Future Strategies for the Assessment of Cartilage and Labral Lesions in Femoroacetabular Impingement

6

Ara Kassarjian, Luis Cerezal, and Eva Llopis

Over the past few years, interest in the concept of femoroacetabular impingement (FAI) has grown tremendously. As the orthopedic community has begun to show intense interest in the apparent relationship between FAI and early onset of degenerative change, there has been a concomitant increase in the desire for high-quality imaging of the hip. Although traditional imaging modalities have, to date, been sufficient for imaging the extra-articular structures and the osseous structures, imaging of intra-articular structures, specifically the cartilage and labrum, remains challenging.

There is mounting evidence that labral lesions and cartilage lesions are intimately related to degenerative change and that treatment of such lesions at earlier stages may result in better outcomes [1]. With the more widespread use of hip arthroscopy and continual advances in treatment of cartilage and labral lesions, there is ever increasing pressure on radiologists to provide high-resolution accurate imaging of subtle cartilage and labral lesions, lesions that were essentially imperceptible with prior imaging techniques. Specifically, the current challenge is to accurately image damage of morphologically normal cartilage, subtle cartilage flaps, thin partial-thickness cartilage surface lesions, and subtle non-displaced labral tears. Preoperative knowledge of the presence and severity of such lesions is important in treatment planning and patient counseling [2]. This chapter will discuss some emerging techniques and strategies for imaging of subtle yet potentially important lesions of the hip cartilage and acetabular labrum.

General Principles

Imaging of the acetabular and femoral cartilage and the acetabular labrum presents significant challenges. To begin with, the hip is a deeply seated joint resulting in some imaging artifacts or attenuation of signal from the intra-articular structures. Also, since the hip is a relatively stable and tight joint, there is typically little separation between the intra-articular structures.

The most widely used techniques for imaging the intra-articular structures of the hip are MR, MR arthrography, and CT arthrography. Aside from demonstrating mineralized intra-articular loose bodies, non-arthrographic CT has a very limited role in assessing the intra-articular structures of the hip.

As in most other joints, conventional hip MR provides excellent overall soft tissue contrast. In addition, MR can demonstrate osseous abnormalities such as marrow edema. However, since the hip is covered by large muscle groups and, in some patients, a significant amount of subcutaneous fat, MR coils cannot be placed in very close proximity to the joint. In addition, since there are currently no dedicated hip coils on the

A. Kassarjian (✉)
Department of Radiology, Division of Musculoskeletal Radiology, Massachusetts General Hospital, Boston, MA, USA

Corades, S.L, Madrid, Spain
e-mail: akassarjian@gmail.com

L. Cerezal
Department of Radiology, Clínica Mompía, Instituto Radiológico Cántabro, Cantabria, Spain
e-mail: lcerezal@gmail.com

E. Llopis
Department of Radiology, Hospital de la Ribera, Valencia, Spain

Ó. Marín-Peña (ed.), *Femoroacetabular Impingement*,
DOI 10.1007/978-3-642-22769-1_6, © Springer-Verlag Berlin Heidelberg 2012

