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Tuberculosis: A Head to Toe Radiological Review

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Abstract

Tuberculosis (TB) results from infection by *Mycobacterium tuberculosis* and can involve any organ or tissue. Early diagnosis of TB is essential for timely initiation of therapy in order to decrease transmission rate and avoid severe morbidity associated with delayed treatment. Although conventional radiography remains the most common initial imaging modality in diagnosis of pulmonary TB, computer tomography (CT) and magnetic resonance imaging (MRI) are modalities of choice with regards to diagnosis of extra-pulmonary TB. The purpose of this paper is to provide a concise review of various imaging manifestations of TB in various organ systems, in order to promote radiologists' and clinicians' familiarity with common radiological findings of this important disease.

Keywords

Mycobacterium tuberculosis, Radiology

1. Introduction

Tuberculosis (TB) results from infection by *Mycobacterium tuberculosis* and can involve any organ or tissue, affecting notably the lungs, heart, bones and joints, central nervous system and intra-abdominal viscera. TB is one of the top ten causes of death overall and the leading cause of death from a single infectious agent [1]. Millions of people continue to contract TB each year. In 2017, TB caused an estimated 1.3 million deaths [1]. Early diagnosis of TB is essential for timely initiation of therapy in order to decrease transmission rate and avoid severe morbidity [1] [2].

As radiologic imaging constitutes an essential part of modern-day TB diag-

nostic pathway, radiologists' and clinicians' ability to promptly recognize various radiological manifestations of tuberculous infection becomes paramount. In the hope to promote physicians' awareness of the multitude of imaging manifestations of TB throughout the body, we have attempted to provide a concise and yet reasonably comprehensive review of major radiological manifestations of TB in various organs, as summarized in **Table 1**, using illustrative examples compiled from our collections of clinical cases.

2. Thoracic Tuberculosis

Tuberculosis most commonly affects the lungs [2] [3] [4]. Pulmonary TB is divided into primary and post-primary [5] [6]. Differentiating these two forms can be challenging, as some of their clinical and radiological features overlap.

Primary pulmonary TB occurs when exposure to *M. tuberculosis* occurs for the first time. Primary pulmonary TB has four most common radiological presentations:

1) *Lymphadenopathy*, which is usually unilateral and commonly occurs in the paratracheal, hilar and subcarinal regions [4]. On CT, lymphadenopathy is usually more than 2 cm in diameter, with a characteristic "rim-sign", consisting of an enhancing rim, due to granulomatous inflammatory tissue, and a low-attenuation center resulting from caseous necrosis [5] [6] (**Figure 1**).

2) *Lung parenchymal involvement*, frequently presenting as a dense, homogeneous consolidation, preferentially involving lower and middle lobes [7] (**Figure 2**). Multi-lobar consolidations are seen in 25% of cases [5]. TB consolidations are indistinguishable from consolidations of bacterial pneumonia.

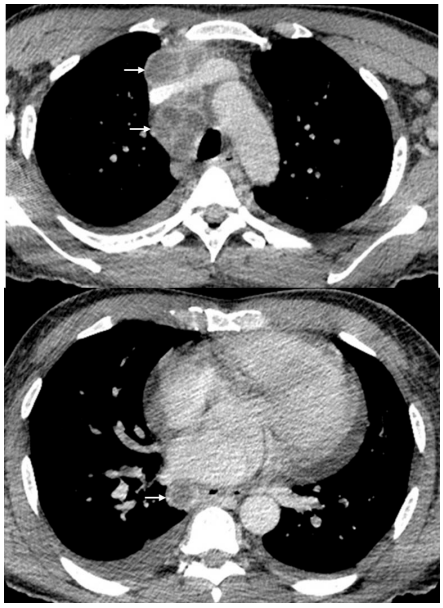

Figure 1. A 45 year-old man with AIDS on highly active antiretroviral therapy, who developed TB adenitis. Contrast-enhanced CT of the chest demonstrates mediastinal lymphadenopathy with peripheral enhancement and central hypodensity (arrows). Small pleural and pericardial effusions are also present.

Table 1. Radiological manifestations of tuberculosis by body system.

