Triad of MR Arthrographic Findings in Patients with Cam-Type Femoroacetabular Impingement[1]

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PURPOSE: To retrospectively analyze magnetic resonance (MR) arthrographic findings in patients with clinical cam-type femoroacetabular impingement.

MATERIALS AND METHODS: This study was approved by the institutional review board, and informed consent was waived. Study was compliant with the Health Insurance Portability and Accountability Act. Forty-two MR arthrograms obtained in 40 patients with clinical femoroacetabular impingement were analyzed retrospectively by two radiologists. Quantitative analysis by using α angle measurement was performed to assess anterosuperior femoral head-neck morphology. Presence of labral tears, articular cartilage lesions, paralabral cysts, os acetabuli, and synovial herniation pits was recorded. Presence of the typical triad of anterosuperior labral tear, anterosuperior cartilage lesion, and abnormal α angle was recorded. Surgical comparison was available for 11 patients.

RESULTS: At imaging, in 40 patients (22 male, 18 female) with a mean age of 36.5 years, 39 of 42 hips (93%) had an abnormal α angle, with a mean angle of 69.7°; 40 of 42 (95%) had an anterosuperior cartilage abnormality; and 42 of 42 (100%) had an anterosuperior labral tear. Thirty-seven of 42 hips (88%) had the triad. Six had paralabral cysts, 17 had an os acetabuli, and two had synovial herniation pits. Surgical comparison for 11 hips led to confirmation of all labral and cartilage abnormalities seen at imaging.

CONCLUSION: MR arthrography demonstrated a triad of abnormal head-neck morphology, anterosuperior cartilage abnormality, and anterosuperior labral abnormality in 37 of 42 patients with cam-type femoroacetabular impingement.

Magnetic resonance (MR) arthrography has been shown to be an accurate technique for the diagnosis of acetabular labral tears (1–4). It allows distinction of the acetabular labrum from the adjacent acetabular cartilage and osseous acetabulum. In addition, MR arthrography is capable of depicting cartilage abnormalities in both the acetabulum and the femoral head (5). Recently, there has been much interest in the identification of lesions of the hip joint, such as labral tears, cartilage abnormalities, and femoroacetabular impingement, that may lead to early degenerative change. Although much has been written regarding the imaging of acetabular labral tears and, to a lesser degree, hip cartilage abnormalities, there are few published data regarding detailed MR arthrographic findings in femoroacetabular impingement.

There are two types of such impingement: pincer (femoral head-neck junction contacts the acetabular rim, typically as a result of an underlying acetabular abnormality) and cam (abnormal morphology of the anterior femoral head-neck junction). Thus, the purpose of our study was to retrospectively analyze MR arthrographic findings in patients with clinical cam-type femoroacetabular impingement.

Author contributions:
Guarantors of integrity of entire study, A.K., L.S.Y.; study concepts/study design or data acquisition or data analysis/interpretation, all authors; manuscript drafting or manuscript revision for important intellectual content, all authors; approval of final version of submitted manuscript, all authors; literature research, A.K., L.S.Y., E.B.; clinical studies, all authors; statistical analysis, A.K., L.S.Y; and manuscript editing, all authors

MATERIALS AND METHODS

This study was approved by the institutional review board of Massachusetts General Hospital, which waived the need for informed consent. The study was compliant with the Health Insurance Portability and Accountability Act.

Patients

A computer search was performed by two radiologists (A.K., L.S.Y.) to identify all patients with clinical signs of femoroacetabular impingement who underwent hip MR arthrography at Massachusetts General Hospital from 1999 to 2004. All patients who underwent prior hip surgery and had evidence of Legg-Calve-Perthes disease or osteonecrosis, radiographic evidence of slipped capital femoral epiphysis or hip dysplasia, or imaging evidence of acetabular retroversion were excluded. All available corresponding medical records were reviewed by three authors (A.K., S.A.C., L.S.Y.) for clinical and surgical findings. On the basis of this review, 40 patients with a clinical diagnosis of femoroacetabular impingement who underwent MR arthrography were identified and formed the study population. Two patients underwent bilateral examinations, bringing the total number of MR arthrographic examinations to 42.

