



1 Patient with multiple coils applied in preparation for a whole body study.

Whole Body MRI – Recent Applications

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Background

Whole body Magnetic Resonance Imaging (MRI) has been established in the imaging literature as a legitimate staging technique and realistic alternative to multimodality conventional staging methods (e.g. Computed Tomography (CT), bone scan) for patients with known malignancy where presence and location of metastases may affect treatment and prognosis [1, 2, 3]. However, MRI examination of the whole body or a large portion of it may also be useful in evaluating non-neoplastic conditions. Distribution of extensive local lesions

and of multi-organ systemic disease may be assessed and monitored, providing useful clinical information. High soft tissue contrast, high spatial resolution, multiplanar capability and lack of ionizing radiation make MRI a suitable modality for examining large areas of the body, particularly in patients who may need numerous follow-up studies in their lifetime. Recent technological advances in MR hardware and software have allowed decreased scan times, without compromising image quality.

Technical innovations enabling whole body MRI

Hardware

Moving table: No repositioning of patient is required during the scan, with 205 cm z-axis coverage on our 1.5T MAGNETOM Avanto.

Integrated coil system: With Tim – the Total imaging matrix – multiple phased array coils are applied simultaneously avoiding the need to change coils mid-exam.

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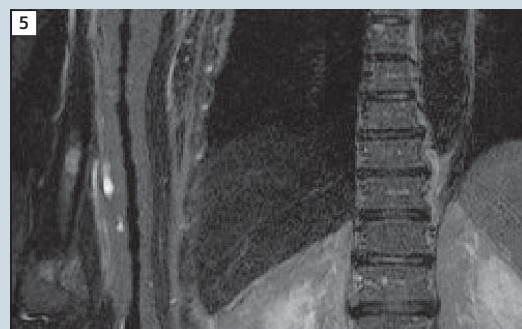
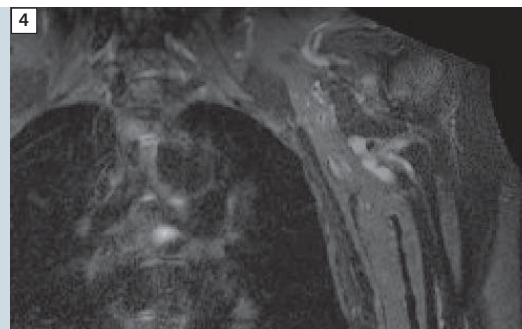
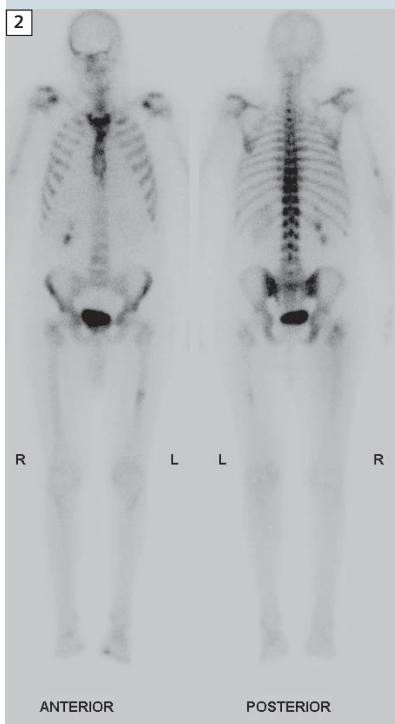
Renal Cell Carcinoma

Case 1

68-year-old male with known right renal mass, and increased uptake in right humerus, right intertrochanteric region and left femoral shaft on bone scan (Fig. 2).

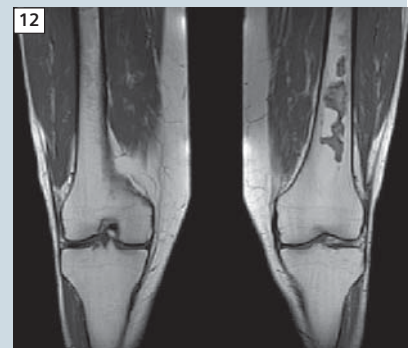
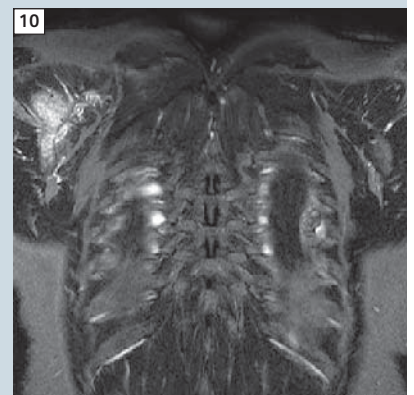
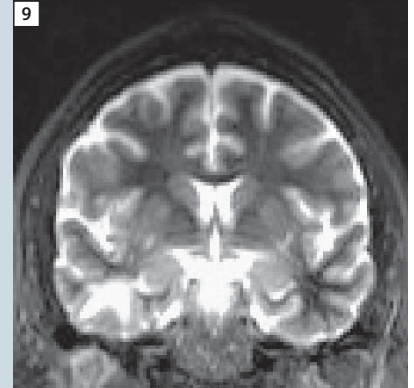
Whole body STIR coronal MRI demonstrates the renal mass & confirms the metastases seen on bone scan (Figs. 3–5).

