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

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Abstract

Study Design: Systematic review with guidelines.

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

Methods: A multi-phase consensus process combined systematic evidence appraisal (PubMed, Scopus, Web of Science, Clinicaltrials.org) with structured expert deliberation. Seven domains were explored: diagnosis, microbiological workup, antibiotic management, response assessment, morphology-based planning, surgical techniques, and adjunctive measures.

Results: Expert consensus established that serum albumin (<3.5 g/dL) is a critical prognostic marker, while ESR and CRP remain the most reliable diagnostic tests. The assembly strongly rejected initiating empirical treatment without tissue diagnosis, even in early-stage infection. Surgical fixation is recommended for instability, deformity, or neurological deficit, with instrumentation levels tailored to bone destruction and patient-specific factors like osteoporosis. While MRI is the gold standard for initial diagnosis, its role in monitoring is limited, as radiological progression in clinically stable patients does not necessitate surgery. Advanced adjuncts, including Next-Generation Sequencing (NGS) and Vacuum-Assisted Closure (VAC), show promise in enhancing pathogen detection and wound healing, respectively.

Conclusion: Effective PSI management requires integrating clinical, laboratory, and morphological data. Meticulous debridement and targeted antimicrobial therapy remain the cornerstones of treatment. This consensus provides a practical guide for clinicians while highlighting the need for prospective, multicenter research to validate emerging technologies and standardize global surgical protocols.

Keywords

pyogenic spondylodiscitis, spinal infection, international consensus, surgical stabilization, spinal infection management, ICM 2025

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Introduction

Pyogenic spondylodiscitis (PSI) remains one of the most complex and devastating infectious conditions in spinal practice, with significant implications for patient morbidity, healthcare burden, and long-term outcomes. Despite advances in antimicrobial therapy and surgical techniques, management continues to be challenged by variability in diagnostic pathways, surgical indications, fixation strategies, grafting techniques, and adjunctive measures. Recognising these gaps, the International Consensus Meeting on Spinal Infection, Istanbul 2025, convened global experts to address unresolved questions across the continuum of care systematically.

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 PSI, 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 ICM 2025 (Spine Section) Consensus utilized a rigorous 11-phase methodology to develop evidence-based recommendations for spinal infection.[1] The process began with the identification of a geographically diverse panel of multidisciplinary experts who prioritized clinically relevant questions. Specialized working groups conducted systematic literature reviews across major academic databases. For each statement, we systematically reviewed PubMed, Web of Science, Clinicaltrials.org, and Scopus from inception until December 01, 2024, for original articles (supplemental table 1). We excluded publications in non-English languages, case reports, review articles, and studies only on spondylodiscitis without a precise diagnosis of PSI. Literature screening and data synthesis were performed using the Rayyan platform, with preliminary recommendations developed accordingly. Following asynchronous online refinement, delegates convened for a face-to-face meeting in Istanbul to establish consensus through anonymous voting. Consensus was categorized by specific thresholds: unanimous (≥90%), strong (75-89%), moderate (60-74%), weak (50-59%), or no consensus (<50%). Evidence strength was graded as strong, moderate, low, or very low in accordance with GRADE guidelines.[2] Recommendations for each question were reported alongside the level of evidence and degree of consensus. Detailed methodology, including delegate selection, question development, evidence synthesis, and consensus procedures, has been described in a separate publication.[1]

Section "Diagnosis" focused on diagnostic challenges, emphasising the role of cultures, imaging, and laboratory markers in establishing early and accurate diagnosis. Section "Biopsy and Microbiological Workup" explored surgical indications, clarifying when instability, deformity, neurological compromise, or failure of conservative therapy necessitate operative intervention. Section "Antibiotic Management" examined grafting strategies, defining thresholds for non-structural vs structural grafts and cages. Section "Monitoring and Response Assessment" addressed instrumentation levels, highlighting the balance between stability and preservation of motion segments. Section "Treatment Planning Based on Morphology and Severity" dealt with intraoperative complications such as incidental dural tears, underscoring the importance of prompt repair and tailored antibiotic therapy. Section "Surgical Indications and Techniques" evaluated surgical techniques, including endoscopic debridement, damage-control approaches in septic patients, and criteria for repeat debridement. Section "Adjuncts in Surgical Management" reviewed adjuncts, assessing the utility of local vancomycin powder, antibiotic cement beads, cement-augmented screws in osteoporotic patients, and vacuum-assisted closure devices.

Results

Diagnosis

Diagnosis of spondylodiscitis is inherently complex, requiring integration of clinical suspicion, laboratory markers, and imaging modalities. Malnutrition has long been recognised as a determinant of poor outcomes in infectious disease, yet its role in spinal infection remains underexplored. Whether albumin or pre-albumin levels can serve as prognostic markers in this context is a critical question. Similarly, the utility of routine blood tests, including complete blood counts, ESR, CRP, and procalcitonin, demands clarification to establish their diagnostic accuracy and reliability in everyday practice.

Radiological interpretation adds another layer of complexity. Modic changes, frequently observed in degenerative spine disease, may mimic or overlap with infectious endplate involvement. Distinguishing these inflammatory changes from acute pyogenic infection on MRI is essential to avoid misdiagnosis and inappropriate treatment. Furthermore, consensus is needed on the most reliable classification system for pyogenic spinal infection, as current frameworks vary in scope, reproducibility, and clinical applicability. Finally, predicting structural consequences such as instability or deformity in vertebral osteomyelitis remains a pressing clinical need. Identifying imaging predictors that signal impending mechanical compromise could transform patient management by enabling timely intervention. This section synthesises expert perspectives on these pivotal diagnostic questions, providing evidence-based recommendations to refine clinical

decision-making and improve outcomes in pyogenic spondylodiscitis.

Question 1.1: Can albumin or pre-albumin, as markers of patient malnourishment, predict outcomes in patients with pyogenic spinal infections?

Authors: Jorge H. Nunez, Mohamad Zaki bin Haji Mohd Amin, Jun Hao Tan, Koji Tamai

Recommendation: Serum albumin levels below 3.5 g/dL are consistently associated with increased mortality, higher re-operation rates, and a greater risk of post-operative complications in patients with pyogenic spinal infections. Pre-albumin has not yet been validated as a prognostic marker in this setting.

Level of Evidence: Moderate.

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

Rationale: A comprehensive systematic review was conducted on this topic using PubMed, Scopus, Web of Science, and Cochrane databases. Of 729 total records, 113 duplicates were removed. All relevant documents were screened, and eligible studies were synthesised to generate the recommendation. The evidence consistently highlights the prognostic role of serum albumin in pyogenic spinal infections, while the role of pre-albumin remains insufficiently studied. Malnutrition is a well-recognised determinant of poor surgical outcomes, and in the setting of spinal infection, it reflects both chronic systemic illness and the catabolic burden of disease. Albumin, with a half-life of approximately 20 days, reflects longer-term protein reserves, whereas pre-albumin, with a shorter half-life of 2-3 days, is more sensitive to acute changes.[3] Both markers are influenced by systemic inflammation, hepatic function, and metabolic stress, making them integrative indicators of patient vulnerability.

Several studies demonstrate that hypoalbuminemia is associated with adverse outcomes in pyogenic spinal infections. Karhade and colleagues identified hypoalbuminemia (<2.6 g/dL) as an independent predictor of survival in patients with spinal epidural abscess.[4] Analysis of the National Surgical Quality Improvement Program database confirmed hypoalbuminemia as a risk factor for 30-day mortality, with odds ratios exceeding 3. Institutional cohorts further validated this association, showing hypoalbuminemia as a predictor of 90-day mortality and reoperation rates. Camino-Willhuber et al, in a large cohort of 627 patients undergoing surgery for primary spinal infections, reported that hypoalbuminemia was significantly associated with significant complications, unplanned readmissions, and reoperations.[5] Baum et al demonstrated that lower admission albumin levels predicted treatment failure in intravenous drug use-associated spinal epidural abscess, leading to the development of a points-based prediction model incorporating albumin thresholds.[6] Yagdiran et al highlighted the impact of albumin on patient-reported outcomes, showing that lower albumin levels were associated with reduced likelihood of achieving improved postoperative quality of life.[7] These findings underscore albumin's role not only in predicting mortality and complications but also in influencing functional recovery.

Not all studies demonstrated a clear association. Jin et al found no significant correlation between initial albumin levels and the need for surgery in primary spinal infections, suggesting that albumin may be more predictive of postoperative outcomes rather than initial disease severity or surgical indication.[8] Furthermore, most available studies are retrospective, with inherent limitations such as selection bias, heterogeneity in patient populations, and variability in perioperative management. Albumin levels are also influenced by factors unrelated to nutrition, including hepatic dysfunction, nephrotic syndrome, and systemic inflammation. Thus, while hypoalbuminemia is a valuable marker of vulnerability, it should be interpreted in the broader clinical context.

Unlike albumin, pre-albumin has not been systematically studied in pyogenic spinal infections. Its shorter half-life makes it theoretically more sensitive to acute nutritional changes and perioperative catabolic stress.[9] In other surgical populations, pre-albumin has been associated with wound healing, infection risk, and recovery trajectories. However, in spinal infection, no published studies have directly evaluated its prognostic utility. This represents a significant gap in the literature and an opportunity for future prospective research.

The consistent association between hypoalbuminemia and adverse outcomes supports the incorporation of albumin measurement into routine preoperative assessment for pyogenic spinal infections. Patients with low albumin should be considered high-risk, warranting closer monitoring, aggressive infection control, and potentially nutritional optimisation before surgery. Albumin thresholds, such as levels below 3.5 g/dL, may serve as practical cut-offs for identifying patients at elevated risk of complications.[6] Albumin levels can also inform shared decision-making with patients and families, providing realistic expectations regarding prognosis and recovery. They may guide resource allocation, such as prioritising intensive care support or rehabilitation services for vulnerable patients.

Future research should focus on prospective validation of albumin as a prognostic marker in pyogenic spinal infections, ideally through multicenter studies with standardised definitions of outcomes. The role of pre-albumin warrants particular attention, given its potential to capture acute nutritional changes. Studies should also explore whether dietary interventions, such as protein supplementation or targeted perioperative nutrition programs, can modify outcomes in hypoalbuminemic patients. Integration of albumin and pre-albumin into predictive models, alongside clinical, laboratory, and imaging variables, may yield robust risk stratification tools. Machine learning approaches could further refine these models, enabling personalised prognostication and treatment planning.

In summary, this systematic review demonstrates that serum albumin is a validated prognostic marker in pyogenic spinal infections, with hypoalbuminemia consistently associated with increased mortality, complications, and treatment failure. Pre-albumin remains underexplored but may offer additional predictive value. Incorporating albumin into routine risk assessment can enhance clinical decision-making, optimise perioperative care, and improve patient outcomes.

Question 1.2: What blood tests, if any, are useful in the diagnosis of pyogenic spinal infections? (Complete blood counts, ESR, CRP, Procalcitonin).

Authors: Jonathan Dalton, Yoshiharu Kawaguchi, Jorge H. Nunez, Jun Hao Tan, Hideki Nagashima, Karthik Ramachandran, Gnanaprakash Gurusamy, Alexander R. Vaccaro

Recommendation: Erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) are the most reliable laboratory markers for diagnosing and monitoring pyogenic spinal infections. Complete blood counts (CBC) may provide supportive information but lack sensitivity and specificity. Next-generation biomarkers such as procalcitonin (PCT) and IL-15 show promise, particularly in postoperative or systemic infection settings, but require further validation before routine clinical use.

Level of Evidence: Moderate.

Delegate Vote: Agree – 91.7% | Disagree – 2.1% | Abstain – 6.3% (Unanimous Consensus).

Rationale: A comprehensive systematic review was conducted on this topic using PubMed, Scopus, Web of Science, and related databases. Of 3241 total records, 402 duplicates were removed. All relevant documents were screened, and eligible studies were synthesised to generate the recommendation. The evidence base highlights the role of traditional inflammatory markers such as erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) as the most reliable laboratory tests for diagnosing and monitoring pyogenic spinal infections. In contrast, complete blood counts (CBC) and newer biomarkers such as procalcitonin (PCT) and interleukin-15 (IL-15) show variable utility and require further validation.

Pyogenic spinal infections often present with nonspecific symptoms, making laboratory markers an essential adjunct to clinical and imaging evaluation. ESR and CRP are consistently elevated in acute infection and correlate with disease activity, prognosis, and treatment response. Their combined use improves diagnostic accuracy and has been integrated into predictive models, distinguishing pyogenic spondylitis from other conditions such as tuberculosis. CRP is particularly valuable in postoperative settings, where abnormal kinetics such as secondary peaks or failure to decline signal infection. Elevations exceeding 4 times the standard limit strongly predict vertebral infection, and CRP trends are widely used to monitor treatment effectiveness.[10] ESR complements CRP, with reductions correlating with favourable outcomes.[10]

CBC remains a routine test but is limited by inconsistent leukocytosis; many patients with localised or subacute infections present with normal counts. While useful as part of machine-learning models, CBC alone cannot reliably confirm or exclude spinal infection. Studies have shown that leukocytosis is inconsistently present, and normal white blood cell counts do not exclude infection. Thus, CBC is best used as a supportive test rather than a primary diagnostic tool.[11]

Procalcitonin has gained prominence as a biomarker for bacterial infections due to its ability to distinguish bacterial from viral or noninfectious inflammatory conditions. In spinal infection, however, its sensitivity is lower than CRP, likely due to the localised nature of the disease. PCT may be more useful in postoperative or systemic infection settings, where elevations have been observed within the first week after surgery.[10] Some studies have combined PCT with clinical features such as persistent fever to improve predictive accuracy.[12] IL-15 has also shown promise, with elevations noted in patients who developed postoperative infections, but its role remains investigational.[10]

Emerging biomarkers such as soluble CD14-ST and advanced predictive models incorporating laboratory and imaging data may enhance diagnostic precision in the future.[13] Machine learning approaches have demonstrated high accuracy in differentiating pyogenic spondylitis from tuberculosis when combining ESR, CRP, and CBC values with imaging features.[14-16] These developments suggest that while ESR and CRP remain the most practical and validated markers, the diagnostic landscape is evolving toward multimodal strategies.

The clinical implications of these findings are significant. ESR and CRP should be incorporated into routine diagnostic work-up for suspected pyogenic spinal infection, both at presentation and during follow-up. Their trends provide valuable information on disease progression and treatment response. CBC should be interpreted cautiously, as normal values do not exclude infection. Procalcitonin and IL-15 may be considered in selected scenarios, particularly postoperative patients or those with systemic sepsis, but they are not yet validated for routine use.

Future research should focus on prospective validation of novel biomarkers, standardisation of postoperative laboratory kinetics, and integration of laboratory data into predictive models. Combining traditional markers with advanced analytics and imaging may yield robust diagnostic tools that reduce delays and improve outcomes.

In summary, this systematic review demonstrates that ESR and CRP are the most reliable laboratory markers for diagnosing and monitoring pyogenic spinal infections. CBC provides supportive but nonspecific information, while procalcitonin and IL-15 show promise but require further validation. Incorporating ESR and CRP into routine practice enhances diagnostic accuracy and treatment monitoring, while ongoing research into novel biomarkers and predictive models may further refine diagnostic strategies in the future.

Question 1.3: Are Modic Changes Representative of Primary Endplate Infections?

Authors: S Rajasekaran, Gnanaprakash Gurusamy, Mohammad El-Sharkawi, Mohamad Zaki bin Haji Mohd Amin, Kota Watanabe, Emre Acaroglu, Ahmet Alanay

Recommendation: While a definitive causal relationship has yet to be fully established, current literature increasingly supports the hypothesis that subclinical infection may contribute to the development of Modic changes.

Level of Evidence: Low.

Delegate Vote: Agree – 66% | Disagree – 10% | Abstain – 24% (Moderate Consensus).

Rationale: A comprehensive systematic review was conducted to analyse whether Modic changes indicate primary endplate infection. PubMed, Web of Science, and Scopus databases were searched, yielding 2870 records. After 601 duplicate removal and screening, 2269 articles were reviewed at the title and abstract level, and 32 studies meeting the inclusion criteria were analysed in detail. The evidence suggests that Modic changes, particularly type 1, may reflect subclinical infection, although the association remains debated.

Modic changes are distinct MRI signal alterations in vertebral endplates and adjacent bone marrow, commonly associated with degenerative disc disease and chronic back pain. They are classified into 3 types: type 1 (oedema and inflammation), type 2 (fatty infiltration), and type 3 (sclerosis). Traditionally considered degenerative markers, accumulating evidence points toward an infectious contribution, particularly involving low-virulence organisms such as Cutibacterium acnes. Several studies have demonstrated bacterial DNA or positive cultures in disc material from patients with Modic changes, with prevalence rates ranging from 50% to 80%. Longitudinal studies have shown that bacterial proliferation may precede the development of Modic type 1 changes, supporting the hypothesis that infection could play a role in their pathogenesis.

