Comparison of conventional 3-T MRI and 1.5-T MR arthrography of femoroacetabular impingement (FAI)

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Aims and objectives

Several publications have advocated the use of direct magnetic resonance arthrography (MRA) for the detection of labral tears because of its higher sensitivity compared with conventional magnetic resonance imaging (MRI) at 1.5-T magnets (1). The challenge for 3-T MRI is to extend accuracy to all areas of the hip without the need for direct arthrography and to improve cartilage abnormality detection (2,3,4).

To our knowledge there is no study in the literature with an intraindividual comparison of 3-T conventional MRI and 1.5-T direct MRA for assessment labrum, labral-chondral transitional zone and articular cartilage integrity with surgical correlation in all patients. Therefore, the purpose of our study was to retrospectively compare the diagnostic performance of MRA and conventional MRI for the detection of acetabular labrum, labral-chondral transitional zone and articular cartilage defects, with surgical findings as the reference standard.

Methods and materials

Subjects

We reviewed non-contrast 3-T MRI and 1.5-T MRA examinations of the hip in patients with femoroacetabular impingement who had underwent hip arthroscopy between January 2012 and December 2013 in the Hospital Universitario Puerta de Hierro Majadahonda.

Exclusion criteria were previous surgery on the hip and other causes of groin pain as hip dysplasia, avascular necrosis, transient osteoporosis, bony lesions (tumors, insufficiency fractures…), synovial pathology (pigmented villonodular synovitis, synovial chondromatosis…), tendinopathy, bursitis and extraarticular diseases (inguinal hernial…).

The study group consisted of 43 patients, 27 males and 16 females; mean age 43 years, and age range 27-58 years old. A history of chronic hip or groin pain and a clinical examination with findings consistent with femoroacetabular impingement were present in all cases. According to radiographic findings, patients with FAI were classified into pincer impingement (18 patients), cam impingement (5 patients) or mixed impingement (20 patients).

Imaging examinations
MRI

Conventional 3-T MRI was performed with a 3-T MR magnet (Achieva dual quasar 3-T Philips, Eindhoven, Paises Bajos) with the body phased array coil 6Ch-Torso-coil. The conventional 3-T MR protocol (Table 1 on page 8) included high resolution proton density (PD) spin echo pulse sequences.

Direct MR arthrography (MRA)

MR examination was performed in a 1.5 T MR magnet (Achieva nova 1.5-T Philips, Eindhoven, Países Bajos) with the cardiac body 5Ch-Cardiac-coil. During MR examination was performed with a 5kg of weight skeletal traction. Pulse sequences were performed are summarized in Table 1 on page 8.

Patients had MRA studies within 30 minutes of contrast injection.

Contrast solution of 15cc contained 0.2cc of gadoterate meglumine (Dotarem®), 3cc lidocaine 1% and 12cc sterile saline.

Intra-articular injection was performed using an echogenic tip Chiba needle (Cook®) under ultrasound guidance.

<table>
<thead>
<tr>
<th>Pulse sequence</th>
<th>Plane</th>
<th>RT</th>
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<th>Matrix size</th>
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Table 1: Protocol of 3-T conventional MRI and direct 1.5-T MR arthrography (MRA) of the hip. It is specified pulse sequence, plane, RT or repetition time (msec), ET or echo time (msec), matrix size, section thickness (mm), gap, echo train length, field of view (FOV), inversion time (IT), flip angle and fat suppression. Pulse sequences included are T1, 3D WATer Selective Fluid (3D-WATSf), STIR, Proton Density- High Resolution (PD-HR) and T1 High-Res Isotropic Volume Excitation (THRIVE). Fat suppression techniques detailed are SPectral Attenuated Inversion Recovery (SPAIR), Spectral
Criteria for Interpretations

Three musculoskeletal radiologists independently reviewed MRA examinations. The final interpretation was based on a majority consensus.

- Acetabular labrum:

Abnormalities of labral morphology and signal intensity were noted. Traditionally, criteria for labral abnormalities were derived from established studies of the glenoid labrum (5).

Two characteristics of the acetabular labrum were evaluated:

(a.1) Labral appearance itself: normal (Fig. 1 on page 9) or degenerative. Understanding as degenerative changes the labral enlargement, intrasubstance areas of intermediate signal intensity, and irregular margins (5). High signal on MRI or contrast material on MR arthrography within the substance of the labrum extending to the articular surface characterized intrasubstancia or flap tears. For the purposes of data analysis, intrasubstancia or flap tears were considered to be degenerative changes. Normal variants, such as labral sulcus (Fig. 2 on page 9) were also recorded.

