The Lisbon Agreement on femoroacetabular impingement imaging — part 1 : overview

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“THE LISBON AGREEMENT ON FAI IMAGING”

ABSTRACT

Objectives: Imaging assessment for the clinical management of femoroacetabular impingement syndrome (FAIS) remains controversial because of a paucity of evidence-based guidance and notable variability in clinical practice, ultimately requiring expert consensus. The purpose of this agreement is to establish expert-based statements on FAIS imaging, using formal techniques of consensus building driven by relevant literature review.

Methods: The validated Delphi method and peer-reviewed literature were used to formally derive consensus among 30 panel members (21 musculoskeletal radiologists and 9 orthopedic surgeons) from 13 countries.

Forty-two questions were agreed on, and recent relevant seminal literature was circulated and classified in five major topics (“General issues”, “Parameters and reporting”, “Radiographic assessment”, “MRI evaluation” and “Ultrasound”) in order to produce answering statements.

The level of evidence was noted for all produced statements and panel members were asked to score their level of agreement with each statement (0 to 10) during iterative rounds. Either “group consensus”, “group agreement” or “no agreement” was achieved. Items near consensus were further queried using 4 moderated group sessions and in 4 Delphi rounds.

Results: Forty-five statements were generated and group consensus was reached for 43 (95.7%). Seventeen of these statements were selected as most important for dissemination in advance. There was no agreement for the two statements pertaining to “Ultrasound”.

Conclusion: The first international Delphi-based consensus for the imaging assessment of FAIS was developed. The resulting consensus can serve as a tool to reduce variability in clinical practices and guide further research for the clinical management of FAIS.

Key Points

- FAI imaging literature is extensive although often of low level of evidence.
- Radiographic evaluation with a reproducible technique is the cornerstone of hip imaging assessment.
- MRI with a dedicated protocol is the gold standard imaging technique for FAI assessment.

Keywords

Hip; Femoroacetabular impingement; Musculoskeletal system; Imaging techniques; Guideline; Delphi

INTRODUCTION

Femoroacetabular impingement syndrome (FAIS) is a motion-related clinical disorder with a triad of symptoms, clinical signs and imaging findings[1, 2], that results from a symptomatic conflicting movement between the proximal femur and the acetabular rim[1, 3]. This abnormal contact has been associated with hip pain, functional impairment and may ultimately lead to premature osteoarthritis (OA) of the hip[4, 5].

FAIS remains controversial in terms of true incidence, diagnosis, prognosis and management[3, 6]. Despite clinicians becoming increasingly familiar with the concept of FAIS, there is no consensus regarding its preoperative diagnostic assessment and what in fact a definite FAI case is. In 2016, the Warwick Agreement represented an important step to better define FAIS and related terminology[7]. This international agreement, mostly amongst clinicians, aimed to reach consensus on the diagnosis, treatment principles and key terminology relating to FAIS[2, 7]. Importantly, an accurate diagnosis is required to ensure that the patient can pursue the optimal treatment strategy[8]. Imaging goals are to diagnose soft-tissue damage, to detect early or focally advanced OA and to assess hip morphologies related to FAIS, such as cam or pincer, which can be differentiated on the basis of a predominance of either a femoral or an acetabular abnormality [1-3, 9].

The Warwick agreement reinforced the importance of radiographs on the initial assessment of FAIS, and advocated the use of cross-sectional imaging to further assess hip morphology as well as cartilage and labral lesions[2]. This has stimulated radiologists as a pivotal part of the diagnostic workup for FAIS, leading to an increased use of different imaging techniques (radiographs, computed tomography (CT) and magnetic resonance imaging (MRI)), alone or in combination, alongside with a multitude of imaging signs and parameters[8, 10, 11]. However, to date, imaging assessment for FAIS remains unstandardized, because of a paucity of evidence-based guidance, with no consensus among radiology experts on which imaging modalities and parameters should be routinely assessed in clinical practice[7, 8]. Consequently, notable variability exists between different practitioners.

The aim of this Delphi-based consensus, "The Lisbon Agreement on FAI Imaging", is to establish expert-based statements on imaging of FAIS, using formal techniques of consensus building among an expert group driven by the results of relevant literature review.

METHODS

This consensus paper is a part of a collaborative project aimed to establish expert-based statements on FAIS imaging. Briefly, after project conception (VVM, MOC and PDA), the process was started with a first meeting during the European Society of Musculoskeletal Radiology (ESSR) 2018 meeting in Amsterdam, followed by four Delphi rounds, culminating in an open meeting at ESSR 2019 giving rise to the Lisbon agreement on FAI imaging. Panel members gave presentations on the final consensus items at the ESSR 2019 annual meeting (http://www.essr.org) held in Lisbon, Portugal, on June 26–29th 2019.

In this paper, we only report a voted-upon selection of most clinically relevant statements. Institutional Review Board approval was not required for the present study as patients were not involved.

Given the lack of high-level evidence in the literature for FAIS imaging assessment, no clinical consensus exists. Accordingly collecting experts' opinions in a structured and systematic manner, by using formal consensus development methods such as the Delphi method, is an acceptable way of creating practice recommendations. This method involves a sequence of discussion rounds to determine the opinion of experts on controversial topics, drafted on the basis of the existing literature, to produce a final consensus agreement. Full details of the Delphi method, including (1) participants; (2) consensus technique; (3) literature review, statement drafting, and level of evidence; (4) final scoring, data analysis and paper drafting are reported as Supplementary material. The Oxford Centre for Evidence-based Medicine evidence levels were applied[12].

RESULTS AND DISCUSSION

A total of 30 panelists were included in this consensus initiative (21 musculoskeletal radiologists and 9 orthopedic surgeons). Ninety and four tenths (90.4%, 19 out of 21) of radiologists had more than 10 years of experience in the field of musculoskeletal imaging and 18 of the radiologists had special dedication or expertise in hip imaging. All orthopedic surgeons had more than 10 years of experience in hip preservation surgery (HPS).

