Global Spine Journal
2026, Vol. 16(3S) 71S-107S
© The Author(s) 2026
Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/21925682261454366
journals.sagepub.com/home/gsj

Recommendations of the International Consensus Meeting (ICM) 2025 on Spinal Infections: Part B Tubercular Spondylodiscitis

Shanmuganathan Rajasekaran, M.S (Ortho), DNB, FRCS, MCh, PhD[1], Gnanaprakash Gurusamy, M.S (Ortho)[1], Sathish Muthu, M.S (Ortho), DNB, PhD[2,3], Javad Parvizi, MD, FRCS[4], and ICM-Spinal Infection Collaborators

Abstract

Study Design: Systematic review with guidelines.

Objective: To develop evidence-based, globally applicable recommendations for diagnosis and management of Tubercular spondylodiscitis (TBSD) as a part of the International Consensus Meeting (ICM) 2025 on Spinal Infection.

Methods: This article represents a structured, multi-phase international consensus process conducted under the auspices of ICM 2025. Systematic literature reviews were performed using PubMed, Scopus, Web of Science, and ClinicalTrials.gov in accordance with Cochrane methodology. Evidence synthesis was integrated with structured expert deliberation. Consensus statements were developed across 7 domains: screening and initial evaluation, imaging, microbiological diagnosis, anti-tubercular therapy, response monitoring and conservative management, surgical indications, and surgical techniques. Recommendations were finalised through structured voting, with levels of evidence assigned to each statement.

Results: The consensus emphasises early recognition, routine HIV screening, lesion-specific tissue diagnosis with drug-susceptibility testing, and a multimodal diagnostic strategy. MRI remains the primary imaging modality but lacks specificity for etiological differentiation. Six months of rifampicin-based chemotherapy is sufficient in clinically responding patients, irrespective of surgery. Surgery is indicated for neurological deficit associated with instability or deformity, progressive deterioration, or failure of conservative management. Posterior-only approaches are appropriate in most thoracic and lumbar cases, with anterior surgery reserved for selected indications.

Conclusion: The ICM 2025 recommendations provide a comprehensive, evidence-informed framework for the diagnosis and management of TBSD and aim to standardise care while guiding future research priorities worldwide.

Keywords

tubercular spondylodiscitis, spinal tuberculosis, international consensus, evidence-based guidelines, spinal infection management

[1]Department of Spine Surgery, Ganga Hospital, Coimbatore, India
[2]Department of Spine Surgery, Orthopaedic Research Group, Coimbatore, India
[3]Central Research Laboratory, Aarupadai Veedu Medical College and Hospital, Vinayaka Mission's Research Foundation (Deemed to be University), Puducherry, India
[4]Department of International Joint Center, Acibadem Mehmet Ali Aydınlar University, Istanbul, Turkey

Corresponding Author:
Shanmuganathan Rajasekaran, M.S (Ortho), DNB, FRCS, MCh, PhD, Department of Orthopaedics and Spine Surgery, Ganga Hospital, 313, Mettupalayam Road, Sabaibaa Colony, Coimbatore 641043, Tamil Nadu, India.
Email: rajasekaran.orth@gmail.com

Creative Commons Non Commercial No Derivs CC BY-NC-ND: This article is distributed under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs 4.0 License (https://creativecommons.org/licenses/by-nc-nd/4.0/) which permits non-commercial use, reproduction and distribution of the work as published without adaptation or alteration, without further permission provided the original work is attributed as specified on the SAGE and Open Access pages (https://us.sagepub.com/en-us/nam/open-access-at-sage).

Introduction

Tubercular spondylodiscitis (TBSD) is a severe and disabling spinal infection with a high risk of leading to neurological deficits, deformity, and long-term disability. In 2024, approximately 10.8 million people worldwide developed TB. Spinal tuberculosis is the most common form of skeletal TB. Despite advances in TB control, TBSD still imposes a significant disease burden, especially in low- and middle-income countries where Mycobacterium tuberculosis remains endemic. Although global improvements have been made in TB diagnosis and treatment, management remains challenging due to delayed presentation, variability in imaging interpretation, inconsistent microbiological confirmation, and differing approaches to the duration and monitoring of anti-tubercular therapy. Recognising these ongoing challenges, the International Consensus Meeting on Spinal Infection, Istanbul 2025, brought together international experts to address key uncertainties in TBSD care.

The experts identified multiple domains with significant gaps in evidence, ranging from early recognition and imaging differentiation to diagnostic pathways, therapeutic decision-making, and surgical indications. Together, these sections provide a unified and practical framework for managing TBSD, integrating available evidence with expert consensus. This paper aims to guide clinicians through complex decision-making and highlight priority areas for future research to support standardised, high-quality care worldwide.

Methods

This study was designed as an international, multi-phase consensus process conducted under the auspices of the ICM on Spinal Infections, held in Istanbul, May 2025. The methodology combined systematic evidence appraisal with structured expert deliberation to generate globally applicable recommendations on TBSD.[1]

Section 1 examined screening and initial evaluation, emphasising the need for early recognition in high-burden regions and outlining the clinical features that should trigger timely imaging and microbiological work-up. Section 2 focused on imaging, detailing MRI characteristics that help distinguish TB from pyogenic and neoplastic lesions, and discussing radiological markers associated with prognosis and healing. Section 3 reviewed tissue diagnosis, outlining the roles of image-guided biopsy, GeneXpert, culture, and histopathology in establishing a definitive diagnosis and identifying drug resistance. Section 4 addressed anti-tubercular therapy, discussing optimal treatment duration, criteria for restarting therapy, and the use of adjunctive agents in selected scenarios. Section 5 explored response monitoring and conservative management, highlighting patterns of clinical, laboratory, and radiological improvement, and identifying situations where non-operative treatment remains appropriate. Section 6 examined surgical indications, clarifying thresholds for intervention in cases of instability, progressive deformity, neurological decline, or inadequate response to medical therapy. Section 7 reviewed surgical techniques and reconstruction strategies, comparing anterior, posterior, and combined approaches, and assessing methods for achieving durable deformity correction and spinal stability.

For each statement, we systematically reviewed PubMed, Web of Science, Clinicaltrials.org, and Scopus from inception until December 01, 2024, for original articles. We excluded publications in non-English languages, case reports, review articles, and studies only on spondylodiscitis without a precise diagnosis of TB. We conducted the systematic review in strict adherence to the guidelines of the Cochrane Handbook of Systematic Reviews for Interventions. We detailed recommendations for each question, level of evidence, and the consensus voting agreement. The detailed methodology involved in the process of delegate identification, recruitment into the recommendation process, selection, finalisation of questions addressed in each section, systematic review, face-to-face consensus meeting, voting, and recommendation generation was given in a separate publication.[1] Consensus was categorized by specific thresholds: unanimous (≥90%), strong (75%−89%), moderate (60%−74%), weak (50%−59%), or no consensus (<50%). Concurrently, evidence strength was graded as strong, moderate, low, or very low according to GRADE working group standards, ensuring a transparent, inclusive, and academically robust framework for global spine care.[2]

Results

Section 1: Screening and Initial Evaluation

The cornerstone of early and accurate TBSD diagnosis is a structured screening and initial evaluation, as the disease often presents insidiously and may progress to significant neurological deficits and spinal deformity. Spinal tuberculosis remains a primary health concern in regions with high endemicity, particularly where HIV co-infection is prevalent. HIV substantially alters the clinical presentation, radiological patterns, and overall progression of spinal TB, contributing to atypical features and higher morbidity. Despite strong epidemiological evidence supporting its importance, routine HIV screening in patients with suspected or confirmed spinal TB is still not consistently implemented in many settings. The diagnosis traditionally depends on clinical assessment and characteristic MRI features; laboratory markers such as ESR, CRP, and immune-response tests are often used as supportive tools. However, their ability to reliably differentiate TB from pyogenic spondylodiscitis is limited, reinforcing their role as adjuncts rather than definitive diagnostic tools. MRI remains the preferred imaging method due to its high sensitivity for early vertebral and soft tissue involvement. At the same time, plain radiographs and CT scans offer limited additional value during initial diagnosis when MRI findings are already

characteristic. Nevertheless, chest radiography is essential for detecting concurrent pulmonary TB, assessing infectivity, and identifying patients who need isolation or multidisciplinary care. Screening for other primary foci is equally important, given the risk of multi-system involvement. The natural history of STB varies significantly across age groups, with children at higher risk for progressive deformity, adults showing more localised disease, and elderly individuals experiencing delayed diagnosis and systemic vulnerability. This section consolidates expert perspectives across these areas to strengthen early evaluation and guide evidence-based clinical practice in spinal tuberculosis.

Question 1.1: Should all patients with spine tuberculosis be routinely tested for human immunodeficiency virus (HIV)?

Authors: Sathish Muthu, Julian Scherer, Ronald P. Tangente

Recommendation: Yes, given the epidemiological evidence, routine HIV screening should be a standard component of spinal TB diagnosis.

Level of Evidence: Low

Delegate Vote: Agree – 98% | Disagree – 0% | Abstain – 2% (Unanimous Consensus)

Rationale: A systematic review was conducted using PubMed, Scopus, Web of Science, and Cochrane databases. Initial screening yielded 676 records; after duplicate removal and title/abstract review, 22 studies underwent full-text analysis, and 11 met the inclusion criteria.[3–13] The majority were retrospective, providing Level IV evidence.

Spinal tuberculosis remains a significant global health burden, particularly in regions with high HIV prevalence. HIV co-infection significantly alters the clinical presentation, radiological patterns, and outcomes of spinal TB, contributing to higher morbidity and diagnostic difficulty. Across included studies, HIV prevalence among spinal TB patients ranged from 27% to 76%, with HIV infection increasing the risk of spinal TB up to eleven-fold.[3] Diagnostic delays were consistently reported in HIV-positive individuals, often resulting in advanced disease and poorer prognoses.[4,5]

HIV modifies disease morphology and host response. Co-infected patients frequently exhibit larger epidural abscesses with less vertebral destruction, multifocal vertebral involvement, and atypical features such as intramedullary tuberculomas. Histologically, granulomas may show CD4:CD8 ratio reversal, reflecting immune dysregulation.[11] HIV also increases the frequency of multidrug-resistant TB (4%−24%)[3,7] and worsens outcomes in patients with low CD4 counts, particularly below 200 cells/mm^3.[3] Severe complications, including extensive abscess formation and fatal consequences, are more common in those with CD4 counts below 50 cells/mm^3.[3,11] TB-associated immune reconstitution inflammatory syndrome (TB-IRIS) is another recognised complication in this population.[8]

Routine HIV screening in all patients with spinal TB is therefore essential to enable early diagnosis, accurate risk stratification, and individualised treatment planning. Screening protocols should integrate drug-susceptibility testing, CD4 count monitoring, and correlation with radiological markers. Optimal management requires a multidisciplinary approach involving infectious disease specialists, spine surgeons, radiologists, and HIV physicians.

In summary, the evidence strongly supports routine HIV testing in spinal TB. Early identification of co-infection improves diagnostic accuracy, informs prognosis, guides therapy, and is critical for optimising patient outcomes.

Question 1.2: Are systemic clinical symptoms like low-grade fever, malaise, fatigue, and weight loss significant in the diagnosis of spinal tuberculosis?

Authors: K Venugopal Menon, Sathish Muthu, Gnanaprakash Gurusamy

Recommendation: Yes, constitutional symptoms are essential, but they do not play a definitive diagnostic role in spinal TB.

Level of Evidence: Low

Delegate Vote: Agree – 100% | Disagree – 0% | Abstain – 0% (Unanimous Consensus)

Rationale: A systematic review was conducted using PubMed, Scopus, Web of Science, and related databases. Initial screening yielded 696 records; after resolving 208 duplicates, eligible 19 full-text articles were included for qualitative synthesis. Most studies were retrospective and provided Level IV evidence.

The clinical presentation of spinal tuberculosis varies widely depending on age, severity, region affected, and associated complications such as instability, deformity, and neurological deficits. Constitutional symptoms are traditionally emphasised in tuberculosis, but their prevalence in spinal TB is inconsistent. Back pain is the most reliable presenting feature, reported in 70%−100% of patients, with median values exceeding 90%.[14–18] In contrast, systemic symptoms such as fever, weight loss, malaise, and night sweats show broad variability. Fever is reported in 17%−35% of cases in most series, weight loss in approximately 30%, and night sweats in about 25%.[14–20] Neurological deficits occur in 40-60% of patients but range from as low as 1% to as high as 77% depending on cohort and geography.[17–20]

Temporal and geographic differences further contribute to heterogeneity. Earlier studies described fever as a consistent feature. At the same time, more recent cohorts from Europe, North America, and South Asia report lower rates of systemic symptoms but higher rates of neurological involvement. These variations reflect differences in host immunity, HIV prevalence, nutrition, and healthcare access.

Taken together, constitutional symptoms remain clinically relevant but lack the sensitivity and specificity required for definitive diagnosis. Their absence does not exclude spinal TB, and their presence should be interpreted as supportive features within a comprehensive diagnostic

framework that integrates clinical, radiological, and microbiological evaluation.

Question 1.3: Are biochemical investigations like ESR, CRP, and tests of immune response critical in the diagnosis of spinal tuberculosis?

Authors: Rishi Mugesh Kanna, Kazutaka Izawa, Julian Scherer

Recommendation: Yes, biochemical investigations such as ESR, CRP, and immune-response tests play a supportive role, but do not serve as confirmatory tests for diagnosing spinal tuberculosis.

Level of Evidence: Low

Delegate Vote: Agree – 100% | Disagree – 0% | Abstain – 0% (Unanimous Consensus)

Rationale: A systematic review was conducted using PubMed, Scopus, and related databases. Initial screening yielded 374 records; after resolving 146 duplicates, eligible 9 full-text articles were screened, and 9 studies met the inclusion criteria. All were retrospective and provided Level IV evidence.

Several biomarkers have been studied to differentiate nonspecific back pain from STB. Mann et al[21] reported fibrinogen, CRP, interferon-gamma, and neural cell adhesive molecule as the most discriminative markers. Lou et al[22] found liposaccharide-binding protein significantly elevated in STB patients compared to controls. Rao and Murthy[23] demonstrated that high-sensitivity CRP (hs-CRP) was raised in 71% of STB patients and correlated with worse pain and neurological status. Other promising markers include neutrophil-to-lymphocyte ratio (NLR), platelet-to-lymphocyte ratio (PLR), and S100-A8 protein.

Immune-response assays such as interferon-gamma release tests (T-SPOT, QuantiFERON-TB Gold) have been evaluated. The QFT-GIT test showed high sensitivity (92%) but low specificity (67%), limiting its diagnostic utility.[24] In high TB-endemic regions and in populations with prior BCG vaccination, the specificity of immune-response assays may be reduced due to latent infection or prior sensitisation. Therefore, these tests should be interpreted cautiously and not used in isolation for diagnosis. Comparative studies between STB and pyogenic infections suggest that STB patients often present with lower WBC counts, neutrophil fractions, ESR, CRP, and serum albumin. Lertudomphonwanit et al[25] reported that WBC $\leq 9700/mm^3$, neutrophil fraction $\leq 78\%$, and ESR ≤ 92 mm/hr were highly predictive of STB, with an AUC of 0.92.

In summary, ESR, CRP, and immune-response assays provide supportive information in suspected spinal TB but lack confirmatory power. Their variability and overlap with pyogenic infections necessitate cautious interpretation. Future prospective studies should validate these biomarkers and explore their integration into multimodal diagnostic models.

Question 1.4: Should plain radiographs and a CT scan be performed in patients with MRI evidence of spinal tuberculosis during the first diagnosis?

Authors: Julian Scherer, Rohit Amritanand, Ashish Jaiswal, Nestor Adolfo Taboada, Juan Esteban Munoz Montoya

Recommendation: No, plain radiographs and CT do not add diagnostic value in the presence of MRI evidence of spinal TB.

Level of Evidence: Low

Delegate Vote: Agree – 98.1% | Disagree – 1.9% | Abstain – 0% (Unanimous Consensus)

Rationale: A systematic review was conducted using PubMed, Scopus, and Web of Science databases. Initial screening yielded 789 records; after resolving 229 duplicates, 7 retrospective studies met the inclusion criteria, all providing Level IV evidence. None directly compared MRI, CT, and radiography prospectively; instead, they described imaging findings retrospectively.

MRI remains the most sensitive modality for diagnosing spinal tuberculosis, consistently demonstrating bone marrow oedema, paradiskal involvement, epidural abscesses, and subligamentous spread. In contrast, radiographs and CT often fail to detect early disease. Dong et al[26] reported fragmentary or osteolytic destruction on CT as predictive of STB, but diagnostic confidence increased only when combined with MRI features. Rivas-Garcia et al[27] noted destructive changes in 70% of radiographs and multifragmentary involvement in 81% of CT scans, but MRI remained superior in detecting soft tissue and epidural disease.

Other studies highlight the limitations of radiographs and CT in early diagnosis. Kostov et al[28] found that initial CT scans were misinterpreted as neoplasms, while radiographs often appeared normal despite active disease. Maeda et al[29] reported that up to 27% of radiographs were normal in elderly patients, whereas MRI was diagnostic in all cases. Abou-Raya et al[30] similarly showed radiographs were negative in 83% of confirmed STB cases. Sinan et al[31] demonstrated that CT, while useful for bony destruction, was inferior to MRI in identifying subligamentous spread and meningeal enhancement.

In summary, MRI provides definitive diagnostic information in spinal TB, while radiographs and CT add little when MRI findings are already characteristic. Radiographs may be helpful for deformity assessment or in resource-limited settings, and CT may serve as an alternative when MRI is contraindicated. However, in the presence of diagnostic MRI evidence, additional radiographs or CT scans do not enhance diagnostic accuracy.

Question 1.5: Should a chest X-ray and efforts to rule out other primary foci of tuberculosis be performed in all patients diagnosed with spinal tuberculosis?

Authors: Bhavuk Garg, Sang-Min Park, Nishank Mehta, Nestor Adolfo Taboada

Recommendation: Yes, chest radiography should be performed in all patients diagnosed with spinal tuberculosis.

Level of Evidence: Low

Delegate Vote: Agree – 100% | Disagree – 0% | Abstain – 0% (Unanimous Consensus)

Rationale: A systematic review was conducted using PubMed, Scopus, Web of Science, and ClinicalTrials.gov to identify 381 records, of which 53 duplicates were resolved, and eligible 7 records were identified to evaluate the role of chest radiography and assessment for other primary foci of tuberculosis in patients with spinal TB were narratively synthesised.

Although direct evidence is limited, multiple epidemiological studies report a substantial prevalence of concomitant pulmonary tuberculosis in patients with spinal disease, ranging from 4% to 66%.[32] Korean cohorts demonstrated pulmonary involvement in 42% of spinal TB patients, while Turkish and Chinese series reported 25%–35%.[33,34] Conversely, Garg et al[35] found only 4% pulmonary involvement in a large Indian cohort, whereas Malaysian studies reported rates as high as 67%. These variations reflect geographic differences, diagnostic practices, and patient populations.

Despite variability, pulmonary TB has significant implications for infectivity, systemic disease burden, and multidisciplinary management. Chest radiography remains the most practical screening tool, particularly in resource-limited settings, and can identify active or healed pulmonary lesions. While CT is more sensitive, its cost and limited availability restrict routine use.[36] Additional sites, such as lymph nodes, pleura, or ribs, may be involved, but evidence is insufficient to recommend routine targeted screening beyond chest imaging.

In summary, routine chest radiography is justified in all patients with spinal TB due to the substantial prevalence of concomitant pulmonary disease and its impact on infection control and treatment planning. This simple, widely available test enhances diagnostic accuracy and supports comprehensive patient management.

Question 1.6: Are there differences in the natural history of spinal tuberculosis between children, adults, and the elderly?

Authors: S Rajasekaran, Narihito Nagoshi, Sudhir Kumar Srivastava, Muralidharan Venkatesan, Gnanaprakash Gurusamy

Recommendation: Yes, the natural history of spinal tuberculosis differs between children, adults, and the elderly due to growth modulation in children, varying immune responses in adults, and comorbidities in the elderly.

Level of Evidence: Low

Delegate Vote: Agree – 91.7% | Disagree – 0% | Abstain – 8.3% (Unanimous Consensus)

Rationale: A systematic review was conducted using PubMed, Scopus, Web of Science, and related databases to identify 118 records, of which 31 duplicates were removed, and eligible 7 studies summarising the natural history of spinal tuberculosis between children, adults, and the elderly were narratively synthesised. The included studies were largely retrospective and provided Level IV evidence.

Spinal tuberculosis demonstrates distinct age-related variations in pathophysiology, disease progression, and long-term outcomes. In children, vertebral bodies contain more cartilaginous tissue and are highly vascular, facilitating rapid hematogenous spread. This leads to extensive vertebral destruction within a short time frame. A significant concern in pediatric TB is progressive deformity, which continues even after microbiological cure due to ongoing spinal growth.[37,38] Rajasekaran et al's landmark 15-year follow-up of 61 children showed that nearly 40% experienced deformity progression, particularly those under 10 years of age, who are most vulnerable due to flexible, immature spines.[39,40]

Adults typically present with more localised disease and slower progression. Kyphotic deformity stabilises after healing, and significant worsening post-cure is uncommon. Functional limitations may persist due to fibrosis and stiffness, but overall deformity patterns are predictable.[41]

In the elderly, spinal TB is increasingly diagnosed due to longer life expectancy. Comorbidities, weakened immunity, and drug interactions complicate management. Elderly patients face higher rates of adverse drug reactions, mortality, and misdiagnosis, often due to overlap with degenerative spine conditions. Delayed diagnosis and poor bone healing further worsen outcomes.[42,43]

In summary, spinal TB behaves differently across age groups: children are at the highest risk for progressive deformity, adults show stable post-healing patterns, and elderly patients demonstrate diagnostic and therapeutic vulnerability. Age-specific strategies for early detection, long-term monitoring, and tailored management are essential to optimise outcomes.

Section 2: Imaging: Role, Differentiation, and Prognosis

Imaging is fundamental to the diagnosis, follow-up, and prognostication of spinal tuberculosis. MRI is the primary imaging modality due to its high sensitivity for early vertebral, discal, epidural, and paravertebral disease. However, significant limitations exist, particularly in differentiating tubercular from pyogenic spondylodiscitis, assessing actual disease activity during treatment, and defining radiological healing.

Overlap in MRI features between infectious etiologies, delayed radiological resolution despite good clinical response, and paradoxical imaging worsening during therapy

frequently complicate management decisions and may lead to unnecessary prolongation of treatment or inappropriate surgery. In addition, while certain imaging features correlate with deformity progression, neurological recovery, and instability, their prognostic value is variable and mainly based on low-level evidence.

This section reviews the current evidence on the role of imaging in spinal tuberculosis, focusing on diagnostic differentiation, prognostic markers, optimal imaging strategies for follow-up, and the clinical relevance of persistent MRI abnormalities. Emphasis is placed on integrating imaging with clinical and laboratory findings to support rational, evidence-based decision-making.

Question 2.1: Can MRI reliably differentiate pyogenic and spinal tuberculosis, and is contrast MRI important in all patients with evidence of spinal tuberculosis?

Authors: Pushpa Bhari Thippeswamy, Pavithra Devi, Juan Esteban Munoz Montoya, Manabu Ito, Sathish Muthu, Abdullah Al Mamun Choudhury, Mohamed M. Aly

Recommendation 1: No, MRI cannot reliably distinguish tubercular from pyogenic spondylodiscitis.

Recommendation 2: Contrast enhances sensitivity and specificity for diagnosing spinal infections, but it is not mandatory in all cases.

Level of Evidence: Low

Delegate Vote: Differentiation: Agree – 94.6% | Disagree – 5.4% | Abstain – 0% (Unanimous Consensus); Contrast MRI: Agree – 94.6% | Disagree – 3.6% | Abstain – 1.8% (Unanimous Consensus)

Rationale: A systematic review was conducted using PubMed, Scopus, Web of Science, and ClinicalTrials.gov to assess MRI reliability in differentiating pyogenic spondylodiscitis from spinal tuberculosis and the role of contrast MRI. Of the total 5362 records, 1324 duplicates were removed, and eligible records were screened. Fourteen retrospective studies met the inclusion criteria, all providing Level IV evidence.[44–57]

MRI remains the principal imaging modality for spinal infections, but no single feature reliably distinguishes tubercular from pyogenic disease. Studies have evaluated multiple variables, including vertebral body destruction, disc space changes, paravertebral and epidural collections, endplate morphology, posterior element involvement, enhancement patterns, subligamentous spread, intraosseous abscesses, and skip lesions. Tubercular disease more often demonstrates paradiskal involvement, subligamentous spread, intraosseous abscesses, and skip lesions, while pyogenic infections typically show rapid disc destruction and localised endplate changes. However, overlap is common, limiting diagnostic certainty.

