CHAPTER **14**

# THE CURRENT ROLE OF MRI IN THE MANAGEMENT OF INFECTION

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Magnetic Resonance Imaging (MRI) is rapidly becoming a valuable tool for assessing bone, joint, and soft tissue pathology. The images are characterized by exquisite contrast and excellent spatial resolution. This allows for superb visualization of anatomic structures and pathological processes. MRI is particularly sensitive to bone marrow alterations and is very effective for detecting a wide variety of soft tissue abnormalities. MRI is also highly sensitive and specific in assessing osteomyelitis in the foot.[1] It can determine the presence or absence of bone infection in addition to mapping out the extent of bone involvement. It is a great asset regarding surgical treatment because it allows the physician to accurately assess the extent of the infectious process. The surgeon can therefore decide whether surgery is indicated, and plan the proper procedure accordingly.

Although MRI can provide valuable information, it is a very expensive adjunctive test. As with any other imaging modality, it should not be used to make a diagnosis. It should only be used if the information provided could not be obtained through simpler means, if it could alter the treatment regimen, or if it could be of benefit for preoperative planning.

## OVERVIEW OF PULSE SEQUENCES

An MRI is conducted utilizing pulse sequences. Although there are many pulse sequences available, the choices can be divided into three main categories based on the combination of TR (time to repetition), and TE (time to echo). Depending on the pathology, certain pulse sequences are preferable over others. The three basic pulse sequences include: T1-weighted images, proton density images, and T2-weighted images. The T1-weighted image combines a short TR (600 msec or less), with a short TE (40 msec or less). The proton (spin) density image combines a long TR (1500 msec or more), with a short TE (40 msec or less). The T2-weighted image combines a long TR (1500 msec or more), with a long TE (90 msec or more). The shorter the TR and TE, the greater the T1 weighting; whereas, the longer the TR and TE, the greater the T2 weighting.[2]

Modifications of these pulse sequences can produce images that are more sensitive in detecting musculoskeletal infections. Short Tau Inversion Recovery (STIR) and fat saturation images display osteomyelitis and soft tissue infections as areas of markedly increased signal intensity, and are more conspicuous than routine spin echo MR images. By utilizing a contrast agent, such as gadolinium, the sensitivity of distinguishing an infectious process versus a noninfectious process is greatly enhanced.

## SPECIFIC PULSE SEQUENCES

The signal intensity of normal bone marrow is variable, being influenced by the percentage of hematopoietic and fatty elements present. The proportions of these cells vary according to age, anatomic location, and physiologic stimulation. Infants have marrow that is predominantly hematopoietic (red marrow). During skeletal growth, this red marrow is progressively replaced by fat (yellow marrow). The normal conversion of red marrow to yellow marrow occurs during the first two decades of life. Also, the epiphyseal and apophyseal growth centers are composed predominantly of yellow marrow throughout life.[2] The signal characteristics of normal adult bone marrow are identical to that of subcutaneous fat.

T1- and T2-weighted images provide the greatest range of contrast; therefore, these images are the first pulse sequences employed on every scan. A T1-weighted image is very useful in displaying normal anatomy. Since subcutaneous fat and bone marrow have the brightest signal, this image is sometimes called the "fat image." Muscle, nerve, and cartilage display an intermediate signal intensity which is gray in appearance. Fluid, tendon, and ligaments have little or no signal intensity on T1-weighted images and appear black. An infectious process warrants an inflammatory response and fluid is seen throughout and around the site. Since fluid displays a decrease in signal intensity on a T1-weighted image, this is a poor image to evaluate an infection.

A T2-weighted image is very useful in displaying pathological processes. It is also called the "water image" because fluid, hematoma, inflammation, and infection have bright signals. Obviously, because of the increase in signal intensity of fluid, T2-weighted images are very sensitive to infection. The difficulty arises in differentiating an infectious process from other pathological processes such as sterile inflammatory responses, neoplasms, post-traumatic episodes, and neuropathic osteoarthropathy. This is where modifications of T1- and T2-weighted images can be helpful.

STIR and fat saturation images are very similar with the exception that a STIR image is not as specific regarding tissues. A STIR image will suppress any tissue with a short T1 value such as fat; whereas, a fat saturation image is specific and will suppress only fat. The STIR and fat saturation techniques are very sensitive to changes in water content. Since the signals of fatty tissues are suppressed, the presence of any fluid is enhanced and well demarcated, providing clear visualization.[3]

Gadolinium is a contrast agent that is often used in combination with other techniques to increase the sensitivity and specificity of diagnosing an infectious process.[4] It is a paramagnetic metal ion and it is usually chelated with DTPA to avoid side effects. Two methods of administration are available, intravenous and intra-articular.

