Received:
26 April 2017

Revised:
04 January 2018

Accepted:
05 February 2018

<https://doi.org/10.1259/bjr.20170301>

Cite this article as:

Rao A, Gandikota G. Beyond ulcers and osteomyelitis: imaging of less common musculoskeletal complications in diabetes mellitus. *Br J Radiol* 2018; **91**: 20170301.

REVIEW ARTICLE

Beyond ulcers and osteomyelitis: imaging of less common musculoskeletal complications in diabetes mellitus

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ABSTRACT

Metabolic perturbations in diabetes mellitus affect various organ systems and can lead to end-organ failure. Though most musculoskeletal (MSK) complications of diabetes mellitus are usually not life-threatening, they are often the cause of significant morbidity. While some of the MSK complications have a proven association with diabetes mellitus, others have been loosely associated because of their frequent coexistence, as are the rheumatologic complications. While many of these conditions are well-known, some are overlooked in routine clinical practice. This article focuses on highlighting key imaging features of less common MSK complications and associations of diabetes mellitus.

INTRODUCTION

Diabetes mellitus is a common endocrine disorder that affects millions of people worldwide. Metabolic perturbations in diabetics can affect multiple organ systems resulting in nephropathy, neuropathy, and retinopathy. In 2014, the global prevalence of diabetes mellitus was estimated to be 8.5% among adults aged 18 years and above.¹ In the USA alone, in the year 2015, 30.3 million people or 9.4% of people have diabetes mellitus.² While some of the musculoskeletal (MSK) complications have a proven association with diabetes mellitus, others have been loosely associated because of their frequent coexistence. The objective of this article is to review the less common/less known musculoskeletal manifestations seen in patients with diabetes mellitus.

Diabetic MSK complications and associations will be discussed under the following categories:

- (1) Muscular: diabetic muscle ischemia; infectious and inflammatory myositis, denervation myositis.
- (2) Rheumatological associations: frozen shoulder, limited joint mobility syndrome (diabetic cheiroopathy), Dupuytren's contracture, trigger finger, reflex sympathetic dystrophy, carpal tunnel syndrome.
- (3) Foot complications: necrobiosis lipoidica diabetorum, Charcot's joint, osteomyelitis, septic arthritis.

- (4) Spinal: diabetic neuropathic osteoarthropathy, diffuse idiopathic skeletal hyperostosis (DISH), dialysis-associated spondyloarthropathy (amyloidosis).
- (5) Skin and soft tissues: cellulitis, necrotizing fasciitis, gas gangrene

Diabetic muscle disorders

Diabetic myopathy could include any or all of the following—muscle inflammation, fibrosis, atrophy, ischemia, infarction, hemorrhage and necrosis.³ Usage of this general terminology can be confusing and should be avoided. Infectious myositis is a well-known pathology involving the muscles in diabetics. Skeletal muscle is usually not prone for infarction because of a rich collateral blood supply.⁴ Inflammatory myositis and denervation myositis may also occur in diabetics.

Diabetic muscle ischemia (DMI)

Also known as diabetic muscle infarction or diabetic myonecrosis is one of the rare complications in poorly controlled long-standing diabetics and is usually a self-limiting condition.⁵ It is important to recognize diabetic muscle ischemia, as it is usually underreported and underappreciated.⁵ Clinical features include sudden onset of the severe pain in thigh or calf. Non-traumatic swelling of the affected extremity is noted that can persist for months. Traditional findings of fever and raised white cell count are usually absent.^{5,6} Multiple muscle

Figure 1. A 60-year-old diabetic patient presented with increasing pain in the left thigh over period of few days. MR-STIR images (coronal A and axial B) of the left thigh showing edema (arrow) confined to a wedge-shaped section of vastus medialis on this non-contrast study with associated extensive adjacent subcutaneous edema. Post-contrast image (C) demonstrating differential enhancement. Diabetic muscle ischemia resulting in infarction was suspected after ruling out infection clinically. Patient was managed conservatively and did well over few weeks. The image D is of a different diabetic patient with abscess in the right groin which shows rim enhancement (arrow)—a key differentiating point, unlike the ischemic muscle infarction in image E which shows some central enhancement with not so well defined rim enhancement (arrow). STIR, short tau inversion-recovery.

involvement is common. The most commonly affected muscles are quadriceps, hip adductors, and hamstrings.⁷ Bilateral involvement has been reported in 8.4% cases and is usually seen in poorly controlled long-standing diabetes mellitus.⁷ Other end-organ failures, as a result of microvascular disease, are common in this subset of patients. Imaging (CT, ultrasound, and X-rays) are non-specific.⁴ MR shows characteristic edematous muscle, though edema is a non-specific finding.⁶ Hyperintensity on unenhanced T_1 weighted images may represent hemorrhagic infarction.³ When contrast is administered, the muscle can show central regions of hypoenhancement or non-enhancement representing areas of infarction. Heterogeneous areas, with linear enhancing streaks traversing non-enhancing central zone enclosed within large regions of enhancing muscle, are another pattern⁵ (Figure 1). MRI also helps in identifying a site for biopsy, when necessary.⁶ Excisional biopsy is not recommended due to the increased risk of hemorrhage. Other causes of muscle edema such as post-traumatic muscle contusions, subacute denervation, radiation therapy, compartment syndrome, polymyositis, infectious myositis, deep vein thrombosis and rhabdomyolysis⁶ should be excluded. Although diabetic myonecrosis has a good short-term prognosis locally, it is an indicator of overall poor long-term prognosis because of chronic vascular compromise.⁷

Infectious myositis

Diabetes mellitus increases susceptibility to infection. Pyomyositis refers to infection of the skeletal muscle usually via hematogenous spread. However, blood cultures are positive in only 5–35% of cases at the time of presentation, and most common cause is *Staphylococcus aureus*.⁸ Ultrasound helps in detection of abscesses and edema. CT shows increased muscular bulk and decreased attenuation due to edema. Intramuscular abscesses are seen as a central zone of low attenuation with intermediate to high attenuation peripheral pseudocapsule and rim enhancement in post-contrast images (Figure 2). Necrotic tumor and intramuscular hematoma are in the differential diagnosis.