Contrast MRI improves sensitivity for detecting abscesses, epidural extension, and subtle enhancement patterns, thereby increasing diagnostic confidence. Nevertheless, contrast is not mandatory in all patients, notably when a non-contrast MRI already demonstrates characteristic features of spinal TB. Its use should be individualised, reserved for equivocal cases or when precise delineation of soft tissue involvement is required for surgical planning.

In summary, MRI alone cannot reliably differentiate tubercular from pyogenic spondylodiscitis. Contrast enhances diagnostic accuracy but is not universally required. A multimodal approach integrating clinical, laboratory, and microbiological data remains essential for definitive diagnosis.

Question 2.2: Are there specific imaging features that can prognosticate treatment outcomes in Spinal Tuberculosis?

Authors: Stefan Zwingenberger, Kosei Nagata, Pushpa Bhari Thippeswamy, Pavithra Devi, Juan Emmerich

Recommendation: Yes, there are radiological features to prognosticate treatment outcomes.

Level of Evidence: Low

Delegate Vote: Agree – 92.9% | Disagree – 1.8% | Abstain – 5.4% (Unanimous Consensus)

Rationale: A comprehensive systematic review was conducted using PubMed, Scopus, Web of Science, and ClinicalTrials.gov to yield 413 records. After 93 duplicate removals, eligible 5 records to evaluate MRI features that may predict treatment outcomes in spinal tuberculosis were summarised below.

A small-sized study showed that significant vertebral collapse (indexed total bone height loss >0.3) in an initial X-ray was predictive of severe kyphotic deformity of the thoracic spine.[58] Computed tomography (CT) and radiographic features are valuable for evaluating bony architecture and kyphosis prediction. Specific features include Bone Height Loss and Kyphosis. Thoracolumbar involvement poses higher risks of progressive deformity.[58] The presence of calcification and sclerosis in lesions suggests the presence of a chronic disease and may indicate treatment resistance.[59]

MRI remains the cornerstone of spinal TB evaluation, but its prognostic role is limited by variability in disease presentation and delayed radiological resolution despite clinical improvement. Several features have been consistently associated with outcomes such as paradiscal involvement and paravertebral abscesses are linked to higher risk of deformity progression; extent of vertebral body destruction predicts instability and kyphotic progression, particularly in children; skip lesions and posterior element involvement are associated with more aggressive disease and poorer outcomes; persistent marrow edema or enhancement may remain long after clinical cure, limiting their utility as markers of healing.[59–62]

Notably, radiological healing often lags behind clinical and laboratory improvement. MRI abnormalities may persist for months or years despite effective therapy, and paradoxical worsening can occur during treatment.[60] Therefore, imaging features should be interpreted in conjunction with clinical status and laboratory markers rather than used in isolation to determine prognosis or treatment duration.

In summary, specific MRI features such as paradiskal involvement, paravertebral abscesses, and vertebral destruction provide prognostic information in spinal TB, but persistent abnormalities do not necessarily indicate active disease. Prognostication requires integration of imaging, clinical, and laboratory findings.

Question 2.3: During follow-up, to assess radiological healing, is MRI alone enough, or a plain radiograph and CT scan also necessary, and how often should radiological investigations be done to confirm healing in spinal tuberculosis?

Authors: Aju Bosco, Sudhir Kumar Srivastava, Andrei Fernandes Joaquim, Toshinori Sakai

Recommendation: To assess radiological healing, plain radiographs and CT do not offer additional value to MRI. MRI can be performed on a case-by-case basis based on the patients' clinical progress, symptoms, and laboratory findings.

Level of Evidence: Very Low

Delegate Vote: Agree – 77.5%| Disagree – 0% | Abstain – 22.5% (Strong Consensus)

Rationale: A systematic review was conducted using PubMed, Scopus, Web of Science, and ClinicalTrials.gov to evaluate the role of imaging in follow-up and radiological healing in spinal tuberculosis yielded 815 records. After removing 296 duplicates, 48 were selected for full-text review. Fifteen were appropriate to the topic in question.

MRI remains the most sensitive modality for detecting vertebral, discal, and soft tissue involvement in spinal TB. The resolution of gadolinium-enhancing lesions, reduction in soft tissue mass, and decreased marrow oedema on serial MRIs are reliable markers of therapeutic success.[59,63] During follow-up, however, radiological resolution often lags behind clinical and laboratory improvement. Persistent marrow oedema, enhancement, or residual collections may be seen for months despite microbiological cure, and paradoxical worsening can occur during therapy.[60] These findings limit the utility of MRI as a sole determinant of healing.

Plain radiographs and CT scans provide limited additional information once an MRI has established the diagnosis. Radiographs may demonstrate deformity progression or fusion, but lack sensitivity for disease activity. CT can delineate bony destruction but does not reliably distinguish active from healed lesions.[63] Thus, neither adds significant value in confirming radiological healing when MRI is available.

Current consensus supports tailoring MRI use to the patient's clinical course. Imaging should be repeated only when symptoms persist, laboratory markers fail to normalise, or complications are suspected. Routine serial MRI in asymptomatic patients is not recommended, as it may lead to unnecessary prolongation of therapy.

In summary, MRI remains the preferred modality for assessing radiological healing in spinal TB, while radiographs and CT offer little additional value. Follow-up imaging should be individualised, guided by clinical and laboratory parameters rather than fixed schedules.

Question 2.4: In a patient with spinal tuberculosis showing good clinical response, is MRI evidence of delayed or non-healing an indication for surgery?

Authors: Naresh Babu J, Andrei Fernandes Joaquim, Abhay Nene, Muzahem M Taha

Recommendation: No, persistent MRI abnormalities alone should not dictate surgical decisions.

Level of Evidence: Moderate

Delegate Vote: Agree – 100%| Disagree – 0%|Abstain – 0% (Unanimous Consensus)

Rationale: A systematic review was conducted using PubMed, Scopus, Web of Science, and ClinicalTrials.gov to evaluate whether persistent MRI abnormalities in spinal tuberculosis should influence surgical decision-making. Of 418 total records, 90 duplicates were removed and 328 records were screened, and 9 retrospective studies met the inclusion criteria, all providing Level IV evidence.

MRI is highly sensitive for detecting vertebral and soft tissue involvement in spinal TB, but radiological resolution often lags behind clinical and laboratory improvement. Jain et al[64] have demonstrated that MRI-confirmed healing progresses gradually, with only 35% of patients achieving MRI-confirmed healing by 8 months of ATT. By 12 months, 47% show resolution of MRI abnormalities, increasing to 68% at 18 months and 95% by 24 months. Persistent marrow oedema, enhancement, or residual collections may remain visible for months or even years despite effective therapy and microbiological cure. According to Mittal et al,[65] persistent MRI enhancement does not necessarily indicate active disease. In cases where FDG-PET/CT was performed, PET/CT confirmed no active disease in all cases where MRI still showed abnormalities, reinforcing the idea that MRI overestimates residual disease activity. In some cases, paradoxical worsening of MRI findings has been reported during treatment, reflecting immune response rather than ongoing infection. Singh et al[59] examined serial MRI findings in spinal TB patients and confirmed that MRI abnormalities persisted even after clinical improvement, delaying ATT discontinuation. The study recommended a combined clinical, haematological, and imaging-based approach to treatment decisions, reserving surgery for progressive neurological deficits, instability, or unresolved abscesses rather than persistent MRI abnormalities alone.

Across available studies, surgical indications were consistently based on clinical parameters, such as progressive neurological deficit, mechanical instability, severe deformity, or failure of medical therapy, rather than imaging alone. Patients with good clinical response and normalised laboratory markers did not benefit from surgery solely due to

persistent MRI abnormalities. Reliance on imaging alone risks unnecessary surgical intervention and associated morbidity.

In summary, persistent MRI abnormalities should not be considered an indication for surgery in patients with spinal TB who demonstrate clinical improvement. Surgical decisions must be guided by symptoms, neurological status, deformity progression, and overall treatment response, with MRI serving as a supportive tool rather than a determinant of operative management.

Section 3: Microbiological and Histopathological Diagnosis

Accurate microbiological and histopathological diagnosis forms the cornerstone of effective management in spinal tuberculosis. Despite advances in imaging and chemotherapy, diagnostic uncertainty continues to pose significant challenges due to the disease's paucibacillary nature, delayed clinical presentation, and radiological overlap with other spinal pathologies. While magnetic resonance imaging (MRI) is highly sensitive for detecting spinal infection and delineating the extent of disease, it lacks specificity. It cannot reliably distinguish tuberculosis from pyogenic, fungal, neoplastic, or inflammatory conditions. Reliance on clinicoradiological diagnosis alone, particularly in tuberculosis-endemic regions, has historically led to empirical therapy, which carries risks of misdiagnosis, delayed identification of alternative pathologies, and failure to detect drug-resistant tuberculosis.

With the global rise in multidrug-resistant and rifampicin-resistant tuberculosis, lesion-specific microbiological confirmation and drug susceptibility testing have become increasingly critical. Tissue-based diagnosis allows not only confirmation of Mycobacterium tuberculosis but also identification of drug resistance, exclusion of mimickers, and rational tailoring of therapy. The evolution of diagnostic modalities, including histopathological examination, mycobacterial culture, and rapid molecular assays such as GeneXpert and Line Probe Assays, has significantly improved diagnostic yield when used in combination. No single test is sufficient in isolation; instead, a multimodal diagnostic strategy integrating clinical assessment, imaging, histopathology, culture, and molecular techniques is required to optimise accuracy and patient outcomes. This section addresses key clinical questions related to biopsy indications, timing, diagnostic modalities, and management strategies in challenging diagnostic scenarios of spinal tuberculosis.

Question 3.1: Is a tissue biopsy required in all patients with typical MRI features of spinal tuberculosis, even in endemic areas for tuberculosis?

Authors: Gomatam Vijay Kumar, Ronald P Tangente

Recommendation: Yes, a tissue biopsy is advisable in all patients, despite typical MRI features of spinal tuberculosis, even in endemic areas.

Level of Evidence: Moderate

Delegate Vote: Agree – 98.1% | Disagree – 0% | Abstain – 1.9% (Unanimous Consensus)

Rationale: A systematic review of PubMed, Scopus, Web of Science, and Cochrane databases was conducted to evaluate whether antitubercular therapy can be initiated without spinal tissue diagnosis in patients with confirmed tuberculosis at another site. Of 1676 total records, 456 duplicates were removed, and the final 12 eligible records were qualitatively synthesised below. The available evidence consistently supports obtaining a site-specific biopsy of the spinal lesion whenever feasible.

Although spinal tuberculosis often demonstrates characteristic MRI findings such as paradiscal involvement, vertebral body destruction, paravertebral collections, and kyphotic deformity, these features are not pathognomonic.[66,67] They may overlap with pyogenic spondylodiscitis, fungal infection, or primary/metastatic spinal malignancies. Reliance on clinical and radiological features alone risks misdiagnosis and inappropriate therapy.

The Xpert MTB/RIF (CBNAAT) assay has significantly improved early detection of Mycobacterium tuberculosis and rifampicin resistance, but optimal diagnostic accuracy requires tissue from the spinal lesion.[68] Notably, drug-resistance patterns may differ between pulmonary and spinal sites, particularly in extrapulmonary disease, necessitating lesion-specific microbiological confirmation.

Unlike tuberculous meningitis, where empirical therapy is often justified due to high mortality and diagnostic limitations, spinal tuberculosis usually allows sufficient time for image-guided or open biopsy without compromising outcomes. Establishing a baseline histopathological and microbiological diagnosis is essential, especially in patients who later show inadequate clinical or radiological response, as it facilitates early identification of drug resistance or alternative pathology.[69]

While uncomplicated spinal tuberculosis responds well to multidrug chemotherapy, with favourable outcomes in 85%−95% of cases, tissue diagnosis remains critical for confirming TB, excluding mimickers, and guiding appropriate therapy.

In summary, despite coexisting pulmonary or systemic tuberculosis, spinal lesions require site-specific biopsy and culture to ensure diagnostic accuracy, enable drug-resistance detection, and optimise patient outcomes.

Question 3.2: In a patient with coexisting pulmonary/systemic tuberculosis and a spinal lesion typical of TB, can drug therapy be started without bone tissue biopsy and culture?

Authors: Saumyajit Basu, Shahidul Islam Akon, Hirokazu Inoue, Arya Nick Shamie, Ayon Ghosh, Vikas Hanasoge

Recommendation: No, a site-specific biopsy is still recommended in a patient with coexisting pulmonary/systemic tuberculosis and a spinal lesion typical of tuberculosis.

Level of Evidence: Low

Delegate Vote: Agree – 98.1%, Disagree – 1.9%, Abstain – 0% (Unanimous Consensus)

Rationale: A systematic review of PubMed, Scopus, Web of Science, and Cochrane databases was performed to assess whether ATT can be initiated without obtaining spinal tissue diagnosis in patients with confirmed tuberculosis at another anatomical site. A total of 439 records were identified, of which 62 duplicates were removed. The remaining 4 eligible studies were subjected to qualitative synthesis. Across the available literature, the evidence consistently supports obtaining a site-specific biopsy of the spinal lesion whenever feasible to confirm diagnosis and guide appropriate management.

Radiological features traditionally considered characteristic of spinal tuberculosis on MRI such as paradiscal involvement, subligamentous spread, vertebral body destruction, and paravertebral abscess formation are well recognised. However, these findings are not pathognomonic. Multiple studies have shown that up to 25%−30% of cases demonstrate atypical imaging features that overlap with pyogenic spondylodiscitis, brucellosis, fungal infection, lymphoma, metastatic disease, and primary spinal tumours.[70] Consequently, spinal tuberculosis has long been described as a "great mimicker," and radiological appearances alone, even in patients with proven pulmonary tuberculosis, cannot reliably distinguish tuberculous infection from alternative pathologies.[71]

Tissue biopsy, therefore, remains fundamental to establishing a definitive diagnosis. Image-guided spinal biopsy is widely regarded as the diagnostic gold standard and has been shown to provide adequate tissue in the majority of patients. Series from high-burden regions report diagnostic yields exceeding 80%−90% with CT-guided biopsy, allowing histopathological confirmation of granulomatous inflammation and identification of acid-fast bacilli.[72–74] Importantly, biopsy enables microbiological culture and molecular testing, including Xpert MTB/RIF, which are essential for detecting rifampicin resistance and guiding further drug-sensitivity testing.[75–77] Contemporary reviews consistently emphasise that microbiological confirmation and resistance profiling influence treatment decisions and outcomes.

The increasing prevalence of drug-resistant spinal tuberculosis further strengthens the case for routine tissue diagnosis. Delays of several months between clinical diagnosis and confirmation of resistance have been reported when biopsy is deferred, during which patients often receive ineffective first-line therapy. Such delays contribute to ongoing disease activity, progression of deformity, neurological deterioration, and poorer functional outcomes.[78] Case series of multidrug-resistant spinal tuberculosis uniformly recommend drug-sensitivity testing in both primary and retreatment cases, which is only feasible when tissue is obtained from the involved vertebral level. Guideline statements align with this approach.[79] Extrapulmonary tuberculosis guidelines from endemic regions recommend biopsy of spinal lesions for etiological confirmation and drug-sensitivity testing whenever feasible, even in patients with confirmed tuberculosis elsewhere. Hence, the available evidence supports routine site-specific biopsy of spinal lesions to ensure diagnostic accuracy and optimise patient outcomes.

In summary, current evidence does not support initiating ATT solely based on systemic or pulmonary TB when a spinal lesion is present. Site-specific biopsy remains essential to ensure diagnostic accuracy, detect drug resistance, and optimise patient outcomes.

Question 3.3: In a Patient Already on Anti-Tubercular Drug Therapy, Should There Be a Window Period Before Biopsy for Culture Studies?

Authors: Kshitij Chaudhary, Kazutaka Izawa, Juan Esteban Munoz Montoya

Recommendation: No, there is no evidence to support stopping anti-tubercular drug therapy before performing a spinal biopsy.

Level of Evidence: Very low

Delegate Vote: Agree – 100% | Disagree – 0% | Abstain – 0% (Unanimous Consensus)

Rationale: A focused review of PubMed, Scopus, Web of Science, and related databases yielded 725 records, of which 196 duplicates were resolved, and the remaining records were screened, but the screening did not identify any study that systematically evaluated the effect of interrupting ATT before spinal biopsy on culture or molecular diagnostic yield. Available data are limited to observational series assessing culture positivity in patients already on treatment at the time of biopsy. Some reports suggest that prior ATT may reduce mycobacterial culture yield from CT-guided spinal biopsies, but findings are inconsistent and insufficient to justify stopping therapy.[80,81]

In contrast to pyogenic spondylodiscitis, where short-term discontinuation of antibiotics is sometimes practised to enhance bacterial culture yield, this strategy is not established for spinal tuberculosis. Mycobacterium tuberculosis replicates slowly (approximately once every 24 h), meaning that a brief "antibiotic holiday" would not meaningfully increase bacillary load or improve culture positivity. Several weeks of interruption would theoretically be required, which is clinically undesirable in a severe spinal infection.

No guideline or major series has recommended withholding ATT before spinal biopsy in spinal TB. With the advent of molecular diagnostics, particularly GeneXpert/CBNAAT, MTB DNA can be detected even in paucibacillary and partially treated lesions, reducing dependence on viable bacilli.[82] Although prolonged ATT may modestly decrease the sensitivity of culture and molecular tests,[76] current evidence does not support routine treatment interruption solely to enhance yield.

Limited, situation-specific exceptions may apply when differential diagnosis is uncertain. For example, if pyogenic infection is a strong alternative consideration, clinicians may elect to stop empiric ATT, particularly rifampicin, which is bactericidal against Staphylococcus aureus, to improve bacterial culture yield. Similarly, in suspected drug resistance with clinical failure of ATT, continuing an ineffective regimen is unlikely to influence culture yield, but stopping it has no proven benefit either.

In summary, no evidence supports a mandatory "window period" off ATT before spinal biopsy in spinal tuberculosis. ATT should not be routinely interrupted; decisions to withhold therapy should be individualised and driven by diagnostic uncertainty regarding non-tubercular pathology rather than expectations of improved mycobacterial culture yield.

Question 3.4: What is the relative importance of all the tissue tests, like Gene Expert, histopathological examination, and AFB culture, in diagnosing spinal tuberculosis?

Authors: Sathish Muthu, Gnanaprakash Gurusamy

Recommendation: No single diagnostic test is sufficient for accurate and early spinal tuberculosis detection. The best strategy involves combining GeneXpert, histopathology, and culture, ensuring timely intervention, accurate drug resistance profiling, and optimal patient outcomes.

Level of Evidence: Low

Delegate Vote: Agree – 86.5% | Disagree – 9.6% | Abstain – 3.8% (Strong Consensus)

Rationale: A comprehensive systematic review of PubMed, Scopus, Web of Science, ClinicalTrials.gov, and related databases evaluated the diagnostic performance of tissue-based tests for spinal tuberculosis (STB). From 2925 screened records, 934 records were removed, and 23 studies met the inclusion criteria and were analysed for sensitivity, specificity, and clinical utility.

Mycobacterial culture remains the gold standard for confirming Mycobacterium tuberculosis and performing phenotypic drug-susceptibility testing (DST). Both the Lowenstein–Jensen (LJ) and the MGIT-960 systems are used. However, culture sensitivity in spinal specimens is variable (16.7%−75.7%), and turnaround times are prolonged.[83,84] Yield is influenced by bacillary load and sample site, with paraspinal tissue often outperforming vertebral biopsy. Culture alone is inadequate for early resistance detection, particularly in MDR-TB.[85]

Histopathological examination (HPE) provides complementary evidence, especially in culture-negative disease. Typical findings include granulomatous inflammation, caseous necrosis, and Langhans giant cells. Sensitivity ranges from 50% to 73%, while specificity consistently exceeds 90%, making HPE valuable for excluding non-tuberculous pathologies such as malignancy.[84,86] However, histology cannot confirm MTB or identify drug resistance, and granulomatous patterns may overlap with fungal infection or sarcoidosis.

GeneXpert MTB/RIF has transformed early diagnosis by enabling rapid molecular detection of MTB DNA and rifampicin resistance within hours. Sensitivity ranges from 53.7% to 86.7%, with specificity approaching 98%–100%.[77,83,84,86,87] It consistently outperforms smear microscopy and culture in paucibacillary disease. Limitations include the inability to detect isoniazid monoresistance, necessitating complementary testing with Line Probe Assay (LPA) or culture-based DST.

Several studies demonstrate that diagnostic accuracy is maximised when tissue samples undergo combined testing: AFB smear, culture, histopathology, GeneXpert/CBNAAT, and LPA, achieving diagnostic accuracy close to 100%. Phenotypic and genotypic DST together identify resistance in nearly 90% of cases, while a small subset with inconclusive results but strong clinical suspicion may be managed empirically as drug-resistant TB.

In summary, no single tissue-based test reliably diagnoses spinal tuberculosis. Culture is essential for definitive confirmation and DST, histopathology provides high specificity for supportive diagnosis, and GeneXpert enables rapid detection and early resistance profiling. A multimodal approach integrating all 3 tests offers the most effective strategy for accurate diagnosis and optimal patient management.

Question 3.5: Should culture for pyogenic organisms and fungal organisms be performed in all patients with suspected spinal tuberculosis?

Authors: Sang Min Park, Janardhana Aithala P, Juan Esteban Munoz Montoya

Recommendation (pyogenic organisms): In patients with suspected spinal tuberculosis, culture for pyogenic microorganisms should be performed in all patients.

Level of Evidence: Moderate

Delegate Vote: Agree – 100% | Disagree – 0% | Abstain – 0% (Unanimous Consensus)

Recommendation (fungal organisms): Fungal organism culture should be performed in all cases of immunocompromised patients and may be considered in selected patients.

Level of Evidence: Moderate

Delegate Vote: Agree – 71.2% | Disagree – 15.4% | Abstain – 13.5% (Moderate Consensus)

Rationale: A comprehensive review of PubMed, Scopus, Web of Science, and Cochrane databases was conducted to yield 442 records, of which 122 duplicates were removed, and the final ten eligible articles that evaluated the need for routine culture of non-mycobacterial pathogens in patients with suspected spinal tuberculosis were qualitatively synthesised. Reliance on clinico-radiological diagnosis alone is unreliable, as tuberculous spondylodiscitis often mimics pyogenic or fungal vertebral osteomyelitis, and even spinal malignancies such as lymphoma or myeloma may present with similar imaging features. Current guidelines, therefore, emphasise biopsy and tissue-based diagnosis, including histopathology and microbiological cultures.

Multiple studies have demonstrated a rising incidence of pyogenic spondylodiscitis, even in TB-endemic regions. Aithala et al[88] found pyogenic infection in 34 of 63 patients initially suspected to have TB, while Mete et al[89] identified 44 pyogenic, 24 brucellar, and only 32 tubercular infections. In a large Chinese cohort, Yee et al[90] reported that 75.8% of spondylodiscitis cases were pyogenic, with tuberculosis accounting for only 24.2%. These findings highlight that empirical antitubercular therapy is unsafe without excluding pyogenic infection. Routine culture for pyogenic organisms is therefore essential, as treatment strategies differ substantially: spinal TB requires prolonged multidrug therapy (6-12 months), whereas pyogenic infections can often be managed with 6-8 weeks of targeted antibiotics.

Fungal spondylodiscitis is rare (0.5%−1.6%) but clinically significant, particularly in immunocompromised patients such as those with diabetes, prolonged steroid use, neutropenia, malignancy, or intravenous drug abuse.[91] The IDSA guidelines recommend fungal cultures in patients with impaired immunity.[92] However, routine fungal testing in all patients is not supported by robust evidence, as most reports are limited to case series and isolated cases.

In summary, all patients with suspected spinal tuberculosis should undergo routine pyogenic bacterial culture to avoid misdiagnosis and inappropriate therapy. Fungal cultures should be reserved for immunocompromised patients or selected cases with persistent clinical suspicion. This approach ensures accurate diagnosis, targeted therapy, and improved patient outcomes.

Question 3.6: In patients with inconclusive biopsy, can an empirical therapeutic trial with anti-tuberculosis drugs be initiated, or is a repeat biopsy necessary?

