The role of MRI in musculoskeletal practice: a clinical perspective

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This clinical perspective presents an overview of current and potential uses for magnetic resonance imaging (MRI) in musculoskeletal practice. Clinical practice guidelines and current evidence for improved outcomes will help providers determine the situations when an MRI is indicated. The advanced competency standard of examination used by physical therapists will be helpful to prevent overuse of musculoskeletal imaging, reduce diagnostic errors, and provide the appropriate clinical context to pathology revealed on MRI. Physical therapists are diagnostically accurate and appropriately conservative in their use of MRI consistent with evidence-based principles of diagnosis and screening.

Keywords: Manual therapy, Physical therapy, Musculoskeletal imaging, Diagnosis, Screening

Introduction

Musculoskeletal (MSK) imaging is an important diagnostic and teaching tool for the spectrum of healthcare providers who treat MSK conditions. Magnetic resonance imaging (MRI) in particular holds great potential for clinical and research purposes due to the ability to display high definition images of the MSK system. While the potential uses of MRI are exciting there are also reasons to be cautious primarily due to the expense and situations where the evidence for improved patient outcomes with increased use of MRI is lacking. This clinical perspective will address past, current, and potential future utilization of MRI by physicians, physical therapists (PTs), and other providers in their clinical decision-making with respect to diagnostic and intervention strategies for common MSK conditions.

MRI and MSK Management Decisions

Whenever a healthcare provider is considering an MRI for an MSK injury or condition, it is essential that the need for the imaging be derived from the comprehensive patient examination. Advanced specialty practice examination principles should guide appropriate clinical decisions regarding MSK imaging.[1,2] These principles include planning and performing an examination that is consistent with hypotheses derived from the patient interview, utilizing appropriate tests and measures, adequately disrobing the patient, carefully palpating all injured structures, examining remote areas for possible associated injuries, and examining structures that may be referring symptoms into the area of concern. Gross diagnostic confusion can result from referred pain leading to MRIs of unrelated structures. Pain may refer from proximal to distal structures of the MSK system such as from the hip and pelvis to the thigh and knee,[3] from upper to lower segmental levels in the cervical and lumbar spine,[4–6] and from other systems such as the cardiovascular, genitourinary, or gastrointestinal to the MSK system.[7–15] Obtaining an MRI of an area of referred pain is an expensive high definition study of unrelated structures that may obscure the true diagnosis.

Another fundamental consideration for MRI, consistent with principles of evidence-based diagnosis, is whether the patient is likely to be better off as a result of the MRI. Expert MSK clinicians use the history and review of systems for early hypothesis formation to guide the selection of tests and measures including imaging and laboratory tests. The expert also uses cumulative knowledge, clinical experience, examination findings, and response to interventions such as physical therapy or manual therapy to determine the need for additional testing including MRI.[16–19] Findings from the comprehensive examination help establish the pre-test probability of pathology and provides the necessary relevance to MRI results.[20]

MRI Potential for MSK Practice

Magnetic resonance imaging has a unique ability to noninvasively display high-resolution anatomy images with unparalleled tissue contrast. This has made MRI a

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primary imaging technology for detecting failure in soft tissues, such as meniscal, ligament and tendon tears, and in occult bone injuries.[21,22] Magnetic resonance imaging has the potential for quantifying physical and physiological attributes of soft tissue such as muscle for the differential diagnosis of neuromuscular disease.[23] The capability to capture exact measurement of muscle or to distinguish muscle from scar tissue might not be warranted for routine rehabilitation purposes but for select advanced surgical procedures such as cellular matrix implants used for gross muscle loss due to blast or similar injury, such capabilities could potentially be useful in determining the success of implanted tissue becoming viable muscle.[24] Increasingly, MRI is used to diagnose and stage myopathic conditions such as polymyositis, Duchenne muscular dystrophy, and polio, potentially leading to earlier medical and physical therapy interventions and delaying progression of the disorder.[25,26]

