Ultrasound in the diagnosis and treatment of hip dysplasia in newborns, infants and older children

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Methods and policy

neonates
infants
older children

No consensus with regard to ultrasound methods or to policy of screening and treatment
Newborns

Why neonatal screening?

• unstable hip joints can be detected by simple clinical tests (Ortolani, Barlow)
• easier treatment and better results
• almost all are born in hospitals
Ortolani’s test

- Simple test, but often unreliable because of inexperienced examiners
- Overdiagnosis and overtreatment
- Still high incidence of late DDH
- Better screening with ultrasound?
Advantages of ultrasonography

- not only bone but also cartilage and soft tissue are seen
- dynamic examination
- no radiation exposure or other side effects
Questions
ultrasonographic screening

• when ultrasound? what method?
• who should perform ultrasonography?
• should all newborns be examined?
• indications for treatment?
• effect of US screening on late-detected HD?
R. Graf (Austria), 1980

- Special pillow for positioning
- lateral position

Graf’s measurements
alpha- and beta angle
<table>
<thead>
<tr>
<th>Type according to Graf</th>
<th>Bony roof / bony roof angle $\alpha$</th>
<th>Superior bony rim (bony promontory)</th>
<th>Cartilaginous roof / cartilage roof angle $\beta$</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TYPE I</strong>&lt;br&gt;mature hip</td>
<td>good&lt;br&gt;$\alpha \geq 60^\circ$</td>
<td>angular / slightly rounded (&quot;blunt&quot;)</td>
<td>covers the femoral head&lt;br&gt;I a $\Rightarrow \beta &lt; 55^\circ$ (extending far distance over the femoral head)&lt;br&gt;I b $\Rightarrow \beta &gt; 55^\circ$ (extending short distance over the femoral head)</td>
<td>any age</td>
</tr>
<tr>
<td><strong>TYPE II a (+)</strong>&lt;br&gt;physiological immature $\Rightarrow$ appropriate for age</td>
<td>adequate (satisfactory)&lt;br&gt;$\alpha = 50-59^\circ$&lt;br&gt;(minimal degree of maturity is attain - look at the &quot;sonometer&quot;)</td>
<td>rounded</td>
<td>covers the femoral head</td>
<td>0 to 12 weeks</td>
</tr>
<tr>
<td><strong>TYPE II a (-)</strong>&lt;br&gt;physiological immature $\Rightarrow$ maturational deficiete</td>
<td>deficient&lt;br&gt;$\alpha = 50-59^\circ$&lt;br&gt;(minimal degree of maturity is not attain - look at the &quot;sonometer&quot;)</td>
<td>rounded</td>
<td>covers the femoral head</td>
<td>&gt; 6 to 12 weeks</td>
</tr>
<tr>
<td><strong>TYPE II b</strong>&lt;br&gt;delay of ossification</td>
<td>deficient&lt;br&gt;$\alpha = 50-59^\circ$</td>
<td>rounded</td>
<td>covers the femoral head</td>
<td>&gt; 12 weeks</td>
</tr>
<tr>
<td><strong>EXCEPTION: Type II coming to maturity</strong></td>
<td>deficient</td>
<td>angular (!)</td>
<td>covers the femoral head, (echogenic because of ossification!)</td>
<td>any age</td>
</tr>
<tr>
<td><strong>TYPE II c</strong>&lt;br&gt;(critical range)&lt;br&gt;II c stable / II c unstable</td>
<td>severely deficient&lt;br&gt;$\alpha = 43-49^\circ$</td>
<td>rounded to flattened</td>
<td>still covers the femoral head&lt;br&gt;$\beta &lt; 77^\circ$</td>
<td>any age</td>
</tr>
<tr>
<td><strong>TYPE D</strong>&lt;br&gt;decentering hip $\Rightarrow \beta &gt; 77^\circ$</td>
<td>severely deficient&lt;br&gt;$\alpha = 43-49^\circ$</td>
<td>rounded to flattened</td>
<td>displaced&lt;br&gt;$\beta &gt; 77^\circ$</td>
<td>any age</td>
</tr>
<tr>
<td><strong>TYPE III a</strong>&lt;br&gt;eccentric hip $\Rightarrow \alpha &lt; 43^\circ$</td>
<td>poor&lt;br&gt;$\alpha &lt; 43^\circ$</td>
<td>flattened</td>
<td>pressed upwards - without structural alteration (devoid of echoes) proximal perichondrium goes up to the contour of the iliac wall</td>
<td>any age</td>
</tr>
<tr>
<td><strong>TYPE III b</strong>&lt;br&gt;eccentric hip $\Rightarrow \alpha &lt; 43^\circ$</td>
<td>poor&lt;br&gt;$\alpha &lt; 43^\circ$</td>
<td>flattened</td>
<td>pressed upwards - with structural alteration (they are echogenic) proximal perichondrium goes up to the contour of the iliac wall</td>
<td>any age</td>
</tr>
<tr>
<td><strong>TYPE IV</strong>&lt;br&gt;eccentric hip $\Rightarrow \alpha &lt; 43^\circ$</td>
<td>poor&lt;br&gt;$\alpha &lt; 43^\circ$</td>
<td>flattened</td>
<td>pressed downwards horizontal or muddled proximal perichondrium</td>
<td>any age</td>
</tr>
</tbody>
</table>
Ultrasound method developed in Trondheim