MR Arthrography

Arthrography was performed by one of five subspecialized musculoskeletal radiologists with 2–13 years of experience in arthrography (A.K., W.E.P.), as of 1999. An anterior approach was used in all patients. Patients were placed in the supine position on the fluoroscopy table, with the symptomatic side in slight internal rotation. The junction of the superior lateral femoral head and neck was localized by using fluoroscopic guidance. With fluoroscopic guidance, sterile technique, and local lidocaine anesthesia, a 22-gauge spinal needle was inserted percutaneously into the hip joint. Approximately 10 mL of contrast material solution was then injected. The solution was made by mixing 50 mL of normal saline with 0.4 mL of gadopentetate dimeglumine (Magnevist; Berlex, Montville, NJ). Ten milliliters of this solution was then mixed with 5 mL of 61% iopamidol (Isovue-M 300; Bracco Diagnostics, Princeton, NJ) and 5 mL of 1% lidocaine.

All MR imaging studies were performed with a 1.5-T unit (Twin Speed; GE Medical Systems, Milwaukee, Minn) by using either a torso coil or a cardiac coil for image acquisition within 30 minutes of arthrography. MR imaging was performed with the patient supine and the symptomatic leg in slight internal rotation to bring the femoral neck into the coronal plane. Fat-saturated spin-echo T1-weighted MR images (repetition time msec/echo time msec, 400–700/8–12; field of view, 16 cm; matrix, 256–320 × 192–256; section thickness, 3–4 mm; number of signals acquired, two) of the hip were obtained in the coronal and sagittal oblique planes (parallel to the femoral neck). Non–fat-saturated T1-weighted MR images with the same parameters were obtained in the coronal and sagittal planes. A fast spin-echo T2-weighted sequence (4500/100; field of view, 16; matrix, 256–320 × 192–256; section thickness, 3–4 mm; number of signals acquired, two; echo train length, eight to 10) was performed in the transverse plane. Although a radial fat-suppressed T1-weighted sequence was performed in some patients, this sequence was not evaluated for the purpose of the present study.

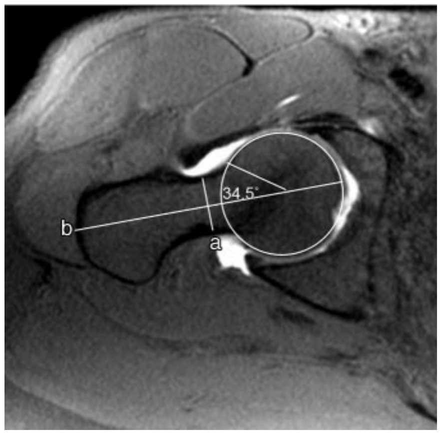


Figure 1. Oblique sagittal fat-saturated T1-weighted MR arthrographic image (450/8) shows method of measuring the α angle in a normal hip. A line *(a)* is drawn perpendicular to the femoral neck at its narrowest point. A second line *(b)* is then drawn perpendicular to this point, bisecting the femoral neck. A best-fit circle is drawn, outlining the femoral head. The α angle is calculated as the angle formed between line *b* and the point where the femoral head protrudes anterior to the circle. An angle of 55° or more is considered abnormal.

Image Interpretation

Imaging data collection included tears of the acetabular labrum, presence of paralabral cysts, abnormalities of the acetabular cartilage, presence of os acetabuli, and the morphology of the anterior femoral head-neck junction, including presence or absence of a femoral synovial herniation pit. All cases were reviewed independently on a clinical workstation by two subspecialized musculoskeletal radiologists (A.K., W.E.P.) with 2 and 13 years of experience, respectively. Disagreements were resolved by means of consensus in five cases. The radiologists were blinded to surgical findings.