The diagnosis, prognosis, and intervention for chronic inflammatory MSK disease such as ankylosing spondylitis may be facilitated by MRI. Based on the ability to provide accurate assessment of inflammatory lesions and bone edema, the effectiveness of therapy may be assessed.[27–29] The implications of such imaging capability for manual therapists (MTs) could be important. If a manual therapy intervention was initiated for a condition such as ankylosing spondylitis and MRI evidence of inflammation subsequently and correspondingly increased, the intensity of the intervention might have to be decreased to limit progression of the disease. At current levels of cost and availability, this does not suggest that serial MRIs should be the assessment standard for MT management of ankylosing spondylitis patients, but rather that information from MRI studies obtained for a variety of reasons may provide information useful to the decision making of the MT. Clinical indicators of increased inflammation include increased stiffness in the morning and after any period of inactivity.[30]

Magnetic resonance imaging is also an excellent modality for evaluation of patients with early manifestation of rheumatoid arthritis. Key features of magnetic resonance images may indicate the presence of rheumatoid arthritis and reveal the joints involved. The appropriate fat-suppressed and contrast-enhanced MRI sequences have excellent sensitivity for detection of boney erosions and earlier changes, such as synovitis and tenosynovitis.[31] Generally, MRI is considered more sensitive than specific and differentiation between the various inflammatory arthritides may be impossible on the basis of MRI alone.[31] Disorders that are secondary to rheumatoid arthritis, such as carpal tunnel syndrome, may also be evaluated by MRI.

Whole-body MRI is increasingly used for imaging of systemic muscle diseases and for tumor screening and staging within the MSK system.[32,33] Advances in multi-channel whole-body scanners make head to toe high quality images in a practical time frame, a realistic option. The technology has evolved to the point of being able to complete a total body scan of an adult in 15 minutes. Whole-body MRI allows successful bone marrow screening for primary malignancies originating from bone marrow such as multiple myeloma or metastatic disease to bone marrow. Systemic muscle diseases such muscular dystrophy may be detected and evaluated with whole-body MRI technology.

Clinical Tests vs MRIs for Select MSK Conditions

While MRI is generally considered to be more sensitive than specific and may assist the MSK diagnosis process, there may be combinations of screening tests and measures that are equally sensitive, more practical, and more cost efficient for MSK providers to use in select clinical situations. An indication for MRI would be strong clinical suspicion of pathology based on appropriate clinical screening that would make the patient/client inappropriate for conservative management. If the suspected pathology was subsequently not present on MRI, the negative findings of the sensitive imaging would allow the provider to proceed with manual therapy or other conservative intervention with greater confidence. This type of combined clinical and imaging screening requires current knowledge of the orthopaedic literature to select the appropriate clinical tests and measures, and to know the outcomes of other treatment options such as surgery. For example, if a given shoulder pathology is suspected due to the results of a thorough clinical examination and there is strong evidence that particular pathology has a better outcome when managed surgically, the provider would be justified in recommending or ordering the MRI. The following MSK injuries and conditions are frequently seen by MTs and also have a large volume of current literature and discussion surrounding the clinical role of MRI.

Shoulder Conditions

There are an exceptional abundance of clinical tests available to MTs for various shoulder pathologies. As with most diagnostic tests, the validity indices of these tests vary with the design of the diagnostic test study.[20] Careful appraisal of the current literature is required to select the tests and measure that will be most useful to rule out or confirm pathology depending on the clinical situation. If the shoulder condition is clearly chronic, testing for specific pathology may be most relevant if the patient fails to respond adequately to MT intervention. In an acute injury there may be positioning or protection

that is required for adequate healing of injured structures or a surgical procedure that is indicated suggesting that a combination of clinical tests and MRI is potentially required.[34] For suspected internal derangement of the shoulder, following a normal contrast arthrogram with MRI increases the overall diagnostic accuracy. The respective effectiveness and cost of contrast arthrography alone, MRI alone, and contrast arthrography selectively followed by MRI are the indexed values of 0.6610, 0.6715, and 0.7204, at $1090, $2033, and $2339, respectively.[35] Sensitivity for detection of labral tears with high-resolution MRI has ranged from 74 to 100%, with specificity of 95 to 100%.[36] The combination of MRI and arthrography is considered the standard in evaluating the glenohumeral joint for pathologic conditions associated with instability and anterior inferior dislocation of the glenohumeral joint.[36] These pathologic conditions include anteroinferior labral tears, classic and osseous Bankart lesions, superior labral anterior to posterior lesions, fracture and sclerosis of the glenoid, and Hill-Sachs lesions of the humeral head.