Thoracic	
	Primary TB
Lymphadenopathy	Usually unilateral; commonly paratracheal, hilar or subcarinal; usually > 2 cm in diameter; can feature "rim-sign": enhancing rim of granulomatous tissue and a low-attenuation necrotic center
Parenchymal involvement	Ghon focus: dense consolidation; preferentially in lower and middle lobes; may heal with residual calcified granuloma; Ghon focus + ipsilateral hilar lymphadenopathy = Ghon's complex; calcified Ghon's complex = Ranke complex
Miliary TB	Pulmonary hematogenous dissemination: 1 - 4 mm granulomata, randomly distributed throughout lungs
Pleural effusion	Commonly on the side of the primary pulmonary focus; pleural thickening/enhancement can be seen with TB empyema; TB empyema may be complicated by broncho-pleural fistula or extension to the chest wall—empyema necessitans; can result in pleural thickening and calcification; may lead to fibrothorax
	Post-primary pulmonary TB
Parenchymal involvement	Poorly-defined consolidation; apical and posterior segments of upper lobes and superior segments of lower lobes predominance; cavitations are common; endobronchial spread results in "tree-in-bud" appearance; cavities can lead to TB empyema, broncho-pleural fistula, spread to the chest wall and pulmonary arterial pseudoaneurysm
Airway involvement	Long segments of airway narrowing with irregular wall thickening; luminal obstruction resulting in lobar collapse, hyperinflation, obstructive pneumonia, mucous impaction and tree-in-bud opacities
Pleural effusion	Less common than in primary TB; usually small, associated with parenchymal disease
Cardiac	
Pericardial effusion and irregular pericardial thickening of more than 3 mm	
Abdominal	
Lymphadenopathy	Most common presentation of abdominal TB; often bulky; can feature "rim-sign"
Peritoneal	Wet ascetic (most common): large amounts of slightly hyperattenuating peritoneal free fluid, peritoneal enhancement common; fibrotic type: large omental and mesenteric masses; dry plastic type (less common): mesenteric thickening, peritoneal caseous nodules and fibrous adhesions

Continued

Gastrointestinal	Vast majority of cases occur at ileo-cecal junction (90%), often extending to terminal ileum and cecum; CT usually shows concentric thickening of the bowel
Renal	Parenchymal hypodense lesions, nodules, abscesses; urothelial thickening/enhancement; caliectasis, infundibular strictures, hydronephrosis; may lead to renal cortical thinning, scarring and calcifications
	Musculoskeletal
Tuberculous spondylitis (*Pott's disease*)	Most common in thoracic spine > lumbar spine; usually begins in anterior vertebral body, adjacent to the end-plate and spreads to intervertebral disk; associated paravertebral abscesses are common
Tuberculous arthritis	Monoarticular, affecting large weight-bearing joints; imaging findings: osteopenia, synovitis, soft-tissue swellings, marginal erosions, cartilage destruction
Tuberculous osteomyelitis	Most common in metaphysis of long bones, pelvis, small bones of hands and feet; common features: osteopenia, relative lack of periostitis or sclerosis around lytic lesions
	Central nervous system
Tuberculous meningitis	Abnormal meningeal enhancement, predominantly in basal cisterns; may lead to deep infarcts, hydrocephalus, cranial nerve involvement; spinal meningitis: obliteration of spinal subarachnoid space, matting of nerve roots in lumbar region, nodular and linear intradural enhancement
CNS parenchymal	tuberculomas: may be solitary, multiple or military; CT and MRI: round or lobulated masses with surrounding edema, can enhance homogeneously or in a ring-like fashion

Figure 2. CT chest in a 41 year-old man, long term smoker, shows an irregular, mass-like lesion in the right lower lobe (arrow), originally believed to be primary lung cancer, which turned out to be active TB. The lesion has completely resolved following antibiotic therapy.

The site of primary TB lung involvement is known as a Ghon focus, which commonly heals with residual calcified granuloma. If a Ghon focus is associated with ipsilateral hilar lymphadenopathy, it is known as the Ghon's complex or primary complex. Calcified Ghon's complex is known as a Ranke complex and its presence is strongly suggestive of previous TB [6] (**Figure 3**).

3) *Pleural effusion*, which is commonly unilateral and complex. Tuberculous effusions are more often found in primary (25%) than in post-primary TB (18%) [2]. Pleural effusion is commonly on the same side as the primary focus of TB (**Figure 4**). Pleural thickening and pleural enhancement can be seen with TB empyema [8]. If not treated, TB empyema may be complicated by broncho-pleural fistula or extension to the chest wall, the latter known as empyema necessitans [8]. After treatment, residual pleural thickening with calcification can develop and may lead to formation of fibrothorax [2] (**Figure 5**).