(a.2) Presence of a tear at the chondro-labral junction. The diagnostic criterion for a labral tear included the presence a cleft at the chondro-labral junction defined by synovial-fluid intensity signal on MRI or contrast material on MR arthrography (6) This labral tear has been defined as a "basal" tear (7) or a longitudinal peripheral tear in Lage’s arthroscopic classification (8).

Fig. 1: Normal hip, sagittal (a) and coronal (b) images on PD-HR weighted sequences on 3-T conventional MRI and coronal THRIVE wi on 1.5-T MRA show acetabular
labrum (red arrow), labral-chondral transitional zone (yellow arrow), acetabular cartilage (green arrow), femoral cartilage (orange arrow) and perilabral recess (blue arrow).

References: Department of Radiology, Hospital Universitario Puerta de Hierro Majadahonda, Madrid/ES

Fig. 2: Labral sulcus as a normal variant in a 22 year-old female with cam FAI. Plain film (a) shows an osseous bump (yellow arrow). Sagittal (b) and coronal (c) images on PD-HR weighted sequences on 3-T conventional MRI show acetabular labrum (orange arrow), hyperintensity in a cleft at the labral-chondral transitional zone (purple arrow), low signal within the cartilage at the labral-chondral transitional zone (blue arrow) and
non-dstended capsule (green arrow). (d) Arthroscopic image shows a labral sulcus (purple arrow) between the labrum (L) and the normal acetabular cartilage (AC).

References: Department of Radiology, Hospital Universitario Puerta de Hierro Majadahonda, Madrid/ES

- Labral-chondral transitional zone:

The evaluation of abnormalities at the labral-chondral transitional zone included an assessment of both separation of the labrum and adjacent cartilage abnormality. The assumption that the two are linked is based on work by Beck et al. (9) and Schmid et al. (10). Pathology was subdivided using the following classification of James (5): grade 1, labral separation, a distinct plane between the labrum and the acetabular cartilage, identified as a high-signal cleft between the low-signal fibrocartilage and the intermediate signal hyaline articular cartilage; grade 2, articular cartilage fraying, thinning, or separation immediately adjacent to the labral attachment (Fig. 3 on page 10); and grade 3, full-thickness loss of articular cartilage leading to bare bone exposure immediately adjacent to the labral attachment.
Fig. 3: 40-year-old man with cam FAI in the left hip. (a) Coronal THRIVE image of MRA at a 1.5-T magnet shows a small cleft (red arrow) full of contrast at the labral-chondral transitional zone, an abnormal signal intensity within the labrum (orange arrow) related to degeneration, hypointensity foci within de acetabular cartilage (green arrows) and a normal perilabral recess distended (blue arrow). (b) Coronal and (c) sagittal PD-HR image at a 3-T magnet shows hiperintensity within the small cleft at the labral-chondral transitional zone. (d) Arthroscopic image shows a small grade 2 chondral lesion at the labral-chondral transitional zone (LCTZ).

References: Department of Radiology, Hospital Universitario Puerta de Hierro Majadahonda, Madrid/ES

- Articular cartilage:
Femoral and acetabular articular surfaces were assessed. Cartilage within the labral-chondral transitional zone was evaluated independently of the rest of the acetabular cartilage.

The articular cartilage was graded on the MRI with a modification of the classification system of Outerbridge (5). Grade 0 indicated intact cartilage; grade 1, chondral softening or blistering with an intact surface; grade 2, shallow superficial ulceration, fibrillation, or fissuring involving less than 50% of the depth of the articular surface; grade 3, deep ulceration, fibrillation, fissuring or a chondral flap involving 50% or more of the depth of the articular cartilage without exposure of subchondral bone; and grade 4, full-thickness chondral wear with exposure of subchondral bone.

For purposes of comparison, we collapse the cartilage grades into arthrosis-negative (grade 0, 1, 2, and 3) and arthrosis-positive (grade 4) states, and we took as standard of reference 3-T conventional MRI as it is more sensible than arthroscopy for arthrosis.