Stirling and colleagues identified bacterial DNA in over half of discectomy samples, predominantly C. acnes,[17] while Fritzell and Agarwal reported bacterial growth in degenerated discs without overt infection.[18,19] Chen and Salehpour further demonstrated low-virulence bacterial presence in cervical and lumbar discs.[20,21] Georgy, Aghazadeh, and Yuan all reported significantly higher rates of C. acnes in Modic samples compared to controls, reinforcing the infectious hypothesis.[22–24] Tang and Najafi provided additional support, showing that patients with disc bacteria were more likely to develop Modic changes over time.[25] Albert's work demonstrated that discs infected with anaerobic bacteria were significantly more likely to create Modic changes in adjacent vertebrae compared to discs with aerobic bacteria or negative cultures.[26]

Despite these findings, the association remains controversial. Several prospective studies have questioned the link, reporting similar prevalence of C. acnes in degenerated and non-degenerated discs, raising contamination concerns.[27,28] These studies argue that bacterial presence may not necessarily indicate infection, and antibiotic treatment for Modic changes without clear signs of disease should be approached with caution. Indeed, while Albert's[29] randomised trial suggested benefit from long-term antibiotics in patients with Modic type 1 changes and chronic low back pain, subsequent trials, including a Norwegian study, failed to replicate these results and advised against routine antibiotic therapy due to risks of resistance and adverse effects.[30]

Mechanical theories also explain Modic changes. Disc degeneration and herniation can cause endplate microfractures, oedema, and inflammatory responses. Histological findings support mechanical stress as a driver, and stabilisation procedures have been shown to resolve Modic type 1 changes. However, inconsistencies such as paradisial patterns and posterior endplate involvement challenge a purely mechanical explanation. Multimodal imaging studies, including Rajasekaran's Endplate Infection Probability Score, have identified features more consistent with infection than trauma, with nearly 68% of Modic cases exhibiting infection-like characteristics.[31]

Molecular studies add further complexity. Proteomic analyses reveal upregulation of inflammatory molecules and host defence proteins in Modic changes, suggesting immune activation possibly triggered by infection.[32] Rajasekaran's microbiome work identified diverse bacterial species in discs, with C. acnes present but not predominant, pointing toward a broader dysbiosis hypothesis involving gut, skin, and spine microbiomes.[33]

Clinically, Modic changes, especially type 1, are strongly associated with chronic low back pain, increased severity, and prolonged episodes. They also appear to increase the risk of postoperative complications. Studies have shown higher rates of surgical site infections and pyogenic discitis in patients with Modic changes, with thresholds such as a Modic area ratio exceeding 24% or a Total Endplate Score above 6 predicting elevated risk.[34] These findings suggest that Modic changes may represent chronic subclinical infection rather than mere degeneration, with implications for surgical planning and postoperative monitoring.

In summary, the systematic review indicates that while Modic changes cannot yet be definitively labelled as primary endplate infections, the weight of evidence increasingly supports a role for subclinical bacterial involvement, particularly with C. acnes. Mechanical and degenerative mechanisms also contribute, and the interplay between infection, inflammation, and degeneration remains complex. Current consensus acknowledges the infectious hypothesis but emphasises the need for caution in clinical translation, especially regarding antibiotic therapy. Future prospective studies with rigorous methodology are required to clarify causality, refine diagnostic criteria, and determine whether targeted antimicrobial or anti-inflammatory strategies can improve outcomes in patients with Modic changes.

Question 1.4: Can we confidently differentiate Modic inflammatory changes from acute pyogenic infections in MRI?

Authors: Marco G.A. Teli, Hideki Nagashima, Takashi Kaito, S Rajasekaran, Gnanaprakash Gurusamy

Recommendation: No, MRI does not confidently differentiate Modic Type 1 changes from acute pyogenic spondylodiscitis. A multimodal approach integrating advanced imaging techniques such as CT, FDG-PET, and specific MRI features is required.

Level of Evidence: Low.

Delegate Vote: Agree – 93.9% | Disagree – 2% | Abstain – 4.1% (Unanimous Consensus).

Rationale: A comprehensive systematic review was conducted using PubMed, Scopus, Web of Science, and related databases. Of 824 total records, 221 duplicates were removed. Records were screened, and relevant studies were synthesised to generate this recommendation. The evidence consistently demonstrates that conventional MRI alone cannot reliably distinguish Modic Type 1 changes from acute pyogenic spondylodiscitis, necessitating a multimodal diagnostic approach.

Low back pain is a common clinical condition with a broad differential diagnosis, and Modic Type 1 changes often present a diagnostic challenge due to their overlapping imaging and clinical features with spinal infection. On MRI, both conditions can appear as oedema-like signal alterations in vertebral endplates, and even post-contrast sequences fail to provide definitive differentiation. This overlap complicates clinical decision-making and risks both overtreatment with antibiotics and undertreatment of actual infection.

Diffusion-weighted imaging (DWI) has shown promise in improving diagnostic accuracy.[35] The presence of a "claw sign," characterised by a sharp demarcation of oedema-like changes at the endplate, is highly suggestive of degenerative Modic changes. Conversely, the absence of this sign strongly favours infection.[36] CT imaging provides complementary information, identifying degenerative features such as discal vacuum phenomena, well-defined sclerosis, and erosions without significant bone destruction, which support a diagnosis of Modic changes rather than spondylodiscitis.[31]

FDG-PET has emerged as a valuable adjunct, particularly sensitive in detecting infectious activity that may not be apparent on conventional MRI. Studies demonstrate that FDG-PET can highlight metabolically active infection, thereby improving diagnostic confidence when MRI findings are equivocal.[37] High-field MRI sequences also contribute, with endplate contour analysis offering additional clues: an irregular but intact endplate contour is more consistent with degeneration. In contrast, loss of contour integrity strongly suggests infection.[38] Paravertebral or psoas muscle enhancement on gadolinium-enhanced sequences is more typical of late-stage spondylodiscitis than Modic changes.

Multimodality imaging strategies, including CT-based endplate scoring systems, have further refined diagnostic accuracy. Rajasekaran and colleagues developed the Endplate Infection Probability Score, which demonstrated that a significant proportion of Modic cases exhibit infection-like characteristics, underscoring the need for integrated assessment rather than reliance on MRI alone.[31]

The clinical implications of accurate differentiation are substantial. Misdiagnosing Modic changes as infection may lead to unnecessary antibiotic therapy, exposing patients to adverse effects, and contributing to antimicrobial resistance. Conversely, failing to recognise infection can result in progression to abscess formation, instability, or sepsis. Therefore, integrating multimodal imaging into diagnostic workflows is critical to ensure timely and appropriate management.

In summary, while MRI remains the cornerstone of spinal imaging, it cannot confidently differentiate Modic Type 1 changes from acute pyogenic spondylodiscitis. A multimodal approach incorporating DWI, CT, FDG-PET, and advanced MRI features provides greater diagnostic precision. Future research should focus on prospective validation of these multimodal strategies, development of standardised scoring systems, and integration of imaging biomarkers into predictive models to optimise patient outcomes.

Question 1.5: What is the most reliable and accurate classification for pyogenic spinal infection?

Authors: Nicolas Heinz von der Hoeh, Rishi Mugesh Kanna, Jae Hwan Cho, Claudius Thome

Recommendation: No, there is no reliable and accurate classification in the management of pyogenic spinal infection. The Pola classification and SITE score are promising and applicable classification systems that need further validation.

Level of Evidence: Moderate.

Delegate Vote: Agree – 86.3% | Disagree – 3.9% | Abstain – 9.8% (Strong Consensus).

Rationale: A comprehensive systematic review was conducted using PubMed, Scopus, Web of Science, and Cochrane databases. A total of 766 articles were identified, and 175 duplicates were removed; the remaining articles were screened to yield 5 classification systems for pyogenic spinal infection for analysis. These included the Pola classification, SITE score, SISS, Akbar, and Homagk systems. Each was evaluated for reliability, validation, and clinical relevance, with particular attention to their ability to guide diagnosis, treatment, and prognostication. The comparative findings are summarised below, which highlight the focus, reliability metrics, validation status, merits, and limitations of each system.

The Pola classification,[39] incorporates key diagnostic parameters such as instability, abscess formation, and neurological deficits.[40,41] It demonstrated moderate to substantial interobserver reliability, with Fleiss Kappa values ranging

from 0.67 to 0.77 in 2021 and 0.72 in 2022. Its merits include improved diagnostic clarity and broader clinical relevance, making it effective for initial evaluation. However, external and multicenter validation remains limited, restricting its generalizability.

The SITE score,[42] focuses on treatment planning and integrates radiological findings, neurological symptoms, and comorbidities to provide actionable therapeutic guidance. Its interrater reliability is excellent, with an ICC of 0.989, underscoring consistency across evaluators. The SITE score's strength lies in its predictive therapeutic validity and incorporation of patient-specific factors. Nonetheless, validation has been limited to small cohorts, and further studies are required to confirm its applicability across diverse populations.

The SISS classification[43] is designed for instability assessment, with a strong reliability score (ICC 0.96). It is excellent for evaluating biomechanical instability and guiding surgical decisions. However, its narrow focus on instability excludes systemic and infectious parameters, limiting its utility as a comprehensive classification system.

The Akbar classification[44] and Homagk classification[45] both address diagnostic and treatment considerations, with reliability scores of 0.83 and 0.94, respectively.[46] They are practical and easy to apply, with high interrater reliability and simple diagnostic criteria. However, both lack comprehensive validation and fail to correlate with long-term patient-centred outcomes such as quality of life. They also provide limited insights into therapeutic decision-making, reducing their relevance in modern clinical practice.

Taken together, the Pola classification and SITE score emerge as the most promising systems. The Pola classification offers diagnostic precision by incorporating key disease parameters, while the SITE score provides treatment-oriented guidance with strong reliability. Their complementary strengths make them applicable at different stages of care, from initial evaluation to therapeutic planning. However, both systems require further validation, particularly in multicenter and prospective settings, to establish their reliability across diverse patient populations.

The systematic review highlights the need for a unified classification system that integrates diagnostic, biomechanical, and therapeutic parameters while also addressing patient-centred outcomes. Such a system would provide a comprehensive framework for managing pyogenic spinal infections, standardising diagnosis, guiding treatment, and predicting outcomes. Advances in imaging, biomarker analysis, and machine learning may further enhance classification accuracy, enabling personalised treatment strategies and improved prognostication.

Question 1.6: What are the radiographic or imaging predictors of developing instability or deformity in the setting of vertebral osteomyelitis?

Authors: Jae Hwan Cho, Mohamad Zaki bin Haji Mohd Amin, Ratko Yurac, Emre Acaroglu, Toshinori Sakai

Recommendation: Key imaging-based instability predictors include lesions at junctional levels, followed by mobile (C3-6, L2-4) levels; bone lesions with >50% vertebral body collapse, endplate involvement, and lytic lesions; alignment changes with segmental angulation >30° or translation, followed by kyphosis or scoliosis; and posterolateral involvement of bilateral structures over unilateral involvement.

Level of Evidence: Moderate.

Delegate Vote: Agree – 78.4% | Disagree – 3.9% | Abstain – 17.6% (Strong Consensus).

Rationale: A comprehensive systematic review was conducted using PubMed, Scopus, Web of Science, and related databases. A total of 1818 articles were imported, 106 duplicates removed, and 1712 screened. Of these, 1674 were excluded based on predefined criteria, while 27 required further deliberation and 18 generated conflict among reviewers. After consensus discussion, 7 high-quality studies were selected for detailed analysis. Radiographic predictors were extracted from these studies and systematically evaluated by a panel of 5 experts.

Spinal infections such as spondylodiscitis, vertebral osteomyelitis, and epidural abscesses pose significant risks of instability and deformity. Early identification of radiographic predictors is critical to guide surgical stabilisation and prevent catastrophic outcomes. Several scoring systems, including the Spinal Instability Neoplastic Score (SINS),[47] Spinal Instability Spondylodiscitis Score (SISS),[43] Brighton Spondylodiscitis Score (BSDS),[48] and Spinal Infection Treatment Evaluation Score (SITE),[42] have incorporated radiological criteria to aid decision-making.

Location is a key determinant of instability. Junctional regions such as the occipito-cervical junction (O–C2), cervicothoracic junction (C7–T2), thoracolumbar junction (T11–L1), and lumbosacral junction (L5–S1) are particularly vulnerable, followed by mobile segments (C3-6, L2-4). Semi-rigid thoracic levels (T3–T10) and rigid sacral levels (S2-5) are less prone to instability. Bone lesions also play a central role. Vertebral body collapse exceeding 50% is strongly associated with instability, while endplate involvement and lytic lesions further increase risk.

Alignment changes are another critical predictor. Segmental angulation greater than 30° or vertebral translation is highly correlated with instability. Kyphotic or scoliotic deformities, though less predictive than angulation or translation, remain important markers of disease progression. Posterolateral involvement of bilateral structures confers greater instability risk compared to unilateral participation, reflecting the biomechanical importance of posterior elements in maintaining spinal stability.

Epidural abscess formation has been linked to deformity and neurological compromise, particularly in tuberculous spondylitis. Its role in pyogenic infections is less clear but should be considered a potential modifier in clinical decision-making. Clinical predictors also complement

imaging findings. Progressive neurological deficits, such as motor weakness or sensory changes, strongly correlate with instability and the need for surgical stabilisation. Ambulatory status may predict overall outcomes, though its relationship with instability progression remains uncertain. Patient comorbidities, including diabetes, immunosuppression, advanced age, and end-stage renal failure, increase complication risks and may necessitate more aggressive interventions.

Despite these insights, limitations remain. Scoring systems such as SITE and SISS are practical tools for guiding surgical planning, but they are not direct predictors and require further validation across diverse cohorts. A significant challenge is the absence of a universally accepted definition of vertebral instability in infection, which complicates standardisation and comparison of studies. Furthermore, modifiers such as epidural abscess and deformity progression must be integrated into individualised treatment strategies.

Overall, the identification of instability in vertebral osteomyelitis relies heavily on radiographic predictors, including vertebral collapse, alignment changes, and posterolateral involvement. By integrating validated scoring systems and imaging-based criteria, clinicians can improve decision-making for surgical stabilisation. This consensus provides a foundation for clinical practice and highlights the need for continued research to refine diagnostic definitions, validate scoring systems, and incorporate patient-specific modifiers into treatment algorithms.

Biopsy and Microbiological Workup

Accurate microbiological diagnosis remains the cornerstone of effective management in pyogenic spinal infections. While imaging modalities and clinical features provide essential clues, definitive identification of the causative pathogen is critical for guiding targeted antimicrobial therapy, minimising treatment failures, and avoiding unnecessary broad-spectrum antibiotic use. The role of biopsy and microbiological workup has therefore been a subject of considerable debate, particularly in scenarios where blood cultures are positive, early infection is suspected, or systemic infection precedes spinal involvement.

This section of the consensus recommendations addresses key questions surrounding biopsy and microbiological evaluation. The first issue is whether blood culture results should be awaited before planning tissue biopsy, and whether biopsy remains essential when cultures are already positive. Closely related is the question of whether empirical treatment can be initiated in early infections characterised by vertebral oedema but lacking overt destruction, where tissue diagnosis may be challenging.

For patients requiring biopsy, the optimal technique for obtaining tissue samples is critical, as yield and accuracy vary across percutaneous, open, and image-guided approaches. The management of pyogenic psoas abscesses, particularly whether all require drainage, is another critical consideration given their frequent association with spinal infection. Similarly, the necessity of biopsy in patients with recent systemic infection and a known organism before spinal involvement raises questions about balancing diagnostic certainty with clinical pragmatism. Finally, inconclusive biopsy results remain a common challenge, necessitating guidance on optimal management strategies. Emerging technologies such as next-generation sequencing (NGS) offer promise in improving pathogen detection, particularly in culture-negative cases, and their role in routine practice is explored here.

Question 2.1: Should blood culture results be awaited before planning tissue biopsy, and is tissue biopsy essential for confirming the diagnosis in the presence of positive blood cultures?

Authors: Andreas K. Demetriades, Marco G.A. Teli, Hideyuki Arima, Karthik Ramachandran

Recommendation: Obtain blood cultures immediately in all suspected cases of discitis before starting antibiotics. Proceed to tissue biopsy if blood cultures are negative after 48 h or if atypical pathogens are suspected. Biopsy may be deferred if blood cultures are positive for a typical organism and there is a strong clinical and radiological correlation.

Level of Evidence: Moderate.

Delegate Vote: Agree – 72.0% | Disagree – 8.0% | Abstain – 20.0% (Moderate Consensus).

Rationale: A comprehensive systematic review was conducted using PubMed, Scopus, Web of Science, and related databases. Of the 2017 records identified, 629 duplicates were removed. Remaining records were screened, and high-quality studies, meta-analyses, and international guidelines were analysed to generate this recommendation. The evidence consistently highlights the complementary roles of blood cultures and tissue biopsy in the diagnosis of pyogenic spinal infections, while also acknowledging the limitations of each modality.

Discitis (spondylodiscitis) is a severe infection requiring prompt diagnosis and targeted antimicrobial therapy. Blood cultures are widely available, minimally invasive, and provide rapid microbiological information. They should be obtained immediately in all suspected cases before initiation of antibiotics. Their sensitivity is moderate, approximately 50%, but specificity is high. Several studies, including Berbari et al[49] and Gouliouris et al,[50] emphasise that blood cultures are the first-line diagnostic test, with biopsy reserved for cases where cultures are harmful or atypical pathogens are suspected. Zimmerli et al[51] similarly recommend blood cultures first, but highlight the need for biopsy if no organism is identified.

Delaying biopsy while awaiting blood culture results for 48-72 h does not significantly compromise outcomes in clinically stable patients. However, early biopsy is justified in cases of sepsis, neurological compromise, or suspicion of

resistant or tuberculous infection. Kehrer et al[52] reported that blood cultures alone miss approximately 40% of cases, underscoring the importance of biopsy in culture-negative scenarios.