The diagnosis of acetabular labral tear at MR arthrography was established when contrast material could be seen traversing the labrum. No distinction was made between displaced and nondisplaced labral tears. If torn, the location of the tear was recorded. The presence of paralabral cysts, defined as a paralabral fluid collection, which was hyperintense on either T1- or T2-weighted MR images, was recorded.

The diagnosis of acetabular cartilage abnormality at MR arthrography was established when contrast material was seen entering the substance of or undercutting the cartilage in any plane. This designation was made when the abnormality could be seen on any T1-weighted MR image, regardless of plane or presence of fat saturation. If abnormal, the location of the cartilage abnormality was noted.

Femoral head-neck morphology was assessed by using a previously described quantitative analysis of head-neck step-off (6). Briefly, the anterior α angle was measured on the sagittal oblique section parallel to the femoral neck and passing through the narrowest portion of the femoral neck by using tools available on the clinical workstation (Fig 1). All angles were measured after the selected image had been magnified by ×5 to assure accurate measurement. An angle of 55° or more was considered abnormal (6). Angles between 54.5° and 55° were rounded up to 55°.

The presence or absence of the triad of an abnormal α angle, anterosuperior cartilage abnormality, and anterosuperior labral tear was recorded.

Clinical Data Collection

Clinical data collection was performed by five authors (A.K., L.S.Y., E.B., S.A.C., M.B.M.) and included patient age and sex, laterality of the examination, presence of clinical signs of internal impingement, surgical findings, and type of surgical procedure, as available, for 11 patients. Clinical evidence of femoroacetabular impingement was characterized by pain and decreased range of motion with flexion, adduction, and internal rotation.

RESULTS

Of the 40 patients with clinical signs of femoroacetabular impingement who underwent MR arthrography, 22 were male, and 18 were female. Ages ranged from 17 to 67 years, with a mean age of 36.5 years. Imaging and surgical findings for the 40 patients are listed in the Table.

Site

The right hip alone was involved in 23 patients, the left hip alone in 15 patients, and both hips in two patients. Per the inclusion criteria, all patients had clinical evidence of hip impingement, as characterized by pain and decreased range of motion with flexion, adduction, and internal rotation.

Imaging Findings

Thirty-nine of 42 hips (93%) had an abnormal α angle, with a mean angle of 69.7° (range, 40.8°–91.3°) (Fig 2a). Forty of 42 hips (95%) had a cartilage abnormality that involved the anterosuperior acetabular cartilage (Fig 2b). One other patient had an anterosuperior cartilage defect at surgery that was not visible at imaging. All 42 hips had an anterosuperior labral tear (Fig 2c). Thirty-seven of 42 hips (88%) had the triad of an abnormal α angle, an anterosuperior cartilage lesion, and a labral tear at imaging. The two patients who underwent bilateral examinations had the abnormal triad bilaterally.

Six hips had paralabral cysts, all of which had the triad of abnormalities. Only two hips had synovial herniation pits, both of which had the triad of abnormalities with α angles of 74.2° and 86.2°. Seventeen hips had os acetabuli, 16 of which had the triad of abnormalities.

Surgery

Eleven patients underwent hip surgery, one of which was arthroscopic. The mean time interval between MR imaging and surgery was 6.9 months (range, 2–14 months). All labral and cartilage lesions seen at imaging were confirmed and treated with débridement of labral tears and chondral flaps, as appropriate. Four patients also underwent femoral neck osteoplasty.

DISCUSSION

Femoroacetabular impingement has been identified as a cause for early-onset degenerative change in an otherwise normal hip. Two types of femoroacetabular impingement have been described. In the older population, particularly older women, impingement is more commonly due to a pincer mechanism, whereby the femoral head-neck junction contacts the acetabular rim, typically as a result of an underlying acetabular abnormality such as coxa profunda or acetabular retroversion (7). This type of impingement initially results in a labral tear or degeneration, with subsequent leveraging of the femoral head in the acetabulum resulting in chondral injury to the posteroinferior acetabulum. In pincer-type impingement, the femoral head-neck morphology is initially normal. The traditional treatment for these patients is reduction of anterior coverage by means of an anteverting periacetabular osteotomy or excision of the osseous prominence at the acetabular rim (8,9). If the patient has developed an extraarticular osseous prominence along the anterior femoral neck, an excision osteoplasty may also be performed.

