The role of magnetic resonance imaging

When to use it and what to look for

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There are no specific MRI features which are diagnostic in bone and soft tissue sarcomas, but a combination of certain findings allows an accurate diagnosis in some cases including giant cell tumour, chondrosarcoma, liposarcoma, neurofibrosarcoma, aggressive fibromatosis and pigmented villonodular synovitis.

MRI is the method of choice for staging bone and soft tissue sarcomas. It is of particular use for identifying satellite nodules and skip lesions within the same bone or anatomical compartment. CT scan is important for screening for pulmonary metastases, and bone scan remains useful for screening for distant skeletal disease.

The biopsy should be planned and performed after any MRI examination.

MRI is the most sensitive post-therapy evaluation for local recurrence of bone and soft tissue sarcoma.

The last decade has seen great progress in the management of bone and soft tissue tumours with the advent of combination chemotherapeutic regimens and new surgical limb-sparing techniques. MRI originally had a major role in detection, diagnosis, staging and post-therapy evaluation of bone tumours, and now has a significant role in operative planning for limb-sparing surgery, and monitoring of response to medical therapy.

The principles of biopsy and definitive surgery are based on the biological behaviour of soft tissue sarcoma. Soft tissue sarcoma grows in a centrifugal fashion. The tumour is surrounded by compressed, non neoplastic tissue that forms a soft pseudocapsule. As the lesion grows microscopic satellite nodules extend into the pseudocapsule, and 20% of high grade soft tissue sarcomas have skip metastases found in normal tissue beyond the pseudocapsule. These satellite tumour nodules and skip metastases are usually confined to the compartment of origin of the lesions and tumour extension is typically in a longitudinal direction within the compartment. Major fascial septa, cortical bone, articular cartilage, joint capsule and neurovascular sheaths constitute the main barriers to tumour extension. Lung metastases occur in 10% of cases at presentation, but eventually more than 25% of patients will develop pulmonary metastases during the course of their illness. Soft tissue sarcoma rarely metastases to lymph nodes except for synovial cell sarcoma and epithelioid sarcoma.

In many countries the general limitations of MRI include cost effectiveness, availability and medical contraindications including biomedical devices, metallic foreign bodies and severe claustrophobia. The examination is more difficult in children and grossly obese people may not fit into the gantry.

Techniques

The examination should include T1 and T2 weighted spin echo images in orthogonal planes, always including the axial plane. Either coronal or sagittal longitudinal images can be performed depending on the location of the lesion. Slice thickness and spacing is chosen so that T1 and T2 weighted sequences can be correlated in the corresponding planes. When fat suppression is used, a corresponding non suppressed T1 weighted sequence should always be obtained. With current technology, fat suppression should only be used when the field of view is relatively small and close to the centre of the magnet. STIR sequences are useful for evaluating subtle marrow abnormalities. In particular, if the abnormality is not obvious on conventional spin/echo sequences, the STIR sequence may guide subsequent detailed examinations.

Gadolinium enhancement is only used for specific purposes including differentiation of post operative scar from local recurrence of tumour, and differentiation of peritumoural oedema from infiltrating tumour.

Surface coils including multi array coils are selected depending on the size of the field of interest. For

bone lesions the entire medullary cavity of the bone in question is examined from the joint above to the joint below to detect any skip lesions. For soft tissue lesions the entire length of the involved anatomical compartment is examined for the same reason.

The long axis sequences should be angled along the long axis of a long bone or anatomical compartment. The femur is angled medially in the coronal plane and bowed anteriorly in the sagittal plane, so both planes may be necessary to avoid volume averaging in marrow lesions.

Diagnosis

Bone sarcoma

The plain film remains the mainstay of diagnosis for bone lesions (Stoker 1989). In many cases the appearance is sufficiently characteristic to establish a working diagnosis with a short list of differentials. Plain radiography clearly demonstrates the pattern of bony destruction, zone of transition, matrix architecture and the nature of any periosteal reaction (Lodwick et al 1980). CT scanning demonstrates the same features but is better for detecting any cortical breach and subtle matrix mineralisation. It also provides specific attenuation values for some tissues eg fat.

MRI usually does not provide a specific diagnosis. MRI has major limitations including demonstrating thin egg shell-like rims of preserved cortex and fine matrix mineralisation. It has been well recognised for many years that there is a significant overlap of MR appearances and signal intensities of benign and malignant bone lesions (Berquist 1993). Some exceptions to these principles exist and are discussed below.

Haemosiderin is seen on MR images of giant cell tumours of bone in two thirds of the cases and is probably related to the extravasated erythrocytes in the tumour and the phagocytic function of the tumour cells. The MR finding of magnetic susceptibility artefact indicating the presence of haemosiderin supports the diagnosis, even in giant cell tumours in uncommon locations or in patients who are not in the typical age range (Aoki et al. 1996).