Numerous additional bone metastases were identified – in the right ischium, left acetabulum and intertrochanteric regions and left glenoid (Figs. 4, 6, 7).

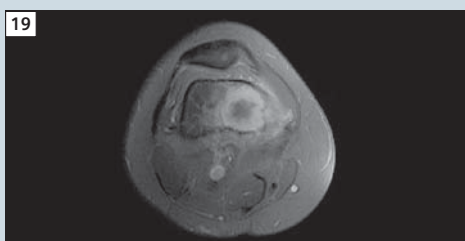
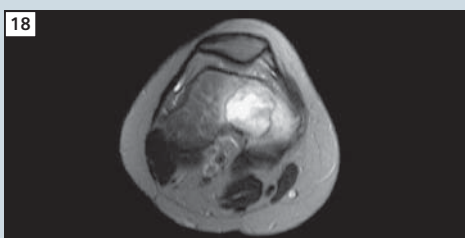
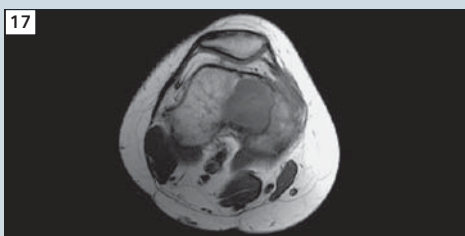
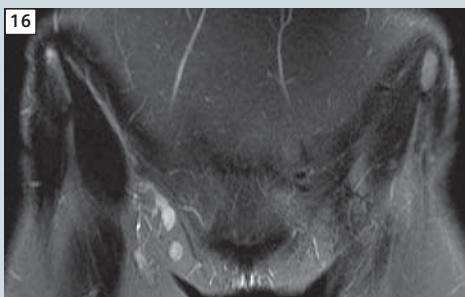
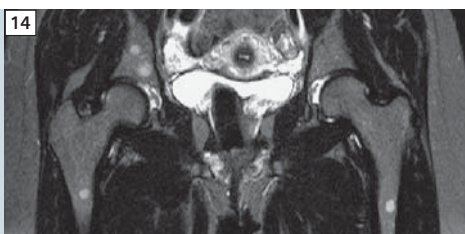


Case 2

50-year-old male presented with previous renal cell carcinoma and right scapular mass. Whole body coronal T1 and STIR sequences were performed to screen for other lesions, revealing a right temporal lobe lesion, left posterior rib metastasis and bone infarcts in the distal femora (Figs. 8, 9, 10, 12), the latter thought due to previous chemotherapy. Axial sequences helped characterise the scapular mass (Fig. 11).

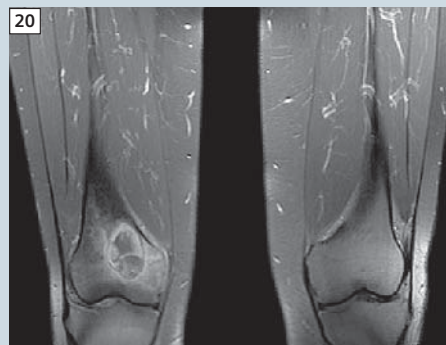


Malignant Melanoma



Case 3

42-year-old female with past history of melanoma, and known lesion in the distal right femoral metaphysis (Fig. 13). At whole body MRI, 4 other right femoral, 1 left femoral, bilateral acetabular and sacral lesions (Figs. 14, 15) and right inguinal lymphadenopathy (Fig. 16) were demonstrated. This precluded radical curative resection of the distal femoral lesion (Figs. 17–20. T1, T2, and fat-saturated post contrast T1 axial and coronal images of the femoral lesion).

