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PRACTICE GUIDELINE FOR THE PERFORMANCE AND INTERPRETATION OF MAGNETIC RESONANCE IMAGING (MRI) OF THE HIP AND PELVIS FOR MUSCULOSKELETAL DISORDERS

PREAMBLE

These guidelines are an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. They are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care. For these reasons and those set forth below, the American College of Radiology cautions against the use of these guidelines in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by the physician or medical physicist in light of all the circumstances presented. Thus, an approach that differs from the guidelines, standing alone, does not necessarily imply that the approach was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in the guidelines when, in the reasonable judgment of the practitioner, such course of action is indicated by the condition of the patient, limitations of available resources, or advances in knowledge or technology subsequent to publication of the guidelines. However, a practitioner who employs an approach substantially different from these guidelines is advised to document in the patient record information sufficient to explain the approach taken.

The practice of medicine involves not only the science, but also the art of dealing with the prevention, diagnosis, alleviation, and treatment of disease. The variety and complexity of human conditions make it impossible to always reach the most appropriate diagnosis or to predict with certainty a particular response to treatment.

Therefore, it should be recognized that adherence to these guidelines will not assure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The sole purpose of these guidelines is to assist practitioners in achieving this objective.

I. INTRODUCTION

This guideline was developed and written collaboratively by the American College of Radiology (ACR) and the Society of Skeletal Radiology (SSR). It addresses MRI performed to evaluate musculoskeletal disorders and to investigate symptoms that are believed to originate in the musculoskeletal system. Guidelines for pelvic MRI examinations performed to evaluate the male and female genitourinary tracts, bowel, and vasculature are not included herein. See the [ACR Practice Guideline for the Performance of Magnetic Resonance Imaging \(MRI\) of the Soft Tissue Components of the Pelvis](#).

Magnetic resonance imaging is a proven, established imaging modality for the detection, evaluation, staging, and follow-up of musculoskeletal conditions of the hip and pelvis. Properly performed and interpreted, MRI not only contributes to diagnosis but also serves as an important guide to treatment planning and prognostication. However, MRI should be performed only for a valid medical reason, and only after careful consideration of alternative imaging modalities. The strengths of MRI and other modalities should be weighed against their suitability in particular patients and in particular clinical conditions.

Radiographs should be the initial imaging study for suspected bone or joint abnormalities of the hip and pelvis [1]. Sequential radiographs are a key component in the postoperative evaluation of hip arthroplasties and other orthopedic procedures [2]. Bone scintigraphy is used to screen the entire skeleton for conditions such as metastases. Additionally, with some limitations [3], bone scans can also detect radiographically occult osteonecrosis [4,5], fractures [6], and stress fractures [7] in the hips and pelvis. Because of its superior sensitivity and specificity, however, MRI has largely replaced scintigraphy for these indications [1,8-10]. Other radionuclide studies do contribute to the evaluation of symptomatic hip arthroplasties [11]. Ultrasound may be used for tendon disorders in the proximal thighs [12-14] and bursitis [15] but is unreliable for detecting hip effusions in adults [16]. In children, sonography can be used to diagnose pelvic apophyseal avulsions [17]. Sonography and conventional arthrography can be used to evaluate developmental hip dysplasia in infants and young children [18]; in adults, the clinical response to intra-articular anesthetic injection in the hip helps predict intra-articular pathology [19]. Hip arthroscopy, an invasive procedure, provides a detailed examination of the internal structures of the hip joint, allowing the surgeon to treat as well as diagnose many internal derangements [20,21].

Computed tomography (CT), especially with multi-row helical scanners using thin collimation, is often preferred to MRI for detailed evaluation of bones. Multiplanar two-dimensional reformatting and three-dimensional volume rendering increase the utility of CT for orthopedic purposes. Typical applications include evaluation of the acetabulum and hip joint after fracture-dislocations [22-24], preoperative planning for complex pelvic osteotomies and arthroplasties [23, 25], and evaluation of osteolysis around hip arthroplasty components [26-28]. MRI has largely replaced CT for detecting femoral head osteonecrosis [5], but CT is still valuable for detecting subchondral fractures in necrotic femoral heads [29]. CT is a reasonable secondary imaging modality (after MRI) for soft tissue disorders such as sports hernias [30], internal snapping hips [14], and monoarticular proliferative arthropathies [1]. Lastly, CT can detect erosions in patients with sacroiliitis but normal radiographs [31].

While MRI is often the most sensitive, noninvasive diagnostic test for detecting anatomic abnormalities of the hip and pelvis, its findings may be misleading if not closely correlated with the clinical history, physical examination, physiologic tests such as nerve conduction analysis and electromyography, and other imaging studies. Adherence to the following guidelines will enhance the probability of detecting such abnormalities.

II. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

See the [ACR Practice Guideline for Performing and Interpreting Magnetic Resonance Imaging \(MRI\)](#).

III. INDICATIONS

A. Primary indications for MRI of the hip and pelvis include, but are not limited to, screening, diagnosis, exclusion, grading, and/or prognostication of suspected:

1. Osteonecrosis of the femoral head(s) [5,32-42].
2. Other marrow abnormalities of the femoral head(s), including transient and migratory osteoporosis, transient marrow edema syndrome, and subchondral insufficiency fractures[42-46]. *
3. Radiographically occult traumatic fractures of the proximal femur and pelvis [9,10,47-51].
4. Stress fractures (fatigue and insufficiency types) of the proximal femur, pelvis, and sacrum [7,8,52-58].
5. Childhood hip disorders: Legg-Calve-Perthes disease, slipped femoral capital epiphysis, coxa vara, proximal femoral focal deficiency [59-61].
6. Acetabular labral disorders: tears, hypertrophy, degeneration, cysts [62-68]. †
7. Muscle, myotendinous, and tendon disorders in the pelvis and proximal thigh (including hamstrings, adductors, glutei, iliopsoas, and obturators): tears, strains, tendonitis, tendonopathy [8,12,57,64,69-79]. *
8. Osteochondral and chondral abnormalities in the hip joint [64,67,80-83]. †
9. Ligamentum teres rupture [84]. †
10. Bursitis in and around the pelvis [15,57,64,75,85-87].
11. Sacral plexus abnormalities [88].