Some cartilaginous tumours show typical MR features and lobular architecture. Low grade chondrosarcomas show septal enhancement and histological correlation shows these septa consist of fibrovascular tissue. The non enhancing areas consist of hypocellular hyaline cartilage, cystic mucoid tissue and necrosis (Geirnaerdt 1993). Inhomogeneous larger areas of enhancement correlate with highly cellular areas at histopathological analysis and are seen in all high grade chondrosarcomas. Osteochondromas show peripheral enhancement that correlates with fibrovascular tissue covering the non-enhancing cartilage cap.

The sensitivity of MR imaging to changes in marrow signal intensity may lead to an over estimation of the aggressiveness of some benign lesions, particularly in children (Hayes et al. 1992). Such lesions include chondroblastoma, osteoid osteoma and eosinophilic granuloma. Potentially misleading MR features include prominent marrow oedema, soft tissue oedema and apparent mass effect adjacent to the bone lesion. It is presumed these lesions cause an associated inflammatory reaction to explain the MR findings and in children this inflammatory reaction is more extensive where the periosteum is more loosely attached.

Soft tissue sarcoma

There is also marked overlap between the characteristics of benign and malignant soft tissue tumours. There are however a few lesions with characteristic appearances which enable more precise differentiation (Ma 1995). The traditional criteria for discrimination of benign and malignant lesions include size, degree of neurovascular involvement, peritumoural oedema, inhomogeneity and involvement of the adjacent bone. These criteria are not useful for discrimination on their own, but with a combination of these and other findings benign and malignant disease can be distinguished by experienced radiologists (Weatherall 1995).

The location of the neoplasm is of great diagnostic value. When a subscapular mass shows MR signal intensities consistent with fibrofatty tissue the diagnosis of benign elastofibroma can be confidently made.

A completely homogeneous appearance on T1 and T2 weighted sequences suggests benign aetiology. The absence of heterogeneity is fairly reliable as a negative predictive indicator for the presence of malignancy. If homogeneous high signal is noted on T2 weighted images then a very high percentage of these lesions will be found to be benign. If the lesion has low signal relative to muscle on T1 weighted sequences and very high signal on T2 weighted sequences, and is homogeneous, then it represents a benign cyst of some type including: synovial cyst, bursal cyst, ganglion cyst, tenosynovial cyst, benign myxoma and old haematoma. The great majority of myxoid sarcomas will be heterogeneous in some way. However, homogeneous low signal lesions on T2 weighted sequences do not have the same benign association. Small, highly cellular malignancies commonly have this pattern, particularly round cell tumours.

Tumours with lobular morphology and curvilinear internal septa are likely to be malignant.

A high degree of vascularity and corresponding rapid contrast enhancement has been associated with malignancy, although with time, this is likely to become a less reliable discriminator with overlap from some benign lesions. In particular, tumour margins definitely do not discriminate between benign and malignant lesions with some reports indicating a higher percentage of malignant lesions with smooth margins than their benign counterparts (Weatherall 1995).

Definitive identification of fat is readily achieved on any MR imaging system. Identification of benign lipomatous neoplasm is highly accurate. Most lipomas have a very homogeneous pattern, with large lobules separated by thin septa. However, inhomogeneity within lipoma is fairly common and does not of itself indicate malignant degeneration. Low grade liposarcomas and benign lipomas are morphologically and histologically similar, and so MR features similarly overlap. Prominent interlobular septa are thought to indicate a more "aggressive" lipoma. Frank sarcomatous degeneration is usually recognised as a large area of heterogeneity.

Nerve sheath tumours are associated with a neurovascular bundle. Neurofibromas have a distinct pattern of internal architecture, consisting of central heterogeneity on T2 weighted sequences, and peripheral high signal intensity greater than fat. This has been described as the "target pattern". In one study this target pattern was not seen in any of the nine malignant nerve sheath tumours and may therefore be a good differentiating feature (Suh et al 1992). The increased vascularity in the central portion of neurofibromas gives rise to a characteristic pattern of rapid central contrast enhancement, early washout and late peripheral staining. Advanced neurofibrosarcomas will commonly have marked inhomogeneity throughout the lesion including areas of necrosis giving the opposite pattern of contrast enhancement.

Intramuscular cavernous and capillary haemangiomas have a distinctive internal architecture. On T1 weighted sequences they commonly have slightly higher signal than adjacent muscle due in part to fat associated with the lesion. On T2 weighted sequences markedly increased signal is seen in globular patterns with intervening tubular flow voids. These lesions are not confined to one anatomical compartment and do not have any mass affect.