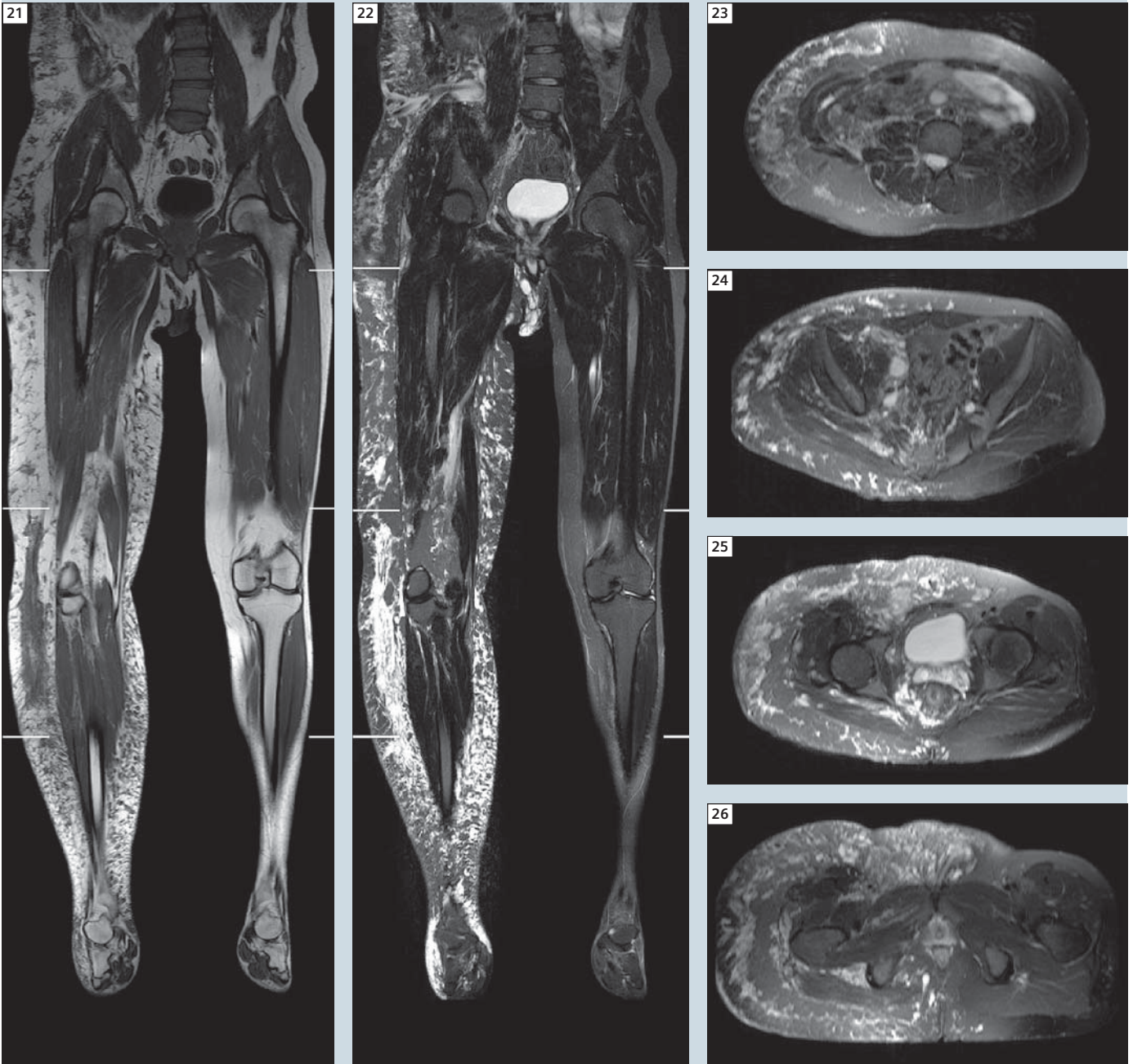


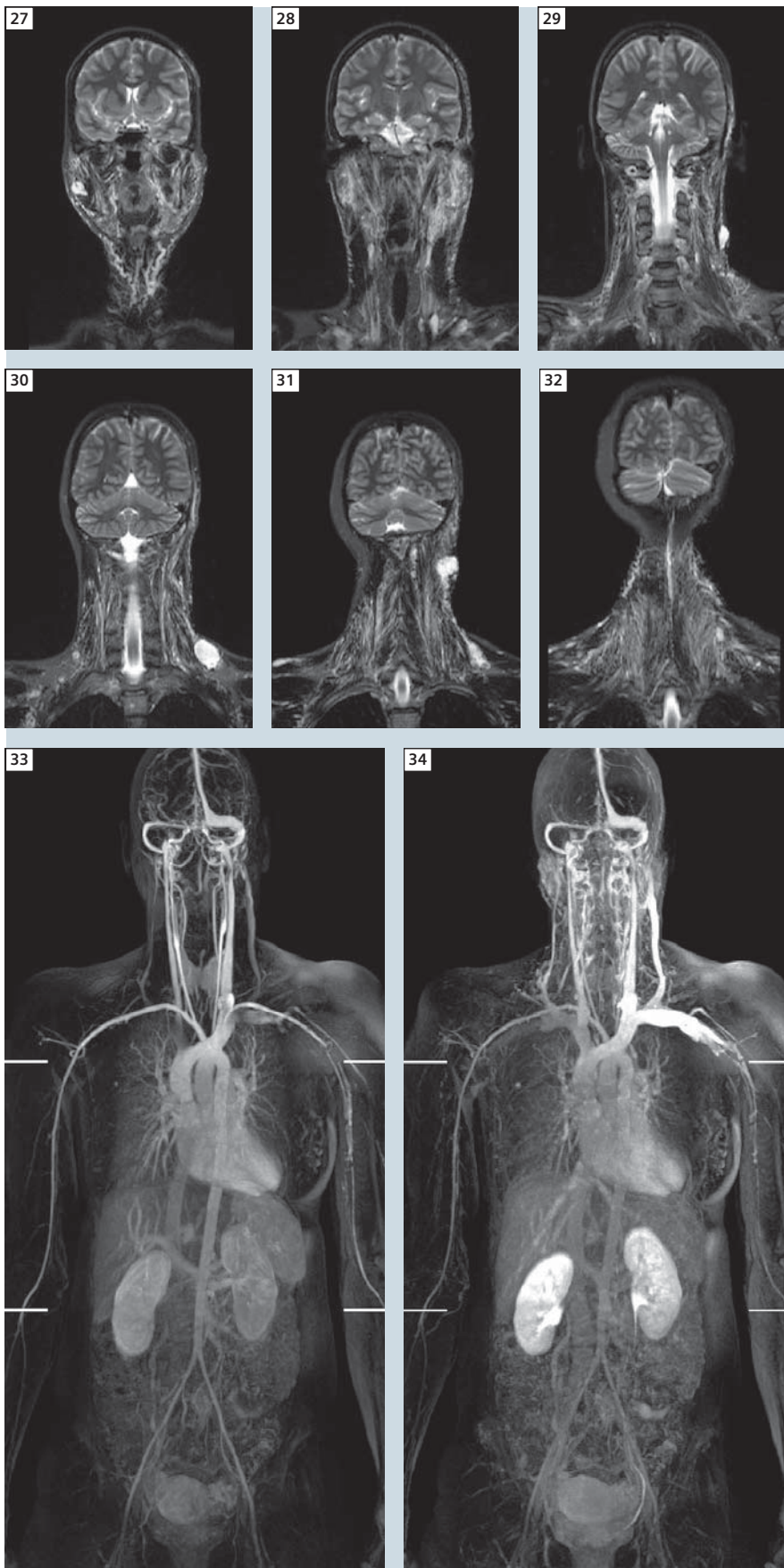
Lymphatic / vascular malformations

Case 4

32-year-old male presented with large lymphatic malformation of the right leg. T1 and STIR coronal sequences (Figs. 21, 22) show an extensive, predominantly subcutaneous malformation involving the leg, thigh, groin/buttock and abdominal wall. Fat saturated T2-weighted axial images (Figs. 23–26) give further anatomical information – the malformation involves the plane between gluteus maximus and the bony pelvis, and also extends into the true pelvis.

Surgical excision is the method of choice for local lymphatic malformations, but complete removal of the epithelium of the lesion is required for success. This is not practical in diffuse disease such as this case, where multiple complex surgical and percutaneous therapies may be required. Accurate anatomic detail is obviously essential prior to considering treatment options [4].

