Measurements in Femoro-Acetabular Impingement: How to do it?

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Learning objectives

1. To provide an overview of current imaging measurements for evaluation of Femoro-Aacetabular Impingement (FAI)

2. To emphasize the minimal technical requirements for each imaging technique allowing correct and reproducible measurements

3. To discuss the merit and limitations of each measurement

Background

FAI has become a hot topic in MSK radiology since the previous decade reflected by the number of reported measurement techniques to evaluate FAI (cam, pincer, mixed).

Most of these measurements are - however - influenced by imaging positioning, exposure dose and imaging protocol), which may vary among different institutions.

Imaging findings OR Procedure Details

Radiographic Technique

Standard conventional radiographic imaging for FAI includes two radiographs: an AP pelvic view and a view of the hip. We use the Dunn view.

For the AP pelvic radiograph, the patient is in the supine position, the legs 15° internally rotated, and the central beam is directed to the midpoint between a line connecting both anterosuperior iliac spines and the superior border of the symphysis, which can be palpated by the technician. Fig. 1 on page 7

The distance from the pubic symphysis to the tip of the coccyx should be not more than 2 cm (no tilting). And secondly, the tip of the coccyx should point toward the midpoint of the superior aspect of the symphysis pubis, and the obturator foramina should be symmetric (no rotation). Fig. 2 on page 8 Fig. 3 on page 9 Fig. 4 on page 10
The Dunn view of the hip can be taken with the hips flexed at 90° and slightly (20°) abducted.

It's particularly useful to evaluate the anterior femoral head-neck junction. Fig. 5 on page 11

Radiographic Signs and Measurements

# Signs of Acetabular Overcoverage

Pincer impingement is the result of acetabular overcoverage, which can be general or focal.

• Signs of General Acetabular Overcoverage

In a normal hip the acetabular fossa lies laterally to the ilioischial line on an AP pelvic radiograph. Fig. 6 on page 12

General acetabular overcoverage consists of deepening of the acetabular fossa. There are 2 distinct subtypes of general overcoverage i.e. coxa profunda and protrusio acetabuli.

In coxa profunda the floor of the fossa acetabuli touches (or overlaps) the ilioischial line medially. Fig. 7 on page 13

Protrusio acetabuli is described when the femoral head is overlapping the ilioischial line medially Fig. 7 on page 13

Evaluation should be done on an AP pelvis.

Increased depth of the acetabulum may be associated with excessive lateral acetabular coverage. Measurements of lateral acetabular coverage are schematically represented in Fig. 8 on page 14

• The acetabular index is the angle formed by a horizontal line and a line drawn tangential to the acetabular roof (most medial point of the sclerotic zone of the acetabulum with the lateral edge of the acetabulum. Fig. 8 on page 14
• The lateral center edge angle is the angle formed by a vertical line and a line connecting the femoral head center with the lateral edge of the
acetabulum, which varies between 25 ° (< dysplasia) and 39 ° Fig. 8 on page 14 (> acetabular overcoverage Fig. 9 on page 15).

- The femoral head **extrusion index** defines the percentage of femoral head that is uncovered (normally less than 25%) Fig. 8 on page 14.

An example of pathological lateral coverage, associated with protrusio acetabuli is illustrated on Fig. 9 on page 15. Normal and abnormal values are indicated in Fig. 10 on page 16.

- **Signs of Focal Acetabular Overcoverage**

**Acetabular retroversion**

In a patient with a normal hip, the acetabulum is anteverted: the posterior rim of the acetabulum lies laterally to the anterior rim. To distinguish between the two lines of the acetabulum, the posterior rim line can be identified when starting from the inferior edge and tracing upwards. Fig. 11 on page 16.

Focal overcoverage of the anterosuperior acetabulum (cranially retroverted acetabulum) Fig. 12 on page 17 is defined as the anterior rim line lying lateral to the posterior rim in the cranial part of the acetabulum (causing a "**figure-of-8**" or "**cross-over**" sign).

**Prominent posterior wall**

In a normal hip the posterior acetabular rim runs approximately through the center point of the femoral head.

In a hip with a more prominent posterior wall, the posterior acetabular rim runs more laterally to the femoral center, which often is associated with coxa profunda or protrusio acetabuli. Fig. 13 on page 17.