The second type of impingement, which is the focus of this study, is referred to as cam impingement. Cam impingement is more common in younger males. Cam impingement results from an abnormal morphology of the anterior femoral head-neck junction. As a result of a decreased offset at this junction, there is premature contact between the femur and the acetabular rim with flexion adduction and internal rotation. This initially results in abrasion and avulsion of the anterosuperior acetabular cartilage from the labrum and subchondral bone. This subsequently leads to tear or detachment of the anterosuperior acetabular labrum (7). Since the femoral head-neck junction is the cause of impingement in the cam type, contouring of the femoral head and neck by means of excision osteoplasty of the femoral neck is performed as surgical treatment (8,9).

At imaging, the abnormal morphology of the anterior femoral head neck junction is best evaluated with MR arthrography in the oblique sagittal plane, running parallel to the femoral neck. Although there are at least four published methods of quantitatively evaluating the anterior femoral head-neck morphology, the current study involved the measurement of the α angle (6,10,11). The α angle measurement method was used because the authors felt it was the simplest method to perform, given the tools available on the clinical workstation. At MR arthrography, the femoral head and neck morphology is demonstrated clearly. The advantage of MR arthrography over nonarthrographic MR imaging is that the intraarticular contrast material distends the joint, separates intraarticular structures, and provides internal contrast to delineate the labrum and cartilage as distinct entities. Although the head-neck morphology could be measured without intraarticular contrast, the associated cartilage and labral abnormalities would be more difficult to see.

Although there is a range of α angles in asymptomatic patients and those with clinical and surgical evidence of femoroacetabular impingement, angles greater that 55° have been shown to be closely associated with impingement. In one study, none of the asymptomatic controls had an α angle greater than 48° (with a mean angle of 42°), while all patients with impingement had angles greater than 55°, with a mean angle of 74° (6). The difference between the two groups was statistically significant ($P < .001$). Our study also demonstrates an increased α angle in patients with cam impingement. Patients with impingement had a mean α angle of 69.7°, and 39 of 42 hips had an abnormal α angle. In addition, MR arthrography demonstrated labral abnormalities in all hips and anterosuperior cartilage abnormalities in 40 of 42 hips. Overall, 37 of 42 hips had what appears to be a typical MR arthrographic triad of an abnormal femoral head-neck junction, anterosuperior cartilage lesion, and anterosuperior labral tear.