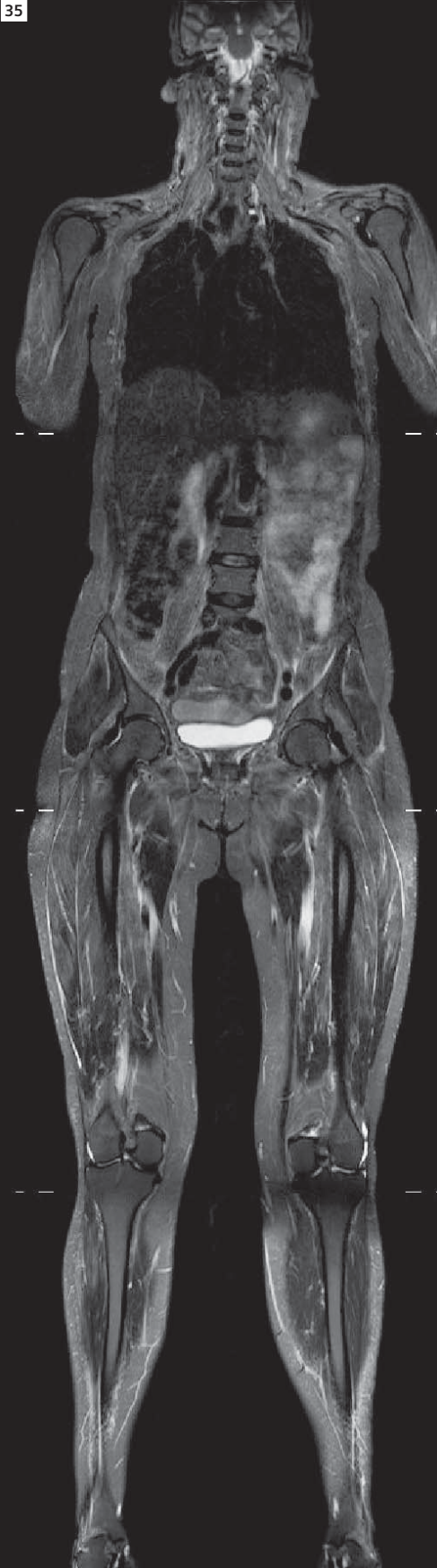




Case 5

32-year-old male presented with large vascular malformation of the neck. Coronal STIR images (Figs. 27–32) show the extent of the lesion, which involves the superficial neck, lower face and left scalp, right masseter and posterior cervical muscles. Arterial phase of post contrast MRA (Fig. 33) demonstrates normal arterial architecture of the neck and upper arms, without early venous filling, indicating a slow flow vascular malformation. The malformation is starting to fill on the venous phase of the dynamic study (Fig. 34).

The two major roles of MRI in adult vascular malformation assessment are to delineate the anatomy of the lesion, and to differentiate slow from high flow vascular malformations. The latter is critical in determining appropriate management – high flow lesions may be treated with embolization, low flow lesions with sclerotherapy [4].