B. MRI of the hip and pelvis may be indicated to further clarify and stage conditions diagnosed clinically and/or suggested by other imaging modalities, including, but not limited to:

1. Hip arthritis and synovitis: inflammatory, infectious, degenerative, crystal-induced, post-traumatic, proliferative [89-96]. *
2. Hip joint effusions [15,35,97].
3. Sacroiliitis (89,98).
4. Primary and secondary bone and soft tissue tumors of the pelvis, proximal femur, and thigh [88,99-102].* See also the [Practice Guideline for the Performance and Interpretation of Magnetic Resonance Imaging \(MRI\) of Bone and Soft Tissue Tumors](#).
5. Fractures and dislocations of the hip and pelvis [17,103,104]. *

6. Osteomyelitis and septic arthritis of the hip and pelvis [91,105]. *
7. Osteitis pubis and sports hernias [25,30,57,106].

C. MRI of the hip and pelvis may be useful to evaluate specific clinical scenarios, including, but not limited to:

1. Prolonged, refractory, or unexplained hip, trochanteric, pubic, or pelvic pain [57,70,75,106,107]. †
2. Pelvic, proximal thigh, or groin pain in athletes [8,12,57,64,73,79,81,106-108]. †
3. Femoroacetabular impingement syndrome [66,68,82,109,110]. †
4. Acute or chronic hip and pelvis trauma with associated soft tissue injuries [24, 51,111]. *
5. Pelvic pain after radiation therapy [53-55].
6. Mechanical symptoms in the hip, including snapping and clicking [14,21,62,67]. †
7. Following reduction of congenital hip dislocation in infants and children [112-115]. * †
8. Symptomatic adults with developmental dysplasia of the hip [25,66]. †
9. Patients for whom diagnostic or therapeutic hip arthroscopy is planned [19,67]. †
10. Symptomatic total hip arthroplasties with suspected soft tissue or periprosthetic abnormalities [2,77,116,117].
11. Pelvimetry in women with obstructed labor [118,119].

* Conditions in which intravenous (IV) contrast may be useful.

† Conditions in which intra-articular contrast (performed by direct intra-articular injection or indirect joint opacification following IV administration) may be useful.

IV. SAFETY GUIDELINES AND POSSIBLE CONTRAINDICATIONS

See the [ACR Practice Guideline for Performing and Interpreting Magnetic Resonance Imaging \(MRI\)](#) and the ACR White Paper on Magnetic Resonance Safety¹.

Peer-reviewed literature pertaining to MR safety should be reviewed on a regular basis [120,121].

V. SPECIFICATIONS OF THE EXAMINATION

The supervising physician must have complete understanding of the indications, risks, and benefits of the examination, as well as alternative imaging procedures.

¹In 2007 the following updated version was published: ACR Guidance Document for Safe MR Practices. AJR 2007;188:1-27.

The physician must be familiar with potential hazards associated with MRI, including potential adverse reactions to contrast media. The physician should be familiar with relevant ancillary studies that the patient may have undergone. The physician performing MRI interpretation must have a clear understanding and knowledge of the anatomy and pathophysiology relevant to the MRI examination.

The written or electronic request for MRI of the hip and pelvis for musculoskeletal disorders should provide sufficient information to demonstrate the medical necessity of the examination and allow for its proper performance and interpretation.

Documentation that satisfies medical necessity includes 1) signs and symptoms and/or 2) relevant history (including known diagnoses). Additional information regarding the specific reason for the examination or a provisional diagnosis would be helpful and may at times be needed to allow for the proper performance and interpretation of the examination.

The request for the examination must be originated by a physician or other appropriately licensed health care provider. The accompanying clinical information should be provided by a physician or other appropriately licensed health care provider familiar with the patient's clinical problem or question and consistent with the state's scope of practice requirements. (ACR Resolution 35, adopted in 2006)

The supervising physician must also understand the pulse sequences to be employed and their effect on the appearance of the images, including the potential generation of image artifacts. Standard imaging protocols may be established and varied on a case-by-case basis when necessary. These protocols should be reviewed and updated periodically.

A. Patient Selection

The physician responsible for the examination shall supervise patient selection and preparation and be available in person or by phone for consultation. Patients shall be screened and interviewed prior to the examination to exclude individuals who may be at risk by exposure to the MR environment.

Certain indications require administration of intravenous (IV) contrast media. IV contrast enhancement should be performed using appropriate injection protocols and in accordance with the institution's policy on IV contrast utilization. (See the [ACR Practice Guideline for the Use of Intravascular Contrast Media](#).)

Patients suffering from anxiety or claustrophobia may require sedation or additional assistance. Administration of moderate sedation may be needed to achieve a successful examination. If moderate sedation is necessary, refer to the [ACR Practice Guideline for Adult Sedation/Analgesia](#) or the [ACR Practice Guideline for Pediatric Sedation/Analgesia](#).

B. Facility Requirements

Appropriate emergency equipment and medications must be immediately available to treat adverse reactions associated with administered medications. The equipment and medications should be monitored for inventory and drug expiration dates on a regular basis. The equipment, medications, and other emergency support must also be appropriate for the range of ages and sizes in the patient population.

C. Examination Technique

Diagnostic quality hip and pelvis MRI can be performed with low, medium, or high-field systems of either closed bore or open design. High-field magnets (1.5-T and higher) have inherently better signal-to-noise ratios than lower field systems, providing greater flexibility to obtain high-resolution images in a reasonable amount of time. However, there are circumstances where lower field strength may be advantageous. These situations include imaging around metallic implants like prostheses and screws [2,122], and imaging in pregnant patients to reduce energy deposition in the fetus [119].

While an initial screen for abnormalities may use a body coil [23,37,123,124], high-resolution images require the use of a local coil. Multicoil arrays work best when imaging the entire pelvis and both hips [125,126]. When detailed images of a single hip or proximal femur are needed, several coil choices are available, ranging in configuration from flexible single coils [48,127], to paired loop-gap designs, to commercially available or custom-built phased arrays [51,117,128-130].

Patients are typically positioned supine. The feet may be internally rotated and gently immobilized with tape if necessary. Slight flexion at the knees may be more comfortable for some patients.

Coronal images are a mainstay of pelvic and hip MRI, and coronal images alone can rapidly screen for fractures [48] or femoral head osteonecrosis [37]. However, a complete examination will also include images in at least one additional imaging plane. Coronal and transverse images constitute a minimum examination for most indications [52,106,107,132]. The addition of sagittal plane images is useful for quantifying the extent of femoral head osteonecrosis [34,39], evaluating the hip joint cartilage and acetabular roof [54,133], investigating

abnormalities of the proximal hamstring muscles and tendons [72,76], and performing MR pelvimetry [118,119]. Additionally, the standard imaging planes may be altered for specific indications.