Thirty, 28, 27 and 26 participants completed rounds 1, 2, 3 and 4, respectively (6 orthopedic surgeons and 20 radiologists answered the final round). The overall dropout rate was 13% (33% amongst orthopedic surgeons and 5% amongst radiologists).

A total of 45 statements were generated and distributed among the topics “General issues” (5 items), “Parameters and reporting” (21 items), “Radiographic assessment” (8 items), “MRI evaluation” (9 items) and “Ultrasound” (2 items). At the end of the Delphi process, 'group consensus' was obtained for 43 statements. Although level 2 evidence exists regarding the use of ultrasound in the evaluation of FAIS, no agreement was reached for the 2 statements on this imaging technique.

In the following paragraphs we present an overview of the Lisbon Agreement on FAI Imaging, containing a voted-upon selection of the most clinically relevant topics and statements, followed by a summary of the panel’s discussion (Table 1 and Figure 1).

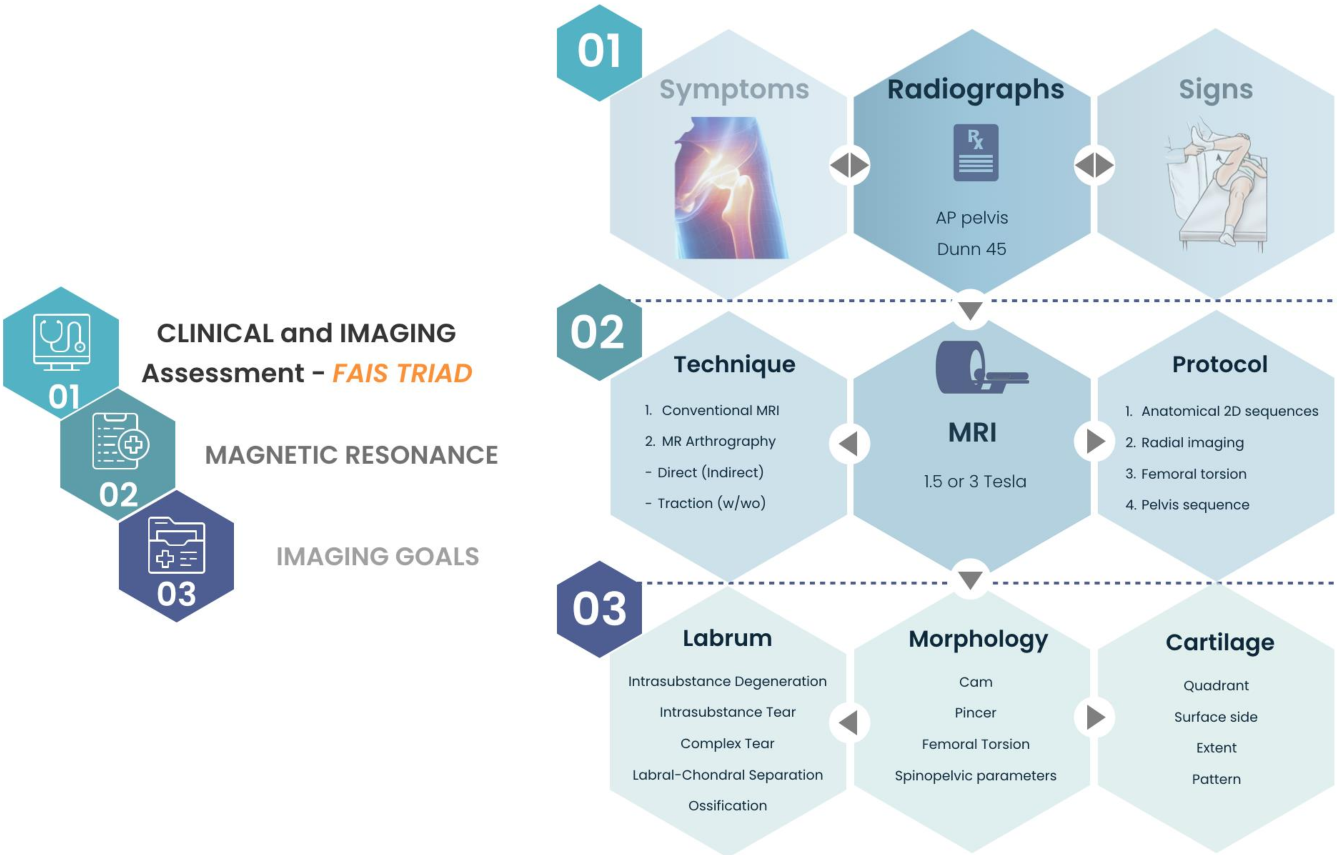


Figure 1. Pathway for the imaging management and assessment of femoroacetabular impingement syndrome (FAIS). W: with. Wo: without. AP: anteroposterior

Table 1. Selection of statements on imaging of FAIS with evidence levels. The listed levels of agreement represent the percentage of votes ≥8 on a 0-10 scale. IQR: Interquartile range. All listed statements obtained group consensus.