After intravenous administration, the gadolinium is quickly distributed to vascularized inflammatory tissue which reveals enhanced signal intensity. Non-vascularized areas, such as abscesses, display either no enhancement, or enhancement only at the margin of the lesion. This rim of enhancement relates to a peripheral inflammatory zone and the central non-enhanced region indicates necrotic tissue. After intra-articular injection of gadolinium, inflammatory synovial membrane, such as in septic arthritis, will display enhanced signal intensity. The gadolinium enhanced fat saturation technique is an excellent image for delineation of an infection. Since the high signal intensity of fat is suppressed, there is great contrast among tissues.

## SPECIFIC IMAGES FOR SPECIFIC PATHOLOGIES

### Cellulitis

T2-weighted and STIR images are the preferred pulse sequences for evaluation of soft tissue infection.[5] As was stated previously, inflammatory fluid collections are displayed as areas of increased signal intensity on these sequences. Cellulitis typically demonstrates a diffuse, infiltrative pattern throughout the subcutaneous tissues. The soft tissues are thickened, and a bright signal, consistent with edema, is noted on a T2-weighted image. On a T1-weighted image, cellulitis is seen as a decrease in signal intensity due to the inflammatory process infiltrating and replacing the normal high signal of the subcutaneous fat.

The limitation of MRI regarding soft tissue infections is the inability to distinguish cellulitis from non-inflammatory edema; therefore, a thorough and accurate history and physical must be obtained to help make the delineation. As with all other etiologies, the clinical examination should always be the key in making the diagnosis, not the imaging modality. The data obtained from the MRI can be very useful when correlated clinically; however, when used solely, a diagnosis is impossible to make when a vast list of differentials exist. It is possible to differentiate cellulitis from non-inflammatory edema utilizing MRI when a physical examination is concomitantly employed.

### Abscesses

T2-weighted and STIR images are also the preferred pulse sequence for abscess detection.[5] In addition, a contrast agent, such as gadolinium, can be utilized to improve the contrast between these pathologic lesions and normal structures. Abscesses are inflammatory fluid collections. They are localized and well-demarcated and appear as a relatively homogeneous high signal intensity on T2-weighted and STIR images. This discrete margination allows for differentiation of abscesses from cellulitis. An abscess is displayed as an increase in signal intensity on T2-weighted images when it contains inflammatory fluid, but if this fluid is replaced by purulence and necrotic tissue, the signal intensity decreases. As opposed to fluid, the presence of gas, in any tissue, is displayed as areas of markedly low signal intensity on all pulse sequences.

**Osteomyelitis**

Osteomyelitis can be a difficult and challenging diagnosis for a physician to make, especially when it involves a diabetic patient. Early recognition and diagnosis of osteomyelitis are critical so that immediate treatment can be employed and further morbidity prevented. While the gold standard for the diagnosis of osteomyelitis remains bone biopsy and culture, MRI has been shown to be advantageous in certain circumstances. It is particularly useful in diabetic patients with a poor potential for healing, and in patients with peripheral vascular disease where the need for surgical intervention could possibly be eliminated, or the level of amputation could be determined preoperatively. MRI has also been shown to have an increase in sensitivity and specificity when compared to other adjunctive tests, such as scintigraphy and CT scans, for the diagnosis of osteomyelitis.[1]

MRI has the ability to detect changes in the medullary canal, as well as changes in the cortex and periosteum. A T2-weighted image is the pulse sequence of choice for the detection of osteomyelitis, primarily because of its ability to detect fluid in osseous structures. There has been some controversy regarding the use of the STIR technique. Yuh et al.,[6] and Unger et al.,[7] advocate the use of the STIR image over the T2-weighted image for the detection of osteomyelitis, relating that the STIR sequence provides greater contrast. Erdman et al.,[8] found that areas of increased signal intensity on the STIR image did not correlate as closely with proven areas of suppurative bone involvement as did areas of increased signal intensity on the T2-weighted images. Most authorities agree with their suggestion that "reliance in the findings on T2-weighted images could provide greater specificity without significant sacrifice of sensitivity."[8]

The majority of osteomyelitis seen in the foot results from contiguous spread and direct extension of contamination. The initial involvement is in the soft tissues, then the contamination progresses through the periosteum and cortex and extends to the medullary canal. Inflammatory cells and fluid then replace the fat in the marrow. On a T1-weighted image, the normally bright signal of fat is replaced by an intermediate or low signal of edema or pus. Due to this increase in water content and inflammatory process, osteomyelitis is seen as an increase in signal intensity on T2-weighted images.