Oblique coronal images angled parallel to the upper sacrum are useful to evaluate the sacroiliac joints [89,98], while either direct or oblique coronal and transverse images can image the sacral plexus [88,134]. Selective use of oblique images along one femoral neck may assist in the diagnosis of subtle fractures [124,127,135], and in the evaluation of the femoral head-neck junction in femoroacetabular impingement syndrome [110]. In some practices, radial images acquired either directly [136] or via multiplanar reformatting of a volumetric data set [137] may assist the diagnosis of labral and cartilage pathology, but acquiring radial images is not routine. Typically, three imaging planes are used for MR arthrography of the hip [62]. These may be oriented orthogonal to the pelvis, or parallel to the femoral neck and perpendicular to the acetabular face for evaluating the acetabular labrum and hip joint capsule [138].

The field of view (FOV) should be tailored to the size of the patient and the structures being examined. To screen the entire pelvis, a 35 to 45 cm FOV is typical, and the images should include enough tissue laterally to encompass the glutei insertions and trochanteric bursae [78]. Images that include the entire pelvis are useful for making side-to-side comparisons [124]. Even when symptoms are one-sided, it may be advantageous to include at least one sequence with a large enough FOV to detect contralateral disease, which is not infrequently present [56]. For screening purposes, 6 to 8 mm thick sections are adequate. However, higher resolution imaging is necessary to distinguish femoral head osteonecrosis from transient marrow conditions [42], to demonstrate subtle fracture lines, and to quantify the extent of osteonecrosis [39]. High-resolution can be accomplished with a relatively large FOV if thin slices and a high imaging matrix are used (for example, 3 to 4 mm slices and a 512 x 512 matrix) [39], or it can be accomplished by reducing the FOV to 16 to 20 cm and imaging each hip separately [51,139]. MR arthrography for labral or articular cartilage disease often requires even higher spatial resolution, with a small FOV to cover just one hip (typically 15 to 22 cm), thin sections (1.5 to 3 mm), and a relatively high matrix (256 phase steps or more) [83,138]. There is a trade-off between spatial resolution and imaging time [125]. Parallel imaging, which is available on some MR systems, allows faster image acquisition without a loss in image quality [140]. Additionally, an interslice gap can increase coverage and decrease signal loss due to cross talk [141] but should be no more than 33% of the slice width and should not impair visualization of the intra-articular structures.

A wide variety of pulse sequences is available to image the pelvis and hips [142]. The choice of sequences, like other aspects of the imaging protocol, can be tailored to optimize the examination to answer the specific clinical questions [23] and may vary due to local preferences. Short TR/TE (T1-weighted) images typically use spin-echo technique, while the fast (turbo) spin-echo sequence can rapidly produce long effective TE and short TI inversion recovery (STIR) images [38]. Gradient-recalled sequences tend to produce larger artifacts and result in lower soft tissue contrast [124] but may be advantageous at lower field strengths [143] and for selected applications, like the demonstration of hemosiderin in hips affected by pigmented villonodular synovitis [96], or as an alternative to evaluate articular cartilage [80,136]. Gradient-echo sequences can also be acquired as a 3D volume, which is partitioned into contiguous thin sections.

An imaging protocol will be composed of one or more pulse sequence types. For each sequence, the exact TR, TE, TI, and flip angle chosen will depend on the field strength of the magnet and the desired contrast weighting. A typical minimal pelvic examination might consist of coronal spin-echo T1-weighted and fat-suppressed, fast spin-echo T2-weighted or STIR images, with an additional transverse T1-weighted, T2-weighted, or T2*-weighted sequence [106,124,132]. The T1-weighted images optimally show anatomic details such as fracture lines [39,48,54,55], while T2-weighted or STIR images demonstrate fluid collections and edema within the soft tissue and bone marrow [54,97,123]; the combination is an effective screen for a variety of hip and pelvic pathologies [58,107,132]. T1-weighted sequences also have a role in characterizing various stages of hemorrhage [144,145] and muscle pathology [146,147], and for showing enhancement when IV gadolinium-based contrast agents are used [148]. T1-weighted images with fat suppression – either 2D (fast) spin-echo [62,83], or 3D spoiled gradient-echo [137,138] – are also used when MR arthrography is performed with a gadolinium-based contrast agent. At least one T2-weighted sequence should also be performed with MR arthrograms to show abnormalities that do not communicate with the injected joint. Additionally, at least T1-weighted sequence without fat suppression is useful for evaluating bone marrow and characterization of soft tissue lesions.

Suppressing the signal from fat may enhance the diagnostic yield of some pulse sequences [142]. Fat suppression can use spectral suppression of water protons, a phase-dependent method such as the Dixon technique, or a STIR sequence [149,150]. The latter two methods may be necessary on low-field systems [151]. Fat suppression increases the conspicuity of marrow abnormalities and soft tissue edema [124], and it may be a useful adjunct when using gadolinium-based contrast

agents. Selective excitation of water protons is an alternative to fat suppression and has been investigated for evaluating the hip articular cartilage [133].

For specific hip and pelvis disorders, IV contrast may be useful. Contrast enhancement suggests femoral head viability in Legg-Perthes disease [152] and femoral neck fractures [103,104]. IV contrast can also aid in the diagnosis of hip joint synovitis [89,91], pelvic infections [105], tendon degeneration [79], and tumors, and it may play a role in the evaluation of the interface surrounding hip prosthesis components [2]. MR arthrography is beneficial for evaluating internal hip derangements [19,21] and sports injury [57]. The MR diagnosis of labral, articular cartilage, and joint capsule abnormalities in the hip is greatly enhanced by the addition of intra-articular contrast [66,67,131,138]. For the hip joint, MR arthrography is usually performed following direct, imaging-guided, intra-articular injection of dilute gadolinium-based contrast or saline. While indirect MR arthrography is also possible for hip imaging, because of the size of the joint, a delay after IV contrast administration is necessary to allow adequate contrast diffusion into the joint [131].

Various techniques are used to reduce artifacts that can reduce imaging quality. When the FOV excludes parts of the pelvis that are within the sensitivity range of the coil (e.g., when imaging a single hip) aliasing artifacts can be reduced by phase over-sampling, or by orienting the phase-encoding direction along the anteroposterior axis [153]. Ensuring patient comfort combined with gentle immobilization when necessary best controls involuntary patient motion [142]. Presaturation pulses and/or gradient moment nulling will reduce ghosting artifacts caused by flowing blood [153,154]. Imaging near metallic implants requires special care to reduce susceptibility to artifacts. Orienting the long axis of the implant along the frequency-encoding gradient [116,128,155], avoiding gradient-recalled sequences [116], and substituting STIR for chemical fat-suppression [2,77,116,156] are important. Fast spin-echo sequences with short interecho spacing, multiple refocusing pulses (long echo trains), and tailored RF pulses will further minimize metallic artifacts [77,117,128,155,157]. Metal artifact is further reduced by using a wide readout bandwidth and small pixel dimensions, which may require more signals averaged to maintain an adequate signal-to-noise ratio [2,117,128,155]. Lastly, artifacts from metal implants are less on low-field compared with high-field systems [2].