Type of statement	Group	Statement	Level of evidence	Median IQR (difference and interval) Level of agreement
GENERAL ASSESSMENT				
What should be the minimal acceptable imaging to support the clinical diagnosis of FAIS?				
Technique	General	An anteroposterior (AP) pelvic radiograph and a lateral view of the hip are the minimal imaging studies that should be performed when assessing patients for FAIS.	4	**10** **0 (10-10)** **96%**
Which combination of radiographic views is the best choice to diagnose cam morphology?				
Technique	Radiographs	An AP pelvis radiograph and a Dunn 45° view are the best choice for the initial radiographic assessment of the FHN junction, as further radial imaging is usually performed when FAIS is clinically suspected.	3	**10** **2 (8-10)** **93%**
PROTOCOL				
Which MRI protocol should be used to assess the young patient with hip pain?				
Technique	MRI	In a young patient with hip pain, the MRI protocol should routinely include unilateral small FOV sequences and radial images, as well as femoral torsion assessment and a fluid-sensitive sequence covering the whole pelvis.	5*	**10** **2 (8-10)** **93%**
What is the best technique to assess intra-articular lesions and provide support in treatment decision?				
Technique	MRI	Generally, direct MR arthrography is superior to non-contrast MRI. Emerging literature suggests that non-contrast 3T MRI is equivalent to 1.5T direct arthrography.	3	**10** **1.25 (8.75-10)** **96%**
FEMORAL HEAD-NECK JUNCTION				
Which modality should be used to assess the configuration of the femoral head-neck junction?				
Technique	Parameters and reporting	Radial MRI or CT are the most accurate imaging modalities for assessing the femoral head-neck junction. Radiographs, although less precise, may also be used to depict cam morphology.	3	**10** **0 (10-10)** **100%**
Which parameters should be used to assess the femoral head-neck junction?				
Interpretation	Parameters and reporting	Alpha angle is convenient to assess the femoral head-neck junction but has limited discriminatory power. Femoral offset is another useful parameter but is less well established.	3	**10** **0.5 (9.5-10)** **100%**
Which reference values should be used for these parameters?				
Interpretation	Parameters and reporting	A threshold of 60° is recommended for the alpha angle, as higher values are reported to be clinically more relevant. An anterior femoral offset <8mm may be regarded as abnormal.	4	**10** **2 (8-10)** **96%**
ACETABULAR COVERAGE				
Which should be the primary modality for assessing acetabular coverage?				
Technique	Parameters and reporting	An AP pelvic radiograph should be the first line modality for assessing acetabular coverage.	3	**10** **0 (10-10)** **100%**
Which measurements should be routinely performed for the assessment of acetabular coverage?				

Interpretation	Parameters and reporting	The center-edge angle of Wiberg and the acetabular index should be routinely assessed.	4	**10** **0 (10-10)** **89%**
What are the reference values for acetabular coverage based on the lateral center-edge angle and acetabular index?				
Interpretation	Parameters and reporting	For the center-edge angle of Wiberg, the classical radiographic based reference intervals are <20° for undercoverage, 20-25° for borderline undercoverage, 25-39° for normal coverage, and ≥40° for overcoverage. An acetabular index of <0º on an AP pelvic radiograph is classically accepted as overcoverage, while a value >13° represents undercoverage.	4	**10** **1 (9-10)** **96%**
ACETABULAR VERSION				
Which modality should be used to perform measurements of acetabular version?				
Technique	Parameters and reporting	An AP pelvic radiograph should be used for the initial assessment of acetabular version, but CT or MRI should be considered when clinical and radiographic evaluation are suggestive of acetabular malversion.	4	**9.5** **2 (8-10)** **100%**
Which signs should be routinely sought when assessing acetabular version?				
Interpretation	Parameters and reporting	On an AP pelvic radiograph, the cross-over sign should be routinely assessed. The posterior wall sign and the ischial spine sign should also be assessed.	4	**10** **0.25 (9.75-10)** **93%**
How should abnormal acetabular version be described?				
Interpretation	Parameters and reporting	An isolated positive cross-over sign is an indication of focal cranial retroversion whereas a positive cross-over sign combined with a posterior wall sign and ischial spine sign is an indication of global retroversion.	3	**10** **1.25 (8.75-10)** **96%**
PINCER AND CAM CRITERIA				
What are the imaging criteria for defining Cam morphology?				
Interpretation	Parameters and reporting	The main imaging criterion for defining cam morphology is an alpha angle above 60° at any location around the anterosuperior FHN junction. Other measurements are used to a lesser extent, such as the head-neck offset and offset ratio.	2	**10** **1.5 (8.5-10)** **96%**
What are the imaging criteria for defining Pincer morphology?				
Interpretation	Parameters and reporting	Pincer morphology can be due to acetabular retroversion and/or overcoverage. Criteria for retroversion on imaging are the presence of a cross-over sign, posterior wall sign or ischial spine sign. Overcoverage is indicated by the presence of protrusio acetabuli, W-CEA ≥ 40° or acetabular index < 0°.	4	**10** **1.5 (8.5-10)** **100%**
LABRUM AND CARTILAGE ASSESSMENT				
How should a suspected labral lesion on imaging be reported?				
Interpretation	MRI	Although several classifications and grading systems have been proposed for labral lesions, there is no outcome-based evidence to support the use of a specific classification/grading. Description of location, configuration and extent of labral lesions may be clinically useful.	2	**10** **1 (9-10)** **100%**
How should cartilage lesions be reported in clinical routine?				
Interpretation	MRI	Although available evidence is limited on how cartilage lesions should be reported, description of the extent, location and pattern/grade is suggested.	5*	**10** **1.25 (8.75-10)** **93%**

* level of evidence 5 represents expert opinion

GENERAL ASSESSMENT

Statement: *An anteroposterior (AP) pelvic radiograph and a lateral view of the hip are the minimal imaging studies that should be performed when assessing patients for FAIS.*

Statement: *An AP pelvis radiograph and a Dunn 45° view are the best choice for the initial radiographic assessment of the FHN junction, as further radial imaging is usually performed when FAIS is clinically suspected.*

Radiographs should be used in first line assessment of patients with suspected FAIS, allowing an overall assessment of the pelvis and hips, as well as exclusion of other causes of symptoms[2]. Conjointly, radiographs and MRI are the standard imaging modalities used for diagnosing hip pathomorphology and planning treatment[13-17].

