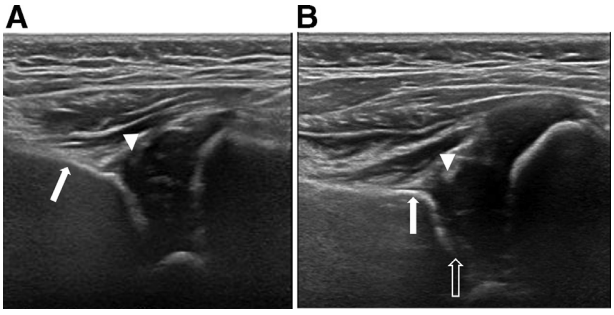

Figure 2 Coronal neutral views of the hip. (A) Incorrect view unsuitable for measurement. Note angled iliac bone (arrow) and poor visibility of labrum tip (arrowhead). (B) Proper view for measurement shows straight iliac line (arrow), tip of os ilium (open arrow), and echogenic tip of the labrum (arrowhead).

Coronal images are obtained with the hip in neutral (extension or physiologic position) and in the flexed position (90°).

Pitfall: Alpha angle measurement or coverage measurement from coronal neutral view on one exam is compared with the measurement made on a coronal flexion view on a follow-up exam. Subtle positional differences with probe position when obtaining these views and inconsistency in the selection of coverage landmarks add to the variation in measurement already known to occur (Fig. 3).

Pearl: It is important to know the difference between the coronal neutral sonogram and the coronal flexion sonogram. They are not interchangeable (Fig. 3). The alpha angle and coverage will usually be slightly greater in the coronal neutral view.[17] In fact, the Graf classification was established from coronal neutral measurements, and, to be technically correct, the alpha angle should be reported from this view. When coverage is reported on either view, it should be compared with appropriate values reported by Terjesen[14] (coronal neutral view) or Morin[15] (coronal flexion view). A clear understanding of the "50%" rule is suggested.[18]

Coronal neutral view

Pitfall: Sequential measurements of alpha angles show worsening of the angles, and it is assumed that acetabular deterioration is occurring. This could be based on comparison of

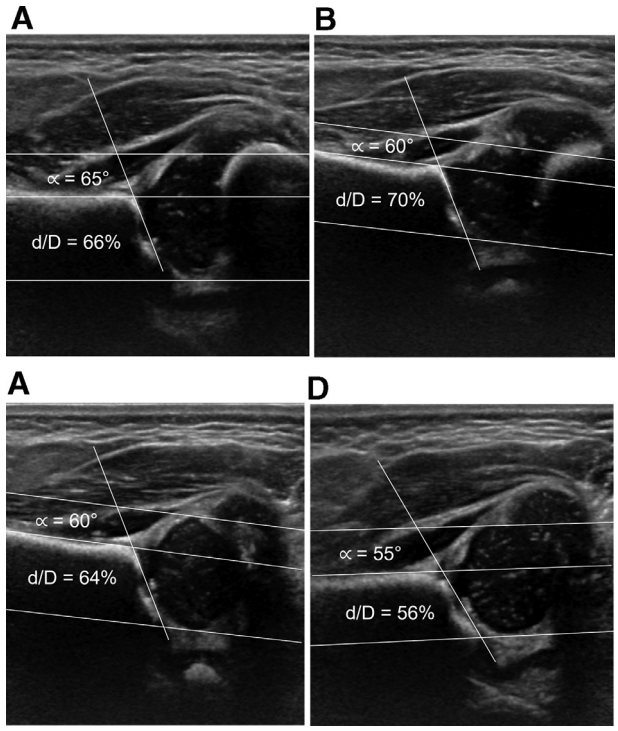

Figure 3 Comparison of alpha angle and femoral head coverage on coronal views. All images of the left hip were obtained at the same examination, first by sonographer (A and C) and then by physician (B and D). Note that coronal neutral (A and B) give slightly higher values of alpha angle and coverage for both examiners, compared with coronal flexion (C and D). These illustrate the variability that occurs with the interobserver examination and measurement.

