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Original Research Article

Exploring Spinal Tuberculosis through MRI: Imaging Features, Pathophysiological Insights and its Clinical Implications

Article History:

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Abstract**: **Background: Spinal tuberculosis (TB), also known as Pott's disease, is the most common form of skeletal tuberculosis and a major cause of spinal deformity and neurological deficit, particularly in developing countries. Early diagnosis is often challenging due to its insidious onset and nonspecific clinical presentation. Among available imaging modalities, magnetic resonance imaging (MRI) has emerged as the gold standard for the evaluation of spinal tuberculosis because of its superior soft tissue contrast, multiplanar capability, and ability to assess bone marrow, intervertebral discs, paraspinal soft tissues, and neural elements simultaneously. ***Objectives:*** This review aims to comprehensively describe the MRI imaging spectrum of spinal tuberculosis, correlate imaging findings with underlying pathophysiology, and highlight the clinical relevance of MRI in diagnosis, disease staging, treatment planning, and follow-up. ***Materials and Methods***: A narrative review of the literature was conducted using PubMed/MEDLINE, Google Scholar, Scopus, and Embase databases. Peer-reviewed original articles, review articles, and consensus guidelines focusing on MRI features, pathophysiology, and clinical outcomes of spinal tuberculosis were included. Data were synthesized to present a structured overview of MRI findings across different disease stages. ***Results:*** MRI demonstrates characteristic findings of spinal tuberculosis, including vertebral body marrow edema, endplate destruction, disc involvement, paraspinal and epidural abscesses, subligamentous spread, and spinal cord compression. MRI patterns reflect disease stage and severity and correlate strongly with neurological deficits and treatment response. ***Conclusion:*** MRI plays a pivotal role in the early diagnosis, comprehensive assessment, and follow-up of spinal tuberculosis. Recognition of characteristic MRI patterns facilitates timely initiation of therapy, prevents irreversible neurological damage, and guides surgical decision-making.

Keywords: Spinal tuberculosis; Pott's disease; MRI spine; Tuberculous spondylitis; Paraspinal abscess

INTRODUCTION

Tuberculosis (TB) continues to pose a significant global health burden despite advances in diagnostics and therapeutics. According to the World Health Organization (WHO), tuberculosis remains among the top ten causes of death worldwide, with extrapulmonary tuberculosis accounting for nearly one-fifth of all TB cases [1]. Among extrapulmonary manifestations, skeletal tuberculosis constitutes approximately 10%, and spinal tuberculosis—also known as Pott's disease—represents the most common and most devastating form of musculoskeletal TB [2,3].

Spinal tuberculosis predominantly affects the thoracic and thoracolumbar regions, followed by the lumbar and cervical spine [4]. The disease commonly affects young adults and children in developing countries, though its incidence is rising in developed nations due to increasing immigration, immunosuppression, HIV infection, diabetes mellitus, malignancy, and prolonged corticosteroid therapy [5,6]. The insidious onset of spinal TB, characterized by chronic back pain, low-grade fever, malaise, weight loss, and night sweats, often leads to delayed diagnosis [7]. As a result, patients frequently present with advanced disease complicated by spinal deformity, instability, and neurological deficits [8].

Neurological complications occur in approximately 10–40% of patients with spinal tuberculosis and represent the most serious consequence of delayed diagnosis and treatment [9]. These deficits arise due to spinal cord or nerve root compression by epidural abscesses, granulation tissue, vertebral collapse, or progressive kyphotic deformity [10]. Early identification of disease extent and neural involvement is therefore critical for preventing irreversible neurological damage.

Conventional radiography has limited sensitivity in early spinal tuberculosis, as radiographic changes typically become apparent only after 30–50% of bone mineral loss [11]. Computed tomography (CT) provides superior visualization of cortical bone destruction and calcification within abscesses but is limited in evaluating early marrow involvement, soft tissue spread, and neural structures [12]. Nuclear medicine techniques, although sensitive, lack specificity and anatomical detail [13].