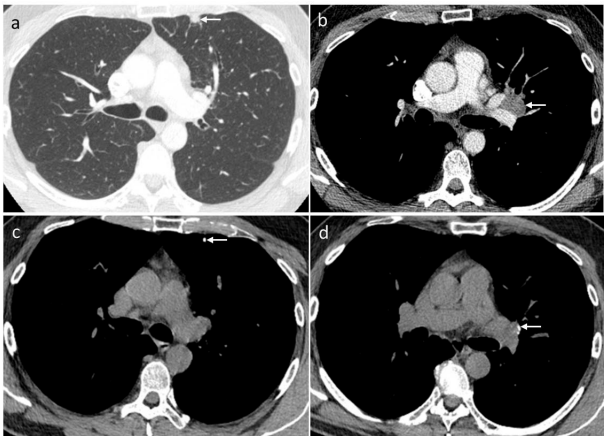

Figure 3. ((a) and (b)) CT chest in a 52 year-old man with active primary TB shows a Ghon's complex, consisting of primary focus of infection (Ghon focus) in the left upper lobe (arrow in (a)) and left hilar enlarged lymph node (arrow in (b)). ((c) and (d)) Follow-up CT performed 8 year later, shows transformation of the Ghon's complex into Ranke complex (arrows), as the Ghon focus and the left hilar lymph node have calcified.

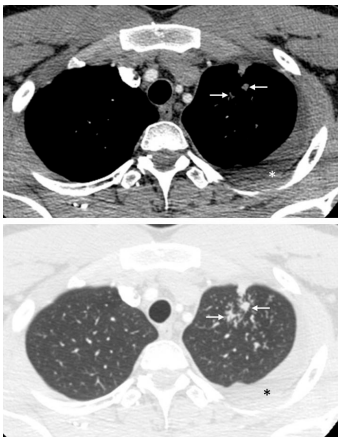

Figure 4. CT chest in an 18 year-old man from Eastern Africa presenting with several months history of night sweats and positive purified protein derivative skin test, shows left upper lobe tree-in-bud nodules (arrows) and left pleural effusion (asterisk).

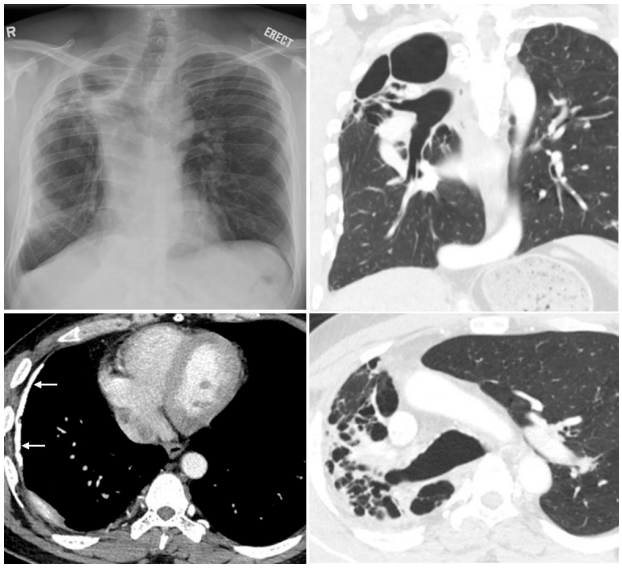

Figure 5. Chest radiograph and CT chest in a 38 year-old man from India show typical findings of chronic post-primary pulmonary TB—extensive right upper lobe scarring, atelectasis, cystic changes, airway narrowing, bronchiectasis and right calcified fibrothorax (arrows).

4) *Miliary TB*, which represents pulmonary dissemination of the disease by hematogenous spread, occurring in 1% - 7% of patients with all forms of TB, and presenting as granulomata 1 - 4 mm in diameter, randomly distributed throughout lungs [8] (**Figure 6**).

Post-primary pulmonary TB occurs as either reactivation of a latent primary infection or as a repeated infection. The classic features of post-primary TB include upper lung zones distribution, cavitation and absence of lymphadenopathy. Post-primary TB can have the following radiologic presentations:

1) *Pulmonary parenchymal* involvement, presenting as a poorly-defined consolidation with predominance in the apical and posterior segments of the upper lobes and superior segments of the lower lobes [5] (**Figure 7**). Cavitations are seen in 20% - 45% of post-primary TB patients [8] and can be multiple [5] (**Figures 8-10**). The most common complication of cavitation is endobronchial spread of infection, resulting in typical "tree-in-bud" appearance, characterized by small centrilobular nodules with concomitant branching opacities [3] (**Figure 9**). Cavities can rupture into the pleural space, resulting in TB empyema, broncho-pleural fistula or spread to the chest wall. Cavitary lesions can occasionally erode into a pulmonary artery, causing a pseudoaneurysm, called Rasmussen aneurysm [5] (**Figure 10**).