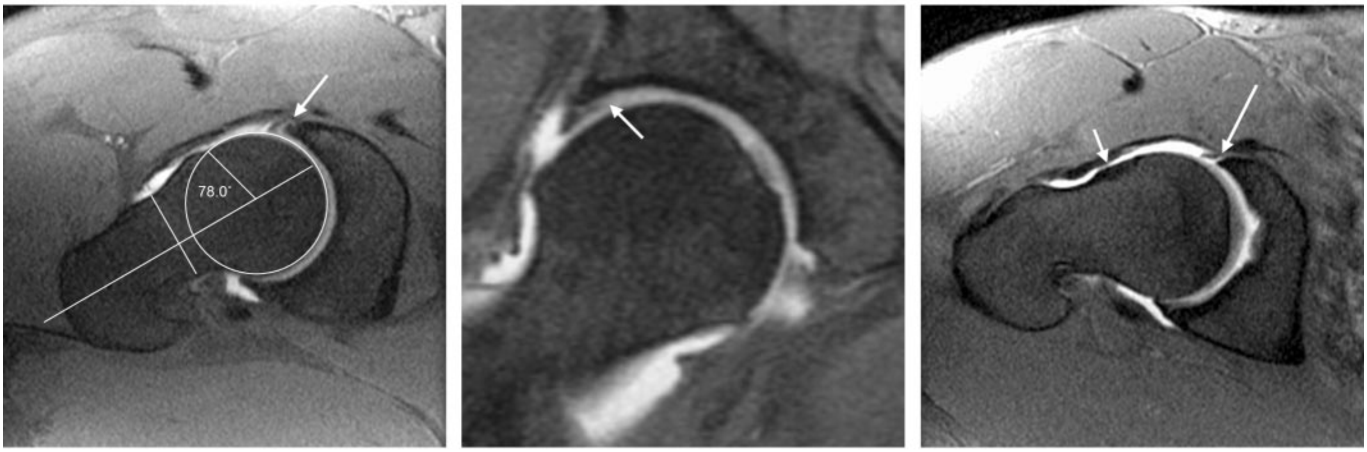
The identification of the abnormal head-neck junction is critical in treating patients with cam-type impingement. If only the labral and cartilage abnormalities are identified and treated, the underlying cause of impingement will remain present, likely resulting in persistent pain, further cartilage and labral damage, and, potentially, further acceleration of degenerative change (12,13). Cam-type impingement is treated with femoral neck osteoplasty with removal of the nonspherical portion of the head, thereby improving the head-neck offset and creating clearance for flexion and internal rotation (7).

The cause for the abnormal morphology of the anterior femoral head neck junction is not entirely clear. Some believe that this is a developmental abnormality, with the most likely cause being a

Clinical and Imaging Findings in 40 Patients (42 Hips) with Clinical Evidence of Femoroacetabular Impingement

Patient Age (y)	α Angle (degrees)	Labral Tear	Cartilage Abnormality	Triad	Paralabral Cyst	Synovial Herniation Pit	Os Acetabuli	Surgical Findings
47.7	55.8	Yes	Yes	Yes	No	No	No	Anterosuperior labral tear and cartilage loss
28.8	69.5	Yes	Yes	Yes	No	No	Yes	
34.4	79.3	Yes	Yes	Yes	No	No	No	
22	69.7	Yes	No	No	No	No	No	
44	67.3	Yes	Yes	Yes	No	No	No	
31	58.1	Yes	Yes	Yes	No	No	No	
19	54.5	Yes	Yes	Yes	No	No	No	
22	74.2	Yes	Yes	Yes	No	Yes	No	
34.1	75.9	Yes	Yes	Yes	No	No	Yes	
31.6	84.4	Yes	Yes	Yes	No	No	Yes	
25	78.8	Yes	Yes	Yes	Yes	No	No	Anterosuperior labral tear and cartilage loss, subsequent femoral neck osteoplasty
42.5	67.7	Yes	Yes	Yes	No	No	Yes	Anterosuperior labral tear and cartilage loss
20.4	79.4	Yes	Yes	Yes	Yes	No	No	Anterosuperior labral tear and cartilage loss, subsequent femoral neck osteoplasty
29.1	86.7	Yes	Yes	Yes	No	No	No	
55.3	87.1	Yes	Yes	Yes	Yes	No	Yes	
35	83.6	Yes	Yes	Yes	No	No	Yes	
28.6	70.1	Yes	Yes	Yes	No	No	Yes	Anterosuperior labral tear and cartilage loss
40.4	60.4	Yes	Yes	Yes	No	No	No	
47.1	79	Yes	Yes	Yes	No	No	Yes	
43.4	73.7	Yes	Yes	Yes	No	No	No	Anterosuperior labral tear and cartilage loss, subsequent femoral neck osteoplasty
41.1	68.2	Yes	Yes	Yes	No	No	Yes	
28.3	41.7	Yes	Yes	No	No	No	No	
39.4	62	Yes	Yes	Yes	No	No	No	
50.9	55.5	Yes	Yes	Yes	No	No	Yes	
38.6	67.8	Yes	Yes	Yes	No	No	No	
26.4	46.1	Yes	Yes	No	No	No	No	
57.8	73.8	Yes	Yes	Yes	No	No	Yes	
51.9	70.3	Yes	Yes	Yes	No	No	No	
66.9	72.2	Yes	Yes	Yes	No	No	Yes	
35.8	91.3	Yes	Yes	Yes	No	No	Yes	
43.1	54.7	Yes	Yes	Yes	No	No	No	
54.5	71.9	Yes	Yes	Yes	Yes	No	No	
19.2	56.3	Yes	Yes	Yes	No	No	Yes	Anterosuperior labral tear and cartilage loss, subsequent femoral neck osteoplasty
32.1	85.9	Yes	Yes	Yes	Yes	No	No	
31.2	81.4	Yes	Yes	Yes	Yes	No	Yes	
57	63.5	Yes	Yes	Yes	No	No	No	
19.2	69.8	Yes	Yes	Yes	No	No	Yes	Anterosuperior labral tear and cartilage loss
40.4	86.2	Yes	Yes	Yes	No	Yes	No	
25.6	64.9	Yes	Yes	Yes	No	No	No	Anterosuperior labral tear and cartilage loss
36.3	46.1	Yes	Yes	No	No	No	Yes	Anterosuperior labral tear and cartilage loss, subsequent periacetabular osteotomy
16.8	70.8	Yes	No	No	No	No	No	Anterosuperior labral tear and cartilage loss
38.2	69.9	Yes	Yes	Yes	No	No	No	

