Leading article

Magnetic resonance imaging in oncology

Magnetic resonance imaging (MRI) has evolved over the past decade as an important new technique, providing in some circumstances unique and, in others, additional information to that obtained with standard investigations. Its role in oncology is currently under investigation in many centres throughout the world, but even today there are clear indications for its use in the central nervous and musculoskeletal systems. In other areas, the role of MRI is not yet fully established but it certainly seems to have several advantages with regard to imaging bone marrow malignancy, staging pelvic cancers, and in head and neck tumours. MRI may also be useful as a problem solving exercise when other imaging methods have failed to resolve a specific clinical problem relating to malignant disease.

MRI has certain advantages over other imaging techniques, in particular computed tomography (CT). Firstly, the technique does not use radiation, which is of importance even in patients with malignant disease, as they are now surviving longer and frequently undergo multiple follow up studies. Secondly, images can be obtained in any plane, which is a significant advantage over the limited cross sectional plane of CT. Thirdly, the technique has a high contrast resolution which means that tumours are frequently shown with greater clarity than with CT. The MR signal is derived from energy released from hydrogen nuclei when subjected to a radio frequency pulse within a uniform magnetic field. The energy released can be measured as relaxation time. There are two types of relaxation time (T1 and T2), which are based on the sensitivity of the hydrogen ions to their local molecular environment. The relaxation times of different tissues depend upon their water content (long for fluids, short for solids). Tumours contain a relatively high water content and therefore have a relatively long T1 and T2 compared with normal soft tissue. Images can be produced which reflect either T1 weighting, T2 weighting, or a combination of both. On T1 weighted images tumours have a low signal intensity, appearing dark; on T2 weighted images they have a higher signal and look bright. New sequences are rapidly being developed – for example, images can now be obtained in which the fat or water component of the tissue is suppressed independently and MR angiography also shows great promise.[1,2] Thus the scope of this new technique is enormous and its technological capabilities are being explored vigorously.

From this brief description it is clear that the information derived from MRI is already significantly greater than that from most of the other imaging techniques. Intravenous contrast medium (Gadolinium DTPA – Gd DTPA, Schering Health Care Ltd), has added a new dimension to MRI, particularly in the central nervous system. Gd-DTPA behaves in a manner similar to the iodinated contrast medium used in CT. Thus tumours in the brain show enhancement due to destruction of the blood/brain barrier and other organs in the body, such as the liver, show enhancement of normal parenchyma.[3,4]

MRI has had a major impact on the diagnosis of primary and secondary tumours within the central nervous system. It was first recognised to be of particular value in the diagnosis of posterior fossa lesions, where CT images are frequently degraded by artefact from bone. The facility to obtain images in the sagittal plane also enables the relationship of tumours to the fourth ventricle to be readily seen. With rapid improvements in the spatial resolution of MRI systems, the greater sensitivity of MRI to pathological change in cerebral tissue has become apparent. In an ideal world, it would now be the preferred method of evaluating brain pathology unless there were a specific contraindication, for example, the presence of ferro-magnetic clips on intracranial vessels.

Supratentorial infiltrating, low grade gliomas are often difficult to identify on CT because they are not associated with significant mass effect and may not enhance with intravenous contrast medium. The extent of tumour apparent on MRI compared with CT is often surprising. Also, lesions that are apparently multifocal on CT may clearly be contiguous on MRI, and spread of tumours across the corpus callosum is well demonstrated.[5]

The development of the MRI contrast medium Gd-DTPA has been valuable in delineating the margins of intracranial tumours. Gd-DTPA is also of value in assessing tumour recurrence after surgery, with the rider that for the first few postoperative months the hypervascular scar tissue does not have a blood/brain barrier and hence enhancement at this stage does not necessarily indicate that residual tumour is present.[6]

MRI has been shown to be more sensitive than CT in demonstrating intracranial metastases, particularly when Gd-DTPA is used.[7,8] Metastases usually appear as areas of high signal on T2-weighted images, although metastases from mucinous adenocarcinoma from the gastrointestinal tract may have a low signal. Demonstration of multiple metastases may be particularly important when planning surgical resection or localised radiotherapy for an apparently solitary metastasis. Alternatively, it may be important to demonstrate the presence of unsuspected brain metastases in high risk patients when planning management. Although CT can be as sensitive as MRI in the detection of nodular leptomeningeal tumour, enhanced MR imaging is more sensitive in the detection of diffuse meningeal enhancement against the inner table of the skull.[9] MRI is also a sensitive way of detecting nodular or diffuse leptomeningeal carcinomatosis in the spinal canal.

