Abstract
Diabetes mellitus (DM) is a major health concern globally, affecting almost every organ of the body. A major issue with DM is that a relatively large proportion of patients remain undiagnosed till the development of complications, many of which may cause permanent impairment. Therefore, early recognition of the radiological manifestations (of DM) is of utmost importance, so that the disease may be diagnosed and managed well in time. Some common and important radiological features encountered in practice are compiled in this article.

Keywords: Computed tomography, Diabetes, Imaging, Magnetic resonance imaging, Ultrasound, X-ray.

Introduction
The systemic effects of diabetes mellitus (DM) are well recognized. The heart, kidney, central and peripheral nervous systems, and the distal parts of the limbs are often the site of end-organ damage resulting from ischaemia. Besides, diabetic patients are considered as a high-risk population for the development of pulmonary tuberculosis (PTB). The radiologist plays an important role in confirming these diabetic complications; furthermore he/she is also involved in the therapeutic management of these patients. A number of radiological changes can be encountered in patients with DM. In this article we have tried to summarize some important radiological findings (system wise) as a clue to DM (Table-1).

Brain Imaging in DM
Diabetes is associated with impaired cognitive functioning and an increased risk of dementia. The CT and MRI studies reveal cerebral atrophy and lacunar infarcts; no consistent relation with white matter lesions (WMLs) has been observed. The MRS studies show elevated myo-inositol-to-creatine ratios and reduced N-acetylaspaltate-to-creatine ratios in diabetic patients. The PET and SPECT studies reveal regional alterations in CBF.1

Diabetic Eye Disease
B-scan US can be used to evaluate the complications of diabetic retinopathy - viz., vitreous haemorrhage, vitreous detachment and retinal detachment.2

Head & Neck involvement in DM
With increasing incidence of diabetes, which compromises the host's immunity, the incidence of fungal infections involving nose and paranasal sinuses is of common occurrence. Fungal sinusitis in diabetics can be of different types with different pathophysiology and clinical presentation. Acute fulminant invasive sinusitis caused by Mucor or Aspergillus, chronic invasive sinusitis, granulomatous invasive sinusitis caused by Rhinosporidiosis, fungal ball caused by Mycetoma, and allergic rhinosinusitis caused by Aspergillus are common variants. Common X-ray/CT findings in patients with fungal sinusitis include an expansile lesion involving the sinus with erosion of sinus wall, heterodense mass (with some hyperdense areas) filling the sinusosal cavity, and the septum being pushed to the opposite side. Orbital extension is common causing proptosis.3

Malignant (necrotizing) otitis externa is a potentially life threatening infection in elderly diabetic patients presenting with severe otalgia. The causative agent is Pseudomonas aeruginosa in most cases. CT/MRI demonstrates invasive lesion of the external auditory canal (EAC), middle ear, mastoid and the temporal bone, with osteomyelitis and abscess formation. Gallium scan and a bone scan (technetium 99m) also help in diagnosing the disease. Cranial neuropathies and skull base infection are common if treatment is delayed. Early diagnosis and treatment improves patient's outcome.4

Diabetic Neuropathy (DN)
Diabetes is the most common cause of neuropathy. The most common form of DN is a length-dependant symmetrical distal axonopathy that may be relentlessly progressive or may remain stable for years. Less commonly, the patients can develop bilateral proximal or regional unilateral focal/multifocal neuropathies that may involve the cranial nerves and the trunk (diabetic...
Table 1: Radiological manifestations of DM.