subclinical slipped capital femoral epiphysis with subsequent decrease in the anterior head-neck step-off (7). This theory is supported by the fact that patients with femoroacetabular impingement and those with known slipped capital femoral epiphysis both have similar morphology to the anterior head-neck junction and, depending on the stage of manifestation, have similar chondral and labral injuries. Also, a similar situation may occur in patients who have had a prior femoral neck



a. b. c.

Figure 2. **(a)** Oblique sagittal fat-saturated T1-weighted MR arthrographic image (550/10) shows abnormal contour of the femoral head-neck junction in a 31-year-old man with femoroacetabular impingement. The α angle measured 78°. There is an anterosuperior labral tear (arrow). **(b)** Sagittal T1-weighted MR arthrographic image (520/10) shows anterosuperior cartilage fissure with a delaminating component (arrow) in a different patient. **(c)** Oblique sagittal fat-saturated T1-weighted MR arthrographic image (600/8) shows abnormal anterior femoral head-neck offset (short arrow) and anterosuperior labral tear (long arrow) in yet a third patient.

fracture with subsequent retrotilt of the femoral head. Another theory is that a growth disturbance may result in delayed separation or eccentric closure of the common physis between the femoral head and the greater trochanter into two distinct physes. This growth disturbance and distortion of the physis results in abnormal extension of the femoral head epiphysis and decreased head-neck offset (11).

Our study has some limitations. Since this was a retrospective study, many patients with femoroacetabular impingement were likely not included in data analysis. This is unavoidable, however, since the patients were selected on the basis of the presence of clinical signs of impingement. Although the α angle was used in quantifying the abnormal head-neck junction, other methods of assessing the head-neck junction have been described previously. All seem to be acceptable quantitative methods. In our study, we used α-angle measurement because it was the most feasible method with regard to the use of existing tools on the clinical workstation. This is important, because it will facilitate quantitative measurement of angles in a clinical setting. Other methods could be used, depending on the tools available on various clinical workstations.

Another limitation is that we did not measure α angles in a control group, although a previous study (6) demonstrated a significant difference between patients with cam impingement and controls. Finally, surgical correlation was available in only 11 patients.

In conclusion, we analyzed MR arthrographic findings in a subset of patients with clinical and surgical evidence of cam-type femoroacetabular impingement. Patients with cam impingement of the hip have an MR arthrographic triad of an abnormal head-neck morphology, anterosuperior cartilage abnormality, and anterosuperior labral tear. Identification of the abnormal head-neck morphology is crucial in assuring appropriate treatment of hip pain in this subset of patients.

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