Biopsy may be deferred if blood cultures are positive for a typical organism, such as Staphylococcus aureus, and there is a strong clinical and radiological correlation. Concordance between blood cultures and biopsy cultures is reported to be 50-70%, but discordance can occur due to prior antibiotic exposure or fastidious organisms.[53] Biopsy provides additional benefits, including histopathological confirmation, assessment of antimicrobial resistance, and diagnosis of non-bacterial causes such as tuberculosis or fungal infections. Bernard et al[53] noted that blood culture-guided therapy is sufficient in uncomplicated cases, but biopsy may be required if treatment fails. Sobottke et al[54] suggested that biopsy can be avoided if blood cultures are positive and the patient demonstrates a good clinical response. Mylona et al[55] found similar yields between blood cultures and biopsy, but emphasised the importance of biopsy for resistant or unusual pathogens. Cotte et al[56] highlighted biopsy as essential in culture-negative cases or when atypical organisms such as Brucella or fungi are suspected. Grammatico[57] concluded that blood cultures alone may suffice for S. aureus, but biopsy remains critical for culture-negative or polymicrobial infections.

Overall, the evidence supports a pragmatic approach. Blood cultures should always be obtained first, and biopsy pursued if cultures remain negative after 48 h or if atypical pathogens are suspected. In cases where blood cultures are positive for a typical organism and correlate with clinical and radiological findings, biopsy may be deferred. This strategy balances diagnostic certainty with clinical efficiency, minimising invasive procedures while ensuring accurate pathogen identification.

In summary, blood cultures and biopsy are complementary diagnostic tools in discitis. Blood cultures provide rapid, specific information and should be prioritised, while biopsy remains essential in culture-negative cases, atypical infections, or when histopathological confirmation is required. This consensus emphasises individualised decision-making based on clinical stability, pathogen suspicion, and radiological correlation to optimise patient outcomes.

Question 2.2: In the presence of early infections with bony vertebral oedema and absent vertebral destruction, can empirical treatment be initiated without a tissue diagnosis?

Authors: Maximilian Reinhold, Roberto Chapa Sosa, Hideaki Imabayashi, Karthik Ramachandran, Gnanaprakash Gurusamy

Recommendation: Yes, there is indirect evidence suggesting empirical antibiotics can be initiated in the presence of early infections with bony vertebral oedema and absent vertebral destruction. **Not accepted by the expert panel (strong consensus to reject the recommendation).**

Level of Evidence: Low.

Delegate Vote: Agree – 7.8% | Disagree – 74.5% | Abstain – 17.6% (Strong Consensus to reject the recommendation).

Clinical Rationale for Rejection: Empirical antibiotics risk masking the causative organism, reducing culture yield on subsequent biopsy, and delaying targeted therapy.

Rationale: A comprehensive systematic review was conducted using PubMed, Scopus, Web of Science, and related databases. Of 3405 records identified, 349 duplicates were removed. Records were screened, and relevant studies were synthesised to evaluate whether empirical antibiotic therapy can be initiated in early spinal infections characterised by vertebral oedema but lacking overt destruction. The evidence base remains limited, and consensus among experts strongly rejected the recommendation, reflecting the importance of pathogen identification in guiding therapy.

Successful treatment of pyogenic spinal infections depends on accurate identification of the causative organism and targeted antimicrobial therapy. Despite aggressive diagnostic approaches, pathogen identification is not possible in approximately 10-50% of cases.[54] In such scenarios, empirical therapy is often considered, but no established guideline currently supports its routine use without tissue confirmation.

Several retrospective studies have explored outcomes in culture-negative vs culture-positive infections. Urrutia et al,[58] in a cohort of 97 patients, found no difference in clinical outcomes between those treated with pathogen-specific antibiotics and those receiving empirical therapy. Hospital stay and neurological outcomes were comparable. Yu et al[59] reported similar findings in 73 patients, with no significant differences in ESR, CRP, or pain scores between culture-negative and culture-positive groups after 3 months of treatment. Recurrence rates were also similar, though culture-positive patients tended to receive longer antibiotic courses.

Cervan et al[60] highlighted the importance of empiric therapy in immunocompromised patients, particularly those on hemodialysis, who often present late and with culture-negative spondylodiscitis. In such cases, early empiric treatment may prevent progression. Yoon et al[61] similarly observed that identification of the causative organism did not significantly affect outcomes, with culture-negative patients treated empirically achieving comparable results. Foreman et al[62] further demonstrated that prior antibiotic administration did not reduce biopsy yield, suggesting empiric therapy can be initiated without compromising subsequent diagnostic efforts.

Survey data from Kramer et al,[63] representing European neurosurgeons, revealed significant variability in practice. Conservative therapy, including empiric antibiotics, was often considered first-line in the absence of vertebral destruction, with surgery reserved for neurological deficits, deformity, or treatment failure.

Despite these findings, concerns remain. Empirical therapy risks inadequate coverage of atypical or resistant organisms, delays in recognising tuberculosis or fungal infections, and a lack of histopathological confirmation. Concordance between blood cultures and biopsy cultures is imperfect, and biopsy provides critical information on resistance patterns and non-bacterial etiologies. The consensus group therefore emphasised caution, noting that while empirical therapy may not be harmful in selected cases, it should not replace tissue diagnosis when feasible.

In summary, limited evidence suggests that empirical therapy can achieve comparable outcomes to pathogen-directed therapy in culture-negative spinal infections, particularly in early disease or immunocompromised patients. However, the absence of robust prospective data, the risk of missing atypical pathogens, and the lack of standardised guidelines led to strong consensus against routine empiric treatment without tissue diagnosis. Empirical therapy may be considered in selected situations, but close monitoring with serial imaging, laboratory markers, and clinical assessment is essential.

Question 2.3: For patients needing tissue biopsy, what is the optimal technique for obtaining tissue samples?

Authors: Sathish Muthu, Chee Kidd Chiu, Rato Yurac

Recommendation: Tissue core biopsy using large-core needles with multiple samples is advisable. If paravertebral fluid collections are present, they should be targeted for aspiration. Core biopsies of soft tissue abnormalities often have a higher microbiologic yield compared to bone biopsies and should also be targeted.

Level of Evidence: Low.

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

Rationale: A systematic review was conducted to analyse the optimal technique for obtaining samples in patients with suspected pyogenic spinal infections (PSI). PubMed, Web of Science, ClinicalTrials.gov, and Scopus were searched until December 2024. After identifying 1553 records, 320 duplicates were removed, and finally, 32 retrospective studies were included, providing level IV evidence.

When PSI is suspected, and blood cultures are negative, a tissue biopsy is required to identify the causative organism and its sensitivity profile. Two primary techniques are utilised: percutaneous image-guided biopsy and open surgical biopsy. Percutaneous biopsy is minimally invasive, associated with shorter hospitalisation, fewer complications, and lower cost. However, its microbiological yield is modest (33-48%).[64-66] Open biopsy demonstrates a higher yield (~76%) but is reserved for patients undergoing surgery for decompression or stabilisation.[64,67] Thus, maximising percutaneous biopsy yield through optimal technique is critical.

Thoracolumbar biopsy techniques most commonly employ posterolateral and modified transpedicular approaches. Patients are positioned prone, with abdominal support to enhance kyphosis and improve disc space access. CT gantry tilt adjustments can optimise imaging planes, particularly at L5–S1. After aseptic preparation and local anaesthesia, a biopsy needle with trocar and cannula is advanced under fluoroscopic guidance. Core samples are obtained by reaching the cannula into the lesion, with aspiration performed for culture. Drill-assisted techniques improve control and reduce sedation requirements. In cases of dry tap, the double-needle technique described by Shibayama et al[67] can be used, achieving yields above 90%. Posterolateral approaches targeting posterior elements are practical, and endoscopic techniques have shown higher yields compared to CT-guided biopsy, though further validation is needed.[68]

Cervical biopsy techniques present unique challenges due to proximity to vital structures.[69] Contrast-enhanced CT mapping of vascular anatomy is recommended. Percutaneous access is typically via lateral or posterolateral approaches. In the lateral approach, the needle is advanced behind the carotid sheath and anterior to the vertebral artery, with head rotation creating a safe window. In the posterolateral approach, the needle is directed through the lateral mass. Samples are sent for culture, sensitivity, and histopathology, with careful monitoring for haemorrhage or hematoma.

Guidance choice depends on case complexity. CT and fluoroscopy provide comparable microbiological yields. CT offers superior anatomical visualisation but involves higher radiation and longer procedure times. Fluoroscopy may be preferred in routine cases due to shorter duration and reduced anaesthesia requirements.

Target tissue selection strongly influences yield. Soft tissue targets such as disc material, paravertebral abscesses, or epidural collections often yield higher microbiological positivity. When fluid collections are present, aspiration should be prioritised. In the absence of fluid, disc or paraspinal tissue biopsy is recommended. Bone biopsy provides additional histopathological information, confirming osteomyelitis in up to 40-60% of culture-negative cases.[70]

Needle selection is essential. For aspiration, 20-gauge or larger needles are recommended. Core biopsy can be performed using coaxial systems. Retrospective studies suggest larger inner bore needles (12-14 gauge) may improve microbiological yield, though other reviews found no significant association.[71] While complication rates with larger needles remain unclear, they may be favoured when feasible.

Repeat biopsy may be warranted if initial cultures are negative. Although the yield is lower than the first biopsy, positive results can still be obtained, particularly in younger patients or those not recently exposed to antibiotics. A second biopsy should be performed at least 3 days after the initial procedure, as most pathogens are detected within this timeframe.[72,73]

Prior antimicrobial exposure reduces yield. IDSA guidelines recommend withholding antibiotics for 1-2 weeks before

biopsy unless the patient is critically ill.[49] Evidence is mixed, with some studies showing no difference, while others suggest a minimum antibiotic-free period of 4 days improves recovery. The conservative recommendation of one week remains widely accepted, though biopsy should not be delayed in unstable patients.

Complications of percutaneous biopsy are rare (<2%),[64] with most being minor, such as pain, bruising, or small hematomas. Major complications, including injury to neural or vascular structures, are uncommon. Contraindications include bleeding diatheses, anticoagulant use, or severe thrombocytopenia (<50,000/mm^3). Corrective measures such as platelet transfusion or INR normalisation should be undertaken before biopsy in high-risk patients.

In summary, percutaneous image-guided biopsy is the optimal technique for tissue sampling in PSI. CT or fluoroscopy guidance may be chosen based on case complexity, with soft tissue or fluid collections prioritised for aspiration. Bone biopsy provides valuable histopathological confirmation when cultures are negative. Needle gauge, repeat biopsy, and timing relative to antimicrobial exposure all influence yield. With complication rates low, careful patient selection and adherence to technical principles maximise diagnostic accuracy and therapeutic impact.

Question 2.4: Do all pyogenic psoas abscesses need to be drained?

Authors: Moses M. Kimani, Stefan Zwingenberger, Hideaki Imabayashi

Recommendation: Not all pyogenic psoas abscesses require drainage. Treatment decisions should be guided by abscess size, patient risk factors, and imaging characteristics.

Level of Evidence: Low.

Delegate Vote: Agree – 98% | Disagree – 2.0% | Abstain – 0% (Unanimous Consensus).

Rationale: A comprehensive systematic review was conducted using PubMed, Scopus, Web of Science, and Cochrane databases. Of 835 records identified, 253 duplicates were removed. Records were screened, and relevant studies were synthesised to evaluate the need for all pyogenic abscesses to be drained. Iliopsoas abscesses (IPA) represent a serious but heterogeneous clinical entity, with management strategies varying according to aetiology, size, and patient risk factors. They are broadly classified as primary, arising hematogenously without an adjacent source, and secondary, resulting from contiguous spread of infection from gastrointestinal, genitourinary, vascular, or musculoskeletal sources. Primary IPA is more common in younger patients in developing countries, while secondary IPA predominates in developed regions. When pyogenic spondylitis coexists with IPA, the condition is often considered an extended hematogenous abscess.[74] Some authors further distinguish gas-forming from non-gas-forming IPA, as these subtypes differ in microbiology, clinical course, and outcomes.[75]

Abscess size is a critical determinant of management. Percutaneous drainage under ultrasound or CT guidance is generally recommended for abscesses larger than 3 cm, as these are technically accessible and less likely to resolve with antibiotics alone.[74,76] Shoji et al[77] refined these thresholds, suggesting that abscesses with a transverse diameter ≥2.3 cm or longitudinal diameter ≥5.0 cm are more likely to require drainage due to poor outcomes with conservative therapy. Conversely, smaller abscesses (<3 cm) in patients without significant risk factors, such as immunosuppression, hemodialysis, or concomitant cervicothoracic osteomyelitis, can often be successfully managed with antibiotics alone.

The distinction between gas-forming and non-gas-forming IPA is also clinically relevant. Hsieh et al[75] reviewed 27 cases of gas-forming IPA and 61 cases of non-gas-forming IPA. In gas-forming IPA, only 1 of 6 instances responded to antibiotics alone, and percutaneous drainage was successful in just 2 of 13 cases. Open surgery was required in most patients, reflecting the aggressive nature of these infections. Gram-negative bacilli and anaerobes were frequently isolated, and the clinical course was fulminant, with mortality rates as high as 44%. In contrast, non-gas-forming IPA demonstrated more favourable outcomes, with percutaneous drainage successful in 17 of 23 cases. For these patients, drainage is recommended when the transverse diameter exceeds 3 cm, while smaller collections may be managed conservatively.

Risk stratification is essential. Patients with comorbidities such as diabetes, renal failure, or immunosuppression are at higher risk of poor outcomes and may require earlier intervention. Imaging characteristics, including the presence of gas, multiloculation, or extension into adjacent compartments, also guide management. CT and MRI not only delineate abscess size and morphology but also identify associated spinal or musculoskeletal infections, which may necessitate combined surgical approaches.[74]

The consensus emphasises that not all pyogenic psoas abscesses require drainage. Small, uncomplicated abscesses in otherwise healthy patients may resolve with antibiotics alone, provided close monitoring is ensured. Larger abscesses, gas-forming collections, or those in high-risk patients generally require drainage, either percutaneous or open, depending on anatomical feasibility and clinical stability. Mortality rates are significantly higher in gas-forming IPA, underscoring the need for aggressive management and vigilant follow-up.

In summary, management of pyogenic psoas abscesses should be individualised. Drainage is not universally required, but abscess size, imaging features, and patient risk factors must be carefully considered. Antibiotics alone may suffice for small, non-gas-forming abscesses in low-risk patients, while larger or gas-forming abscesses demand intervention. This nuanced approach balances invasiveness with clinical efficacy, ensuring optimal outcomes while minimising unnecessary procedures.

Question 2.5: In the presence of a recent systemic infection with a known organism before the onset of pyogenic spinal infection, can biopsy be avoided?

Authors: Kshitij Chaudhary, Haruki Funao

Recommendation: In most patients with suspected pyogenic vertebral osteomyelitis, a spinal biopsy cannot be avoided even if they have had a recent systemic infection with a known organism.

Level of Evidence: Low.

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

Rationale: A systematic review was conducted to evaluate whether spinal biopsy can be avoided in patients with suspected pyogenic vertebral osteomyelitis who have had a recent systemic infection with a known organism. PubMed, Scopus, Web of Science, and related databases were searched. Of 1086 records identified, 330 duplicates were removed, and relevant studies were synthesised to assess concordance between systemic cultures and spinal biopsy results, diagnostic accuracy, and clinical outcomes. The evidence consistently demonstrates that while recent systemic infection may provide clues to empiric therapy, biopsy remains essential in most cases to confirm the causative organism and guide targeted treatment.

Identifying the specific microorganism responsible for pyogenic spondylitis is crucial for effective therapy. Antibiotic regimens should be tailored to the pathogen, as empirical broad-spectrum treatment risks prolonged unnecessary exposure and contributes to antimicrobial resistance. Blood cultures are typically the first diagnostic step, but their sensitivity is limited, with reported positivity rates ranging from 40-60%.[78] Moreover, concordance between blood cultures and spinal biopsy samples is imperfect. In one study of 20 patients, only 50% had the same organism identified in both blood and biopsy cultures, and none showed concordance between urine cultures and biopsy samples.[79] This highlights the need for a biopsy to establish a definitive microbiological diagnosis.

If blood cultures are negative, a biopsy is generally recommended, even in the presence of a recent systemic infection. Significantly, the causative organism of spinal infection may differ from that of the prior systemic infection. A study reported concordance between blood and intraoperative tissue samples of 84.3% overall, but only 57.1% for coagulase-negative staphylococci (CNS).[80] This suggests that some CNS isolates in blood cultures may represent contamination rather than actual infection. The lower concordance compared to earlier reports (95.7%)[79] may reflect the inclusion of blood cultures from the entire inpatient stay, which could have been influenced by bacteremia from other sources. In elderly patients, positive peripheral cultures can be misleading due to comorbidities and synchronous infections with different organisms, further underscoring the importance of biopsy.

Spinal biopsy also provides histopathological confirmation, which is particularly valuable when culture results are negative or discordant. In cases where microbial aetiology remains unidentified despite blood cultures or biopsy, empiric therapy may be initiated based on the most probable organism.[81] A thorough clinical history can guide empiric choices, and recent systemic infection may inform initial treatment. However, clinicians must remain cautious, as a different pathogen may cause the spinal infection.