It is the responsibility of the supervising physician to determine whether additional or unconventional pulse sequences or imaging techniques would confer added benefit for the diagnosis and management of the patient. Examinations that employ techniques not approved by the Food and Drug Administration — such as the

intraarticular injection of gadolinium chelates (direct MR arthrography) [158] — should be considered only when they are judged to be medically appropriate.

VI. DOCUMENTATION

Reporting should be in accordance with the [ACR Practice Guideline for Communication of Diagnostic Imaging Findings](#).

At a minimum, the report should address any abnormalities in the bone marrow, soft tissues, and joints. In selected cases, a description of findings in specific muscles and tendons, articular cartilage, fibrocartilage, synovium, neurovascular structures, cortical bone, and surrounding bursae would be appropriate. For MR arthrograms of the hip, the report should also specifically indicate the condition of the acetabular labrum and articular cartilage. Whenever possible, the report should use standard anatomic nomenclature and precise terms for describing identified abnormalities.

VII. EQUIPMENT SPECIFICATIONS

The MRI equipment specifications and performance shall meet all state and federal requirements. The requirements include, but are not limited to, specifications of maximum static magnetic strength, maximum rate of change of the magnetic field strength (dB/dt), maximum radiofrequency power deposition (specific absorption rate), and maximum acoustic noise levels.

VIII. QUALITY CONTROL AND IMPROVEMENT, SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION

Policies and procedures related to quality, patient education, infection control, and safety should be developed and implemented in accordance with the ACR Policy on Quality Control and Improvement, Safety, Infection Control, and Patient Education appearing elsewhere as part of the ACR Practice Guidelines and Technical Standards.

Specific policies and procedures related to MRI safety should be in place along with documentation that is updated annually and compiled under the supervision and direction of the supervising MRI physician. Guidelines should be provided that deal with potential hazards associated with the MRI examination of the patient as well as to others in the immediate area. [120,121,159]. Screening forms must also be provided to detect those patients who may be at risk for adverse events associated with the MRI examination [160].

Equipment monitoring should be in accordance with the [ACR Technical Standard for Diagnostic Medical Physics](#)

Performance Monitoring of Magnetic Resonance Imaging (MRI) Equipment.

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REFERENCES

1. Newberg AH, Newman JS. Imaging the painful hip. *Clin Orthop* 2003;406:19-28.
2. Sugimoto H, Hirose I, Miyaoka E, et al. Low-field-strength MR imaging of failed hip arthroplasty: association of femoral periprosthetic signal intensity with radiographic, surgical, and pathologic findings. *Radiology* 2003;229:718-723.
3. Garcia-Morales F, Seo GS, Chengazi V, et al. Collar osteophytes: a cause of false-positive findings in bone scans for hip fractures. *AJR* 2003;181:191-194.

4. Ryu JS, Kim JS, Moon DH, et al. Bone SPECT is more sensitive than MRI in the detection of early osteonecrosis of the femoral head after renal transplantation. *J Nucl Med* 2002;43:1006-1011.
5. Mitchell MD, Kundel HL, Steinberg ME, et al. Avascular necrosis of the hip: comparison of MR, CT, and scintigraphy. *AJR* 1986;147:67-71.
6. Holder LE, Schwarz C, Wernicke PG, et al. Radionuclide bone imaging in the early detection of fractures of the proximal femur (hip): multifactorial analysis. *Radiology* 1990;174:509-515.
7. Song WS, Yoo JJ, Koo KH, et al. Subchondral fatigue fracture of the femoral head in military recruits. *J Bone Joint Surg* 2004;86-A:1917-1924.
8. Shin AY, Morin WD, Gorman JD, et al. The superiority of magnetic resonance imaging in differentiating the cause of hip pain in endurance athletes. *Am J Sports Med* 1996;24:168-176.
9. Feldman F, Staron RB. MRI of seemingly isolated greater trochanteric fractures. *AJR* 2004;183:323-329.
10. Rubin SJ, Marquardt JD, Gottlieb RH, et al. Magnetic resonance imaging: a cost-effective alternative to bone scintigraphy in the evaluation of patients with suspected hip fractures. *Skeletal Radiol* 1998;27:199-204.
11. Stumpe KD, Notzli HP, Zanetti M, et al. FDG PET for differentiation of infection and aseptic loosening in total hip replacements: comparison with conventional radiography and three-phase bone scintigraphy. *Radiology* 2004;231:333-341.
12. Connell DA, Schneider-Kolsky ME, Hoving JL, et al. Longitudinal study comparing sonographic and MRI assessments of acute and healing hamstring injuries. *AJR* 2004;183:975-984.
13. Wahl CJ, Warren RF, Adler RS, et al. Internal coxa saltans (snapping hip) as a result of overtraining: a report of 3 cases in professional athletes with a review of causes and the role of ultrasound in early diagnosis and management. *Am J Sports Med* 2004;32:1302-1309.
14. Wunderbaldinger P, Bremer C, Matuszewski L, et al. Efficient radiological assessment of the internal snapping hip syndrome. *Eur Radiol* 2001;11:1743-1747.
15. Wunderbaldinger P, Bremer C, Schellenberger E, et al. Imaging features of iliopsoas bursitis. *Eur Radiol* 2002;12:409-415.
16. Weybright PN, Jacobson JA, Murry KH, et al. Limited effectiveness of sonography in revealing hip joint effusion: preliminary results in 21 adult patients with native and postoperative hips. *AJR* 2003;181:215-218.
17. Pisacano RM, Miller TT. Comparing sonography with MR imaging of apophyseal injuries of the pelvis in four boys. *AJR* 2003;181:223-230.
18. Liu JS, Kuo KN, Lubicky JP. Arthrographic evaluation of developmental dysplasia of the hip: outcome prediction. *Clin Orthop* 1996;326:229-237.
19. Byrd JW, Jones KS. Diagnostic accuracy of clinical assessment, magnetic resonance imaging, magnetic resonance arthrography, and intra-articular injection in hip arthroscopy patients. *Am J Sports Med* 2004;32:1668-1674.
20. Kelly BT, Williams RJ 3rd, Philippon MJ. Hip arthroscopy: current indications, treatment options, and management issues. *Am J Sports Med* 2003;31:1020-1037.
21. McCarthy JC, Lee JA. Arthroscopic intervention in early hip disease. *Clin Orthop* 2004;429:157-162.
22. Brooks RA, Ribbans WJ. Diagnosis and imaging studies of traumatic hip dislocations in the adult. *Clin Orthop* 2000;377:15-23.
23. Conway WF, Totty WG, McEnery KW. CT and MR imaging of the hip. *Radiology* 1996;198:297-307.
24. Potter HG, Montgomery KD, Heise CW, et al. MR imaging of acetabular fractures: value in detecting femoral head injury, intraarticular fragments, and sciatic nerve injury. *AJR* 1994;163:881-886.
25. Garbuz DS, Masri BA, Haddad F, et al. Clinical and radiographic assessment of the young adult with symptomatic hip dysplasia. *Clin Orthop* 2004;418:18-22.
26. Claus AM, Totterman SM, Sychterz CJ, et al. Computed tomography to assess pelvic lysis after total hip replacement. *Clin Orthop* 2004;422:167-174.
27. Park JS, Ryu KN, Hong HP, et al. Focal osteolysis in total hip replacement: CT findings. *Skeletal Radiol* 2004;33:632-640.
28. Puri L, Wixson RL, Stern SH, et al. Use of helical computed tomography for the assessment of acetabular osteolysis after total hip arthroplasty. *J Bone Joint Surg* 2002;84-A:609-614.
29. Stevens K, Tao C, Lee SU, Salem N, et al. Subchondral fractures in osteonecrosis of the femoral head: comparison of radiography, CT, and MR imaging. *AJR* 2003;180:363-368.
30. Fon LJ, Spence RA. Sportsman's hernia. *Br J Surg* 2000;87:545-552.
31. Kozin F, Carrera GF, Ryan LM, et al. Computed tomography in the diagnosis of sacroiliitis. *Arthritis Rheum* 1981;24:1479-1485.
32. Coleman BG, Kressel HY, Dalinka MK, et al. Radiographically negative avascular necrosis: detection with MR imaging. *Radiology* 1988;168:525-528.
33. Beltran J, Knight CT, Zuelzer WA, et al. Core decompression for avascular necrosis of the femoral head: correlation between long-term