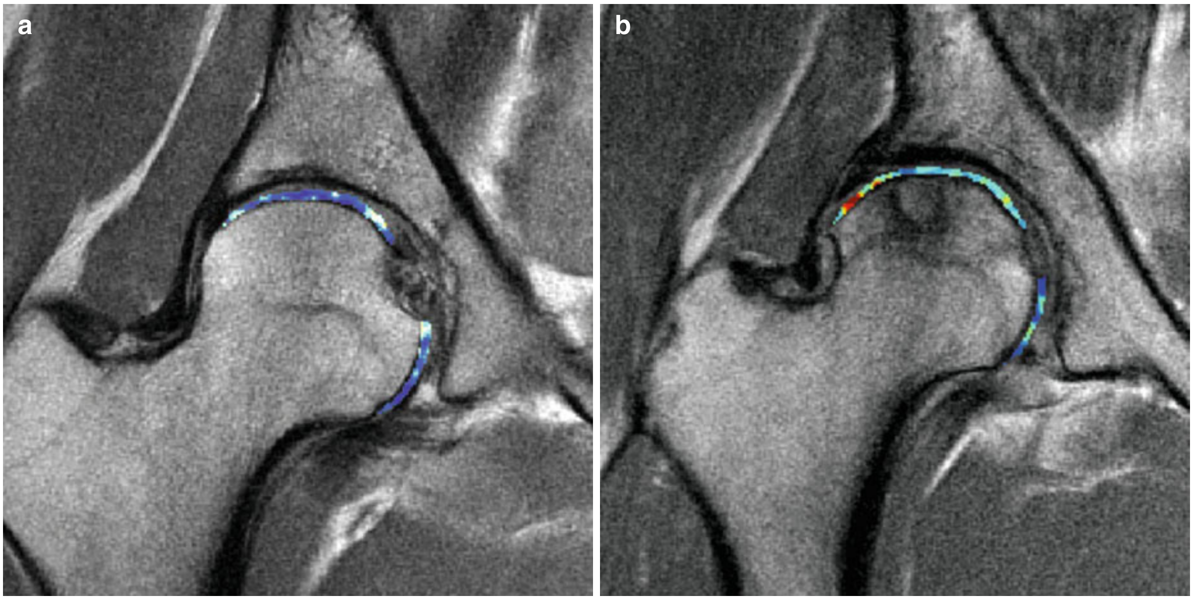

Fig. 6.1 (**a**) T2 map demonstrates normal cartilage T2 values in the hip. (**b**) T2 map shows degeneration of hip cartilage (Images courtesy of Atsuya Watanabe M.D., Ph.D.)

market, imaging is typically done with some level of improvisation such as using a combination of flex coils, torso coils, or even cardiac coils. Even with adequate signal to noise and reasonable spatial resolution, it is challenging to accurately image the very thin cartilage of the acetabulum and femur and the small acetabular labrum not only due to their small dimensions but also due to the fact that they are very closely opposed to one another. For this reason, although conventional MR can be used to assess the hip cartilage and labrum, its accuracy in assessing intra-articular structures is generally inferior to that of MR arthrography [3]. Two possible exceptions that will subsequently be discussed are the techniques of MR T2 mapping and delayed gadolinium-enhanced MR imaging of cartilage (dGEMRIC).

At MR arthrography or CT arthrography, introduction of contrast into the hip joint results in joint distention and some separation of the intra-articular structures. This aids in assessing the surfaces of these structures. If there is a defect along the articular surface of these structures (e.g., labral tear, cartilage defect), the contrast can flow into the defect and thus make it more conspicuous at imaging. For this reason, when assessing intra-articular lesions of the hip, it is common to choose MR arthrography or CT arthrography over conventional non-arthrographic MR imaging [4].

Cartilage

Non-arthrographic Imaging

To date, conventional (non-arthrographic) MR imaging has poor sensitivity and poor to moderate accuracy in assessing hip cartilage [3]. Although higher field strength (e.g., 3T) appears to improve accuracy, published figures are still suboptimal [5].

T2 mapping of hip cartilage has been receiving increasing attention recently. One of the reasons is that advances in MR hardware and software have made it possible to apply this technique to the hip despite the absence of dedicated hip coils. The lack of such a coil is partially overcome by increasing field strengths. With T2 mapping, one can indirectly assess cartilage macromolecular orientation and organization and cartilage water content [6]. The main theoretical advantage of T2 mapping is that it can detect structural abnormalities in grossly morphologically normal cartilage and can do so in a noninva sive manner (Fig. 6.1). This may be a significant prognostic indicator as cartilage treatment procedures evolve. One of the major drawbacks to T2 mapping is that there is no consistent widely agreed-upon definition of what constitutes a “normal” T2 map of acetabular and femoral cartilage. Preliminary studies have demonstrated that there are definite zonal variations in the hip [7]. Studies demonstrating potential normal variations associated with level of activity, intensity or timing of exercise, and surrounding osseous morphology are lacking. With further study and establishment of normal values and patterns of distribution of the T2 characteristics of hip cartilage, T2 mapping has the potential to become a powerful tool for evaluating the structural integrity of morphologically normal cartilage. However, the actual application and clinical utility of such a technique, as well as its potential effect on decision-making and outcomes, is unknown.