2) *Airway* involvement can occur from direct extension from TB infected lymph nodes, endobronchial spread or lymphatic dissemination [5]. Imaging features of airway involvement include long segments of airway narrowing with irregular wall thickening, luminal obstruction resulting in lobar collapse, hyperinflation, obstructive pneumonia, mucous impaction and tree-in-bud opacities (**Figure 5**).

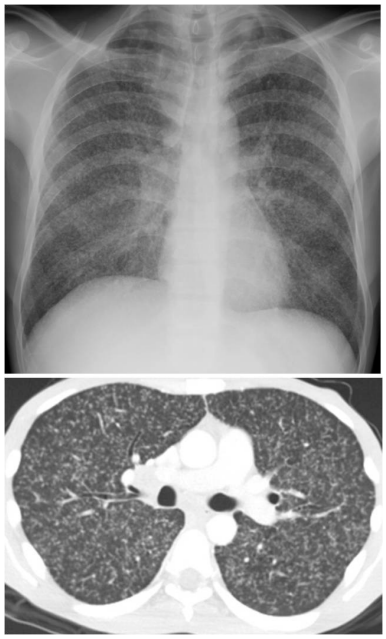

Figure 6. Chest radiograph and CT chest in a 30 year-old man with active TB, show innumerable randomly distributed pulmonary micronodules, in keeping with miliary TB. There is also right hilar lymphadenopathy.

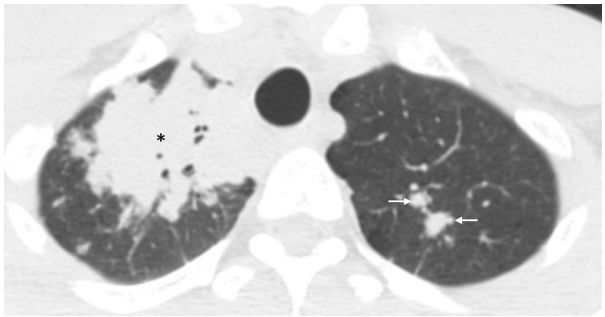

Figure 7. CT chest in a 40 year-old man from India with active post-primary TB, shows right upper lobe consolidation (asterisk) and left upper lobe nodules (arrows).

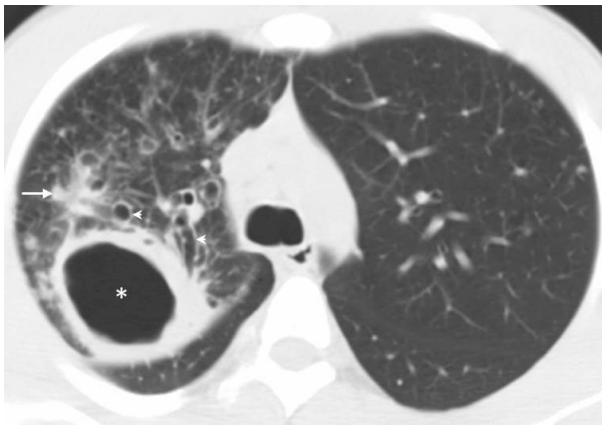

Figure 8. CT chest in a 35 year-old man with active post-primary TB shows a thick-walled cavity (asterisk), adjacent irregular nodular density (arrow) and bronchiectasis (arrowheads) in the right upper lobe.

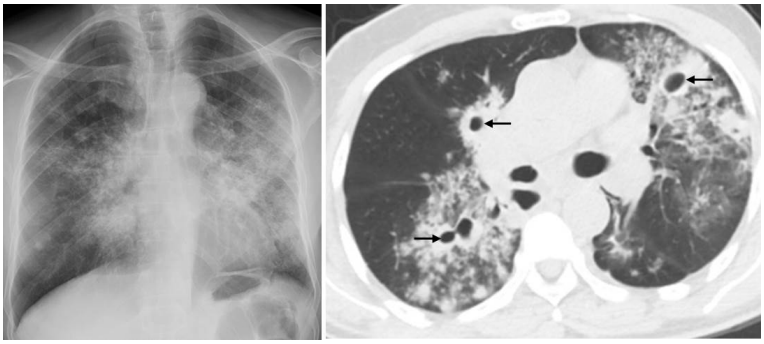

Figure 9. Chest radiograph and CT chest in a 70 year-old man with active post-primary TB show bilateral multifocal consolidations, "tree-in-bud" nodules and small cavities (arrows).