Authors: Harvinder Singh Chhabra, Sudhir Ganesan, Sathish Muthu, Juan Emmerich, Sang Min Park, Sharif Ahmed Jonayed

Recommendation: No, repeat biopsy combined with advanced diagnostics like GeneXpert, PCR, and LPA is recommended before starting anti-tubercular treatment.

Level of Evidence: Low

Delegate Vote: Agree – 100% | Disagree – 0% | Abstain – 0% (Unanimous Consensus)

Rationale: A comprehensive review of PubMed, Scopus, Web of Science, and Cochrane databases was undertaken. Of 1714 records identified, 390 duplicates were removed, and the remaining articles were screened, and identified 4 articles that evaluated management strategies for patients with suspected spinal tuberculosis (TB) and inconclusive biopsy results. While TB remains a major global health problem requiring early diagnosis and treatment, inappropriate empirical therapy carries risks of misdiagnosis, drug toxicity, and delayed identification of alternative pathologies.

Historically, empirical therapy has been used in endemic regions based on clinical and radiological features. However, conventional radiography lacks sensitivity, often requiring >50% vertebral decalcification before changes appear. MRI is highly sensitive for detecting features such as bone marrow oedema, endplate erosion, vertebral destruction, paravertebral abscess, and neural compression.[66] Still, it lacks specificity and cannot reliably distinguish TB from malignancy, pyogenic infection, or other granulomatous disorders. Reliance on imaging alone therefore risks diagnostic errors.

Although some authors suggest empirical ATT may be justified in select high-risk settings (eg, immunocompromised patients, severe disease, or strongly suggestive epidemiological profiles), this approach remains controversial.[93] Empirical therapy may mask alternative diagnoses, expose patients to unnecessary drug toxicity, and contribute to antimicrobial resistance due to inappropriate or unnecessary use of antitubercular drugs.

When biopsy results are inconclusive, a repeat biopsy is strongly recommended, notably if malignancy, fungal infection, pyogenic spondylodiscitis, or inflammatory disorders have not been excluded. Biopsy failure may result from inadequate sampling, necrotic tissue, or absence of granulomas/AFB. Repeat tissue acquisition, preferably image-guided or open biopsy, improves diagnostic yield.

A repeat biopsy should be coupled with advanced diagnostic techniques, including CBNAAT/GeneXpert, PCR-based assays, Line Probe Assay, liquid mycobacterial culture, and, where available, metagenomic next-generation sequencing (mNGS).[94] These modalities significantly enhance diagnostic accuracy and allow early detection of drug resistance. With declining TB prevalence in some regions and evolving disease epidemiology, exclusion of non-tubercular etiologies such as malignancy, fungal/bacterial infections, and spondyloarthropathies has become increasingly important.[66]

In summary, empirical anti-tubercular therapy should be avoided in patients with inconclusive biopsy results. A repeat biopsy combined with advanced molecular diagnostics provides diagnostic certainty, guides appropriate treatment, and prevents mismanagement, thereby improving patient outcomes.

Question 3.7: Management of a patient not responding clinically to anti-tubercular therapy - Should second-line drugs be started, or a repeat biopsy be needed to confirm resistance to primary drugs?

Authors: Anil Kumar Jain, Binod Bijukachhe, Kazutaka Izawa

Recommendation: Compliant patients with spinal tuberculosis who do not respond clinico-radiologically after 4 months of first-line antitubercular therapy should undergo repeat biopsy. The tissue obtained should be subjected to histology, AFB culture (phenotypic DST), and GeneXpert and Line Probe Assay (genotypic DST) to confirm diagnosis and drug resistance.

Level of Evidence: Moderate

Delegate Vote: Agree – 100% | Disagree – 0% | Abstain – 0% (Unanimous Consensus)

Rationale: A comprehensive systematic review of PubMed, Scopus, Web of Science, and Cochrane databases was conducted. Of 238 records identified, 92 duplicates were removed, and eligible records that evaluated the optimal management of spinal tuberculosis patients who fail to respond to first-line antitubercular therapy were qualitatively synthesised. Drug-resistant TB represents a growing global burden, with an estimated 150 000 deaths due to multidrug-resistant (MDR) or rifampicin-resistant TB reported worldwide in 2023.[95] The National Drug Resistance Survey reported resistance to at least one antitubercular drug in 28% of TB patients and MDR-TB in 6.19%, with isoniazid resistance acting as a major driver for rifampicin resistance.[96]

Clinical series consistently demonstrate significant rates of drug resistance among culture-positive spinal TB. Bhosale et al[97] reported resistance in 43 of 150 MGIT culture-positive cases, while Mohan et al[98] identified 111 resistant cases among 686 culture-positive patients. Li et al[99] reported resistance in 39 of 127 culture-positive spinal TB cases, all managed with individualised second-line therapy with or without surgery. Significantly, these studies relied on microbiological confirmation before altering chemotherapy.

Abhimanyu, Yadav, and Gain et al[100-102] demonstrated that diagnostic accuracy for spinal TB is highest when tissue samples are simultaneously subjected to AFB smear, mycobacterial culture, histopathology, CBNAAT/GeneXpert, and Line Probe Assay, achieving diagnostic accuracy approaching 100%. Phenotypic and genotypic DST identified resistance patterns in nearly 90% of cases. At the same time, a small subset with inconclusive laboratory results but strong clinical suspicion was managed as clinical drug-resistant TB using MDR protocols.

In summary, in compliant spinal TB patients not responding after 4 months of first-line therapy, repeat biopsy with comprehensive microbiological and molecular evaluation is mandatory. Empirical initiation of second-line drugs without confirmation risks toxicity, overtreatment, and amplification of resistance. Targeted, evidence-based escalation of therapy improves diagnostic precision and patient outcomes.

Section 4: Anti-Tubercular Therapy (ATT): Duration, Restart, and Adjuncts

Anti-tubercular therapy (ATT) is the foundation of treatment in spinal tuberculosis. Yet, important questions remain regarding the optimal duration of therapy, management of treatment interruption, and the role of adjunctive or perioperative chemotherapy. Historically, prolonged regimens were recommended due to concerns about poor drug penetration into bone and the risk of relapse. However, with rifampicin-based regimens, improved imaging, and modern surgical techniques, evidence increasingly supports shorter, standardised treatment durations in clinically responsive patients.

In addition, real-world challenges such as treatment default, drug toxicity, and variability in surgical practice necessitate clear guidance on restarting ATT and aligning chemotherapy duration across conservative and surgical management. This section synthesises evidence from randomised trials, meta-analyses, and extensive cohort studies to provide consensus-based recommendations on ATT duration, neo-adjuvant therapy, management of defaulters, equivalence of treatment in surgical vs non-surgical care, and the role of ATT in healed disease undergoing deformity correction, aiming to promote effective, safe, and individualised treatment strategies.

Question 4.1: How long should drug therapy be given in patients responding well to anti-tubercular medications?

Authors: Robert Dunn, Benjamin Mukulu Ndeleva, Harvinder Singh Chhabra, S Rajasekaran

Recommendation: There is increasing recent evidence to support 6-month (2RHZE/4RH) chemotherapy in clinically responding patients.

Level of Evidence: Moderate

Delegate Vote: Agree – 58.7% | Disagree – 21.7% | Abstain – 19.6% (Weak Consensus)

Rationale: A systematic evaluation of PubMed, Scopus, Web of Science, and Cochrane databases yielded 179 total records. After removing 60 duplicates remaining 11 articles that dealt with the duration of chemotherapy were qualitatively synthesised. The evidence demonstrates an evolving shift toward shorter-duration chemotherapy in clinically responsive spinal tuberculosis. Historically, treatment durations of 9-12 months were commonly advocated, particularly after adoption of the intensive 2RHZE phase (rifampicin, isoniazid, pyrazinamide, ethambutol), followed by a continuation phase with rifampicin and isoniazid (RH).[103,104] Earlier Medical Research Council (MRC) trials, conducted in the era of PAS and streptomycin and often combined with radical surgical debridement, showed comparable 5-year outcomes with 6- and 9-month regimens, suggesting prolonged therapy may not be universally necessary.[105,106]

Subsequent studies in the pre-rifampicin era considered 9 months a "short course." Rajeswari et al[107] reported favourable outcomes with 9 months of therapy combined with surgery, while Ramachandran et al[108] raised concerns regarding relapse after 6 months in a small cohort. Cormican et al[16] using MRI at 6 and 12 months, noted that radiological resolution often lags behind clinical improvement, questioning fixed-duration therapy. Jain et al[64] further demonstrated that only 35% of patients achieved MRI-confirmed healing at 8 months, emphasising that rigid time-based cessation may be unscientific.

In contrast, more recent evidence supports shorter regimens in the context of modern chemotherapy and surgical techniques. Dai et al[109] reported complete healing in 57 patients treated with 9 months of RHE (Rifampicin, Isoniazid,

Ethambutol) following anterior surgery, while Wang et al[110] compared a short course (average 4.5 months) with a 9-month regimen after radical debridement and fixation, finding comparable long-term outcomes with fewer drug-related adverse effects in the short-course group. Nene et al[111] conducted a randomised pilot study comparing 6- and 9-month regimens of 2RHZE/4RH, (2 months- Rifampicin, Isoniazid, Pyrazinamide, Ethambutol and 4 months- Rifampicin and Isoniazid) reporting no disease recurrence and similar outcomes at 24 months. Aryal et al[112] in a meta-analysis of 8 heterogeneous studies, found equivalent healing rates between 6-month and more extended regimens. Lin et al[113] analysed 6 Chinese studies involving 851 patients and demonstrated no significant differences in outcomes between ≤6-month and ≥9-month regimens, with lower toxicity in shorter courses. Van Loenhout-Rooyackers et al[114] similarly reported no increase in relapse with 6-month therapy.

In summary, accumulating evidence suggests that 6 months of standard chemotherapy is sufficient in patients with spinal tuberculosis who show good clinical response, particularly when combined with appropriate surgical debridement where indicated. Longer durations may be reserved for poor responders or complicated disease, underscoring the need for individualised treatment rather than routine prolongation.

Question 4.2: Is there a value of neo-adjuvant chemotherapy for spinal tuberculosis in patients planned for surgery?

Authors: Feng Zhu, Gomatam Vijay Kumar, Kei Yamada, S Rajasekaran

Recommendation: Yes, preoperative chemotherapy, whenever possible, holds significant clinical value in the surgical management of spinal tuberculosis, functioning as an effective therapeutic strategy for local infection control and lesion reduction.

Level of Evidence: Low

Delegate Vote: Agree – 55.6% | Disagree – 31.3% | Abstain – 13.3% (Weak Consensus)

Rationale: A systematic review of PubMed, Scopus, Web of Science, and Cochrane databases was performed to yield 929 records. After removing 406 duplicates, eligible 7 records that evaluated the role of neo-adjuvant chemotherapy in spinal tuberculosis patients planned for surgery were qualitatively synthesised. The available evidence, primarily derived from retrospective cohort studies, suggests that preoperative anti-tubercular therapy (ATT) provides significant biological and surgical advantages, although high-quality comparative data remain limited.

Neo-adjuvant ATT aims to reduce mycobacterial burden, suppress active inflammation, limit abscess size, and improve demarcation between diseased and healthy tissue before surgical intervention.[81] These effects may facilitate safer debridement, reduce intraoperative contamination, and improve postoperative wound healing and neurological recovery. While ATT is the cornerstone of treatment, surgery is often required for patients with neurological deficits, instability, deformity, or failure of conservative therapy, making optimisation before surgery clinically relevant.

Several studies support the feasibility and benefit of preoperative chemotherapy. Jia et al[115] demonstrated that surgery performed after less than 4 weeks of ATT in thoracic spinal TB with neurological deficit was safe and resulted in meaningful neurological improvement. A large retrospective series of 434 patients reported low recurrence rates irrespective of preoperative ATT duration; recurrence was uncommon even when surgery followed very short preoperative exposure, emphasising the importance of adequate debridement rather than prolonged preoperative therapy.[116]

More recent work has focused on shortening preoperative chemotherapy to avoid surgical delay, particularly in patients with progressive neurological impairment. Liu et al[117] reported that 1 week of preoperative ATT combined with radical lesion clearance achieved neurological recovery, bone fusion, and recurrence rates comparable to traditional 2-4 week regimens. Similarly, Chen et al[118] found no significant differences between short-course (1-7 days) intensive chemotherapy and conventional preoperative protocols in thoracolumbar disease. Multiple retrospective studies have found no clear correlation between preoperative ATT duration and recurrence or fusion outcomes.

In summary, neo-adjuvant ATT provides clinical value by improving local disease control before surgery in spinal tuberculosis. Short-course preoperative therapy appears sufficient in many cases, particularly when early surgery is indicated. Duration should be individualised based on neurological status, disease severity, and surgical urgency until higher-quality evidence becomes available.

Question 4.3: If the patient has stopped drug therapy during the course of treatment for more than a month, should the drug therapy be restarted and continued as for a new patient with spinal tuberculosis?

Authors: Rishi Mugesh Kanna, Aju Bosco, Teruaki Endo

Recommendation: There is no evidence in the literature for spinal tuberculosis on this aspect. Drawing parallels from defaulters of pulmonary tuberculosis, we recommend that it is essential to restart ATT from the intensive phase to avoid the development of drug resistance and poor outcomes.

Level of Evidence: Very Low

Vote: Agree – 86.4% | Disagree – 9.1% | Abstain – 4.5% (Strong Consensus)

Rationale: Tuberculosis treatment relies on prolonged administration of anti-tubercular medications, typically for 6-12 months. However, treatment default is standard and contributes to persistent disease, relapse, and the emergence of drug resistance. The World Health Organisation (WHO) defines a treatment defaulter as a patient who stops medication for at least 2 months. Reported default rates range from 10% to 30%, with younger age, drug-induced side effects,

perceived early improvement, and migration among the common causes.

Of 2045 articles identified, 869 duplicates were removed to identify only 4 studies documenting treatment default in spinal TB, with incidence ranging from 2.2% to 30%.[119–122] None of these studies systematically evaluated outcomes in defaulters. Wang et al[124] reported 6 defaulters among 72 cervical TB cases, with 1 recurrence. Li et al[99] found that 61.5% of drug-resistant spinal TB patients had received irregular chemotherapy, with higher rates among MDR-TB cases (66.7%) compared to single-drug-resistant (21.7%) and non-MDR cases. These findings suggest that irregular therapy is strongly associated with drug resistance in spinal TB.

Current evidence indicates that treatment default in spinal TB is under-reported and poorly studied. Given the lack of direct data, parallels are drawn from pulmonary TB, where restarting therapy from the intensive phase is recommended to minimise the risk of resistance and poor outcomes.

In summary, although evidence in spinal TB is limited, restarting ATT from the intensive phase after treatment interruption of more than a month is advisable, based on pulmonary TB experience, to reduce relapse and drug resistance.

Question 4.4: Is there a difference in the duration of drug therapy between patients who are conservatively treated and those who undergo surgical debridement and stabilisation in spinal tuberculosis?

Authors: Jason Pui Yin Cheung, Chee Kidd Chiu, Gomatam Vijay Kumar, Ajoy Prasad Shetty

Recommendation: No, the duration of drug therapy should be the same for conservative and surgically managed spinal tuberculosis patients.

Level of Evidence: Moderate

Delegate Vote: Agree – 92.9% | Disagree – 2.4% | Abstain – 4.8% (Unanimous Consensus)

Rationale: A systematic review of PubMed, Scopus, Web of Science, and Cochrane databases was performed. One hundred seventy-nine records were identified, of which 59 duplicates were removed, and the 8 eligible articles were evaluated to determine whether surgical diebridement and stabilisation permit a shorter duration of antitubercular therapy (ATT) compared with conservative management in spinal tuberculosis.

Spinal TB traditionally requires prolonged chemotherapy due to relatively poor drug penetration into bone. Surgical debridement theoretically reduces bacillary load, raising the question of whether shorter chemotherapy regimens could achieve equivalent eradication. Prolonged ATT is associated with toxicity, drug interactions, and reduced adherence, further motivating re-evaluation of treatment duration.

The most robust evidence comes from the Medical Research Council (MRC) trials. In the 14th MRC report,[123] outcomes from 3 randomised trials comparing 6-, 9-, and 18-month regimens were analysed in patients managed both surgically and non-surgically. Across all centres, 6- and 9-month regimens achieved outcomes comparable to 18 months, irrespective of surgical intervention.

Long-term follow-up of the Hong Kong cohort confirmed no differences in recurrence, deformity progression, or functional outcomes among patients treated with 6, 9, or 18 months of ATT. Patients receiving 6-month regimens following radical surgery achieved durable eradication, comparable fusion rates, and stable deformity correction.[106]

Subsequent retrospective studies reinforce these findings. Dai et al[109] reported successful eradication and universal fusion in 57 patients undergoing anterior radical debridement with 9 months of postoperative ATT. Multicenter data from Korea involving 137 patients showed no difference in outcomes between ≤9 months and >12 months of ATT, regardless of surgical intervention.[104,124] More recent observational studies comparing short-course (<12 months) and long-course (>12 months) regimens demonstrated no advantage of extended treatment, even in surgically treated severe cases.[124] A meta-analysis of 6 trials including 851 surgically treated patients confirmed that ≤6-month regimens were equivalent to longer courses in terms of cure, fusion, inflammatory markers, kyphosis correction, and functional recovery.[113]

A modern randomised controlled trial comparing 6 vs 12 months of standard four-drug therapy further validated that shorter regimens were non-inferior, irrespective of surgical management, including patients treated with contemporary instrumentation techniques.[111,125] Although isolated observational studies have suggested that radical surgery may permit even shorter courses, these reports lack methodological rigour and cannot be generalised.

In summary, available evidence indicates that 6 months of chemotherapy is adequate for both conservatively and surgically managed spinal TB patients. Longer durations may be reserved for poor responders or complicated disease, but surgery itself does not necessitate extended ATT.

Question 4.5: In Patients Undergoing Surgery for Correction of Healed Post-TB Spinal Kyphosis, Is There a Need to Give Preoperative ATT to Prevent Recurrence of the Disease?

Authors: Yong Hai, Siddharth Aiyer, Koji Yamada

Recommendation: No, there is no evidence to support the use of anti-tubercular therapy in patients undergoing corrective surgery for healed post-tuberculosis spinal kyphosis.

Level of Evidence: Very low

Delegate Vote: Agree – 100.0% | Disagree – 0% | Abstain – 0% (Unanimous Consensus)

Rationale: A systematic review of PubMed, Scopus, Web of Science, and Cochrane databases was performed. Of 163 identified records, 67 duplicates were removed, and no direct study compared whether preoperative anti-tubercular therapy (ATT) reduces the risk of recurrence in patients undergoing corrective surgery for healed post-tuberculous spinal kyphosis. The available evidence is limited to small

retrospective studies and case series, with no high-quality comparative data addressing this specific question.

In patients with healed spinal tuberculosis, disease quiescence is established by the absence of constitutional symptoms, normalisation of inflammatory markers, and imaging findings showing sclerosis, fusion, and lack of active bone destruction or paraspinal collections. Patients who have completed an adequate course of ATT and remain clinically and radiologically healed demonstrate a low risk of reactivation, reported at approximately 1%−2% in long-term follow-up studies.[126] Routine prophylactic ATT before deformity correction surgery has not been shown to reduce recurrence rates. However, patients with incomplete prior treatment or treatment interruptions should restart ATT for 4-6 weeks before surgery.[125]

Corrective surgery for healed post-TB kyphosis is often extensive, involving osteotomies, exposure of previously infected bone, and implantation of spinal instrumentation. Although theoretical concerns exist regarding reactivation of dormant mycobacteria due to surgical trauma or implants, current literature does not provide evidence that routine preoperative ATT alters these risks. Moreover, unnecessary ATT exposes patients to adverse drug reactions, hepatotoxicity, drug–drug interactions, and adherence challenges without proven benefit. A recent series on the surgical correction of thoracic and thoracolumbar TB kyphosis classified patients into active and healed groups, explicitly stating that ATT was not restarted preoperatively in the healed group. ATT was reinitiated only when histopathology or GeneXpert results from surgical samples raised suspicion of reactivation.[127]

Recurrence following deformity correction is more often associated with misclassification of active disease as healed, incomplete prior chemotherapy, or patient-related factors such as immunosuppression, rather than the absence of perioperative ATT. Accurate confirmation of healed disease status before surgery is therefore paramount, requiring detailed clinical assessment, laboratory evaluation, and careful review of cross-sectional imaging.

In summary, current evidence does not support routine preoperative ATT in patients undergoing corrective surgery for healed post-TB kyphosis. Emphasis should be placed on accurate confirmation of disease healing and individualised perioperative assessment, with ATT reserved for selected high-risk scenarios such as uncertain disease quiescence, incomplete prior treatment, or significant immunocompromise.

Section 5: Response Monitoring and Conservative Management

Conservative management remains the cornerstone of treatment for the majority of patients with spinal tuberculosis, particularly those without significant neurological deficit, mechanical instability, or severe deformity. While antitubercular chemotherapy is highly effective in eradicating infection, optimal outcomes depend on accurate monitoring of treatment response, early identification of complications, and appropriate supportive measures during recovery. Unlike many other spinal pathologies, spinal tuberculosis follows a slow and variable disease course, and radiological or clinical worsening may coexist temporarily with biological healing. This makes response assessment and decision-making during conservative therapy especially challenging.

There is no single validated parameter that reliably defines disease resolution in spinal tuberculosis. Clinicians therefore rely on a combination of clinical improvement and laboratory markers of inflammation, with imaging used selectively when clinically indicated, to guide ongoing management. In parallel, several practical questions arise during conservative treatment, including whether the final deformity can be predicted, the need for activity restriction or bed rest, and the role of external bracing in pain control and deformity prevention. These issues have important implications for patient quality of life, healthcare utilisation, and long-term functional outcomes.

This section synthesises available evidence addressing response monitoring and key aspects of conservative care in spinal tuberculosis, including multimodal assessment of treatment response, prediction of deformity progression, ambulatory vs bed-rest–based care, and the clinical utility of spinal braces. The aim is to provide an evidence-informed framework to support consistent, safe, and patient-centred conservative management strategies.

Question 5.1: What is the best method of assessment of response (clinical/ serological/ radiological) to conservative treatment in spinal tuberculosis?

Authors: Robert Dunn, Gaurav Raj Dhakal, S Rajasekaran, Adriaan Johannes Vlok

Recommendation: Based on available data, assessment of response should follow a multifactorial approach utilising clinical features (pain relief, weight gain, and appetite), sequential plain radiographs (to exclude progression of kyphosis), and MRI imaging, when clinically indicated.

Level of Evidence: Low

Delegate Vote: Agree – 84.1% | Disagree – 6.8% | Abstain – 9.1% (Strong Consensus)

Rationale: Assessment of response to conservative treatment in spinal tuberculosis (STB) remains challenging due to the absence of a single validated clinical, serological, or radiological marker that reliably reflects disease resolution. A review of 272 abstracts identified 85 duplicates, and upon screening 24 studies for full-text assessment, 13 directly addressed response evaluation. Most studies employed combinations of clinical, laboratory, and imaging parameters, but few provided clear definitions or validated sensitivity and specificity.

Clinical features remain the most consistent and practical indicators of treatment response. Resolution of back pain, improvement in constitutional symptoms, weight gain, and return of appetite are commonly reported endpoints. Singh et al[59] demonstrated progressive reduction in pain and systemic symptoms over 12 months, underscoring the reliability of serial clinical assessment. These parameters are particularly valuable in resource-limited settings and reflect both disease control and overall recovery.

Serological markers such as ESR and CRP are frequently used as adjuncts. ESR normalisation is often interpreted as disease resolution, but these markers lack specificity, may remain elevated due to other inflammatory conditions, and do not reliably correlate with structural healing or deformity progression.[128] None of the reviewed studies formally validated their predictive accuracy in isolation.

Radiological assessment with sequential plain radiographs remains central to follow-up. Early changes may include progressive bony destruction and vertebral height loss within the first 3-6 months, even in clinically improving patients. Later findings, such as sclerosis, disc space narrowing, and anterior ankylosis, are regarded as signs of healing.[129,130] Importantly, progression of kyphosis is a critical adverse outcome, requiring careful surveillance.

MRI plays an important role in follow-up, particularly in assessing soft tissue resolution, abscess size, and neural element involvement. It is especially useful in patients with persistent symptoms or when there is uncertainty in clinical or laboratory response. However, its role in routine monitoring remains limited due to variability in imaging findings. Furthermore, evidence suggests that MRI findings may lag behind clinical and laboratory improvement, with persistent abnormalities seen despite effective treatment and microbiological cure. Therefore, MRI should not be used in isolation to define treatment response and is best reserved for cases with clinical–radiological discordance or suspected complications.[57,62,63]

Advanced imaging such as FDG PET-CT has been explored, particularly in postoperative patients or when artefacts limit MRI. Declining FDG uptake has been associated with successful treatment, but variability in SUVmax values, limited availability, cost, and lack of standardised thresholds currently limit routine use.[65,131] Other investigational tools, including nuclear imaging and genomic biomarkers, remain experimental.