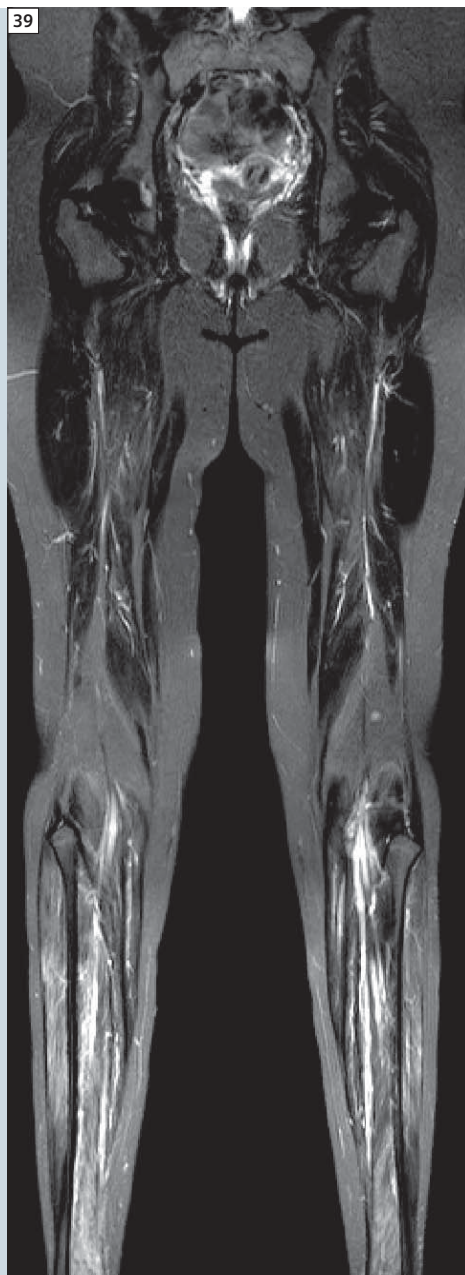
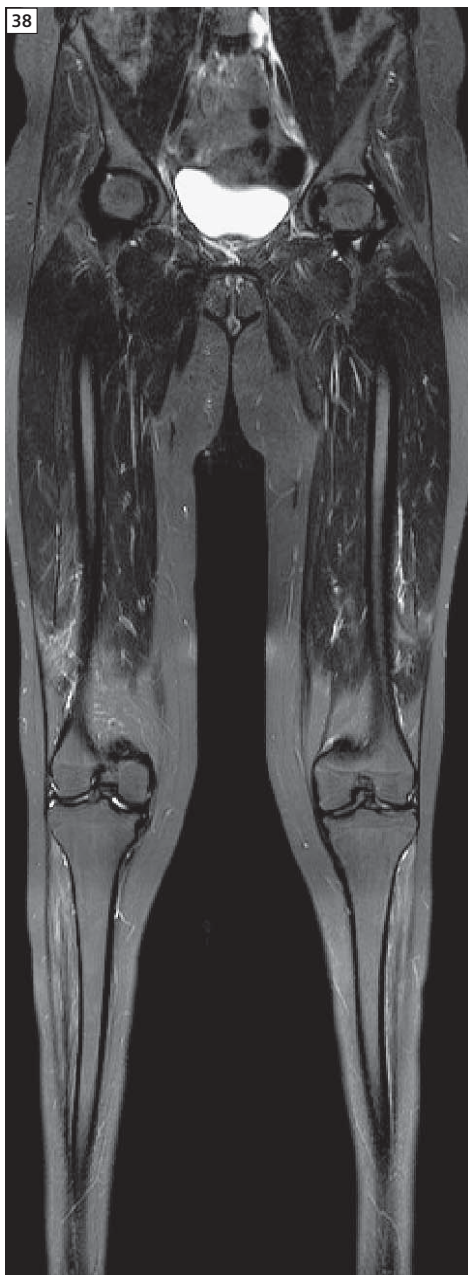
Muscle disorders

MRI is being used increasingly in assessment of inherited neuromuscular disorders including muscular dystrophies and mitochondrial disorders, and in acquired myopathies/myositis. Abnormal muscle signal, atrophy and fatty or fibrotic infiltration is well depicted. Distribution of disease can help direct appropriate genetic and biochemical investigations, and help target diagnostic muscle biopsy [5].



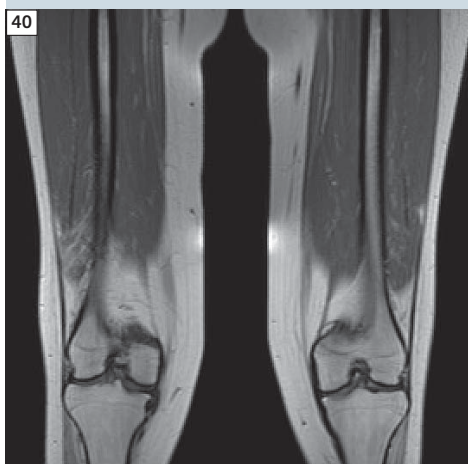
Case 6

54-year-old female presented with proximal limb weakness. Abnormally high signal in quadriceps muscles bilaterally were seen on STIR (Figs. 35, 36), without fatty infiltration on T1-weighted images (Fig. 37). This helped guide muscle biopsy, with subsequent diagnosis of dermatomyositis.



Case 7

14-year-old female presented with known hereditary myopathy, of uncertain type. The distribution of involved muscles is demonstrated, with abnormal signal on STIR (Figs. 38, 39) and fatty infiltration on T1-weighted images (Figs. 40, 41) in the distal vastus lateralis, and marked atrophy of the calf muscles bilaterally.

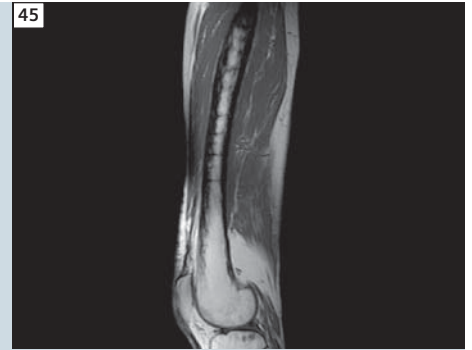


Bone disease

Extended portions of the skeletal system may be covered with MRI.

