Ultrasound in developmental dislocation and dysplasia of the hip

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Learning objectives

- Review the role of ultrasonography in the diagnosis of developmental dysplasia of the hip (DDH).
- Illustrate the sonographic findings of DDH.

Background

Developmental dysplasia of the hip (DDH), formerly known as congenital dislocation of the hip, comprises a spectrum of abnormalities, affecting the proximal femur and acetabulum including abnormal acetabular shape (dysplasia) and malposition of the femoral head, ranging from dislocatable hip and mild subluxation to fixed dislocation [1].

DDH is a relatively common disorder, being the most common congenital musculoskeletal disorder in childhood [2], however it is difficult to assess its true incidence because its definition varies and there is no gold standard test. Incidence varies from 1.5 to 20 per 1,000 births. In the United States, DDH affects approximately 1.5 per 1,000 of the Caucasian population. DDH most commonly occurs in otherwise healthy infants [3] and it is four to eight times more common in females. It is also more common in patients with a family history of DDH, in first-born children, in large infants, and in infants with a history of oligohydramnios. It is three times more common in the left hip than the right, likely due to the normal left occiput anterior position in-utero, which places the left hip against the mother's spine and limits its abduction [1].

Newborns are often found to have some laxity in the hip and immaturity of the development of the acetabulum during the first few weeks of life. In most cases, the laxity resolves and the acetabulum proceeds to develop normally. With careful physical examination of the hip and assessment of risk factors, the majority of hips with instability and/or dysplasia can be identified and observed or treated without progression or long-term problems [3], however, if not detected and treated in infancy, can result in significant morbidity.

Ultrasonography is the primary imaging technique for assessing the morphology and stability of the hip and is an important adjunct to the clinical evaluation until 6 months of age. It affords direct visualization of the cartilaginous components of the hip joint. It can be helpful in confirming physical examination findings, evaluating high-risk infants, and making treatment decisions [3]. US enables direct imaging of the cartilaginous
portions of the hip that cannot be seen on plain radiograph. The value of ultrasound diminishes as the femoral head ossifies. For patients between 6 months and 1 year of age, radiography becomes more reliable. The major drawback of ultrasonography is that accurate interpretation requires training and experience.

US during the first 4 weeks of life often reveals the presence of minor degrees of instability and acetabular immaturity, but nearly all of them resolve on follow-up. It is therefore recommended to perform US studies at the age of 4 to 6 weeks [1].

**Imaging findings OR Procedure details**

A retrospective review of all patients who underwent US for screening of DDH at our hospital during a period of 2 years was performed.

US evaluation of the hip is performed using the highest-frequency linear transducer that provides adequate penetration of the soft tissues to the depth required. For infants up to 3 months of age, the 7.5MHz transducer is successful. A 5MHz transducer is generally required between 3 and 7 months of age.

Ultrasonographic criteria for DDH have been established for static imaging (which includes coronal and transverse planes) and dynamic imaging of the flexed hip with and without a modified Barlow stress maneuver. Two methods have emerged: a static acetabular morphology method proposed by Graf and a dynamic stress technique proposed by Harcke [1].

The dynamic technique uses axial and coronal images with real time stress of the femoral head similar to the instability test maneuvers. In the first few days of life, 4 to 6 mm of laxity is considered normal. Dynamic imaging is usually omitted when the hips are examined during treatment. The combination of static and dynamic imaging permits evaluation of hip morphology, position, and stability. We used a static method, with a coronal view, based on the Morin Index and the Graf classification.

To have the anatomic coronal plane, the infant should be in the lateral decubitus position and the hips flexed at 30 to 45° [3]. The standard plane is approximately parallel to the posterior skin surface of the infant. If the superior edge of the transducer is rotated 10 to 15 degrees (usually posteriorly) into an oblique coronal plane, the ilium will appear straight, and after adjustment to ensure that the imaging plane is through the deepest part of the acetabulum, the resulting image will be a coronal view in the standard plane [4] (Fig. 1, fig 2 [video 1] and fig 3 [video 2]).
**Fig.**: Coronal view of a normal hip - standard view.