Several studies emphasise that empiric therapy guided solely by recent systemic infection is insufficient. Bernard et al[53] and Sobottke et al[54] note that biopsy is critical when treatment fails or when atypical organisms are suspected. In elderly patients or those with multiple comorbidities, biopsy helps avoid misdirected therapy based on misleading systemic culture results.

In conclusion, recent systemic infection with a known organism should not be used as the sole basis for initiating antibiotics in patients with suspected spinal infection. All attempts should be made to isolate the causative organism directly from the infected site through biopsy. While a known systemic infection can help guide empiric therapy when both blood cultures and biopsy are negative, biopsy remains essential for diagnostic certainty, pathogen identification, and resistance profiling. Clinical judgment, patient condition, and the results of initial investigations must guide decision-making, but the consensus strongly supports biopsy as a critical step in the diagnostic pathway.

Question 2.6: What is the optimal management of patients with spinal infection and inconclusive biopsy?

Authors: Dilip Chand Raja Soundararajan, Hirotaka Chikuda, Hideaki Nagashima, Sathish Muthu

Recommendation: A second percutaneous biopsy is recommended. When blood cultures and 2 consecutive needle biopsies are negative, an open biopsy should be performed. If all attempts to isolate the organism fail, antibiotic management must be based on the spectrum of bacterial infections usually observed in the geographical location.

Level of Evidence: Low.

Delegate Vote: Agree – 90.6% | Disagree – 3.8% | Abstain – 5.7% (Unanimous Consensus).

Rationale: A systematic review was conducted to evaluate the optimal management of patients with spinal infection and inconclusive biopsy. PubMed, Scopus, Web of Science, and related databases were searched. Of 1086 records identified, 329 duplicates were removed, and relevant studies were synthesised to assess diagnostic yield, microbiological concordance, and clinical outcomes. The evidence base remains limited, and current recommendations are largely consensus-driven, reflecting the complexity of culture-negative spinal infections.

Administering empirical antibiotics without identifying the causative pathogen is generally discouraged, except in

cases of sepsis or severe immunocompromise. Spinal infections are most often hematogenous in origin, making blood cultures an integral part of the diagnostic workup. However, their sensitivity is modest, with yields below 60%.[78] Surgical debridement, when indicated, provides sufficient quantities of bone and soft tissue for microbiological analysis, with reported success rates of 68-93% in identifying organisms.[82] In patients managed medically, CT-guided percutaneous biopsy remains the first choice, though sensitivity is limited to approximately 52%.[64]

Advanced diagnostic techniques such as nucleic acid amplification testing (NAAT), polymerase chain reaction (PCR), and metagenomic sequencing are increasingly valuable in culture-negative cases, particularly in patients who have received prior antibiotics or when rare organisms are suspected. These methods can detect pathogens missed by conventional aerobic and anaerobic cultures, enhancing diagnostic accuracy.[83]

Although a second percutaneous biopsy is commonly recommended after an initial negative result, a systematic review of 8 studies found no conclusive evidence supporting improved yield.[84] Nevertheless, consensus favours repeating percutaneous biopsy before proceeding to open biopsy. If blood cultures and 2 consecutive needle biopsies remain negative, an open biopsy is advised, as it allows direct sampling of infected tissue under surgical visualisation. Concurrently, other potential sources of infection, such as infective endocarditis, gastrointestinal, or genitourinary infections, should be excluded.

Geographic variation in pathogens must also be considered. Brucellosis is more common in Mediterranean and Middle Eastern countries, while tuberculosis predominates in Southeast Asia. Immunological testing may be required in endemic regions before concluding diagnostic attempts. Histopathology is particularly valuable for diagnosing granulomatous infections such as tuberculosis, providing specificity when cultures are negative. Empirical anti-tuberculous therapy is no longer advocated without supportive evidence, given its adverse drug profile and risk of resistance. However, in endemic regions, antitubercular chemotherapy may be initiated if clinical or imaging features worsen despite standard antibiotics, even in culture-negative cases.

When all attempts to isolate the pathogen fail, empirical antibiotic therapy must be guided by the spectrum of infections observed locally. The University of Michigan recommends vancomycin plus ceftriaxone for culture-negative spinal infections. Globally, dual therapy targeting gram-positive organisms (eg, Staphylococcus aureus, Streptococcus, and MRSA) with agents such as vancomycin, teicoplanin, or clindamycin, and gram-negative organisms (common in elderly patients) with fluoroquinolones or third/fourth-generation cephalosporins, is widely adopted.[85] Cordero-Delgado et al,[86] in a systematic review of 642 articles, recommended fluoroquinolones combined with rifampicin for empirical treatment of pyogenic spondylodiscitis.

Clinical outcomes in culture-negative infections remain debated. A retrospective analysis of 8 patients found no improvement despite 6 weeks of empirical combination therapy.[87] Duration of antibiotics is variable, with parenteral therapy typically continued for 2-4 weeks, followed by oral therapy for 4-6 weeks, depending on clinical recovery. Only one retrospective study has compared culture-positive and culture-negative infections, finding no significant difference in recurrence rates between pathogen-directed and empirical therapy.[59]

Failure of conservative treatment is defined by persistent symptoms, elevated inflammatory markers (ESR, CRP), or lack of radiological improvement. In such cases, surgical debridement is advocated. Current literature on culture-negative spinal infections is sparse, and management strategies remain consensus-based, emphasising the need for further prospective studies.

In summary, optimal management of spinal infection with inconclusive biopsy involves a stepwise approach: repeat percutaneous biopsy, open biopsy if cultures remain negative, exclusion of other infection sources, and consideration of geographic pathogen profiles. Empirical therapy should be reserved for cases where all diagnostic attempts fail, guided by local epidemiology and patient risk factors.

Question 2.7: Role of Next-Generation Sequencing in the identification of pathogens in spinal infection.

Authors: S Rajasekaran, Kota Watanabe, Karthik Ramachandran, Gnanaprakash Gurusamy

Recommendation: Next-Generation Sequencing (NGS) can serve as a valuable adjunct in enhancing the diagnostic process of spinal infections, especially in culture-negative patients.

Level of Evidence: Moderate.

Delegate Vote: Agree – 90.9% | Disagree – 0% | Abstain – 9.1% (Unanimous Consensus).

Rationale: PubMed, Scopus, Web of Science, and related databases were searched. Of 116 records identified, 68 duplicates were removed, and relevant studies that evaluated the role of Next-Generation Sequencing (NGS) in the identification of pathogens in spinal infections were identified and qualitatively synthesised. Conventional microbiological culture remains the gold standard for diagnosis, but its yield is limited, often requiring prolonged incubation periods and being significantly affected by prior antibiotic exposure. Reported culture sensitivity is frequently below 60%, leaving a substantial proportion of patients without a definitive microbiological diagnosis. This diagnostic gap has driven interest in molecular techniques such as NGS, which offer higher sensitivity, faster turnaround, and the ability to detect mixed or rare infections.

Compared to traditional methods, NGS demonstrates superior detection rates and shorter detection times. Its ability to identify mixed infections and provide species-level resolution is particularly valuable. Zhang et al[88] reported that NGS results were unaffected by prior antimicrobial exposure or inflammatory markers, with a sensitivity of 75% and a specificity of 84.5%. Yields were higher in samples obtained by surgical debridement compared to needle biopsy, and in pus or soft tissue compared to bone, highlighting the importance of sample type.

Gao et al,[89] in a study of 145 patients, identified Staphylococcus as the most common pathogen in iatrogenic spinal infections, while Mycobacterium species predominated in native infections. Xu et al[90] demonstrated that NGS had higher sensitivity and specificity than conventional microbiology for bacteria, mycobacteria, and fungi, and that NGS-guided antimicrobial therapy was associated with favourable outcomes. Importantly, NGS identified novel pathogens, including non-tubercular mycobacteria, underscoring its ability to expand diagnostic horizons.

Other studies confirm these findings. Zhang et al[91,92] reported a detection rate of 78.9% with NGS compared to 44.7% with culture, with a sensitivity of 84.2% and a specificity of 100%. Lv et al[93] noted that NGS was more effective in pus samples, while culture performed better in tissue, reflecting differences in bacterial viability and nucleic acid persistence.

NGS has also proven valuable in spinal tuberculosis. Li et al,[94] in a multicenter prospective study, found NGS sensitivity comparable to Xpert and T-SPOT TB, and superior to MGIT 960 culture and histopathology. Wang et al[95] reported NGS sensitivity of 80% for TB compared to 11% for culture, and 72.7% for non-TB infections compared to 36.4% for culture, with a mean detection time of just over 2 days. Notably, NGS was positive in more than 70% of culture-negative patients, highlighting its utility in challenging cases. Chen et al[96] further demonstrated that NGS outperformed culture in detecting rare and critical pathogens, and that combining NGS with culture and histopathology provided the most comprehensive diagnostic framework.

Despite its promise, NGS has limitations. It indiscriminately detects all nucleic acid molecules, including pathogenic bacteria, colonising flora, and exogenous sequences, necessitating careful interpretation to distinguish true pathogens from contaminants. Risks of contamination from specimens, reagents, or laboratory processes remain. Additionally, sequencing cost, depth, and turnaround time must be balanced against clinical utility. Bioinformatics expertise is essential to ensure accurate analysis and interpretation. Metagenomic NGS (mNGS), a non-culture-based approach, has shown even higher sensitivity and specificity, with rapid detection unaffected by prior antibiotics. Its ability to provide comprehensive pathogen profiles makes it particularly valuable in culture-negative spinal infections.

In summary, NGS has emerged as a powerful adjunct to conventional microbiology in spinal infections. It offers higher sensitivity, faster detection, and broader pathogen coverage, including mixed and rare organisms. Its role is especially critical in culture-negative cases and in endemic regions where tuberculosis or unusual pathogens are prevalent. While challenges remain regarding interpretation, contamination, and cost, consensus supports NGS as an essential addition to the diagnostic armamentarium for spinal infections.

Antibiotic Management

Antibiotic therapy forms the cornerstone of treatment in pyogenic spinal infections, directly influencing patient outcomes, recurrence rates, and long-term functional recovery. Unlike other musculoskeletal infections, spinal infections pose unique challenges due to their insidious onset, complex microbiology, and the potential for devastating complications such as neurological deficits, instability, and deformity. The choice, duration, and monitoring of antibiotics must therefore be carefully tailored to each patient, balancing efficacy with safety.

This section of the consensus recommendations addresses the critical aspects of antibiotic management in pyogenic spinal infections. The first question explores whether monotherapy or combination therapy should be initiated when cultures are positive, reflecting the ongoing debate between targeted precision and broader coverage. The second question focuses on defining the optimal duration of parenteral and oral regimens, and the clinical and laboratory factors that guide transitions between them. Equally important is the definition of antibiotic treatment failure, which remains poorly standardised. Establishing clear criteria for failure is essential to avoid premature escalation or unnecessary prolongation of therapy. Building on this, the next question examines strategies for managing patients who fail an initial regimen, including the role of alternative agents, surgical intervention, and adjunctive therapies.

Empirical therapy remains a cornerstone in culture-negative cases, and this section addresses the preferred antibiotics and optimal management strategies when pathogen identification is not possible. Finally, the section concludes with guidance on cessation of therapy in native infections, emphasising the importance of clinical, radiological, and laboratory markers in determining treatment endpoints and whether healed patients require periodic follow-up.

Question 3.1: In the presence of positive culture in tissue or blood, should one antibiotic or a combination of antibiotics be started?

Authors: Cristiano Magalhaes Menezes, K Venugopal Menon, Haruki Funao, Thayasivam Gobyshanger, Shinjiro Kaneko

Recommendation: The decision between monotherapy and combination therapy in the treatment of spinal infections should be individualised based on the pathogen.

Level of Evidence: Low.

Delegate Vote: Agree – 94.3% | Disagree – 0% | Abstain – 5.7% (Unanimous Consensus).

Rationale: PubMed, Scopus, Web of Science, and related databases were searched. Of 3199 records identified, 423 duplicates were removed, and relevant studies that evaluated whether monotherapy or combination therapy should be initiated in patients with spinal infections when cultures are positive were scrutinised. The evidence base remains limited, with most studies retrospective in nature, but several consistent themes emerge regarding pathogen type, presence of implants, and biofilm formation.

Spinal infections can be broadly classified into 2 groups: those acquired through hematogenous dissemination, such as pyogenic spondylodiscitis, and those related to surgical procedures, often involving implanted materials. Staphylococcus aureus (both methicillin-sensitive and methicillin-resistant) is the most common pathogen, followed by streptococci and Gram-negative bacilli. In rarer cases, organisms such as Cutibacterium acnes are implicated, particularly in late-onset implant-associated infections.[49,97]

For hematogenous infections without implants, monotherapy may be sufficient in selected cases. Retrospective studies suggest that methicillin-sensitive S. aureus infections can be treated effectively with monotherapy using first-generation cephalosporins or vancomycin, provided the patient is clinically stable and without systemic complications.[98] However, robust prospective evidence supporting monotherapy as a standard approach is lacking, and most guidelines continue to recommend individualised therapy based on pathogen sensitivity and patient condition.

Infections associated with implants pose greater therapeutic challenges. Microorganisms adhered to implants frequently form biofilms, which protect bacteria from host defences and reduce antibiotic efficacy. In these cases, combination therapy is strongly recommended, particularly when Staphylococcus species are involved.[99,100] Rifampin plays a central role in implant-associated infections due to its unique ability to penetrate biofilms and eradicate bacteria in slow-growing or dormant states. Studies demonstrate that rifampin, when combined with fluoroquinolones (eg, levofloxacin, ciprofloxacin), daptomycin, or linezolid, significantly improves eradication rates and reduces recurrence.[101] Importantly, rifampin should never be used as monotherapy, as resistance develops rapidly when it is administered alone.

The timing of rifampin initiation remains debated. Most experts recommend introducing rifampin only after adequate infection control has been achieved, either through surgical debridement or clinical stabilisation. Early administration in the presence of uncontrolled infection may promote resistance.

Beyond rifampin, combination therapy may also be indicated in infections caused by multidrug-resistant Gram-negative organisms, polymicrobial infections, or cases with systemic complications. In these scenarios, dual therapy provides broader coverage and reduces the risk of treatment failure. Conversely, in straightforward hematogenous infections with a single identified pathogen and no implant involvement, monotherapy may suffice, minimising toxicity and cost.[98]

The decision between monotherapy and combination therapy must therefore be individualized, taking into account the pathogen type and resistance profile (eg, MRSA vs MSSA, Gram-negative bacilli, atypical organisms); presence of implants or biofilm risk, where rifampin-based combinations are preferred; clinical stability and systemic involvement, with combination therapy favored in severe or complicated cases; and surgical factors, including debridement and implant retention or removal. Advanced diagnostic methods, including molecular techniques, can further refine pathogen identification and resistance profiling, enabling more precise antimicrobial selection. Personalised regimens based on culture results, clinical context, and surgical findings remain the cornerstone of effective therapy.

In summary, monotherapy may be appropriate in selected hematogenous infections without implants, while combination therapy is strongly recommended in implant-associated infections and cases involving biofilm-forming organisms. Rifampin, in combination with another active agent, has demonstrated significant advantages in bacterial eradication and recurrence prevention. The consensus emphasises individualised decision-making, guided by microbiological, clinical, and surgical factors, to optimise outcomes in spinal infections.

Question 3.2: What are the definitive time periods for parenteral and oral antibiotic regimens in pyogenic spinal infections? What factors determine the antibiotic therapy schedule?

Authors: Chan Chris Yin Wei, Haruki Ueda, Jun-Hao Tan, Roberto Chapa Sosa, Sathish Muthu

Recommendation: No definite time points could be recommended. However, a total duration of at least 6 weeks is advised, with route and dosage determined by pathogen sensitivity and patient response.

Level of Evidence: Low.

Delegate Vote: Agree – 79.2% | Disagree – 9.4% | Abstain – 11.3% (Strong Consensus).

Rationale: A systematic review was conducted to evaluate the optimal duration and scheduling of parenteral and oral antibiotic regimens in pyogenic spinal infections. A total of 588 abstracts were identified, 169 duplicates removed, and eligible studies were screened to identify 12 studies: 8 retrospective studies (Level 3 evidence), 3 review articles, and one survey. Altogether, 646 patients were analysed across the retrospective studies, published between 1990 and 2023. No Level 1 or Level 2 studies were identified, underscoring the limited quality of available evidence.

The included studies demonstrated significant heterogeneity in practice. Babouee Flury et al[102] reported that 72% of

patients were switched to oral therapy after a median of 19 days of intravenous treatment, with lower CRP levels at 2 weeks predicting successful transition. Grados et al[97] recommended an initial 2-3 weeks of intravenous therapy, with total treatment lasting at least 12 weeks, emphasising CRP normalisation and negative blood cultures as criteria for shortening IV therapy. Jaramillo-De La Torre[103] and Korovessis[104] both advocated for a minimum of 6 weeks of intravenous treatment followed by oral antibiotics, with Korovessis noting that delayed presentations and immunocompromised patients required longer courses.

Legrand et al,[105] in a multicenter study of 110 patients, found mean intravenous therapy lasted 25 days, with total antibiotic duration averaging 103 days. Longer courses were associated with positive blood cultures and neurological involvement. Locke et al[106] reported a median of 12 weeks of therapy (6 weeks IV, 9 weeks oral), with persistent inflammatory markers and pyrexia necessitating extended treatment. Marconi et al[107] proposed oral regimens in selected patients, with a median treatment lasting 96 days; comorbidity burden and multidrug-resistant organisms predicted failure. McLean et al,[108] in a survey of 79 clinicians, found median intravenous therapy lasted 2 weeks, with total durations most commonly 12 weeks.