Case 8

This 83-year-old male with known Paget's disease presented with increasing left hip and thigh pain. Coronal T1-weighted and STIR sequences (Figs. 43, 44) demonstrate changes of Paget's, without oedema, frank fracture or aggressive bone lesion identified. Note previous open reduction and internal fixation (ORIF), right femur. Following initial image acquisition, coronal and sagittal curved MPR's of the bowed left femur were reconstructed to better evaluate the entire length of bone in continuity (Figs. 42, 45).



Neurofibromatosis

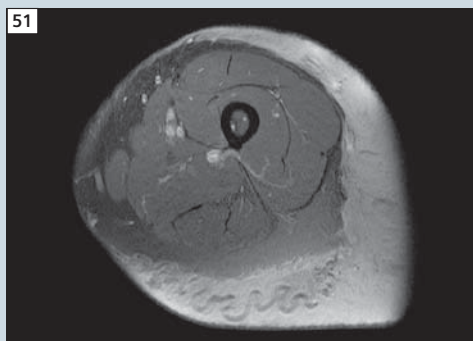
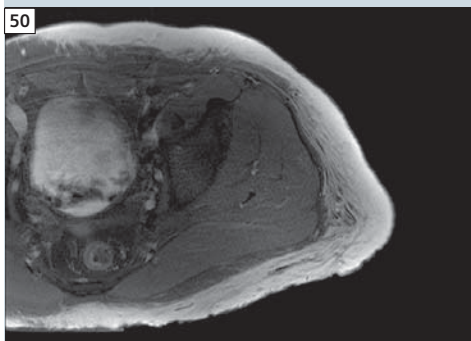
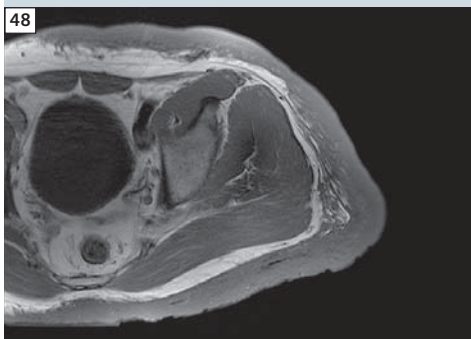


Case 9

35-year-old male with large plexiform neurofibroma of left buttock and thigh. These lesions are frequently disfiguring, disabling and if large, are prone to spontaneous haemorrhage. This was a pre-operative study prior to debulking, following numerous previous episodes of haemorrhage.

Coronal STIR and sagittal T1-weighted sequences from above pelvis to below knee show an extensive but superficial lesion, confined to skin and subcutaneous tissue (Figs. 46, 47).

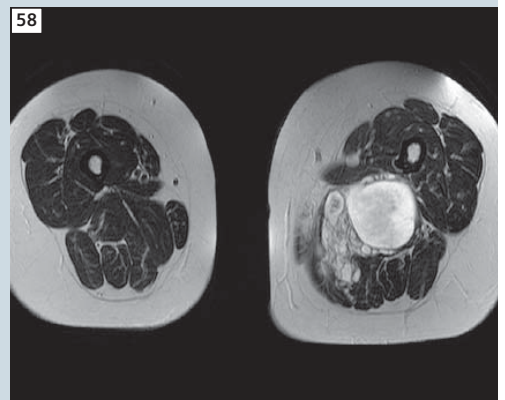
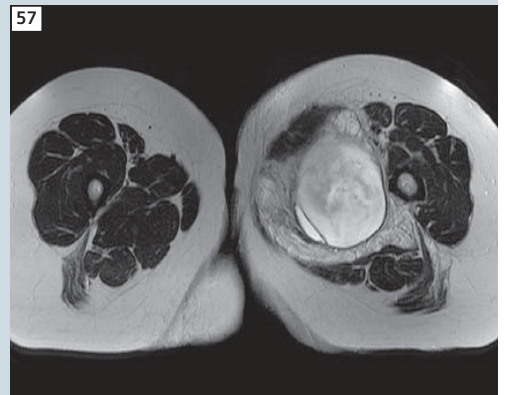
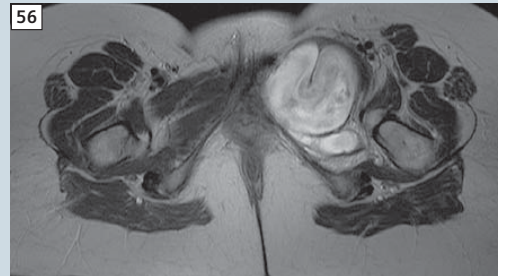
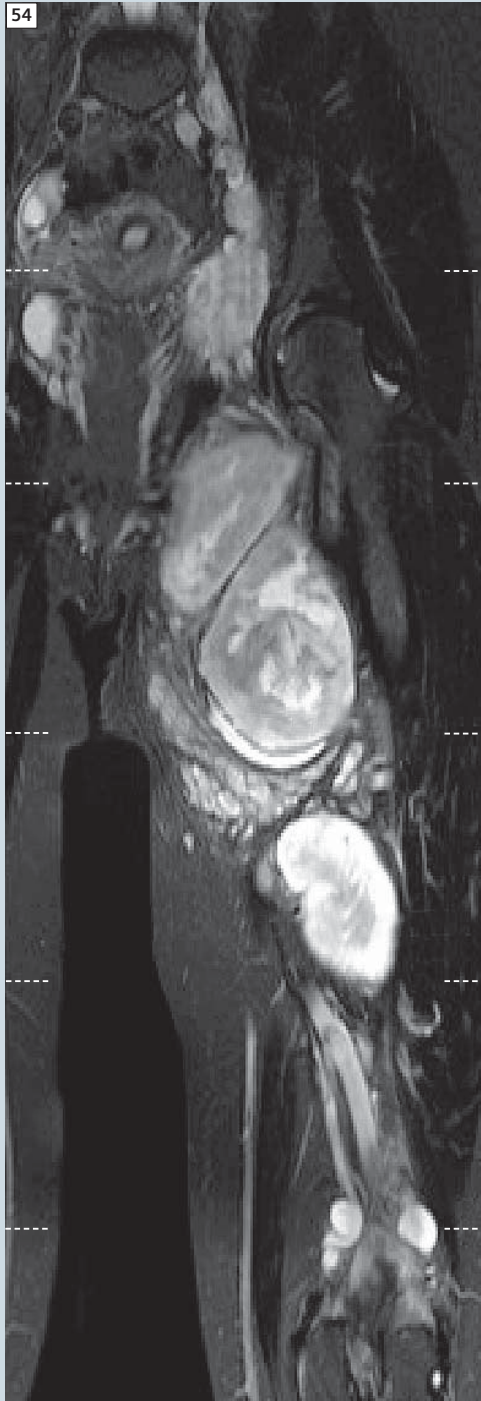
Axial T1-weighted pre and post gadolinium images show vivid enhancement of the tumor. Large vessels are evident within the lesion (Figs. 48–51).