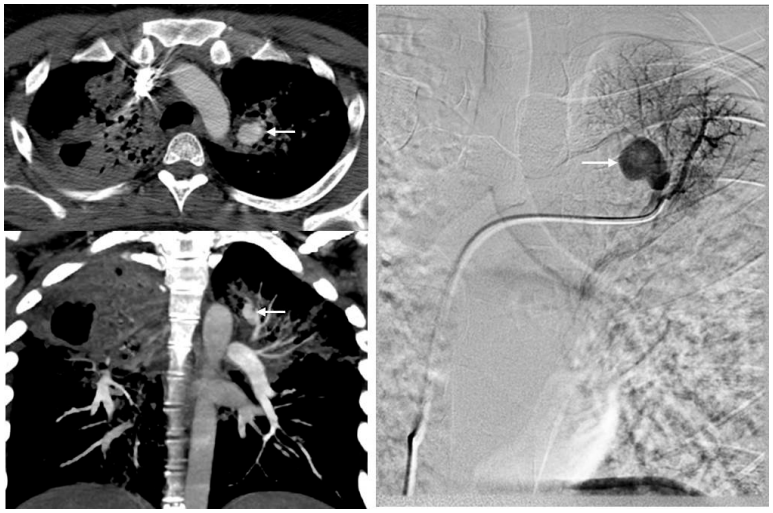

Figure 10. Rasmussen aneurysm in a 29 year-old woman with active pulmonary TB. CT chest and subsequent conventional pulmonary angiography demonstrate saccular aneurysm of a left upper lobe segmental pulmonary artery. CT images also show left upper lobe cavitary parenchymal disease adjacent to the aneurysm, and a large consolidation with a cavity in the right upper lobe.

3) *Pleural effusion* can occur in 18% of patients with post-primary tuberculosis, is usually small and associated with parenchymal disease [5].

3. Cardiac Tuberculosis

Cardiac tuberculosis is rare and only accounts for 0.5% of extra-pulmonary TB [3]. Most common presentation is pericardial involvement and can be demonstrated by CT as pericardial effusion and irregular pericardial thickening of more than 3 mm [3] (**Figure 11**).

4. Abdominal Tuberculosis

Abdominal TB can have the following radiologic presentations:

1) *Lymphadenopathy*, which can be necrotic, is the most common presentation of abdominal TB, accounting for 55% - 66% of cases [9] (**Figure 12**).

Figure 11. Culture proven TB pericarditis in a 49 year-old man. CT chest demonstrates moderate pericardial effusion (asterisks) and mild diffuse pericardial enhancement. There are also bilateral pleural effusions and left lower lobe atelectasis.

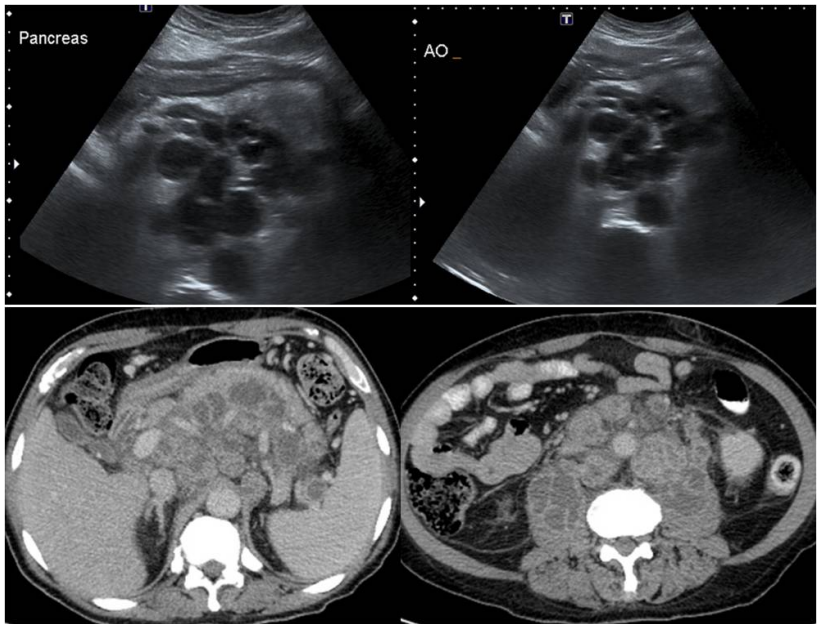

Figure 12. A 60 year-old man with AIDS and diffuse nodal TB. Abdominal ultrasound and CT demonstrate retroperitoneal bulky necrotic lymphadenopathy (arrows).