Lumbar Spine Conditions

Plain radiographs and MRI studies are generally over-utilized in the management of lower back pain (LBP).[37–39] A proposed LBP classification system useful for imaging decisions consists of: LBP from potentially serious underlying conditions, including infections, fractures, neoplasms, aortic abdominal aneurysms, inflammatory conditions of the kidneys, and cauda equina syndrome; LBP with sciatica from irritation or impingement of lumbosacral nerve roots; and LBP with nonspecific symptoms thought to be from the spectrum of musculoligamentous and degenerative conditions.[38] Most LBP fits into the last category and typically improves significantly with proper treatment within 4 weeks thereby not requiring MSK imaging and particularly not advanced imaging such as an MRI.[40]

Although patients may request an MRI to satisfy their fears regarding the source of their LBP, those who receive an adequate explanation for their symptoms are less likely to want additional diagnostic tests.[38,41,42] Patients may well benefit from an explanation that describes how pathologic conditions demonstrated on MRI may not be relevant to their symptoms. Studies on MRI findings in asymptomatic subjects have shown a high incidence of bulging discs, disc protrusions, and annual tears at one or more spinal levels.[16,43] Any patient with LBP who has been told that pathology demonstrated on their MRI is why their back hurts and subsequently referred to a MT may wonder how manual therapy treatment will change their pathology. These clinical situations are more challenging to the MT than if MRI studies were appropriately obtained consistent with established clinical practice guidelines or if identified pathology was explained in the context that it may or may not be the reason for the patient's back pain. In most clinical situations where red flags are not present and a patient with LBP has not yet had conservative care, an MRI is simply not indicated or appropriate. For the patient who requests an MRI when not indicated, it may be useful to explain that patients with LBP who undergo advanced imaging earlier in their presentation, not consistent with best practice guidelines, are more likely to enter a management pathway of greater risk that includes surgery and other invasive procedures.[38,44–46]

When red flags or examination findings suggest the presence of a serious underlying spinal condition such as fracture, tumor, infection, or cauda equina syndrome, the need for more extensive diagnostic evaluation including MRI is indicated even if the initial radiographic findings are negative. The sensitivity of MRI for cancer ranges from 83 to 93% with a specificity of 90 to 97%.[38] For spinal infection MRI is 96% sensitive and 92% specific with an overall diagnostic accuracy of 94%.[38,47] A screening strategy for patients with acute low back pain based on easily obtained clinical information consisting of: (1) age less than 50; (2) no unexplained weight loss; (3) responding to conservative therapy; and (4) no history of cancer; is 100% sensitive for occult neoplasms.[38] Another low cost screening strategy also with reported 100% sensitivity for occult neoplasms and recommended to screen for spinal infections consists of anterior to posterior view plain radiographs combined with basic laboratory studies such as an erythrocyte sedimentation rate.[38] These strategies that are most useful when negative were retrospectively derived from published cases and may therefore not be perfectly sensitive. However, the sensitivity of these strategies may equal or exceed the imperfect screening of MRI for occult neoplasms with false negative rates of 17 to 7%.[38] Prompt emergency consultation is reserved for patients with back pain who also have findings of cauda equina syndrome or progressive or severe neurologic impairment.