The excellent soft tissue resolution and multiplanar capability of MRI are of particular value in imaging the pituitary fossa, where the relationship of tumours to the optic chiasm and other important surrounding structures can be shown.[10] Acoustic neuromas and other extra-axial tumours are also visualised optimally on contrast enhanced MRI.[11]

Although CT is still the most widely used method of evaluating the head and neck, the superior demonstration of soft tissue planes with MRI enables more accurate delineation of the extent of head and neck tumours and also helps in differentiating between inflammatory and neoplastic conditions.[12] Short TI inversion recovery MRI sequences enable a tumour of the base of skull to be more readily identified by nulling the high signal from bone marrow, and Gd-DTPA is of particular value in the assessment of lesions of the base of skull and sinuses and in assessing intracranial spread of tumours.[13]

Myelography and CT are still widely used in the evaluation of spinal pathology but MRI is superior and is likely to

replace myelography, particularly as it is possible to visualise the spinal cord without introducing intrathecal contrast medium. Gd-DTPA enhancement of tumour helps to distinguish tumour from the normal spinal cord and a benign syrinx. The sagittal plane is the most helpful for imaging spinal pathology, supplemented by axial images of the area of abnormality or suspected pathology. Coronal images are also of value in the assessment of paraspinal masses with an associated intraspinal component.

Before the advent of MRI intramedullary tumours were often difficult to detect on myelography, particularly infiltrating lesions with only minimal expansion of the cord. Intradural extramedullary metastases from primary intracranial malignancies are also readily identified on contrast enhanced MRI.[14]

The evaluation of spinal cord compression from metastatic bone disease with MRI is another area in which this technique excels.[15] The patient does not have to be positioned uncomfortably as in myelography and multiple sites of cord compression, which are often not seen on myelography or CT myelography, can be visualised.

MRI has already made a valuable contribution to the management of patients with musculoskeletal tumours and has become the investigation of choice for staging patients with primary bone tumours.[16,17] The technique, however, is of little value in predicting the histological tumour type. Thus, the distinction between a benign and malignant lesion may be impossible since signal intensity values are similar for both, and, furthermore, the characteristic patterns of cortical bone destruction and new bone formation cannot be well visualised on MRI. Plain radiography, with its superior spatial resolution, remains a key investigation in the initial diagnosis of a primary bone tumour.[17] After initial diagnosis, MRI is the ideal method of demonstrating the extent of bone marrow involvement and the presence and extent of an associated soft tissue mass. Its multiplanar capability is an added advantage in evaluating musculoskeletal tumours because these frequently develop in the limbs which can be imaged in the longitudinal plane.

Soft tissue sarcomas, although rare, are also very well demonstrated with MRI because of the high contrast between muscle (low signal) and tumour (high signal) on T2 weighted sequences. In addition, involvement of major neurovascular structures and bone can also be diagnosed with a high degree of accuracy.[18] As with primary bone tumours, MRI should be regarded as the investigation of choice before surgery for soft tissue sarcoma and is also helpful for monitoring the response to treatment and detecting any recurrence.

Bone marrow imaging is emerging as a very exciting new application of MRI.[19] In adults, normal bone marrow contains largely fat and therefore has a high signal. Tumours within the bone marrow have a low signal and are therefore clearly depicted against a background of fatty marrow. There is a rapidly growing body of literature supporting the efficacy of MRI for evaluating patients with bone marrow malignancy, and the technique has already been shown to be highly sensitive for detecting bone marrow metastases even in the absence of abnormal plain radiographs, conventional computed tomograms and radionuclide studies.[20] MRI may also have a useful role in monitoring response and detecting relapse in patients with diffuse bone marrow malignancies such as leukaemia,[21] multiple myeloma, and lymphoma. At present MRI is not routinely used in clinical practice for assessing bone marrow malignancy, but as scanners become more widely available, there is little doubt that this field will expand into one of the major applications of MRI in oncology.

The use of MRI for staging pelvic cancers has recently increased and as technology advances with the development of surface coils and endoscopic coils, pelvic imaging is likely to become a prominent application. Numerous studies published over recent years have shown the potential advantages of MRI for staging pelvic tumours.[22-24] MRI is likely to become the prefered technique because the internal anatomy of organs such as the uterus, cervix, and prostate, is clearly shown on T2 weighted sequences. Furthermore, the ability to image in multiple planes is particularly valuable in the pelvis, where extension of a tumour into adjacent structures may not be detected on a cross sectional CT image.