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<th>Complications of DM</th>
<th>Diagnostic Clue(s)</th>
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| Head and Neck: Brain Involvement | **CT/MRI:** Cerebral atrophy and lacunar infarcts.  
**MRS:** Elevated myo-inositol-to-creatine ratio and reduced N-acetylaspartate-to-creatine ratio in a patient with impaired cognitive function and dementia. |
| Diabetic Retinopathy           | **B-scan US:** Vitreous haemorrhage, vitreous/retinal detachment.                                                                                                                                                        |
| Fungal Sinusitis               | **CT:** Hyperdense mass filling the sinonasal cavity with associated bone erosion/destruction.                                                                                                                     |
| Malignant (Necrotizing) Otitis Externa | **CT/MRI:** Invasive lesion of external auditory canal, middle ear, mastoid and temporal bone, with osteomyelitis and abscess formation in an elderly patient with severe otalgia.  
**MRI:** Fascicular enlargement and abnormal T2 hyperintensity observed in the acute and subacute stage or intraperineural fat deposition and fascicular atrophy in the chronic stage of the disease.  
**CT/MRI:** Length-dependent symmetrical distal axonopathy that may be relentlessly progressive or may remain stable for years. |
| Diabetic Neuropathy            |                                                                                                                                                                                                                         |
| Thorax: Pulmonary Tuberculosis | **CT:** Atypical radiological presentation with lower lobe involvement and multilobular disease. Parenchymal lesions may be nodular, exudative or mixed variety. Cavitary lesions are more common. |
| Diabetic Mastopathy            |                                                                                                                                                                                                                         |
| Abdomen: Non Alcoholic Fatty Liver Disease (NAFLD) | **US:** Dense breast tissue on mammogram and dense posterior acoustic shadowing on US.                                                                                                                                     |
| Fibrocalculous pancreatic diabetes | **CT:** Chronic pancreatitis with parenchymal atrophy and pancreatic lithiasis.                                                                                                                                          |
| Diabetic Nephropathy           | **US/Colour Doppler:** Early: Enlarged kidney (may also be seen in amyloidosis & lymphoma).  
**Later:** Small shrunken kidney with diffuse increase in parenchymal echogenicity and increased RI (>0.7) in a patient with impaired renal function and clinical evidence of retinopathy. |
| Emphysematous Pyelonephritis   | **Abdominal Radiograph:** Air in renal fossa region.                                                                                                                                                                     |
| Emphysematous cholecystitis    | **CT:** Renal/perirenal infection with presence of air locule(s).                                                                                                                                                        |
| Emphysematous Cystitis         | **Radiograph/CT:** Air within the wall/lumen of GB, in absence of any abnormal communication with the gastrointestinal tract.                                                                                             |
| Diabetic Cystopathy           | **Radiograph/CT:** Streaky luencies/air locule(s) in bladder wall, within the bladder or tracking proximally into the ureters.                                                                                              |
| Ectopic Calcifications in Different Tissues | **US/MCU:** A large atomic bladder with bilateral vesico-ureteric reflux and funneling of urethra.  
Calcification of pelvic, ovarian and uterine vessels.  
Calcification of vas deferens.  
Calcification of necrotic renal papillae. |
| Limbs: Charcot Neuro-Osteoarthropathy | **Foot Radiograph:** Midfoot involvement with resorption of tuft of phalanges and metatarsals with characteristic "penetrating" or "lick & candy" appearance of metatarsal shafts, destruction of calcaneotarsal articulation, subchondral cysts and intra-articular loose bodies. |
| Osteomyelitis                  | **MRI:** Preservation of subcutaneous fat, absent soft tissue/joint fluid collection.                                                                                                                                      |
|                                | **Foot Radiograph:** Soft tissue gas and entheseopathy at attachment of Achilles tendon/plantar fascia in a patient with oedematous/erythematous ankle with large wound/ulceration of foot. |
|                                | **MRI:** Bone marrow/soft tissue oedema, joint effusion, periarticular enhancement and a sinus tract.                                                                                                                      |
amyotrophy); isolated limb neuropathies may also be encountered. A high resolution high field (3-Tesla) fat suppressed heavy T2-weighted (2D and 3D) MR imaging is an excellent technique to image the peripheral nerve anatomy and pathology. A spectrum of MR imaging abnormalities is observed in patients with DN. Fascicular enlargement and abnormal T2 hyperintensity is commonly observed in the acute and subacute stage. Intraperineurial fat deposition and fascicular atrophy is seen in the chronic stage of the disease. 5

Pulmonary Tuberculosis in Diabetics
Unlike non-diabetics, diabetic patients may have atypical radiological presentation of PTB that includes lower lobe involvement and multilobar disease on chest x-ray. Parenchymal lesions may be nodular, exudative or mixed. Cavitory lesions are more common among diabetic patients. Clinically, this is important because lower lobe tuberculosis is often misdiagnosed as pneumonia, lung abscess or carcinoma. 6

Diabetic Mastopathy
Diabetic mastopathy is an uncommon condition affecting patients with a history of long-standing insulin-dependent DM. Discrete palpable breast masses are noted clinically. Imaging (mammography/US) findings suggestive of gynecomastia are present, classically showing dense breast tissue on mammograms and dense posterior acoustic shadowing on US. 7

Gastrointestinal Complications of Diabetes
Gastro-esophageal reflux disease (GERD), gastroparesis, enteropathy and non alcoholic fatty liver disease (NAFLD) associated with DM are responsible for characteristic radiological changes. 8

Pancreatitis and DM
Diabetes is a common complication of chronic pancreatitis and affects about half of the people with the condition. Chronic pancreatitis is characterized by a persistent destruction of the pancreatic parenchyma replaced by fibrosis. On CT scan, chronic pancreatitis (termed fibrocalculous pancreatic diabetes) demonstrates parenchymal atrophy and pancreatic lithiasis (pancreatic duct stones - along the course of main pancreatic duct/side branches) in > 95% cases. 9,10