**Arthroscopic Evaluation**

Arthroscopic findings were used as the standard of reference. Surgery was performed by an orthopedic surgeon (JCLV) with extensive experience in hip arthroscopy. The orthopedic surgeons was aware of the MR imaging findings of the patient at the time of arthroscopy. The surgeon provided dictated operative reports about all patients who underwent hip arthroscopy. Each report included an assessment of the integrity of the labrum, the labral-chondral transitional zone and articular cartilage and description of the treatment administered. The labrum was considered abnormal if treated with débridement or repair and normal if described as intact.

**Statistical Analysis**

The sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), accuracy of MRA examination were calculated with a 95% confidence interval, using arthroscopy as the reference standard.

Cohen’s kappa index was used to measure agreement between hip MRA and arthroscopy for determining the presence of lesions at the labrum, the grade assigned to lesions at the labral-chondral transitional zone and the grade assigned to articular chondral lesions. Agreement was assessed, according to the recommendations of Landis and Koch (12) as follows: Kappa values between 0-0.20 indicates a slight agreement, 0.21-0.40 fair agreement, 0.41-0.60 moderate agreement, 0.61-0.80 substantial agreement, and 0.81-1 almost perfect agreement.

**Images for this section:**
Table 1: Protocol of 3-T conventional MRI and direct 1.5-T MR arthrography (MRA) of the hip. It is specified pulse sequence, plane, RT or repetition time (msec), ET or echo time (msec), matrix size, section thickness (mm), gap, echo train length, field of view (FOV), inversion time (IT), flip angle and fat suppression. Pulse sequences included are T1, 3D WATer Selective Fluid (3D-WATSf), STIR, Proton Density- High Resolution (PD-HR) and T1 High-Res Isotropic Volume Excitation (THRIVE). Fat suppression techniques detailed are SPectral Attenuated Inversion Recovery (SPAIR), Spectral Presaturation with Inversion Recovery (SPIR) and PRinciple Of Selective Excitation Technique (ProSet).

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Fig. 1: Normal hip, sagittal (a) and coronal (b) images on PD-HR weighted sequences on 3-T conventional MRI and coronal THRIVE wi on 1.5-T MRA show acetabular labrum (red arrow), labral-chondral transitional zone (yellow arrow), acetabular cartilage (green arrow), femoral cartilage (orange arrow) and perilabral recess (blue arrow).
Fig. 2: Labral sulcus as a normal variant in a 22 year-old female with cam FAI. Plain film (a) shows an osseous bump (yellow arrow). Sagittal (b) and coronal (c) images on PD-HR weighted sequences on 3-T conventional MRI show acetabular labrum (orange arrow), hyperintensity in a cleft at the labral-chondral transitional zone (purple arrow), low signal within the cartilage at the labral-chondral transitional zone (blue arrow) and non-distended capsule (green arrow). (d) Arthroscopic image shows a labral sulcus (purple arrow) between the labrum (L) and the normal acetabular cartilage (AC).
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## Results

Of the 43 patients with PFA who underwent hip arthroscopy, 37 tears at the labral-chondral transitional zone and 2 intrasustantia labral tears (flap) were found in 37 hips and 6 hips were normal with respect to the labrum and the labral-chondral transitional zone.

**Diagnostic performance** of hip 3-T conventional MRI and 1.5-T direct MR arthrography using hip arthroscopy as standard of reference was evaluated by the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), accuracy and Cohen's kappa index, calculated with a 95% confidence interval. Statistical indicators of both imaging techniques are presented in Table 2 on page 14 and Table 3 on page 15.

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<td>Specificity</td>
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**Table 2:** Statistical indicators of the comparison between hip 3-T conventional MRI and 1.5T MRA and for diagnosis of labral pathology. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), accuracy of MRA examination (using arthroscopy as the reference standard) and also Cohen’s kappa index were calculated with a 95% confidence interval.

**References:** Department of Radiology, Hospital Universitario Puerta de Hierro Majadahonda, Madrid/ES
Table 3: Statistical indicators of the comparison between hip1.5-T MRA and arthroscopy for diagnosis of cartilage abnormalities. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), accuracy of MRA examination (using 3-T conventional MRI as the reference standard) and also Cohen's kappa index were calculated with a 95% confidence interval.

References: Department of Radiology, Hospital Universitario Puerta de Hierro Majadahonda, Madrid/ES

Acetabular labrum abnormalities

On arthroscopic evaluation, 30 patients were identified as having labral abnormalities: 25 degenerated labrum, 3 hipoplastic labrum and 2 intrasubstantia tears. The retrospective review of imaging examinations yielded a total of 7 discordant cases on 3-T conventional MRI and 12 discordant cases on 1.5-T MR arthrography.