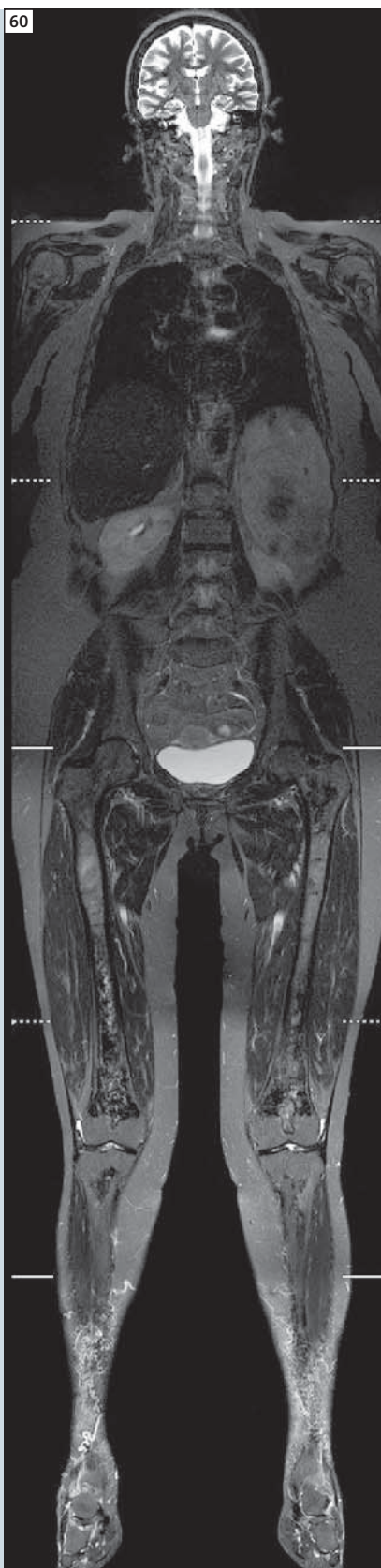
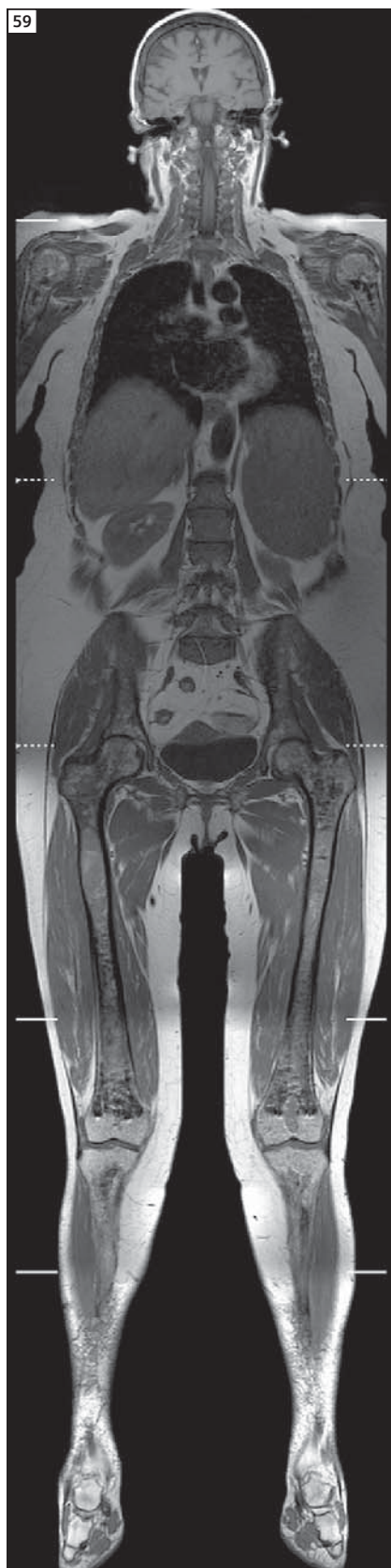


