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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 on 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 [ACR 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 Safety](#)¹.

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

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

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. 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 scope of practice requirements. (2006 - ACR Resolution 35)

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 or "conscious" 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.

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 CONCERNS

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 Concerns 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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