For an initial diagnostic clinical approach, AP pelvis and lateral radiographs[2, 8, 13, 14] have been traditionally used and recommended, as the shape and orientation of the acetabulum may be assessed on the AP view and the morphology of the proximal femur best assessed on the orthogonal view of the femoral neck[18] (Figure 2).

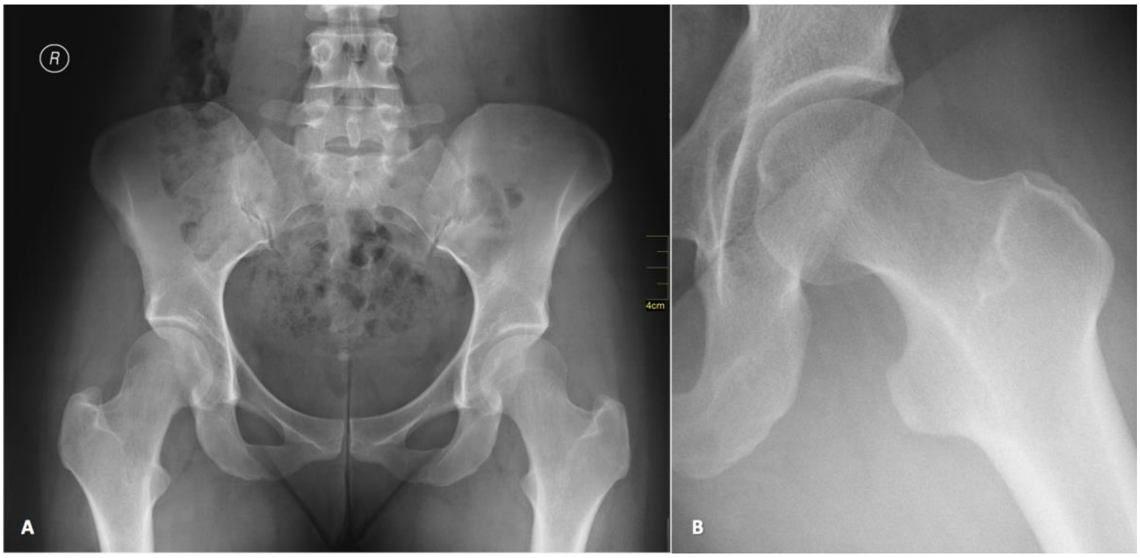


Figure 2. Minimal recommended radiographic series to evaluate a patient with suspected FAIS. (A) AP pelvic radiograph. Excessive tilt, obliquity and rotation should be avoided by following a standardized technique. Acetabular coverage and version may be initially assessed in this view. (B) Dunn 45° radiograph. It is obtained with the hip in 45° of flexion and 20° of abduction. This view may be used as first line assessment of proximal femoral morphologies.

Femoral head-neck (FHN) asphericity in hips with FAIS is most often localized in the anterosuperior region[19-21]. Although not unanimously accepted, these asphericities are usually best shown with a view with the hips in 45° of flexion and 20° of abduction (Dunn 45° view)[22-26]. The consistent use of this view in the radiographic evaluation of suspected FAIS would provide clinicians with the highest accuracy in demonstrating cam morphology[22, 25]. However it is notable that alpha angle (α°) and head-neck offset measurements from these and other radiographic views reportedly reflect only 50% of the overall variation in the shape of the proximal femur[18, 27]. Given that the hip is a 3D anatomic structure, imaging assessment currently used to evaluate pre-arthritic hip conditions is facilitated with MRI and CT volumetric imaging[28].

MRI PROTOCOL

Statement*: In a young patient with hip pain the MRI protocol should routinely include unilateral small FOV sequences and radial images, as well as femoral torsion assessment and a fluid sensitive sequence covering the whole pelvis.*

Statement*: Generally, direct MR arthrography is superior to non-contrast MRI. Emerging literature suggests that non-contrast 3T MRI is equivalent to 1.5T direct arthrography.*

There is no definite evidence comparing different imaging protocols or their accuracy. Different authors strive to optimize diagnostic examinations and routinely perform smaller field-of-view (FOV) sequences focusing on a single hip[9, 22, 29] in several imaging planes. Conceptually, acceptable minimum thresholds for adequate spatial resolution are a FOV of 16 cm and a matrix of 256 x 256. If the FOV is larger, matrix must be adjusted accordingly (e.g. for a FOV of 20 cm, minimum matrix should be 320 x 320).

Panel members agree that radial imaging as well as fast images of the knee and pelvis should be performed to accurately characterize the morphology of the FHN junction and to assess femoral torsion, respectively. A fluid-sensitive sequence with a large FOV covering the whole pelvis should be routinely included, to screen for pathology beyond the hip and overcome potential limitations in clinical assessment, which may result in misguided referrals for hip dedicated imaging. However, whole pelvis imaging must not be regarded as a substitute for focused imaging (e.g. sacroiliac, pubic symphysis) (Figure 3).

Radial images rotating around the femoral neck axis allow a circumferential assessment of the hip joint in a clockwise fashion to depict FAI morphologies that are typically located in the anterosuperior quadrant of the FHN junction (3 o'clock to 12 o'clock) [30]. Radial slices can be obtained either through reconstructed 3D volumetric datasets[19, 21] or direct 2D radial sequences based on a sagittal oblique localizer (providing higher resolution images)[31]. It has been shown that biplanar radiographs do not exclude the presence of a cam morphology and, additionally, underestimate its severity [32]. Accordingly, the highest correlation between increased α° measured on radial MRI sequences and the Dunn 45° view has been noted[25]. The added value of radial imaging for assessing the acetabulum and/or labrum is not definitely established [33]

