
PICTORIAL ESSAY

T2 Dark Lesions of the Musculoskeletal System: A Pictorial Essay

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INTRODUCTION

A T2 'dark' or hypointense lesion is one that shows signal intensity lower than that of muscle on T2-weighted (T2W) sequences on magnetic resonance imaging (MRI). Since the suppressed signal of fat can also account for a hypointense signal on fat-suppressed T2W images, both fat-suppressed and non-fat-suppressed T2W images should be evaluated before classification of a lesion as hypointense on T2W images.

The signal intensity of tissues on T2W sequences depends on their relaxation time. The spin of free and bound protons and water content of tissues affect their T2 relaxation time. The T2 relaxation time also depends on the arrangement of macromolecules and local inhomogeneities in the tissue. Tissues with a long T2 relaxation time show hyperintense signal while those with short T2 relaxation time show hypointense signal on T2W images.¹

A hypointense signal on T2W sequences is the result of T2 shortening.¹ An increase in local inhomogeneities in tissue leads to T2 shortening. Paramagnetic materials such as haemosiderin, gadolinium, free radicals, and diamagnetic materials such as calcium cause T2 shortening by increasing the local inhomogeneities.¹

For the same reason, metals (ferromagnetic) also result in hypointense signal on T2W sequences. The susceptibility artefact or the blooming artefact produced by paramagnetic and ferromagnetic substances is more pronounced on T2 gradient recalled echo (GRE) sequences than on spin echo sequences. This helps in better detection of blood products such as haemosiderin.

Most musculoskeletal pathologies such as infections, tumours and synovitis appear hyperintense or 'bright' on T2W sequences. The hyperintense signal is due to increased perfusion or fluid content. Musculoskeletal lesions that show low signal intensity on T2W sequences are less commonly seen in clinical practice and may be overlooked sometimes by the radiologist. We describe a few examples of the common T2W hypointense musculoskeletal lesions arising from the synovium, bone, and soft tissues in this pictorial essay.

EXAMPLES

T2-weighted Dark Synovial Lesions

Pigmented Villonodular Synovitis

Pigmented villonodular synovitis (PVNS) is an uncommon benign, hypertrophic process characterised by villous, nodular and villonodular proliferation of the synovium with haemosiderin deposition. In the

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intraarticular form, there is diffuse or focal involvement of the synovium of the joint while extraarticular PVNS occurs in a bursa or tendon sheath. Involvement of the bursa is referred to as pigmented villonodular bursitis or giant cell tumour of bursa while involvement of the tendon sheath is known as pigmented villonodular tenosynovitis or giant cell tumour of the tendon sheath or tenosynovial giant cell tumour. The knee is the most common site of intraarticular PVNS and pigmented villonodular bursitis, while the commonest site of pigmented villonodular tenosynovitis is the tendon sheath in the hand and foot. The intraarticular and extraarticular forms are subdivided into diffuse (23%) and localised (77%).²

MRI of intraarticular PVNS reveals diffuse and

heterogeneous thickening of the synovium that may show nodularity.² The synovial thickening shows low-to-intermediate signal intensity on all pulse sequences with multiple low signal intensity foci lining it that show “blooming” on GRE sequences (Figure 1). The low signal intensity foci represent haemosiderin. The synovial thickening shows prominent diffuse enhancement on post-contrast scans. Associated joint effusion and subchondral erosions can also be seen. Giant cell tumour of the tendon sheath is seen as a well-circumscribed soft tissue mass in close relationship to the tendon, showing hypointense signal on both T1-weighted (T1W) and T2W sequences (Figure 2). Giant cell tumour of the bursa has a typical bursal location and shows signal characteristics similar to intraarticular PVNS.