dGEMRIC has been widely cited in the evaluation of knee cartilage. Although this is not a new technique, its application in the evaluation of hip cartilage is relatively recent [8, 9]. Briefly, dGEMRIC uses the properties of intravenously injected gadolinium to indirectly assess the biochemical composition of cartilage [10]. Regions of degenerated cartilage theoretically have lower glycosaminoglycan (GAG) concentrations. Due to the negative charge of gadolinium (Gd-DTPA), and the negative charge of GAGs, more gadolinium will theoretically bind to the degenerated (and thus GAG-deficient) regions of cartilage. Using this technique, 1–2 h following the intravenous administration of gadolinium, a conventional MR is performed, and the biochemical nature of cartilage can be inferred based on the amount of T1 shortening of the cartilage. The main advantage of dGEMRIC is that it may demonstrate abnormal biochemical properties of grossly morphologically normal cartilage. However, dGEMRIC does have some disadvantages. First of all, one must wait a significant amount of time between injection and imaging. This can prove to be impractical in a busy clinical setting. Also, reproducibility of the technique may not be as high as widely believed. A recent study looking at dGEMRIC of knee cartilage demonstrated 10–15% test-retest variability [11].

Although diffusion-weighted imaging and tractography have been applied to cartilage imaging (mainly in the knee), their feasibility and utility in hip cartilage imaging are currently not known.

Both T2 mapping and dGEMRIC have the theoretical advantage of detecting cartilage structural and biochemical abnormalities before they are visible at standard imaging or at arthroscopy. Since it appears that outcomes of treatment of FAI may be related to the degree of cartilage damage at the time of surgery, the potential of detecting subtle structural and biochemical lesions may eventually be of use in determining whether surgery would be expected to have good outcomes and, if so, which type of surgery would be best. Perhaps the degree of structural or biomechanical cartilage damage at presentation will determine the best treatment: osteochondroplasty vs. resurfacing vs. hemi- or total arthroplasty vs. other yet to be determined procedures. Currently, these decisions are often based on the degree of *visible* cartilage damage.

Arthrographic Imaging

Until the true accuracy and utility of non-arthrographic techniques such as T2 mapping and dGEMRIC become evident, currently available and widespread techniques continue to be improved.

For MR arthrography, ever-improving MR hardware and software including the design of better coils and more robust gradients has increased the spatial and contrast resolution that can be achieved within a reasonable scan time. For example, the recent description of very subtle cartilage signal abnormalities at 3T which indicate underlying delaminating cartilage lesions (although the actual lesion is not visible) is an example of better use and understanding of currently available tools [12]. In addition, a recent study has demonstrated that placing traction on the leg at the time of MR imaging can help separate the femoral and acetabular cartilage surfaces and thus enable visualization of subtle surface lesions [13] (Fig. 6.2). Knowledge of the presence of these subtle cartilage lesions is having increasing influence on the timing and type of FAI surgery. Recently, the experimental use of direct MR arthrography and subsequent intra-articular gadolinium-enhanced MR imaging of cartilage (iGEMRIC) of the hip has been described [14]. This has the potential to provide the best of both worlds as the arthrographic component provides morphologic data while the delayed imaging provides biochemical data.

For CT arthrography, advances in gantry design, tube design, and detector configurations have led to exquisite imaging of femoral and acetabular cartilage. The isotropic data sets that are obtained with multi-detector scanners can then be reformatted retrospectively in any desired plane yielding detailed imaging of the areas of interest (Fig. 6.3). Although scientific evidence is sparse, it appears that CT arthrography with modern equipment