Denervation myositis

Subacute denervation causes uniform muscle edema usually after 2–4 weeks after the event of denervation.⁹ Edema is said to be due to the shift of intracellular water to extracellular compartment.⁹ Muscle atrophy and fatty infiltration are the features of chronic denervation (Figure 3).

RHEUMATOLOGICAL ASSOCIATIONS

Many rheumatological manifestations which have been associated with diabetes mellitus, affect the quality of life but are often overlooked in routine clinical practice. A sustained high

Figure 2. A 70-year-old gentleman with long-standing diabetes mellitus presenting with pain and swelling in the left mid thigh: MR images STIR axial (A) and coronal (B) showing multiple loculated collections (arrows) in the left upper thigh. This patient underwent ultrasound-guided repeated aspiration of these collections with appropriate antibiotics. STIR, short tau-inversion-recovery.

blood sugar concentration leads to increased advanced glycosylation end products, which have been implicated in promoting increased collagen cross-linking, which, in turn, decreases the pliability of collagen resulting in increased stiffness of collagen and the structures built on a collagenous framework like tendons, thus making them more vulnerable to contractures.¹⁰ In addition, collagen accumulation is noted in the skin and periarticular connective tissue.¹¹

Frozen shoulder (adhesive capsulitis)

The prevalence of frozen shoulder in diabetic patients is 11–30% with the estimated prevalence in non-diabetics being at 2–10%.¹² The joint capsule is thickened and is closely approximated to the humeral head, with resultant loss in joint space.¹³ Three noticeable phases are recognized: painful, adhesive, and resolution phases.¹² On conventional shoulder arthrography pain after injection of low volumes of contrast (less than 10 ml) is said to be diagnostic. Thickening of the joint capsule in the axillary recess is associated with adhesive capsulitis. Synovitis at the anterosuperior gleno humeral joint and obliteration of the

Figure 3. A 62-year-old male with long-standing diabetes, now complaining of subacute weakness during flexion of the distal phalanx of the thumb and index finger. Axial MR images of the left forearm showing hyperintensity in the pronator quadratus muscle. The features probably could represent denervation myositis due to anterior interosseous nerve involvement.

Figure 4. A 61-year-old diabetic complaining of pain and restricted movements in right shoulder. T_1 and STIR MR images (A,) showing soft tissue thickening in the rotator cuff interval (circle) and the inferior glenohumeral ligament (arrow) suggestive of adhesive capsulitis. STIR, short tau-inversion-recovery.

fat triangle inferior to the coracoid process, are other important findings.¹⁴ On MR, there are no characteristic features, but the diagnosis is favored, when the thickness of the capsule and synovial lining at the axillary recess is greater than 3 mm, measured in coronal non-fat saturated sequence.¹⁵ In a study by Song et al¹⁶ it was noted that enhancing soft tissue in the rotator interval and thickening and enhancement of the soft tissue and capsule in the axillary recess are suggestive of adhesive capsulitis on MRI (Figure 4).

Diabetic cheiroarthropathy (stiff hand syndrome)

Clinical features include limited joint mobility, thickened, stiff, waxy skin of the dorsal hand and flexion contractures of the digits.¹² On ultrasound, thickening of the flexor tendon sheaths and subcutaneous tissues can be seen. Thickening and enhancement of the flexor tendon sheaths are seen on MRI.¹⁷

Dupuytren's contracture

Findings include focal thickening and shortening of the superficial palmar aponeurosis resulting in tethering and flexion contractures of the hands. Halesha et al reported 20 to 63% prevalence of Dupuytren's contracture in diabetic patients, a significant increase when compared to the prevalence (13%) seen in the general population.¹² In diabetics, the middle and ring finger are more often involved.³ The diagnostic imaging findings include nodularity with tethering involving the palmar aspect of the hand and digit, pre-tendinous band, and flexion digital contracture. Ultrasound of the palmar fascia in Dupuytren's contracture can demonstrate nodules and cords at the distal palmar crease. Third and fourth fingers are commonly involved. The superficial palmar aponeurosis is a thin flat superficial soft tissue band, just deep to the skin. Hypoechoic bands adhering to the margins of the flexor tendons and deep surface of the dermis appears to be key finding. Early on, the nodules are hypoechoic and usually hypervascular. Over time, the nodules become more echogenic, losing vascularity (Figure 5). Arterial encasement by fibrous or scarring tissue can also be shown on ultrasound.¹⁸ On MR, subcutaneous nodules are usually identified as cords extending parallel and superficial to the flexor tendons, at the distal palmar crease.¹⁹

Figure 5. A 60-year-old diabetic patient presented with pain and contracture involving the left fourth and fifth digits. Ultrasound scan (longitudinal view) showing a hypoechoic plaque (arrows) involving the palmar fascia at the level of left distal palmar crease (A). Axial ultrasound image showing similar hypoechoic nodular lesion (straight arrows in B) overlying the flexor tendon. Also, note mild thickening of the A1 pulley in this patient (curved arrows in b). The patient also had symptoms of trigger finger.

Trigger finger

Prevalence is 11% in diabetics while it is less than 1% in non-diabetics, most often involving the ring finger. Inflammation of the A1 pulley causes, pain, clicking, limited motion of the finger. A2 and A3 pulleys can also be involved.^{20–22} On the ultrasound, A1 pulley is seen as a focal thin hypoechoic band superficial to the flexor tendon at the level of the metacarpophalangeal joints. In a study published by Henri Guerini et al, measurements of A1 pulley thickness were smaller (mean = 0.5 mm; range, 0.4–0.6 mm) in normal fingers than with trigger fingers (mean = 1.8 mm; range, 1.1–2.9 mm).²³ Thickening of the A1 pulley, assessed at the level of metacarpophalangeal joint, is, therefore, the key finding on the ultrasound in trigger finger. This is often associated with restricted movement of the underlying flexor

tendon with a possible snap during extension. The friction can result in thickening, tendinosis, and tenosynovitis of the underlying flexor tendon.