The sensitivity and specificity of MRI for herniated discs is higher than computed tomography but very close to computed tomography for spinal stenosis.[38] The clinical examination for patients with sciatica should include straight leg raising and neurologic testing. A straight leg raise test is more sensitive than specific for disc herniation with reported sensitivity of 91% and specificity of 26%.[48–50]

Manual therapists who treat patients with chronic LBP are familiar with the clinical presentation and typical intolerance to upright activities associated with spinal stenosis. Tolerance to treadmill walking

correlates with the MRI-demonstrated area of the dural sac and may help correctly classify both stenotic and nonstenotic subjects.[51,52] There is also evidence for the successful MT management of spinal stenosis.[53] Correspondingly, clinical testing and MT intervention is appropriate before surgical consideration at which time advanced imaging such as MRI may be warranted.

Wrist Injuries

The scaphoid bone of the wrist is commonly fractured and is prone to developing avascular necrosis due to fracture. The sensitivity of plain radiographs for scaphoid fractures is limited and the common clinical strategy of repeating radiographs two weeks after injury has a reported sensitivity of 11–49% and a negative predictive value of 31–40%.[54] With poor sensitivity, poor negative predictive value, and poor reliability, follow-up radiography cannot be considered a valid diagnostic examination for the detection of scaphoid fracture in patients with normal initial radiographs.[54] Magnetic resonance imaging can distinguish occult fractures from bone bruises, provide detail of ligamentous injury, and reveal avascular necrosis.[55] Use of MRI in the management of occult scaphoid fracture reduces the number of days of unnecessary immobilization and use of healthcare units with minor increases in healthcare costs that may be offset by reduced productivity losses.[56] Magnetic resonance imaging of the wrist may improve diagnostic certainty leading to better patient care without increasing the use of surgical interventions.[57]

Knee Conditions

Knee MRI studies are frequently used to diagnose acute and chronic injuries to a variety of structures. While the diagnostic indices of clinical tests for meniscal pathology are generally considered to be limited, recent diagnostic studies have found that carefully performed clinical examinations may provide equal or better diagnostic information than MRI.[58–60] Accuracy of the clinical examination was 90 and 64% for the clinical examination for anterior cruciate ligament and meniscal tears while MRI had an accuracy of 91, 68, and 86% for anterior cruciate ligament, medial meniscus, and lateral meniscus tears.[60] These studies also concluded that MRI was generally more useful to rule out injuries than to diagnose them. In a comparision of knee imaging strategies for suspected knee fractures between plain radiographs and brief MRI examinations, the addition of a brief MRI to normal plain film radiographs reduced cost and increased diagnostic effectiveness in patients with acute knee injury without an apparent fracture on radiography.[61]

Diagnosis of articular cartilage injuries requires a careful clinical examination and the appropriate MRI sequences such as spoiled gradient echo with fat suppression.[62,63] Detection and proper management of articular cartilage defects is important to preserve joint health particularly in weight bearing joints. The MT must be wary of articular cartilage injury in both acute and chronic injuries with persistent pain or mechanical dysfunction. The lesions of osteochondritis dissecans are commonly found on the articular surfaces of the distal femur, the talus, and the patella.[63]

Osteoarthritis of the knee is another excellent example of a condition in which manual therapy treatment should not be based on the results of MSK imaging. Clinical diagnostic criteria developed by Altman[64] are 89% sensitive and 88% specific for knee osteoarthritis. Physical therapy based on clinical findings and not radiographic findings has been demonstrated to be of high benefit, low cost, and without any known risk to the patient.[65–67] There is level one evidence that arthroscopic surgery is not of benefit for patients with knee OA.[68–72] The suspected presence of degenerative meniscal tears does not suggest a need for MRI or surgery in patients with knee OA.[73]

Foot and Ankle Injuries

Magnetic resonance imaging is increasingly utilized in the evaluation of foot and ankle disorders.[74] While MRI may provide the ability to classify injuries for diagnostic purposes, if the intervention is unchanged, the MRI may not be necessary. For example, ankle ligament injuries of grades I & II and even grade III are typically managed conservatively due to a lack of evidence that surgery improves outcomes thereby making MRI unnecessary strictly for evaluation of the ligaments.[75] However osteochondral lesions of the weight bearing surfaces of the ankle may be present in patients with a history of either acute or chronic ankle sprains. As weight bearing status, activity levels, and even the need for surgery are influenced by the presence of this pathology, an MRI to screen for the pathology may be important to patient management. This screening may be indicated when ankle pain persists beyond typical ligament healing times and can be localized to intra-articular structures.

