REVIEWS

Magnetic resonance imaging in rheumatology

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Magnetic resonance imaging (MRI) is ideally suited to the examination of the musculoskeletal system and is already widely used for this purpose. The technique provides excellent inherent soft tissue contrast allowing direct visualisation of cartilage, muscle, tendons, and other soft tissues, in addition to bones. Further advantages include the multiplanar imaging capability and absence of ionising radiation. The application of specialised surface coils and other technical advances results in high resolution images. Resolution is also improved by using instruments operating at high field strength. This paper reviews the application of MRI to the musculoskeletal system with a particular emphasis on conditions of rheumatological importance.

Spine

Magnetic resonance imaging has assumed a major role in spinal imaging and is now the preferred examination technique after plain film radiography for the investigation of most spinal disorders. The requirement for intrathecal contrast with its attendant risks is obviated by MRI. It is also possible to screen large areas of the spine and follow this with a more detailed examination of a suspect area. This is not

possible using computed tomography (CT) scanning and less effective using myelography. One of the most important advances given to rheumatologists in spinal imaging by MRI has been the direct observation of rheumatoid disease processes affecting the cervical spine and their effect on the spinal cord and brain stem. Although, in contrast with CT scanning, the bony cortex is not seen directly as calcium appears as a signal void on MRI, subcortical bone is clearly seen. As a result of this and also because of the tomographic nature of MRI bony erosions are often more readily depicted. Atlantoaxial subluxation, atlantoaxial impaction, and subluxations occurring at lower levels in the cervical spine are well appreciated on MRI and the effect of flexion and extension of the neck may be examined.¹⁻³ In addition to cord compression due to instability it is possible to identify impingement due to pannus formation, which can be directly seen with MRI (fig 1). The depiction of pannus situated between the anterior arch of the atlas and odontoid is of value in explaining the cause of non-reducible atlantoaxial subluxations.¹⁻³

In the assessment of lumbar radiculopathy MRI has an accuracy of 90%, which is equal or superior to CT scanning after intrathecal contrast.⁴⁻⁵ A specific advantage of MRI is its

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Figure 1 (A) T1 weighted image (TR 500 ms, TE 20 ms) in the sagittal projection in a patient with rheumatoid arthritis. The image was obtained with the neck flexed and the distance between the posterior aspect of the anterior arch of the atlas and the anterior aspect of the odontoid peg is increased, measuring 6 mm. Erosions affecting the superior and posterior aspect of the odontoid are also present (arrows) and the cord is narrowed at the craniocervical junction. (B) T2 weighted image (TR 2700 ms, TE 80 ms) obtained in the sagittal projection in the same patient as in (A) with the neck extended. The narrowed cord at the craniocervical junction is seen and pannus causing erosion of the odontoid and impingement on the theca is seen as a region of high signal intensity (arrow).

ability to show the whole lumbar spine and thoracolumbar junction including the lower cord, thereby ensuring that unsuspected proximal lesions are not overlooked (fig 2). As the bony cortex is not seen directly it may occasionally be difficult to differentiate a hypertrophic spur from a disc protrusion or fully delineate facet joint hypertrophy. In practice the importance of this shortcoming is usually small because the more critical clinical information is the location and extent of impingement on the theca, which is well assessed using MRI. Magnetic resonance imaging is usually recommended in preference to CT in the evaluation of spinal stenosis, but because of the limitation just described it may occasionally be necessary to supplement the MRI examination with limited CT sections. In the detection of thoracic disc disease MRI is also the technique of choice.^{6,7} Studies suggest that CT myelography is slightly more accurate than MRI compared with surgery in the diagnosis of cervical disc disease and stenosis.⁸⁻¹¹ Since these studies were performed there have been considerable technical advances in MRI and it is probable that MRI is now the most accurate technique. The strength of MRI is in the direct observation of intramedullary abnormalities but the relative weakness, in common with the lumbar spine, is in the differentiation of bony protrusions from disc material and this is especially true in the exit foraminae. Plain radiographs, CT scanning, and MRI may need to be used in combination for accurate assessment of the cervical spine.

Further advantages are offered by MRI in the assessment of various types of disc disease. In the degenerative disc there is an overall reduction in hydration of the anulus and nucleus pulposus to about 70%. As the magnetic resonance image is highly sensitive to the degree of hydration of individual tissues the degenerate disc can be identified in the absence of morphological

abnormalities (fig 2).¹² Magnetic resonance imaging has largely replaced discography in the preoperative planning of patients requiring spinal fusion. In the assessment of disc space infection the MRI appearances are highly sensitive and specific.¹³ Nuclear medicine studies using a combination of gallium and technetium 99m bone scanning achieve an accuracy of 94%, which is equivalent to MRI.¹⁴ As MRI provides more information about the thecal sac it is likely to replace radionuclide bone scanning in the investigation of discitis. In patients with discovertebral destruction due to ankylosing spondylitis the plain radiographic changes may be difficult to differentiate from infection. The signal intensity of the disc and adjacent bone seen on MRI combined with the lack of soft tissue swelling which would be expected in infection allow discrimination.¹⁵ Evaluation of the spine after an operation represents a taxing clinical and imaging problem. Contrast enhanced MRI using intravenous gadolinium DTPA is now clearly established as the imaging technique of choice in this context.¹⁶ This paramagnetic agent causes preferential enhancement of scar tissue which can therefore be differentiated from recurrent disc material. An accuracy of 96% has been reported in the differentiation of scar tissue from recurrent disc prolapse.¹⁷