Reflex sympathetic dystrophy (RSD)

Reflex sympathetic dystrophy (RSD) is also known as complex regional pain syndrome (CRPS). Uncontrolled hyperglycemia can affect CRPS occurrence. In a study by Choi et al²⁴, as HbA1c values increased, CRPS prevalence increased, thus, highlighting the association of diabetes mellitus in these groups of patients. Pain, vasomotor symptoms, swelling, hyperhidrosis, hair changes, impaired mobility, tremor and muscle spasm at the affected region are the main clinical symptoms. This typically improves after sympathetic denervation.²⁵ Three stages are described.²⁶ Stage 1 (acute): plain radiographs showing a patchy bone loss. In Stage 2 (dystrophic): plain radiographs show a diffuse bone loss, appearing like diffuse ground glass appearance. In Stage 3 (atrophic): disuse atrophy overlaps the changes in Stage 3. However, these stages are not well-defined clinically or radiologically and may not help much in guiding treatment or in providing prognostic information. MR demonstrates marrow edema in RSD, which again is a non-specific finding. In a study by Mark et al²⁵, MR images, in Stage 1 RSD showed, enhancing periarticular, subcutaneous tissues and skin thickening with occasional muscle and fascial edema. In Stage 2 and 3, no contrast enhancement was demonstrated. Muscle atrophy was seen in Stage 3, which was considered as a sign of irreversibility (Figure 6). Thus, MR is useful in Stage 1 and 3. Recurrence is known to occur in RSD.²⁶

Figure 6. A 53-year-old diabetic presenting with pain in the left ankle: AP radiograph (a) and the corresponding coronal reformat CT image (b) showing patchy lucencies predominantly in the talus (arrow), also in the distal tibia and fibula. MR image [STIR coronal] (c) also demonstrates patchy juxta articular heterogeneous signal intensities (arrow) in the talus. This was diagnosed as reflex sympathetic dystrophy. AP, anteroposterior; STIR, short tau inversion-recovery.

Figure 7. A 58-year-old diabetic female with pain, numbness and tingling sensation in the thumb, index and middle fingers: carpal tunnel syndrome: MR (A—fat suppressed) and (B— T_1 image) showing, slightly hyperintense median nerve (arrows). Axial ultrasound images of a different patient with carpal tunnel syndrome [(C, D) showing mild enlargement of the nerve (arrow)] just proximal to carpal tunnel with cross-sectional area of 0.19 cm^2 (arrow in C), the relatively flattened median nerve can be seen in the proximal carpal tunnel (arrows in D).

Carpal tunnel syndrome (CTS)

Carpal tunnel syndrome (CTS) is believed to result from compression of the median nerve at the wrist, deep to the transverse carpal ligament.²⁷ The prevalence of CTS in diabetics is reported to be in the range of 13–49%, significantly more, when compared to the prevalence in non-diabetics (1.6–13%).^{11,12} Nerve conduction studies may be useful. Imaging is often used to look for any space-occupying lesions like flexor tenosynovitis, ganglion, mass, gout deposits in the carpal tunnel and for evaluating residual scarring or fibrosis in post-surgical cases.²⁸ The characteristic diagnostic ultrasound findings of carpal tunnel syndrome are swollen nerve at the distal skin crease, just proximal to carpal tunnel, flattening of the nerve within the distal tunnel, and palmar bowing of the transverse carpal ligament. The diagnosis should be considered when the maximum cross-sectional area of the focally enlarged median nerve is greater than 0.09 cm^2 at the wrist (any level) (Figure 7).²⁸ Nerve enlargement is measured where the nerve appears maximally enlarged and often corresponds to the level of the pisiform bone.²⁷

The subjective assessment of reduced sliding of the median nerve in the transverse plane, deep to the flexor retinaculum during flexion and extension of the index finger is known to occur. Klauser et al²⁹ concluded that an increase in median nerve cross-sectional area of 2 mm^2 between proximal (measured at proximal pronator quadratus) and distal (measured just

proximal to the flexor retinaculum inlet) measurements, provides 99% sensitivity and 100% specificity for the diagnosis of CTS.

Hyperintensity of the nerve is noted on T_2 fat suppressed or short tau in version-recovery (STIR) images.²⁷ Post-surgical evaluation mainly involves assessment of nerve appearance and its ability to slide freely beneath the retinaculum. In addition, cleft in the retinaculum may be seen. Postoperative symptoms can be due to inadequate resection of the retinaculum. Scar tissue formation is another complication and cause of late recurrence of symptoms.²⁸

FOOT COMPLICATIONS

A diabetic foot is vulnerable to infection, ulceration, neuroarthropathy, and fracture. Wound healing is a challenge in these groups of patients. It is estimated that diabetics have 15% lifetime risk of developing a foot ulcer. The 10-year cumulative incidence of lower extremity amputation is estimated to be 5 to 7% in diabetic foot.¹⁰ Imaging plays a crucial role in the diagnosis of infection/osteomyelitis/ abscess, depth of the ulcer, joint/tendon exposure to the wound, presence of ischemia and gangrene.