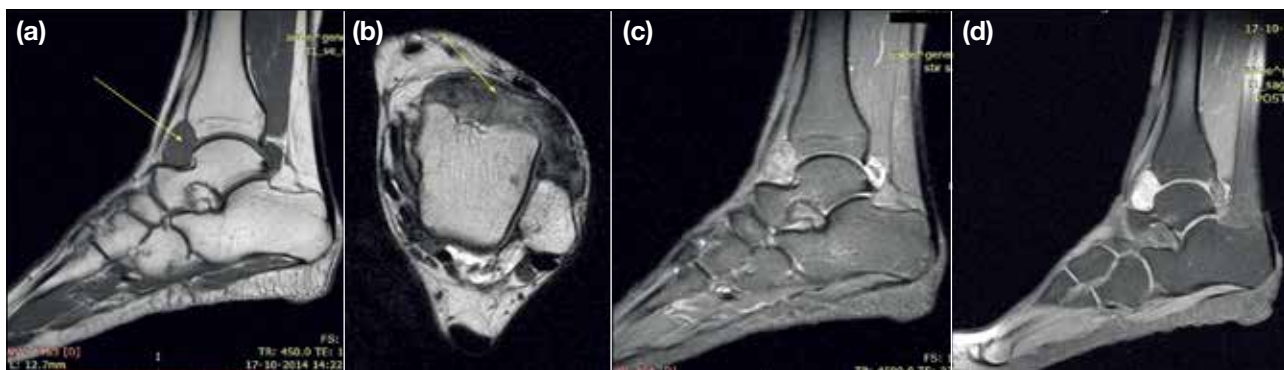


Figure 1. Intraarticular pigmented villonodular synovitis. (a) Sagittal T1-weighted image of the left ankle showing a focal nodular mass (arrow) involving the synovium of anterior recess of the ankle joint showing hypointense signal intensity. (b) Axial T2-weighted image the mass (arrow) showing low signal intensity. (c) Sagittal short tau inversion recovery image showing intermediate signal intensity of the mass. (d) Sagittal post-contrast image showing intense enhancement of the mass. Minimal joint effusion is also noted along the posterior tibiotalar joint. Biopsy revealed pigmented villonodular synovitis.



Figure 2. Giant cell tumour of the tendon sheath. (a) Axial T2-weighted image showing a well-defined hypointense soft tissue mass (asterisk) on the flexor aspect of the middle finger of the right hand. (b) Sagittal and (c) coronal short tau inversion recovery images of the third finger showing low signal intensity of the mass. The mass (asterisk) is seen adjacent to and partially encasing the flexor tendon (arrow) of the middle finger. (d) Coronal post-contrast image showing heterogeneous enhancement within the lesion. Biopsy revealed tenosynovial giant cell tumour.

Synovial Osteochondromatosis

Synovial osteochondromatosis is divided into primary and secondary forms. The primary form is a rare idiopathic process characterised by proliferation and metaplasia of the synovium into osteocartilaginous nodules. These nodules eventually dissociate from the synovium and result in multiple intraarticular loose bodies. The knee joint is the most commonly involved joint.³ Secondary synovial chondromatosis is a similar condition but is associated with underlying joint pathologies. Also, the osteocartilaginous nodules in the secondary form are fewer and of variable size and shape contrary to the primary form where nodules are approximately the same size and shape.³

MRI findings depend on the degree of mineralisation of the cartilaginous nodules. Mineralised cartilaginous bodies show hypointense signal on T2W images

(Figure 3) while nodules having chondroid components show only a hyperintense signal. Extension of intraarticular chondromatosis into the bursa can also be seen. Synovial thickening and bone erosions are other additional MRI findings.

Haemophilic Arthropathy

Haemophilia is an X-linked recessive disorder with deficiency of coagulation factors. Multiple episodes of bleeding into a joint (haemarthrosis) in patients with haemophilia lead to haemophilic arthropathy. The arthropathy is characterised by synovial inflammation and fibrosis with haemosiderin deposition. There may be associated erosion of the cartilage or the subchondral bone. Haemophilic pseudotumour formation can also be seen in some patients. Pseudotumours are cystic masses formed in the bones or soft tissues as a result of recurrent haemorrhage into these structures.



Figure 3. Synovial osteochondromatosis. (a) Axial T1-weighted and (b) sagittal T2-weighted images of the right knee showing knee joint effusion. (b) Sagittal T2-weighted image showing multiple small low signal intensity intraarticular bodies (arrow) of different shapes and sizes in the suprapatellar recess. (c) These intraarticular bodies (arrow) are better appreciated on the sagittal gradient recalled echo image. (d) Axial post-contrast image showing synovial thickening and enhancement.