Myelopathy from whatever cause is ideally investigated by MRI. In the context of neoplastic disease MRI allows excellent observation of the superior and inferior extent of compressive lesions. It also allows detection of unsuspected bony and soft tissue disease at sites distant to the cause of the myelopathy and other coexistent problems such as degenerative disc disease.¹⁸⁻²¹

Joint disease

As in the spine, MRI of joints allows direct depiction of disease processes thereby allowing a more accurate assessment of disease extent. Magnetic resonance imaging has a higher sensitivity in the detection of erosions and subarticular cysts than conventional radiography.²²⁻²⁴ It has been suggested that the superior ability of MRI to show erosions may allow identification of subgroups of patients with early aggressive disease and a poor prognosis in whom the impact of prompt treatment could be assessed.²⁴ In addition, MRI allows numerous other radiographically occult abnormalities to be seen. These include joint effusions, cartilage irregularities and thinning, pannus formation, avascular necrosis of bone, various grades of tendon inflammation, and rupture and muscle atrophy. Such changes have been described in relation to multiple joints and a variety of inflammatory arthropathies.²⁵⁻²⁸ An important development has been the use of intravenous magnetic resonance contrast agents in joint imaging.²⁹⁻³³ On unenhanced images it may be difficult to differentiate joint effusions from synovitis and subchondral pannus from subchondral sclerosis. Magnetic resonance imaging after intravenous paramagnetic contrast using appropriate pulse sequences allows these processes to be differentiated and also allows

Figure 2 T2 weighted image (TR 2700 ms, TE 80 ms) of the lumbar spine in the sagittal projection in a patient with low back pain. There is a reduction in signal intensity in the L5/S1 intervertebral disc reflecting a loss of hydration and indicating degenerative change. Minor posterior disc bulging is present. The thoracolumbar junction, lower cord, and cauda equina are clearly seen on this sagittal scan.

hypervascular pannus seen in acute inflammation to be distinguished from fibrous pannus which implies inactive disease. Such information may be of value in assessing response to treatment and in pre-operative planning for patients in whom synovectomy is necessary.^{22 24–33} Synovial tumours and other synovial disorders such as pigmented villonodular synovitis are clearly seen on MRI.^{34 35} It is often not possible to differentiate benign from malignant processes with any degree of certainty but MRI is helpful in assessing the extent of the lesion and degree of bony and soft tissue disease. Owing to the deposition of haemosiderin in pigmented villonodular synovitis the MRI appearances are fairly characteristic, but similar MRI findings may occur in synovial osteochondromatosis. To differentiate the two disorders a knowledge of the presence of calcification on plain radiographs or CT scanning, which usually occurs in the latter disorder, is important. As a result of the difficulty in appreciating matrix mineralisation due to the signal void produced by calcification on MRI no soft tissue or bony tumour should be interpreted without knowledge of the plain radiographic findings.

Magnetic resonance imaging is not only the technique of choice in defining internal derangement of joints due to inflammatory arthropathies; it is also highly accurate in the assessment of internal derangement which may have a traumatic or degenerative aetiology (fig 3). In the assessment of meniscal and cruciate ligament tears in the knee MRI should achieve an accuracy of approximately 95%.^{36–39} Magnetic resonance imaging offers particular advantages in shoulder impingement as the exact site of

impingement can be determined and changes of tendonitis or partial rupture can be detected within the supraspinatus tendon (fig 4) allowing operative decompression before the development of a full thickness rotator cuff tear.^{40 41} In the diagnosis of established rotator cuff tears accuracies of over 90% are reported for MRI, whereas in the assessment of glenoid labral tears slightly lower accuracy rates are generally reported.^{42–45} There are many other areas where MRI has proved to be highly effective in the assessment of trauma, whether it is chronic or acute. Two notable areas include the diagnosis of tears of the triangular fibrocartilage where MRI has an accuracy of at least 90%, and the diagnosis of tendon injuries and tenosynovitis.^{46–48} Magnetic resonance imaging can detect various degrees of cartilage abnormality and it is becoming established as the technique of choice in the diagnosis of chondromalacia patellae and also in assessing the viability and extent of loosening of osteochondral lesions in osteochondritis dissecans.^{49 50} Studies using MRI in osteoarthritis indicate that additional detail is obtained about the nature and severity of abnormalities.^{51 52} Subcortical bony lesions can be characterised and shown in certain instances to have a high fat content and this is also true of some osteophytes. Further work is necessary to determine the importance of these findings. In osteoarthritis of the knee a high incidence of meniscal abnormalities has been observed, raising questions about cause and effect.