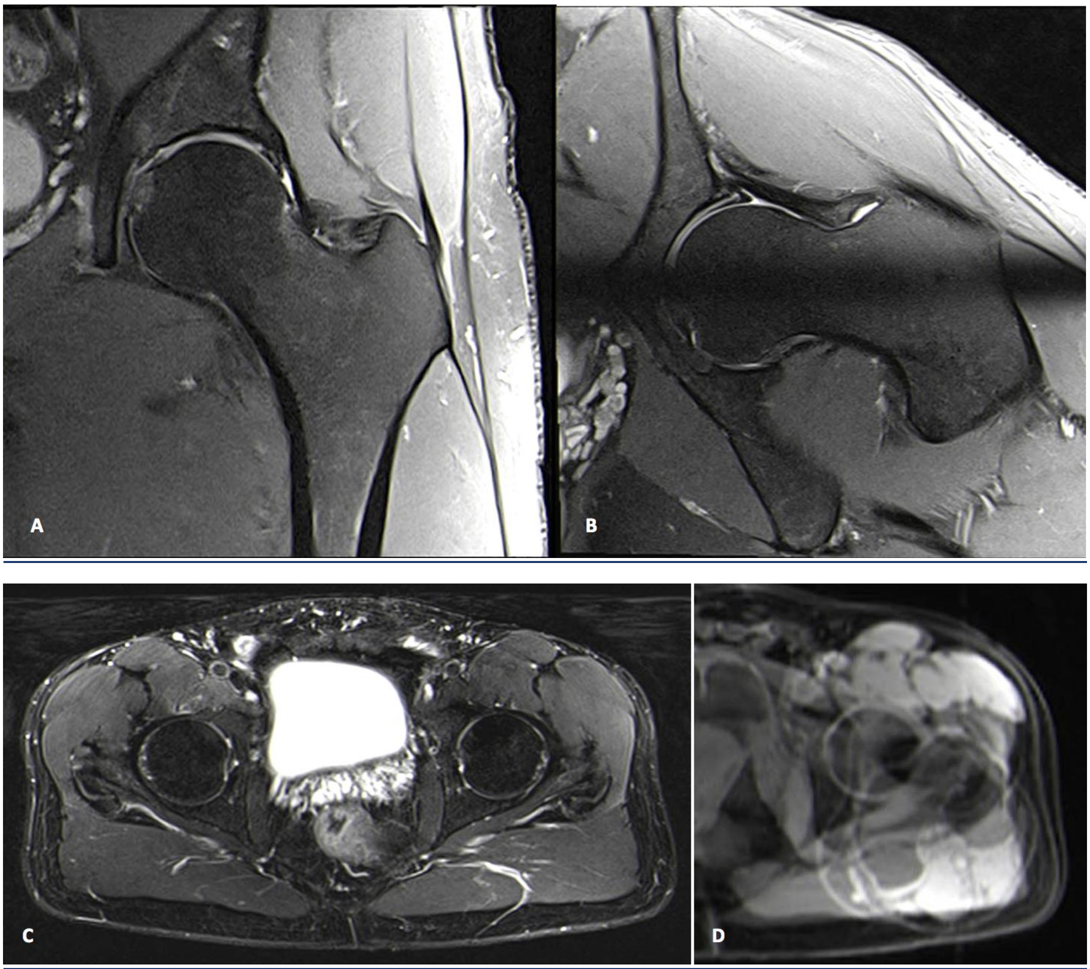


Figure 3. Sequences that should be included on the proposed routine MRI protocol for the assessment of suspected FAIS, include unilateral hip 2D sequences (coronal, axial oblique and sagittal are most useful), radial imaging (either a 2D sequence or reformats from a 3D acquisition), a pelvic fluid-sensitive sequence

and femoral torsion assessment. Unilateral FOV coronal fat-suppressed proton-density (A) and radial (B) sequences might be used for hip detailed assessment. A 2D large-FOV axial sequence of the pelvis(C) is used to screen for other possible differential diagnosis. Assessment of femoral torsion (D): different slices may be superimposed on a single image with postprocessing software, making it easy to measure.

Participants in this consensus consider imaging an important factor in treatment decision although its role is mostly limited to characterization of osseous morphology and determination of labral/chondral damage severity[1, 2, 34].

For cartilage assessment, radiographs can only indirectly assess chondral pathology by depicting hip OA. However, if there are no signs of OA, MRI, magnetic resonance arthrography (MRA) and CT arthrography (CTA) appear to help in decision making as they may demonstrate focal/regional high grade cartilage lesions despite minimal radiographic findings. In such cases, these techniques are able to diagnose severe/extensive cartilage damage with acceptable accuracy (those are the lesions that may influence surgical versus non-surgical management)[1, 3, 35].

Unenhanced unilateral hip MRI, direct MR arthrography (dMRA) and less frequently indirect MRA are the techniques of choice for the detection of hip chondro-labral lesions, although the diagnostic test accuracy is superior for dMRA when compared with MRI. Current evidence indicates that dMRA is the best technique to study intra-articular structural lesions[4, 5, 36-38], with authors often comparing 1.5T dMRA to MRI. 3T MRI was reportedly equivalent to 1.5T dMRA for diagnosing labral tears and cartilage delamination, although superior for diagnosing acetabular cartilage defects[3, 6, 39]. Additionally 3T MRI demonstrated similar sensitivity to 3T dMRA for the detection of acetabular labral tears, although dMRA is more sensitive for detecting acetabular chondral lesions[7, 40]. dMRA can be further combined with leg traction to distract the hip joint and has shown encouraging first results[41] .

Literature is scarce comparing indirect MRA to MRI, but it shows less overall accuracy of indirect MRA when compared to dMRA[2, 7, 36, 37].