**References**: P. M. M. Lopes; Imagiology, Hospital de Santarém, Grijó. V. N. de Gaia, PORTUGAL
**Fig.** Video 1: a normal right hip - standard coronal view

**References:** P. M. M. Lopes; Imagiology, Hospital de Santarém, Grijó. V. N. de Gaia, PORTUGAL
The standard plane is defined by identifying a straight iliac line, the tip of the acetabular labrum and the transition from the os ilium to the triradiate cartilage (Figure 4). This view can also be performed with the hip in the physiologic neutral (15 to 20 degrees) or flexed position during treatment [4].

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At this plane, acetabular morphology is assessed and the femoral head position and displacement are noted. Validation by femoral head coverage measures - Morin Index (Table 1) - and by Graaf method (Table 2) should be done. The Morin Index is expressed as a ratio calculated as follows: draw a line through the ilium and two lines parallel to that, one through the tip of the labrum and the other through the most profound aspect of the femoral head. Distances are measured at right angles to the base line and expressed as ratios (figure 5 and figure 6 [table 1]).

**Fig.**: Morin Index - In this infant the Morin index is normal (10/16.6 60%)

**References:** P. M. M. Lopes; Imagiology, Hospital de Santarém, Grijó. V. N. de Gaia, PORTUGAL
Graf developed a morphologic and geometric hip classification scheme (types I-IV) (figure 7 [table 2]; figure 8) using an alpha angle, which measures the osseous acetabular roof angle, and a beta angle, which defines the position of the echogenic fibrocartilaginous acetabular labrum. The # angle is formed by the acetabular roof to the vertical cortex of the ilium. The normal value is greater than or equal to 60 degrees. The normal value is greater than or equal to 60 degrees. The # is defined as the angle formed between the vertical cortex of the ilium and the triangular labral fibrocartilage called the echogenic triangle (figure 9) [6].
<table>
<thead>
<tr>
<th>Type</th>
<th>Angles</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>α &gt; 60; β &lt; 77</td>
<td>Normal fully mature hips. The acetabular cup is deep and the acetabular rim is angular. The cartilaginous roof extends over the femoral head</td>
</tr>
<tr>
<td>IIa</td>
<td>50 &lt; α &lt; 59; β &lt; 77</td>
<td>Infants younger than 3 months. Represents physiologic immaturity; 98-99% resolve spontaneously. The femoral head is in normal position, the acetabular cup is slightly shallow, and the acetabular rim is round. The cartilaginous roof covers the femoral head.</td>
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<td>IIb</td>
<td>50 &lt; α &lt; 59; β &lt; 77</td>
<td>Similar to IIa but in infants older than 3 months. This type is abnormal and requires treatment to prevent further deterioration and dislocation.</td>
</tr>
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<td>IIc</td>
<td>43 &lt; α &lt; 50; β &lt; 77</td>
<td>Abnormal hip, slightly dislocated. The labrum covers the femoral head but the acetabulum is shallow.</td>
</tr>
<tr>
<td>D</td>
<td>43 &lt; α &lt; 50; β &gt; 77</td>
<td>Similar to type IIc but the hip is slightly decentered.</td>
</tr>
<tr>
<td>III</td>
<td>α &lt; 43; β &gt; 77</td>
<td>Sub-luxation. The acetabulum is shallow. The bony roof is deficient and the labrum is everted.</td>
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<td>IV</td>
<td>α &lt; 43; β &gt; 77</td>
<td>Dislocated. The acetabulum is almost flat and the cartilaginous roof is markedly displaced; the labrum is interposed between the femoral head and the acetabulum.</td>
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**Fig.:** Table 2 - Graf classification

**References:** P. M. M. Lopes; Imagiology, Hospital de Santarém, Grijó. V. N. de Gaia, PORTUGAL

**Fig.:** Schematic representation of Graf classification
The different categories of Graf classification can be grouped in three hip types:

- **Normal hip**: Type I hips are normal and require no treatment. The alpha angle is greater than 60 degrees.
- **Immature hip**: Type IIa hips are seen in infants less than 3 months of age. The hip is normally located, but the bony acetabulum promontory is rounded and the alpha angle is 50-59 degrees. These patients require no treatment, and there is a small risk of delayed DDH. Follow-up is recommended to confirm normal development.
- **Abnormal hip**: Type IIb has similar features as type IIa, but is detected in children older than 3 months. Types IIc, D, III, and IV represent progressive abnormal hips with frank subluxation in types III and IV. Alpha angle is <50 degrees in types IIc and D and <43 degrees in types III and IV.
Pathological findings

Immature hip:

Fig.: Acetabular coverage slightly slower than 50% and # angle between 50-59 degrees in a 1 month infant

References: P. M. M. Lopes; Imagiology, Hospital de Santarém, Grijó. V. N. de Gala, PORTUGAL

Sub-luxation:
**Fig.**: the femoral head is partially covered by the cartilaginous roof and is aligned with the acetabulum but is partially out the acetabular cup with a Morin index much lower than 50%.

**References:** P. M. M. Lopes; Imagiology, Hospital de Santarém, Grijó. V. N. de Gaia, PORTUGAL

**Luxation:**
**Fig.**: Type IV hip - the femoral head is totally out the acetabular cup and is not aligned with the acetabulum

**References**: P. M. M. Lopes; Imagiology, Hospital de Santarém, Grijó. V. N. de Gaia, PORTUGAL

**Fig.**: same infant as in fig 12 after 2 months of treatment. The femoral head is still out the femoral cup but is already aligned with the acetabulum.

**References**: P. M. M. Lopes; Imagiology, Hospital de Santarém, Grijó. V. N. de Gaia, PORTUGAL

**Images for this section:**
Fig. 1: Coronal view of a normal hip - standard view.
Fig. 2: Video 1: a normal right hip - standard coronal view

Fig. 3: Video 2: a normal left hip - standard coronal view
Fig. 4: Coronal view. c- capsule; G- gluteus muscles; H- cartilaginous femoral head; IL - ilium; IS- Ischium; L- labrum; LT- ligamentum teres; Tr-triradiate cartilage
Fig. 5: Morin Index - In this infant the Morin index is normal (10/16.6 60%)
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<td>&gt;50%</td>
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<tr>
<td>46-50%</td>
<td>Borderline</td>
</tr>
<tr>
<td>&lt; 46%</td>
<td>Abnormal</td>
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**Fig. 6:** Table 1 - Morin index
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**Fig. 7:** Table 2 - Graf classification

**Fig. 8:** Schematic representation of Graf classification
Fig. 9: Measure of # and # angles - type I hip.
**Fig. 10:** Acetabular coverage slightly slower than 50% and # angle between 50-59 degrees in a 1month infant
Fig. 11: the femoral head is partially covered by the cartilaginous roof and is aligned with the acetabulum but is partially out the acetabular cup with a Morin index much lower than 50%.

Fig. 12: Type IV hip - the femoral head is totally out the acetabular cup and is not aligned with the acetabulum
Fig. 13: same infant as in fig 12 after 2 months of treatment. The femoral head is still out the femoral cup but is already aligned with the acetabulum.
Conclusion

Ultrasonography is the primary imaging technique for assessing the morphology and stability of the hip and is an important adjunct to the clinical evaluation until 6 months of age. It affords direct visualization of the cartilaginous components of the hip joint. It can be helpful in confirming physical examination findings, evaluating high-risk infants, and making treatment decisions [3]. US enables direct imaging of the cartilaginous portions of the hip that cannot be seen on plain radiograph. The value of ultrasound diminishes as the femoral head ossifies. For patients between 6 months and 1 year of age, radiography becomes more reliable.

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It is possible to diagnose hip developmental pathology with good sensibility using US. Knowledge of sonographic findings of DDH and experience in performing this exam is important for a good diagnostic accuracy.

Personal Information

Pedro Miguel Marinho Lopes
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