Necrobiosis lipoidica diabeticorum

Necrobiosis lipoidica diabeticorum incidence ranges from 0.3 to 1.6% of the diabetic patients per year.³⁰ This is a disorder of the soft tissues caused by microangiopathy, often manifests as

coalescing painless red skin papules to form granulomatous masses in the pre-tibial region and along the dorsal aspect of the foot. They may then infiltrate adjacent bone or resolve spontaneously.³¹ Diagnosis is made by clinical examination.³⁰ However high-frequency ultrasound would help us identify foci of inflammation in the mid and deep dermis, and to locate the presence of panniculitis with edema. Dermal inflammation is often seen as hypoechoic areas, which have increased blood flow on color Doppler as studied by Gracia et al³² in a patient of necrobiosis lipoidica, however, in a non diabetic patient.

Charcot's joints

Charcot's joints occur in up to 15% of diabetics.²¹ Peripheral neuropathy results in lack of proprioception and pain sensation. The joint and ligament damage can be caused by normal weight-bearing activities, further increasing malalignment resulting in abnormal mobility and progressive disintegration.³³ Progressive changes from hypervascularity to non-vascularity are thought to contribute to the trophic changes.³⁴ Weight-bearing joints (tarsometatarsal and intertarsal joints) are mainly affected. Other joints like spine, knee and upper extremities are less commonly involved. Increased bone Density, joint Distension, articular Disorganization, osseous Debris, Destruction, and joint Dislocation are the six D's noted in Charcot's joint²¹ (Figure 8). In chronic neuropathic osteoarthropathy, MR has characteristic decreased signal intensity in the bone marrow, consistent with osteosclerosis on all sequences and cyst-like lesions in the bone marrow.³⁴ Hammer toes and collapse of the midtarsus can result.²²

Recent rapidly evolving neuropathic osteoarthropathy is a close mimic for osteomyelitis. MR images show low signal intensity on T_1 in the bone marrow on and high signal intensity on T_2 weighted MR images. Recent fractures related to the neuropathic joint may cause signal changes in the marrow and cortex. Soft tissue infection in this setting is another condition that complicates the diagnosis, in differentiating osteomyelitis from acute neuropathic changes.³⁴

Osteomyelitis

Osteomyelitis occurs in up to 15% of diabetics.³⁴ Osteomyelitis is an infection of bone marrow, while infective osteitis refers to infection of the cortex and infective periostitis is an infection of the periosteum.³⁵ Soft tissue and bone marrow edema, periostitis, erosions, and osteopenia are the common findings on imaging. Chronic osteomyelitis is seen as bone sclerosis, islands of dead bone (sequestra). Involucrum is reparative bone formation, seen around the margin of non-viable bone. Cloacae are sinus tracts which traverse through the cortex.^{21,35} Radiographs are insensitive in early stages and take weeks (7–15 days) to show cortical destruction and periostitis.³⁶ MRI is the investigation of choice (sensitivity of 90% and specificity of 83%) for detecting foot osteomyelitis and soft-tissue infection.³⁷ STIR is the most sensitive imaging modality for diagnosis, with marrow hyperintensity on STIR corresponding to T_1 hypointensity. STIR hyperintensity without significant T_1 hypointensity may just represent edematous changes due to hyperemia related to soft tissue infection. Paul et al³⁸ has emphasized that STIR, T_2 weighted, and contrast-enhanced sequences should be

Figure 8. A 67-year-old gentleman with long-standing history of diabetes mellitus, presented with pain in the right foot with difficulty in walking. The radiograph of the foot shows gross disorganization of the proximal metatarsals and the tarsal bones with destruction of some of the tarsal bones (asterisk). Increased density of the bones are noted (white arrow). Neuropathic Lisfranc dislocation can be observed as seen by the lateral displacement of the base of the metatarsals.

interpreted in association with findings on the T_1 weighted images. They described that confluent pattern of decreased marrow signal on T_1 images with medullary distribution correlated well with the presence of osteomyelitis. Limited, non-homogeneous subcortical distribution of T_1 signal changes of abnormal marrow signal on T_1 weighted images do not favor established osteomyelitis and likely represents reactive edema.³⁸ Adjacent soft tissue edema, ulcer, and abscess may be seen²¹ (Figures 9 and 10). Differentiating viable from the non-enhancing non-viable tissue by contrast study is important, as it indicates the need for surgical debridement in addition to antibiotic therapy.³⁵ Acute neuropathic arthropathy can be a mimic.

Figure 9. A 78-year-old gentleman with 25 years of diabetic history presenting with infection in the right foot. T_1 (A), STIR (B) MR images showing confluent marrow signal changes; geographic area of decreased T_1 and increased signal on STIR [asterisk] images are seen suggestive of osteomyelitis: post-contrast (C) study helps detection of abscess (arrow) formation. STIR, short tau inversion-recovery.

Multiple bone and joint involvement, periarticular and subchondral predilection, overlying intact skin, the absence of ulcers and sinus tracts favor the diagnosis of Charcot's neuropathic joint rather

than osteomyelitis.³⁷ In chronic arthropathy, differentiation is easy given the paucity of marrow edema; however, the disappearance of previously seen subchondral cysts or of intra-articular bodies in patients with neuroarthropathy indicates a superimposed infection.³⁷ Another feature noted by Ahmed et al³⁹ is that frequency of intraarticular loose bodies are less in infected neuropathic joint, probably attributed to the dissolution of these bodies after infection sets in, or that their signal intensity may change to the fluid signal due to the surrounding edema and they get obscured.

Septic arthritis

Usually joint infection is initiated by the spread from the adjacent infected bone. Joint effusion, erosions, periarticular osteopenia are the common findings in early stages. Late changes include loss of joint space and destruction.²¹ Septic arthritis is to be treated urgently as joint infection leads to rapid destruction of the cartilage with the permanent joint loss. MR findings of septic arthritis include joint effusion, pericapsular edema, uniform cartilage destruction, bone erosions, marrow edema, synovitis, abscess, infections of tendon/muscle and pannus. MRI has a role, especially when sent for evaluation after a dry tap of the joint, to demonstrate loculated fluid, pannus to support septic arthritis or to propose a different diagnosis.