On MRI, the synovium appears diffusely thickened. On T2W sequences, multiple foci of low signal intensity lining the synovium are seen that show blooming on GRE sequences (Figure 4). Other MRI findings in haemophilic arthropathy include synovial enhancement, joint effusion and cartilage erosions. Haemophilic pseudotumours

are seen as lesions with fluid components that show heterogeneous signal intensities (Figure 5). A low signal peripheral rim may be seen, appearing hypointense on all sequences. The heterogeneous signal reflects the blood products in various stages of evolution and the dark peripheral rim denotes haemosiderin or fibrous capsule.⁴

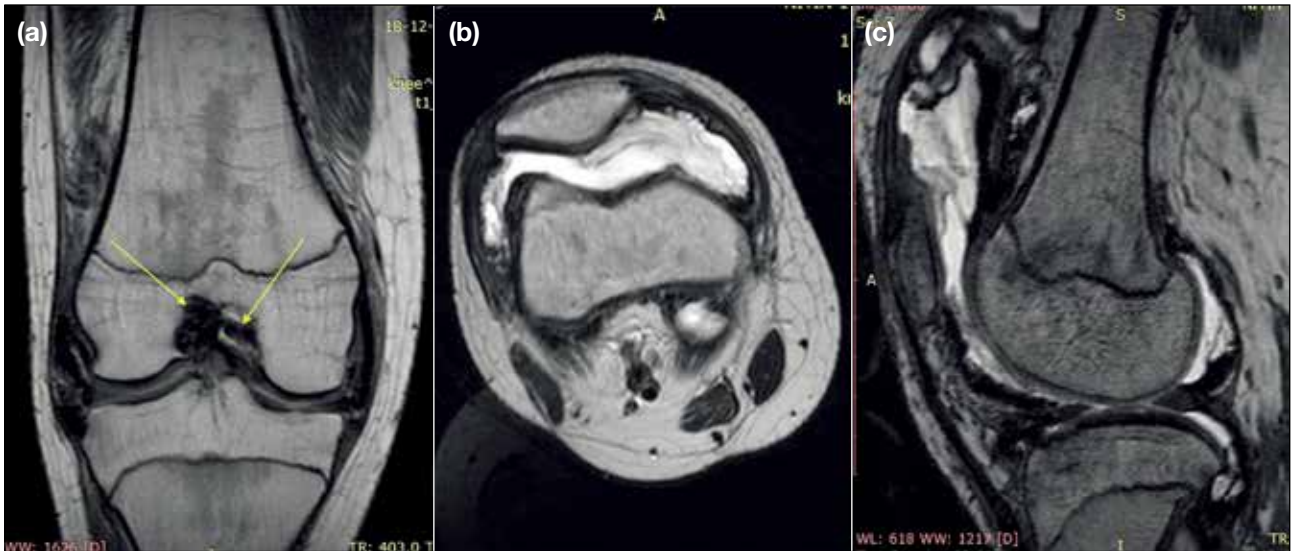


Figure 4. Haemophilic arthropathy. (a) Coronal T1-weighted image of the left knee in a patient of haemophilia showing hypointense foci (arrows) lining the synovium secondary to haemosiderin deposition. (b) Axial T2-weighted image showing heterogeneous signal intensity in the synovial fluid reflecting different stages of haemorrhage. (c) Sagittal T2-weighted gradient recalled echo image showing thickened and hypointense synovium with clumps of low signal lining and blooming suggestive of haemosiderin deposition. Haemarthrosis is also noted extending to the suprapatellar bursa and soft tissues.