Simple periosteal elevation from the outer cortex can be seen as a single, linear, low signal band paralleling the outer bony cortex. Laminated periosteal reaction can also be recognized and displayed as concentric low signal intensity lines parallel to the outer cortical margin. High signal intensity, representing pus or non-inflammatory edema, can be seen interposed between these periosteal changes and bony cortex.[9] A similar problem exists for osteomyelitis as with soft tissue infections. Distinguishing infection from a non-infectious process can create a diagnostic dilemma. One of the keys to making the distinction between signal changes reflecting noninfectious bone marrow edema from those representing osteomyelitis is by analysis of the surrounding cortex, periosteum, and soft tissues. Marrow signal changes alone, without concomitant changes of the cortex or periosteum, are not suggestive of osteomyelitis. If signal changes of the marrow only are present, neuropathic osteoarthropathy should be considered.[5]

Chronic osteomyelitis must be discussed separately, because as opposed to acute osteomyelitis, where the cortex and medullary canal are destroyed, they are being remodeled in the chronic state. Cortical changes are typically more extensive than the marrow and are seen as low signal intensity expansions. Areas of active infection may still remain, and can be seen as an increase in signal intensity on a T2-weighted image, contrasted against the lower signal intensity of the thickened surrounding bone. Often, a "rim sign" is noted. This rim is a low signal intensity that reflects fibrous tissue surrounding an area of focal, active disease.[8] "Healed" osteomyelitis is best seen as an increase in marrow signal on a T1-weighted image. This represents the infiltration of fat back into the marrow after resolution of the infection. Sinus tracts are often seen with chronic osteomyelitis and are identified as linear areas of increased signal intensity on T2-weighted images extending from the bone to the surface of the skin. Soft tissue changes are usually localized to the immediate area surrounding the sinus.

### Septic Arthritis

Joint fluid is best detected with T2-weighted and STIR sequences; therefore, changes consistent with septic arthritis are best detected with these images. During an infectious process, the synovial membrane becomes hypertrophied, and increased amounts of joint fluid are produced. Purulence then accumulates within the joint, and the cartilage becomes destroyed. Adjacent osseous structures may become involved and result in osteomyelitis. Joint fluid is detected as an increase in signal intensity on T2-weighted and STIR images. In order to differentiate septic arthritis from a noninfectious effusion, an increase in signal intensity of the surrounding soft tissues, which is reflective of edema, must also be seen.[10] Also, an intra-articular injection of gadolinium may be used to enhance the increase in signal intensity seen in septic arthritis.

## ADVANTAGES OF MRI

MRI has rapidly become a valuable tool for evaluating soft tissue, bone, and joint infection. MRI has several advantages over other diagnostic modalities. One of the main advantages is that it can assist the surgeon preoperatively. It can help localize an infection and determine the proximal and distal boundaries of the infectious process. This is particularly beneficial when assessing osteomyelitis, especially of the long bones. An MRI will outline the boundaries of an infection and help determine how much of a particular bone, such as a metatarsal, needs to be debrided. An MRI will allow the physician to analyze the entire extent of the infection and determine the necessary level of amputation. Although intra-operative findings will ultimately direct the surgeon to the appropriate level of resection, an MRI is an excellent pre-operative guide.

One of the other advantages of an MRI is its ability to asses a patient for other possible sources of infection. An example would be a patient admitted for cellulitis or an infected ulceration that has not responded to intravenous antibiotics and local wound care. Something else must be done for this patient and a different treatment protocol must be implemented. This is where the use of an MRI is validated. An MRI can display secondary sites of infection, such as an abscess or osteomyelitis, that the physician sometimes is unable to assess clinically. If a patient is not responding to current therapies it is time to look for other pathologies, and an MRI is an excellent guide.

Another use for MRI, that is not often utilized but deserves to be mentioned, is to monitor an infectious process. The use of an MRI in this manner has limitations, and should only be used in appropriate situations. One circumstance that would warrant this proper use is osteomyelitis that has not been surgically treated. An MRI would allow the physician to monitor the infection and determine the particular stage of the disease process.

## CONCLUSION

The authors have reviewed the basic MRI pulse sequences available and the most advantageous images to utilize in evaluating a particular pathology. Besides confirming or eliminating a diagnosis, the physician should be aware of the other uses of MRI. An MRI is an excellent pre-operative guide to help the physician localize an infectious process and determine an appropriate level of amputation. It is also a valuable aid in assessing other possible sites of infection, particularly when a patient has not responded to current treatment modalities.

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