In summary, no single modality reliably defines treatment response in spinal tuberculosis. A multifactorial approach combining serial clinical assessment, inflammatory markers as adjuncts, sequential radiographs to exclude deformity progression, and MRI, when clinically indicated, provides the most comprehensive evaluation of therapeutic response.

Question 5.2: Is it possible to predict the final deformity in spinal tuberculosis in patients undergoing conservative treatment?

Authors: Saumyajit Basu, S Rajasekaran, Hirokazu Inoue, Mohammad El-Sharkawi, Vikas Hanasoge, Ayon Ghosh

Recommendation: Based on the existing literature, it is possible to predict the final deformity in patients undergoing conservative management.

Level of Evidence: Low

Delegates vote: Agree – 56.8% | Disagree – 20.5% | Abstain – 22.7% (Weak Consensus)

Rationale: A systematic review of PubMed, Web of Science, Scopus, and Cochrane databases identified 347 records, of which 157 duplicates were removed, and eligible records that demonstrated consistent interest in identifying radiological and biomechanical predictors of deformity progression in conservatively treated spinal tuberculosis (STB) were identified and qualitatively synthesised. Most evidence is derived from retrospective cohort studies with heterogeneous methodologies.

Adult Patients. Rajasekaran et al[38] analysed 90 non-operatively treated patients and demonstrated that pretreatment vertebral body loss strongly correlated with final kyphotic deformity at 5-year follow-up. They proposed a predictive formula ($Y = a + bX$), where Y represents predicted kyphosis and X represents initial vertebral body loss. Their findings showed that destruction of a single vertebral body resulted in an average kyphosis of 30-35° in the thoracic/thoracolumbar spine and ~20° in the lumbar spine. Based on this, surgical intervention was recommended for patients with ≥0.75 vertebral body loss in the thoracic/thoracolumbar spine or complete loss of one lumbar vertebra to limit final deformity to <30°.

Pediatric Patients. Prediction is more complex in children, who often present with larger deformities, greater collapse during the active disease phase, and continued progression even after healing and growth completion. Rajasekaran introduced the concept of "spine-at-risk signs," which identify ongoing instability and progressive deformity, emphasising the need for early surgical stabilisation.[39] These signs highlight risk but do not precisely predict the final magnitude of deformity.

Patterns of Collapse. Chemotherapy eradicates infection, but vertebral collapse may continue until adjacent healthy vertebrae approximate anteriorly and achieve stability. Rajasekaran described distinct collapse patterns based on vertebral body loss, each associated with predictable final deformity, reinforcing the importance of early radiological assessment.[132]

Long-Term Outcomes. Data from the Medical Research Council (MRC) working party support these observations. Conservatively treated patients demonstrated progressive kyphosis, averaging 21° at 5 years and increasing to 25° at 15 years. In contrast, patients undergoing radical debridement

and fusion showed sustained deformity correction over long-term follow-up.[133]

In summary, available literature supports the ability to predict final deformity in adult patients undergoing conservative treatment for spinal tuberculosis, primarily based on initial vertebral body loss and spinal level involved. This allows early risk stratification and informed surgical decision-making, though prediction remains less precise in pediatric patients.

Question 5.3: Is there any need for strict bed rest during conservative therapy in spinal tuberculosis, and what are the indications for ambulatory chemotherapy?

Authors: Andrei Fernandes Joaquim, Teruaki Endo

Recommendation: No, there is no need for strict bed rest. Temporary bed rest or a spinal corset may be advised only until pain subsides. All patients suitable for conservative chemotherapy can be recommended for ambulatory chemotherapy.

Level of evidence: Moderate

Delegate Vote: Agree – 100% | Disagree – 0% | Abstain – 0% (Unanimous Consensus)

Rationale: A systematic review of PubMed, Web of Science, Scopus, and Cochrane databases identified 132 records, of which 53 duplicates were removed to identify records that evaluated the role of strict bed rest vs ambulatory chemotherapy in patients with spinal tuberculosis undergoing conservative treatment. Seven eligible studies were included that reported on ambulatory chemotherapy in patients with spinal tuberculosis managed conservatively.

Traditional Approach. Prolonged bed rest was historically considered essential, based on concerns that mobilisation might worsen pain, deformity, or neurological status.

Contemporary Practice. Current TB management principles emphasise ambulatory care as the standard for both drug-susceptible and drug-resistant TB, with hospitalisation reserved for selected circumstances.[134,135] Effective ATT rapidly reduces mycobacterial load, with a significant decline within ~2 weeks of initiation, making prolonged immobilisation unnecessary.

Clinical Evidence. Case series have reported successful outcomes with ambulatory management, including adequate pain control, infection resolution, and acceptable radiological outcomes without routine bed rest.[138] There is no robust evidence that prolonged immobilisation prevents kyphotic progression or improves neurological outcomes in patients without instability or neurological compromise.

Risks of Prolonged Bed Rest. Extended immobilisation is associated with complications such as muscle wasting, joint stiffness, pressure ulcers, venous thromboembolism, pulmonary issues, and general deconditioning. These risks are particularly relevant in elderly and malnourished patients, and prolonged hospitalisation increases healthcare costs while reducing quality of life.

Practical Considerations. Temporary bed rest or spinal bracing may be used during the acute painful phase for comfort and short-term support. Once pain subsides and neurological status is stable, gradual mobilisation should be encouraged. Ambulatory chemotherapy is appropriate for most patients unless significant mechanical instability, progressive neurological deficit, or uncontrolled pain is present.[135-138]

In summary, strict bed rest is not required during conservative treatment of spinal tuberculosis. Most patients can be safely managed with ambulatory chemotherapy, with short-term bed rest or bracing reserved for pain control, and early mobilisation encouraged once symptoms improve.

Question 5.4: Does the use of braces help in reducing pain, deformity, and collapse in conservative therapy in spinal tuberculosis?

Authors: Sathish Muthu, Guna Pratheep Kalanjiyam, Stefan Zwingenberger, So Kato, Shinsuke Sato

Recommendation: Braces help in reducing pain but have no influence on the final deformity or collapse.

Level of Evidence: Very Low

Delegate Vote: Agree – 42.9% | Disagree – 11.9% | Abstain – 45.2% (No Consensus)

Rationale: A systematic review was conducted to evaluate the role of bracing in adult patients with thoracolumbar spinal tuberculosis managed conservatively. A comprehensive search of PubMed, Web of Science, ClinicalTrials.gov, and Scopus (up to December 1, 2024) identified 167 records, of which 63 duplicates were removed. After screening, only 3 retrospective studies met the inclusion criteria, involving 91 patients (41 males, 50 females; mean age 31 years), most with stable disease and no gross neurological deficits.[139–141]

Clinical Outcomes. Back pain was reported in 91.3% of patients across 2 studies. At final follow-up, 69.4% achieved pain-free status. Bracing, therefore, appears to provide symptomatic relief.[141]

Radiological Outcomes. Solid bony fusion was reported in 67.7% of patients. Among those with initial kyphosis <30°, 91.6% did not progress further, while progression was more common in patients starting with moderate deformity (30-60°). In severe cases (>50% vertebral body height loss, wedge compression, or paraplegia), bracing frequently failed, necessitating surgery.[141]

Brace Types and Protocols. Orthoses varied across studies, including plaster, custom plastic, and leather braces. Duration of bracing averaged 14 months, but protocols differed significantly.[141] One study mandated 2 months of bed rest before mobilisation with a brace.[139]

Overall, bracing was associated with pain reduction and apparent stability in patients with mild kyphosis (<30°). However, this likely reflects the benign natural course of stable lesions rather than an actual biomechanical effect of bracing. Bracing did not reliably prevent collapse or alter the natural history of deformity progression in unstable disease. Significant heterogeneity in treatment protocols, immobilisation duration, follow-up periods, and outcome reporting limits robust conclusions.

In summary, current evidence suggests that bracing may provide meaningful pain relief in conservatively managed thoracolumbar spinal tuberculosis but does not reliably influence final deformity or vertebral collapse. Given the very low quality of evidence, bracing should be considered a symptomatic adjunct rather than a deformity-modifying intervention.

Section 6: Surgical Indications and Decision-Making

Spinal tuberculosis presents with a broad clinical spectrum ranging from isolated vertebral involvement to complex disease characterised by deformity, instability, neurological deficit, and paraspinal abscess formation. While antitubercular therapy remains the cornerstone of treatment, timely surgical intervention is crucial in preventing irreversible neurological injury, progressive deformity, and mechanical failure. Decision-making in spinal tuberculosis is particularly challenging due to the disease's indolent course, variable natural history, and the absence of universally accepted criteria defining instability, neurological deterioration, or failure of conservative management. Advances in imaging, improved understanding of disease biomechanics, and the development of objective instability and neurological grading systems have refined surgical indications over time. This section synthesises available evidence to address key clinical questions related to radiological instability, neurological deficits, timing of surgery, adjunctive therapies, and management of associated psoas abscesses, to provide a structured, evidence-based framework to guide surgical decision-making in spinal tuberculosis.

Question 6.1: What are the radiological parameters for reliably describing instability and the value of instability scores for planning surgical stabilisation in spinal tuberculosis?

Authors: Muralidharan Venkatesan, Chan Chris Yin Wei, Yogesh Kishorkant Pithwa, Ronald P Tangente, Subbiah Meenakshisundaram

Recommendation (Radiological Parameters): *Thoracolumbar spine:* Kyphosis >30°, vertebral body loss/destruction exceeding 1-1.5 vertebrae, involvement of ≥3 contiguous vertebrae, pan-vertebral involvement, junctional disease, and the presence of "spine-at-risk" signs are reliable radiological parameters for instability. *Craniovertebral junction:* Instability is defined by migration of the odontoid tip above the McRae line or the presence of atlantoaxial instability. *Subaxial cervical spine:* Cervical kyphosis >30° is the only consistently documented radiological parameter for instability.

Level of Evidence: Low

Delegate Vote: Agree – 68.3% | Disagree – 4.9% | Abstain – 26.8% (Moderate Consensus)

Recommendation (Instability Scores): Scoring systems to assess stability in spinal tuberculosis can aid clinicians in surgical decision-making and help establish universally applicable, consistent treatment guidelines.

Level of Evidence: Very low

Delegate Vote: Agree – 75.6% | Disagree – 2.4% | Abstain – 22.0% (Strong Consensus)

Rationale: A systematic review of PubMed, Web of Science, Scopus, and Cochrane databases identified 200 records, of which 89 duplicates were removed to identify records that evaluated the radiological parameters for reliably describing instability and the value of instability scores for planning surgical stabilisation in spinal tuberculosis. Final 16 eligible records were qualitatively summarised.

Spinal instability is a widely accepted absolute indication for surgical intervention in spinal tuberculosis (TB). However, defining instability in TB spine remains challenging due to its slow, progressive nature and the lack of uniform radiological criteria. Over the years, multiple authors have proposed different parameters to identify instability, but no universal consensus has been established. A recent systematic review highlighted significant heterogeneity and gaps in the literature regarding reliable radiological definitions of instability.[142]

Progressive kyphotic deformity is one of the most commonly used indicators of instability. Destruction of the anterior column due to TB, combined with repetitive physiological loading, can eventually lead to failure of the posterior column, resulting in instability. Various kyphotic thresholds have been proposed as indications for surgical stabilisation. Some authors have used a pretreatment kyphosis of 30°, while others have suggested 40°.[128,143,144,145] Jain et al[146] advocated the use of predicted kyphosis, recommending surgery when a final deformity of 60° or more is anticipated based on Rajasekaran's predictive formula. Rajasekaran further emphasised the need for early surgical stabilisation in children with kyphosis exceeding 30°, given the higher risk of progression.[37,128,143,144]

Pan-vertebral involvement, characterised by disease affecting all 3 columns or destruction of facet joints, is another recognised marker of instability. Such involvement may present radiologically as scoliosis, severe kyphosis, or translational deformity. Facet joint destruction, subluxation, or dislocation on CT or MRI signifies posterior column compromise and mechanical instability. Rajasekaran's landmark work on pediatric spinal TB described 4 "spine-at-risk" sign: facet dislocation, posterior vertebral retropulsion,

lateral translation, and vertebral toppling, where the presence of 2 or more signs reliably indicated instability.[39]

Junctional involvement is another critical determinant of instability. Diseases affecting transition zones between rigid and mobile spinal segments, such as the cervicothoracic, thoracolumbar, or lumbosacral junctions, are more susceptible to translational forces, accelerating displacement and deformity progression under normal biomechanical loads.[37,146] Multilevel contiguous disease and the extent of vertebral body destruction also correlate with instability. Involvement of 3 or more vertebrae or destruction exceeding 1 to 1 and a half vertebral bodies has consistently been associated with progressive deformity and instability.[143,147]

In craniovertebral junction TB, instability is defined by atlantoaxial subluxation or vertical migration of the odontoid process beyond the McRae or McGregor line. In contrast, literature defining instability in subaxial cervical TB is limited, with cervical kyphosis greater than 30° being the only consistently documented criterion.[148]

Given the complexity and variability of these parameters, objective scoring systems may improve decision-making. Several scoring systems, including the Tuberculosis Spine Instability Score (TSIS),[149] Rajasekaran instability score,[150] extrapolated SINS,[151] and Spondylodiscitis Instability Score (SISS),[154] have demonstrated reliability and validity in identifying instability and guiding surgical stabilisation. Ahuja et al developed the TSIS, integrating demographic, anatomical, clinical, and radiological parameters to predict instability and guide surgical stabilisation in spinal tuberculosis with minimal or no neurological deficit.[149] Rajasekaran proposed a simplified, validated score based on age, junctional involvement, kyphosis severity, vertebral body loss, and spine-at-risk signs.[150] Pithwa demonstrated the applicability of the Spinal Instability Neoplastic Score (SINS) to spinal tuberculosis,[151] while Schömig introduced the SISS.[152]

Collectively, these scoring systems offer reliable, objective tools for identifying instability and supporting surgical decision-making in spinal tuberculosis. They mirror the role of scoring systems in trauma and spinal metastasis, and their adoption in TB spine may help establish universally applicable, consistent treatment guidelines.

Question 6.2: What are the indications for surgical intervention in terms of neurological deficit in spinal tuberculosis?

Authors: Mohammad M. Aly, Edurado Laos Plasier, Benjamin Mukulu Ndeleva, Abdullah Al Mamun Choudhury, Karthik Ramachandran, S Rajasekaran

Recommendation: Neurological deficit in the presence of mechanical instability or deformity, severe deficit, or rapidly progressive neurological deficit not responding to conservative care is an absolute indication for surgical decompression and stabilisation. Late-onset paraplegia should be treated surgically with deformity correction.

Level of Evidence: Very Low

Delegate Vote: Agree – 97.5% | Disagree – 0% | Abstain – 2.5% (Unanimous Consensus)

Rationale: A systematic review of PubMed, Web of Science, Scopus, and Cochrane databases identified 1141 records of which 489 duplicates were removed to identify records that evaluated surgical indications in spinal tuberculosis patients presenting with neurological deficits. Final 9 eligible records were qualitatively summarized.

Surgical correction of deformity remains the standard treatment for late-onset paraplegia, which is typically associated with a poorer neurological prognosis.[153] Late-onset paraplegia develops years after apparent healing and is usually caused by intrinsic spinal cord damage or chronic compression from a healed deformity, such as a bony ridge or constrictive fibrous band.[154]

In contrast, early-onset paraplegia occurs within 2 years of disease onset and is managed initially with antitubercular therapy (ATT), with or without surgical decompression. However, there is no clear consensus regarding the indications for surgical intervention in early-onset paraplegia. Several studies, including the landmark Medical Research Council trials, have demonstrated favourable rates of neurological recovery with ATT alone.[155] Tuli reported that 38% of patients with tuberculous paraplegia improved neurologically after 4-6 weeks of ATT alone, while 62% ultimately required surgical decompression. Based on these findings, Tuli proposed the "middle-path regimen," in which all patients are initially treated with ATT and surgery is reserved for those who deteriorate neurologically or fail to improve within 4-6 weeks.[156] This approach gained widespread acceptance in TB-endemic regions because it reduced surgical morbidity and costs while allowing time to optimise patients' general health and nutritional status. In contrast, many surgeons in developed healthcare systems favour early surgical decompression, citing higher rates and more rapid neurological recovery. Consequently, 2 differing management philosophies persist, primarily influenced by limited high-quality evidence and variations in healthcare resources.

Several clinical and demographic factors have been associated with delayed or incomplete neurological recovery following conservative treatment and may warrant consideration of early surgery. Severe, flaccid, or rapidly progressive motor weakness has been consistently linked to poorer neurological outcomes.[156] Advanced age and malnutrition have also been shown to affect neurological recovery adversely. Tuberculous paraplegia accompanied by mechanical instability or spinal deformity may particularly benefit from surgical decompression and stabilisation, as instability can result in rapid and progressive neural compromise. Rajasekaran proposed objective criteria for assessing instability in spinal tuberculosis, including age ≤15 years, involvement of the cervicothoracic or thoracolumbar junction, a sagittal deformity angle ratio ≥15°, a vertebral body loss–segmental ratio ≥0.5, and the presence of spine-at-risk signs.[150] Early surgical stabilisation in such cases may also reduce the likelihood of late-onset paraplegia, which is technically

challenging and associated with inferior neurological outcomes.

MRI plays a critical role in differentiating compressive from non-compressive pathology and identifying intrinsic cord changes such as oedema, myelomalacia, and cord atrophy, which correlate with the severity of deficit and response to treatment. Patients with myelitis, oedema, or arachnoiditis without significant cord compression may recover satisfactorily with ATT alone.[62,153] In contrast, considerable cord compression generally favours surgical decompression, although the threshold for clinically relevant compression remains debated. Intrinsic cord oedema with preserved cord size is associated with better recovery, whereas myelomalacia or cord atrophy predicts limited neurological improvement. Advanced MRI techniques, including diffusion tensor imaging, have further demonstrated that reduced fractional anisotropy values correlate with slower neurological recovery and may indicate the need for early surgical intervention.[157]

MRI also aids in characterising compressive lesions. Fluid-rich extradural collections ("wet" lesions) typically respond well to ATT alone, whereas solid extradural granulomas, sequestrated disc material, or bony sequestra ("dry" lesions) often require early surgical decompression.[154,156]

In summary, a neurological deficit associated with mechanical instability, deformity, severe or rapidly progressive weakness, or failure of conservative treatment constitutes an absolute indication for surgical decompression and stabilisation. Late-onset paraplegia should be treated surgically with deformity correction.

Question 6.3: Is it safe to add corticosteroids in spinal tuberculosis with neurological deficit, planned for conservative drug therapy?

Authors: Sudhir Kumar Srivastava, Jonathan Dalton, Komang Agung Irianto, Sathish Muthu, Gregory D Schroeder

Recommendation: Given the limited evidence in the literature, the safety of corticosteroid use cannot be recommended in patients with TB spondylodiscitis presenting with neurological deficit.

Level of Evidence: Very low

Delegate Vote: Agree – 95.0% | Disagree – 0% | Abstain – 5.0% (Unanimous Consensus)

Rationale: A systematic review of PubMed, Web of Science, Scopus, and Cochrane databases identified 77 records, of which 17 duplicates were removed to identify records that evaluated the role of corticosteroids in patients with spinal tuberculosis presenting with neurological deficits managed conservatively. The final 7 eligible records were qualitatively summarised.

Standard management of spinal tuberculosis includes antitubercular therapy (ATT), with surgical decompression indicated in selected patients. Still, the role of adjunctive corticosteroids in patients with spinal tuberculosis presenting with neurological deficit but planned for conservative treatment remains controversial.

Corticosteroids are well established in the management of tuberculous meningitis, where they reduce inflammation, cerebral oedema, and mortality by modulating the host immune response.[158,159] In spinal tuberculosis, corticosteroids theoretically reduce inflammatory oedema and mass effect around neural elements, potentially improving neurological recovery. However, concerns persist regarding their systemic immunosuppressive effects, risk of delayed bacterial clearance, and potential progression of spinal infection.[160] Current recommendations for steroid use in spinal TB, typically dexamethasone or prednisolone at doses of 0.75-1 mg/kg/day with gradual tapering, are extrapolated mainly from central nervous system tuberculosis literature rather than derived from robust spine-specific evidence.[161]

The available literature evaluating corticosteroid use in spinal tuberculosis with neurological deficit is limited to small observational studies, case series, and isolated case reports. Ayele et al[160] reported neurological recovery in a patient with paraparesis treated with ATT and prolonged corticosteroid therapy, while a prospective study from Sri Lanka suggested that short-term corticosteroid use (4-6 weeks) may be safe in patients without extensive vertebral destruction or large paraspinal abscesses.[162] However, these findings are not supported by high-quality comparative studies. Reviews of central nervous system tuberculosis suggest that corticosteroids may benefit patients with worsening neurological symptoms despite ATT, particularly in spinal cord involvement. However, their impact on long-term neurological outcomes remains inconsistent. Systematic reviews indicate a reduction in mortality with corticosteroid use in CNS tuberculosis, but no conclusive benefit in sustained neurological recovery.[163]

Corticosteroids are also commonly used in paradoxical worsening or immune reconstitution inflammatory syndrome (TB-IRIS), characterised by clinical or radiological deterioration despite effective ATT, where they may serve as rescue therapy rather than routine adjunctive treatment.[164] However, inappropriate or prolonged steroid use has been associated with adverse outcomes, and a case series by Loughenbury et al highlighted the potential for worsening spinal infection in patients receiving corticosteroids for non-TB indications, such as antenatal fetal lung maturation, in the presence of advanced spinal disease.[165]

The risks associated with corticosteroid therapy are substantial and include increased susceptibility to secondary bacterial and fungal infections, delayed mycobacterial clearance, metabolic complications such as hyperglycemia and osteoporosis, and prolonged dependence in TB-IRIS. These risks are particularly concerning in patients managed conservatively without surgical decompression or abscess drainage.

Question 6.4: In a spinal tuberculosis patient with neurological deficit, how long can we wait for a response with drug therapy before deciding on surgery?

Authors: Edurado Laos Plasier, Janardhana Aithala P, Marcelo Valacco

Recommendation: Based on available data, in patients with spinal tuberculosis and neurological deficits, there is low-quality evidence to establish an adequate waiting time to evaluate the response to drug therapy before deciding on surgery. In patients with moderate or severe neurological deficits (MRC ≤3/5), the literature suggests starting chemotherapy and performing surgery as soon as possible. In patients with mild neurological deficit (MRC ≥4/5), the literature suggests starting chemotherapy and re-evaluating the possibility of surgery after 4 weeks.

Level of Evidence: Very Low

Delegate Vote: Agree – 94.7% | Disagree – 2.6% | Abstain – 2.6% (Unanimous Consensus)

Rationale: A systematic review of PubMed, Web of Science, Scopus, and Cochrane databases identified 422 records, of which 198 duplicates were removed to identify records that evaluated the optimal timing of surgery in spinal tuberculosis with neurological deficit. The final 8 eligible records were qualitatively summarised.

Multiple retrospective studies identify worsening neurological deficits during ATT as a clear indication for surgery. Lack of neurological improvement during chemotherapy has also been considered an indication for surgical decompression, although there is no consensus regarding the optimal duration of conservative treatment before surgery. While most authors do not specify a definitive waiting period, several studies have proposed time thresholds ranging from 4 to 12 weeks.[115]

There is relative agreement that the severity of neurological deficit strongly influences the timing of surgery. Nene and Bhojraj[128] identified advanced neurological deficit (MRC <3/5) and neurological worsening during ATT as absolute indications for surgery. Bhandari et al[166] classified motor power > grade 4 as a minor deficit, recommending initial medical management, whereas motor power ≤ grade 4 was considered a primary deficit warranting early surgery. Chandra et al[167] used a protocol combining neurological status and radiological risk factors, reserving surgery for patients with poor neurological grade (Frankel A/B) and those with deterioration during medical therapy. In their cohort, 38% of patients initially treated conservatively eventually required surgery, while 62% improved on ATT alone.