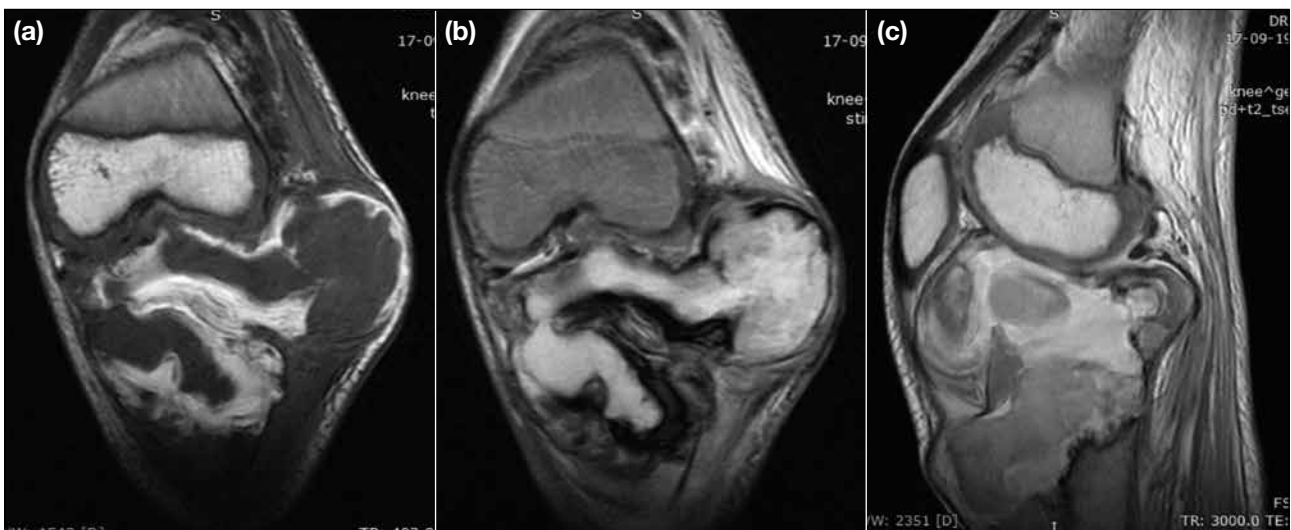


Figure 5. Haemophilic arthropathy with pseudotumour. (a) Axial T1-weighted image of the left knee in another patient with haemophilia showing a massive intraarticular bleed with extension into the adjacent soft tissue. (b) Coronal short tau inversion recovery image showing hypointense signal lining the synovium. (c) Sagittal proton density image showing extension of bleed into proximal tibia and adjacent soft tissue suggestive of pseudotumour formation. Synovial fluid showing heterogeneous signal intensity due to blood products at different stages.

Rice Bodies

Rice bodies are commonly seen in chronic inflammatory or infectious arthritis such as rheumatoid arthritis and tuberculosis. Inflammation in these conditions leads to synovial hyperplasia with consequent erosions of the cartilage and subchondral bone. As a result, multiple small intraarticular loose bodies are formed. These intraarticular loose bodies resemble grains of rice in morphology, hence are named rice bodies. On MRI, rice bodies are seen as numerous T1 and T2 hypointense intraarticular bodies of approximately the same size and shape.⁵ Joint effusion and synovial thickening showing vivid post-contrast enhancement can be seen (Figure 6). Imaging features of underlying pathology such as tenosynovitis and chondral and subchondral bone erosions can also be seen.

T2 Dark Soft Tissue Lesions

Fibromatosis

It is a benign condition that includes a spectrum of fibroblastic and myofibroblastic neoplasms. The lesions show a strong tendency for local recurrence but never metastasise.⁶ The lesions can have a well-circumscribed or infiltrative margin. On MRI, they show inhomogeneous signal on T2W images. Low signal is noted in areas with abundant collagen content while more cellular areas show intermediate signal.⁶

Fibromatosis is classified according to its location: superficial or deep. Superficial fibromatosis includes palmar, plantar, or infrapatellar fat pad fibromatosis among which palmar is the most common.¹ MRI

in palmar fibromatosis shows nodular or cord-like structures with signal intensity the same as that of tendons originating from and running parallel to the palmar aponeurosis. Enhancement with gadolinium contrast material is variable. Plantar fibromatosis is seen as well-defined or ill-defined lesions showing intermediate-to-low signal on T2W images. These lesions are continuous with plantar aponeurosis and show extension along the aponeurosis (Figure 7).¹