Stress Fractures

Stress fractures are common injuries in populations of athletes or soldiers accounting for up to 10% of all sports injuries.[76] Radiographs typically do not reveal early-stage stress fractures. More sensitive imaging procedures such as MRI or bone scans may be required to reveal the fracture. While bone scans are more sensitive for stress fractures, they are not specific with fractures, neoplasms, and infections all

having a similar appearance. Some clinicians may prefer MRI studies for grading stress fractures because of the risk associated with the ionizing radiation exposure from bone scans and the excellent anatomic detail provided by MRI.[77–80] Although bone scans remain the gold standard for detecting stress fractures, conventional T1-weighted and T2-weighted MRI sequences reveal tissue damage associated with a stress fracture. Stress fracture tissue changes typically seen on MRI include periosteal and bone marrow edema.[78] Therefore, MR images of stress fractures may be more useful than bone scans to the MT as an aid in designing rehabilitation programs based on the extent of the injury. A published MSK case report describes how a PT working in a primary care setting was able to differentially diagnose a fibular stress fracture from old injury and a potential metastatic lesion in an active female runner with ankle pain and a history of primary breast cancer.[81] The PT sequentially and appropriately ordered plain radiographs, a bone scan, and an MRI. The initial radiograph was read as normal by the radiologist but the PT observed cortical irregularity at the site of symptoms. The readily available bone scan revealed that it was indeed an active process while the subsequently ordered MRI adequately differentiated between a stress fracture and metastatic disease.

Soft Tissue Conditions

Magnetic resonance imaging may assist with definitive diagnoses of common benign soft tissue lesions although biopsy remains the gold standard for malignant and benign soft tissue masses.[82] The most common benign lesions are hemangioma/lymphangioma, lipoma, periarticular cyst, inflammatory masses, fat necrosis, neurofibroma, and giant cell tumor of the tendon sheath.[82] Adding contrast to the MRI study can add specificity in tissue characterization, help determine the local extent of the tumor, and aid in biopsy planning.[83] Whole-body MRI may also have important implications for evaluating soft tissue conditions of the MSK system such as polymyositis, dermatomyositis, and muscular dystrophy.[84] Whole-body MRI sensitively visualizes the distribution of muscle involvement throughout the body. The most sensitive and specific sequences for this type of pathology are T2 weighted with fat suppression or short tau inversion recovery.[85]

Potential Errors Associated with MRI Studies

The MT is in an excellent position to facilitate diagnostic accuracy with MRI studies. A comprehensive clinical examination provides the appropriate context and meaning for any pathology identified on MSK imaging. This is particularly true for MRI due to the relatively high levels of sensitivity for various pathologies. There are numerous studies that have identified pathology in asymptomatic subjects with MRI studies.[16,43,86–91] Disc protrusions, bulges, and annular tears are present in subjects without LBP.[16,43] The incidence of rotator cuff tears increase with age and are present in 50% of asymptomatic subjects by age 70.[87] Studies on asymptomatic jet fighter pilots have found MRI evidence of advanced cervical spine degenerative changes.[88] Tendonopathy, bone bruises, and discoid menisci were present in a studied population of young asymptomatic basketball players.[92] Standard sequence MRIs performed on volunteers with no history of foot or ankle injury or symptoms revealed anatomic variants commonly associated with peroneal tendon disorders in symptomatic ankles.[93] The MSK patient is potentially placed at risk in situations where asymptomatic pathology is mistaken for a source of symptoms and subsequently treated with an invasive procedure. It may be even more risky when the true source of symptoms is a serious threat to the patient and the asymptomatic pathology is mistakenly the focus of clinical attention. This body of evidence with the corresponding potential for diagnostic error places responsibility on the provider ordering or recommending the MRI to provide clinical relevance to identified pathology.