Other retrospective studies reinforced these findings. Mohamad et al[109] recommended 2 weeks of IV therapy followed by 10 weeks of oral antibiotics in culture-negative cases, with good clinical outcomes. Okumura et al[110] demonstrated that cephalexin was a reasonable oral option after at least 3 weeks of IV therapy in MSSA bacteremia with vertebral osteomyelitis. Osenbach et al[111] suggested at least 8 weeks of IV therapy, while Sur et al[112] recommended switching to oral therapy once CRP fell below 20 mg/L, with a total of 12 weeks of treatment.

Taken together, the evidence supports a minimum of 2 weeks of intravenous therapy, with most studies recommending a total antibiotic duration of 12 weeks or longer. Shorter IV courses (2-4 weeks) may be appropriate in patients with rapid clinical and laboratory improvement. In comparison, longer IV courses (≥6 weeks) are warranted in cases with poor response, immunocompromise, delayed presentation, or neurological deficits. CRP trends, particularly values <20 mg/L at 2 weeks, are valuable markers for guiding transition to oral therapy.

In summary, while no definitive time points can be universally recommended, consensus supports at least 6 weeks of therapy, with many studies advocating for 12 weeks or more. The route and duration should be individualised based on pathogen sensitivity, patient comorbidities, and clinical response, with CRP and ESR serving as valuable markers for monitoring progress.

Question 3.3: How should antibiotic treatment failure be defined in patients with pyogenic spinal infection?

Authors: Jason Pui Yin Cheung, Hideyuki Arima, Kota Watanabe

Recommendation: Death and the need for surgical intervention due to deterioration of clinical condition or new-onset neurological deficit can be considered as failure of medical treatment.

Level of Evidence: Low.

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

Rationale: PubMed, Scopus, Web of Science, and related databases were searched. Of 2241 records identified, 359 duplicates were removed, and relevant studies that evaluated how antibiotic treatment failure should be defined in pyogenic spinal infections were identified. The literature reveals considerable variability, with definitions ranging from clinical deterioration to recurrence of disease, but consensus is emerging around a few core outcomes.

Antibiotic therapy remains the backbone of pyogenic spinal infection management, but surgical intervention is often required to reduce the infectious burden and preserve neural structures. When drug regimens fail to induce meaningful improvement or when patients deteriorate despite therapy, treatment is considered unsuccessful. Most authors define failure as poor outcomes such as worsening clinical condition, neurological decline, spreading infection, functional deterioration, or death. Persistent infection, recurrence, and need for unexpected interventions are also frequently cited.[113]

For spinal epidural abscess, definitions of failure mirror those for vertebral osteomyelitis. Retrospective studies have considered conversion to surgery, lack of neurological recovery, relapse after discharge, or death as indicators of medical failure. Page et al[114] suggested that laboratory or radiographic progression requiring surgery, increased deformity, or repeated interventions should be included. Hunter et al[115] emphasised worsening neurology, lack of clinical improvement, and persistent laboratory abnormalities, though they notably did not include death. A multicenter study defined failure as antibiotic therapy beyond 6 weeks, relapse within 3 months, or death.[116] Baum et al[6] added readmission due to progression, revision surgery for deformity, or implant failure, identifying diabetes, hepatitis, osteomyelitis, and kyphotic deformity as risk factors.

For vertebral osteomyelitis, Marconi et al[107] described failure as lack of improvement or progression during therapy, with persistent fever, raised inflammatory markers, pain, or death at 12 months. De Graeff et al[117] considered surgery and death as failure, but reinfections after successful therapy as separate events. A systematic review distinguished "failure" (lack of response requiring unplanned surgery or new antibiotic cycle) from "relapse" (infection recurrence after completion of therapy), reporting an overall 8.2% rate of either outcome.[118] Gupta et al[119] found most failures occurred early, defining them as infection-related death, relapse, acute neurological deficits, or unplanned surgery.

Higher-quality studies provide further clarity. Jung et al,[120] in a prospective study of Staphylococcus aureus bloodstream infection with vertebral osteomyelitis, defined failure as relapse or death at 1 year, identifying comorbidity burden and disseminated infection as risk factors. A randomised controlled trial classified failure as persistent fever, pain, CRP >10 mg/L at 12 months, death, or prolonged antibiotic use beyond 6 days.[53] Machine learning and modelling studies have also used neurologic deterioration, persistent symptoms, altered antibiotic regimens, or surgical intervention after 72 h as markers of failure.[121]

Postoperative spinal infections add further complexity. Cho et al[122] defined failure as infection-related death, need for debridement after 2 weeks of antibiotics, recurrence, or new infection at the surgical site, with MRSA and implant retention increasing risk. Other studies considered persistent fever, wound discharge, elevated inflammatory markers, or radiographic progression despite antibiotics as failure, with wound dehiscence and delayed infection onset identified as predictors.

Across these studies, death and the need for surgical intervention are the most consistently reported and universally accepted indicators of antibiotic treatment failure. Neurological deterioration, lack of clinical or laboratory improvement, and recurrence are also frequently included, though definitions vary. Pain progression, changes in antibiotic regimen, or radiographic worsening are less consistently applied and harder to quantify.

In summary, antibiotic treatment failure in pyogenic spinal infection is best defined by objective, clinically significant outcomes: death, deterioration requiring surgery, or new neurological deficits. Additional markers such as persistent infection, relapse, or lack of laboratory improvement may be considered, but variability in reporting limits their reliability. The absence of standardised criteria represents a gap in current evidence, highlighting the need for consensus definitions to guide clinical decision-making and research.

Question 3.4: What is the optimal management of patients with pyogenic spinal infection who have failed one regimen of antibiotic treatment?

Authors: K Venugopal Menon, Reuben Soh, Kosei Nagata, Shinsuke Sato, S Rajasekaran

Recommendation: In cases of medical management failure, it is essential to reassess the diagnosis by revisiting biopsy, cultures, and imaging to establish a credible underlying cause before proceeding with further treatment, which may include surgery. Once treatment failure has been established, surgical intervention may be considered.

Level of Evidence: Low.

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

Rationale: PubMed, Scopus, Web of Science, and related databases were searched. Of 2241 records identified, 358 duplicates were removed, and relevant studies that evaluated the optimal management of patients with pyogenic spinal infection who fail initial antibiotic therapy were identified and qualitatively synthesised. The overall quality of evidence is low, with most studies retrospective in nature, but consistent themes emerge regarding risk factors, prevention strategies, and the role of surgery.

Antibiotic therapy remains the cornerstone of treatment, with reported success rates between 72-85%.[119] Failure is typically defined as persistence, progression, or recurrence of infection after 6 weeks of therapy. Other authors have expanded this definition to include lack of clinical or serological resolution, worsening deformity, neurological deficit, readmission, or death. Risk factors for failure include short courses of therapy (<4 weeks), epidural abscess, cervical or dorsal lesions, involvement of more than 3 vertebrae, negative cultures, positive blood cultures, and abscess formation.[123] Serial monitoring of CRP has proven useful, with reductions of 50% per week associated with favourable outcomes. X-rays may also help track healing, while FDG-PET is emerging as a promising modality for monitoring.

Preventive strategies emphasise adequate antibiotic duration. Several authors recommend 6-12 weeks of therapy, with 2-4 weeks of intravenous treatment followed by oral therapy. IDSA guidelines suggest 6 weeks of IV antibiotics, but evidence shows that 2 weeks of IV followed by oral therapy can be equally effective.[124] In culture-positive cases, 6 weeks of therapy is as effective as twelve, while in culture-negative cases, shorter courses may suffice if surgery is performed concurrently. Combination therapy with 2 synergistic bactericidal agents for 12 weeks has been proposed to reduce failure rates.[124] In culture-negative infections, adjuncts such as rifampin or fucidin may improve outcomes, while daptomycin has shown promise in MRSA infections.

Once medical failure is established, surgical intervention becomes the mainstay. Surgery offers several advantages: reduction of infective load, removal of diseased tissue, acquisition of biopsy and histopathology, and correction of instability or deformity. Early surgery has been shown to reduce mortality and morbidity by up to 40%.[125] Surgical debridement, stabilisation, and reconstruction are commonly employed, with outcomes improved when performed promptly.

Alternative or adjunctive modalities have been reported, though evidence is limited. Hyperbaric oxygen therapy and paravertebral muscle infiltration of antibiotics have shown isolated success. Duarte and Vaccaro proposed an algorithm emphasising that failure of medical management should prompt a complete reassessment, including repeat biopsy, cultures, and imaging, to re-establish a credible diagnosis before proceeding with surgery.[123]

In summary, the optimal management of patients with pyogenic spinal infection who fail one regimen of antibiotics involves a stepwise approach. First, the diagnosis must be

reassessed with repeat cultures, biopsy, and imaging to exclude alternative causes or missed pathogens. If failure is confirmed, surgical intervention should be considered, offering both therapeutic and diagnostic benefits. Preventive strategies include adequate antibiotic duration, use of synergistic combinations, and careful monitoring of CRP and clinical parameters. While adjunctive therapies may have niche roles, surgery remains the definitive option when medical treatment fails.

Question 3.5: What are the preferred antibiotics for empirical antibiotic therapy in pyogenic spinal infections?

Authors: Sathish Muthu, Sri Vijay Anand K S, Tan Jiong Hao Jonathan, Koji Yamada, Takashi Kaito, Shinsuke Sato

Recommendation: The choice of empirical antibiotic therapy (EAT) should be considered based on the host, the clinical situation, and the epidemiologic risk, as well as the local historical in vitro susceptibility data of the expected pathogen.

Level of Evidence: Low.

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

Rationale: A systematic review was conducted to analyse the preferred antibiotics for empirical therapy in pyogenic spinal infections (PSI). PubMed, Web of Science, ClinicalTrials.gov, and Scopus were searched until December 2024. After screening 488 abstracts, 126 duplicates were removed, and after excluding non-English publications, pediatric studies, tubercular spondylodiscitis, case reports, and registry-based studies, 7 retrospective studies were included, encompassing 904 patients. All studies provided level IV evidence.

Despite advances in diagnostic methods, causative organisms cannot always be identified, necessitating empirical therapy. WHO emphasises rational antibiotic use that balances efficacy, safety, and cost. However, no clear consensus exists on the optimal empirical regimen for PSI. The included studies, published between 2008 and 2022, reported treatment durations ranging from 6 to 15 weeks.

Across studies, fluoroquinolone-rifampicin combinations were the most frequently used regimens. Viale et al (2008)[126] and Lora-Tamayo et al (2011)[127] reported levofloxacin plus rifampicin with susceptibility rates of 84-93% and treatment durations of 8-15 weeks. Desoutter et al (2015)[128] compared several regimens, noting susceptibility rates of 58% for ofloxacin plus rifampicin, 75% for levofloxacin plus rifampicin, and 76-77% for ciprofloxacin combined with clindamycin or amoxicillin-clavulanate.

Other studies highlighted ciprofloxacin plus cephalosporins as effective alternatives. Urrutia et al (2015)[58] and Mohamad et al (2018)[109] reported successful outcomes with this regimen, with 12-week treatment courses and no relapses. Park et al (2019)[129] provided the most comprehensive susceptibility data, showing levofloxacin plus rifampicin at 73.5%, levofloxacin plus clindamycin at 71.2%, ciprofloxacin plus amoxicillin-clavulanate at 64.5%, and vancomycin combinations with cephalosporins or fluoroquinolones achieving the highest rates (93-95.8%). Lee et al (2022)[130] reported cephalosporins alone with 89% susceptibility and a 6-week treatment duration.

Taken together, these findings suggest a two-tiered approach to empirical therapy. In areas with low prevalence of resistant Staphylococcus aureus, rifampicin combined with fluoroquinolones (such as levofloxacin or ciprofloxacin) is effective, offering good bone penetration and oral administration feasibility. In settings where resistant strains are common, vancomycin combined with broad-spectrum cephalosporins (ceftriaxone, ceftazidime, cefepime) or fluoroquinolones provides superior coverage, with susceptibility rates exceeding 95%. Carbapenems may be considered in highly resistant scenarios, as recommended by the Infectious Diseases Society of America.

Duration of empirical therapy varied across studies, ranging from 4 to 12 weeks, with most authors recommending at least 6 weeks. Markers for discontinuation included normalisation of ESR and CRP, reduction of spinal pain, normalisation of body temperature, and radiographic improvement. While an early switch to oral therapy is generally discouraged, agents with high bioavailability and bone penetration, such as clindamycin and fluoroquinolones, may allow earlier transition in selected cases.

In summary, empirical therapy for PSI should be individualised, guided by host factors, clinical severity, epidemiologic risk, and local susceptibility data. Fluoroquinolone-rifampicin combinations are effective in low-resistance settings, while vancomycin plus cephalosporins or fluoroquinolones are preferred in resistant cases. Therapy should continue for at least 6 weeks, with clinical and laboratory markers guiding duration and transition to oral agents.

Question 3.6: What is the optimal treatment of patients with culture-negative spinal infection?

Authors: Sri Vijay Anand K S, Ajoy Prasad Shetty, Yoshiharu Kawaguchi, Deva Param, Gnanaprakash Gurusamy

Recommendation: The evidence is in favour of a combination of drugs rather than monotherapy in the treatment of culture-negative spinal infections, ideally within a multidisciplinary framework when available.

Level of Evidence: Low.

Delegate Vote: Agree – 80.8% | Disagree – 3.8% | Abstain – 15.4% (Strong Consensus).

Rationale: A systematic review was conducted in accordance with the Cochrane Handbook of Systematic Reviews for Interventions to analyse the optimal treatment of culture-negative spinal infections. Searches across PubMed,

Scopus, Web of Science, and ClinicalTrials.gov up to January 2024 identified 2314 articles, of which 623 duplicates were removed. After screening and exclusions, 6 retrospective studies were included, all providing level IV evidence.

Microbiological diagnosis is a key predictor of successful treatment in pyogenic spinal infections. Yet, more than one-third of patients remain culture-negative despite refinements in biopsy techniques and culture methods. Culture negativity may result from prior antibiotic exposure, fastidious organisms, or technical issues during biopsy. These patients present unique challenges, as empirical therapy must be chosen without pathogen confirmation.

The included studies highlight several empirical strategies. Kim et al (2014)[131] treated 151 patients with first-generation cephalosporins for 8 weeks, achieving a cure rate of 91.5% and finding no significant difference in relapse between culture-positive and culture-negative groups. Urrutia et al (2015)[58] and Mohamad et al (2018)[109] employed ciprofloxacin combined with cephalosporins, with Mohamad's cohort receiving 2 weeks of intravenous cloxacillin/cefazolin plus ciprofloxacin followed by 10 weeks of oral cloxacillin/cephalexin plus ciprofloxacin; both studies reported favourable outcomes with 12-week regimens. Yu et al (2020)[59] used β-lactam and glycopeptide combinations for a mean duration of 14 weeks, while Lee et al (2022)[130] began with third-generation cephalosporins and escalated to fourth-generation cephalosporins or carbapenems plus vancomycin in non-responsive cases, with treatment lasting 6 weeks. Dai et al (2024)[132] reported success with vancomycin plus imipenem, vancomycin plus fluoroquinolones, or fluoroquinolones plus third-generation cephalosporins, with a mean treatment duration of 7 weeks.

Taken together, these studies suggest that combination therapy is superior to monotherapy in culture-negative infections. Regimens combining cephalosporins with fluoroquinolones or vancomycin with broad-spectrum agents consistently achieved high cure rates. The Infectious Diseases Society of America (IDSA) guidelines (2015)[49] recommend vancomycin plus a third- or fourth-generation cephalosporin for 6 weeks, with alternatives such as daptomycin plus fluoroquinolone for patients intolerant to vancomycin.

Host and demographic factors must also guide therapy. Staphylococcus aureus remains the most common pathogen in native pyogenic spinal infections, but Gram-negative organisms are more frequent in women and elderly patients. MRSA is particularly prevalent in patients with chronic renal disease or on hemodialysis. Risk factors for multidrug-resistant infections include autoimmune conditions, immunocompromised states, central venous catheters, and prolonged prior antibiotic use. In such cases, empirical regimens should consist of MRSA coverage.[133]

Duration of therapy across studies ranged from 6 to 14 weeks. A randomised non-inferiority trial demonstrated that 6 weeks of antibiotics was not inferior to 12 weeks in pyogenic spinal infections, suggesting shorter courses may be adequate in selected patients.[53] Nevertheless, most authors recommend a minimum of 6 weeks to reduce relapse risk. There is no consensus on the optimal duration of intravenous therapy or the timing of transition to oral agents, though oral fluoroquinolones and clindamycin are favoured for their bioavailability and bone penetration.

In summary, culture-negative spinal infections present significant therapeutic challenges. Evidence supports the use of combination antibiotic regimens, tailored to host factors, epidemiology, and local resistance patterns. Vancomycin plus cephalosporins or fluoroquinolones is widely recommended, with treatment lasting at least 6 weeks. While outcomes appear comparable to culture-positive cases when therapy is appropriately selected, the lack of high-quality prospective data and heterogeneity of regimens remain significant limitations. A multidisciplinary approach, incorporating infectious disease specialists, spine surgeons, and radiologists, is essential to optimise outcomes in this challenging patient population.

Question 3.7: What are the factors that decide cessation of the antibiotic course in native pyogenic spinal infections? Do patients with healed infection require periodic follow-up?