In hips with a deficient posterior wall, the posterior wall lies medial to the femoral head, which often is associated with acetabular retroversion or dysplasia.

# Sphericity of femoral head

At the femoral side, evaluation should be done of the sphericity of the femoral head. Cam impingement can be caused by an osseous bump, typically located either laterally (so
called pistol grip deformity, seen on an AP pelvic radiograph), or located anterosuperiorly
(not seen on an AP view, an axial cross table view or Dunn view is needed). Fig. 14 on
page 18 Fig. 15 on page 19 Fig. 16 on page 20

A **pistol grip deformity** is characterized on radiographs by flattening of the usual
concave surface of the lateral aspect of the femoral head due to an abnormal extension
of the more horizontally oriented femoral epiphysis. Fig. 15 on page 19

An **anterosuperior osseous bump** should be looked for on a Dunn view. Quantification
of the amount of asphericity can be done by measuring the alfa angle and the femoral
offset. Fig. 16 on page 20

- **Alfa angle** is the angle between the femoral neck axis and a line connecting
  the head center with the point of beginning asphericity of the head-neck
  contour. The normal value is less than 50-55°.
- **The anterior offset** is the difference in radius between the anterior femoral
  head and the anterior femoral neck. (a value less than 10 mm strongly
  suggests cam impingement).

# Coxa vara

Another cause of cam impingement is coxa vara, defined by a Center Collum Diaphyseal
Angle (CCDA) of less than 120° Fig. 17 on page 21

# Secondary findings

Secondary findings caused by impingement include ossa acetabuli (reactive ossification
of the acetabular labrum, often separated from the adjacent bone), herniation pits
(radiolucencies with sclerotic rim, located in the anterosuperior proximal part of the
femoral neck), acetabular roof cysts (mostly in the lateral part) and postero-inferior joint
space narrowing (represents a bad prognostic sign) Fig. 18 on page 22

**MR-Arthrography Technique**

Direct arthrography technique is preferred, with injection of a a diluted gadolinium
solution, mixed with iodine, under fluoroscopic guidance.

In our institution following sequences are used Fig. 19 on page 23:
• coronal STIR sequence of both hips: sensitive for evaluation of bone marrow edema and to detect exclude other extra-articular pathology; allows bilateral evaluation
• coronal (FS) SE T1 sequence: visualisation of the labrum (and bone marrow)
• coronal interm-w FSE FS sequence: to differentiate between contrast and fluid
• sagittal DESS sequence: cartilage evaluation
• transverse oblique 3D GRE sequence: radial reconstructions makes this sequence extremely useful to evaluate the extent of labral damage and to evaluate alfa angle

MR-Arthrographic Signs and Measurements

MRI allows detailed analysis of labral and cartilage pathology and may be an additional tool for quantification of femoroacetabular impingement

# Labral tear and other signs

The following labral abnormalities should be analysed:
- labral tears
- labral detachment
- cyst formation

Either than using the Czerny classification in the radi Fig. 23 on page 27 ological report, an accurate description of the lesion is preferred. In addition, good communication between radiologist and orthopedic surgeon is of utmost importance. Fig. 20 on page 24

Other signs to be analyzed include acetabular roocysts, chondral fissures and a bump-cysts complex Fig. 22 on page 26

# Alfa Angle

The nonspherical shape of the femoral head-neck junction can be quantified by the alfa angle, according by the method of Notzli.
The first line defining the alfa angle is the axis of the femoral neck (running through the center the femoral head and the center of the femoral neck at its narrowest point).

The second line runs between the center of the femoral head and the point where the distance from the center of the femoral head to the peripheral contour of the femoral head exceeds the radius of the femoral head.

These measurements can be done on radial reformations, on the location where the osseous bump is most pronounced, mostly at anterosuperior position (clock 1-3h).

The larger the alfa angle, the more pronounced nonspherical shape of the femoral head (cut off value 50-55°).