In patients with bladder cancer, MRI has a small but significant advantage over CT in assessing the presence of extra vesical spread. For example, MRI may show tumour spread beyond the bladder wall in the sagittal or coronal plane which cannot be seen on CT.[24] MRI may also show early organ invasion which cannot be detected on CT.[25] In addition to these advantages, MRI seems to be a reliable method of distinguishing between tumours that affect the deep muscle of the bladder wall and those affecting the superficial layers.[24,26] Again, this is a significant advantage over CT which is totally unreliable for staging early tumours.

CT is a poor technique for staging prostatic cancer and there is now substantial evidence to demonstrate that MRI is significantly better.[23,27] Transrectal ultrasound and MRI should therefore be regarded as the techniques of choice for staging prostatic cancer, but as yet there is no firm agreement as to which of these techniques is the most accurate.[28,29] The development of endorectal coils for MRI is likely to improve further the results with this technique.[30]

The gynaecological organs are elegantly demonstrated on T2 weighted sequences. The uterus can be readily distinguished from the cervix and furthermore, the endometrium can be distinguished from the 'junctional zone' and myometrium. Local spread of tumours arising in the cervix or uterus can be much more accurately assessed than with CT, because of the high contrast between the abnormal tumour and the surrounding normal structures. Accuracy rates in the region of 80–90% can be achieved for staging both prostatic and cervical cancer with MRI.[23,27,31]

The efficacy of MRI for evaluating tumours in the chest is not yet clear. There are occasions when MRI provides better information than CT, largely because intravenous contrast medium is not required to distinguish vessels from tumour. In addition, MRI may show extension of the tumour through the chest wall which cannot readily be seen on CT because of the lack of contrast between the tumour and chest wall muscles. The multiplanar capability of MRI is also useful for examination of the chest, and of areas such as the branchial plexus and axillae in patients with suspected recurrent breast cancer.[32] One of the major disadvantages of MRI in the chest is the inability to visualise the lungs, which are simply seen as a signal void. Thus CT remains the most effective method for diagnosing small pulmonary metastases.

In the abdomen, MRI has not yet found its place in routine clinical practice. One of the major drawbacks is that no good bowel contrast agent is commercially available and it is therefore frequently difficult to distinguish tumour from loops of bowel. Furthermore, respiratory and bowel motion cause movement artefacts that frequently degrade the image. However, the current situation is likely to change over the next few years, as major advances in technology take place. The liver is the one organ in the abdomen in which MRI has been shown to be slightly better than CT in the detection of focal lesions.[33-35] However, MRI is currently used as a second line investigation, for example to characterise a known liver lesion seen on CT rather than for full abdominal staging. MRI may show involvement of the renal veins and inferior vena cava in renal cell carcinoma and has the advantage over CT of demonstrating the tumour thrombus not only in the axial but in the coronal plane where the superior and inferior extent of involvement can be clearly shown.[36]

Compared with the wealth of information already available in the assessment of untreated tumours, relatively little attention has yet been given to the role of MRI in monitoring tumour behaviour in response to treatment and detecting relapse. As with CT, MRI can show changes in tumour volume, but in addition changes in signal intensity of the tumour may also be observed. For example, soft tissue sarcomas and lymphomatous masses show a reduction in signal on T2 weighted images in response to treatment, and bone tumours may show a mixed response with persistent areas of low signal remaining and areas of high signal developing within the bone marrow.[37] It is probable that these changes in signal represent areas of necrosis, granulation tissue, and fibrosis but their importance in terms of clinical management and in identifying residual active cancer remains uncertain. There is some evidence to indicate that MRI is a useful technique for diagnosing tumour recurrence since malignant tumour masses can be distinguished from fibrotic tissue on the basis of signal intensity.[38] However, small foci of tumour within an area of fibrosis may be undetectable on MRI, which means that the technique cannot be regarded as completely reliable.

MRI has been much slower to develop than CT, but its impact in those areas where it clearly has a substantial advantage has been enormous, namely the central nervous system and the musculoskeletal system. Furthermore, the value of MRI in other areas of oncology, is beginning to be recognised and there is little doubt that further advances in technology and in the development of new contrast agents will carry MRI into a new era.

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