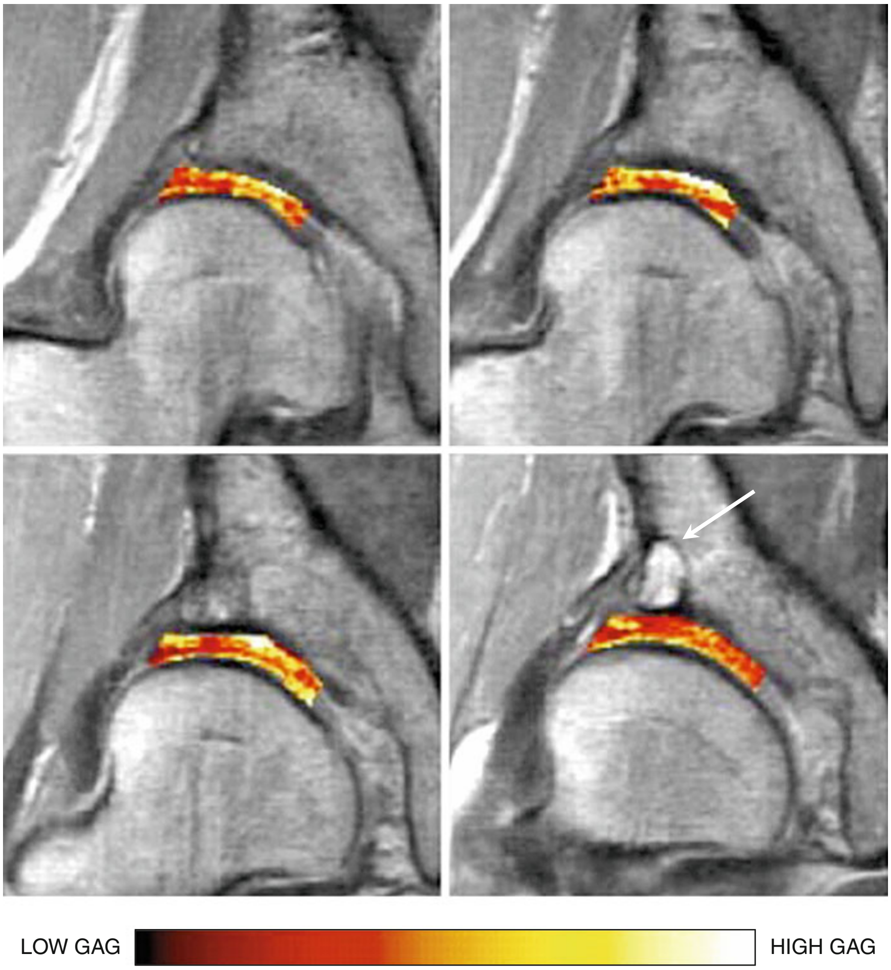

Fig. 6.2 Multiple images from dGEMRIC study of hip show low GAG content (*red areas*) most prominent adjacent to acetabular subchondral cyst (*arrow*) (Reprinted with permission from Cunningham et al. [8])

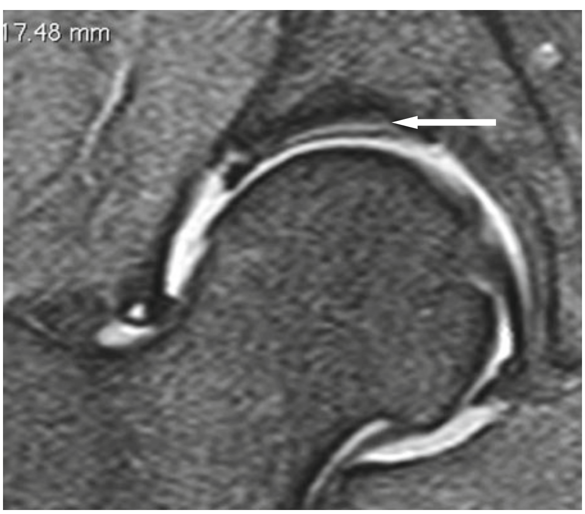

Fig. 6.3 Hip MR arthrography with traction demonstrates a delaminating lesion (*arrow*) of the acetabular cartilage

is equal to, if not superior to, MR arthrography in the detection of hip cartilage lesions [15]. Also, as with MR arthrography, addition of leg traction may prove beneficial in allowing better visualization of the cartilage surfaces. However, CT arthrography provides little information regarding cartilage signal and composition, and detection of delaminating lesions remains difficult (Fig. 6.4). Finally, since many patients with cam-type FAI are young, one must always take into account the gonadal radiation dose from high-resolution hip CT imaging.

As the indications and prognostic factors of FAI surgery evolve, the role of the acetabular cartilage at the time of surgery appears to be a focal point. As a result, investigations and applications of new and improved hip cartilage imaging techniques (both macroscopic and structural/biomechanical) should be a focus of future research.

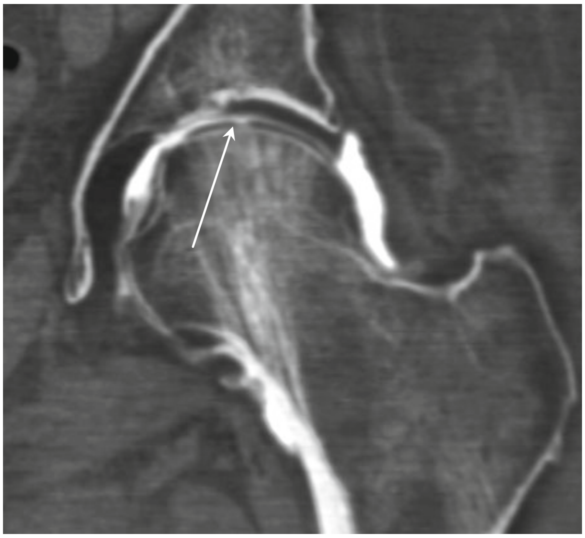

Fig. 6.4 Hip CT arthrography shows a subtle cartilage lesion (*arrow*)