A comprehensive clinical examination that fully considers the potential for referred pain from remote MSK or visceral structures is more likely to result in images of the source of the symptoms rather than the area of referred pain. Injection studies reveal that upper lumbar and cervical segments commonly refer symptoms to lower segments.[4,5,94] Even in asymptomatic subjects these lower spinal segments are associated with more pathology such as disc bulges, protrusions and annular tears.[16,43] Correspondingly, referred symptoms create the potential to mistake asymptomatic pathology identified on MRI in the lower lumbar or cervical segnments as the source of symptoms when indeed the pain generator exists at a more proximal spinal level.

Interpretation of an MRI may be another source of diagnostic error. In an expert MSK radiologist panel review of 56 MRIs of suspected MSK neoplasms originally evaluated by outside radiologists, only 35 of the 56 (54%) outside reports listed the most likely diagnosis.[95] An appropriate differential diagnosis was listed in only 22 (39%) of the outside reports.[95] Interpretation errors could possibly be reduced through direct communication between the MT and the radiologist. Communicating key aspects of the patient examination such as the exact anatomical location of symptoms as well as key negative examination and palpation findings facilitates accurate MRI interpretation and initiates important diagnostic dialogue with the radiologist.

Other possible sources of MSK imaging test error with MRI studies include imaging the wrong body region or side of the patient and confusing one set of images with those of another patient. The author treated a patient with a history of primary breast cancer and shoulder pain whose primary care provider ordered an MRI of her shoulder to help rule out metastatic disease. Unfortunately, the provider ordered an MRI of the wrong shoulder and the technician at the imaging center would only perform the study as ordered. The patient thought that having a study of her uninvolved shoulder was better than no study so she brought the MRI of the asymptomatic shoulder with her to start therapy.

Physical Therapist Utilization of MRI

The opportunity to routinely order or view MSK images varies greatly in the spectrum of PT practice settings.[89] Starting in the US Army in the 1970s and progressing through other branches of the Military Health System, military PTs have successfully worked as formally credentialed direct access providers with privileges to order a variety of MSK imaging procedures including MRI.[96–100] The ability of PTs to integrate a comprehensive knowledge of clinical anatomy and evidence-based examination and differential diagnosis skills with access to MSK imaging has resulted in improved healthcare for US Military Health System MSK patients.[96–100]

There are excellent case examples of PTs in various practice settings appropriately using MRI to facilitate the differential diagnosis in challenging orthopaedic cases.[81,101–103] Physical therapists appropriately sequence MSK imaging by utilizing plain film radiographs prior to ordering MRI.[100] The pre-MRI to post-MRI clinical diagnostic accuracy of PTs is equal to orthopaedic surgeons and exceeds medical providers of other specialties.[100] Studies on the use of MSK imaging by PTs compared to other providers demonstrate that PTs utilize 50% less imaging in their management strategies.[44,96,97] The direct involvement of PTs in the decision making for MSK imaging procedures including MRI, is cost effective, facilitates accurate diagnoses, and reduces the incidence of surgical procedures thereby reducing risk for their patients.[44,97–100]

MRI in Primary Care Settings: Implications for Manual Therapists

There is debate over ready access to MRI for the management of MSK problems in primary care.[104] This debate has potential practice implications for the MT due to common two way referrral practices between MTs and primary care providers. Advances in technology have increased the availability of MRI to more typical clinical settings by reducing the size and cost of the unit.[22] The potential negative impact of increased availability and utilization of MRI is not only increased cost but also that more advanced imaging is performed without evidence to suggest that outcomes are improved. When there is adequate pre-test probability of an injury or pathology combined with good evidence that the likely pathology is best managed through a select pathway, the MRI is seemingly justified. For example, there is current evidence that the selective use of a short MRI examination saves costs and increases effectiveness in patients with acute knee injury without apparent fracture on radiography by reducing the duration of the diagnostic work-up, absence from work, and the number of diagnostic examinations.[61,105]