Magnetic resonance imaging (MRI) has emerged as the imaging modality of choice for spinal tuberculosis due to its excellent soft tissue contrast, multiplanar capability, and ability to detect early inflammatory changes in bone marrow, intervertebral discs, ligaments, paraspinal tissues, and neural elements [14,15]. MRI not only facilitates early diagnosis but also provides comprehensive information regarding disease activity, extent, complications, and response to therapy [16].

The characteristic MRI features of spinal tuberculosis—such as multilevel vertebral involvement, subligamentous spread, relative disc preservation in early stages, large paraspinal abscesses with thin and smooth walls, and epidural extension—allow differentiation from other causes of infectious and neoplastic spondylitis [17–19]. Additionally, contrast-enhanced MRI plays a pivotal role in identifying active disease, necrotic components, and epidural granulation tissue responsible for neural compression [20].

Given the continued prevalence of spinal tuberculosis and the central role of MRI in its diagnosis and management, a thorough understanding of the MRI imaging spectrum and its pathophysiological basis is essential for radiologists and clinicians alike. This review aims to provide a comprehensive overview of the MRI features of spinal tuberculosis, correlate imaging findings with underlying disease mechanisms, and emphasize the clinical relevance of MRI in diagnosis, staging, treatment planning, and follow-up.

Table 1. MRI Imaging Features of Spinal Tuberculosis and Pathophysiological Correlation

MRI Feature	Imaging Appearance	Underlying Pathophysiology
Vertebral marrow edema	T1 hypointense, T2/STIR hyperintense	Granulomatous inflammation and caseous necrosis
Vertebral body destruction	Endplate irregularity, collapse	Progressive bone resorption due to infection
Intervertebral disc involvement	Late disc signal alteration	Secondary spread through destroyed endplates
Subligamentous spread	Multilevel anterior vertebral involvement	Spread beneath anterior longitudinal ligament
Paraspinal abscess	T2 hyperintense with thin rim enhancement	Liquefied caseous material
Epidural extension	Enhancing soft tissue in spinal canal	Granulation tissue causing cord compression
Spinal cord edema	T2 hyperintensity	Ischemia and inflammatory compression
Myelomalacia	T1 hypointense, T2 hyperintense	Chronic irreversible cord damage

Table 2. MRI Features Differentiating Spinal Tuberculosis from Other Spinal Pathologies

Feature	Spinal Tuberculosis	Pyogenic Spondylitis	Metastatic Disease
Vertebral involvement	Multilevel, contiguous	Usually single level	Noncontiguous
Disc involvement	Late	Early	Rare
Paraspinal abscess	Large, thin-walled	Small, thick-walled	Rare
Subligamentous spread	Common	Rare	Absent
Enhancement pattern	Rim and heterogeneous	Diffuse	Solid
Spinal deformity	Common kyphosis	Uncommon	Collapse without abscess
Systemic toxicity	Mild	Severe	Variable

Table 3. Role of MRI in Clinical Management of Spinal Tuberculosis

Clinical Scenario	MRI Contribution
Early diagnosis	Detects marrow changes before X-ray/CT
Neurological deficit	Identifies cord compression and edema
Surgical planning	Defines abscess extent and instability
Treatment monitoring	Assesses resolution of inflammation
Suspected relapse	Differentiates active vs healed lesions
Drug resistance suspicion	Persistent enhancement despite therapy

Table 4. Advanced MRI Techniques in Spinal Tuberculosis

Technique	Utility	Clinical Significance
Diffusion-weighted imaging	Restricted diffusion in abscess	Confirms active infection
ADC mapping	Quantifies disease activity	Differentiates healed lesions
Contrast-enhanced MRI	Defines abscess and granulation tissue	Surgical decision-making
Whole-spine MRI	Detects skip lesions	Prevents underdiagnosis
Radiomics / AI	Texture-based differentiation	Research and future practice

MATERIALS AND METHODS

This review was conducted as a narrative, non-systematic review of published literature focusing on the role of magnetic resonance imaging (MRI) in spinal tuberculosis, with particular emphasis on imaging spectrum, pathophysiological correlation, and clinical relevance.