Deep fibromatosis is also known as desmoid-type fibromatosis and can be extra-abdominal, intraabdominal or abdominal wall type. Extra-abdominal desmoids are mostly located in an intermuscular plane along the deep fascia and have a predilection for the upper torso.⁷ Intraabdominal fibromatosis is rare and occurs in the pelvis, mesentery or retroperitoneum.⁷ Abdominal wall fibromatosis often arises from the rectus abdominis or internal oblique muscles and their fascia and usually affect women of childbearing age.⁷ On MRI, the lesions of deep fibromatosis show highly variable signal intensity pattern with the most common being heterogeneous signal intensity on T2W images (Figure 8).⁶

T2 Dark Bone Lesions

Myelofibrosis

Myelofibrosis is a disorder of the bone marrow in which there is replacement of the marrow fat by collagen, reticulin fibres, and cellular material. It can be primary or secondary to haematological malignancies. On MRI, the marrow of normal adults appears more hyperintense on T1W images and isointense or

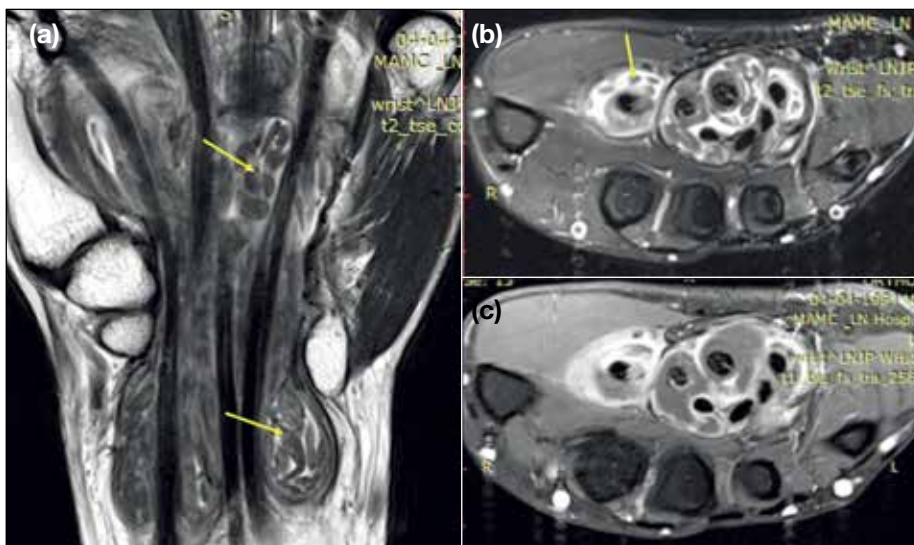


Figure 6. Tubercular tenosynovitis with rice bodies. (a) Coronal T2-weighted image and (b) axial T2-weighted fat-saturated image of the left wrist in a case of pulmonary tuberculosis showing synovial effusion along the sheaths of the flexor tendons. Multiple small low signal intensity intraarticular bodies (arrows) of approximately the same shape and size are seen in the synovial fluid. (c) Post-contrast image showing diffuse synovial thickening and enhancement with non-enhancing intraarticular bodies. Aspiration of the synovial fluid revealed acid-fast positive bacilli.