from 1985

Static and dynamic assessment

• baby in supine position, supported by the mother
• no rotation of the child
• linear transducer
• one hand holds the transducer
• the other hand holds the leg, slight flexion of the hip
Static measurement  Femoral head coverage, FHC

- Lateral longitudinal scan through the center of the hip joint
- 2 distances from the acetabular floor parallel to Hilgenreiner’s line
  
  \[ a \text{ to Perkins’ line} \]
  \[ b \text{ to the lateral joint capsule} \]

FHC
\[ a/b \times 100 \]
Iliac bone to the right

Iliac bone to the left

US rotated 90°
Femoral head coverage

Normal FHC

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Lower normal limit (mean - 2 SD)</th>
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</thead>
<tbody>
<tr>
<td>Newborns</td>
<td>55 %</td>
<td>45</td>
</tr>
<tr>
<td>1 - 2 months</td>
<td>60 %</td>
<td>50</td>
</tr>
</tbody>
</table>
Neonatal hip instability (NHI)

Femoral head coverage

mean 36%

most hips with NHI are subluxated (not dislocated)
Neonatal hip instability  NHI

Dynamic assessment

the hip is subluxated when the leg is in neutral position,
the hip is reduced when the leg is flexed and abducted

subluxation  reduction
Transverse ultrasound scan

Detects anterior, posterior and lateral displacements

positive Ortolani,
posterior displacement

Arrow: post acetabular rim

subluxated

reduced by abduction
Universal or selective screening in newborns?

Randomized prospective studies

Trondheim 1988 – 92, 15529 newborns (Holen et al. 2002)  
**Late-detected DDH**

- Clinical screening, US in risk groups  
  0.67 per 1000
- Universal ultrasound screening  
  0.14 ” ”

**Difference not sign, p = 0.22**

Bergen 1988 – 90, 11925 newborns (Rosendahl et al. 1994)

- Clinical screening, US in risk groups  
  0.7 per 1000
- Universal ultrasound screening  
  0.3 ” ”

**Difference not sign, p = 0.11**
Conclusion  Screening of hips in newborns

- If good quality* of clinical screening:
  US in risk groups only

- If poor quality of clinical screening:
  improve screening by more experienced examiners
  or
  sonography of all neonates

* Late DDH < 0.5 - 1 per 1000
Selective sonography in newborns

**Clinical indication**
- positive or uncertain Ortolani
- reduced/asymm abduction (<60°)

**US time**
- 1-3 day
- 

**High risk groups**
- family DDH
- breech position
- foot deformities

**US time**
- 3-4 weeks
- ”
- ”
Treatment policy and natural history

Which hips need treatment?

What is the natural history of neonatal hip instability?

What is the natural history of hips with normal clinical findings and US abnormalities and vice versa?
Natural history: Neonatal hip instability

Positive Ortolani
>50 % normalize spontaneously

The remaining:
manifest hip dysplasia
dislocation, sublux, dysplasia
Natural history

hips with normal clinical findings and US abnormalities

Trondheim, 9952 newborns (Terjesen et al. 1996)

306 babies normal clinical, abnormal ultrasound

no treatment from birth

follow-up at 4-5 months

291 had normal hips

15 had abnormal findings: abduction splint

Conclusion: only 5% needed treatment
Natural history

hips with normal ultrasound and abnormal or suspicious clinical findings

Trondheim  (Holen et al. 1997)

94 newborns

no treatment from birth

follow-up at 4-5 months

92 had normal hips

2 had abnormal findings: abduction splint

Conclusion: only 2 % needed treatment
Treatment indication Newborns

Positive Ortolani and abnormal ultrasound

Treatment from birth

Normal clinical findings and abnormal ultrasound and vice versa:
marked trend towards normal development