SPINAL COMPLICATIONS

Spinal neuroarthropathy

Diabetes mellitus contributes significantly to chronic kidney disease (CKD). The estimated prevalence among adults with Type 2 diabetes mellitus of CKD is 34.5–42.3%. Additionally, diabetes is present in approximately 30–40% of all cases of end-stage renal disease in the USA.⁴⁰ Spinal neuroarthropathy also termed as Charcot's spine, is a condition resulting from

Figure 10. Amputated foot of a 70-year-old gentleman with diabetes mellitus, who presented with history of pain in the fifth toe: MR-STIR (A) image showing hyperintense signal (arrow) within the fifth phalanx. However, T_1 images (B) do not show significant marrow signal changes (arrow), except for subtle subcortical hypointense signal at the base, the finding in (A) is artefactual in nature due to incomplete fat saturation, and no osteomyelitis. In contrast to the above, osteomyelitis in another patient with amputated foot showing T_1 hypointensity in the fifth metatarsal bone (arrows in C) corresponding to STIR hyperintensity (arrows in D). The confluent T_1 hypointensity is the key imaging feature for the diagnosis of osteomyelitis. STIR, short tau inversion-recovery.

progressive loss of pain sensation and proprioception resulting in the progressive aseptic destruction of the spine, including the disc, vertebral bodies, and the facet joints.³³ Tabes dorsalis, syringomyelia, traumatic brain and spinal cord injury are some of the other causes of Charcot's spine. Alexis et al³³ have described two stages in the development of Charcot's spine. First, non-specific inflammatory type changes occur in two adjacent endplates, mimicking disc degeneration $\pm$ inflammation. Vacuum phenomena may be present in the disk and facet joints. In the second and final stage, destruction of the end plates and intervening disc with bone sclerosis and new bone formation is seen.³³ Similar findings can also be noted in facet joints. Infection is a close mimic. Differentiating features of Charcot's spine include intradiscal vacuum phenomena with osseous fragmentation, joint disorganization and dislocations, spondylolisthesis, and facet joint involvement.³³ In Charcot's spine, the entire vertebral bodies demonstrate high-intensity signal on T_2 -weighted sequences and post-contrast imaging, whereas, in infection, the signal changes are usually restricted to the endplates. Early diagnosis and treatment at the earlier stage of inflammation is likely to contain further destruction.

DISH (Forestier disease)

DISH (Forestier disease) is a condition commonly seen in diabetics, more frequently in Type 2 disease. Prevalence is 13–49% in diabetic patients and 1.6–13% in non-diabetics.¹² It has been suggested that prolonged high levels of insulin and insulin-like growth factors associated with diabetes mellitus, may be stimulating new bone growth.^{12,13} New bone formation, most frequently involves the thoracolumbar vertebra, with calcification of the spinal ligaments as its typical feature.¹⁰ The lower cervical spine may also demonstrate posterior osteophytes, ossification of the posterior longitudinal ligament in addition to the anterior longitudinal ligament calcification.⁴¹ New bone formation characteristically appears in the form of bone bridging between consecutive vertebral bodies. In the thorax, it more

prominent on the right side of the thoracic vertebra, with paucity on the left side being explained by inhibition of new bone formation because of the presence of left-sided pulsating descending thoracic aorta.^{12,41} Criteria for DISH diagnosis is demonstrating the involvement of at least four contiguous thoracic spine vertebrae usually with preserved intervertebral disc space, and absence of inflammatory changes in sacroiliac joints.^{13,41} Hyperostosis of heel, elbow, and spine may be present. Extraspinal enthesopathic changes may be seen at heel, patella, and pelvis⁴¹ (Figure 11). Treatment is usually conservative.

Amyloidosis and dialysis-associated spondyloarthropathy

The presence of diabetes mellitus among patients with end-stage renal disease is approximately 30–40%. CKD can lead to amyloidosis. Given this strong association, we have included a brief note on amyloidosis and dialysis-associated spondyloarthropathy in this review.⁴⁰ Amyloid deposition occurs in 20% of the patients who have undergone long term hemodialysis.⁵ Amyloid deposition consists of β_2 -microglobulin. Amyloid can deposit (Figure 12) in the tendons, synovial sheaths around the carpal tunnel and can lead to median nerve compression. Amyloid deposits can lead to radiolucent areas (dialysis cysts) usually seen in the carpal bones, phalanges, humeral head, and around the hips, and can enlarge in size with continued dialysis. Osseous imaging findings of amyloidosis include focal lytic lesions, endosteal scalloping, osteopenia and pathological fractures. Large soft-tissue masses can cause adjacent osseous scalloping. Long-standing amyloidosis leads to extensive joint destruction.

Dialysis-associated spondyloarthropathy

Dialysis-associated spondyloarthropathy, first recognized in 1984 by Kuntz et al⁴² as destructive spondyloarthropathy, is an uncommon complication that occurs in patients who have had hemodialysis treatment for a period of at least 2 years.⁴³ They

Figure 11. DISH involving the cervical spine (A), foot (B) and right hip (C) in a 67-year-old diabetic patient showing continuous calcification of anterior longitudinal ligaments in the cervical spine (arrow), excessive new bone formation and osteophytes (arrow) in the foot and right hip (arrows), predominantly along the right iliac bone and greater trochanter. DISH, diffuse idiopathic skeletal hyperostosis.