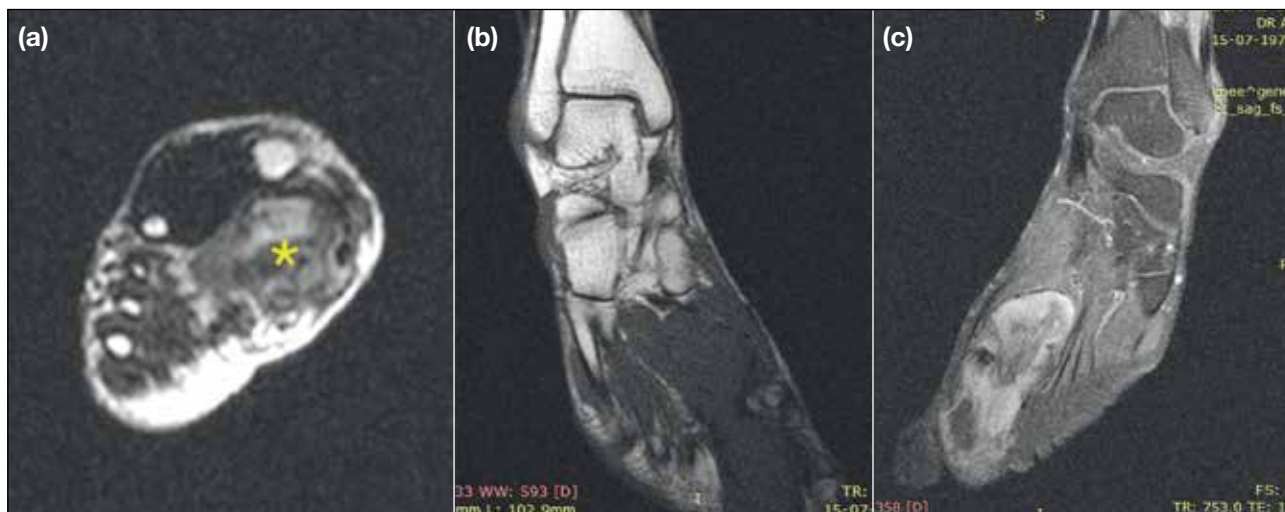


Figure 7. Superficial fibromatosis. (a) Axial T2-weighted image of the right foot showing an ill-defined soft tissue mass with predominantly low signal in the first intermetatarsal space extending both superiorly to the dorsum of the foot and inferiorly to the plantar aspect along the plantar aponeurosis. An area of T2 hyperintense signal (asterisk) is seen in the plantar aspect of the mass, likely representing area of high cellularity. (b) Coronal T1-weighted image showing hypointense lesion on the dorsal aspect of the foot. (c) Coronal post-contrast image of the plantar aspect of the same foot showing heterogeneous enhancement within the lesion. Biopsy revealed plantar fibromatosis.

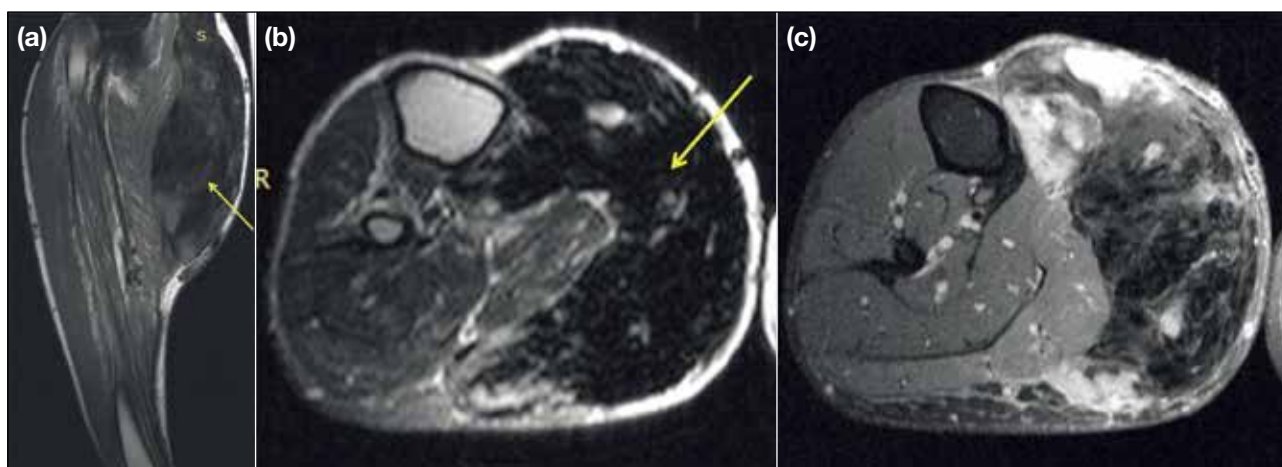


Figure 8. Desmoid-type deep fibromatosis. (a) Coronal T1-weighted image of the right leg showing a well-defined hypointense lesion in the subcutaneous plane (arrow) on the medial side of the knee extending to the middle third of the right leg. (b) Axial T2-weighted image showing that the lesion appears T2 hypointense (arrow) and is seen extending along the fascial planes. A few tiny areas of hyperintense signal were seen within the lesion. (c) Axial post-contrast image showing heterogeneous enhancement within the lesion.