2) *Peritoneal tuberculosis*, which can present as either wet ascitic, fixed fibrotic and dry plastic types. The most common type, wet ascitic (90% of cases of peritoneal TB) is associated with large amounts of slightly hyperattenuating peritoneal free fluid, often accompanied by peritoneal enhancement [2]. The fibrotic type (60% of cases of peritoneal TB), is characterized by large omental and mesenteric cake-like masses [2] (**Figure 13**). The dry plastic type is less common, and presents as mesenteric thickening, peritoneal caseous nodules and fibrous adhesions [2].

3) *Gastrointestinal tuberculosis* is rare. Although it may occur anywhere along the gastrointestinal tract, the vast majority of cases involve the ileo-cecal junction (90%), often extending to the terminal ileum and cecum [9]. CT usually shows concentric thickening of the bowel [3] (**Figure 14**).

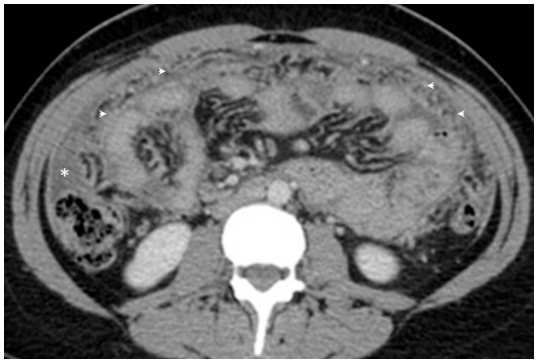

Figure 13. A 34 year-old female with Crohn's disease and disseminated active intra-thoracic and CNS tuberculosis. Contrast-enhanced CT abdomen shows mild ascites (asterisk), and diffuses peritoneal and omental thickening and nodularity (arrowheads). Biopsy of the omentum demonstrated granulomatous peritonitis.

Figure 14. A 40 year-old woman with active pulmonary and colonic TB. CT abdomen demonstrates marked circumferential wall thickening of the ascending colon (arrows).

4) *Solid organs* tuberculosis can involve any visceral organ; however, the genitourinary system is most commonly affected, accounting for 15% - 20% of extra-pulmonary TB [10]. CT findings may include renal parenchymal hypodense lesions, nodules and abscesses, urothelial thickening and enhancement, caliectasis, infundibular strictures and hydronephrosis [10] (**Figure 15**). Chronic cases may show renal cortical thinning, scarring and calcifications (**Figure 16**).

5. Musculoskeletal Tuberculosis

Musculoskeletal (MSK) TB is rare, reported in 1% - 3% of cases [3]. The main route of infection is via hematogenous spread from the lungs or activation of latent infection in bone or joint post-trauma [9]. MSK TB is classified into three subclasses:

1) *Tuberculous spondylitis* (*Pott's disease*) is the most common type of skeletal TB, accounting for 25% - 60% of MSK cases [11]. It most commonly affects the thoracic spine and, to a lesser degree, lumbar spine. Infection normally begins in the anterior part of the vertebral body, adjacent to the end-plate and spreads to the intervertebral disk. It then may progress to additional spinal segments and paraspinal tissues and result in formation of paravertebral abscesses [2] [12] (**Figure 17**).

Figure 15. A 47 year-old man with active renal and bladder TB. CT abdomen shows bilateral hydronephrosis (asterisks), left upper renal pole caliectasis (black arrow), left ureter diffuse circumferential thickening and enhancement (white arrow), and diffuse wall thickening and trabeculations of the urinary bladder wall (arrowheads). Several retroperitoneal necrotic lymph nodes are also present.

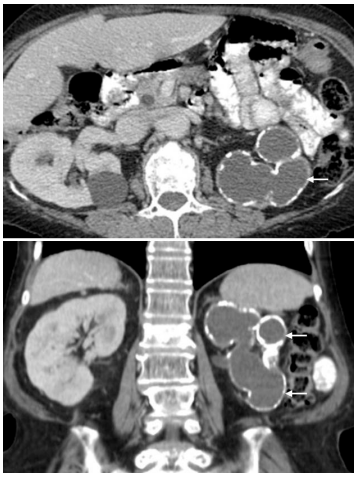

Figure 16. A 70 year-old woman with remote pulmonary and left renal TB. CT abdomen shows left renal atrophy with peripheral coarse calcifications (arrows).