Some authors advocate a trial of ATT for at least 4 weeks before surgery, citing stabilisation of systemic parameters such as body temperature, erythrocyte sedimentation rate, C-reactive protein, and haemoglobin levels. Jia et al[115] reported superior early neurological recovery in patients undergoing surgery within 4 weeks of starting ATT, although long-term outcomes were similar irrespective of preoperative chemotherapy duration. Liu and Nie et al[168] found that neurological recovery correlated more strongly with the duration of neurological symptoms rather than with the extent of deficit or duration of preoperative ATT, concluding that 4 weeks of chemotherapy before surgery is acceptable.

More extended periods of conservative treatment have also been described. Garg et al[169] reported that neurological improvement may continue up to 12 weeks of ATT, although a subset of patients experienced deterioration or lack of improvement necessitating surgery. Njoku et al[170] observed that early neurological improvement typically occurred within 4-8 weeks, while the absence of improvement after 6 months was associated with poor recovery.

In summary, there is no high-quality evidence defining a fixed duration of drug therapy before surgery in spinal tuberculosis with neurological deficit. Early surgery is recommended for moderate to severe deficits (MRC ≤3/5) and neurodeficits associated with instability, deformity, dry lesions like sequestrum, bone fragments, extruded disc material and progressive deficit, while a closely monitored 4-week trial of antitubercular therapy may be reasonable in patients with mild neurological impairment (MRC ≥4/5) without any contraindication.

Question 6.5: Do all psoas abscesses need to be drained? What are the indications for CT-guided drainage, pig–tail catheter, or open drainage of psoas abscess?

Authors: Siddharth Aiyer, Jonathan Dalton, Cristiano Magalhaes Menezes, Gregory D Schroeder, Arya Nick Shamie

Recommendation: No, not all tubercular psoas abscesses need drainage. Psoas abscess, causing mechanical symptoms or clinically apparent, can be subjected to image-guided drainage. Open drainage may be considered in patients requiring surgery otherwise.

Level of evidence: Low

Delegate Vote: Agree – 100% | Disagree – 0% | Abstain – 0% (Unanimous Consensus)

Rationale: A systematic review of PubMed, Web of Science, Scopus, and Cochrane databases identified 165 records, of which 64 duplicates were removed to identify records that evaluated the need for psoas abscess draining in STB. The final 12 eligible records were qualitatively summarised. The available evidence suggests that not all tuberculous psoas abscesses require drainage, with management guided by abscess size, symptomatology, and associated spinal or systemic complications.

Psoas abscess is a heterogeneous condition with diverse microbiological etiologies. Primary psoas abscess is most commonly caused by Staphylococcus aureus. In contrast, secondary psoas abscess frequently results from contiguous spread of infection due to *Mycobacterium tuberculosis, Streptococcus agalactiae, Escherichia coli,* and *Klebsiella species*. Tuberculous infection of the spine is associated with psoas abscess formation in approximately 60%−75% of cases, particularly in endemic regions.[171]

The decision to drain a psoas abscess depends on multiple clinical and radiological factors, including abscess size, degree of liquefaction, microbial aetiology, need for source control to prevent sepsis, coexistence of abdominal

pathology, severity of spondylodiscitis, and mechanical or neurological complications related to abscess mass effect. Management strategies differ between pyogenic and tuberculous psoas abscesses. Pyogenic abscesses typically require early and aggressive drainage due to the higher risk of septic progression and mortality.[172] In contrast, tuberculous abscesses often demonstrate a more indolent course and may respond to chemotherapy alone.

In patients with tuberculous spondylodiscitis, a psoas abscess is common. Surgical or open drainage may be indicated in cases associated with spinal instability, epidural abscess, progressive neurological deficit, extensive vertebral destruction, or failure of conservative treatment. Ibrahim et al[173] reported favourable outcomes in 28 patients treated using a minimally invasive transverse process osteotomy through a Wiltse paraspinal approach, demonstrating that targeted drainage can be safely achieved when indicated.

Small psoas abscesses associated with early-stage tuberculous spondylodiscitis may be treated successfully with antitubercular chemotherapy alone. Fei Ye et al,[174] in a cohort of 74 patients, recommended avoiding percutaneous continuous drainage for abscesses with multiple loculations, caseous necrosis without liquefaction, or those measuring less than 3 cm. In contrast, larger abscesses (>3 cm), abscesses causing mechanical symptoms, or those extending to superficial or accessible locations are appropriate candidates for image-guided percutaneous drainage with CT-guided catheter placement.

CT-guided percutaneous drainage with pigtail catheter placement is a safe and effective modality for large tuberculous psoas abscesses. Dave et al[172] reported satisfactory outcomes in 29 patients with abscesses larger than 5 cm treated using catheter placement over a guidewire based on preoperative imaging. Similarly, Zhen Lai et al[175] demonstrated that preoperative CT-guided drainage enhances the efficacy of antitubercular therapy, reduces surgical morbidity, and lowers postoperative complication rates in lumbar spinal tuberculosis with psoas abscess. Catheters are typically maintained for 2-4 weeks, sometimes with adjunctive antibiotic irrigation, resulting in high resolution rates and low recurrence or sinus formation.

In summary, the literature suggests that drainage of psoas abscess should be individualised. Small, non-liquefied tuberculous abscesses may be managed conservatively, while larger, symptomatic, or complicated abscesses benefit from image-guided or surgical drainage depending on abscess characteristics and associated spinal pathology.

Section 7: Surgical Techniques and Reconstruction Strategies

Although medical therapy remains the foundation of treatment, surgery becomes necessary when deformity, instability, abscess formation, or neural compression affects the long-term outcomes. Over the past 2 decades, surgical practice has evolved considerably, with increasing use of minimally invasive techniques and a growing reliance on posterior-only approaches for debridement, reconstruction, and stabilisation. These developments have prompted important questions regarding when limited procedures, such as endoscopic or transpedicular debridement, are sufficient and when more extensive reconstruction is required.

This section examines the role of these evolving techniques, the circumstances under which anterior surgery remains indicated in an era dominated by posterior approaches, and the deformity thresholds that warrant fixation or reconstruction. It also outlines how to select between stabilisation alone, posterior column shortening, or combined anterior reconstruction based on vertebral body loss and kyphosis. Finally, it reviews the available options for anterior column reconstruction, including structural grafts and titanium mesh cages, and the clinical situations in which each material may be preferred. Together, these topics provide a framework for rational, evidence-based surgical planning in spinal tuberculosis.

Question 7.1: Is there a role for only decompression and debridement of the infection focus by Endoscopic or transpedicular approaches in spinal tuberculosis?

Authors: Sudhir Ganesan, Naresh Babu

Recommendation: Yes, decompression and debridement of the infective focus using endoscopic or transpedicular approaches is a viable option for treating spinal tuberculosis in a select group of patients. However, the procedure is not recommended for patients with spinal instability, kyphosis >25°, destruction of more than half of the vertebral body, or a large abscess.

Level of Evidence: Moderate

Delegate Vote: Agree – 82.6% | Disagree – 0% | Abstain – 17.4% (Strong Consensus)

Rationale: A systematic review of PubMed, Web of Science, Scopus, and related databases identified 245 records, of which 107 duplicates were removed to identify records that assessed the role of minimally invasive decompression and debridement techniques, including endoscopic and transpedicular approaches, in the management of spinal tuberculosis. The final eligible 9 records were qualitatively summarised. Studies were examined to evaluate procedural efficacy, safety, indications, and limitations. The collective evidence demonstrates that these techniques offer meaningful clinical benefits in carefully selected patients, while highlighting clear contraindications where more traditional stabilising procedures remain necessary.

Management principles emphasise adequate debridement, decompression, and stabilisation when neurological deficits or instability are present. Although CT-guided aspiration and biopsy remain useful, their diagnostic yield is variable, prompting increasing interest in minimally invasive techniques. Since the advent of percutaneous endoscopic

discectomy in the early 1980s, endoscopic approaches have gained prominence due to advantages such as reduced blood loss, shorter hospital stay, minimal tissue disruption, and earlier postoperative mobilisation. Percutaneous endoscopic debridement and decompression are safe and effective for treating tuberculous spondylodiscitis. In a retrospective series of 105 patients, Abudurexiti et al[176] reported that endoscopic procedures were associated with shorter operative time, less intraoperative bleeding, lower transfusion rates, shorter hospitalisation, and reduced recurrence compared with open surgery.

Wu et al[177] compared unilateral Percutaneous Endoscopic Debridement and Lavage (PEDL) with bilateral PEDL and demonstrated that the unilateral transforaminal approach, performed under local anaesthesia with irrigation and suction channels introduced through a single working sleeve, significantly reduced both fluoroscopy time and overall operative duration. Despite these procedural efficiencies, both unilateral and bilateral PEDL achieved comparable functional and radiological outcomes. Another minimally invasive method, unilateral biportal endoscopy (UBE), has been utilised for thorough debridement and neural decompression, expanding the armamentarium of endoscopic options for infectious spondylodiscitis. Local antibiotic administration following PEDL, frequently using streptomycin or isoniazid, has also shown promising results, although no controlled studies have directly compared outcomes with and without intralesional antibiotic delivery.[178,179]

Safety and feasibility of endoscopic debridement have been further supported in thoracic spinal tuberculosis, where studies reported minimal postoperative kyphotic progression and no significant vertebral destruction.[179,180] In patients with anterior thoracic disease who are medically unfit for an anterior approach, transpedicular decompression represents a viable alternative that permits anterior access through a posterior trajectory.

Although minimally invasive, endoscopic debridement adheres to core surgical principles similar to those used in open procedures, including meticulous removal of necrotic tissue, granulation tissue, and sequestrum, and retrieval of biopsy material. However, it also requires unique technical considerations such as dry endoscopy, continuous saline irrigation, direct visualisation for disc-space debridement, and appropriate bone grafting when indicated.[181–183] The advantages of percutaneous endoscopic techniques include shorter operative time, reduced blood loss, quicker postoperative recovery, the ability to operate under local anaesthesia (particularly beneficial for high-risk patients), and enhanced magnified visualisation that can facilitate complete clearance of the infective focus. Additional benefits include targeted antibiotic delivery and effective decompression of neural structures.

Despite these strengths, endoscopic procedures have clear contraindications. These include spinal instability, kyphotic deformity exceeding 20-25°, involvement of more than 1 vertebral segment, and the presence of large paravertebral or epidural abscesses. Complications such as postoperative paraesthesias are typically transient. Progressive kyphosis may occur in some patients due to the absence of structural grafts or cages, though this is usually limited. Particular caution is warranted during thoracic procedures, where saline pressure control and accurate trocar placement are critical to avoid complications.

Overall, endoscopic and transpedicular techniques provide effective minimally invasive options for selected patients with spinal tuberculosis. However, careful patient selection, surgeon expertise, and radiological assessment remain essential, and future randomised trials are needed to refine indications further and evaluate long-term outcomes.

Question 7.2: In the present age of 'posterior only' surgeries, when is anterior surgery required in spinal tuberculosis?

Authors: Phedy Phedy, Robert Dunn, Aries Rakhmat Hidayat, Benny Lay, Komang Agung Irianto, Shunsuke Katsumi

Recommendation: There is growing evidence in the literature that most of the spinal tuberculosis in the thoracic, thoracolumbar, and lumbar regions can be treated with anterior column debridement and reconstruction and spinal stabilisation by an 'all-posterior approach'. In view of this, the need for the anterior approach is limited. Most of the cervical spinal diseases are treated anteriorly. In the thoracic, thoracolumbar, and lumbar spine, the indications for the anterior approach are severe multisegmental disease with a vertebral bone loss of >2, recurrent or resistant disease where a thorough debridement is required, and where lumbar lordosis needs to be restored in the lumbosacral TB.

Level of Evidence: Low

Delegate Vote: Agree – 93.3% | Disagree – 2.2% | Abstain – 4.4% (Unanimous Consensus)

Rationale: A systematic review was conducted to assess the contemporary indications for anterior surgery in spinal tuberculosis. PubMed, Scopus, Web of Science, and ClinicalTrials.gov identified 1446 records, of which 667 duplicates were removed, and the remaining records were searched. Twenty three relevant studies were synthesised to evaluate surgical rationale, disease-specific factors, and comparative outcomes between anterior and posterior approaches. The emerging evidence indicates that posterior-only techniques are sufficient for most thoracic and lumbar cases. At the same time, anterior surgery is reserved for select scenarios such as extensive vertebral body loss, refractory infection, or the need for lumbosacral alignment restoration. However, the evidence base remains heterogeneous and predominantly retrospective, and current recommendations continue to rely heavily on expert consensus.

In cervicothoracic TB, Wu et al[184] reported no significant differences between anterior-only and posterior-only

surgery with respect to hospital stay, operative duration, blood loss, kyphosis correction, or maintenance of correction. Both groups demonstrated neurological improvement and better VAS, NDI, and JOA scores. Despite similar outcomes, they advised anterior surgery when disease involved both anterior and posterior columns, when an abscess or sequestrum caused spinal cord compression, or when instability and kyphosis were present. Posterior-only surgery was recommended only for lesions confined to the posterior column or in patients unfit for anterior access due to comorbidities or prior operations. Zeng et al[185] reported comparable operative parameters but noted higher correction loss and hardware complications in anterior-only cases. They recommended anterior surgery for single-segment lower cervical lesions (C6–T1) with anterior column destruction and mild kyphosis (<30°). In contrast, posterior-only surgery was suited for kyphosis <50°, multicentric disease with accessible posterior targets, or situations involving revision anterior surgery, severe progressive neurology, or intolerance to extensive intervention.

In subaxial cervical TB, where pathology predominantly affects the anterior and middle columns, the anterior approach remains preferred due to direct exposure and ease of fixation. Studies consistently show significant postoperative improvements in JOA, VAS, and NDI scores. Luan et al[186] demonstrated favourable results in patients with C2–C7 Cobb angle >0° or SVA >4 cm, and individual case reports and retrospective analyses confirm reliable deformity correction and neurological recovery with anterior surgery.

Thoracic TB frequently affects the anterior and middle columns, and several studies support an anterior approach in cases with mild kyphosis (<30°), recurrent disease after posterior decompression, or multilevel involvement. Comparative analyses show better kyphosis correction and bone fusion with anterior surgery, although overall clinical outcomes remain[187,188] similar between approaches.

At the thoracolumbar junction, anterior surgery allows effective neural decompression and direct debridement. It is recommended when neurological deficits persist after 4-6 weeks of chemotherapy, when kyphosis exceeds 40°, or when instability is present. However, it is not advised for lesions above T5, kyphosis >60°, posterior element involvement, or poor pulmonary reserve.[189]

In lumbar TB, both anterior and posterior approaches are viable. Anterior surgery may offer improved kyphosis correction and fusion in selected single-segment cases, while posterior-only approaches provide shorter operative times and less[190] blood loss.

For lumbosacral TB, anterior surgery yields better deformity correction and neurological outcomes in some studies, particularly at L4-5 and L5–S1, though risks of vascular and peritoneal injury may favour posterior approaches in selected cases.[191–193]

In summary, growing evidence shows that posterior-only approaches provide adequate anterior column debridement, reconstruction, and stabilisation in most thoracic, thoracolumbar, and lumbar TB cases, with comparable outcomes and lower morbidity than anterior surgery. Thus, anterior approaches are now limited to select situations such as multilevel vertebral destruction, refractory or recurrent infection, or the need to restore lumbosacral lordosis. Cervical TB remains best treated anteriorly due to predominantly anterior pathology. Overall, the data support a posterior-first strategy with focused anterior indications.

Question 7.3: How much of pre-treatment local kyphosis can be accepted, and what level of kyphosis is an indication for spinal fixation and reconstruction in spinal tuberculosis?

Authors: Yogesh Kishorkant Pithwa, Benny Lay, Phedy Phedy, Aries Rakhmat Hidayat, Feifei Zhou

Recommendations: Indications for spinal fixation of spinal tuberculosis are kyphosis >30° in the paediatric population and kyphosis >40° in the adult population.

Level of Evidence: Moderate

Delegate Vote: Agree – 77.8% | Disagree – 0% | Abstain – 22.2% (Strong Consensus)

Rationale: A systematic review of PubMed, Scopus, Web of Science, and ClinicalTrials.gov was performed to identify 1877 records, of which 895 duplicate records were removed to identify records that evaluated acceptable kyphosis and surgical thresholds in spinal tuberculosis. Eleven eligible studies were qualitatively summarised. Evidence suggests differing deformity behaviour in children and adults, supporting age-specific kyphosis cut-offs for fixation, despite limitations from retrospective study designs and heterogeneous measurement methods.

Most studies on tubercular kyphosis have focused on patients with advanced deformity, limiting their applicability in defining early surgical thresholds. Smith IE et al[194] evaluated pulmonary compromise in patients with thoracic kyphosis secondary to spinal tuberculosis, including only 7 patients, all with extreme deformity; the minimum kyphosis in this cohort was 95°. Similarly, Zhao et al[195] investigated predictive factors for late-onset neurological deficits but restricted their analysis to adults with thoracic kyphosis exceeding 80°. Wong et al[196] studied long-term outcomes of severe thoracolumbar angular kyphosis, using >65° as an inclusion criterion, thereby focusing on advanced deformity rather than identifying thresholds for earlier intervention.

In contrast, Rajasekaran's landmark work on pediatric spinal tuberculosis identified "spine-at-risk" signs, establishing kyphosis as a key predictor of progression. He subsequently proposed a predictive formula correlating final kyphosis with initial vertebral body loss.[39] Building on this, Ahuja et al[149] introduced the Tuberculosis Spine Instability Score, incorporating adjusted kyphosis as a significant parameter and assigning increasing weight to kyphosis >30°, >60°, and >90°, after adjustment for physiological lordosis.

Long-term natural history data from the 13th MRC trial involving 350 patients treated nonoperatively demonstrated a mean kyphosis progression of 21° over 5 years and 25° over 15 years.[197] However, most patients were children, limiting extrapolation to adult populations. Parthasarathy et al[198] provided age-stratified long-term data, showing minimal progression when initial kyphosis was <30° across age groups. Notably, children under 15 years with kyphosis >30° exhibited significantly greater progression (mean 30°), highlighting the vulnerability of the growing spine.

Adult-specific data suggest a more benign course for moderate deformity. Nene and Bhojraj[128] reported excellent nonoperative outcomes in adults with kyphosis <40°, with a mean progression of only 5° and rare neurological deterioration. Similar findings were reported by Kotil et al,[199] who followed adults presenting with kyphosis <30° and observed minimal progression over 40 months. Other conservative series restricted to kyphosis <30° also demonstrated acceptable outcomes with negligible functional consequences despite radiographic progression.[130]

Cervical and subaxial spinal tuberculosis data further support conservative management in selected cases. Aggarwal et al[193] treated subaxial cervical TB nonoperatively, achieving deformity improvement and neurological recovery in most patients, despite minor progression in a few instances.

Taken together, evidence indicates that children with kyphosis exceeding 30° are at high risk for progression and warrant early surgical stabilisation. In adults, nonoperative treatment yields favourable outcomes even when kyphosis exceeds 30°, but deformities beyond 40° have been associated with poorer long-term functional and biomechanical consequences. While adjustment for physiological lordosis is advisable, definitive correction factors remain undefined. Therefore, kyphosis >30° in children and >40° in adults represents reasonable, evidence-based surgical thresholds in spinal tuberculosis.

Question 7.4: In the posterior-only approach, what are the indications for only spinal stabilisation, spinal stabilisation with spinal column shortening, and spinal stabilisation with anterior reconstruction?

Authors: Abhay Nene, Sri Vijay Anand K S, Mohammad El-Sharkawi, Benny Lay, Phedy Phedy, Stefano Conti, Gnanaprakash Gurusamy

Recommendation: Spinal stabilisation alone is indicated in patients with severe pain and instability, but with minimal destruction of vertebral bodies, and when there is sufficient bone-on-bone contact. Spinal column shortening is appropriate when there is moderate vertebral body loss, and bone-to-bone contact can be achieved after debridement and posterior column shortening. However, in cases of substantial vertebral body loss (VBL >0.5) or deformity >30° that compromise bone-on-bone contact after posterior column shortening, anterior column reconstruction will be required.

Level of Evidence: Moderate

Delegate Vote: Agree – 97.8% | Disagree – 0% | Abstain – 2.2% (Unanimous Consensus)

Rationale: A systematic review of PubMed, Scopus, Web of Science, and ClinicalTrials.gov was conducted to identify 1712 records, of which 864 duplicates were removed. Eligible 14 records that defined indications for posterior-only spinal stabilisation, posterior column shortening, and posterior stabilisation with anterior reconstruction in spinal tuberculosis were included and qualitatively synthesised. The literature supports a posterior-first strategy in most cases, with stabilisation alone being sufficient in minimal vertebral destruction, column shortening appropriate in moderate bone loss where contact can be restored, and anterior reconstruction required when vertebral body loss or deformity compromises stability. Across studies, neurological recovery and disease healing were comparable, while differences were noted in deformity correction, operative morbidity, and stability. Evidence remains limited by retrospective study designs, heterogeneous disease severity, variable reconstruction thresholds, and inconsistent reporting of vertebral loss and kyphosis, restricting definitive recommendations.

Evidence supports the posterior-only approach as a safe and effective surgical strategy in spinal tuberculosis, particularly in early-stage disease with limited vertebral body destruction.[200] Single-stage posterior surgery has gained wide acceptance as it allows adequate debridement, neural decompression, deformity correction, and stabilisation through a familiar and less morbid approach. However, the optimal posterior surgical strategy, especially the need for anterior reconstruction and the choice of graft material, remains an area of active debate.

Du et al[201] compared structural and non-structural bone grafts in single-segment thoracic spinal tuberculosis treated with one-stage posterior surgery and demonstrated comparable improvements in pain, inflammatory markers, and neurological status with both techniques. Structural grafts provided superior initial kyphosis correction but were associated with greater loss of correction over time, whereas non-structural grafts resulted in shorter operative time, reduced blood loss, and faster fusion, making them a less invasive yet effective option in appropriately selected cases.

In patients with borderline vertebral body loss (0.5-1), Ramakrishnan et al[202] showed that posterior-only stabilisation and global reconstruction via an all-posterior approach yielded similar neurological, functional, and radiological outcomes at final follow-up. Posterior-only stabilisation was associated with shorter operative time and better ODI scores, while global reconstruction achieved slightly better kyphosis correction and maintenance, with comparable fusion times.

Xu et al[203] reported favourable outcomes using posterior debridement with compact bone grafting and posterior column shortening in mono-segmental lumbar disease. Subbiah et al further refined patient selection by proposing

that anterior reconstruction is necessary when both endplates and vertebral bodies are involved. In contrast, isolated disc-space disease can be adequately managed with posterior stabilisation alone.

Kalanjiyam et al[204] compared 3 posterior-only techniques and demonstrated that anterior reconstruction is generally required when vertebral body loss exceeds 50% or kyphotic deformity exceeds 30°. While overall outcomes were similar, titanium cages provided superior initial deformity correction by acting as a stable pivot, particularly in severe deformity, albeit with increased operative time, blood loss, and hospital stay.

In summary, posterior-only stabilisation is sufficient in minimal destruction, column shortening is appropriate in moderate loss with restorable contact, and anterior reconstruction, preferably with cages, is essential in advanced vertebral loss or severe deformity to ensure alignment and neurological safety.

Question 7.5: In anterior column reconstruction, is there a preference in the usage of various Bone grafts like ribs, fibula, or iliac crest/ and when is a titanium cage preferred?

Authors: Janardhana Aithala, Bhavuk Garg, Abhay Nene, Dilip Chand Raja Soundarajan, Komang Agung Irianto

Recommendation: No, there is no sufficient evidence to recommend the preference of bone grafts from ribs, fibula, or iliac crest over the others. However, there is low-quality evidence showing a preference for titanium mesh cages in the case of significant defects. There is low-quality evidence that autologous iliac crest grafts can be associated with higher operating time, blood loss, and donor-site related problems. There is also low-quality evidence that, in minor defects, local bone grafts can reduce surgical time and blood loss with equally good results.

Level of Evidence: Low

Delegate Vote: Agree – 60% | Disagree – 0% | Abstain – 40% (Moderate Consensus)

Rationale: A systematic review of PubMed, Scopus, Web of Science, and ClinicalTrials.gov was undertaken to identify 745 records, of which 304 duplicates were removed. The final eligible 25 articles that evaluated criteria guiding graft or cage selection for anterior reconstruction in spinal tuberculosis were included and qualitatively synthesised. Numerous options exist, including local grafts, iliac crest, rib, fibula, allograft, titanium mesh cages, PEEK, and expandable cages, but the literature does not clearly favour 1 material. Across studies, fusion, healing, and neurological recovery were comparable, though differences existed in blood loss, operating time, complications, and deformity correction. Available evidence is limited by retrospective designs, non-randomised graft selection, inconsistent kyphosis measurements, and heterogeneity in defect size, vertebral involvement, and reporting, restricting definitive comparisons.