hyperintense on T2W images when compared to the intervertebral disks. In myelofibrosis, the marrow shows a homogeneously lower signal than the intervertebral disks on both T1W and T2W images (Figure 9).⁸ Similar hypointense signal in the marrow can also be seen due to haemosiderosis, Gaucher's disease, mastocytosis and renal osteodystrophy, fluorosis and dysplasias.

Giant Cell Tumour of Bone

It is a benign but aggressive primary bone neoplasm that

typically arises from the metaphysis of long bones and extends to the epiphysis adjacent to the joint surface. These tumours show a narrow zone of transition in between the tumour and the normal bone. On MRI, the tumour shows hypointense-to-isointense signal on T1W sequences and heterogeneously high signal with large areas of low signal intensity within on T2W sequences. The low signal areas on T2W sequences usually represent haemosiderin deposition.⁹ Post-contrast scans show heterogeneous enhancement (Figure 10).



Figure 9. Myelofibrosis. (a) Sagittal T1-weighted and T2-weighted (b) images of the whole spine in a case of chronic myeloid leukaemia showing diffuse hypointense signal on both T1- and T2-weighted images. Also seen is the presence of granulocytic sarcoma as an ill-defined epidural soft tissue mass (arrows) extending from T12 to L3 vertebra, appearing T1 hypointense and showing intermediate signal intensity on T2-weighted images. (c) Axial T2-weighted image at the level of T12 vertebra showing the mass in the posterior and right lateral epidural space appearing T2 hyperintense and extending into the paravertebral space. (d) Axial post-contrast image showing the mass causing narrowing of the spinal canal and compression of nerve roots at the same level with homogeneous enhancement.



Figure 10. Giant cell tumour of the femur. (a) Coronal T2-weighted image of the left knee showing a well-defined predominantly hypointense lesion involving the distal epiphysis and metaphysis of the lateral femoral condyle and extending to the articular surface. (b) Coronal short tau inversion recovery image showing the lesion with heterogeneous signal intensity signal. (c) Axial post-contrast image showing the lesion with heterogeneous post-contrast enhancement. Left knee joint effusion is also noted.

Deferiprone-induced Arthropathy

Deferiprone is an iron chelator used for the treatment of thalassaemia and other conditions that require multiple blood transfusions. Arthropathy associated with deferiprone is hypothesised to be due to the toxic effects of deferiprone.¹⁰ The MRI findings include hypointense

bone marrow on all sequences due to haemosiderosis. Irregular thickening of cartilage, subchondral erosions, joint effusion and hypointense bands in the infrapatellar fat can be seen (Figure 11).¹¹ Synovial thickening and enhancement and the presence of synovial bands have also been reported.¹²