# Acetabular Depth

The depth of the acetabulum is defined as the distance between two parallel lines: a line connecting the anterior to the posterior acetabular rim and a line through the femoral center. Measurements should be done on a transverse oblique image obtained through the center of the femoral neck. If the center of the femoral neck is medial to the line connecting the acetabular rims, this value is negative. The acetabulum is mostly deeper in patients with pincer (negative values) than in patients with cam FAI (positive values) Fig. 24 on page 28

Images for this section:
**Fig. 1:** Imaging technique and correct positioning for AP pelvic radiograph: the patient is in the supine position, the legs are 15° internally rotated, and the central beam is directed to the midpoint between a line connecting both anterosuperior iliac spines and the superior border of the symphysis, which can be palpated by the technician.
Fig. 2: AP pelvis: Ideally, the distance from pubic symphysis to the tip of the coccyx should be not more than 2 cm (no tilting) and the obturator foramina should be symmetric in appearance (no rotation).
**Fig. 3:** Example of rotation of the pelvis: Ideally, the distance from pubic symphysis to the tip of the coccyx should be not more than 2 cm (no tilting) and the obturator foramina should be symmetric in appearance (no rotation). In this case, the tip of the coccyx does not point toward the midpoint of the superior aspect of the symphysis pubis, and the obturator foramina are not symmetric (rotation). Measurements on acetabular retroversion cannot be made correctly on this radiograph.
Fig. 4: Example of tilting of the pelvis: Ideally, the distance from pubic symphysis to the tip of the coccyx should be not more than 2 cm. In this case, the distance is more than 2 cm, in keeping with tilting. Measurements on acetabular retroversion cannot be made correctly on this radiograph.
Fig. 5: Imaging technique and correct positioning for the Dunn view of the hip. Patient is supine, with the hips flexed 90° degrees and slightly abducted (20°). As for the AP pelvis, the central beam is directed between the superior symphysis pubis and a line connecting both superior iliac spines.
Fig. 6: Evaluation of general over coverage compared to normal coverage, to be evaluated on an AP pelvis and not on a hip view. Left image: normal hip (acetabular fossa lying lateral to the ilioischial line) Middle image: coxa profunda (floor of the fossa acetabuli touching or overlapping the ilioischial line medially) Right image: protrusio acetabuli (femoral head overlapping the ilioischial line medially)
Fig. 7: Examples of general overcoverage. On the left image, the fossa acetabuli is crossing the ilioischial line medially (coxa profunda); on the right image, the femoral head is overlapping the ilioischial line medially (protrusio acetabuli). Note that we evaluate this on an AP pelvic radiograph (images are enlarged views derived from an AP pelvis).
**Fig. 8:** Evaluation of lateral coverage on a normal hip: the acetabular index (AI) should be positive (more than 0°), the lateral center edge (LCE) measures between 25-39° and the extrusion index (EI) +/- 25%. (detailed view derived from an AP pelvic radiograph)
Fig. 9: Detailed view of AP pelvic radiograph in a patient with protrusio acetabuli: notice a negative acetabular index (AI), an increased lateral center edge (LCE) and an extrusion index (EI) that is zero.

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<th>Normal</th>
<th>Dysplasia</th>
<th>Profunda/Protrusio</th>
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<tbody>
<tr>
<td>AI</td>
<td>positive</td>
<td>&gt; 14°</td>
<td>≤ 0</td>
</tr>
<tr>
<td>LCE</td>
<td>25-39°</td>
<td>&lt;25°</td>
<td>&gt;39°</td>
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<tr>
<td>EI</td>
<td>max 25%</td>
<td>&gt; 25 %</td>
<td>&lt; 10 %</td>
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Fig. 10: Overview of parameters and values for evaluating acetabular coverage in normal individuals, patients with dysplasia (undercoverage) and patients with protrusio/coxa profunda (overcoverage)