images that are not obtained with correctly established landmarks or comparison of neutral and flexion views. Often, it is forgotten that measurement variation commonly exceeds 5°.[11,16,19]

Pearl: The iliac line must be horizontal to accurately evaluate the acetabulum. When examining the hip, probe rotation corrects the plane of interrogation. When the iliac line is sloped, it is too anterior and is corrected by rotating the probe clockwise. It will typically make the acetabulum look abnormally shallow (Fig. 4 A and B). A sagging iliac line is too posterior, and correction is made by rotating the probe clockwise. When the iliac line is horizontal, note that acetabular notching is a sign of delayed development (Fig. 4 C and D).

Coronal flexion view

Views of the hip are obtained in the mid-acetabulum and over the posterior lip. Normally, the femoral head should be in the mid-acetabulum and is never seen over the posterior lip, with or without stress. Subluxated and dislocated hips are laterally and posteriorly displaced with soft-tissue echoes seen between the femoral head and the acetabulum. Stress includes adduction and pistoning, simulating the Barlow maneuver.

Pitfall: When the acetabulum is very dysplastic, it may be difficult to be certain where the mid-acetabulum is located for accurate assessment of position, and posterior displacement may not recognized.

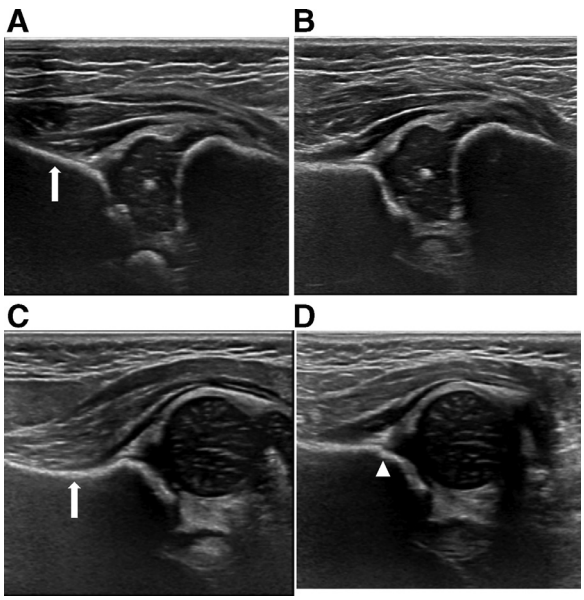

Figure 4 Iliac line variations on coronal sonograms. (A) Coronal neutral with iliac line angled toward the probe is angled anteriorly (arrow). (B) Clockwise probe rotation corrects the angulation. (C) Coronal flexion view made with the probe angled posteriorly shows a sagging (concave) iliac line (arrow). (D) Counter-clockwise probe rotation corrects the angulation and reveals a notch defect (arrowhead) at the acetabular corner consistent with delayed development.

Pearl: Using the posterior lip view in addition to the mid-acetabular position at rest together with and without stress typically will determine level of stability (Fig. 5). The other views will also clarify position of the femoral head. When stress is performed, the transducer needs to be moved in tandem with the hip so that the view remains over the mid-acetabulum or the posterior lip.

Transverse flexion view

In this view, the hip is flexed at least 90°, and the transducer is positioned posterolaterally, allowing a view of the femoral head with metaphysis anteriorly and the ischium posteriorly. If the view is obtained properly, the margins of the metaphysis and the ischium will be at approximately the same level on the image, and the convex margin of the pubic bone will be seen deep to the acetabulum. The femoral head should normally be seen deep in the acetabulum, and there should be no significant change with abduction and adduction, including stress (adduction/push). With subluxation and dislocation, there is displacement of the femoral head laterally and posteriorly, and soft-tissue echoes will be seen between the femoral head and the acetabulum.