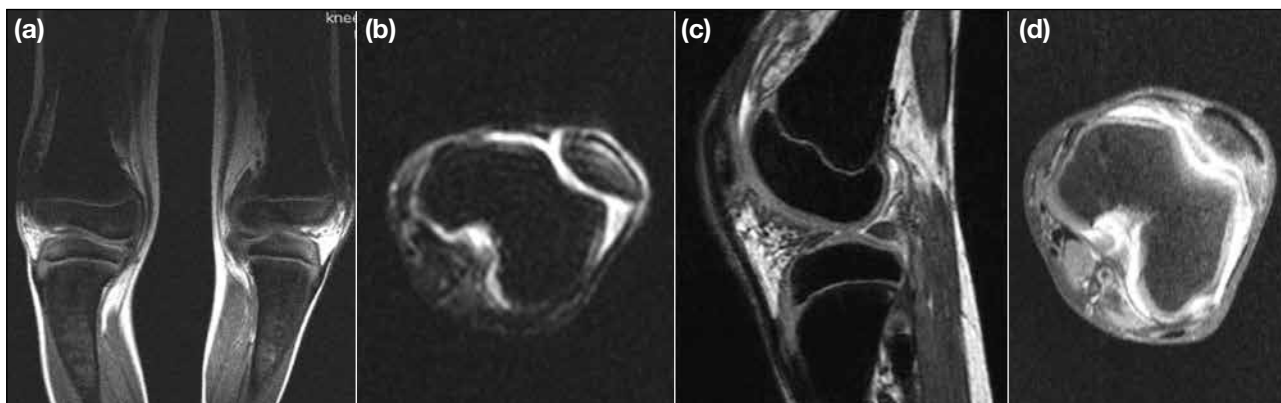


Figure 11. Deferiprone-induced arthropathy. (a) Coronal T1-weighted image of bilateral knees in a patient with thalassaemia prescribed deferiprone showing diffuse hypointense signal in bilateral femurs and tibial epiphysis and metaphysis secondary to haemosiderosis. (b) Axial T2-weighted image of the left knee showing joint effusion with diffuse hypointense signal of femoral condyles. (c) Sagittal gradient recalled echo image of the left knee showing subtle irregularity of articular cartilage over the lateral tibial condyle. (d) Axial post-contrast image of the left knee showing thickened and enhancing synovium with joint effusion.

Osteoblastic Metastasis

Osteoblastic or sclerotic bone metastases are characterised by deposition of new bone. These most frequently arise from carcinomas of the prostate gland and the breast. Other primary malignancies resulting in osteoblastic metastases include mucinous adenocarcinoma of the gastrointestinal tract, lymphoma, neuroendocrine tumours, and transitional cell carcinoma. Metastases to the axial skeleton (especially spine and pelvis) are more common than to the appendicular skeleton. Diffuse or multifocal patterns of involvement are more common than solitary lesions.¹ On MRI, the lesions exhibit low signal on both T1W and T2W sequences with enhancement on post-contrast scans (Figure 12).

CONCLUSION

A number of musculoskeletal lesions show areas of low signal intensity on T2W sequences on MRI. The morphology and location of the lesions along with systematic analysis of potential underlying low T2W signal intensity tissue components help narrow the differential diagnoses.

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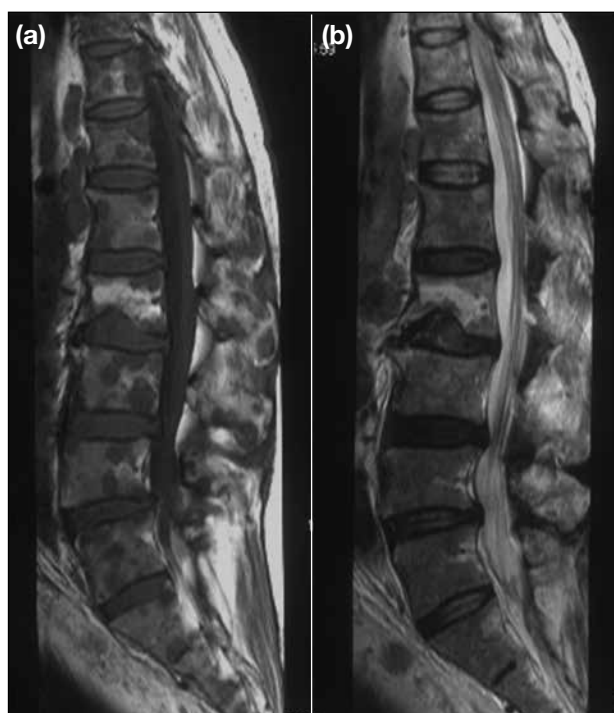


Figure 12. Multifocal osteoblastic metastases. (a) Sagittal T1-weighted and (b) T2-weighted images of the lumbosacral spine in a case of prostatic carcinoma showing multiple well-defined focal lesions in the vertebral bodies and posterior elements, appearing T1 and T2 hypointense. Degenerative changes are also noted in the spine.

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