Multiple retrospective studies have compared various graft options and titanium mesh cages for anterior column reconstruction in spinal tuberculosis, although the overall quality of evidence remains low. Dingyu Jiang et al[205] compared titanium mesh cages, allogenic grafts, and autogenous iliac crest grafts in mid-thoracic TB. Fusion and deformity correction were similar, but allografts healed more slowly, and iliac crest grafts produced higher blood loss and donor-site morbidity, leading the authors to favour titanium cages. Xu et al[206] showed that local morselized bone grafts resulted in shorter operative time and less blood loss than iliac crest grafts, with similar fusion and correction. However, donor-site complications were more common with iliac crest harvest.

Assaghir et al[207] reported that rib strut grafts maintained vertebral height better than iliac crest grafts in larger defects, despite slower healing. Zhang et al[208] found similar outcomes between titanium cages and structural allografts, though higher complication rates were associated with allografts, confounded by combined anterior–posterior approaches. Dian Zhong et al[209] found no significant differences among iliac crest grafts, titanium mesh cages, and polyamide cages in terms of fusion, kyphosis correction, complications, or vertebral height restoration, with polyamide cages demonstrating the least subsidence.

Kalidindi et al[210] reported similar healing and fusion between posterior instrumentation alone vs additional anterior reconstruction with mesh or PEEK cages, although anterior reconstruction increased operative time and blood loss, primarily influenced by defect size. Du et al[201] showed faster fusion but greater correction loss with granular grafts compared to transverse process structural grafts. Zhang et al[211] reported similar healing, neurological recovery, and deformity correction among titanium mesh cages, cage–spinous process constructs, and allografts, though operative time and blood loss were higher with allografts. Zhenchao Xu et al[212] found the least loss of correction with titanium cages, higher blood loss with autografts, and delayed fusion with allografts.

Wence Wu et al[213] and Gao et al[214] demonstrated similar fusion but greater blood loss and correction loss with iliac crest grafts, particularly in multilevel disease, where titanium cages performed better. Suya et al[215] and Du et al[201] showed that nonstructural grafts in monosegmental disease reduced operative time and blood loss with comparable recovery, though with slightly increased correction loss. Kalanjiyam et al[204] noted better deformity correction with anterior cages in severe deformity. Jia-Ming Liu et al[216] reported higher complications and blood loss with structural grafts.

Meta-analyses demonstrate that both titanium mesh cages and bone grafting are effective and safe for anterior reconstruction in spinal tuberculosis, with no statistically significant differences in fusion, complications, or clinical outcomes, thereby not confirming the previously suggested superiority of titanium mesh cages.[217] However, these findings are limited by reliance on non-randomised studies and small sample sizes. He et al[218] reported comparable safety

between cages and grafts, though some individual studies indicate advantages of titanium cages in multisegmental disease, including faster healing and reduced loss of correction. Conversely, monosegmental disease shows similar outcomes with local grafts, which reduce blood loss and operative time but may have slightly higher correction loss. Iliac crest grafts carry higher donor-site morbidity.

Overall, available evidence shows comparable fusion and clinical outcomes across grafts and cages in spinal tuberculosis. Titanium mesh cages offer mechanical advantages in significant or multilevel defects, while local nonstructural grafts reduce surgical morbidity in small, monosegmental disease. Defect size and extent of vertebral destruction should guide reconstruction choice.

Limitations

This consensus manuscript has several limitations that warrant acknowledgment. First, although the PICO framework and study selection criteria were defined a priori, explicit reporting was not uniform across all sections, which may affect reproducibility. PROSPERO registration was not performed,this omission remains a limitation. Restricting inclusion to English-language studies may have introduced language bias, potentially limiting regional evidence. Review articles were excluded to avoid duplication, though this may have reduced access to synthesized data, they are utilised in discussion if deemed necessary. In some domains, outcomes were reported as ranges from narrative synthesis rather than pooled estimates, limiting precision. Formal assessment of publication bias was not performed due to heterogeneity. Additionally, selective referencing was employed; not all eligible studies could be explicitly cited, with priority given to the most relevant and influential evidence. These constraints highlight areas for future methodological refinement and research.

Conclusion

This systematic review and consensus process across 7 sections provides a comprehensive synthesis of current evidence and expert opinion on the surgical management of spinal tuberculosis. Despite the heterogeneity of available studies and the generally low to moderate levels of evidence, several consistent principles emerge that can guide clinical practice.

The recommendations emphasis the importance of accurate diagnosis, early initiation of antitubercular therapy, and careful patient selection for surgical intervention. The review highlights the evolving role of MRI, microbiological confirmation, molecular diagnostics, and response monitoring in improving diagnostic accuracy and treatment planning. It also supports a more individualised approach to antitubercular chemotherapy including treatment duration, monitoring of response, and strategies in case of interrupted therapy or suspected resistance. Surgical indications are primarily driven by instability, deformity, neurological compromise, and failure of conservative therapy, with fixation and reconstruction strategies tailored to the extent of vertebral destruction and patient age, non-structural grafts may suffice in minor defects, while structural grafts or titanium cages are preferred in larger or multisegmental defects. The review also underscored that instrumentation levels should be individualised, ranging from short-segment fixation in moderate cases to extended constructs in severe destruction or osteoporosis.

Bracing may provide pain relief, they do not reliably prevent deformity progression or collapse. The review also explored surgical indications in neurological deficit, defining absolute criteria for decompression and stabilisation, the limited role of corticosteroids, and the importance of timely surgical decision-making when deficits fail to improve with chemotherapy. In addition, it examined evolving surgical strategies, including minimally invasive endoscopic and transpedicular approaches, the selective role of anterior surgery, thresholds for kyphosis correction, posterior-only stabilisation strategies, and reconstruction choices between bone grafts and titanium cages.

In summary, meticulous debridement, effective antitubercular chemotherapy, and individualised stabilisation remain the cornerstones of spinal tuberculosis surgical management. Posterior-only approaches are increasingly favoured, with anterior surgery reserved for select indications. Reconstruction choices should be guided by defect size and vertebral body loss, while bracing serves primarily as a symptomatic adjunct. Future multicenter prospective studies are essential to establish standardised, evidence-based protocols that optimise infection control, deformity correction, stability, and long-term patient outcomes.

Acknowledgement

We are grateful for the contribution of the ICM Spine Infection Collaborators for their efforts towards making this recommendation. The following experts participated in the consensus framework on tubercular spondylodiscitis: Abhay Nene, WeAreSpine, Bombay, India; Abdullah Al Mamun Choudhury, National Institute of Traumatology and Orthopaedic Rehabilitation, Dhaka, Bangladesh; Adriaan Johannes Vlok, Stellenbosch University, Cape Town, South Africa; Ajoy Prasad Shetty, Ganga Medical Centre & Hospitals Pvt Ltd, Coimbatore, India; Aju Bosco, Institute of Orthopaedics and Traumatology, Madras Medical College, Chennai, India; Andrei Fernandes Joaquim, University of Campinas (UNICAMP), Campinas, Brazil; Aries Rakhmat Hidayat, Dr Soetomo General Academic Hospital, Surabaya, Indonesia; Arya Nick Shamie, David Geffen School of Medicine at UCLA, Los Angeles, USA; Ayon Ghosh, Kothari Medical Centre, Kolkata, India; Benjamin Mukulu Ndeleva, Kenyatta National Hospital, Nairobi, Kenya; Benny Lay, Haji Adam Malik General Hospital, Medan, Indonesia; Bhavuk Garg, All India Institute of Medical Sciences, New Delhi, India; Binod Bijukachhe, Spine Division, Nepal; Chan Chris Yin Wei,

Universiti Malaya, Kuala Lumpur, Malaysia; Chee Kidd Chiu, Universiti Malaya, Kuala Lumpur, Malaysia; Cristiano Magalhães Menezes, Federal University of Minas Gerais, Belo Horizonte, Brazil; Dilip Chand Raja Soundarajan, Kauvery Hospital, Chennai, India; Eduardo Laos Plasier, Almenara Hospital, Lima, Peru; Feifei Zhou, Peking University Third Hospital, Beijing, China; Feng Zhu, Zhenjiang Ruikang Hospital, Zhenjiang, China; Gnanaprakash Gurusamy, Ganga Hospital, Coimbatore, India; Gomatam Vijay Kumar, Fortis Hospital Anandapur, Kolkata, India; Gaurav Raj Dhakal, Manmohan Memorial Teaching Hospital, Kathmandu, Nepal; Gregory D Schroeder, Rothman Orthopedic Institute, Philadelphia, USA; Guna Pratheep Kalanjiyam, Meenakshi Mission Hospital and Research Centre, Madurai, India; Harvinder Singh Chhabra, Sri Balaji Action Medical Institute, New Delhi, India; Hirokazu Inoue, Jichi Medical University, Shimotsuke, Japan; Jason Pui Yin Cheung, The University of Hong Kong, Hong Kong; Jay Dalton, Rothman Orthopedic Institute, Philadelphia, USA; Julian Scherer, University of Cape Town, South Africa/University Hospital of Zurich, Switzerland; Juan Emmerich, Spanish Hospital, La Plata, Argentina; Juan Esteban Muñoz Montoya, Clinica San Rafael, Bogotá, Colombia; Kazutaka Izawa, NHO Osaka Toneyama Medical Center, Toyonaka, Japan; Kei Yamada, Kurume University School of Medicine, Kurume, Japan; Komang Agung Irianto, Dr Soetomo General Hospital, Surabaya, Indonesia; Kosei Nagata, The University of Tokyo Hospital, Tokyo, Japan; Kshitij Chaudhary, PD Hinduja Hospital, Mumbai, India; Manabu Ito, Hokkaido Medical Center, Sapporo, Japan; Marcelo Valacco, Hospital Churruca Visca, Buenos Aires, Argentina; Mohamed M Aly, Prince Mohamed Ben Abdulaziz Hospital, Riyadh, Saudi Arabia; Mohammad El-Sharkawi, Assiut University, Assiut, Egypt; Muzahem M Taha, Erbil International Hospital, Erbil, Iraq; Muralidharan Venkatesan, Apollo Hospitals, Chennai, India; Naresh-Babu J, Mallika Spine Centre, Guntur, India; Narihito Nagoshi, Keio University School of Medicine, Tokyo, Japan; Nestor Adolfo Taboada Taboada, Clinica Portoazul, Barranquilla, Colombia; Nishank Mehta, All India Institute of Medical Sciences, New Delhi, India; Phedy Phedy, Gatam Institute, Eka Hospital BSD, Tangerang Selatan, Indonesia; Pushpa Bhari Thippeswamy, Ganga Hospital, Coimbatore, India; Rishi Mugesh Kanna, Ganga Hospital, Coimbatore, India; Robert Dunn, University of Cape Town, South Africa; Rohit Amritanand, Christian Medical College, Vellore, India; Ronald P Tangente, Davao Doctors Hospital, Davao City, Philippines; Sakinsuke Toshinori, Tokushima University, Tokushima, Japan; Sang-Min Park, Bundang Jesaeng Hospital, Seongnam-si, South Korea; Sathish Muthu, Orthopaedic Research Group, Coimbatore/Aarupadai Veedu Medical College, Puducherry, India; Saumyajit Basu, Kothari Medical Centre, Kolkata, India; Shahid Akon, Dhaka Medical College Hospital, Dhaka, Bangladesh; Shanmuganathan Rajasekaran, Ganga Hospital, Coimbatore, India; Sharif Ahmed Jonayed, NITOR, Dhaka, Bangladesh; Shinsuke Sato, JCHO Tokyo Shinjuku Medical Center, Tokyo, Japan; Shunsuke Katsumi, The Jikei University School of Medicine, Tokyo, Japan; Siddharth Aiyer, Sancheti Institute for Orthopaedics and Rehabilitation, Pune, India; So Kato, The University of Tokyo, Tokyo, Japan; Sri Vijay Anand K S, Ganga Hospital, Coimbatore, India; Stefan Zwingenberger, University Hospital Carl Gustav Carus, Dresden, Germany; Stefano Conti, Sapienza University of Rome, Rome, Italy; Sudhir Ganesan, Sri Ramachandra Institute of Higher Education and Research, Chennai, India; Sudhir Kumar Srivastava, K.J. Somaiya Medical College, Mumbai, India; Teruaki Endo, Japanese Red Cross Koga Hospital, Koga, Japan; Venugopal Menon, Rajagiri Hospital, Aluva, India; Vikas Hanasoge, Kothari Medical Centre, Kolkata, India; Yogesh Kishorkant Pithwa, Sattvik Spine And Scoliosis Center, India; Yong Hai, Beijing Chaoyang Hospital, Capital Medical University, Beijing, China.

ORCID iDs

Shanmuganathan Rajasekaran https://orcid.org/0000-0001-6043-006X
Gnanaprakash Gurusamy https://orcid.org/0009-0006-7167-2228
Sathish Muthu https://orcid.org/0000-0002-7143-4354

Funding

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: The project was funded by International Consensus Meeting on Infection (ICMI), a non-profit organization focused on reducing orthopaedic-related infections.

Declaration of Conflicting Interests

The authors declare that there are no conflicts of interest relevant to this manuscript. Individual author conflict-of-interest disclosure forms have been submitted in accordance with journal requirements.

References

1. Muthu S, Gurusamy G, Rajasekaran S, Parvizi J, ICM-Spinal Infection Collaborators. Methodological framework for global expert consensus on musculoskeletal infection: establishing the ICM 2025 recommendations. *Global Spine J*. 2026. In press. doi:10.1177/21925682261442201.
2. Atkin D, Best D, Briss PA, et al. Grading quality of evidence and strength of recommendations. *Br Med J (Clin Res Ed)*. 2004;328(7454):1490. doi:10.1136/BMJ.328.7454.1490.
3. Weinstein MA, Eismont FJ. Infections of the spine in patients with human immunodeficiency virus. *J Bone Joint Surg Am*. 2005;87(3):604-609. doi:10.2106/JBJS.C.01062.
4. Leibert E, Schluger NW, Bonk S, Rom WN. Spinal tuberculosis in patients with human immunodeficiency virus infection: clinical presentation, therapy and outcome. *Tuber Lung Dis*. 1996;77(4):329-334. doi:10.1016/S0962-8479(96)90097-0.
5. Marais S, Roos I, Mitha A, Mabusha SJ, Patel V, Bhigjee AI. Spinal tuberculosis: clinicoradiological findings in 274 patients. *Clin Infect Dis*. 2018;67(1):89-98. doi:10.1093/CID/CIY020.
6. Dunn R, Van Der Horst A, Lippross S. Tuberculosis of the spine--Prospective neurological and patient reported outcome study. *Clin Neurol Neurosurg*. 2015;133:96-101. doi:10.1016/J.CLINEURO.2015.03.015.
7. Held MFG, Hoppe S, Laubscher M, et al. Epidemiology of musculoskeletal tuberculosis in an area with high disease

prevalence. *Asian Spine J*. 2017;11(3):405-411. doi:10.4184/ASJ.2017.11.3.405.

8. Walters E, Duvenhage J, Draper HR, et al. Severe manifestations of extrapulmonary tuberculosis in HIV-infected children initiating antiretroviral therapy before 2 years of age. *Arch Dis Child*. 2014;99(11):998-1003. doi:10.1136/ARCHDISCHILD-2013-305509.
9. Sagane SS, Patil VS, Bartakke GD, Kale KY. Assessment of clinical and radiological parameters in spinal tuberculosis: comparison between human immunodeficiency virus-positive and human immunodeficiency virus-negative patients. *Asian Spine J*. 2020;14(6):857-863. doi:10.31616/ASJ.2019.0251.
10. Anley C, Brandt A, Dunn R. Magnetic resonance imaging findings in spinal tuberculosis: comparison of HIV positive and negative patients. *Indian J Orthop*. 2012;46(2):186-190. doi:10.4103/0019-5413.93688.
11. Danaviah S, Govender S, Cassol S. Histopathology and genotyping in infectious spondylitis of HIV- and HIV+ patients. *Clin Orthop Relat Res*. 2007;460:50-55. doi:10.1097/BLO.0B013E31806A9147.
12. Govender S, Annamalai K, Kumar KPS, Govender UG. Spinal tuberculosis in HIV positive and negative patients: immunological response and clinical outcome. *Int Orthop*. 2000;24(3):163-166. doi:10.1007/S002640000125.
13. Corti M, Villafañe MF, Palmieri O, Gilardi L. Mycobacterium tuberculosis como agente etiológico de espondilodiscitis infecciosa del adulto [Mycobacterium tuberculosis as etiological agent of adult infectious spondylodiscitis]. *Rev Clin Esp*. 2012;212(7):369-371. doi:10.1016/j.rce.2012.03.016.
14. Chen CH, Chen YM, Lee CW, Chang YJ, Cheng CY, Hung JK. Early diagnosis of spinal tuberculosis. *J Formos Med Assoc*. 2016;115(10):825-836. doi:10.1016/J.JFMA.2016.07.001.
15. Alavi SM, Sharifi M. Tuberculous spondylitis: risk factors and clinical/paraclinical aspects in the South West of Iran. *J Infect Public Health*. 2010;3(4):196-200. doi:10.1016/J.JIPH.2010.09.005.
16. Cormican L, Hammal R, Messenger J, Milburn HJ. Current difficulties in the diagnosis and management of spinal tuberculosis. *Postgrad Med J*. 2006;82(963):46-51. doi:10.1136/PGMJ.2005.032862.
17. Su SH, Tsai WC, Lin CY, et al. Clinical features and outcomes of spinal tuberculosis in Southern Taiwan. *J Microbiol Immunol Infect*. 2010;43(4):291-300. doi:10.1016/S1684-1182(10)60046-1.
18. Turunc T, Demiroglu YZ, Uncu H, Colakoglu S, Arslan H. A comparative analysis of tuberculous, brucellar and pyogenic spontaneous spondylodiscitis patients. *J Infect*. 2007;55(2):158-163. doi:10.1016/j.jinf.2007.04.002.
19. Kim CJ, Song KH, Jeon JH, et al. A comparative study of pyogenic and tuberculous spondylodiscitis. *Spine (Phila Pa 1976)*. 2010;35(21):E1096-E1100. doi:10.1097/BRS.0B013E3181E04DD3.
20. Alothman A, Memish ZA, Awada A, et al. Tuberculous spondylitis: analysis of 69 cases from Saudi Arabia. *Spine (Phila Pa 1976)*. 2001;26(24):E565-E570. doi:10.1097/00007632-200112150-00020.
21. Mann TN, Davis JH, Walzl G, et al. Candidate biomarkers to distinguish spinal tuberculosis from mechanical back pain in a tuberculosis endemic setting. *Front Immunol*. 2021;12:768040. doi:10.3389/FIMMU.2021.768040.
22. Lou C, Liu J, Ren Z, et al. Analysis of the value of serum biomarker LBP in the diagnosis of spinal tuberculosis. *Infect Drug Resist*. 2022;15:4915-4926. doi:10.2147/IDR.S377182.
23. Rao V, Murthy KS. High-sensitivity C-reactive protein? Is it Significant in Tuberculous Spondylitis. *Int J Sci Study*. 2016;3(12):274.
24. Hu X, Zhang H, Li Y, et al. Analysis of the diagnostic efficacy of the QuantiFERON-TB gold in-tube assay for preoperative differential diagnosis of spinal tuberculosis. *Front Cell Infect Microbiol*. 2022;12:983579. doi:10.3389/FCIMB.2022.983579.
25. Lertudomphonwanit T, Somboonprasert C, Lilakhunakon K, et al. A clinical prediction model to differentiate tuberculous spondylodiscitis from pyogenic spontaneous spondylodiscitis. *PLoS One*. 2023;18(8):e0290361. doi:10.1371/JOURNAL.PONE.0290361.
26. Dong Z, Wang S, Jia C, Wang H, Ding W. Predictive value of vertebral bone destruction classification based on computed tomography in diagnosing on adult spinal tuberculosis. *World Neurosurg*. 2024;183:e801-e812. doi:10.1016/J.WNEU.2024.01.033.
27. Rivas-Garcia A, Sarria-Estrada S, Torrents-Odin C, Casas-Gomila L, Franquet E. Imaging findings of Pott's disease. *Eur Spine J*. 2013;22(Suppl 4):567-578. doi:10.1007/S00586-012-2333-9.
28. Kostov K, Petrov I. Tuberculous spondylitis–analysis of 22 cases. *Acta Neurol Belg*. 2009;109(2):127-131. https://www.researchgate.net/profile/Kosta-Kostov-2/publication/26742718_Tuberculous_spondylitis–analysis_of_22_cases/links/00b495191f05a8591b000000/Tuberculous-spondylitis–analysis-of-22-cases.pdf. Accessed 1 January 2026.
29. Maeda Y, Izawa K, Nabeshima T, Yonenobu K. Tuberculous spondylitis in elderly Japanese patients. *J Orthop Sci*. 2008;13(1):16-20. doi:10.1007/S00776-007-1197-Z.
30. Abou-Raya S, Abou-Raya A. Spinal tuberculosis: Overlooked? *J Intern Med*. 2006;260(2):160-163. doi:10.1111/J.1365-2796.2006.01675.X.
31. Sinan T, Al-Khawari H, Ismail M, Ben-Nakhi A, Sheikh M. Spinal tuberculosis: CT and MRI feature. *Ann Saudi Med*. 2004;24(6):437-441. doi:10.5144/0256-4947.2004.437.
32. Shim EJ, Shin SY, Seo M, Lee SH, Kim JI, Lee HN. Co-existing active pulmonary tuberculosis in tuberculous spondylitis: the prevalence and the role of chest CT. *J Thorac Dis*. 2020;12(4):1635-1638. doi:10.21037/JTD.2020.02.48.
33. Turgut M. Spinal tuberculosis (Pott's disease): its clinical presentation, surgical management, and outcome. A survey study on 694 patients. *Neurosurg Rev*. 2001;24(1):8-13. doi:10.1007/PL00011973.
34. Wang H, Li C, Wang J, Zhang Z, Zhou Y. Characteristics of patients with spinal tuberculosis: seven-year experience of a

teaching hospital in Southwest China. *Int Orthop*. 2012;36(7):1429-1434. doi:10.1007/S00264-012-1511-Z.