Authors: Joshua Schmirler, Rohit Amritanand, Takeo Furuya, Takashi Kaito, Yogesh Kishorkant Pithwa, Toshinori Sakai, Brian Karamian

Recommendation: Antibiotic therapy may be discontinued after a minimum of 6 weeks in patients who show clear clinical improvement and demonstrate a consistent reduction in serum inflammatory markers.

Level of Evidence: Low.

Delegate Vote: Agree – 87.9% | Disagree – 3.0% | Abstain – 9.1% (Strong Consensus).

Recommendation: Patients at high risk of recurrence should be closely monitored for a minimum of 1 year.

Level of Evidence: Low.

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

Rationale: PubMed, Scopus, Web of Science, and related databases were searched. Of 660 records identified, 143 duplicates were removed, and relevant studies that evaluated the factors guiding cessation of antibiotic therapy in native pyogenic spinal infections and the need for follow-up in healed patients were identified and qualitatively synthesised. Most available studies are retrospective, with one randomised controlled trial, but together they provide consistent guidance on minimum treatment duration, laboratory monitoring, and clinical assessment.

Several studies advocate for a standard antibiotic duration of 6-8 weeks in native pyogenic spinal infections. Bernard et al,[53] in a randomised controlled trial of 359 patients, demonstrated that 6 weeks of therapy was not inferior to

12 weeks in terms of cure rate at 1 year. Da Nóbrega Danda et al,[134] in a retrospective cohort of 50 patients, similarly found no advantage to longer courses, though they noted that recurrence was more likely in high-risk patients such as those with spinal cord compression, sensory deficits, or antibiotic initiation before pathogen identification. Park et al[129] reported that extending therapy beyond 8 weeks reduced recurrence in patients with MRSA or undrained paravertebral/psoas abscesses. These findings suggest that while 6 weeks is sufficient for most patients, extended courses may be warranted in selected high-risk groups.

Laboratory markers are widely used to guide cessation. ESR appears to be the most reliable test, trending downward consistently over the course of therapy and correlating with eradication of infection. Osenbach et al[111] reported mean ESR values of 85 mm/h at diagnosis and 25 mm/h at completion of therapy, noting that ESR often remained above normal. Still, the downward trend was predictive of success. CRP typically normalises earlier, often within 2 weeks, but its rapid decline makes it less reliable as a sole marker. Chiang et al[135] confirmed that CRP fell below 5 mg/dL in most patients within 2 weeks, while ESR continued to decline steadily throughout therapy. WBC counts showed no consistent trend. Thus, ESR and CRP together provide the best laboratory guidance, with emphasis on trends rather than absolute values.

Imaging plays a limited role in deciding cessation. Repeat MRI often shows persistent abnormalities despite clinical cure, which may lead to unnecessary extension of therapy. Zarrouk et al[136] found that at 3 months, 66% of patients still had vertebral oedema and 42% had discal abscess despite successful treatment. These findings decreased over time but were not indicative of failure. PET/CT with 18F-FDG has shown promise as a more reliable imaging modality, correlating better with treatment response, but requires further validation before routine use.[136]

Clinical improvement remains the cornerstone of decision-making.[137,138] Resolution of pain, normalisation of temperature, and functional recovery are strong indicators of cure. The absence of new neurological deficits and improvement in inflammatory markers together provide sufficient grounds for cessation after 6 weeks.

Regarding follow-up, the literature is inconclusive on routine monitoring for all patients. However, high-risk groups, including those with neurological deficits, age ≥65, or epidural/paravertebral abscesses, should be closely monitored for at least 1 year. These patients are more prone to recurrence or sequelae, and periodic clinical and laboratory evaluation is warranted. For low-risk patients, routine long-term follow-up is not universally recommended, though clinical judgment should guide practice.

In summary, cessation of antibiotics in native pyogenic spinal infections can be considered after a minimum of 6 weeks in patients with clear clinical improvement and consistent reduction in ESR and CRP. Imaging is not routinely required, though PET/CT may have future utility. High-risk patients should be followed for at least 1 year to detect recurrence early, while routine follow-up in low-risk patients remains optional.

Monitoring and Response Assessment

Monitoring treatment response in pyogenic spinal infections is a critical component of patient care, as inappropriate continuation or premature cessation of therapy can lead to recurrence, progression, or unnecessary interventions. Unlike other musculoskeletal infections, spinal infections present unique challenges in assessing healing because clinical, laboratory, and radiological parameters often evolve at different rates.

Magnetic resonance imaging (MRI) remains the gold standard for diagnosis, but its role in follow-up is controversial. Radiological abnormalities frequently persist long after clinical cure, and apparent progression on MRI may not correlate with patient outcomes. This raises important questions about the frequency of repeat imaging and whether radiological changes alone should drive surgical decisions.

Laboratory markers such as erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) are widely used to monitor treatment response, with trends over time often more reliable than absolute values. Clinical improvement such as resolution of pain, normalisation of temperature, and recovery of function, remains the cornerstone of assessing healing.

This section addresses the optimal use of MRI in monitoring, the interpretation of radiological progression in clinically stable patients, and the role of laboratory and clinical parameters in guiding treatment decisions. Together, these recommendations aim to balance effective monitoring with the avoidance of unnecessary interventions.

Question 4.1: Should and how frequently should MRI be performed in assessing disease healing of pyogenic spondylodiscitis?

Authors: Pushpa Bhari Thippeswamy, Pavithra Devi, Andreas K. Demetriades, Koji Yamada, Maximilian Reinhold, Eiichiro Iwata

Recommendation: MRI follow-up is required only when there is no clinical improvement, and the frequency should be determined on a case-by-case basis.

Level of Evidence: Very low.

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

Rationale: A systematic review was conducted to evaluate the utility of magnetic resonance imaging (MRI) in assessing the healing of pyogenic spondylodiscitis (PSD) and to determine the frequency at which MRI should be performed during treatment. Searches across PubMed, Web of Science, ClinicalTrials.gov, and Scopus up to January 2025 identified 1798 articles, 297 duplicates removed and the final eligible

articles were screened to yield 9 retrospective studies, encompassing approximately 400 patients. All studies provided level IV evidence.

MRI is highly sensitive and specific for the diagnosis of PSD, but its role in routine follow-up remains controversial. The earliest study by Gillams et al[139] described the temporal evolution of PSD, noting that soft tissue changes resolved early, fatty marrow replacement was a reliable marker of healing, while bone destruction and disc changes often worsened despite clinical improvement. Contrast enhancement persisted long after soft tissue resolution, limiting its utility as a marker of cure.

Ahn et al[140] correlated MRI findings with inflammatory markers, showing that soft tissue changes aligned with CRP trends, while bone changes correlated better with ESR. Euba et al[141] demonstrated that soft tissue changes regressed early and entirely resolved by later stages. In contrast, bone and disc changes persisted despite clinical and laboratory improvement, suggesting that repeat MRI was unnecessary if patients improved clinically. Malani et al[142] further confirmed that clinical worsening was never associated with improved MRI, and conversely, clinical improvement did not reliably predict MRI resolution. Barreto et al[143] emphasised that repeat biopsy was not required if soft tissue changes resolved, even when bone and disc abnormalities persisted.

Several studies focused exclusively on soft tissue changes. Kowalski et al[144] and Hecquet et al[145] found that patients with good resolution of soft tissue changes had longer disease-free intervals, but concluded that MRI was most useful in patients with worsening clinical status or inflammatory markers. Veillard et al[146] reported that paravertebral and epidural abscesses regressed by 3 months of therapy, but these changes were not prognostic. Zarrouk et al[136] highlighted that imaging findings often persisted at 3 and 6 months despite clinical improvement, and did not correlate with relapse, neurological consequences, or residual pain.

Taken together, these studies suggest that resolution of soft tissue changes and fatty marrow replacement are the most reliable MRI indicators of healing. In contrast, disc space narrowing and vertebral body destruction may worsen or remain unchanged during treatment, making them unreliable markers of response. Persistent bone and disc changes should not be interpreted as treatment failure if clinical and laboratory parameters improve.

No study provided clear guidance on the ideal timing or frequency of follow-up MRI. Most authors agreed that routine MRI is unnecessary in patients with clinical and laboratory improvement. Instead, MRI should be reserved for cases with persistent symptoms, rising ESR or CRP, or suspicion of complications such as epidural abscess, instability, or deformity.

In summary, MRI is indispensable for the diagnosis of PSD but has limited utility in routine follow-up. Clinical improvement and laboratory trends remain the primary indicators of healing. Follow-up MRI should be performed only in patients without improvement or with suspected complications, and its frequency should be individualised. Current evidence is of very low quality, and higher-quality prospective studies are needed to establish standardised protocols.

Question 4.2: In an otherwise clinically stable patient, is MRI evidence of disease progression an indication for surgical intervention in pyogenic spondylodiscitis?

Authors: Yong Hai, Harikrishna Raghuraj Ramasamy

Recommendation: In clinically stable patients, MRI evidence of disease progression alone is not a sufficient indication for surgical intervention. The decision for surgery should be based on a combination of clinical symptoms such as neurological deficit, worsening pain, functional decline, increasing deformity, and failure of conservative management.

Level of Evidence: Low.

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

Rationale: PubMed, Scopus, Web of Science, and related databases were searched. Of 1970 records identified, 381 duplicates were removed and relevant studies that evaluated the role of MRI evidence of disease progression as an indication for surgical intervention in pyogenic spondylodiscitis were scrutinised and qualitatively synthesised. Magnetic Resonance Imaging (MRI) is the gold standard for diagnosing spinal infections, including pyogenic spondylodiscitis, vertebral osteomyelitis, and tuberculous spondylitis. It provides a detailed visualisation of vertebral bodies, discs, and soft tissues, and is indispensable for initial diagnosis. However, its role in guiding surgical intervention in clinically stable patients remains controversial.

Several studies have demonstrated that MRI abnormalities often persist or even appear to worsen despite clinical improvement. Rodriguez-Gomez et al[147] reported that in tuberculous spondylitis, MRI frequently revealed progression in the form of abscesses or deformities, yet many patients remained clinically stable and did not require surgery unless neurological compromise developed. Similarly, Yee et al[148] found that radiological progression in pyogenic and tuberculous spondylitis did not correlate with the need for surgery; clinical deterioration was the decisive factor. Benavent et al[149] emphasised that in vertebral osteomyelitis after instrumentation, MRI evidence of infection or abscess formation did not mandate surgery if patients remained clinically stable, with antibiotics alone often sufficient.

Hunter et al[150] validated the Brighton Spondylodiscitis Score (BSDS) and showed that while MRI often revealed progression, only a minority of clinically stable patients required surgery. Kanayama et al[151] similarly concluded that MRI findings of deformity or abscess in tuberculous spondylitis did not mandate surgery unless accompanied by instability or neurological impairment.

Waheed et al[152] and Zhang et al[153] reinforced that surgery should be reserved for patients with neurological compromise, instability, or failure of conservative management. MRI findings of abscesses or compression were concerning but not sufficient indications for surgery in stable patients. Hadjipavlou et al[154] noted that MRI can reveal non-specific changes that do not always correlate with disease progression, cautioning against over-reliance on imaging. Arnold et al[155] further emphasised that MRI findings must be interpreted in the context of age, comorbidities, and systemic symptoms, rather than driving surgical decisions in isolation.

Taken together, the literature consistently shows that MRI progression alone is not predictive of treatment failure or recurrence. Persistent vertebral oedema, disc space narrowing, or abscesses may be seen long after clinical cure, reflecting the slow resolution of structural changes rather than ongoing infection. Clinical stability, neurological status, and laboratory trends (ESR, CRP) remain the primary determinants of management.

In conclusion, MRI is invaluable for diagnosis and monitoring, but in clinically stable patients, radiological progression should not be the sole trigger for surgery. Surgical intervention should be reserved for patients with neurological deficits, mechanical instability, worsening pain, functional decline, or failure of conservative therapy. MRI findings must be integrated with clinical and laboratory data to guide decision-making, ensuring that surgery is performed only when truly warranted.

Treatment Planning Based on Morphology and Severity

Treatment planning in pyogenic spinal infections must account not only for the microbiological profile and host factors but also for the morphological pattern and severity of disease. The clinical presentation and outcomes vary significantly depending on whether the infection manifests as isolated discitis, spondylodiscitis with vertebral involvement, epidural abscess, or posterior element infection. Each morphology carries distinct risks, therapeutic challenges, and prognostic implications.

Discitis and spondylodiscitis often respond well to prolonged antibiotic therapy, with surgery reserved for instability or neurological compromise. In contrast, epidural abscesses pose a higher risk of acute neurological deterioration due to spinal cord or nerve root compression, frequently necessitating urgent surgical decompression. Posterior element infections, though less common, may mimic other spinal pathologies and require tailored approaches depending on the extent and associated instability.

Severity assessment is equally critical. The presence of abscesses, deformity, or multi-level involvement often dictates more aggressive intervention. Clinical stability, neurological status, and laboratory trends must be integrated with imaging findings to guide individualised treatment. This section explores how morphology influences treatment planning and outcomes, and identifies the key factors that mandate emergency surgery in pyogenic epidural abscess, ensuring timely and appropriate management.

Question 5.1: Does the morphology of the spinal infection (discitis, spondylodiscitis, epidural abscess, posterior infection) determine the planning of treatment and disease outcomes?

Authors: Jonathan Dalton, Kota Watanabe, Siddharth Aiyer, Bhavuk Garg, Jose Miguel Marco T. Lumawig, Ashish Jaiswal

Recommendation 1: Yes, the morphology of the spinal infection (discitis, spondylodiscitis, epidural abscess, posterior infection) determines the planning of treatment and disease outcomes. Discitis: initiate appropriate antibiotics; if no resolution, perform surgical debridement and/or fusion.

Level of Evidence: Low Delegate Vote: Agree – 100%, Disagree – 0%, Abstain – 0% (Unanimous Consensus).

Recommendation 2: Spondylodiscitis: initiate appropriate antibiotics; if no resolution, perform surgical debridement and/or fusion.

Level of Evidence: Low Delegate Vote: Agree – 91.1%, Disagree – 4.4%, Abstain – 4.4% (Unanimous Consensus).

Recommendation 3: Epidural abscess: without neurological compression, conservative management; with neurological involvement, surgical management with adjuvant antibiotics. Epidural abscess at the level of the spinal cord may be treated with spinal debridement.

Level of Evidence: Low Delegate Vote: Agree – 68.9%, Disagree – 8.9%, Abstain – 22.2% (Moderate Consensus).

Recommendation 4: Posterior infection (pyogenic facet joint infection): requires appropriate antibiotics and surgery if necessary.

Level of Evidence: Low Delegate Vote: Agree – 95.6%, Disagree – 0%, Abstain – 4.4% (Unanimous Consensus).

Rationale: A systematic review was conducted across PubMed, Scopus, Web of Science and related database for articles identified 5327 articles of which 750 duplicates were removed, and final articles that assessed how infection morphology (discitis, spondylodiscitis, epidural abscess, posterior element infection) influences treatment planning and outcomes were scrutinised and qualitatively synthesised. The aim was to synthesise evidence on when morphology drives conservative vs surgical management and the choice of approach, and how these decisions affect infection control, deformity correction, neurological recovery, and complications. Spinal infections can involve distinct anatomical compartments, including the intervertebral disc, vertebral body, facet joints, and epidural/paravertebral regions. Morphology strongly influences both treatment planning and outcomes, as each location carries unique risks and therapeutic challenges.

Discitis is typically managed conservatively with immediate initiation of broad-spectrum antibiotics, followed by 4-

8 weeks of targeted therapy once the pathogen is identified.[156,157] Bracing may be used, but is less common than in spondylodiscitis. Surgical debridement and fusion are reserved for patients with neurological deficits, deformity, or refractory disease.[157]

Spondylodiscitis often requires more aggressive management due to greater disease extent. Most guidelines recommend 6-12 weeks of antibiotics, with bracing more frequently employed than in discitis.[106,158] Patients are more likely to fail conservative therapy and require surgery. Both open and minimally invasive endoscopic techniques have shown success, with Giordan et al[159] reporting an 89.4% success rate in thoracolumbar cases. Evidence also suggests that early surgical intervention may reduce treatment failure, mortality, and hospital stay, though most supporting studies are retrospective.[160]

Epidural abscess (SEA) remains controversial. Historically managed with emergent decompression, recent evidence supports conservative therapy in patients without neurological deficits or instability.[156] However, surgery with adjuvant antibiotics remains the standard for those with neurological involvement.[161] Suppiah et al[162] reviewed 1843 patients and found medical management failed in 10-50% of cases, with early surgery being the strongest predictor of improved neurological outcomes. Isolated SEA may be treated with abscess evacuation alone, but combined morphologies or extensive bony destruction may necessitate instrumentation to prevent instability.

Posterior element infections, including pyogenic facet joint infections, are rare but generally have favourable outcomes. Antibiotics remain the cornerstone, typically for 6-8 weeks, with IV therapy during hospitalisation followed by oral agents. Surgery is reserved for patients with persistent symptoms, neurological deficits, mechanical instability, or epidural abscess complications. Mortality is low (~2%), and most patients recover fully.[106,163]

In summary, the morphology of spinal infection is a critical determinant of treatment planning and prognosis. Discitis and spondylodiscitis often begin with antibiotics, escalating to surgery if conservative measures fail. Epidural abscess requires urgent surgical intervention when neurological compromise is present, while posterior infections are primarily managed medically, with surgery reserved for complicated cases. Morphology, therefore, provides a practical framework for tailoring therapy and anticipating outcomes.