Urinary Tract Involvement in DM
Diabetic nephropathy, a common complication in patients with long standing DM, is characterized by presence of small shrunken kidney with diffuse increase in parenchymal echogenicity on ultrasound (US). An increased RI (≥0.7) on colour Doppler is associated with impaired renal function. Diabetic nephropathy is usually preceded by the onset of diabetic retinopathy. 11

Emphysematous pyelonephritis is a life threatening, fulminant and necrotizing upper urinary tract infection with gas forming organism, and is relatively common in patients with DM. In emphysematous pyelonephritis, gas is observed within the renal parenchyma; gas confined to renal pelvis is called emphysematous pyelitis, and gas confined to perinephric space is termed perinephric emphysema. Plain radiograph better depicts air in the renal collecting system than US. CT is apparently the best imaging modality in detecting air locule(s), and it detects presence of air within the renal tract along with renal and perirenal infection. 12

Emphysematous cystitis is nearly always associated with DM. Conventional radiograph demonstrates streaky lucencies in the bladder wall. Gas may also be seen in the bladder or tracking proximally into the ureters. On IVU, air-contrast level may be seen within the bladder on erect images. Cystitis is seen as irregular or nodular mucosal thickening on US and contrast-cystography. 14

Diabetic cystopathy with neurogenic bladder is a well recognized complication of DM. Abnormal bladder function is responsible for characteristic radiological change. A large atonic bladder with bilateral vesico-ureteric reflux and funneling of urethra is commonly encountered. 15
**Musculoskeletal (MSK) complications of DM**

Diabetic foot secondary to neuropathy is the most common complication of long standing DM and is associated with high morbidity. It is believed to be caused either by repeated traumatization of an injured insensitive foot, or by a neurogenic bone dystrophy. Charcot neuro-oisteoarthropathy, a primary articular disease, is characterized by resorption of tuft of phalanges and metatarsals leading to characteristic “pencilling” or “lick & candy” appearance of metatarsal shafts on foot-radiograph. Destruction of the calcaneotalar articulation, demineralization of tarsal and metatarsal bones, fragmentation and sclerosis with soft tissue swelling are other findings observed on foot x-ray, consistent with diabetic neuropathic arthropathy. Occult sequelae of previous traumatic injuries associated with Charcot’s arthropathy are best detected on MRI.17-19

Ulceration of the foot with superimposed infection of underlying bone results in osteomyelitis. Oedematous/erythematous ankle, large wound/ulceration of foot on clinical examination; soft tissue gas and enthesophytes at the attachment of the Achilles tendon/plantar fascia on X-ray foot favour osteomyelitis. Bone marrow/soft tissue oedema, joint effusion, periarticular enhancement and sinus tract associated with osteomyelitis are best detected by MRI.17,18

It is very difficult to differentiate between acute neuroarthropathy and osteomyelitis, especially osteomyelitis in a patient with neuroarthropathy, as both of these are destructive processes. Location and MRI findings may be of some help. Neuroarthropathy often occurs in the midfoot. Osteomyelitis starts distal to the Lisfranc joint or in the posterior calcaneous, but can spread to midfoot. On MRI, replacement of soft tissue fat, extensive or diffuse marrow oedema, joint effusion, enhancement and erosion support osteomyelitis superimposed upon neuroarthropathy; while, abnormal joint in a diabetic foot, preservation of subcutaneous fat, absence of soft-tissue/joint fluid collection, presence of subchondral cysts and intra-articular loose bodies support neuroarthropathy without infection.20

Tendinopathies (Tendonitis, tendon rupture and tenosinovitis) are of common occurrence in diabetics.17,18

Subchondral and periarticular cystic changes in hands and shoulders, and periarticular cortical erosions in phalanges may be observed on plain radiograph/CT/MRI.17,18

**Diabetic Myopathy**

Diabetic myopathy is often seen with long-standing, poorly controlled diabetes. Patient usually presents with pain, swelling and palpable soft tissue mass in the affected area. It encompasses a spectrum of diseases including muscle inflammation, ischaemia, haemorrhage, infarction, necrosis, fibrosis and fatty atrophy. With a typical clinical presentation and MRI findings, a confident diagnosis can usually be made, thereby avoiding the potentially harmful biopsy.21

**Ectopic Calcifications in Different Tissues**

These are best appreciated on radiographs, and include vascular calcification (Monckeberg's sclerosis-linear medial calcification) especially involving metatarsal arteries and may also involve pelvic, ovarian, uterine and forelimb vessels; calcification of vas deferens; calcific tendinitis; chondrocalcinosis; and calcification of necrotic renal papillae.16

**Conclusion**

A vast variety of radiological changes may be noted in a diabetic patient. Although DM is better diagnosed by hyperglycaemia, as is suggested by the American Diabetes Association (ADA) and the World Health Organization (WHO) guidelines,21,22 imaging findings should warrant a search for hyperglycaemia or immunocompromised status of the patient.

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