35. Garg B, Mehta N, Mukherjee RN, Swamy AM, Siamwala BS, Malik G. Epidemiological insights from 1,652 patients with spinal tuberculosis managed at a single center: a retrospective review of 5-year data. *Asian Spine J*. 2022;16(2):162-172. doi:10.31616/ASJ.2021.0137.
36. Skoura E, Zumla A, Bomanji J. Imaging in tuberculosis. *Int J Infect Dis*. 2015;32:87-93. doi:10.1016/j.ijid.2014.12.007.
37. Rajasekaran S. Natural history of Pott's kyphosis. *Eur Spine J*. 2013;22(SUPPL.4):634. doi:10.1007/S00586-012-2336-6
38. Rajasekaran S, Shanmugasundaram TK. Prediction of the angle of gibbus deformity in tuberculosis of the spine. *J Bone Joint Surg Am*. 1987;69:503. https://journals.lww.com/jbjsjournal/abstract/1987/69040/Prediction_of_the_angle_of_gibbus_deformity_in.5.aspx. Accessed 1 January 2026.
39. Rajasekaran S. The natural history of post-tubercular kyphosis in children: radiological signs which predict late increase in deformity. *J Bone Joint Surg Br*. 2001;83(7):954-962. doi:10.1302/0301-620X.83B7.12170
40. Rajasekaran S, Shanmugasundaram TK, Prabhakar R, Dheenadhayalan J, Shetty AP, Shetty DK. Tuberculous lesions of the lumbosacral region: a 15-year follow-up of patients treated by ambulant chemotherapy. *Spine (Phila Pa 1976)*. 1998;23(10):1163-1167. doi:10.1097/00007632-199805150-00018.
41. Rajasekaran S. The problem of deformity in spinal tuberculosis. *Clin Orthop Relat Res*. 2002;398(398):85-92. doi:10.1097/00003086-200205000-00012.
42. Rajagopalan S, Yoshikawa TT. Tuberculosis in the elderly. *Z Gerontol Geriatr*. 2000;33(5):374-380. doi:10.1007/S003910070034.
43. Teale C, Goldman JM, Pearson SB. The association of age with the presentation and outcome of tuberculosis: a five-year survey. *Age Ageing*. 1993;22(4):289-293. doi:10.1093/AGEING/22.4.289.
44. Wang J, Li Z, Chi X, et al. Development of a diagnostic model for differentiating tuberculous spondylitis and pyogenic spondylitis with MRI: a multicenter retrospective observational study. *Spine (Phila Pa 1976)*. 2024;49(1):34-45. doi:10.1097/BRS.0000000000004848.
45. Yueniwati Y, Christina E. The challenges in differentiating tuberculous from pyogenic spondylitis using magnetic resonance imaging. *Rep Med Imag*. 2017;10:37-43. doi:10.2147/RMI.S129533.
46. Naselli N, Facchini G, Lima GM, et al. MRI in differential diagnosis between tuberculous and pyogenic spondylodiscitis. *Eur Spine J*. 2022;31(2):431-441. doi:10.1007/S00586-021-06952-8.
47. Miyamoto H, Akagi M. Usefulness of dynamic contrast-enhanced magnetic resonance images for distinguishing between pyogenic spondylitis and tuberculous spondylitis. *Eur Spine J*. 2019;28(12):3011-3017. doi:10.1007/S00586-019-06057-3.
48. Arizono T, Oga M, Shiota E, Honda K, Sugioka Y. Differentiation of vertebral osteomyelitis and tuberculous spondylitis by magnetic resonance imaging. *Int Orthop*. 1995;19(5):319-322. doi:10.1007/BF00181119.
49. Frel M, Białecki J, Wieczorek J, Paluch Ł, Dąbrowska-Thing A, Walecki J. Magnetic resonance imaging in differentatial diagnosis of pyogenic spondylodiscitis and tuberculous spondylodiscitis. *Pol J Radiol*. 2017;82:71-87. doi:10.12659/PJR.899606.
50. Zhang N, Zeng X, He L, et al. The value of MR imaging in comparative analysis of spinal infection in adults: pyogenic versus tuberculous. *World Neurosurg*. 2019;128:e806-e813. doi:10.1016/j.wneu.2019.04.260.
51. Lee Y, Kim BJ, Kim SH, Lee SH, Kim WH, Jin SW. Comparative analysis of spontaneous infectious spondylitis: pyogenic versus tuberculous. *J Korean Neurosurg Soc*. 2017;61(1):81-88. doi:10.3340/JKNS.2016.1212.005.
52. Chang MC, Wu HTH, Lee CH, Liu CL, Chen TH. Tuberculous spondylitis and pyogenic spondylitis: comparative magnetic resonance imaging features. *Spine (Phila Pa 1976)*. 2006;31(7):782-788. doi:10.1097/01.BRS.0000206385.11684.D5.
53. Gupta N, Kadavigere R, Malla S, Bhat SN, Saravu K. Differentiating tubercular from pyogenic causes of spine involvement on magnetic resonance imaging. *Inf Med*. 2023;31(1):62-69. doi:10.53854/LIIM-3101-9.
54. Galhotra RD, Jain T, Sandhu P, Galhotra V. Utility of magnetic resonance imaging in the differential diagnosis of tubercular and pyogenic spondylodiscitis. *J Nat Sci Biol Med*. 2015;6(2):388-393. doi:10.4103/0976-9668.160016.
55. Jung NY, Jee WH, Ha KY, Park CK, Byun JY. Discrimination of tuberculous spondylitis from pyogenic spondylitis on MRI. *Am J Roentgenol*. 2004;182(6):1405-1410. doi:10.2214/AJR.182.6.1821405.
56. Tanaviriyachai T, Pornsopanakorn P, Choovongkomol K, et al. A comparative factor analysis and new magnetic resonance imaging scoring system for differentiating pyogenic versus tuberculous spondylodiscitis. *Neurospine*. 2024;21(2):690-700. doi:10.14245/NS.2448120.060.
57. Andronikou S, Jadwat S, Douis H. Patterns of disease on MRI in 53 children with tuberculous spondylitis and the role of gadolinium. *Pediatr Radiol*. 2002;32(11):798-805. doi:10.1007/S00247-002-0766-8.
58. Jutte P, Wuite S, The B, Van Altena R, Veldhuizen A. Prediction of deformity in spinal tuberculosis. *Clin Orthop Relat Res*. 2007;455:196-201. doi:10.1097/01.BLO.0000246559.27596.33.
59. Singh R, Magu NK, Rohilla RK. Clinicoradiologic profile of involvement and healing in tuberculosis of the spine. *Ann Med Health Sci Res*. 2016;6(5):311. doi:10.4103/AMHSR.AMHSR_188_15.
60. Misra UK, Warrier S, Kalita J, Kumar S. MRI findings in Pott's spine and correlating clinical progress with radiological findings. *Neuroradiology*. 2020;62(7):825-832. doi:10.1007/S00234-020-02402-2.

61. Gupta A, Kumar C, Kumar P, Verma A, Nath R, Kulkarni C. Correlation between neurological recovery and magnetic resonance imaging in Pott's paraplegia. *Indian J Orthop*. 2014; 48(4):366-373. doi:10.4103/0019-5413.136228.
62. Jain A, Jena A, Dhammi IK. Correlation of clinical course with magnetic resonance imaging in tuberculous myelopathy. *Neurol India*. 2000;48:132. https://journals.lww.com/neur/abstract/2000/48020/correlation_of_clinical_course_with_magnetic.7.aspx. Accessed 1 January 2026.
63. Gupta A, Paliwal VK, Bharatveer S, Mishra P, Jain N. Clinical and radiological end points to stop anti-tubercular treatment in central nervous system tuberculoma and predictors of poor outcome: A retrospective study. *Am J Trop Med Hyg*. 2023; 109:1141. https://pmc.ncbi.nlm.nih.gov/articles/PMC10622483/. Accessed January 1, 2026.
64. Jain AK, Srivastava A, Saini NS, Dhammi IK, Sreenivasan R, Kumar S. Efficacy of extended DOTS category I chemotherapy in spinal tuberculosis based on MRI-based healed status. *Indian J Orthop*. 2012;46(6):633-639. doi:10.4103/0019-5413.104191.
65. Mittal S, Jain AK, Chakraborti KL, Aggarwal AN, Upreti L, Bhayana H. Evaluation of healed status in tuberculosis of spine by fluorodeoxyglucose-positron emission tomography/computed tomography and contrast magnetic resonance imaging. *Indian J Orthop*. 2019;53(1):160-168. doi:10.4103/ORTHO.IJORTHO_224_18.
66. Sahoo MM, Mahapatra SK, Sethi GC, Sahoo A, Kar BK. Role of percutaneous transpedicular biopsy in diagnosis of spinal tuberculosis and its correlation with the clinico-radiological features. *Indian J Tubercul*. 2019;66(3):388-393. doi:10.1016/j.ijtb.2018.05.019.
67. Kanna RM, Babu N, Kannan M, Shetty AP, Rajasekaran S. Diagnostic accuracy of whole spine magnetic resonance imaging in spinal tuberculosis validated through tissue studies. *Eur Spine J*. 2019;28(12):3003-3010. doi:10.1007/S00586-019-06031-Z.
68. Jain A, Kandwal P, Sarkar B, et al. Utility of clinicoradiological, microbiological, histopathological, and molecular methods in the diagnosis of spinal tuberculosis. *Eur Spine J*. 2023;32(12):4229-4237. doi:10.1007/S00586-023-07683-8.
69. Rajasekaran S, Soundararajan DCR, Shetty AP, Kanna RM. Spinal tuberculosis: current concepts. *Global Spine J*. 2018; 8(4 Suppl):96S-108S. doi:10.1177/2192568218769053.
70. Kubihal V, Sharma R, Krishna Kumar RG, Chandrashekhara SH, Garg R. Imaging update in spinal tuberculosis. *J Clin Orthop Trauma*. 2021;25:101742. doi:10.1016/J.JCOT.2021.101742.
71. Dunn R, Zondagh I. Spinal tuberculosis: diagnostic biopsy is mandatory. *S Afr Med J*. 2008;98:360. https://www.scielo.org.za/scielo.php?pid=S0256-95742008000500014&script=sci_arttext. Accessed 6 January 2026.
72. Czuczman GJ, Marrero DE, Huang AJ, Mandell JC, Ghazikhanian V, Simeone FJ. Diagnostic yield of repeat CT-guided biopsy for suspected infectious spondylodiscitis. *Skelet Radiol*. 2018;47(10):1403-1410. doi:10.1007/S00256-018-2972-Y.
73. Michel SCA, Pfirrmann CWA, Boos N, Hodler J. CT-guided core biopsy of subchondral bone and intervertebral space in suspected spondylodiskitis. *Am J Roentgenol*. 2006;186(4): 977-980. doi:10.2214/AJR.05.0109.
74. McNamara AL, Dickerson EC, Gomez-Hassan DM, Cinti SK, Srinivasan A. Yield of image-guided needle biopsy for infectious discitis: a systematic review and meta-analysis. *Am J Neuroradiol*. 2017;38(10):2021-2027. doi:10.3174/AJNR.A5337.
75. Arockiaraj J, Michael JS, Amritanand R, David KS, Krishnan V. The role of Xpert MTB/RIF assay in the diagnosis of tubercular spondylodiscitis. *Eur Spine J*. 2017;26(12): 3162-3169. doi:10.1007/S00586-017-5076-9.
76. Patel J, Upadhyay M, Kundnani V, Merchant Z, Jain S, Kire N. Diagnostic efficacy, sensitivity, and specificity of Xpert MTB/RIF assay for spinal tuberculosis and Rifampicin resistance. *Spine (Phila Pa 1976)*. 2020;45(3):163-169. doi:10.1097/BRS.0000000000003225.
77. Waters R, Laubscher M, Dunn RN, Adikary N, Coussens AK, Held M. Higher sensitivity of Xpert MTB/RIF ultra over tuberculosis culture for the diagnosis of spinal tuberculosis with open or computed tomography-guided biopsies. *Open Forum Infect Dis*. 2023;11(1):ofad621. doi:10.1093/OFID/OFAD621.
78. Jain AK, Jaggi KR, Bhayana H, Saha R. Drug-resistant spinal tuberculosis. *Indian J Orthop*. 2018;52(2):100-107. doi:10.4103/ORTHO.IJORTHO_306_17.
79. Bhosale S, Ariwala DM, Phupate A, Marathe N, Seshadri H, Sheth U. Multidrug-resistant tuberculosis of spine diagnosis and management: an institutional experience of 21 cases. *Surg Neurol Int*. 2024;15:344. doi:10.25259/SNI_398_2024.
80. Watt JP, Davis JH. Percutaneous core needle biopsies: the yield in spinal tuberculosis. *S Afr Med J*. 2013;104(1):29-32. doi:10.7196/SAMJ.6868.
81. Fan J, Lan T, Tang K, et al. The comparative influence of 2 and 4 weeks preoperative antituberculosis treatment on spinal tuberculosis surgery: a multicenter, prospective, randomized clinical trial. *Infect Dis Ther*. 2021;10(3):1451-1463. doi:10.1007/S40121-021-00462-2.
82. Held M, Laubscher M, Zar HJ, Dunn RN. GeneXpert polymerase chain reaction for spinal tuberculosis: an accurate and rapid diagnostic test. *Bone Joint J*. 2014;96-B(10):1366-1369. doi:10.1302/0301-620X.96B10.34048.
83. Zakham F, Bazoui H, Akrim M, et al. Evaluation of conventional molecular diagnosis of Mycobacterium tuberculosis in clinical specimens from Morocco. *J Infect Dev Ctries*. 2012; 6(1):40-45. doi:10.3855/JIDC.1857.
84. Li Z, Wang J, Xiu X, Shi Z, Zhang Q, Chen D. Evaluation of different diagnostic methods for spinal tuberculosis infection. *BMC Infect Dis*. 2023;23(1):695. doi:10.1186/S12879-023-08655-5.

85. Lee CM, Lee Y, Kang SJ, et al. Positivity rates of mycobacterial culture in patients with tuberculous spondylitis according to methods and sites of biopsies: an analysis of 206 cases. *Int J Infect Dis*. 2022;121:161-165. doi:10.1016/j.ijid.2022.05.021.
86. Yu Y, Kong Y, Ye J, Wang A. Performance of conventional histopathology and GeneXpert MTB/RIF in the diagnosis of spinal tuberculosis from bone specimens: a prospective clinical study. *Clin Biochem*. 2020;85:33-37. doi:10.1016/j.clinbiochem.2020.08.010.
87. Wu W, Lyu J, Cheng P, et al. Improvement in clinical outcome and infection control using molecular diagnostic techniques for early detection of MDR tuberculous spondylitis: a multicenter retrospective study. *Emerg Microbes Infect*. 2017;6(11):e97. doi:10.1038/EMI.2017.83.
88. Aithala JP, Attar A, Imthiaz AKA, Rai M. Is there a change in trend towards pyogenous spondylodiscitis compared to tubercular spondylodiscitis in India-A study of percutaneous biopsy evaluation in spondylodiscitis. *Indian J Tubercul*. 2020;67(4):509-514. doi:10.1016/J.IJTB.2020.07.002.
89. Mete B, Kurt C, Yilmaz MH, et al. Vertebral osteomyelitis: eight years' experience of 100 cases. *Rheumatol Int*. 2012;32(11):3591-3597. doi:10.1007/S00296-011-2233-Z.
90. Yee DKH, Samartzis D, Wong YW, Luk KDK, Cheung KMC. Infective spondylitis in Southern Chinese: a descriptive and comparative study of ninety-one cases. *Spine (Phila Pa 1976)*. 2010;35(6):635-641. doi:10.1097/BRS.0B013E3181CFF4F6.
91. Gouliouris T, Aliyu SH, Brown NM. Spondylodiscitis: update on diagnosis and management. *J Antimicrob Chemother*. 2010;65(SUPPL. 3):iii11-iii24. doi:10.1093/JAC/DKQ303.
92. Berbari EF, Kanj SS, Kowalski TJ, et al. Infectious Diseases Society of America (IDSA) clinical practice guidelines for the diagnosis and treatment of native vertebral osteomyelitis in adults. *Clin Infect Dis*. 2015;61(6):e26-e46. doi:10.1093/CID/CIV482
93. Erkens CGM, Kamphorst M, Abubakar I, et al. Tuberculosis contact investigation in low prevalence countries: a European consensus. *Eur Respir J*. 2010;36(4):925-949. doi:10.1183/09031936.00201609.
94. Rodino KG, Simner PJ. Status check: next-generation sequencing for infectious-disease diagnostics. *J Clin Investig*. 2024;134(4):e178003. doi:10.1172/JCI178003.
95. Global Tuberculosis Report 2024. https://www.who.int/teams/global-programme-on-tuberculosis-and-lung-health/tb-reports/global-tuberculosis-report-2024. Accessed January 3, 2026.
96. Mishra G, Mulani J. First national anti-tuberculosis drug resistance survey (NDRS) from India - an eye opener. *J Infect*. 2018;1(2):26-29. doi:10.29245/2689-9981/2018/2.1117.
97. Bhosale S, Prabhakar A, Srivastava S, Raj A, Purohit S, Marathe N. Pattern of drug resistance in primary spinal tuberculosis: a single-center study from India. *Global Spine J*. 2021;11(7):1070-1075. doi:10.1177/2192568220941445.
98. Mohan K, Rawall S, Pawar UM, et al. Drug resistance patterns in 111 cases of drug-resistant tuberculosis spine. *Eur Spine J*. 2012;22(Suppl 4):647-652. doi:10.1007/S00586-012-2154-X.
99. Li L, Zhang Z, Luo F, et al. Management of drug-resistant spinal tuberculosis with a combination of surgery and individualised chemotherapy: a retrospective analysis of thirty-five patients. *Int Orthop*. 2012;36(2):277-283. doi:10.1007/S00264-011-1398-0.
100. Abhimanyu S, Jain AK, Myneedu VP, Arora VK, Chadha M, Sarin R. The role of cartridge-based nucleic acid amplification test (CBNAAT), line probe assay (LPA), liquid culture, acid-fast Bacilli (AFB) smear and histopathology in the diagnosis of osteoarticular tuberculosis. *Indian J Orthop*. 2021;55(Suppl 1):157-166. doi:10.1007/S43465-020-00326-W.
101. Yadav M, Jain AK, Singhal R, Chadha M, Arora VK, Bhargava A. Incidence and patterns of drug resistance in patients with spinal tuberculosis: a prospective, single-center study from a tuberculosis-endemic country. *Indian J Orthop*. 2023;57(11):1833-1841. doi:10.1007/S43465-023-00986-4.
102. Gain A, Jain AK, Bhalla M, Aggarwal AN, Dhammi IK, Arora VK. Drug resistance in osteoarticular tuberculosis: a study from an endemic zone. *Cureus*. 2023;15(8):e44173. doi:10.7759/CUREUS.44173.
103. Mohapatra B. Comparison of 9 versus 12 months' antitubercular drug regimen in pott spine: a prospective study. *Global Spine J*. 2015;5(1_suppl):s-0035-1554182. doi:10.1055/S-0035-1554182.
104. Park DW, Sohn JW, Kim EH, et al. Outcome and management of spinal tuberculosis according to the severity of disease: a retrospective study of 137 adult patients at Korean teaching hospitals. *Spine (Phila Pa 1976)*. 2007;32(4):E130-E135. doi:10.1097/01.BRS.0000255216.54085.21.
105. MRC Working Party on Tuberculosis of the Spine. Darbyshire J. Five-year assessment of controlled trials of short-course chemotherapy regimens of 6, 9 or 18 months' duration for spinal tuberculosis in patients ambulatory from the start or undergoing radical surgery. Fourteenth report of the Medical Research Council. *Int Orthop*. 1999;23(2):73-81. doi:10.1007/S002640050311.
106. Upadhyay SS, Saji MJ, Yau ACMC. Duration of antituberculosis chemotherapy in conjunction with radical surgery in the management of spinal tuberculosis. *Spine (Phila Pa 1976)*. 1996;21(16):1898-1903. doi:10.1097/00007632-199608150-00014.
107. Rajeswari R, Balasubramanian R, Venkatesan P, et al. Short course chemotherapy in the treatment of Pott's paraplegia – report on five year follow-up. *Int J Tuberc Lung Dis*. 1997;1(2):152-158. https://www.ingentaconnect.com/content/iuatld/ijtld/1997/00000001/00000002/art00010. Accessed 3 January 2026.
108. Ramachandran S, Clifton IJ, Collyns TA, Watson JP, Pearson SB. The treatment of spinal tuberculosis: a retrospective study. *Int J Tubercul Lung Dis*. 2005;9(5):541-544.

109. Dai LY, Jiang LS, Wang YR, Jiang SD. Chemotherapy in anterior instrumentation for spinal tuberculosis: highlighting a 9-month three-drug regimen. *World Neurosurg*. 2010;73(5):560-564. doi:10.1016/J.WNEU.2010.02.023.
110. Wang Z, Shi J, Geng G, Qiu H. Ultra-short-course chemotherapy for spinal tuberculosis: five years of observation. *Eur Spine J*. 2012;22(2):274-281. doi:10.1007/S00586-012-2536-0.
111. Nene AM, Patil S, Kathare AP, Nagad P, Nene A, Kapadia F. Six versus 12 months of anti tubercular therapy in patients with biopsy proven spinal tuberculosis: a single center, open labeled, prospective randomized clinical trial-a pilot study. *Spine (Phila Pa 1976)*. 2019;44(1):E1-E6. doi:10.1097/BRS.0000000000002811.
112. Aryal A, Garg B, Mehta N, Shekhar S, Gupta V. Is 6 months of antitubercular chemotherapy as effective as more than 6 months regimen in spinal tuberculosis? A systematic review and meta-analysis. *Asian Spine J*. 2022;16(5):749-763. doi:10.31616/ASJ.2021.0104.
113. Lin L, Ke Z, Cheng S. Efficacy and safety of short-term chemotherapy for patients with spinal tuberculosis undergoing surgery in Chinese population: a meta-analysis. *J Orthop Surg Res*. 2021;16(1):229. doi:10.1186/S13018-021-02375-9.
114. van Loenhout-Rooyackers J, Verbeek A, Jutte P. Chemotherapeutic treatment for spinal tuberculosis. *Int J Tubercul Lung Dis*. 2002;6(3):259-265. https://research.rug.nl/en/publications/chemotherapeutic-treatment-for-spinal-tuberculosis/. Accessed 3 January 2026.
115. Jia C, Gao J, Liu F, et al. Efficacy, safety and prognosis of treating neurological deficits caused by spinal tuberculosis within 4 weeks' standard anti-tuberculosis treatment: a single medical center's experience. *Exp Ther Med*. 2020;19(1):519-526. doi:10.3892/ETM.2019.8253.
116. Alici E, Akçali Ö, Tatari H, Günal I. Effect of preoperative chemotherapy on the outcome of surgical treatment of vertebral tuberculosis: retrospective analysis of 434 cases. *Arch Orthop Trauma Surg*. 2001;121(1-2):65-66. doi:10.1007/S004020000163.
117. Liu Q, Ma L, Yanga Z, et al. How to determine the course of preoperative chemotherapy for spinal tuberculosis: a single-center clinical study. *Medicine*. 2024;103(43):e40232. doi:10.1097/MD.0000000000040232.
118. Chen L, Zhang J. Retrospective evaluation of short-course versus traditional preoperative chemotherapy in thoracolumbar spinal tuberculosis patients. *Med Sci Monit*. 2023;29:e941003. doi:10.12659/MSM.941003.
119. Gupta A, Paliwal VK, Bharatveer S, Mishra P, Jain N. Clinical and radiological end points to stop anti-tubercular treatment in central nervous system tuberculoma and predictors of poor outcome: a retrospective study. *Am J Trop Med Hyg*. 2023;109(5):1141-1147. doi:10.4269/AJTMH.23-0183.
120. Yao Y, Song W, Wang K, et al. Features of 921 patients with spinal tuberculosis: a 16-year investigation of a general Hospital in Southwest China. *Orthopedics*. 2017;40(6):e1017-e1023. doi:10.3928/01477447-20171012-03.
121. Solagberu BA, Ayorinde RO. Tuberculosis of the spine in Ilorin, Nigeria. *East Afr Med J*. 2001;78(4):197-199. doi:10.4314/EAMJ.V78I4.9062.
122. Wang XY, Luo CK, Li WW, et al. A practical therapeutic protocol for cervical tuberculosis. *Eur J Trauma Emerg Surg*. 2013;39(1):93-99. doi:10.1007/S00068-012-0243-5.
123. MRC Working Party on Tuberculosis of the Spine. Darbyshire J, Five-year assessment of controlled trials of short-course chemotherapy regimens of 6, 9 or 18 months' duration for spinal tuberculosis in patients ambulatory from the start or undergoing radical surgery. Fourteenth report of the Medical Research Council Working Party on Tuberculosis of the Spine. *Int Orthop*. 1999;23(2):73-81. doi:10.1007/S002640050311.
124. Tang L, Fu CG, Zhou ZY, et al. Clinical features and outcomes of spinal tuberculosis in central China. *Infect Drug Resist*. 2022;15:6641-6650. doi:10.2147/IDR.S384442.
125. *WHO Consolidated Guidelines on Tuberculosis. Module 4: Treatment - Drug-Resistant Tuberculosis Treatment, 2022 Update*. Geneva: World Health Organization. 2023.
126. Pandita A, Madhuripan N, Pandita S, Hurtado RM. Challenges and controversies in the treatment of spinal tuberculosis. *J Clin Tuberc Other Mycobact Dis*. 2020;19:100151. doi:10.1016/J.JCTUBE.2020.100151.
127. Kalanjiyam GP, Ramachandran K, Rajasekaran S, Shetty AP, Kanna RM. Surgical correction of thoracic and thoracolumbar TB kyphosis by posterior only approach using Rajasekaran's kyphosis classification. *Global Spine J*. 2025;15(5):2726-2735. doi:10.1177/21925682241310828.
128. Nene A, Bhojraj S, Ortho D. Results of nonsurgical treatment of thoracic spinal tuberculosis in adults. *Spine J*. 2005;5(1):79-84. doi:10.1016/j.spinee.2004.05.255.
129. Boxer DI, Pratt C, Hine AL, McNicol M. Radiological features during and following treatment of spinal tuberculosis. *Br J Radiol*. 1992;65(774):476-479. doi:10.1259/0007-1285-65-774-476.
130. Zhang Z, Luo F, Zhou Q, Dai F, Sun D, Xu J. The outcomes of chemotherapy only treatment on mild spinal tuberculosis. *J Orthop Surg Res*. 2016;11(1):49. doi:10.1186/S13018-016-0385-Y.
131. Mann TN, Warwick J, Chegou NN, et al. Biomarkers to predict FDG PET/CT activity after the standard duration of treatment for spinal tuberculosis: an exploratory study. *Tuberculosis*. 2021;129:102107. doi:10.1016/j.tube.2021.102107.
132. Rajasekaran S. Kyphotic deformity in spinal tuberculosis and its management. *Int Orthop*. 2012;36(2):359-365. doi:10.1007/S00264-011-1469-2
133. Derbyshire J. A 15-year assessment of controlled trials of the management of tuberculosis of the spine in Korea and Hong Kong. Thirteenth report of the Medical Research Council Working Party on Tuberculosis of the Spine. *J Bone Joint Surg Br*. 1998;80(3):456-462. doi:10.1302/0301-620X.80B3.8544.
134. World Health Organization. Regional Office for Europe. *Ambulatory Care and Infectiousness in Tuberculosis*. World Health Organization, Regional Office for Europe; 2018.