Figure 12. Fat suppressed coronal and axial MR images showing punched out lytic lesions in the left femoral head (arrows) in a 69-year-old diabetic patient (A,B). These lesions were proved to be due to amyloid deposits by biopsy (Congo red stain).

are more frequently seen in the cervical and lumbar vertebrae.^{5,43} Multiple spinal levels are usually involved simultaneously, in the disease process.⁵ 15% prevalence has been noted in dialysis patients with rapid progression in 33%, increasing with increase in duration of dialysis.^{5,44} Clinical symptoms include mild to moderate pain, patients often remaining asymptomatic; despite extensive destructive findings on imaging.⁵ Characteristic findings are diskovertebral junction erosions with sclerosis, vertebral body compression, disk space narrowing, Schmorl node formation, and facet involvement with subluxation (Figure 12). Lack or very minimal osteophytosis and extensive end plate erosions are diagnostic, which is the differentiating feature when compared to degenerative disc disease.^{5,44} Infectious spondylodiscitis may be a differential in later stages when disk space narrowing and subchondral sclerosis are the imaging findings. Advanced stages show an extensive fracture, collapse, subluxation, and listhesis. T_1 weighted MR show disk and adjacent vertebral marrow replacement and the lack of a paravertebral soft-tissue mass. On T_2 weighted images, those abnormal areas on T_1 weighted images show hypointense signal which differentiates from infection.^{5,42,44} Confirmation is by demonstrating serum antibodies to β_2 -microglobulin and Congo red staining of biopsy samples.⁴³

In addition, other MSK manifestations of chronic renal failure are common in patients with long-standing diabetics, manifesting as subperiosteal, subligamentous, subchondral resorptions, incomplete pseudo fractures, and brown tumors, vascular and soft tissue calcifications, collectively referred to as renal osteodystrophy.

SKIN AND SOFT TISSUE COMPLICATIONS

Cellulitis

Skin and soft tissue associated complications are five times higher and associated hospitalizations are four times higher, in patients with diabetes compared to those without diabetes.⁴⁵ Peripheral neuropathy can result in repetitive unrecognized microtrauma with dry cracked skin. This may initially be seen as callus formation, later manifesting as soft tissue injury, ulceration and abscess formation. Peripheral vascular disease

Figure 13. A 54-year-old female with diabetes presenting with swelling in the left foot. Coronal STIR (A) and contrast enhanced (B) showing hyperintense signal in the soft tissues of the dorsum of the foot (arrows) demonstrating enhancement on contrast study, suggestive of cellulitis. No abnormal signal changes or enhancement of the bone marrow is noted, excluding osteomyelitis. STIR, short tauinversion-recovery.

results in poor healing. Hyperglycemia leads to altered immunologic response to infection and delays wound healing. Cellulitis is the infection of the skin and subcutaneous tissue usually caused by Gram positive cocci. The findings on ultrasound include subcutaneous edema, skin thickening and hypervascularity with fluid surrounding hyperechoic fat lobule and extending along interlobular septa. Ultrasound also plays an important role to determine the patency of the underlying deep veins. MR findings of cellulitis include increased signal intensity in subcutaneous fat on fluid-sensitive sequences and low signal on T_1 weighted images with diffuse enhancement on contrast studies^{34,46} (Figure 13). Enhancement of the soft tissues on post contrast study is an important factor which distinguishes cellulitis from simple edema due to volume overload, congestive heart failure or lymphatic obstruction.³⁵

Figure 14. Necrotizing fasciitis: 63-year-old diabetic, presented with pain and swelling in the left groin and medial aspect of the left thigh. CT shows thickened subcutaneous tissues and fascia and pockets of air (arrow) in the medial aspect of the proximal thigh in the skin and deep subcutaneous tissues.

Necrotizing fasciitis

Necrotizing fasciitis is a rapidly progressive infection centered around the deep fascia, progressing to tissue necrosis and systemic toxicity. Emergency surgical intervention is essential to save the limb. Non-specific fascial thickening (>3 mm), edema, enhancement of fascia on contrast images are the MR findings. The presence of gas in the deep fascial planes, in the absence of penetrating trauma, ulcer or recent surgery is a strong indicator of necrotizing fasciitis under appropriate clinical circumstances and is better seen on CT or even on radiographs. However, the presence of gas is not necessary for the diagnosis as in early stages; fascial thickening and skin thickening are the only features (Figure 14). In addition, waiting for MR is not advisable, as this is a surgical emergency.

Gas gangrene

Gas gangrene is rapidly progressive and life-threatening bacterial (often clostridial) infection and can lead to septicemia. Presence of gas bubbles in soft tissues is felt as crepitus on clinical

examination and is diagnostic on plain films. Urgent surgical exploration and administration of antibiotics is the treatment of choice. Cross-sectional imaging (CT, MRI) can delay surgical exploration, and should only be included as a diagnostic tool with caution.⁸

CONCLUSION

Awareness of the imaging findings of the described, less well-known MSK complications and rheumatological associations of diabetes mellitus would help with early and accurate diagnosis, reducing morbidity and improving the quality of life. Recognition of imaging limitations and appreciation of overlap of findings with the mimics will lead to more accurate diagnosis and better management of this chronic disease.

ACKNOWLEDGEMENT

We thank Dr Catherine J Brandon, University of Michigan for her assistance with obtaining some of the images and helpful comments that have helped shape this publication.