Potential patient management pathways indicated by primary care MRI studies could be physical therapy interventions with strategies such as specific exercise, manual therapy, or immobilization or protected activity, to protect healing structures.[34,106] In other cases where the evidence indicates a favorable risk to benefit ratio, surgery for MRI identified pathology may be an option. There is a trend to use increasingly specialized MRI sequences for select MSK pathologies that are currently of surgical interest.[107,108] Unfortunately, paticularly in the early adoptive stages of new surgical approaches, evidence for the benefit of the surgery may be lacking thereby increasing the use of imaging and driving up cost without knowing if outcomes support the cost of the imaging or the risk of the surgery.[107,108] Potentially, the greatest advantage of ready access to MRI for MSK conditions by direct access MTs or primary care physicians would be that surgical referrral is not needed in order to obtain an MRI. Once the patient has entered the surgical management pathway, the chances that the patient will indeed receive sugery are increased, potentially adding increased cost and increased risk to patient management.[44,109–113]

A challenge for all primary care providers will be to utilize MRI in a manner that is consistent with best evidence and current practice guidelines. A recent retrospective review of MRI and CT imaging procedures ordered by primary care providers and analyzed for appropriateness against evidence-based guidelines revealed that 26% of the procedures did not meet the criteria for the imaging and less than half of the unnecessary procedures revealed anything that guided intervention.[114] Examples of inappropriate MRI studies were for acute low back pain and osteoarthritis of the knee and shoulder.[114] A review of Medicare Part B datasets revealed that growth in the performance of MRI procedures by radiologists between 2000 and 2005 was 85%, while the performance of MRI by nonradiologist physicians increased by 285%.[115] Due to the increase in MRI utlization by nonradiologist physicians, there is concern expressed within the radiology literature over potentially abusive self-referrral practices

when imaging devices are owned by the physician or group of physicians ordering the study.[115]

As the evidence is quite positive for the diagnostic accuracy and appropriately conservative use of MSK imaging by PTs, they could well serve as consultants to primary care providers on the clinical situations meriting MRI. When PTs help identify the clinical situations appropriate for MRI studies, they will faciliate accurate diagnoses and cost-effective patient management. Most providers who refer their patients to PTs routinely order MSK imaging but their knowledge of evidence-based MSK screening and diagnosis strategies may be limited.[100,116–118]

Patient Safety with MRI Studies

Very strong electromagnetic fields are used in the acquisition of magnetic resonance images. Devices such as pacemakers whose function could be disrupted by the magnetic field as well as ferromagnetic implants or foreign bodies are considered contraindications for MRI studies. The Food and Drug Administration states that a device is magnetic resonance safe if the device, when used in the magnetic resonance environment, has been demonstrated to present no additional risk to the patient but may affect the quality of the diagnostic information. In addition, a device is magnetic resonance compatible if the device, when used in the magnetic resonance environment, neither significantly effects the quality of the diagnostic information nor are its operations affected by the magnetic resonance device.[119]

The increasing numbers of military casualties and civilians injured by explosions with retained metal fragments creates imaging challenges for the providers of these patients. Obtaining plain radiographs prior to an MRI study helps screen for retained metal fragments in the imaged body region. Even patients with a history of seemingly innocuous prior injuries such a skin abrasion may have introduced metallic fragments under the skin. Depending on their location, such fragments could cause significant pain during the study, interfere with MRI image quality, and if the fragments are in the proximity of sensitive or delicate structures, cause additional injury. A patient referred to one of our MT fellows in training with a referral diagnosis of plantar fasciitis had an unsuspected 5-centimeter sewing needle deeply embedded in his foot parallel to the metatarsals. The needle was identified when the fellow in training appropriately ordered a radiographic study prior to the desired MRI for the atypical foot pain.