Labrum

As with imaging of hip cartilage, most studies demonstrate the superiority of MR and CT arthrography over non-arthrographic studies. In comparing CT arthrography with MR arthrography, results seem to be similar in recent studies [4]. Although CT has the advantage of slightly higher spatial resolution, MR typically provides higher contrast resolution. MR has the advantage of demonstrating other factors such as bone marrow edema and cartilage signal abnormalities that would not be appreciated on CT arthrography. Finally, the superior soft tissue contrast of MR provides the additional advantage of allowing accurate evaluation of extra-articular causes of hip pain.

In 1996, there were two publications concerning the classification of acetabular labral tears which have since served as the most widely used classification systems [16, 17]. Czerny et al. proposed a classification system based on labral morphological abnormalities as seen at MR arthrography. This classification system has similarities to the meniscal tear classification system with the added component of including the presence or absence of enlargement/loss of triangular configuration and presence/absence of a paralabral recess of the labrum. In the same year, Lage et al. published an arthroscopic classification of acetabular labral tears based on the morphology and location of the tear. These included radial flap tears, radial fibrillated tears, longitudinal peripheral tears, and unstable tears. Clearly, these two classification systems use different criteria and different aspects of tear morphology to classify the tears. Also, the concept of an unstable tear is difficult to apply directly to imaging. Ideally, the classification system used at imaging should be similar to that used at arthroscopy. With this in mind, Blankenbaker et al. compared the Czerny classification system as well as a modified MR arthrographic version of the Lage classification system to arthroscopic Lage classification in 65 patients with arthroscopically proven labral tears [18]. They found that the Czerny classification did not have significant correlations with the arthroscopic Lage classification. In addition, they found only borderline correlation between the modified MR arthrographic Lage classification and the arthroscopic Lage classification. However, MR arthrography and arthroscopy had good agreement regarding the location of the tear (based on a clockface).

As has been done for the shoulder, a consensus classification system needs to be developed to better correlate the findings at MR arthrography (or CT arthrography) and arthroscopy. Most radiologists and orthopedists would agree that the location and extent of a labral tear based on a clockface numbering system are fundamental components of such a classification system. However, agreement must be reached as to which arthrographic and arthroscopic classification system should be used. Having a consistent reproducible classification system will be important as treatment of labral tears continues to evolve with increasing use of labral repair and reattachment procedures.

As both arthroscopic and MR arthrographic experience of labral lesions increases, there is increasing interest in potential normal variants in labral morphology. Although the concept of a normal recess along the posteroinferior labrum is widely accepted, there remains controversy regarding a possible normal recess along the anterosuperior labrum [19]. This is an important region to study as approximately 90% of labral tears involve this region. In addition, there are variants in the shape of the labrum (rounded, hypoplastic, etc.) that have yet to be adequately studied in a scientific manner. As was done with the glenoid labrum, further study is needed into the normal variants that may be encountered in the acetabular labrum and assessment as to whether some of these normal variants are associated with an increased risk of labral tears.

In conclusion, although there have been significant advances in imaging of hip cartilage and labrum, there is much room for improvement. Structural and biomechanical imaging of cartilage as well as better imaging of cartilage flaps and subtle cartilage surface lesions may a have significant impact on the preoperative evaluation and intraoperative treatment of cartilage lesions. Although imaging of the acetabular labrum has become quite accurate, the focus should now shift to better correlation between the findings at imaging and arthrography. A classification system that encompasses and incorporates imaging findings, arthroscopic findings, and potential treatments should be devised. In addition, better understanding of normal variants of the acetabular labrum is needed.