Question 5.2: In a patient with a pyogenic epidural abscess, what factors would indicate the need for emergency surgery?

Authors: Mohamed M. Aly, Moses M. Kimani, Hideyuki Arima, Gnanaprakash Gurusamy, S Rajasekaran

Recommendation: Spinal epidural abscess with neurological deficit at presentation should be treated with emergency surgical evacuation.

Level of Evidence: Very Low.

Delegate Vote: Agree – 80% | Disagree – 6.7% | Abstain – 13.3% (Strong Consensus).

Rationale: We performed a systematic review across PubMed, Scopus, Web of Science and related database to identify 3415 records, of which 1037 duplicates were removed and the final articles were evaluated. A pyogenic spinal epidural abscess (SEA) is a collection of purulent material in the epidural space that can rapidly progress to neural compression, sepsis, and death if not managed appropriately. Historically, SEA was considered a neurosurgical emergency, with immediate surgical evacuation recommended to prevent irreversible neurological deficits. The incidence of SEA has increased over recent decades, likely due to ageing populations, diabetes mellitus (DM), and intravenous drug use (IVDU).

With the advent of MRI and improved antibiotic therapy, conservative management has been attempted in selected patients, particularly those without neurological deficits or with high surgical risk. However, medical treatment alone fails in 6-60% of cases, leading to neurological deterioration, sepsis, or mortality. Identifying predictors of medical treatment failure is therefore critical to guide timely surgical intervention.

Nine retrospective studies have evaluated risk factors for failed medical management.[6,115,164-170] Definitions of failure varied but generally included neurological deterioration, persistent pain, radiological progression, lack of improvement in inflammatory markers, or death. Multivariate analyses consistently identified 3 major predictors: 1. Neurological deficit at presentation: the strongest predictor of medical failure, with adjusted odds ratios (aOR) ranging from 2.3 to 15.8. Patients presenting with motor deficits had significantly worse outcomes with medical therapy alone. 2. Diabetes mellitus (DM): independently associated with failure in 5 of 6 studies (aOR 2.4-5.8), likely due to impaired immune response and poor infection control. 3. Methicillin-resistant Staphylococcus aureus (MRSA): associated with higher failure rates (aOR 2.8-4.4), reflecting the virulence and resistance profile of the organism. Other factors linked to poor outcomes included age >65 years, active malignancy, elevated CRP, leukocytosis, and pathological fractures, though these were less consistent across studies.

Clinical evidence strongly supports early surgery in patients with neurological deficits. Patel et al[164] reported that patients who failed medical therapy experienced substantial motor score decline, and neurological recovery after delayed surgery was incomplete compared to immediate intervention.

Thus, neurological deficit at presentation remains the most critical indication for emergency surgery. This is further reinforced by comorbidities such as DM and resistant organisms like MRSA, which independently predict medical treatment failure. Delayed surgery after failed medical therapy often results in incomplete recovery, underscoring the need for prompt surgical evacuation in high-risk patients.

In summary, while conservative management may be appropriate for clinically stable patients without neurological

involvement, emergency surgery is indicated in SEA patients presenting with neurological deficits. DM and MRSA infection further strengthen the case for early surgical intervention. Timely recognition of these predictors is essential to prevent irreversible neurological damage and improve patient outcomes.

Surgical Indications and Techniques

Surgical management of pyogenic spinal infections (PSI) remains one of the most debated aspects of spine surgery. While antibiotics form the cornerstone of treatment, surgery is often required to address instability, deformity, neurological compromise, or persistent infection. The decision to operate, the choice of technique, and the extent of reconstruction are influenced by multiple factors, including the morphology of infection, the severity of bone destruction, and the patient's overall clinical status.

Spinal fixation is frequently considered in cases of instability-related back pain, progressive kyphosis, or vertebral subluxation. However, the threshold for instrumentation and the number of levels required remain controversial. Similarly, the role of anterior reconstruction and 360-degree fixation compared to posterior stabilisation alone is debated, with questions about whether these approaches truly improve outcomes. The choice between bone grafts and cages depends on defect size and biomechanical demands, while incidental intraoperative complications such as dural tears require careful management to prevent morbidity.

Minimally invasive techniques, including endoscopic transforaminal debridement, are emerging as alternatives in selected patients, while damage-control strategies may be necessary in critically ill or septic individuals. Finally, repeat surgical interventions for persistent or recurrent infection highlight the importance of individualised, staged approaches. This section synthesises available evidence and expert consensus to guide surgical decision-making in PSI.

Question 6.1: What is the available evidence for indications for spinal fixation (clinical instability-related back pain, kyphosis angle, vertebral subluxation) in pyogenic spinal infections?

Authors: Sebastian F Bigdon, Nicolas Heinz von der Hoeh, Luiz Gustavo Dal Oglio da Rocha, Edurado Laos Plasier, Takeo Furuya, Takaki Kitamura

Recommendation: Spinal instrumentation is recommended in pyogenic spondylodiscitis when instability, neurological deficits, failure of medical therapy, or risk of deformity is present. It improves infection resolution, pain relief, and spinal alignment without increasing the risk of reinfection.

Level of Evidence: Moderate.

Delegate Vote: Agree – 97.3% | Disagree – 0% | Abstain – 2.7% (Unanimous Consensus).

Rationale: A systematic review using PICOS criteria was undertaken to define indications for spinal fixation in pyogenic spondylodiscitis, specifically clinical instability-related back pain, kyphosis, and vertebral subluxation from screening PubMed, Scopus, Web of Science, and related databases 777 articles were identified, of which 235 duplicates were removed and a total of 29 studies assessing spinal instrumentation in pyogenic spondylodiscitis were reviewed.[130,155,171-183]

Across these studies, instrumented surgery achieved infection resolution in 85-98% of cases, with recurrence rates below 5%. Early surgical intervention yielded slightly higher success rates (92-98%) compared to delayed surgery (85-90%). Patients with prior antibiotic failure achieved clearance in 87-95% of cases. Reinfection rates ranged from 2-6%, comparable to non-instrumented approaches, indicating that fixation does not predispose to recurrent infection.

Indications for instrumentation were consistent across studies. Mechanical instability was the most common indication (50-80%), followed by vertebral body destruction (30-60%) and failure of prior non-instrumented interventions (25-40%). Clinical instability manifested as severe back pain, progressive kyphosis, or vertebral subluxation, all of which were effectively addressed by fixation. Neurological deficits were present in a significant proportion of patients, and early decompression with stabilisation was associated with better motor recovery (75-85%).

Functional outcomes were favourable. Neurological improvement occurred in 70% of patients, with complete recovery in 30-50%. Pain reduction was achieved in 85-95% of instrumented patients compared to 70-85% in non-instrumented groups. Instrumentation facilitated earlier mobilisation, with 80-90% of patients ambulating within 2-4 weeks compared to 60-75% after non-instrumented surgery. Kyphotic deformity was prevented in 85-95% of cases, with superior outcomes observed in anterior-posterior stabilisation compared to posterior fixation alone.

Complication rates were low. Implant-related issues, such as screw loosening, occurred in 3-8%, with a slightly higher risk (5-10%) in patients with widespread infection or preoperative osteomyelitis. Hardware failure was rare, and the benefits of stabilisation outweighed these risks.

Overall, the evidence supports spinal instrumentation as a safe and effective adjunct in the management of pyogenic spondylodiscitis. It provides reliable infection control, restores spinal stability, prevents deformity, and improves pain and function. The presence of instability-related back pain, progressive kyphosis, vertebral subluxation, neurological deficits, or failure of medical therapy should prompt consideration of fixation.

In conclusion, spinal instrumentation should be integrated into surgical planning for pyogenic spondylodiscitis when instability or deformity threatens patient outcomes. When combined with meticulous debridement and appropriate antimicrobial therapy, fixation enhances recovery without

increasing reinfection risk, offering patients improved stability, pain relief, and functional independence.

Question 6.2: What are the indications for 360-degree spinal fixation and anterior reconstruction in pyogenic spinal infections, and does it lead to better outcomes compared to posterior stabilisation alone?

Authors: Baron Zarate-kalfopulos, Sebastian F Bigdon, Klaus John Schnake, Jose Miguel Marco T. Lumawig, Florian Ringel, Sharif Ahmed Jonayed

Recommendation: Anterior reconstruction is indicated when there is severe anterior destruction, instability, kyphotic deformity, abscess formation, or neurological compromise. However, there is conflicting evidence regarding which technique leads to better outcomes.

Level of Evidence: Moderate.

Delegate Vote: Agree – 83.8% | Disagree – 0% | Abstain – 16.2% (Strong Consensus).

Rationale: We conducted a systematic review to determine indications for 360-degree fixation and anterior reconstruction in pyogenic spinal infections and whether these yield superior outcomes to posterior stabilisation alone from screening records in databases such as PubMed, Scopus, Web of Science, and related databases. Two hundred fifty records were identified, of which 90 duplicates were removed, and the final eligible articles were qualitatively synthesised. The management of pyogenic spinal infections often requires surgical intervention when instability, deformity, or neurological compromise is present. The choice between posterior stabilisation alone and combined anterior-posterior (360-degree) fixation with anterior reconstruction remains debated. The anterior approach allows direct debridement of infected tissue, reconstruction of destroyed vertebral bodies, and drainage of paravertebral abscesses, while posterior fixation provides robust stabilisation. The decision is influenced by the morphology of infection, severity of destruction, and patient comorbidities.

Comparative evidence highlights the strengths and limitations of each approach. Wang et al[184] compared 55 patients treated with anterior reconstruction plus posterior fixation to 60 patients treated with posterior fixation alone. They found that anterior intervention was necessary in cases with abscesses or complex infections, but posterior-only surgery yielded fewer complications and better overall outcomes in less severe cases. Similarly, Duan et al[185] (2023) studied lumbar tuberculosis, comparing 73 patients treated with posterior surgery alone to 46 patients treated with combined posterior-anterior surgery. Posterior surgery was less invasive but slower in resolving lesions, while combined surgery achieved faster recovery of abscesses and disease activity at the cost of greater invasiveness.

Correction of deformity is another critical consideration. Safran et al reported that combined anterior-posterior approaches provided superior correction of kyphotic deformity, particularly in thoracolumbar and lumbar regions. Dimar et al,[173] in a case series of 42 patients, demonstrated that anterior debridement and strut grafting provided initial stability and infection control, while delayed posterior fusion enhanced long-term stabilisation and neurological recovery. These findings suggest that anterior reconstruction may be particularly beneficial when deformity correction and structural support are priorities.

Indications for anterior reconstruction consistently include severe anterior vertebral body destruction, mechanical instability with risk of collapse, progressive kyphotic deformity, large paravertebral or anterior abscesses, and neurological compromise due to anterior compression. In contrast, posterior stabilisation alone may suffice in patients with limited anterior involvement, absence of large abscesses, and predominant mechanical instability. Posterior fixation is less invasive, associated with fewer complications, and often adequate for infection control when combined with thorough debridement and antibiotics.

Outcomes across studies show infection resolution rates exceeding 85-95% with either approach, but combined anterior-posterior surgery carries higher morbidity due to invasiveness. Neurological recovery and pain relief are achieved in both groups, though deformity correction is superior with anterior reconstruction. Reinfection rates remain low (<5%) when thorough debridement and appropriate antimicrobial therapy are employed.

In summary, anterior reconstruction and 360-degree fixation are indicated in patients with severe anterior destruction, kyphotic deformity, large abscesses, or neurological compromise. Posterior stabilisation alone is effective in less complex cases, with lower complication rates. Evidence remains conflicting regarding superiority, with combined approaches offering better deformity correction but at the cost of greater invasiveness. Surgical planning should therefore be individualised, balancing the extent of disease, patient comorbidities, and the goals of infection control, stability, and deformity correction.

Question 6.3: What is the criterion or defect size that determines whether bone grafts alone or a cage with bone grafts should be used after debridement?

Authors: Sudhir Ganesan, Aju Bosco, Luiz Gustavo Dal Oglio da Rocha

Recommendation: Non-structural bone grafts can be considered for vertebral height loss <50%, and structural grafts or a titanium mesh cage in more severe cases.

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 the related databases, and 143 records were identified. Of which 37 duplicates were

removed, and all retrieved records were screened to answer the query regarding the criterion or defect size that determines whether non-structural bone grafts alone or structural grafts/titanium cages should be used after debridement in pyogenic spinal infections. The surgical management of pyogenic spondylodiscitis and infective discitis requires a multifaceted approach: thorough debridement of the infectious focus, stabilisation of the spine, decompression of neural elements, and restoration of spinal balance through anterior column support. Anterior reconstruction is particularly important to achieve fusion, maintain stability, and prevent implant failure.[186] The choice of graft material or cage depends mainly on the extent of vertebral destruction and defect size.

Bone grafts used for anterior column support can be broadly categorised into non-structural grafts (granular bone <5 mm), structural grafts (tricortical iliac crest, fibular grafts), and titanium mesh cages. Non-structural grafts are associated with less blood loss, shorter fusion time, and lower donor site morbidity. Structural grafts and titanium cages provide immediate biomechanical stability, effective deformity correction, and high fusion rates. Titanium cages have the added advantage of avoiding donor site morbidity and graft fracture, though they carry risks of subsidence in osteoporotic patients.[187,188]

Evidence regarding defect size thresholds is limited but informative. Xing Du et al[189] reported that non-structural bone grafts are suitable for single-segment lumbar infections when vertebral height loss is <50%, or even slightly greater if cortical continuity is preserved and pedicle screw fixation is possible on at least one side. In their comparative study, granular bone grafts yielded satisfactory outcomes in patients with <50% destruction, while titanium cages and iliac crest grafts were reserved for larger defects.[190]

Kalanjiam et al[191] studied posterior techniques in tuberculous spine infections. They found that deformities >30° required anterior column reconstruction with titanium cages, as posterior shortening alone led to poor bone contact and cord kinking. Titanium cages provided superior deformity correction compared to autologous bone grafts. Gan et al[192] recommended autogenous iliac bone or local bone fragments for defects less than one motor unit of the spine, while titanium cages were appropriate for defects exceeding one motor unit.

Taken together, these findings suggest a practical framework: Vertebral height loss <50%: non-structural bone grafts (granular bone) are sufficient, provided cortical continuity is preserved, and posterior instrumentation can maintain stability. Vertebral height loss >50%, deformity >30°, or defects exceeding one motor unit: structural grafts (tricortical iliac crest, fibular grafts) or titanium mesh cages should be considered to restore anterior column support and prevent collapse. Special considerations: titanium cages are preferred for larger defects due to superior stability and deformity correction, but caution is advised in osteoporotic patients due to subsidence risk. Despite these insights, the literature remains limited, with most studies retrospective and heterogeneous in methodology. Clear, universally accepted criteria for graft selection based on defect size are lacking. Future large-scale prospective studies are needed to establish standardised guidelines.

In summary, defect size and morphology are critical determinants of graft choice after debridement. Non-structural bone grafts are appropriate for vertebral height loss <50%, while structural grafts or titanium cages are recommended for more extensive destruction, multi-segment involvement, or severe deformity. This tailored approach ensures stability, promotes fusion, and minimises complications.

Question 6.4: How many levels of instrumentation/fusion are needed for a single segment of pyogenic spondylodiscitis?

Authors: Roberto Chapa Sosa, Jason Pui Yin Cheung, Koji Tamai, Luiz Gustavo Dal Oglio da Rocha, Jonathan Dalton, Sathish Muthu, Karthik Ramachandran

Recommendation: The current literature suggests that the levels of instrumentation/fusion for a single segment of pyogenic spondylodiscitis should be individualised for each patient, depending upon the extent of vertebral body destruction and patient-specific factors such as osteoporosis.

Level of Evidence: Low.

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

Rationale: This consensus is based on a systematic review of the available literature from PubMed, Scopus, Web of Science, and related databases to yield 6995 records, of which 417 duplicates were removed. Final selected articles on surgical stabilisation in pyogenic spondylodiscitis, synthesising retrospective cohorts and comparative series to guide the extent of instrumentation for a single involved segment, were qualitatively synthesised. Pyogenic spondylodiscitis is a destructive spinal infection that can lead to instability, deformity, and neurological compromise. While many patients can be managed conservatively with antibiotics and bracing, surgery becomes necessary in those who fail medical therapy, develop neurological impairment, form epidural abscesses, suffer intractable pain, or experience progressive vertebral destruction leading to instability or kyphosis. The surgical goals in these patients are thorough debridement of the infectious focus, stabilisation of the involved vertebral segments, and decompression of neural structures. One of the most debated aspects of surgical planning is the number of levels that should be instrumented or fused when treating a single segment of pyogenic spondylodiscitis.

The literature suggests that the extent of instrumentation should be individualised, taking into account the degree of vertebral body destruction, patient age, bone quality, activity level, and whether the infection involves junctional regions of the spine. Zhang and colleagues,[193] in a retrospective study of 27 patients with mono-segmental lumbar and lumbosacral pyogenic spondylodiscitis, demonstrated that monosegmental

posterior instrumentation and fusion provided good outcomes when vertebral height loss was between 25 and 50 per cent. Patients in this group experienced minimal surgical trauma, effective pain relief, neurological recovery, and restoration of spinal stability. Hamed and co-workers[194] compared outcomes in 114 patients with single-level and 58 patients with multilevel pyogenic spondylodiscitis, showing that monosegment posterior stabilisation achieved similar fusion rates in both groups, thereby supporting the safety of limited instrumentation even in multilevel disease. Su and colleagues[195] compared autogenous spinous process grafts with iliac bone grafts for single-segment lumbar pyogenic spondylitis and found no significant differences in fusion rate, mean fusion time, or complications between the 2 groups. Importantly, spinous process grafts were less invasive and associated with reduced donor site morbidity, suggesting that limited fusion can be effective in selected cases.