In 4 cases on 3-T conventional MRI and 5 cases on 1.5-T MR arthrography were read as negative for labral abnormality for which the operative report was positive (false negatives). In 3 cases the 3-T conventional MRI and 7 cases on 1.5-T MR arthrography were read as positive, but the arthroscopic operative reports were negative (false positives).

Labral-chondral transitional zone tears

Of the 37 cases with arthroscopically diagnosed tears at the labral-chondral transitional zone, a tear was detected with conventional 3-T MRI in 35 of the 37 cases (94.6%) and with 1.5-T MR arthrography in all the cases. On 1.5-T MR arthrography there was a false positive. The two tears missed on 3-T conventional MRI were adecuated depicted on 1.5-T MR arthrography.

Chondral lesions
For **femoral articular cartilage**, agreement of arthroscopy and MRI, either on 3-T conventional MRI or on 1.5-T MR arthrography about 76.7% of patients due to high percentage of normal findings with all the techniques.

For **labral-chondral transitional zone**, agreement of MRI, either on 3-T conventional MRI or and on 1.5-T MR arthrography, with arthoscopy within the grade was about one half of patients (22 out of 43).

On arthroscopic evaluation, 4 patients were found to be normal cartilage at the labral-chondral transitional zone, 11 patients were identified as having grade 1, 11 patients grade 2, 10 grade 3 and 6 grade 4 chondral lesions. On 3-T conventional MRI, only 3 patients were identified as having grade 3 chondral lesions and 10 patients grade IV.

Collapsing the cartilage grades into arthrosis-negative (grade 0, 1, 2, and 3) and arthrosis-positive (grade 4) states, the statistics in Table 3 on page 15 compare 1.5-T MR arthrography and arthroscopy with the standart of 3-T conventional MRI.

For **acetabular cartilage**, agreement of MRI, either on 3-T conventional MRI or and on 1.5-T MR arthrography, with arthroscopy within the grade was about 58% of patients.

On arthroscopic evaluation, 10 patients were found to be normal cartilage at the acetabullar surface, 5 patients were identified as having grade 1, 7 patients grade 2, 6 grade 3 and 9 grade 4 chondral lesions. On 3-T conventional MRI, 4 patients were identified as having grade 3 chondral lesions and 18 patients grade 4.

Collapsing the cartilage grades into arthrosis-negative (grade 0, 1, 2, and 3) and arthrosis-positive (grade 4) states, the statistics Table 3 on page 15 compare 1.5-T MR arthrography and arthroscopy with the standart of 3-T conventional MRI.

Images for this section:
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</tr>
<tr>
<td>PPV</td>
<td>100 (98,6-100)</td>
<td>97.4 (91-100)</td>
</tr>
<tr>
<td>NPV</td>
<td>78 (38,74-100)</td>
<td>100 (90-100)</td>
</tr>
<tr>
<td>Accuracy</td>
<td>95.3 (87,9-100)</td>
<td>97.7 (92-100)</td>
</tr>
<tr>
<td>Kappa coefficient</td>
<td>0.83 (0,6-1)</td>
<td>0.89 (0,69-1)</td>
</tr>
</tbody>
</table>

Table 3: Statistical indicators of the comparison between hip 1.5-T MRA and arthroscopy for diagnosis of cartilage abnormalities. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), accuracy of MRA examination (using 3-T conventional MRI as the reference standard) and also Cohen’s kappa index were calculated with a 95% confidence interval.

<table>
<thead>
<tr>
<th></th>
<th>Chondral lesions grade 4 at the labral-chondral transitional zone</th>
<th>Chondral lesions grade 4 at the acetabulum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.5T MR arthrography</td>
<td>Hip arthroscopy</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>58.3 (26,3-90,4)</td>
<td>41.7 (9,6-73,7)</td>
</tr>
<tr>
<td>Specificity</td>
<td>90.3 (78,3-100)</td>
<td>96.8 (88,9-100)</td>
</tr>
<tr>
<td>PPV</td>
<td>70 (36,6-100)</td>
<td>83.3 (45,2-100)</td>
</tr>
<tr>
<td>NPV</td>
<td>84,8 (71,1-98,6)</td>
<td>81,1 (67,1-95)</td>
</tr>
<tr>
<td>Accuracy</td>
<td>81,4 (68,6-94,2)</td>
<td>81,4 (68,6-94,2)</td>
</tr>
<tr>
<td>Kappa coefficient</td>
<td>0,51 (0,22-0,8)</td>
<td>0,45 (0,15-0,75)</td>
</tr>
</tbody>
</table>
Conclusion