REFERENCES

1. <http://www.who.int>. Global status report on noncommunicable diseases 2014, Diabetes fact sheet, Updated November 2017. 2017. Available from: <http://www.who.int/mediacentre/factsheets/fs312/en/>.
2. <https://www.cdc.gov>. Centre for disease control and prevention of diabetes and its burden. national diabetes statistics report, 2017 estimates of diabetes and its burden in the United States updated: July 17, 2017. 2017. Available from: <https://www.cdc.gov/diabetes/pdfs/data/statistics/national-diabetes-statistics-report.pdf>.
3. Huang BK, Monu JU, Doumanian J. Diabetic myopathy: MRI patterns and current trends. *AJR Am J Roentgenol* 2010; **195**: 198–204. doi: <https://doi.org/10.2214/AJR.09.2494>
4. Kattapuram TM, Suri R, Rosol MS, Rosenberg AE, Kattapuram SV, Taj M. Idiopathic and diabetic skeletal muscle necrosis: evaluation by magnetic resonance imaging. *Skeletal Radiol* 2005; **34**: 203–9. doi: <https://doi.org/10.1007/s00256-004-0881-8>
5. Baker JC, Demertzis JL, Rhodes NG, Wessell DE, Rubin DA. Diabetic musculoskeletal complications and their imaging mimics. *Radiographics* 2012; **32**: 1959–1974. doi: <https://doi.org/10.1148/rg.327125054>
6. Ly JQ, Yi EK, Beall DP, Douglas P. Diabetic muscle infarction. *AJR Am J Roentgenol* 2003; **181**: 1216. doi: <https://doi.org/10.2214/ajr.181.5.1811216>
7. Sran S, Sran M, Ferguson N, Anand P. Diabetic myonecrosis: uncommon complications in common diseases. *Case Rep Endocrinol* 2014; **2014**: 1–. doi: <https://doi.org/10.1155/2014/175029>
8. Garcia J. MRI in inflammatory myopathies. *Skeletal Radiol* 2000; **29**: 425–38. doi: <https://doi.org/10.1007/s002560000238>
9. May DA, Disler DG, Jones EA, Balkissoon AA, Manaster BJ. Abnormal signal intensity in skeletal muscle at MR imaging: patterns, pearls, and pitfalls. *Radiographics* 2000; **20 Spec No**: S295–S315. doi: https://doi.org/10.1148/radiographics.20.suppl_1.g00oc18s295
10. Uhl RL, Rosenbaum AJ, Dipreta JA, Desemone J, Mulligan M. Diabetes mellitus: musculoskeletal manifestations and perioperative considerations for the orthopaedic surgeon. *J Am Acad Orthop Surg* 2014; **22**: 183–92. doi: <https://doi.org/10.5435/JAAOS-22-03-183>
11. Halesha BR, Krishnamurthy VR. A Study of rheumatological manifestations of diabetes mellitus in a tertiary care centre of southern India. *J of Evolution of Med and Dent Sci* 2014; **3**: 11881–6.
12. Smith LL, Burnet SP, McNeil JD. Musculoskeletal manifestations of diabetes mellitus. *Br J Sports Med* 2003; **37**: 30–5. doi: <https://doi.org/10.1136/bjism.37.1.30>
13. Bañón S, Isenberg DA, Bañón DA, Isenberg S. Rheumatological manifestations occurring in patients with diabetes mellitus. *Scand J Rheumatol* 2013; **42**: 1–10. doi: <https://doi.org/10.3109/03009742.2012.713983>
14. Nakata W, Katou S, Fujita A, Nakata M, Lefor AT, Sugimoto H. Biceps pulley: normal anatomy and associated lesions at MR arthrography. *Radiographics* 2011; **31**: 791–810. doi: <https://doi.org/10.1148/rg.313105507>
15. Jung JY, Jee WH, Chun HJ, Kim YS, Chung YG, Kim JM. Adhesive capsulitis of the shoulder: evaluation with MR arthrography. *Eur Radiol* 2006; **16**: 791–6. doi: <https://doi.org/10.1007/s00330-005-0020-5>
16. Song KD, Kwon JW, Yoon YC, Choi SH. Indirect MR arthrographic findings of adhesive capsulitis. *AJR Am J Roentgenol* 2011; **197**: 6: W1105–W1109. doi: <https://doi.org/10.2214/AJR.10.6099>
17. Mihmanli I, Khanna G, Ferguson P. MRI of diabetic cheiroarthropathy. *AJR Am J Roentgenol* 2007; **188**: W94–W95. doi: <https://doi.org/10.2214/AJR.06.0672>
18. Crêteur V, Madani A G. Ultrasound imaging of Dupuytren contracture, see comment in PubMed commons below. *J Radiol*. 2010; **91**: 687–91.
19. Yacoe ME, Bergman AG, Ladd AL, Hellman BH, Barry H. Dupuytren's contracture: MR imaging findings and correlation between MR signal intensity and cellularity of lesions. *AJR Am J Roentgenol* 1993; **160**: 813–7. doi: <https://doi.org/10.2214/ajr.160.4.8456670>
20. Makkouk AH, Oetgen ME, Swigart CR, Dodds SD. Trigger finger: etiology, evaluation, and treatment. *Curr Rev Musculoskelet Med* 2008; **1**: 92–6. doi: <https://doi.org/10.1007/s12178-007-9012-1>