Pitfall: If the transducer is placed laterally rather than posterolaterally, the acetabulum is incompletely seen, and there are often echoes in the medial acetabulum that falsely make the hip appear subluxated or dislocated (Fig. 6 A and B).

Pearl: It is especially important to see the pubic bone echoes deep to the acetabulum to be sure to be centered at the correct level over the acetabulum. Use of a rolled towel "bump" behind the infant's back will hold the body in an

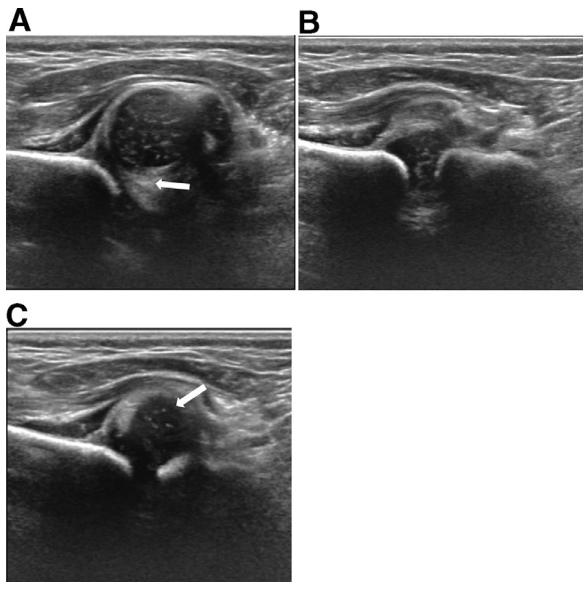

Figure 5 Use of the coronal flexion posterior lip sonogram to document instability. (A) Mid-acetabulum view of an unstressed, laterally subluxated hip (arrow). (B) Posterior lip of the acetabulum at rest shows no part of the femoral head. (C) With posterior stress (pistoning) of the femur (see Fig. 1B), part of the femoral head becomes visible indicating posterior displacement (arrow).

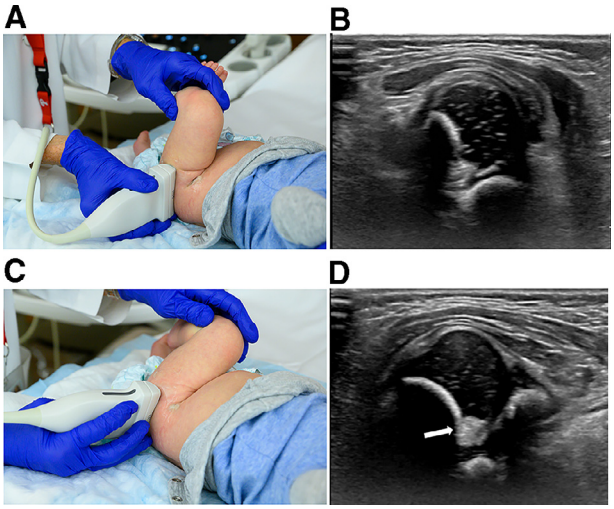

Figure 6 Obtaining a proper transverse flexion view. When the probe is too lateral on the hip (A), the image falsely mimics abnormality like dislocation (B). A correct posterolateral probe position (C) shows the hip to be mildly subluxated with increased echoes in the medial acetabulum (arrow) (D).

anterior oblique position and facilitate placing the transducer posterior enough to view the hip joint (Fig. 6C). Inclusion of the pubic bone echo ensures correct probe position (Fig. 6D).

*Pitfall:*Viewing sonographic images in transverse flexion without clear understanding of the difference in femoral head position that occurs with abduction/adduction, and failure to include the pubic bone echo on the image, lead to errors of interpretation.

Pearl: Including the echoes from the proximal shaft of the femur where it joins the physis allows the observer of the image to know the position of the femur at the time the image was recorded, AD-duction (Fig. 7A) or AB-duction (Fig. 7B). While the technologist should label the image accordingly, this may not be done or it might be done incorrectly; a "V" configuration is seen in AD-duction (Fig. 7A), and a "U" configuration in AB-duction (Fig. 7B).