No treatment from birth;
follow-up with US at 1 - 2 months
Diagnosis **after** neonatal period (> 1 month)

Reduced abduction

**Ultrasound**

*FHC if no (or small) ossification center (as in newborns)*
Ultrasound in infants with **ossification center** of the femoral head

**Lateral Head Distance**  
**LHD**  
distance from the lateral acetabular rim to the lateral tangent of the ossification center

Measures the **uncovered part** of the femoral head; indirect measurement of femoral head coverage
Lateral Head Distance

girl, 9 months left hip normal right hip dislocated

LHD increases with increasing degrees of pathology

Upper normal limit < 2 years 4 mm

Subluxation mean LHD 7 mm

Dislocation: ” ” 12 mm
Comparison ultrasound and radiography

LHD Radiography: LHDR

Good correlation LHD/LHDR

US reliable in measuring the lateralization of the femoral head
Dislocation in infants: Treatment

**Closed reduction** after preliminary traction

Open reduction if closed not possible
- Lig. teres or transversum, joint capsule, hypertrophy of labrum

Closed reduction can be guided by dynamic ultrasonography
Dynamic ultrasound

Closed reduction: Flexion, abduction and sometimes internal rotation

The maneuver of closed reduction is visualized and guided by US (reduction of LHD)

Effects of positioning are assessed

• position of redislocation
• position of optimal stability

Girl, 15 months
Hip spica plaster in "human position"

90° flexion, <60° abduction

Sonography to ensure good position in hip spica
Sonography in children above 2 years (also adolescents and adults)

Lateral longitudinal (L) and anterior (A) scan

Lateral head distance, LHD just as in infants
Lateral head distance, LHD
measures the uncovered lateral part
of the femoral head

**LHD increases with age**

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>mean LHD</th>
<th>upper normal limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 – 3</td>
<td>1</td>
<td>4 mm</td>
</tr>
<tr>
<td>4 – 7</td>
<td>2</td>
<td>5 mm</td>
</tr>
<tr>
<td>8 – 11</td>
<td>3</td>
<td>6 mm</td>
</tr>
<tr>
<td>&gt; 12</td>
<td>4</td>
<td>7 mm</td>
</tr>
</tbody>
</table>

LHD above the normal limit indicates acetabular dysplasia
and/or subluxation or dislocation
girl, 18 years, dysplasia right hip

Increased LHD of right hip, indicating hip dysplasia

right hip    left
Follow-up

• to skeletal maturity

• ultrasound could replace radiography as the primary imaging method

• dynamic ultrasound neutral, abduction, rotation, standing

• radiography only if US abnormal or suspicious
Resubluxation during follow-up

Dynamic ultrasound to simulate femoral osteotomy

Better head coverage (normal LHD) by abduction and internal rotation

Varus derotation osteotomy
Anterior ultrasound scan

- Anterior head distance  AHD  anterior coverage
- Anterior capsule distance  ACD  intraarticular fluid
- Bony structure of the femoral head
Perthes disease

Translucent synovitis

Slipped capital femoral epiphysis

boy 5 years
irregular bone structure (arrow)
Anteversion angle of femur

AV angle often increased in DDH

- Radiography
  Rippstein
- CT
- Ultrasound

- supine position, knees flexed 90º, lower legs parallel
- only one anterior scan
- head-trochanter tangent is reference line (HT-tangent)

Lower legs strapped vertical

HT-tangent
Measurement of femoral anteversion

The transducer is tilted until the HT-tangent is seen horizontal

Clinometer attached to the transducer reads the angle of tilt

HT-tangent horizontal
Femoral anteversion; US versus radiography

Slightly different anatomic angles

- **US**: anterior HT-tangent
- **Radiography**: center axis neck-head

• Correction factor
  - $5^\circ$ should be subtracted in children;
  - $10^\circ$ in adolescents and adults

AV-angles: good correlation
US/radiography
Conclusions ultrasonography

- **Femoral head coverage** can be measured by ultrasound in all age groups from newborns to adults.

- Sonography is recommended as the **primary imaging technique** in both referred patients and in follow-up.

- **Dynamic ultrasound** is useful in guiding closed reduction, in simulating femoral osteotomy, and measurement of femoral AV angles.

- Sonography can substantially **reduce the exposure to radiation** in patients with hip disorders.