- results and preoperative MR staging. *Radiology* 1990;175:533-536.
34. Koo KH, Kim R. Quantifying the extent of osteonecrosis of the femoral head: a new method using MRI. *J Bone Joint Surg* 1995;77-B:875-880.
 35. Huang GS, Chan WP, Chang YC, et al. MR imaging of bone marrow edema and joint effusion in patients with osteonecrosis of the femoral head: relationship to pain. *AJR* 2003;181:545-549.
 36. Iida S, Harada Y, Shimizu K, et al. Correlation between bone marrow edema and collapse of the femoral head in steroid-induced osteonecrosis. *AJR* 2000;174:735-743.
 37. Khanna AJ, Yoon TR, Mont MA, et al. Femoral head osteonecrosis: detection and grading by using a rapid MR imaging protocol. *Radiology* 2000;217:188-192.
 38. May DA, Disler DG. Screening for avascular necrosis of the hip with rapid MRI: preliminary experience. *J Comput Assist Tomogr* 2000;24:284-287.
 39. Cherian SF, Laorr A, Saleh KJ, et al. Quantifying the extent of femoral head involvement in osteonecrosis. *J Bone Joint Surg* 2003;85-A:309-315.
 40. Cheng EY, Thongtrangan I, Laorr A, et al. Spontaneous resolution of osteonecrosis of the femoral head. *J Bone Joint Surg* 2004;86-A:2594-2599.
 41. Radke S, Kirschner S, Seipel V, et al. Magnetic resonance imaging criteria of successful core decompression in avascular necrosis of the hip. *Skeletal Radiol* 2004;33:519-523.
 42. Watson RM, Roach NA, Dalinka MK. Avascular necrosis and bone marrow edema syndrome. *Radiol Clin North Am* 2004;42:207-219.
 43. Bloem JL. Transient osteoporosis of the hip: MR imaging. *Radiology* 1988;167:753-755.
 44. Neuhold A, Hofmann S, Engel A, et al. Bone marrow edema of the hip: MR findings after core decompression. *J Comput Assist Tomogr* 1992;16:951-955.
 45. Vande Berg BC, Malghem JJ, Lecouvet FE, et al. Idiopathic bone marrow edema lesions of the femoral head: predictive value of MR imaging findings. *Radiology* 1999;212:527-535.
 46. Malizos KN, Zibis AH, Dailiana Z, et al. MR imaging findings in transient osteoporosis of the hip. *Eur J Radiol* 2004;50:238-244.
 47. Deutsch AL, Mink JH, Waxman AD. Occult fractures of the proximal femur: MR imaging. *Radiology* 1989;170:113-116.
 48. Quinn SF, McCarthy JL. Prospective evaluation of patients with suspected hip fracture and indeterminate radiographs: use of T1-weighted MR images. *Radiology* 1993;187:469-471.
 49. Rizzo PF, Gould ES, Lyden JP, et al. Diagnosis of occult fractures about the hip: magnetic resonance imaging compared with bone-scanning. *J Bone Joint Surg* 1993;75:395-401.
 50. Haramati N, Staron RB, Barax C, et al. Magnetic resonance imaging of occult fractures of the proximal femur. *Skeletal Radiol* 1994;23:19-22.
 51. Oka M, Monu JU. Prevalence and patterns of occult hip fractures and mimics revealed by MRI. *AJR* 2004;182:283-288.
 52. Slocum KA, Gorman JD, Puckett ML, et al. Resolution of abnormal MR signal intensity in patients with stress fractures of the femoral neck. *AJR* 1997;168:1295-1299.
 53. Blomlie V, Rofstad EK, Talle K, et al. Incidence of radiation-induced insufficiency fractures of the female pelvis: evaluation with MR imaging. *AJR* 1996;167:1205-1210.
 54. Grangier C, Garcia J, Howarth NR, et al. Role of MRI in the diagnosis of insufficiency fractures of the sacrum and acetabular roof. *Skeletal Radiol* 1997;26:517-524.
 55. Otte MT, Helms CA, Fritz RC. MR imaging of supra-acetabular insufficiency fractures. *Skeletal Radiol* 1997;26:279-283.
 56. Kiuru MJ, Pihlajamaki HK, Ahovuo JA. Fatigue stress injuries of the pelvic bones and proximal femur: evaluation with MR imaging. *Eur Radiol* 2003;13:605-611.
 57. Overdeck KH, Palmer WE. Imaging of hip and groin injuries in athletes. *Semin Musculoskelet Radiol* 2004;8:41-55.
 58. Ahovuo JA, Kiuru MJ, Visuri T. Fatigue stress fractures of the sacrum: diagnosis with MR imaging. *Eur Radiol* 2004;14:500-505.
 59. Jaramillo D, Kasser JR, Villegas-Medina OL, et al. Cartilaginous abnormalities and growth disturbances in Legg-Calve-Perthes disease: evaluation with MR imaging. *Radiology* 1995;197:767-773.
 60. Kaniklides C, Lonnerholm T, Moberg A, et al. Legg-Calve-Perthes disease. Comparison of conventional radiography, MR imaging, bone scintigraphy and arthrography. *Acta Radiol* 1995;36:434-439.
 61. Futami T, Suzuki S, Seto Y, et al. Sequential magnetic resonance imaging in slipped capital femoral epiphysis: assessment of preslip in the contralateral hip. *J Pediatr Orthop* 2001;10:298-303.
 62. Petersilge CA, Haque MA, Petersilge WJ, et al. Acetabular labral tears: evaluation with MR arthrography. *Radiology* 1996;200:231-235.
 63. Schnarkowski P, Steinbach LS, Tirman PF, et al. Magnetic resonance imaging of labral cysts of the hip. *Skeletal Radiol* 1996;25:733-737.
 64. Boutin RD, Newman JS. MR imaging of sports-related hip disorders. *Magn Reson Imaging Clin N Am* 2003;11:255-281.