A retrospective review of 10,332 metal screening forms identified 17 patients with verified retained fragments who had underwent an MRI.[120] Upon interview, one of the 17 patients reported a superficial migration of a 10-millimeter fragment post-MRI. The authors concluded that MRI is relatively safe in these patients with particular caution for fragments in the vicinity of vital organs.[120] Industrial metal workers are a population considered at risk when placed in the magnetic field of an MRI. These workers could have undetected metal slivers lodged in their eye that would move under the influence of the strong magnetic field causing ocular damage. Some patients with body tattoos experience pain and skin reactions at the site of the tattoo during and after MRI.[121] Other potential risks with MRI include small to very large foreign ferromagnetic objects attracted into the magnetic field, procedural complications from invasive procedures including infection, and reaction to contrast materials.[122]

Economics of MRI

The economic impact of MRI and other forms of advanced imaging reached the level of presidential debates and many discussions on health care reform in the United States. Despite evidence suggesting that early and inappropriate use of MRI may actually worsen patient outcomes, many providers are pressured by patients or the parents of young athletes to order such imaging. The real economic impact is challenging to determine and may require very large studies and significant resources to perform them. Groot Koerkamp *et al.* used a sample of 189 patients with acute knee trauma to compare radiography alone with radiography plus MRI to determine the optimal design and number of subjects for an MRI study.[123] The authors concluded that a trial should have 3500 patients per trial arm, and collect data on the number of quality-adjusted life-years, cost of an overnight hospital stay, and friction costs. Solomon *et al.* reporting on the trends of utilization of MRI determined that during the period of 1991 to 1995, knee MRI use increased sharply but the proportion of such patients who had a prior diagnosis of internal derangement or subsequently saw a knee specialist or underwent knee surgery decreased.[124] This finding indicates that the criteria for knee MRI appear to have broadened substantially during this period. Such findings suggest that even when the indications for MRI increase, that the number of surgical procedures and the risk within the management pathway may not increase. Vincken *et al.* reported that MRI used as a primary screening tool for non-acute knee pain can be used to successfully triage patients into surgical and nonsurgical groups reducing the number of arthroscopic surgical procedures, the associated total society costs, and the risks associated with surgery.[125,126] In a retrospective review of the records of 204 emergency department pediatric patients with suspected fractures, 51% of patients without fractures were over-treated while 29% with fractures were undertreated.[127] The

authors subsequently proposed that overtreatment and under-treatment of fractures in skeletally immature patients might be reduced with timely access to limited trauma MRI without increasing direct cost.

There are excellent discussions on the use of MRI for a cost conscious provider that are useful in making decisions on expensive tests such as an MRI. Provider beliefs such as 'my patient comes first' versus 'evidence-based decisions' are presented in the context of decisions for an MRI.[128,129]

Summary

Selective and appropriate use of MRI holds great potential for MSK practice. Clinical examination strategies should use the most appropriate clinical tests and measures first and combine MRI as indicated. Inappropriate early use of MRI may complicate patient management and increase patient exposure to risk. Physical therapists working in direct access settings with privileges to order MRI are diagnostically accurate and reduce the need for imaging while decreasing episodes of care and the associated costs of many MSK injuries and conditions. Patients will benefit when family practice or other physicians with less MSK experience receive guidance from PTs or MTs on the situations that merit an MRI. Equally important these MSK experts can help determine the body region that needs to be imaged, and provide key examination findings for the radiologist. The findings from the appropriately comprehensive patient examination will provide the necessary clinical context to MRI findings.

Key Points

1. MRI provides sensitive studies of MSK structures.
2. Patient history information or physical examination tests may equal or exceed the screening capability of MRI.
3. MRI studies are indicated when best evidence suggests the patient will likely benefit.
4. Diagnostic accuracy with MRI requires a competent MSK examination.
5. PTs are diagnostically accurate and appropriate in their use of MRI for MSK patients.
6. Pathology identified on MRI commonly exists in asymptomatic persons.
7. The comprehensive clinical examination provides relevance to identified pathology.

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