https://iris.who.int/handle/10665/345730-GoogleSearch. Accessed 5 January 2026.
135. Rajasekaran S, Kanna RM, Shetty AP. Pathophysiology and treatment of spinal tuberculosis. *JBJS Rev*. 2014;2(9):e4. doi:10.2106/JBJS.RVW.M.00130.
136. Rathod AK, Singh V, Patil P, Singh H. Is decompressive surgery the only treatment option? A case series of patients with spinal tuberculosis in advanced pregnancy. *Eur Spine J*. 2017;26(12):3170-3177. doi:10.1007/S00586-017-5143-2.
137. Misra UK, Warrier S, Kalita J, Tripathi A, Kumar S. Treatment response and complications during management of Pott's spine. *J Neuroimmunol*. 2022;373:577979. doi:10.1016/J.JNEUROIM.2022.577979.
138. Kumar K. Spinal tuberculosis, natural history of disease, classifications and principles of management with historical perspective. *Eur J Orthop Surg Traumatol*. 2016;26(6):551-558. doi:10.1007/S00590-016-1811-X.
139. Alwali AA. Spinal brace in tuberculosis of spine. *Saudi Med J*. 2002. Published online.
140. Wimmer C, Ogon M, Sterzinger W, Landauer F, Stöckl B. Conservative treatment of tuberculous spondylitis: a long-term follow-up study. *J Spinal Disord*. 1997;10(5):417-419. https://pure.pmu.ac.at/en/publications/conservative-treatment-of-tuberculous-spondylitis-a-long-term-fol/. Accessed 5 January 2026.
141. Nussbaum ES, Rockswold GL, Bergman TA, Erickson DL, Seljeskog EL. Spinal tuberculosis: a diagnostic and management challenge. *J Neurosurg*. 1995;83(2):243-247. doi:10.3171/JNS.1995.83.2.0243.
142. Ahuja K, Ifthekar S, Mittal S, Yadav G, Sarkar B, Kandwal P. Defining mechanical instability in tuberculosis of the spine: a systematic review. *EFORT Open Rev*. 2021;6(3):202-210. doi:10.1302/2058-5241.6.200113.
143. Jutte PC, van Loenhout-Rooyackers JH. Routine surgery in addition to chemotherapy for treating spinal tuberculosis. *Cochrane Database Syst Rev*. 2006;2006(5):CD004532. doi:10.1002/14651858.CD004532.pub2.
144. Mehta JS, Bhojraj SY. Tuberculosis of the thoracic spine. A classification based on the selection of surgical strategies. *J Bone Joint Surg Br*. 2001;83(6):859-863. doi:10.1302/0301-620X.83B6.11142.
145. Jain AK, Dhammi IK, Prashad B, Sinha S, Mishra P. Simultaneous anterior decompression and posterior instrumentation of the tuberculous spine using an anterolateral extrapleural approach. *J Bone Joint Surg Br*. 2008;90(11):1477-1481. doi:10.1302/0301-620X.90B11.20972.
146. Jain AK, Jain S. Instrumented stabilization in spinal tuberculosis. *Int Orthop*. 2011;36(2):285-292. doi:10.1007/S00264-011-1296-5.
147. Djientcheu VP, Mouafo Tambo FF, Ndougsa IS, et al. The role of surgery in the management of Pott's disease in Yaoundé. A review of 43 cases. *Orthop Traumatol Surg Res*. 2013;99(4):419-423. doi:10.1016/j.otsr.2012.12.022.
148. He M, Xu H, Zhao J, Wang Z. Anterior debridement, decompression, bone grafting, and instrumentation for lower cervical spine tuberculosis. *Spine J*. 2014;14(4):619-627. doi:10.1016/J.SPINEE.2013.06.076.
149. Ahuja K, Kandwal P, Ifthekar S, et al. Development of tuberculosis spine instability score (TSIS): an evidence-based and expert consensus-based content validation study among spine surgeons. *Spine (Phila Pa 1976)*. 2022;47(3):242-251. doi:10.1097/BRS.0000000000004173.
150. Rajasekaran S, Soundararajan DCR, Reddy GJ, Shetty AP, Kanna RM. A validated score for evaluating spinal instability to assess surgical candidacy in active spinal tuberculosis-an evidence based approach and multinational expert consensus study. *Global Spine J*. 2023;13(8):2296-2309. doi:10.1177/21925682221080102.
151. Pithwa YK, Sinha Roy V. Can we extrapolate SINS score to evaluate instability in spinal tuberculosis? *Global Spine J*. 2023;13(5):1305-1310. doi:10.1177/21925682211030876.
152. Schömig F, Li Z, Perka L, et al. Georg schmorl prize of the German spine society (DWG) 2021: spinal instability spondylodiscitis score (SISS)-a novel classification system for spinal instability in spontaneous spondylodiscitis. *Eur Spine J*. 2022;31(5):1099-1106. doi:10.1007/S00586-022-07157-3.
153. Jain AK, Kumar J. Tuberculosis of spine: neurological deficit. *Eur Spine J*. 2013;22(Suppl 4):624-633. doi:10.1007/S00586-012-2335-7.
154. Garg RK, Somvanshi DS. Spinal tuberculosis: a review. *J Spinal Cord Med*. 2011;34(5):440-454. doi:10.1179/2045772311Y.0000000023.
155. A controlled trial of anterior spinal fusion and débridement in the surgical management of tuberculosis of the spine in patients on standard chemotherapy: a study in Hong Kong. *Br J Surg*. 1974;61(11):853-866. doi:10.1002/BJS.1800611102
156. Tuli SM. Historical aspects of Pott's disease (spinal tuberculosis) management. *Eur Spine J*. 2012;22(Suppl 4):529-538. doi:10.1007/S00586-012-2388-7.
157. Ahuja K, Ifthekar S, Mittal S, et al. Role of diffusion tensor imaging in neurological prognostication in spinal tuberculosis – a prospective pilot study. *Eur J Radiol*. 2022;157:110530. doi:10.1016/j.ejrad.2022.110530.
158. Zandvakili A, Kobayashi T, Kaewpoowat Q, et al. Pelvic and central nervous system tuberculosis complicated by a paradoxical response manifesting as a spinal tuberculoma: a case report. *BMC Infect Dis*. 2022;22(1):750. doi:10.1186/S12879-022-07731-6.
159. Prasad K, Singh MB, Ryan H. Corticosteroids for managing tuberculous meningitis. *Cochrane Database Syst Rev*. 2016;4(4):CD002244. doi:10.1002/14651858.CD002244.PUB4.
160. Ayele BA, Wako A, Tadesse J, et al. Pott's paraplegia and role of neuroimaging in resource limited setting: a case report and brief review of the literatures. *J Clin Tuberc Other Mycobact Dis*. 2021;25:100283. doi:10.1016/j.jctube.2021.100283.
161. Das A, Das S, Mandal A, Halder A. Cerebral tuberculoma as a manifestation of paradoxical reaction in patients with pulmonary and extrapulmonary tuberculosis. *J Neurosci Rural Pract*. 2012;3(3):350-354. doi:10.4103/0976-3147.102622.

162. Yasaratne B, Wijesinghe S, Madegedara R. Spinal tuberculosis: a study of the disease pattern, diagnosis and outcome of medical management in Sri Lanka. *Indian J Tuberc*. 2013; 2013(60):208.
163. Cherian A, Ajitha KC, Iype T, Divya KP. Neurotuberculosis: an update. *Acta Neurol Belg*. 2021;121(1):11-21. doi:10.1007/s13760-020-01575-0.
164. Weber MR, Fehr JS, Kuhn FP, Kaelin MB. Approach for tuberculosis-associated immune reconstitution inflammatory syndrome in an HIV-negative patient. *BMJ Case Rep*. 2021; 14(8):e232639. doi:10.1136/BCR-2019-232639.
165. Loughenbury P, Pavlou G, Dunsmuir R. Surgical treatment of tuberculous paraparesis in the third trimester: a report of two cases and review of the literature. *Gynecol Obstet Invest*. 2009; 68(3):213-216. doi:10.1159/000235869.
166. Bhandari A, Garg RK, Malhotra HS, et al. Outcome assessment in conservatively managed patients with cervical spine tuberculosis. *Spinal Cord*. 2014;52(6):489-493. doi:10.1038/SC.2014.49.
167. Chandra SP, Singh A, Goyal N, et al. Analysis of changing paradigms of management in 179 patients with spinal tuberculosis over a 12-year period and proposal of a new management algorithm. *World Neurosurg*. 2013;80(1-2):190-203. doi:10.1016/j.wneu.2012.12.019.
168. Liu P, Nie H. The effect of time-to-surgery on outcome in patients with neurological deficits caused by spinal tuberculosis. *Turk Neurosurg*. 2018;28(2):275-281. doi:10.5137/1019-5149.JTN.18736-16.1.
169. Garg B, Mehta N, Mukherjee RN, Swamy AM, Siamwala BS, Malik G. Epidemiological insights from 1,652 patients with spinal tuberculosis managed at a single center: a retrospective review of 5-Year data. *Asian Spine J*. 2022;16(2):162-172. doi:10.31616/ASJ.2021.0137.
170. Njoku CH, Makusidi MA, Ezunu EO. Experiences in management of Pott's paraplegia and paraparesis in medical wards of Usmanu Danfodiyo University Teaching Hospital, Sokoto, Nigeria. *Ann Afr Med*. 2007;6(1):22-25. doi:10.4103/1596-3519.55735.
171. Baloch I, Shaikh B, Asif M, et al. Outcome of ultrasound guided percutaneous needle aspiration in treatment of psoas abscess. Published Online. doi:10.12809/hkmj133793.
172. Dave BR, Kurupati RB, Shah D, Degulamadi D, Borgohain N, Krishnan A. Outcome of percutaneous continuous drainage of psoas abscess: a clinically guided technique. *Indian J Orthop*. 2014;48(1):67-73. doi:10.4103/0019-5413.125506.
173. Ibrahim FMF, EL-rady AERMA. Transverse process osteotomy for surgical drainage of primary iliopsoas abscess and secondary cases combined with spondylodiscitis. *Int Orthop*. 2021;45(1):165-171. doi:10.1007/S00264-020-04732-5.
174. Ye F, Zhou Q, Feng D. Comparison of the anteroposterior and posterior approaches for percutaneous catheter drainage of tuberculous psoas abscess. *Med Sci Monit*. 2017;23: 5374-5381. doi:10.12659/MSM.902848.
175. Lai Z, Shi S, Fei J, Han G, Hu S. A comparative study to evaluate the feasibility of preoperative percutaneous catheter drainage for the treatment of lumbar spinal tuberculosis with psoas abscess. *J Orthop Surg Res*. 2018;13(1):290. doi:10.1186/S13018-018-0993-9.
176. Abudurexiti T, Haibier A, Yusufu A, Shoukeer K, Lin H. Retrospective analysis of the efficacy and safety of endoscopic spinal tuberculosis focus removal versus posterior pedicle lesion removal, bone grafting, and internal fixation combined with drug chemotherapy for thoracolumbar tuberculosis. *Infect Drug Resist*. 2024;17:733-748. doi:10.2147/IDR.S449684.
177. Wu D, Sun J, Fan W, Yuan F. Unilateral or bilateral percutaneous endoscopic debridement and lavage treatment for lumbar spinal tuberculosis. *World Neurosurg*. 2020;140: e73-e80. doi:10.1016/j.wneu.2020.04.132.
178. Pawar A, Manwani C, Thete R, Bapat M, Peshettiwar V, Gore S. Endoscopic decompression can be effective for diagnosing and treating tubercular spondylodiskitis with early epidural spinal compression: a retrospective study of 18 cases. *Asian Spine J*. 2018;12(5):803-809. doi:10.31616/ASJ.2018.12.5.803.
179. Kang J, Xia X, Shang R, et al. Bilateral endoscopic debridement combined with local antituberculosis drugs for thoracic tuberculosis with large paravertebral abscess: a multicenter study with 4-year follow-up. *World Neurosurg*. 2024;185:e1160-e1168. doi:10.1016/J.WNEU.2024.03.042.
180. Xu Z, Zheng Y. Percutaneous endoscopic debridement and irrigation for thoracic infections. *Rev Assoc Med Bras*. 2018; 64(6):518-524. doi:10.1590/1806-9282.64.06.518.
181. Kim KH, Choi EJ, Kim SY, et al. Percutaneous endoscopic debridement and drainage with four different approach methods for the treatment of spinal infection. *Pain Physician*. 2017;20:933-940. https://www.painphysicianjournal.com/current/pdf?article=NDYyMg%3D%3D&journal=107. Accessed 31 December 2025.
182. Fu TS, Wang YC, Lin TY, Chang CW, Wong CB, Su JY. Comparison of percutaneous endoscopic surgery and traditional anterior open surgery for treating lumbar infectious spondylitis. *J Clin Med*. 2019;8(9):1356. doi:10.3390/JCM8091356.
183. Zhang X, Wang K, Xia Y, Gao X, Du Y, Chen L. Treatment of lavage drainage under spinal endoscopy on lumbar spinal tuberculosis with vertebral lesions. *Eur J Inflamm*. 2020;18: 205873922096119. doi:10.1177/2058739220961192.
184. Wu WJ, Tang Y, Lyu JT, et al. Clinical efficacy of three surgical approaches for the treatment of cervicothoracic tuberculosis: a multicenter retrospective study. *Orthop Surg*. 2020;12(6):1579-1588. doi:10.1111/OS.12527.
185. Zeng H, Shen X, Luo C, et al. Comparison of three surgical approaches for cervicothoracic spinal tuberculosis: a retrospective case-control study. *J Orthop Surg Res*. 2015;10(1): 100. doi:10.1186/S13018-015-0238-0.
186. Luan H, Liu K, Wang Y, et al. Efficacy of anterior debridement and bone grafting with fusion using internal fixation combined with anti-tuberculosis chemotherapy in the treatment of subaxial cervical tuberculosis. *BMC Surg*. 2022;22(1):150. doi:10.1186/S12893-022-01606-Y.

187. Benli IT, Kaya A, Acaroğlu E. Anterior instrumentation in tuberculous spondylitis: is it effective and safe? *Clin Orthop Relat Res*. 2007;460:108-116. doi:10.1097/BLO.0B013E318065B70D.
188. Çavuşŏglu H, Kaya RA, Türkmenŏglu ON, Tuncer C, Çolak I, Aydin Y. A long-term follow-up study of anterior tibial allografting and instrumentation in the management of thoracolumbar tuberculous spondylitis. *J Neurosurg Spine*. 2008;8(1):30-38. doi:10.3171/SPI-08/01/030.
189. Garg B, Kandwal P, Nagaraja UB, Goswami A, Jayaswal A. Anterior versus posterior procedure for surgical treatment of thoracolumbar tuberculosis: a retrospective analysis. *Indian J Orthop*. 2012;46(2):165-170. doi:10.4103/0019-5413.93682.
190. Qiu J, Peng Y, Qiu X, et al. Comparison of anterior or posterior approach in surgical treatment of thoracic and lumbar tuberculosis: a retrospective case-control study. *BMC Surg*. 2022;22(1):161. doi:10.1186/S12893-022-01611-1.
191. Wang WJ, Chen WK, Yan YG, Yao NZ, Wang C. Application of anterior debridement and reconstruction with anatomical screw-plate fixation for lumbosacral tuberculosis: a 2-year-plus follow-up. *Medicine*. 2017;96(26):e7103. doi:10.1097/MD.0000000000007103.
192. Jiang T, Zhao J, He M, Wang K, Fowdur M, Wu Y. Outcomes and treatment of Lumbosacral spinal tuberculosis: a retrospective study of 53 patients. *PLoS One*. 2015;10(6):e0130185. doi:10.1371/JOURNAL.PONE.0130185.
193. Aggarwal A, Jain A, Jajoida N, Nand R, Kumar C, Kumar S. Fate of kyphosis in tuberculosis of subaxial cervical spine treated non-operatively. *Acta Orthop Belg*. 2014;80(4):451-456. https://europepmc.org/article/med/26280715
194. Smith IE, Laroche CM, Jamieson SA, Shneerson JM. Kyphosis secondary to tuberculosis osteomyelitis as a cause of ventilatory failure: clinical features, mechanisms, and management. *Chest*. 1996;110(4):1105-1110. doi:10.1378/chest.110.4.1105.
195. Zhao J, Cai Z, Meng Y, Zhou X, Jiang H. Predictive factors for late-onset neurological deficits in patients with post-tuberculous thoracic kyphosis. *Biomed Res Int*. 2022;2022:8555924. doi:10.1155/2022/8555924.
196. Wong YW, Samartzis D, Cheung KMC, Luk K. Tuberculosis of the spine with severe angular kyphosis: mean 34-year post-operative follow-up shows that prevention is better than salvage. *Bone Joint J*. 2017;99-B(10):1381-1388. doi:10.1302/0301-620X.99B10.BJJ-2017-0148.R1.
197. Derbyshire J. A 15-year assessment of controlled trials of the management of tuberculosis of the spine in Korea and Hong Kong. Thirteenth Report of the Medical Research Council Working Party on Tuberculosis of the Spine. *J Bone Joint Surg Br*. 1998;80(3):456-462. doi:10.1302/0301-620X.80B3.8544.
198. Parthasarathy R, Sriram K, Santha T, Prabhakar R, Somasundaram PR, Sivasubramanian S. Short-course chemotherapy for tuberculosis of the spine. A comparison between ambulant treatment and radical surgery--ten-year report. *J Bone Joint Surg Br*. 1999;81(3):464-471. doi:10.1302/0301-620X.81B3.9043.
199. Kotil K, Alan MS, Bilge T. Medical management of Pott disease in the thoracic and lumbar spine: a prospective clinical study. *J Neurosurg Spine*. 2007;6(3):222-228. doi:10.3171/SPI.2007.6.3.222.
200. Sahoo MM, Mahapatra SK, Sethi GC, Dash SK. Posterior-only approach surgery for fixation and decompression of thoracolumbar spinal tuberculosis: a retrospective study. *J Spinal Disord Tech*. 2012;25(7):E217-E223. doi:10.1097/BSD.0B013E31826A088E.
201. Du X, Ou YS, Zhu Y, et al. One stage posterior debridement, non-structural bone graft in the surgical treatment of single segment thoracic tuberculosis: a retrospective single-center cohort study. *Int J Surg*. 2019;65:134-139. doi:10.1016/J.IJSU.2019.04.002.
202. Ramakrishnan RK, Barma SD, Shetty AP, Viswanathan VK, Kanna RM, Rajasekaran S. Posterior-only stabilization versus global reconstruction in thoracic and thoracolumbar spinal tuberculosis; a prospective randomized study. *Int Orthop*. 2022;46(3):597-603. doi:10.1007/S00264-021-05296-8.
203. Xu Z, Wang X, Wu P, et al. Surgical treatment for monosegmental lumbar tuberculosis by single-stage posterior debridement, compact bone grafting and posterior single-segment fixation. *Injury*. 2015;46(7):1311-1316. doi:10.1016/j.injury.2015.03.023.
204. Kalanjiyam GP, Dilip Chand Raja S, Rajasekaran S, Shetty AP, Kanna RM. A prospective study comparing three different all-posterior surgical techniques in the management of thoracolumbar spinal tuberculosis. *J Clin Orthop Trauma*. 2022;34:102026. doi:10.1016/J.JCOT.2022.102026.
205. Jiang D, Sun G, Jia R, Zhang Y, Wang X, Xu Z. Comparing bone graft techniques for interbody fusion through a posterior approach for treating mid-thoracic spinal tuberculosis: a retrospective analysis. *Orthop Surg*. 2023;15(1):53-61. doi:10.1111/OS.13565.
206. Xu S, Zhang S, Wang G, Yang J, Song Y, Wang Q. Comparison of clinical and radiological outcomes of local morselized bone grafts and structural iliac bone grafts in the treatment of lumbar tuberculosis with posterior-only surgery. *BMC Surg*. 2022;22(1):184. doi:10.1186/S12893-022-01638-4.
207. Assaghir YM, Refae HH, Alam-Eddin M. Anterior versus posterior debridement fusion for single-level dorsal tuberculosis: the role of graft-type and level of fixation on determining the outcome. *Eur Spine J*. 2016;25(12):3884-3893. doi:10.1007/S00586-016-4516-2.
208. Zhang HQ, Lin MZ, Li JS, et al. One-stage posterior debridement, transforaminal lumbar interbody fusion and instrumentation in treatment of lumbar spinal tuberculosis: a retrospective case series. *Arch Orthop Trauma Surg*. 2013;133(3):333-341. doi:10.1007/S00402-012-1669-2.
209. Zhong D, Lin L, Liu Y, Ke ZY, Wang Y. Analysis of Nanohydroxyapatite/Polyamide-66 cage, titanium mesh, and iliac crest in spinal reconstruction of the patients with thoracic

and lumbar tuberculosis. *Neurol India*. 2022;70(Supplement): S230-S238. doi:10.4103/0028-3886.360908.

210. Kalidindi KKV, Bansal K, Biswas G, et al. Surgical outcomes of transpedicular decompression with or without global reconstruction in thoracic/thoracolumbar Pott's spine: a 7-year institutional retrospective study. *Asian Spine J*. 2022;16(2): 173-182. doi:10.31616/ASJ.2021.0008.
211. Zhang H, Xiao L, Tang M, Yang G. Spinous process combined with a titanium mesh cage as a bone graft in the stability reconstruction of lumbar or lumbosacral spinal tuberculosis. *Front Surg*. 2022;9:818926. doi:10.3389/FSURG.2022.818926.
212. Xu Z, Wang X, Zhang Z, Jiang D, Jia R, Zhang Y. A comparison of three bone graft struts for interbody fusion using a posterior approach for lower lumbar spinal tuberculosis in adults: a midterm follow-up study. *BMC Musculoskelet Disord*. 2022;23(1):590. doi:10.1186/S12891-022-05539-8.
213. Wu W, Wang S, Li Z, Lin R, Lin J. Posterior-only approach with titanium mesh cages versus autogenous iliac bone graft for thoracic and lumbar spinal tuberculosis. *J Spinal Cord Med*. 2021;44(4):598-605. doi:10.1080/10790268.2019.1675953.
214. Gao Y, Ou Y, Deng Q, He B, Du X, Li J. Comparison between titanium mesh and autogenous iliac bone graft to restore vertebral height through posterior approach for the treatment of thoracic and lumbar spinal tuberculosis. *PLoS One*. 2017; 12(4):e0175567. doi:10.1371/JOURNAL.PONE.0175567.
215. Suya D, Shao L, Gu R, Xu Q, Luo W. Could nonstructural interbody fusion be an alternative surgical technique for treatment of single segment thoracic and lumbar spinal tuberculosis via a posterior- only approach? *World Neurosurg*. 2019;130:e316-e323. doi:10.1016/j.wneu.2019.06.072.
216. Liu JM, Chen XY, Zhou Y, et al. Is nonstructural bone graft useful in surgical treatment of lumbar spinal tuberculosis?: a retrospective case-control study. *Medicine*. 2016;95(35): e4677. doi:10.1097/MD.0000000000004677.
217. Deng F, Chen B, Guo H, Chen Q, Wang F. Effectiveness and safety analysis of titanium mesh grafting versus bone grafting in the treatment of spinal tuberculosis: a systematic review and meta-analysis. *BMC Surg*. 2023;23(1):377. doi:10.1186/S12893-023-02283-1.
218. He Z, Ou Y, Hou B, Wei J, Mu X. A meta-analysis of the safety and effectiveness of titanium mesh versus bone graft alone for the treatment of thoracolumbar tuberculosis. *Eur Spine J*. 2020;29(7):1505-1517. doi:10.1007/S00586-019-06260-2.