21. Boswell SB, Patel DB, White EA, Gottsegen CJ, Forrester DM, Masih S, et al. Musculoskeletal manifestations of endocrine disorders. *Clin Imaging* 2014; **38**: 384–96. doi: <https://doi.org/10.1016/j.clinimag.2014.02.014>
22. Moore TE, Yuh WT, Kathol MH, El-Khoury GY, Corson JD. Abnormalities of the foot in patients with diabetes mellitus: findings on MR imaging. *AJR Am J Roentgenol* 1991; **157**: 813–6. doi: <https://doi.org/10.2214/ajr.157.4.1892042>
23. Guerini H, Pessis E, Theumann N, Le Quintrec JS, Campagna R, Chevrot A, et al. Sonographic appearance of trigger fingers. *J Ultrasound Med* 2008; **27**: 1407–13. doi: <https://doi.org/10.7863/jum.2008.27.10.1407>
24. Choi JH, Yu KP, Yoon YS, Kim ES, Jeon JH. Relationship between HbA1c and complex regional pain syndrome in stroke patients with type 2 diabetes mellitus. *Ann Rehabil Med* 2016; **40**: 779–85. doi: <https://doi.org/10.5535/arm.2016.40.5.779>
25. Schweitzer ME, Mandel S, Schwartzman RJ, Knobler RL, Tahmouh AJ. Reflex sympathetic dystrophy revisited: MR imaging findings before and after infusion of contrast material. *Radiology* 1995; **195**: 211–4. doi: <https://doi.org/10.1148/radiology.195.1.7892471>
26. Marshall, Crisp AJ. Reflex sympathetic dystrophy. *Rheumatology* 2000; **39**: 692–5.
27. Andreisek G, Crook DW, Burg D, Marincek B, Weishaupt D, BorutMarincek DW. Peripheral neuropathies of the median, radial, and ulnar nerves: MR imaging features. *Radiographics* 2006; **26**: 1267–87. doi: <https://doi.org/10.1148/rg.265055712>
28. Martinoli C, Bianchi S, Gandolfo N, Valle M, Simonetti S, Derchi LE. US of nerve entrapments in osteofibrous tunnels of the upper and lower limbs. *Radiographics* 2000; **20 Spec No**: S199–S217. doi: https://doi.org/10.1148/radiographics.20.suppl_1.g00oc08s199
29. Klauser AS, Halpern EJ, De Zordo T, Feuchtner GM, Arora R, Gruber J, et al. Carpal tunnel syndrome assessment with US: value of additional cross-sectional area measurements of the median nerve in patients versus healthy volunteers. *Radiology* 2009; **1250**: 171–7. doi: <https://doi.org/10.1148/radiol.2501080397>
30. Mendes AL, Miot HA, Haddad V, Junior H V. Diabetes mellitus and the skin. *An Bras Dermatol* 2017; **92**: 8–20. doi: <https://doi.org/10.1590/abd1806-4841.20175514>
31. Gold RH, Tong DJ, Crim JR, Seeger LL. Imaging the diabetic foot. *Skeletal Radiol* 1995; **24**: 563–71. doi: <https://doi.org/10.1007/BF00204853>
32. García-Gavín J, Comba Pérez-Pérez L, Requena L, Wortsman X. Sarcoidal necrobiosis lipoidica in a nondiabetic patient: usefulness of skin ultrasound. *Actas Dermosifiliogr* 2016; **107**: 525–7. doi: <https://doi.org/10.1016/j.ad.2016.01.011>
33. Lacout A, Lebreton C, Mompont D, Mokhtari S, Vallée CA, Carlier RY. CT and MRI of spinal neuroarthropathy. *AJR Am J Roentgenol* 2009; **193**: W505–W514. doi: <https://doi.org/10.2214/AJR.09.2268>
34. Marcus CD, Ladam-Marcus VJ, Leone J. Dominiqueamalgrange, francoise m bonnet-gausserand, bernard p menanteau. MR imaging of osteomyelitis and neuropathic osteoarthropathy in the feet of diabetics. *RadioGraphics* 1996; **16**: 1337–48.
35. Baker JC, Hillen TJ, Demertzis JL. The role of imaging in musculoskeletal emergencies. *Semin Roentgenol* 2014; **49**: 169–85. doi: <https://doi.org/10.1053/j.ro.2014.01.001>
36. William C, Corson JDYuh, Baraniewski HM, KanmRezai. Osteomyelitis of the foot in diabetic patients: evaluation with plain film, 99mTc-MDP bone scintigraphy, and MR imaging. *Am J Roentgenol Radium Ther* 1989; **4**: 795–152800.
37. Pectasides M, Kalva SP, MelinaPectasides SP. Diabetes revealed: multisystem danger. *AJR Am J Roentgenol* 2011; **196**: 274–86. doi: <https://doi.org/10.2214/AJR.10.5922>
38. Johnson PW, Collins MS, Wenger DE. Diagnostic utility of T1-weighted MRI characteristics in evaluation of osteomyelitis of the foot. *AJR Am J Roentgenol* 2009; **192**: 96–100. doi: <https://doi.org/10.2214/AJR.08.1376>
39. Ahmadi ME, Morrison WB, Carrino JA, Schweitzer ME, Raikin SM, Ledermann HP. Neuropathic arthropathy of the foot with and without superimposed osteomyelitis: MR imaging characteristics. *Radiology* 2006; **238**: 622–31. doi: <https://doi.org/10.1148/radiol.2382041393>
40. Wu B, Bell K, Stanford A, Kern DM, Tunceli O, Vupputuri S, et al. Understanding CKD among patients with T2DM: prevalence, temporal trends, and treatment patterns-NHANES 2007–2012. *BMJ Open Diabetes Res Care* 2016; **4**: e000154. doi: <https://doi.org/10.1136/bmjdc-2015-000154>
41. Iyer SG, Saxena P, Sharma GL, Saxena UD. Forestier disease - an unusual cause of dysphagia. *Indian J Radiol Imaging* 2003; **13**: 79–80.
42. Theodorou DJ, Theodorou SJ, Resnick D. Imaging in dialysis spondyloarthropathy. *Semin Dial* 2002; **15**: 290–6.
43. Brahee DD, Guebert GM, Virgin B. Dialysis-related spondyloarthropathy. *J Manipulative Physiol Ther* 2001; **24**: 127–30. doi: <https://doi.org/10.1067/mmt.2001.112560>
44. Murphey MD, Sartoris DJ, Quale JL, Pathria MN, Martin NL. Musculoskeletal manifestations of chronic renal insufficiency. *Radiographics* 1993; **13**: 357–79. doi: <https://doi.org/10.1148/radiographics.13.2.8460225>
45. Suaya JA, Eisenberg DF, Fang C, Miller LG. Skin and soft tissue infections and associated complications among commercially insured patients aged 0–64 years with and without diabetes in the U.S. *PLoS One* 2013; **8**: e60057. doi: <https://doi.org/10.1371/journal.pone.0060057>
46. Turecki MB, Taljanovic MS, Stubbs AY, Graham AR, Holden DA, Hunter TB, et al. Imaging of musculoskeletal soft tissue infections. *Skeletal Radiol* 2010; **39**: 957–. doi: <https://doi.org/10.1007/s00256-009-0780-0>