Case 10

17-year-old female with type 1 neurofibromatosis, prior to debulking of left pelvic / thigh plexiform neurofibroma. The study was performed to evaluate the anatomy and extent of the tumor, and to screen for other lesions. The extensive lobulated plexiform lesion involves the left pelvic side wall, adductor and extensor compartments of the thigh, and extends along the neurovascular bundle down to the popliteal fossa (Figs. 53–58). Prior ultrasound had suggested a left adnexal mass – MRI showed no other lesion in the pelvis apart from the large neurofibroma. Small mediastinal neurofibromas are also evident (Fig. 52). No other lesions were identified.



Gaucher's disease



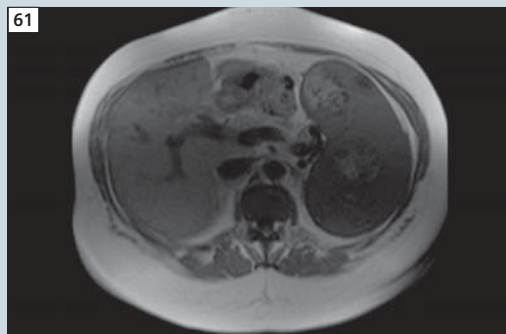
Case 11

69-year-old female with Gaucher's disease, a lysosomal storage disease due to deficiency of the enzyme glucocerebrosidase, leading to accumulation of glucocerebroside in liver, spleen, bone marrow and rarely, the lungs and brain. Complications of the commonest, non-neuronopathic form of the disease may include hepatomegaly, splenomegaly, hypersplenism, bone pain, bone infarcts and fractures due to osteopaenia and cortical thinning.

Radiologic findings include hepatosplenomegaly, osteopaenia, osteonecrosis, bone infarcts and bone deformity such as Erlenmeyer flask deformity. Radiologic assessment is useful in determining pattern of disease, and monitoring response to enzyme replacement therapy [6].

T1 and STIR coronal sequences of the whole body demonstrate marrow infiltration and bone infarcts in both femora, and hepatosplenomegaly (Figs. 59, 60).

The focal splenic lesions seen best on T1-weighted axial and coronal TrueFISP sequences (Figs. 61, 62) are thought to be clusters of Gaucher cells – monocyte/macrophages laden with glucocerebroside [7].



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Multiple input channels: Allow simultaneous signal reception from multiple coils, reducing exam time.

Improved magnet design: Short bore, quieter machines improve patient comfort.

Software

Sequences: Turbo Spin Echo (TSE) techniques.

Parallel acquisition technique: iPAT decreases exam time, as spatial information from multiple receiver coils is used to reconstruct a single image.

Improved user interface and post processing: For example automatic composing software.

Imaging protocol

Advised protocols vary between authors and institutions. Most published material relates to imaging for metastases or vascular disease.

At our institution, we tailor our study depending on the primary pathology under investigation. Coronal T1 and STIR sequences are used predominantly, with additional sequences as required, for example:

- T1 and T2 axial sequences of the primary area of pathology are often performed for anatomic detail.
- When screening for metastases, dynamic post contrast liver, post contrast T1-weighted coronal sequences of the whole body and FLAIR sequences of the brain are added.
- When characterizing vascular malformations, MR Angiography (MRA) is added.

Total examination time is usually 30–45 minutes.

The shown cases are some examples of the use of whole body MRI, beginning with staging studies of patients with known malignancy, followed by other examples of the use of the technique.

Limitations of whole body MRI

- **Usual contraindications to MRI**
For example pacemaker, claustrophobia, large body size, patients over 550 lbs
- **Availability of current generation scanner**
- **Lymph node evaluation**
Differentiating reactive nodes from malignant nodes remains problematic.
- **Post-operative evaluation**
Differentiating post-operative changes from residual or recurrent tumor can be difficult.
- **Organ-specific problems in detecting metastases or synchronous disease:**
 - Bone** – scintigraphy may be more sensitive in rib, scapula and skull metastases [1].
 - Lung** – CT is more sensitive in detecting nodules < 6 mm [1].
 - Colon** – MR is not sensitive in detecting neoplasms unless MR colonography is performed.
- **Follow-up requirements**
If a lesion is detected during screening for metastases, a patient may need to return for dedicated diagnostic study of the lesion.

Conclusion

Due to ongoing technical advances, MRI has become a practical method of rapidly and accurately assessing the whole body or large body areas. Ongoing evaluation will be required to determine the diagnostic performance and cost-effectiveness of whole body MRI in cancer patients, but it offers a promising single-modality screening method for metastatic disease. In non-neoplastic conditions, whole body MRI may be the imaging test of choice due to lack of ionizing radiation, excellent soft tissue contrast and multiplanar capability.

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