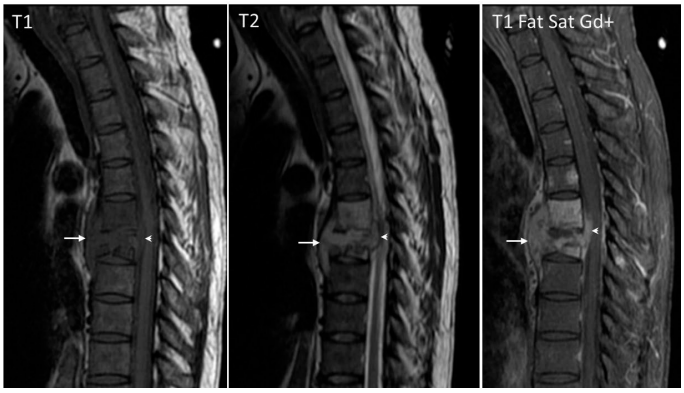

Figure 17. Cervical and dorsal tuberculous spondylodiscitis in a 41 year-old man with active pulmonary TB. Multisequential sagittal MRI of the dorsal spine demonstrates abnormal signal intensity and loss of T6-T7 disc space, opposing end plate irregularities, bone marrow enhancement of T6 and T7, and severe destruction of T7 vertebra. There is associated paravertebral collection (arrows) and small anterior intracanalicular epidural extension (arrowheads), compressing the spinal cord.

2) *Tuberculous arthritis* is characteristically monoarticular, affecting large weight-bearing joints. The imaging findings are nonspecific and include osteopenia, synovitis, soft-tissue swelling, marginal erosions, and cartilage destruction [13] (**Figure 18**).

3) *Tuberculous osteomyelitis* is most commonly seen in the metaphysis of long bones, in the pelvis, and small bones of the hands and feet [13] (**Figure 19**). TB osteomyelitis is difficult to differentiate from chronic pyogenic osteomyelitis, but the presence of osteopenia and relative lack of periostitis or sclerosis around lytic lesions may favor diagnosis of TB. Tuberculous dactylitis, a form of tubercular osteomyelitis ("spina ventosa"), refers to painless involvement of the short tubular bones of hands and feet [14].

6. Central Nervous System Tuberculosis

Central neural system (CNS) involvement occurs in about 5% of patients with TB and MRI is considered the imaging modality of choice for its diagnosis [3]. TB can involve the CNS in the following ways:

1) *Tuberculous meningitis* is the most common presentation of CNS TB and usually occurs by haematogenous spread of pulmonary TB. Typical MRI finding is abnormal meningeal enhancement, predominantly involving the basal cisterns [15] (**Figure 20**). Complications of TB meningitis include deep infarcts due to occlusion of penetrating lenticulo-striate vessels, hydrocephalus and cranial nerve involvement. Spinal TB meningitis can present on MRI as obliteration of the spinal subarachnoid space, and matting of the nerve roots in the lumbar spine region. Contrast-enhanced MRI can show nodular, thick and linear intradural enhancement [15].

2) *CNS parenchymal tuberculosis* is usually manifested by tuberculomas, which may be solitary, multiple or miliary. On CT and MRI, tuberculomas usually appear as round or lobulated masses with surrounding edema, and can enhance either homogeneously or in a ring-like fashion [15] (**Figure 21**).

Figure 18. Tuberculous arthritis in a 42 year-old woman with active pulmonary TB. Top panel: multiplanar, multisequential MRI of the pelvis shows marked synovitis and effusion of the left hip joint, with associated bone marrow edema involving the acetabular and femoral sides. Bottom panel: three years later, radiograph and CT of the pelvis demonstrate left hip degenerative changes which required total hip joint replacement.