Magnetic resonance imaging is the most sensitive and specific technique for the diagnosis of avascular necrosis.^{53 54} The MRI appearances are dependent on the stage of the disease, which can be assessed accurately, as can its extent. Specific findings have been described in transient regional osteoporosis which is another disorder which may present with joint pain and normal radiographs.^{55 56} On T1 weighted

Figure 3 Gradient echo image (TR 30 ms, TE 12 ms, and flip angle 40°) of the knee in the sagittal projection. The posterior horn of the medial meniscus should appear of uniform low signal intensity but there is a region of high signal intensity running horizontally through the meniscus and extending to the inferior articular surface of the meniscus (straight arrow). These findings indicate a meniscal tear which was confirmed on arthroscopy. A joint effusion is also seen as the region of high signal intensity in the lateral recess of the suprapatellar pouch (curved arrow).

Figure 4 Proton density image (TR 1900 ms, TE 30 ms) of the right shoulder obtained in an oblique coronal projection parallel to the supraspinatus muscle and tendon. There is evidence of impingement syndrome. The acromioclavicular joint (arrow) is degenerative with a large osteophyte projecting from the inferior surface. The adjacent supraspinatus tendon is compressed and there is increased signal intensity within it at this site in keeping with chronic tendonitis.

images the bone marrow is of reduced signal intensity, whereas on T2 weighted images it is of increased signal intensity, indicating increased fluid within the bone marrow. As a result of these appearances this disorder is now sometimes referred to as transient bone marrow oedema.

Carpal tunnel syndrome

The anatomy of the carpal tunnel is clearly seen by MRI and various abnormal appearances have been described in carpal tunnel syndrome (fig 5), including enlargement of the flexor tendon sheaths, bowing of the flexor retinaculum and presumed oedema of the median nerve.⁴⁶ Magnetic resonance imaging may be helpful in suggesting the aetiology, as in patients in whom anatomical variants of the course of the flexor tendons, soft tissue tumours or other abnormalities are seen. It is also clear that MRI may assist in identifying causes such as fibrosis or lack of division of the flexor retinaculum in patients who have had a poor response to an operation for carpal tunnel decompression.

Brain

Magnetic resonance imaging was initially applied to imaging the central nervous system and the sensitivity of MRI in identifying lesions within the brain remains unparalleled. In patients with systemic lupus erythematosus and Sjögren's syndrome MRI can detect various types of white and grey matter changes (fig 6), which are thought to be indicative of small vessel vasculitis, frank infarction, and haemorrhage.^{57 58} These changes, which are often not visible on CT scanning, are strongly associated with neuropsychiatric disease.

In certain areas MRI has proved to be such a sensitive technique that it may reveal lesions in patients who are asymptomatic. These range from ischaemic changes in the brain to occult cervical and lumbar disc prolapses and meniscal tears.^{59 60} As with any imaging technique the findings must be considered in the light of the clinical circumstances. Mention should be made of other potential problems which may arise in

Figure 5 Proton density image (TR 2500 ms, TE 25 ms) of the wrist in the axial projection in a patient with carpal tunnel syndrome. The flexor tendons are more widely separated than normal due to fluid within the tendon sheaths indicating tenosynovitis (long arrow). There is palmar bowing of the flexor retinaculum (curved arrow) and compression of the median nerve (short arrow).

Figure 6 T2 weighted image (TR 3200 ms, TE 90 ms) of the brain in the axial projection in a 35 year old patient with systemic lupus erythematosus. There are multiple small areas of high signal intensity in the deep cerebral white matter (one of these is indicated by the arrow). These are typical of small vessel ischaemia.

relation to MRI. The number of patients with claustrophobia who are unable to enter the scanner is reducing due to the fact that most modern instruments have a more open design. In any event this difficulty can usually be overcome by reassurance or, if necessary, intravenous sedation. There are certain groups of patients such as those with cardiac pacemakers and some patients who have had a cerebral operation who are unsuitable for MRI scanning.

The advantages and limitations of MRI in musculoskeletal imaging have now been clearly defined. In most circumstances where arthrography has been applied to joint imaging this will be replaced by MRI as soon as availability allows. Compared with arthroscopy MRI is an accurate non-invasive technique without morbidity or mortality. It offers a wider field of view and the examination is less costly. As a diagnostic technique it is being used in preference to arthroscopy. At the present time the role of MRI in rheumatology is continuing to evolve, but it is clear that the possibilities are considerable. The potential roles in diagnosis and monitoring of responses to treatment are increasing and becoming more widely appreciated. This is bound to be reflected in a fuller incorporation of MRI into clinical practice.

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