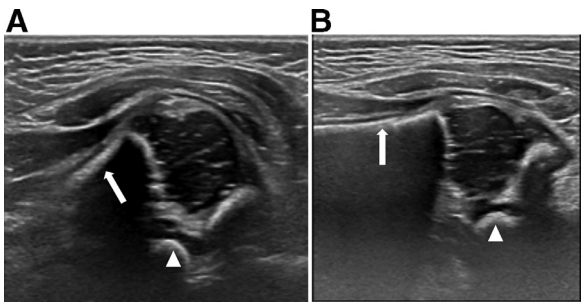

Figure 7 Transverse flexion sonograms can readily show femur position when the proximal part of the bony shaft is included. (A) Adduction view; the shaft echo is angled away from the probe (arrow). (B) Abduction view; the shaft echo is angled toward the probe (arrow). Note that both views include echoes from the pubic bone (arrowhead), a key feature in defining the acetabulum in this view. Adduction produces a "V" configuration, and abduction shows a "U" configuration.

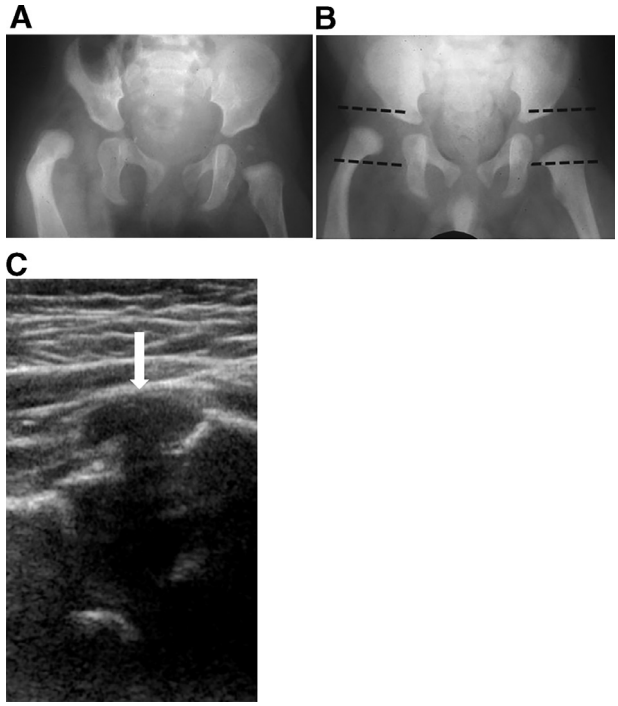

Figure 8 Congenital coxa vara can be misinterpreted as hip dislocation on sonograms. (A) pelvic radiograph shows coxa vara deformity of the proximal right femur. (B) The acoustic window of the hip is reduced by the deformity (dashed lines) compared with normal. (C) the coronal neutral sonogram shows a cartilage mass lateral to the acetabulum (arrow). This is the trochanter and should not be mistaken for dislocation.

Potentially confusing cases

When there is coxa vara, the greater trochanter can masquerade as the femoral head (Fig. 8). This deformity is present in congenital femoral anomalies and many skeletal dysplasias.[20]

*Pitfall:*The sonogram in the coronal plane shows a prominent mass of unossified cartilage lateral to the acetabulum (the greater trochanter) (Fig. 8C). This is mistaken for the femoral head, and the hip is incorrectly termed "dislocated."

*Pearl:*Adducting the femur will open the acoustic window into the hip joint, allowing discrimination between the greater trochanter and the femoral head. With movement of the femur, the cartilage of the enlarged trochanter and the femoral head will move together. This confirms presence of a femoral head and connection to the trochanter.

In conclusion, we have presented examples of anatomic features and suboptimal technique that may lead to incorrect assessment of DDH and its key elements: position, stability, and morphology. The suggestions of how to eliminate common errors will improve the accuracy of hip sonography.

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