Fig. 11: Schematic drawing of signs of focal acetabular overcoverage, which can be anterior (acetabular retroversion) or posterior (prominent posterior wall). Posterior rim line = solid line Anterior rim line = dashed line
Fig. 12: Schematic drawing and detailed view of an AP pelvic radiograph of a patient with acetabular retroversion. The anterior rim line (blue dashed line) runs lateral to the posterior rim (blue solid line) in the cranial part of the acetabulum and crosses the latter more distally. (figure-of-8 configuration or cross-over sign). The posterior rim line can be identified when starting from the inferior edge of the acetabulum and tracing upwards (purple line).
Fig. 13: Detailed view of an AP pelvic radiograph in a patient with coxa profunda: the posterior rim (blue solid line) lies lateral to the femoral head center (red arrow from the femoral center to the posterior rim line), indicating a more prominent posterior wall.
**Fig. 14:** Schematic drawing of the sphericity of the femoral head: osseous bump located laterally (so called pistol grip deformity, seen on an AP pelvic radiograph) or anterosuperiorly (seen on an axial cross table view or Dunn view).
Fig. 15: Pistol grip deformity, characterized on AP pelvic radiographic (enlarged view), by flattening of the usual concave surface of the lateral aspect of the femoral head (dashed blue line) due to an abnormal extension of the more horizontally oriented femoral epiphysis (arrows). The blue circle indicates the normal outline of the femoral head.
Fig. 16: Dunn view of a hip with anterosuperior osseous bump: Alfa angle is the angle between the femoral neck axis and a line connecting the head center with the point of beginning asphericity of the head-neck contour (red lines). The Anterior offset (OS) is the difference in radius between the anterior femoral head and the anterior femoral neck (green lines).
Fig. 17: Schematic drawing of coxa vara and valga, with values for center collum diaphyseal angle (CCDA)
**Fig. 18:** Secondary signs of FAI: os acetabuli, herniation pit, acetabular roof cyst and postero-inferior joint space narrowing.
Fig. 19: Overview of sequences (direct MR orthography) used in our institution
Fig. 20: Schematic overview of labral tears, according to the Czerny classification. Transverse oblique 3D GRE images (direct MR-arthrography) of normal labrum (blue arrow), labral tear (red arrow), labral detachment (yellow arrow) and detachment with cyst formation (green arrow).
**Fig. 21:** Paracoronal reconstruction of a transverse oblique 3D GRE shows an acetabular roof cyst (red arrow), chondral fissure (yellow arrow), labral tear (blue arrow) and bump-cyst complex (green arrow).
**Fig. 22:** Transverse oblique 3D GRE images and reformats in different planes. The transverse oblique image shows a cam lesion (bump) and tear in the anterosuperior labrum (red arrows). The coronal reformatted image shows the extent of the labral detachment (yellow arrows) and the sagittal reformatted image shows narrowing of the postero-inferior joint space (blue arrows), which is a bad prognostic sign. All the images are reconstructed from a single 3D data set.
Fig. 23: Schematic drawing showing the measurement of the alpha angle (left normal, right cam lesion): First line defining the alfa angle is the axis of the femoral neck, which is defined as a line that passes through the center of the femoral head and the center of the femoral neck at its narrowest point (red line). Second line defining the alfa angle is located between the center of the femoral head and the point where the distance from the center of the femoral head to the peripheral contour of the femoral head exceeds the radius of the femoral head (green line).
**Fig. 24:** The depth of the acetabulum is defined as the distance between a line connecting the anterior to the posterior acetabular rim and a parallel line through the femoral center (purple lines). The value is positive if the center of the femoral neck is lateral to the line connecting the acetabular rim. (also annotated : measurement of the alfa angle, see fig. 21).

*Reference:*

> Radiographic signs associated with femoroacetabular impingement occur with high prevalence at all ages in a hospital population

F. de Bruin · M. Reijnsie · V. Farhang-Razi · J. L. Bloem
**Fig. 25:** Radiographic signs of FAI may also occur in an asymptomatic population. Interpretation of morphology should occur in conjunction with clinical findings.
Conclusion

- The main objectives for hip imaging of patients with suspected FAI are:
  - to look for abnormalities associated with impingement.
  - to exclude advanced joint degeneration.
  - to select these patients who can still benefit from arthroscopy.

- Good quality radiographs are a prerequisite for correct evaluation.

- Interpretation of an AP pelvis is different from analysis of a hip view.

- Do not rely solely on imaging findings. Radiographic signs of FAI may also occur in an asymptomatic population. Interpretation of morphology should occur in conjunction with clinical findings. Fig. 25 on page 31

- Good communication between radiologist and orthopedic surgeon is the key to success.

Images for this section:

Fig. 25: Radiographic signs of FAI may also occur in an asymptomatic population. Interpretation of morphology should occur in conjunction with clinical findings
References

- **Tannast M, Siebenrock KA., Anderson SE.** Femoroacetabular Impingement : Radiographic Diagnosis - What the Radiologis should know. AJR 2007;188 : 1540-1552

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