References

1. Beck M, Kalhor M, Leunig M, Ganz R (2005) Hip morphology influences the pattern of damage to the acetabular cartilage: femoroacetabular impingement as a cause of early osteoarthritis of the hip. J Bone Joint Surg Br 87: 1012–1018
2. Peters CL, Erickson JA (2006) Treatment of femoro-acetabular impingement with surgical dislocation and débridement in young adults. J Bone Joint Surg Am 88:1735–1741
3. Schmid MR, Nötzli HP, Zanetti M, Wyss TF, Hodler J (2003) Cartilage lesions in the hip: diagnostic effectiveness of MR arthrography. Radiology 226(2):382–386
4. Wyler A, Bousson V, Bergot C, Polivka M, Leveque E, Vicaut E, Laredo JD (2009) Comparison of MR-arthrography and CT-arthrography in hyaline cartilage-thickness measurement in radiographically normal cadaver hips with anatomy as gold standard. Osteoarthritis Cartilage 17(1):19–25, Epub Jul 9, 2008
5. Ramnath RR (2006) 3T MR imaging of the musculoskeletal system (part II): clinical applications. Magn Reson Imaging Clin N Am 14(1):41–62
6. Dardzinski BJ, Mosher TJ, Li S, Van Slyke MA, Smith MB (1997) Spatial variation of T2 in human articular cartilage. Radiology 205:546–550
7. Watanabe A, Boesch C, Siebenrock K, Obata T, Anderson SE (2007) T2 mapping of hip articular cartilage in healthy volunteers at 3T: a study of topographic variation. J Magn Reson Imaging 26(1):165–171
8. Cunningham T, Jessel R, Zurakowski D, Millis MB, Kim YJ (2006) Delayed gadolinium-enhanced magnetic resonance imaging of cartilage to predict early failure of Bernese periacetabular osteotomy for hip dysplasia. J Bone Joint Surg Am 88(7):1540–1548
9. Kim YJ, Jaramillo D, Millis MB, Gray ML, Burstein D (2003) Assessment of early osteoarthritis in hip dysplasia with delayed gadolinium-enhanced magnetic resonance imaging of cartilage. J Bone Joint Surg Am 85-A(10):1987–1992
10. Bashir A, Gray ML, Boutin RD, Burstein D (1997) Glycosaminoglycan in articular cartilage: in vivo assessment with delayed Gd(DTPA)(2-)-enhanced MR imaging. Radiology 205(2):551–558
11. Ssakainen J, Multanen J, Rauvala E, Lammentausta E, Ojala R, Kiviranta I, Hakkinen A, Heinonen (2008) Scandinavian Physiological Society's Annual Meeting. Acta Physiologica 193(Suppl 664):p34
12. Pfirrmann CW, Duc SR, Zanetti M, Dora C, Hodler J (2008) MR arthrography of acetabular cartilage delamination in femoroacetabular cam impingement. Radiology 249(1):236–241, Epub Aug 5, 2008
13. Llopis E, Cerezal L, Kassarjian A, Higueras V, Fernandez E (2008) Direct MR arthrography of the hip with leg traction: feasibility for assessing articular cartilage. AJR Am J Roentgenol 190(4):1124–1128
14. Boesen M, Jensen KE, Qvistgaard E, Danneskiold-Samsøe B, Thomsen C, Ostergaard M, Bliddal H (2006) Delayed gadolinium-enhanced magnetic resonance imaging (dGEMRIC) of hip joint cartilage: better cartilage delineation after intra-articular than intravenous gadolinium injection. Acta Radiol 47(4):391–396
15. Nishii T, Tanaka H, Sugano N, Miki H, Takao M, Yoshikawa H (2007) Disorders of acetabular labrum and articular cartilage in hip dysplasia: evaluation using isotropic high-resolutional CT arthrography with sequential radial reformation. Osteoarthritis Cartilage 15(3):251–257, Epub Sep 20, 2006
16. Czerny C, Hofmann S, Neuhold A, Tschauner C, Engel A, Recht MP, Kramer J (1996) Lesions of the acetabular labrum: accuracy of MR imaging and MR arthrography in detection and staging. Radiology 200(1):225–230
17. Lage LA, Patel JV, Villar RN (1996) The acetabular labral tear: an arthroscopic classification. Arthroscopy 12(3):269–272
18. Blankenbaker DG, De Smet AA, Keene JS, Fine JP (2007) Classification and localization of acetabular labral tears. Skeletal Radiol 36(5):391–397, Epub Jan 17, 2007
19. Studler U, Kalberer F, Leunig M, Zanetti M, Hodler J, Dora C, Pfirrmann CW (2008) MR arthrography of the hip: differentiation between an anterior sublabral recess as a normal variant and a labral tear. Radiology 249(3):947–954, Epub Oct 7, 2008