Imaging of the acetabular labrum in the past has relied on conventional contrast arthrography (13); more recently, direct MRA at 1.5-T has been shown to be a reliable method to define and detect acetabular labral tears, with a sensitivity of approximately 87% (1,14,15) and cartilage lesions in the hip (16).

Mintz et al reported a good diagnostic performance of 1.5-T conventional MRI for depiction of acetabular labral tears (17). In this study of 92 patients who had MRI of the hip followed by arthroscopic surgery of that hip, 84 (95%) of the 88 labral tears present at surgery were correctly identified on MRI.

Sutter et al compared hip conventional MRI and direct MRA with 1.5-T magnets for assessment of both labrum and articular cartilage integrity with surgical correlation in all patients. For labral tears, sensitivity of conventional MRI is 50% while for MRA is 81% respectively and a similar specificity of both imaging techniques (50%). MRA had an advantage over conventional MRI for detecting acetabular cartilage defects (sensitivity of MRA, 92%; sensitivity of conventional MRI, 83%) (18).

Based on some of these studies and others, the authors of a recent meta-analysis reported that the overall diagnostic accuracy achieved by MRA for detecting labral tears appeared to be superior to conventional MRI (1). Sensitivity and specificity of conventional MRI are 66% and 79% while for MRA are 87% and 64% respectively. This meta-analysis also indicates several limitations as a wide range of magnetic fields (0.5-3-T), limited sample sizes and poorly described population characteristics.

A preliminary report comparing 3-T MRI and 1.5-T MRA in the acetabular labrum evaluation provided encouraging support for evaluation with 3-T MRI over 1.5-T MRA (19). To our knowledge, only one retrospective study has compared the diagnostic performance of 3-T conventional MRI and 1.5-T MRA for evaluating the acetabular labrum. In this study of 90 labral tears diagnosed at arthroscopy, Tian et al (20) reported that 3-T MRI sensitivity for the detection of labral tears was 66.1%, specificity was 74.2%, PPV was 82.9% and NPV was 53.4%. Of the 90 patients, 34 had also underwent 1.5-T MRA. The sensitivity, specificity, PPV and NPV of MRA for assessing the acetabular labral tears were 95.2%, 84.6%, 90.9% and 91.7%. Surprisingly, statistical indicators of diagnostic performance of 3-T conventional MRI reported in this article are worse than those of 1.5-T conventional MRI (17).

Our results with 3-T conventional MRI are in keeping with the results of previous studies with a 1.5-T MRA and fairly close in our intraindividual comparison of 3-T conventional MRI and 1.5-T direct MRA for assessment labrum, labral-chondral transitional zone and articular cartilage integrity.
The difficulty in distinguishing labral sulcus (as a normal variant Fig. 2 on page 17) from labral tears may decrease as 3-T conventional MRI adds value for cartilage abnormalities in the labral-chondral transitional zone.

Is intraarticular contrast material necessary at 3-T? Our preliminary results show that fewer labral tears were missed with 3-T conventional MRI and so further investigations are needed because it may not be justified its use in all hips with suspected labral tears.

Also, our preliminary results suggest that conventional 3-T MRI adds value for diagnosing chondral abnormalities in FAI compared with 1.5-T MR arthrography.

**Conclusion of our study is that 3-T conventional MRI can provide routine, less invasive assessment of the hip for FAI.**

*Images for this section:*
Fig. 2: Labral sulcus as a normal variant in a 22 year-old female with cam FAI. Plain film (a) shows an osseous bump (yellow arrow). Sagittal (b) and coronal (c) images on PD-HR weighted sequences on 3-T conventional MRI show acetabular labrum (orange arrow), hyperintensity in a cleft at the labral-chondral transitional zone (purple arrow), low signal within the cartilage at the labral-chondral transitional zone (blue arrow) and non-dstended capsule (green arrow). (d) Arthroscopic image shows a labral sulcus (purple arrow) between the labrum (L) and the normal acetabular cartilage (AC).
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References