FEMORAL HEAD NECK JUNCTION

Statement: *Radial MRI or CT are the most accurate imaging modalities for assessing the femoral head-neck junction. Radiographs, although less precise, may also be used to depict cam morphology.*

Statement: *Alpha angle is convenient to assess the femoral head-neck junction but has limited discriminatory power. Femoral offset is another useful parameter but is less well established*

Several reports highlighted the gap in knowledge regarding hip morphology prevalence and its role in the pathogenesis of FAI. FAI-like morphology has been detected in all populations, although few studies use the same case definitions for Cam or Pincer morphology while others used a different definition for males/females[3, 8]. Additionally, other studies use a variety of imaging modalities including radiographs, CT and MRI and measured α° at different FHN positions[1-3, 9].

Cam morphology corresponds to an asphericity of the FHN junction, most commonly at an antero-superior location (1-2 o'clock on the clock face) and is usually assessed by measuring the α°[2, 42].

The α° and femoral offset (FO) describe different features of the FHN junction. The α°reflects the proximal aspect of the asphericity, while the FO describes the width of the femoral neck relative to the femoral head[8, 10, 11, 43]. Although these parameters are useful to quantify the FHN junction particularly in a research setting, caution is warranted when using them in routine clinical practice. The use of the α° to quantify cam morphology is controversial due to its moderate reproducibility, moderate discriminative ability to differentiate patients from healthy subjects and the lack of conclusive data on ideal threshold values[7, 8, 20]

Statement: *A threshold of 60° is recommended for the alpha angle, as higher values are reported to be clinically more relevant. An anterior femoral offset < 8 mm may be regarded as abnormal.*

Statement: *The main imaging criterion for defining cam morphology is an alpha angle above 60° at any location around the anterosuperior FHN junction. Other measurements are used to a lesser extent, such as the head-neck offset and offset ratio.*

Since the original description of the α° by Nötzli *et al*, there has been much debate regarding its thresholds [12, 42], although currently there is evidence that α° thresholds should be defined according to the location around the FHN[2, 19, 21, 44]. Based on cross-sectional studies comparing asymptomatic volunteers with cam FAIS patients, and on the natural course of FAIS (short- and mid-term OA progression in symptomatic hips with α°>60°), an α° threshold of 60°

may be recommended[13-17, 20, 44-46]. Recent research suggests that a cam morphology with α° measurements above 57° to 60° at the 1:30- to 2-o'clock position is probably symptomatic. Using this threshold would optimize discriminative power while favoring specificity[2, 8, 13, 14, 20]. Conversely, increasing the threshold will increase specificity although decreasing sensitivity.

However, this threshold must be viewed with caution. Several patients with cam morphology have signs of impingement with α°<60°, while others above that cut-off will remain asymptomatic[18, 20]. As substantial overlap exists, other variables should be considered to explain the different clinical manifestations, such as the combination with certain anatomical factors (e.g. decreased femoral anteversion, spinopelvic parameters), sex and athletic performance[19-21, 47-50].

Other measurements are used to a lesser extent, such as the FO and offset ratio[11, 22-26, 51]. There is only very limited data for the FO, but a value of <8 mm has been reported as abnormal[11, 17, 22, 25, 52] (Table 2).

Based on these considerations, available evidence and panel consensus, Cam criteria are suggested (Table 2).

Table 2. Criteria proposed by the panel for classifying cam morphology in a research setting (regardless of the symptomatic state)

CAM morphology CRITERIA
*1. Osseous convexity of the FHN junction**
OR
*2. Alpha angle ≥ 60 °**
OR
*3. HN offset < 7 mm AND HN offset ratio ≤ 0.15**

** at any location around the FHN junction. Evaluation using radiography (preferably assessed by an AP Pelvis and Dunn 45 °), CT or MRI (with radial imaging/reformats).*

ACETABULUM ASSESSMENT

a) COVERAGE

Statement: *An AP pelvic radiograph should be the first line modality for assessing acetabular coverage.*

Statement: *The center-edge angle of Wiberg and the acetabular index should be routinely assessed for the assessment of acetabular coverage.*

An AP pelvic radiograph should be the initial examination for assessing acetabular coverage, although cross-sectional imaging may be also used to assess coverage, providing similar measurements for most parameters[18, 27, 53-55]. Conflicting reports exist regarding the effect of pelvic positioning on radiographic parameters of coverage[28, 56-58], although tilt and rotation seem to mainly influence radiographic signs of acetabular retroversion[9, 22, 29, 59, 60].

The center-edge angle of Wiberg (W-CEA) and acetabular index (AI) are the most often used parameters of superior-lateral coverage[30, 55, 61]. Anterior and posterior acetabular coverage may be quantified using the anterior and posterior wall indices[62]. Other parameters, such as the anterior center-edge angle, extrusion index or Sharp angle, are less frequently used[19, 21, 56]. The presence of *protrusio acetabuli* should always be noted as it is a clinically relevant condition[31, 63]. *Coxa profunda*, previously regarded as indicative of pincer morphology, is a common radiographic finding and should be abandoned as a sign of acetabular overcoverage[32, 64, 65].

Statement: *For the center-edge angle of Wiberg, the classical radiographic based reference intervals are <20° for undercoverage, 20-25° for borderline undercoverage, 25-39° for normal coverage, and ≥40° for overcoverage. An acetabular index of less than 0° on an AP pelvic radiograph is classically accepted as overcoverage, while a value over 13° represents undercoverage.*

The cut-off values for the W-CEA originally reported by Wiberg[25, 66] have been considered gold standard and are recommended by this consensus group.

A recent large population-based study[67] reported reference intervals (RefInt) for the W-CEA of 18-43° for males and 17-42° for females, which are significantly broader compared to the classical W-CEA threshold of <25° for borderline undercoverage. The same authors reported RefInt for the AI of -4,7 to 14,8° for males and -4,1 to 15,6° for females, which are also significantly wider than the classical reference values[68, 69]. Interestingly, if these updated reference values for the AI and for W-CEA were to be used, many hips considered pathologic using the classical RefInt would now be classified as normal. This strongly suggests the need to update the RefInt used in the classification of lateral acetabular coverage based on the natural course of the disease.