Search Strategy

A comprehensive literature search was performed using the electronic databases PubMed/MEDLINE, Google Scholar, Scopus, and Embase. The search included articles published up to June 2025. The following keywords and Medical Subject Headings (MeSH) terms were used in various combinations:
"spinal tuberculosis," "Pott's disease," "tuberculous spondylitis," "MRI spine," "magnetic resonance imaging," "paraspinal abscess," "epidural abscess," "diffusion-weighted imaging," and "neurological complications."
Eligibility Criteria

Inclusion criteria were:

Original research articles, review articles, and consensus guidelines
Studies describing MRI findings, disease mechanisms, or clinical outcomes of spinal tuberculosis
Articles published in English
Human studies involving adult and pediatric populations

Exclusion criteria were:

Case reports with limited imaging description
Studies focusing solely on non-spinal musculoskeletal tuberculosis
Articles without MRI correlation
Data Extraction and Synthesis
Relevant data were extracted independently and synthesized qualitatively. Emphasis was placed on:

MRI patterns at different disease stages
Correlation of imaging findings with pathophysiology
Diagnostic differentiation from other spinal pathologies
Clinical implications for treatment planning and follow-up
Given the narrative nature of the review, statistical meta-analysis was not performed.

RESULT

The literature review demonstrated that MRI consistently provides early, sensitive, and comprehensive evaluation of spinal tuberculosis. Across studies, MRI was shown to detect pathological changes well before radiographs or CT scans, particularly in early disease stages.

Osseous Involvement

MRI commonly demonstrated hypointense signals on T1-weighted images and hyperintense signals on T2/STIR sequences in affected vertebral bodies, reflecting marrow edema and granulomatous inflammation. Multilevel contiguous vertebral involvement with endplate destruction was frequently reported, especially in thoracic and thoracolumbar regions.

Intervertebral Disc and Subligamentous Spread

Relative preservation of the intervertebral disc in early disease emerged as a characteristic feature of spinal tuberculosis. Disc involvement occurred later, following endplate erosion. Subligamentous spread beneath the anterior longitudinal ligament, often extending across multiple vertebral levels, was consistently identified as a distinguishing imaging feature.

Paraspinal and Epidural Disease

Large paraspinal abscesses with thin, smooth rim enhancement were a hallmark finding across studies. Epidural extension was frequently associated with spinal canal compromise and neurological deficits. MRI effectively delineated the extent of epidural disease and its relationship to neural structures.

Neurological Involvement

MRI findings of spinal cord compression, cord edema, and myelomalacia correlated strongly with the severity of neurological deficits. T2-weighted hyperintensity within the spinal cord was identified as an important prognostic indicator.

Advanced MRI Techniques

Diffusion-weighted imaging (DWI) demonstrated restricted diffusion in abscesses and granulation tissue, supporting an infective etiology. Whole-spine MRI improved detection of skip lesions, while emerging radiomics and AI-based approaches showed promise in differentiating spinal tuberculosis from neoplastic and pyogenic conditions.

DISCUSSION

Spinal tuberculosis presents a wide spectrum of imaging findings that reflect the underlying pathophysiological processes and disease progression. MRI has revolutionized the evaluation of spinal TB by enabling early detection and accurate delineation of disease extent, thereby significantly influencing patient management and outcomes [21].

MRI–Pathophysiology Correlation

The disease typically begins in the anterior part of the vertebral body, close to the subchondral plate, owing to the rich metaphyseal blood supply [22]. Hematogenous dissemination of Mycobacterium tuberculosis leads to granuloma formation, caseous necrosis, and progressive destruction of cancellous bone. On MRI, this corresponds to hypointense signal on T1-weighted images and hyperintense signal on T2-weighted and STIR images, representing marrow edema and inflammation [23].
As the disease progresses, contiguous vertebral involvement occurs through endplate erosion and subligamentous spread beneath the anterior longitudinal ligament. This pattern of spread explains the frequent involvement of multiple adjacent vertebrae with relative disc preservation in early disease—a key imaging feature that helps differentiate tuberculosis from pyogenic spondylodiscitis [24,25].