65. Magee T, Hinson G. Association of paralabral cysts with acetabular disorders. *AJR* 2000;174:1381-1384.
66. Leunig M, Podeszwa D, Beck M, et al. Magnetic resonance arthrography of labral disorders in hips with dysplasia and impingement. *Clin Orthop* 2004;418:74-80.
67. Keeney JA, Peelle MW, Jackson J, et al. Magnetic resonance arthrography versus arthroscopy in the evaluation of articular hip pathology. *Clin Orthop* 2004;429:163-169.
68. Ito K, Leunig M, Ganz R. Histopathologic features of the acetabular labrum in femoroacetabular impingement. *Clin Orthop* 2004;429:262-271.
69. Chung CB, Robertson JE, Cho GJ, et al. Gluteus medius tendon tears and avulsive injuries in elderly women: imaging findings in six patients. *AJR* 1999;173:351-353.
70. Kingzett-Taylor A, Tirman PF, Feller J, et al. Tendinosis and tears of gluteus medius and minimus muscles as a cause of hip pain: MR imaging findings. *AJR* 1999;173:1123-1126.
71. Kagan A 2nd. Rotator cuff tears of the hip. *Clin Orthop* 1999;368:135-140.
72. De Smet AA, Best TM. MR imaging of the distribution and location of acute hamstring injuries in athletes. *AJR* 2000;174:393-399.
73. Anderson MW, Kaplan PA, Dussault RG. Adductor insertion avulsion syndrome (thigh splints): spectrum of MR imaging features. *AJR* 2001;177:673-675.
74. Anderson SE, Johnston JO, O'Donnell R, et al. MR Imaging of sports-related pseudotumor in children: mid femoral diaphyseal periostitis at insertion site of adductor musculature. *AJR* 2001;176:1227-1231.
75. Bird PA, Oakley SP, Shnier R, et al. Prospective evaluation of magnetic resonance imaging and physical examination findings in patients with greater trochanteric pain syndrome. *Arthritis Rheum* 2001;44:2138-2145.
76. Slavotinek JP, Verrall GM, Fon GT. Hamstring injury in athletes: using MR imaging measurements to compare extent of muscle injury with amount of time lost from competition. *AJR* 2002;179:1621-1628.
77. Twair A, Ryan M, O'Connell M, et al. MRI of failed total hip replacement caused by abductor muscle avulsion. *AJR* 2003;181:1547-1550.
78. Cvitanic O, Henzie G, Skezas N, et al. MRI diagnosis of tears of the hip abductor tendons (gluteus medius and gluteus minimus). *AJR* 2004;182:137-143.
79. Robinson P, Barron DA, Parsons W, et al. Adductor-related groin pain in athletes: correlation of MR imaging with clinical findings. *Skeletal Radiol* 2004;33:451-457.
80. Nishii T, Nakanishi K, Sugano N, et al. Articular cartilage evaluation in osteoarthritis of the hip with MR imaging under continuous leg traction. *Magn Reson Imaging* 1998;16:871-875.
81. Weaver CJ, Major NM, Garrett WE, et al. Femoral head osteochondral lesions in painful hips of athletes: MR imaging findings. *AJR* 2002;178:973-977.
82. Schmid MR, Notzli HP, Zanetti M, et al. Cartilage lesions in the hip: diagnostic effectiveness of MR arthrography. *Radiology* 2003;226:382-386.
83. Beaulé PE, Zaragoza E, Copelan N. Magnetic resonance imaging with gadolinium arthrography to assess acetabular cartilage delamination: a report of four cases. *J Bone Joint Surg* 2004;86-A:2294-2298.
84. Byrd JW, Jones KS. Traumatic rupture of the ligamentum teres as a source of hip pain. *Arthroscopy* 2004;20:385-391.
85. Varma DG, Richli WR, Charnsangavej C, et al. MR appearance of the distended iliopsoas bursa. *AJR* 1991;156:1025-1028.
86. Kozlov DB, Sonin AH. Iliopsoas bursitis: diagnosis by MRI. *J Comput Assist Tomogr* 1998;22:625-628.
87. Robinson P, White LM, Agur A, et al. Obturator externus bursa: anatomic origin and MR imaging features of pathologic involvement. *Radiology* 2003;228:230-234.
88. Gierada DS, Erickson SJ. MR imaging of the sacral plexus: abnormal findings. *AJR* 1993;160:1067-1071.
89. Bollow M, Braun J, Hamm B, et al. Early sacroiliitis in patients with spondyloarthropathy: evaluation with dynamic gadolinium-enhanced MR imaging. *Radiology* 1995;194:529-536.
90. Otake S, Tsuruta Y, Yamana D, et al. Amyloid arthropathy of the hip joint: MR demonstration of presumed amyloid lesions in 152 patients with long-term hemodialysis. *Eur Radiol* 1998;8:1352-1356.
91. Lee SK, Suh KJ, Kim YW, et al. Septic arthritis versus transient synovitis at MR imaging: preliminary assessment with signal intensity alterations in bone marrow. *Radiology* 1999;211:459-465.
92. Soini I, Kotaniemi A, Kautiainen H, et al. US assessment of hip joint synovitis in rheumatic diseases: a comparison with MR imaging. *Acta Radiol* 2003;44:72-78.
93. Sugano N, Ohzono K, Nishii T, et al. Early MRI findings of rapidly destructive coxopathy. *Magn Reson Imaging* 2001;19:47-50.
94. Watanabe W, Itoi E, Yamada S. Early MRI findings of rapidly destructive coxarthrosis. *Skeletal Radiol* 2002;31:35-38.