Other authors defined RefInt in surgically treated symptomatic hips although their application to the asymptomatic general population and its relevance for the natural history of hip disease are yet to be proven (W-CEA/AI: dysplasia <22°/>14°, normal coverage 23-33°/3-13°, overcoverage 34-39°/(-7)-2° and severe overcoverage >40°/<-8°)[56].

b) VERSION

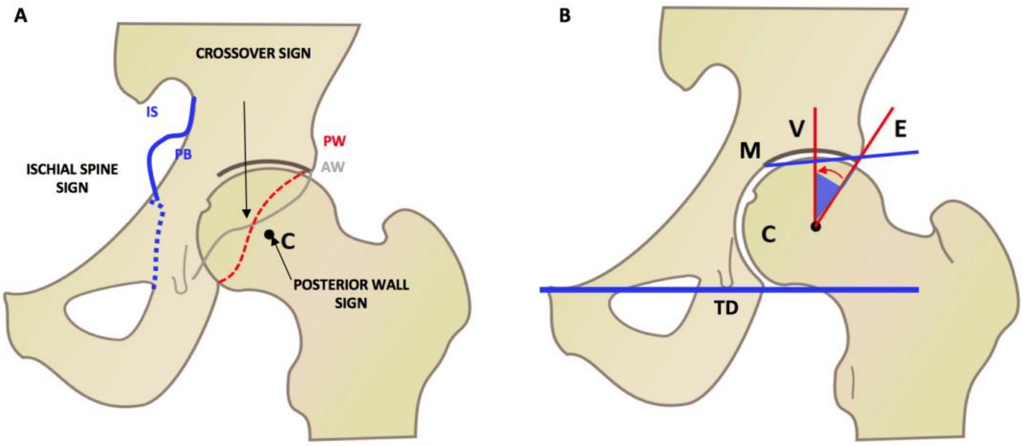
Statement: *An AP pelvic radiograph should be used for the initial assessment of acetabular version, but CT or MRI should be considered when clinical and radiographic evaluation are suggestive of acetabular malversion.*

Statement: *On an AP pelvic radiograph, the cross-over sign should be routinely assessed. The posterior wall sign and the ischial spine sign should also be assessed.*

Statement: *An isolated positive cross-over sign is an indication of focal cranial retroversion whereas a positive cross-over sign combined with a posterior wall sign and ischial spine sign is an indication of global retroversion.*

The most commonly used imaging modality for assessment of acetabular version is the AP pelvic radiograph[55]. Accordingly, surgical planning for correcting abnormal acetabular version has most commonly been based on radiographic signs of retroversion[70-73]. Nevertheless, measurements of acetabular version on radiographs were reported to be less reliable (significant incidence of false positives in assessing retroversion) compared to those obtained in cross-sectional and 3D imaging[74-77], which may more accurately identify and quantify individual acetabular morphologies. Limitations in conventional radiographic evaluation of acetabular version are both inherent to the imaging technique and related to pelvic tilt[76].

The cross-over sign (COS), posterior wall sign (PWS) and ischial spine (ISS) sign (Figure 4) should be assessed on radiographs, as there is evidence that depending on the presence of different signs and degree of acetabular retroversion, different surgical approaches may be considered[78]. In contrast to cranial retroversion, patients with a global retroversion may benefit from a pelvic reorientation procedure instead of acetabular rim trimming[78]. In fact, there is evidence suggesting that hips with global retroversion (defined as positive COS, PWS and ISS) have a smaller lunate surface and a malrotated acetabulum[79].
Caution is warranted however, as a) these radiographic signs are commonly present among asymptomatic subjects[64, 80, 81], b) their accuracy *per se* is questionable [74, 76] and c) radiographs may overestimate acetabular retroversion. Advanced imaging should thus be considered when clinical findings and radiographs are consistent with pincer FAIS and retroversion, although its clinical added value remains to be established.



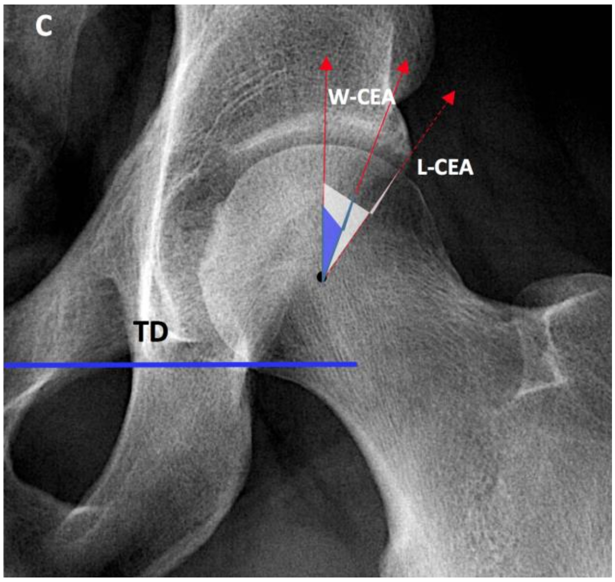


Figure 4. (A) The **crossover sign** is considered positive when the contour of the anterior wall (AW) intersects and becomes lateral to the contour of the posterior wall (PW). The **PW sign** is considered positive when the projection of the posterior acetabular wall is medial to the projection of the femoral head center[11]. The **ischial spine (IS)** sign is considered positive when the projected triangular shape of the IS protrudes and is visible medially to the pelvic brim (PB). (B) **Center-edge angle of Wiberg**(W-CEA): Angle formed by a perpendicular line (v) to a line connecting the tear drops (TD), and a line through the center of the FH (c) and the lateral end of the sourcil (E) (i.e., the sclerotic weight-bearing area of the acetabulum), rather than the lateral rim of the acetabulum. **Acetabular index or Acetabular inclination:** Angle formed by a line connecting the tear drops (TD), and a line through the medial (M) and lateral edge of the acetabular sourcil (E). (C) The W-CEA should be distinguished from the lateral center-edge (L-CEA), as the most lateral point to consider would be the lateral end of the sourcil (W-CEA) rather than the most lateral rim of the acetabulum (L-CEA). Frequently, these two reference points might coincide.