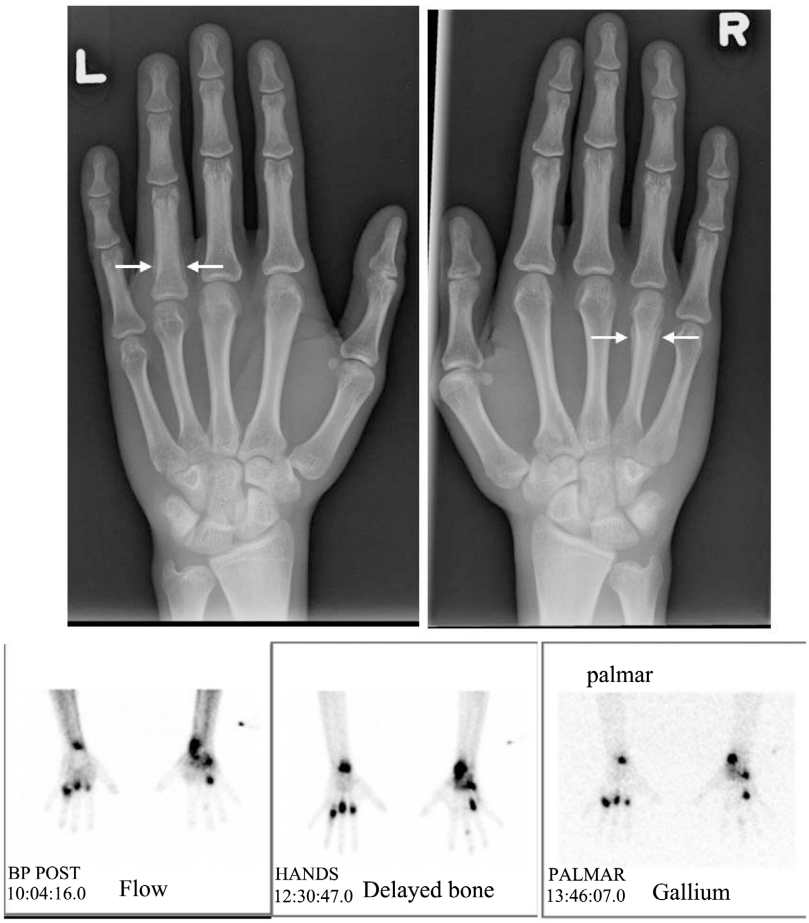

Figure 19. A 15 year-old man with active pulmonary TB and multifocal osteomyelitis. Radiographs of both hands show periosteal reaction around left 4th proximal phalanx and right 4th metacarpal. Bone scan shows hyperemia on flow study and increased activity on delayed images in right 4th MCP, wrist and distal right radius, left 2nd, 3rd and 4th MCP and distal left radius. The 48 hour gallium scan shows increased activity in the left 2nd, 3rd and 4th MCPs, in the right 4th MCP, in both distal radial metaphyses, and diffuse increased activity in the right wrist.

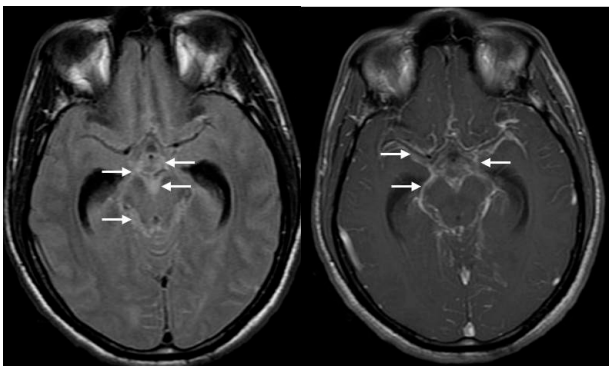

Figure 20. A 32 year-old man with pulmonary military and nodal TB, and TB meningitis. MRI of the brain shows increased signal intensity of the subarachnoid spaces in the FLAIR sequence, and diffuse ependymal enhancement of the basal cisterns and leptomeningeal enhancement around the brainstem following gadolinium administration (arrows).

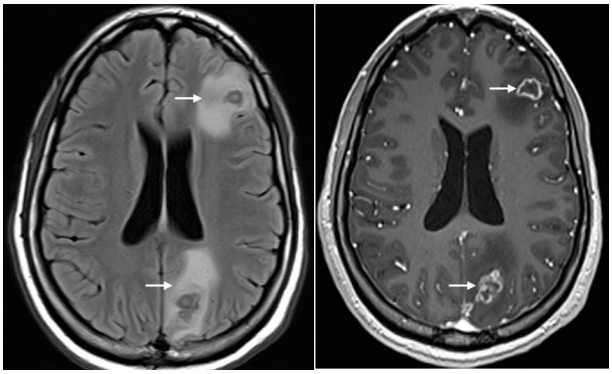

Figure 21. A 33 year-old woman with active mediastinal and retroperitoneal nodal, and cerebral TB. FLAIR and T1 post-gadolinium brain MRI images show ring-enhancing lesions associated with vasogenic edema (arrows).

7. Conclusion

Tuberculosis is still impacting millions of people worldwide. The intention of this review is to familiarize radiologists and clinicians with common radiologic manifestations of TB in various body systems.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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