95. Boutry N, Paul C, Leroy X, et al. Rapidly destructive osteoarthritis of the hip: MR imaging findings. *AJR* 2002;179:657-663.
96. Cheng XG, You YH, Liu W, et al. MRI features of pigmented villonodular synovitis (PVNS). *Clin Rheumatol* 2004;23:31-34.
97. Moss SG, Schweitzer ME, Jacobson JA, et al. Hip joint fluid: detection and distribution at MR imaging and US with cadaveric correlation. *Radiology* 1998;208:43-48.
98. Murphey MD, Wetzel LH, Bramble JM, et al. Sacroiliitis: MR imaging findings. *Radiology* 1991;180:239-244.
99. Disler DG, Miklic D. Imaging findings in tumors of the sacrum. *AJR* 1999;173:1699-1706.
100. Llauger J, Palmer J, Amores S, et al. Primary tumors of the sacrum: diagnostic imaging. *AJR* 2000;174:417-424.
101. Ozaki T, Putzke M, Burger H, et al. Infiltration of sarcomas into the hip joint: comparison of CT, MRI and histologic findings in 67 cases. *Acta Orthop Scand* 2002;73:220-226.
102. Gaeta M, Minutoli F, Pandolfo I, et al. Magnetic resonance imaging findings of osteoid osteoma of the proximal femur. *Eur Radiol* 2004;14:1582-1589.
103. Kamano M, Narita S, Honda Y, et al. Contrast enhanced magnetic resonance imaging for femoral neck fracture. *Clin Orthop* 1998;350:179-186.
104. Hirata T, Konishiike T, Kawai A, et al. Dynamic magnetic resonance imaging of femoral head perfusion in femoral neck fracture. *Clin Orthop* 2001;393:294-301.
105. Huang AB, Schweitzer ME, Hume E, et al. Osteomyelitis of the pelvis/hips in paralyzed patients: accuracy and clinical utility of MRI. *J Comput Assist Tomogr* 1998;22:437-443.
106. Albers SL, Spritzer CE, Garrett WE Jr, et al. MR findings in athletes with pubalgia. *Skeletal Radiol* 2001;30:270-277.
107. Brennan D, O'Connell MJ, Ryan M, et al. Secondary cleft sign as a marker of injury in athletes with groin pain: MR image appearance and interpretation. *Radiology* 2005;235:162-167.
108. Bencardino JT, Kassarian A, Palmer WE. Magnetic resonance imaging of the hip: sports-related injuries. *Top Magn Reson Imaging* 2003;14:145-160.
109. Ito K, Minka MA 2nd, Leunig M, et al. Femoroacetabular impingement and the cam-effect: a MRI-based quantitative anatomical study of the femoral head-neck offset. *J Bone Joint Surg* 2001;83:171-176.
110. Nötzli HP, Wyss TF, Stoecklin CH, et al. The contour of the femoral head-neck junction as a predictor for the risk of anterior impingement. *J Bone Joint Surg* 2002;84:556-560.
111. Mellado JM, Perez del Palomar L, Diaz L, et al. Long-standing Morel-Lavallee lesions of the trochanteric region and proximal thigh: MRI features in five patients. *AJR* 2004;182:1289-1294.
112. Jaramillo D, Villegas-Medina O, Laor T, et al. Gadolinium-enhanced MR imaging of pediatric patients after reduction of dysplastic hips: assessment of femoral head position, factors impeding reduction, and femoral head ischemia. *AJR* 1998;170:1633-1637.
113. Kawaguchi AT, Otsuka NY, Delgado ED, et al. Magnetic resonance arthrography in children with developmental hip dysplasia. *Clin Orthop* 2000;374:235-246.
114. Duffy CM, Taylor FN, Coleman L, et al. Magnetic resonance imaging evaluation of surgical management in developmental dysplasia of the hip in childhood. *J Pediatr Orthop* 2002;22:92-100.
115. Westhoff B, Wild A, Seller K, et al. Magnetic resonance imaging after reduction for congenital dislocation of the hip. *Arch Orthop Trauma Surg* 2003;123:289-292.
116. White LM, Kim JK, Mehta M, et al. Complications of total hip arthroplasty: MR imaging: initial experience. *Radiology* 2000;215:254-262.
117. Potter HG, Nestor BJ, Sofka CM, et al. Magnetic resonance imaging after total hip arthroplasty: evaluation of periprosthetic soft tissue. *J Bone Joint Surg* 2004;86-A:1947-1954.
118. Stark DD, McCarthy SM, Filly RA, et al. Pelvimetry by magnetic resonance imaging. *AJR* 1985;144:947-950.
119. Tukeva TA, Aronen HJ, Karjalainen PT, et al. Low-field MRI pelvimetry. *Eur Radiol* 1997;7:230-234.
120. Shellock FG, Crues JV. MR procedures: biologic effects, safety, and patient care. *Radiology* 2004;232:635-652.
121. Shellock FG. *Reference Manual for Magnetic Resonance Safety, Implants, and Devices*. 2005 edition. Los Angeles, Calif: Biomedical Research Publishing, 2005.
122. Ragnarsson JI, Ekelund L, Karrholm J, et al. Low field magnetic resonance imaging of femoral neck fractures. *Acta Radiol* 1989;30:247-252.
123. Bogost GA, Lizerbram EK, Crues JV 3rd. MR imaging in evaluation of suspected hip fracture: frequency of unsuspected bone and soft tissue injury. *Radiology* 1995;197:263-267.
124. Hayes CW, Balkissoon AA. Magnetic resonance imaging of the musculoskeletal system. II: the hip. *Clin Orthop* 1996;322:297-309.
125. Hayes CE, Dietz MJ, King BF, et al. Pelvic imaging with phased-array coils: quantitative assessment of signal-to-noise ratio improvement. *J Magn Reson Imaging* 1992;2:321-326.
126. Niitsu M, Mishima H, Miyakawa S, et al. High resolution MR imaging of the bilateral hips with