c) PINCER Criteria

Statement: *Pincer morphology can be due to acetabular retroversion and/or overcoverage. Criteria for retroversion on imaging are the presence of a cross-over sign, posterior wall sign or ischial spine sign. Overcoverage is indicated by the presence of protrusio acetabuli, W-CEA ≥ 40° or acetabular index < 0°.*

Imaging signs of pincer morphology include markers of increased acetabular coverage and of abnormal acetabular version. Caution is warranted when interpreting radiographs, as pelvic tilt and rotation are known to affect some of these parameters, particularly AP coverage and retroversion[59]. Although generally supported by the literature[55], high quality research is needed in order to more precisely define the value of radiographic signs in the diagnosis of pincer morphologies (particularly the COS, PWS and ISS), as well as the clinical relevance of cross-sectional imaging in this setting. Based on the above-mentioned rationale, published evidence and panel consensus, Pincer criteria are suggested (Table 3).

Table 3. Criteria proposed by the panel for classifying pincer morphology in a research setting (regardless of the symptomatic state). COS: Cross-over sign. W-CEA: Center-edge-angle of Wiberg.

GLOBAL PINCER*	*Protrusio acetabuli* OR W-CEA ≥ 40° OR W-CEA ≥ 35° AND acetabular index < 0°
	Positive COS AND Posterior Wall Sign AND Ischial Spine Sign **(Global RETROVERSION)**
FOCAL PINCER (cranial retroversion in non-dysplastic hips)*	Positive COS** OR Cranial acetabular version < 0°***

** evaluation of standardized AP pelvic radiographic images is required.*

*** confirmation of the presence of acetabular retroversion using CT or MRI may be recommended due to false positive COS in pelvic radiographs.*

**** evaluation using MRI or CT (adequately centered and corrected for tilt on the coronal plane and rotation in the axial plane).*

LABRUM AND CARTILAGE ASSESSMENT

a) LABRUM

***Statement**: Although several classifications and grading systems have been proposed for labral lesions, there is no outcome-based evidence to support the use of a specific classification/grading. Description of location, configuration and extent of labral lesions may be clinically useful.*

Several surgical and MRI-based classifications for description of labrum lesions have been proposed[82-84]. Currently, no evidence supports the use of a specific description of labral injury based on treatment outcomes. Due to the weak agreement between these classifications, imaging assessment of the acetabular labrum may instead focus on an accurate descriptive report, including location, configuration and extent of labral tears and associated cartilage and osseous changes[41] (Table 4).

Table 4. Recommended descriptors of labral injury, based on inferential evidence [36, 40, 85].

Type of lesion	DESCRIPTION
1	Intrasubstance labrum degeneration
2	Intrasubstance labral tear
3	Complex labral tear (both intrasubstance tear and labral-chondral separation)
4	Labral-chondral separation (= labral detachment)
5	Labral ossification

b) CARTILAGE

***Statement**: Although available evidence is limited on how cartilage lesions should be reported, description of the extent, location and pattern/grade is suggested.*

Currently, there is only outcome-based evidence supporting the description of the extent of cartilage damage, while only inferential evidence is available for the remaining features.

Nevertheless, description of the location, surface and pattern/grade is recommended by the panel of experts (Table 5).

The extent of cartilage damage evaluated by MRA is reportedly an independent prognostic factor for long-term outcome of FAIS surgery (worse if greater than 60° around the clock face)[63]. In the presence of extensive cartilage loss some surgeons may choose not to perform corrective FAIS surgery.

The involved joint surface has also surgical planning and prognostic implications, as femoral cartilage damage is a) a poor prognostic factor, b), is indicative for progressive joint degeneration, and c) is easier to treat with open surgery than with hip arthroscopy[86, 87].

The pattern of cartilage lesion can also affect surgical planning: acetabular rim trimming (e.g. complete cartilage loss in the chondro-labral junction), or cartilage repair procedures such as subchondral drilling or autologous matrix-induced chondrogenesis (e.g. cartilage damage located centrally).

Location has also diagnostic and surgical planning implications as a) typically located lesions support a cam or pincer FAI mechanism and corresponding treatment, and b) posterior lesions are difficult to access arthroscopically[88]. Conversely, atypically located lesions may support other etiologies (e.g. trauma, overuse)[9].

Table 5. Recommended descriptors of cartilage lesions on a hip MRI study.

PARAMETERS	DESCRIPTION
LOCATION **	Quadrant description
SURFACE SIDE **	Acetabular or femoral
EXTENT *	Any MRI cartilage damage extending <2/ >2 'hours' on the clock-face
PATTERN **	3 grades: 1. no damage 2. any cartilage damage 3. complete cartilage loss Other descriptors: 1. peripheral (chondrolabral junction) vs central 2. any cartilage damage: if possible add details, such as 'superficial cartilage damage' or 'cartilage delamination'

* Recommendations based on outcome evidence.

**Recommendations based on inferential evidence.

CONCLUSION

In conclusion, the first international, multidisciplinary Delphi-based consensus for imaging of FAI was developed. We critically reviewed the available evidence, the roles and limitations of each technique, and highlighted recommended protocols, imaging parameters, classifications and criteria. The resulting consensus statements can serve as a tool to reduce variability in preoperative, intraoperative and postoperative practices and guide further research for the clinical management of FAIS.

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