The characteristic pattern for aggressive fibromatosis is central "fingers" of low signal intensity on both T1 and T2 weighted sequences. When non vascular signal voids are seen on T1 weighted sequences directly adjacent to an aponeurosis then a strong presumptive diagnosis of benign fibromatosis can be made.

Pigmented villonodular synovitis is almost always intracapsular in location and the low signal intensity seen on T2 weighted spin echo sequences relates to haemosiderin deposition and is a fairly reliable marker for this disease. Giant cell tumours of tendon sheaths resemble pigmented villonodular synovitis histologically. Unfortunately, the haemosiderin magnetic susceptibility artefact is not seen as commonly in this condition (Gelinek 1989).

Staging

The staging of bone and soft tissue sarcoma depends on histological grade, anatomical extent and presence or absence of metastases. One of the primary roles of MRI is assessing the anatomical extent of bone and soft tissue sarcomas.

The limbs are divided into various compartments separated by natural relative barriers such as the periosteum, articular cartilage, joint capsule, fascial planes and neurovascular sheaths. These barriers can be penetrated by tumour or by surgical procedures. These barriers are relatively deficient in some areas including the trunk, the root of the limbs, and periarticular regions.

CT has been shown to be superior to plain radiography for assessment of intramedullary extent, extraosseous extent and relationship to neurovascular bundles. CT is also the primary modality of choice for detection of pulmonary metastases in bone and soft tissue sarcoma.

MRI has been shown to be superior to CT in assessment of intramedullary and extraosseous extent of bone sarcoma and relationship to neurovascular bundles of soft tissue sarcoma. MRI has superior multiplanar capability for assessment of boundaries of anatomic compartments of the extremities for staging of soft tissue sarcoma.

One of the limitations of the MRI is the differentiation of peritumoral oedema from actual tumour extent. Some authors believe that images derived from sequential post contrast MR studies showing initial rates of enhancement allow differentiation between tumour and non neoplastic oedema thereby guiding the surgeon in planning limb-sparing procedures (Lang et al. 1995).

For the assessment of metastases the following principles can be applied:

1. Thin section overlapping helical CT with high spatial resolution reconstruction algorithm and single breath hold examination is the technique of choice for detection of pulmonary metastases.
2. For patients without localising skeletal symptomatology whole body bone scintigraphy including all

of the axial and appendicular skeleton is the screening method of choice.
3. For those cases where investigation of the axial skeleton is required in the presence of clinical symptomatology whole spine MRI examination is recommended (Pomeranz et al. 1994).

Biopsy

Any biopsy should be carefully planned to avoid transgression of natural compartmental barriers. Image guided biopsies are best performed using fluoroscopic or CT technologies. However, MRI can and should be used to plan the biopsy route in the following ways:

1. The site to be biopsied should be selected to be representative of the bulk of the lesion, to avoid areas of necrosis, or to demonstrate the histology in the most aggressive part of a predominantly benign appearing lesion.
2. The needle track should be planned to avoid transgression of compartmental barriers and damage to regional vital neurovascular structures; and designed to be excised along with the relevant compartment in any subsequent definite surgical procedure.
3. In this way, any staging MRI examination can be performed before the definitive biopsy procedure, thus avoiding the well known problems of post biopsy haemorrhage which make it difficult or impossible to accurately stage the lesion.

Posttherapy evaluation

Assessment after surgery and/or radiotherapy

Serial MRI examination is the most sensitive test for local recurrence. If there is any suggestion of lump or mass effect, post contrast scans can be used to differentiate recurrent tumour from surgical scar.

Radiation changes in the marrow are most obvious in the vertebra. Fatty replacement may be noted as soon as two weeks after initiation of therapy. Return of haemopoietic marrow can occur after this period, and may be difficult to differentiate from recurrent tumour. Thallium scan is useful in this setting.

Metal implants can lead to significant artefact and image degredation post operatively, however, MR imaging can still provide useful information with less artefact than CT. Metal implants cause less artefact on low field machines (less than 0.5T). T1 weighted sequences are affected less than T2 weighted sequences and many gradient echo sequences. Therefore, simple pre and post contrast T1 weighted spin echo images can be used to determine if recurrent or residual tumour is present in this setting.

Assessment of response to chemotherapeutic regimes

Anatomical response is assessed by changes in size of lesion as shown by MR examination. In addition, change in signal intensity and improved demarcation reflect a good response to therapy, whereas increase in size and increase in peritumoural oedema indicate a poor response to therapy. Functional response can also be assessed with physiologic tracers chelated to radioisotopes, which may carry greater prognostic significance than morphological changes in lesion size (Rosen et al. 1993).

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