- dual phased-array coil. *J Magn Reson Imaging* 1996;6:950-953.
127. Do-Dai DD, Youngberg RA. MRI of the hip with a shoulder surface coil in off-coronal plane. *J Comput Assist Tomogr* 1995;19:336-338.
 128. Cook SM, Pellicci PM, Potter HG. Use of magnetic resonance imaging in the diagnosis of an occult fracture of the femoral component after total hip arthroplasty: a case report. *J Bone Joint Surg* 2004;86:149-153.
 129. Rubin SJ, Totterman SM, Meyers SP, et al. Magnetic resonance imaging of the hip with a pelvic phased-array surface coil: a technical note. *Skeletal Radiol* 1998;27:77-82.
 130. Kwok WE, Lo KK, Seo G, et al. A volume adjustable four-coil phased array for high resolution MR imaging of the hip. *MAGMA* 1999;9:59-64.
 131. Nishii T, Nakanishi K, Sugano N, et al. Acetabular labral tears: contrast-enhanced MR imaging under continuous leg traction. *Skeletal Radiol* 1996;25:349-356.
 132. Khoury NJ, Birjawi GA, Chaaya M, et al. Use of limited MR protocol (coronal STIR) in the evaluation of patients with hip pain. *Skeletal Radiol* 2003;32:567-574.
 133. Knuesel PR, Pfirrmann CW, Noetzi HP, et al. MR arthrography of the hip: diagnostic performance of a dedicated water-excitation 3D double-echo steady-state sequence to detect cartilage lesions. *AJR* 2004;183:1729-1735.
 134. Blake LC, Robertson WD, Hayes CE. Sacral plexus: optimal imaging planes for MR assessment. *Radiology* 1996;199:767-772.
 135. Toda K, Yoneda S, Urabe A, et al. Oblique axial and oblique coronal MR imaging of the proximal femur. *AJR* 1997;168:1622-1623.
 136. Horii M, Kubo T, Hirasawa Y. Radial MRI of the hip with moderate osteoarthritis. *J Bone Joint Surg* 2000;82:364-368.
 137. Plotz GM, Brossmann J, von Knoch M, et al. Magnetic resonance arthrography of the acetabular labrum: value of radial reconstructions. *Arch Orthop Trauma Surg* 2001;121:450-457.
 138. Czerny C, Hofmann S, Urban M, et al. MR arthrography of the adult acetabular capsular-labral complex: correlation with surgery and anatomy. *AJR* 1999;173:345-349.
 139. Shuman WP, Castagno AA, Baron RL, et al. MR imaging of avascular necrosis of the femoral head: value of small-field-of-view sagittal surface-coil images. *AJR* 1988;150:1073-1078.
 140. Ryan M, Cunningham P, Cantwell C, et al. A comparison of fast MRI of hips with and without parallel imaging using SENSE. *Br J Radiol* 2005;78:299-302.
 141. Kneeland JB, Shimakawa A, Wehrli FW. Effect of intersection spacing on MR image contrast and study time. *Radiology* 1986;158:819-822.
 142. Rubin DA, Kneeland JB. MR imaging of the musculoskeletal system: technical considerations for enhancing image quality and diagnostic yield. *AJR* 1994;163:1155-1163.
 143. Aydingoz U, Ozturk MH. MR imaging of the acetabular labrum: a comparative study of both hips in 180 asymptomatic volunteers. *Eur Radiol* 2001;11:567-574.
 144. De Smet AA, Fisher DR, Heiner JP, et al. Magnetic resonance imaging of muscle tears. *Skeletal Radiol* 1990;19:283-286.
 145. Bush CH. The magnetic resonance imaging of musculoskeletal hemorrhage. *Skeletal Radiol* 2000;29:1-9.
 146. De Smet AA. Magnetic resonance findings in skeletal muscle tears. *Skeletal Radiol* 1993;22:479-484.
 147. Nguyen B, Brandser E, Rubin DA. Pains, strains, and fasciculations: lower extremity muscle disorders. *Magn Reson Imaging Clin N Am* 2000;8:391-408.
 148. Wolf GL, Joseph PM, Goldstein EJ. Optimal pulsing sequences for MR contrast agents. *AJR* 1986;147:367-371.
 149. Weinberger E, Shaw DW, White KS, et al. Nontraumatic pediatric musculoskeletal MR imaging: comparison of conventional and fast-spin-echo short inversion time inversion-recovery technique. *Radiology* 1995;194:721-726.
 150. Rybicki FJ, Chung T, Reid J, et al. Fast three-point Dixon MR imaging using low-resolution images for phase correction: a comparison with chemical shift selective fat suppression for pediatric musculoskeletal imaging. *AJR* 2001;177:1019-1023.
 151. Bredella MA, Losasso C, Moellenken SC, et al. Three-point Dixon chemical-shift imaging for evaluating articular cartilage defects in the knee joint on a low-field-strength open magnet. *AJR* 2001;177:1371-1375.
 152. Mahnken AH, Staatz G, Ihme N, et al. MR signal intensity characteristics in Legg-Calve-Perthes disease: value of fat-suppressed (STIR) images and contrast-enhanced T1-weighted images. *Acta Radiol* 2002;43:329-335.
 153. Peh WC, Chan JH. Artifacts in musculoskeletal magnetic resonance imaging: identification and correction. *Skeletal Radiol* 2001;30:179-191.
 154. Haacke EM, Lenz GW. Improving MR image quality in the presence of motion by using rephasing gradients. *AJR* 1987;148:1251-1258.
 155. Tormanen J, Tervonen O, Koivula A, et al. Image technique optimization in MR imaging of a

- titanium alloy joint prosthesis. *J Magn Reson Imaging* 1996;6:805-811.
156. Hilfiker P, Zanetti M, Debatin JF, et al. Fast spin-echo inversion-recovery imaging versus fast T2-weighted spin-echo imaging in bone marrow abnormalities. *Invest Radiol* 1995;30:110-114.
 157. Eustace S, Jara H, Goldberg R, et al. A comparison of conventional spin-echo and turbo spin-echo imaging of soft tissues adjacent to orthopedic hardware. *AJR* 1998;170:455-458.
 158. Schulte-Altendorneburg G, Gebhard M, Wohlgemuth WA, et al. MR arthrography: pharmacology, efficacy, and safety in clinical trials. *Skeletal Radiol* 2003;32:1-12.
 159. Shellock FG. *Guide to MR Procedures and Metallic Objects*. 7th edition. Philadelphia, Pa: Lippincott Williams and Wilkins, 2001.
 160. Sawyer-Glover AM, Shellock FG. Pre-MRI procedure screening: recommendations and safety considerations for biomedical implants and devices. *J Magn Reson Imaging* 2000;12:92-106.

*Guidelines and standards are published annually with an effective date of October 1 in the year in which amended, revised or approved by the ACR Council. For guidelines and standards published before 1999, the effective date was January 1 following the year in which the guideline or standard was amended, revised, or approved by the ACR Council.

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