Intervertebral Disc and Paraspinal Involvement

Unlike pyogenic infections, where disc involvement is early and prominent, spinal tuberculosis often spares the disc initially due to the avascular nature of adult intervertebral discs [26]. Disc involvement typically occurs in later stages as infection spreads through the endplates. MRI demonstrates disc signal alteration, loss of disc height, and post-contrast enhancement in advanced disease [27].

Paraspinal abscess formation is a hallmark of spinal tuberculosis and reflects liquefaction of caseous necrotic material [28]. MRI characteristically shows large paraspinal collections with thin, smooth rim enhancement, often extending over several vertebral levels. These abscesses may track along fascial planes into the psoas muscle or posterior paraspinal muscles [29]. The presence of large abscesses with minimal systemic toxicity is a classical feature of tuberculosis and helps distinguish it from pyogenic infections [30].

Epidural Disease and Neurological Complications

Epidural extension of infection is a critical determinant of neurological outcome. Epidural abscesses and granulation tissue cause spinal cord or nerve root compression, leading to neurological deficits [31]. MRI is unparalleled in evaluating epidural disease, spinal canal compromise, cord compression, cord edema, and myelomalacia [32].

T2-weighted hyperintensity within the spinal cord indicates edema or ischemia and correlates with the severity and duration of neurological deficits [33]. Chronic compression may result in irreversible cord changes, emphasizing the importance of early MRI evaluation in suspected cases [34].

Differentiation from Other Spinal Pathologies

MRI plays a vital role in differentiating spinal tuberculosis from other conditions such as pyogenic spondylitis, metastatic disease, brucellar spondylitis, and fungal infections [35]. Features favoring tuberculosis include multilevel involvement, subligamentous spread, relative disc preservation, large paraspinal abscesses with thin walls, and absence of significant vertebral sclerosis in early disease [36–38].

Diffusion-weighted imaging (DWI) and advanced MRI techniques have further improved diagnostic confidence. Restricted diffusion within abscesses and granulation tissue supports an infective etiology and may assist in differentiating tuberculosis from neoplastic lesions [39].

Role of MRI in Treatment Planning and Follow-up

MRI findings directly influence therapeutic decision-making. Patients without significant neurological deficits or instability may be managed conservatively with antitubercular therapy, while those with severe cord compression, progressive neurological deficits, or spinal instability require surgical intervention [40,41].

MRI is also valuable in monitoring treatment response. Resolution of marrow edema, reduction in abscess size, and decrease in contrast enhancement indicate favorable response, whereas persistent or worsening findings may suggest drug resistance, poor compliance, or alternative diagnoses [42,43]. However, residual MRI abnormalities may persist despite clinical improvement, necessitating careful correlation with clinical and laboratory parameters [44].

Recent Advances and Future Perspectives

Recent studies emphasize the role of whole-spine MRI in detecting skip lesions and subclinical involvement, particularly in immunocompromised patients [45]. Advanced techniques such as dynamic contrast-enhanced MRI and quantitative imaging biomarkers are being explored to assess disease activity and predict treatment response [46].

Artificial intelligence and radiomics are emerging tools that may further enhance diagnostic accuracy by identifying subtle imaging patterns and differentiating spinal TB from mimics with higher precision [47].

CONCLUSION

MRI is indispensable in the evaluation of spinal tuberculosis, providing comprehensive assessment of osseous, soft tissue, and neural involvement. A thorough understanding of the MRI imaging spectrum and its correlation with pathophysiology enables early diagnosis, guides management, and improves neurological outcomes.

DECLARATIONS:

There is no any conflict of interest.

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LIMITATIONS

Despite its advantages, MRI may not always distinguish active disease from healed lesions, and findings must be interpreted in conjunction with clinical, laboratory, and microbiological data.

Limited availability and cost may restrict access in resource-limited settings.

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