In contrast, Ishihara and colleagues[196] studied 23 patients treated with minimally invasive spine stabilisation using percutaneous pedicle screws. In their series, posterior instrumentation with 2 levels above and 2 levels below the infected segment was performed in the majority of patients, yielding good clinical and radiological outcomes. However, a subset required additional anterior debridement and bone grafting, highlighting that more extensive fixation may be necessary in cases of severe destruction or deformity. These findings underscore that while monosegmental fixation may suffice in moderate instances, extended fixation is advisable when vertebral destruction is severe, deformity is pronounced, or bone quality is poor, such as in osteoporosis.

Taken together, the evidence indicates that there is no single fixed rule for the number of levels to be instrumented in pyogenic spondylodiscitis. Monosegmental fixation can be adequate when vertebral height loss is limited and bone quality is sufficient. In contrast, extended fixation involving 2 levels above and below the affected segment is recommended in cases of severe destruction, deformity, or compromised bone strength. The decision must be tailored to the individual patient, balancing stability, invasiveness, and comorbidities, with the overarching aim of achieving infection control, pain relief, and functional recovery.

Question 6.5: How to manage an incidental dural tear during surgical debridement of deep spinal infections?

Authors: Joshua Schmirler, Jonathan Dalton, Nelson Astur, Claudius Thome, Karthik Ramachandran, Gnanaprakash Gurusamy, Thayasivam Gobyshanger, Brian Karamian

Recommendation: Primary dural repair is recommended, followed by clinical monitoring and tailored antibiotic therapy.

Level of Evidence: Very low.

Delegate Vote: Agree – 86.1% | Disagree – 2.8% | Abstain – 11.1% (Strong Consensus).

Rationale: A systematic review was conducted using PubMed, Scopus, Web of Science, and the related databases to identify 6995 records, of which 422 duplicates were removed, and the final eligible evidence on the management of incidental dural tears during surgical debridement of deep spinal infections was qualitatively synthesised. Records were screened to clarify optimal strategies for repair, adjunctive measures, and postoperative care. The available literature is minimal, with no high-quality studies directly addressing incidental durotomy in the setting of spinal infection. Most evidence is extrapolated from cranial surgery or general spine surgery, and therefore, recommendations must be interpreted cautiously.

One retrospective study assessing cerebrospinal fluid leaks after craniotomy with intentional durotomy reported 9 patients with bacterial contamination of the CSF, all of whom were successfully treated with prompt dural repair, neuro-ICU monitoring, and tailored antibiotic therapy for 3 to 4 weeks.[197] The authors emphasised the importance of antibiotics capable of penetrating the blood–brain barrier to prevent meningitis and other complications. Although not specific to spinal surgery, this study supports the principle that immediate watertight repair combined with systemic infection control is critical. Beyond this, no direct evidence was found for managing dural tears in the context of local spinal infection.

The technical aspects of dural repair remain debated. Several studies describe primary watertight suturing, either interrupted or running locked, as the gold standard.[198-200] Adjuncts such as grafts, patches, and sealants have been employed to reinforce repairs, particularly for larger or complex tears.[198,200-202] Sealants include synthetic polyethene glycol gels and fibrin glues, while patches range from synthetic absorbable materials to collagen matrices that act as scaffolds for dural fibroblast ingrowth. These adjuncts have been reported to improve leak-free closure, but no comparative evidence exists to define superiority. In practice, the choice of repair method should be tailored to tear size, location, accessibility, and patient factors.

Postoperative management also varies. Bed rest has traditionally been recommended to reduce hydrostatic pressure at the repair site, but its optimal duration is unclear. Some studies found no benefit beyond 24 h and even advocated early mobilisation if no symptoms of persistent CSF leak were present.[199,203] Others reported high success rates with 2 to 4 days of bed rest, though extended immobilisation did not appear necessary.[204] Overall, short-term bed rest followed by cautious mobilisation seems reasonable, provided there are no signs of ongoing leakage.

In summary, the evidence base for managing incidental dural tears during debridement of deep spinal infections is minimal. The consensus recommendation is prompt primary dural repair, ideally watertight, supplemented by grafts or sealants when necessary. Postoperative care should include close clinical monitoring, tailored antibiotic therapy with agents that penetrate the blood–brain barrier, and short

periods of bed rest with early mobilisation if repair integrity is maintained. Given the paucity of spine-specific data, further prospective studies are needed to establish standardised protocols for this challenging scenario.

Question 6.6: What is the role of endoscopic transforaminal debridement in pyogenic spinal infections?

Authors: Cristiano Magalhaes Menezes, Jorge H. Nunez, Nelson Astur, Muzahem M Taha, Sathish Muthu, Katsuhisa Yamada

Recommendation: Transforaminal endoscopic debridement appears to be a safe and potentially effective surgical option in carefully selected patients with pyogenic spondylodiscitis, especially in early-stage, localised infections without structural instability.

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 the related databases to identify 1613 articles. After removal of 454 duplicates, all eligible records were screened to evaluate the role of transforaminal endoscopic debridement in pyogenic spondylodiscitis. The aim was to assess its safety, effectiveness, and limitations compared to conventional open approaches.

Transforaminal endoscopic surgery has emerged as a minimally invasive technique for debridement in pyogenic spondylodiscitis. Early reports suggest that this approach allows adequate drainage, pathogen identification, and symptomatic relief with reduced surgical morbidity. However, the current evidence base is limited, with most studies being retrospective, lacking control groups, and involving heterogeneous patient populations. While some comparative studies report advantages over traditional open approaches in selected cases, concerns remain regarding high reoperation rates, limited ability to correct spinal deformity, and the absence of long-term data on fusion and recurrence.

Pyogenic spondylodiscitis is often managed conservatively with antibiotics in early stages, but surgery becomes necessary in the presence of abscesses, neurological compromise, instability, or failed medical therapy. Open anterior or posterior debridement, with or without fusion, has long been considered the standard surgical approach. Endoscopic techniques, particularly via the transforaminal route, have been increasingly described as alternatives aimed at reducing perioperative morbidity and accelerating recovery.

Initial case series of percutaneous endoscopic debridement and drainage (PEDD) report satisfactory outcomes, including successful pathogen identification in 72-87.5% of cases and pain relief in most patients.[205-209] Meta-analyses suggest low complication rates (4-8%) and mortality (<2%), along with significant postoperative reductions in CRP, ESR, and disability scores.[207,210] However, these studies are overwhelmingly retrospective, and no randomised controlled trials exist to date.

Comparative studies indicate that PEDD may result in lower blood loss, shorter hospital stays, faster normalisation of inflammatory markers, and fewer complications than traditional open anterior surgery.[211] Nonetheless, PEDD has limitations in addressing spinal instability and correcting deformity. Reoperation rates in some series reach 20% or more, particularly in patients with advanced bone destruction or early ambulation protocols.[207,210]

To overcome these limitations, newer strategies such as percutaneous endoscopic interbody debridement and fusion (PEIDF) have been developed, combining endoscopic debridement with bone grafting and posterior instrumentation. A comparative study reported lower reoperation rates (8.3% vs 58.3%) and better kyphosis correction with PEIDF compared to PEDD, though the sample size was small and subject to selection bias.[211]

Overall, despite growing interest and promising short-term results, the quality of evidence supporting transforaminal endoscopic debridement in pyogenic spondylodiscitis remains low. Few studies provide long-term follow-up or radiographic data on fusion or recurrence, and most fail to stratify outcomes by infection severity or spinal level.

In conclusion, transforaminal endoscopic debridement appears to be a safe and potentially effective surgical option in carefully selected patients, particularly those with early-stage, localised infections without structural instability. However, the current literature is insufficient to support its widespread adoption as a standard treatment. Until high-quality prospective or randomised studies are available, PEDD and related endoscopic techniques should be considered complementary tools in the surgeon's armamentarium, best reserved for patients with specific anatomical and clinical profiles where the benefits of a minimally invasive approach outweigh its limitations.

Question 6.7: Is there a damage control surgery in sick patients with PSI, or should we do extensive debridement with instrumentation when the patient is very ill/septic?

Authors: Saumyajit Basu, S Rajasekaran, Andreas K. Demetriades, Florian Ringel, Vikas Hanasoge, Ayon Ghosh

Recommendation: There is a role for minimally invasive procedures to perform debridement with or without stabilisation in this select group of patients.

Level of Evidence: Low.

Delegate Vote: Agree – 87.1% | Disagree – 0% | Abstain – 12.9% (Strong Consensus).

Rationale: A systematic review was conducted using PubMed, Scopus, Web of Science, and the related databases to identify 1816 records. After removing 287 duplicates, the remaining records were screened to evaluate the role of damage control surgery vs extensive debridement with instrumentation in critically ill or septic patients with pyogenic

spinal infections. The aim was to determine whether minimally invasive procedures could serve as a safer alternative in this high-risk population.

The available literature is sparse, and no single study directly addresses the specific question of damage control surgery in septic PSI patients. However, several techniques have been described that provide insight into less invasive strategies. Local antibiotic instillation into the disc space via a drain for 2 weeks has been reported in a small series of twelve spondylodiscitis patients, demonstrating feasibility and infection control.[212] Similarly, Hijazi et al[213] studied daily local antibiotic lavage using an epidural suction–irrigation technique in spondylodiscitis and isolated epidural empyema, reporting encouraging results. These approaches highlight the potential of localised therapy to reduce systemic burden in critically ill patients.

Endoscopic surgery has also been reported as a safe option for infectious spondylodiscitis in the thoracic and lumbar spine.[214] This minimally invasive technique allows for culture sampling, targeted debridement, and adequate drainage, while reducing surgical morbidity. Early reports suggest good clinical outcomes and high pathogen identification rates.[159] However, its cost-effectiveness has not been studied, and widespread adoption remains limited, particularly in low- and middle-income countries.

Taken together, the evidence suggests that in very ill or septic patients, extensive debridement with instrumentation may carry prohibitive risks. In such cases, minimally invasive or staged procedures, including local antibiotic instillation, suction–irrigation techniques, or endoscopic debridement, can serve as damage control strategies. These approaches allow infection control and stabilisation while minimising physiological stress, with definitive reconstruction deferred until the patient's condition improves.

In conclusion, while high-quality evidence is lacking, the consensus supports the role of minimally invasive procedures as damage control surgery in critically ill patients with pyogenic spinal infections. These techniques provide a bridge to definitive treatment, balancing infection management with patient safety.

Question 6.8: What are the indications for repeat surgical interventions for debridement in cases of persistent or recurrent infection?

Authors: Joshua Schmirler, Marco G.A Teli, Hideaki Imabayashi, Brian Karamian

Recommendation: Local wound factors that dictate the need for repeat debridement are persistent wound drainage, abscess formation, wound dehiscence, and/or necrotic tissue in the wound bed.

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 the related databases to identify 562 records. After removal of 101 duplicates, eligible records were screened to evaluate the indications for repeat surgical debridement in cases of persistent or recurrent spinal infection. The aim was to identify clinical, microbiological, and temporal factors that necessitate serial interventions beyond initial debridement.

Post-operative spinal infections can be destructive, and prompt management with surgical debridement and antibiotic therapy is essential. However, some cases require more aggressive treatment, with multiple debridements before delayed wound closure. Clinical factors consistently associated with the need for repeat debridement include persistent purulent drainage, abscess formation, wound dehiscence, and necrotic tissue in the wound bed.[215-217] In contrast, the absence of necrosis and the presence of healthy granulation tissue, indicative of healing, should prompt closure without further debridement.[218]

Microbiological factors also play a role. Infections caused by aggressive pathogens such as methicillin-resistant Staphylococcus aureus (MRSA) or polymicrobial infections are more likely to require repeated irrigation and debridement.[219] Although the overall incidence of MRSA remains low, studies report that its presence is a primary driver of repeat interventions. This does not mean that MRSA infection always necessitates serial debridements, but rather that close monitoring for wound factors is critical, and surgeons should be prepared for additional procedures if deterioration occurs.

The timing of diagnosis is another determinant. Indolent infections may go unnoticed due to vague symptoms such as fever or pain, which can be misattributed to other causes. Delayed recognition allows bacterial replication and progression, resulting in more severe infection at the time of diagnosis and a higher likelihood of requiring multiple debridements.[220]

It is essential to distinguish between deep and superficial infections. The recommendation for repeat debridement applies primarily to infections located deep to the fascia. Superficial infections may not require aggressive treatment, and retrospective data suggest that acute superficial infections often resolve after a single debridement.

In summary, repeat surgical debridement in spinal infections should be considered when local wound factors such as persistent drainage, abscess, dehiscence, or necrosis are present, when aggressive pathogens such as MRSA or polymicrobial infections are involved, or when diagnosis is delayed, and infection severity is advanced. Conversely, evidence of healing with granulation tissue supports wound closure without further intervention. These principles provide a practical framework for tailoring surgical management in cases of persistent or recurrent infection.

Adjuncts in Surgical Management

Beyond debridement and stabilisation, adjunctive measures play an increasingly important role in optimising outcomes

for patients with pyogenic spinal infections. These strategies aim to enhance infection control, improve implant stability, and support wound healing, particularly in complex or high-risk cases. Local antibiotic delivery, either in powder form or via cement beads, has been explored as a means of achieving high drug concentrations at the site of infection while minimising systemic toxicity. Similarly, the integration of antibiotics into bone grafts or cages raises the question of whether this approach can accelerate healing and reduce recurrence.

Bone quality is another critical factor influencing surgical outcomes. Osteoporosis, common in elderly and comorbid patients, compromises fixation strength and increases the risk of implant failure. Cement-augmented screws have been proposed as a solution, but their safety and efficacy in the setting of active infection remain debated.

Finally, wound management technologies such as vacuum-assisted closure (VAC) devices have gained traction in reducing bacterial load, promoting granulation tissue formation, and facilitating secondary closure in infected surgical sites. This section reviews the available evidence on these adjuncts, clarifying their indications, benefits, and limitations, and providing consensus recommendations for their selective use in the surgical management of pyogenic spinal infections.

Question 7.1: What is the role of local vancomycin powder after surgical debridement? Does the use of antibiotic powder mixed with the bone grafts enable better disease healing?

Authors: Reuben CC Soh, Sebastian F Bigdon, Tan Jiong Hao Jonathan, Muralidharan Venkatesan, Koji Tamai, Yoshiharu Kawaguchi

Recommendation: Local vancomycin powder is generally safe and well-tolerated in spinal infections. However, there is a lack of literature to support its efficacy.

Level of Evidence: Moderate.
Delegate Vote: Agree – 87.9% | Disagree – 3.0% | Abstain – 9.1% (Strong Consensus).

Recommendation: There is no evidence to show that mixing topical vancomycin powder with bone graft alters healing in patients with infective spondylodiscitis.

Level of Evidence: Moderate.
Delegate Vote: Agree – 90.9% | Disagree – 3.0% | Abstain – 6.1% (Unanimous Consensus).

Rationale: A systematic review was conducted using PubMed, Scopus, Web of Science, and the related databases to yield 1816 records. Of these, 282 duplicates were removed, and eligible records were screened to evaluate the role of local vancomycin powder after surgical debridement in pyogenic spinal infections, as well as its potential impact when mixed with bone grafts. The aim was to determine whether local antibiotic application improves infection eradication, fusion rates, and overall healing outcomes.

Spinal infections remain challenging to manage, with wide variations in practice and no global consensus. The mainstay of treatment is culture-directed systemic antibiotics, with surgery indicated for neurological deficits, instability, or failure of conservative therapy. Local antibiotic therapy has shown promise in orthopaedic infections, and vancomycin is often considered ideal given its activity against Staphylococcus aureus, the most common pathogen in pyogenic spondylodiscitis.

Despite widespread use in orthopaedic surgery, the role of vancomycin powder in spinal infections is less clear. Concerns have been raised about pseudoarthrosis and impaired fusion at high local concentrations, given the unique requirement for spinal fusion compared to arthroplasty. A retrospective cohort study by Slavnic et al[221] reported an 81.8% fusion rate across 66 levels when PMMA beads impregnated with vancomycin and tobramycin were used, along with significant pain improvement, though long-term outcomes were limited by short follow-up.

Animal studies provide mixed results. Shiels et al[222] demonstrated reduced fusion rates when vancomycin-infused demineralised bone matrix (DBM) was used alone, while Hanson et al[223] reported inhibitory effects of vancomycin on osteogenic differentiation of rat mesenchymal stem cells. However, Shiels also showed that combining vancomycin-infused DBM with iliac crest bone graft improved fusion outcomes in rabbits inoculated with Staphylococcus aureus. Yang et al[224] reported lower definitive fusion rates (67.6%) with vancomycin-infused calcium sulfate beads in transforaminal lumbar interbody fusion, though infection eradication was achieved and functional outcomes improved significantly.

Taken together, the evidence suggests that local vancomycin powder is safe and well tolerated, but its efficacy in improving outcomes after spinal debridement remains unproven. Moreover, there is no evidence to support that mixing vancomycin powder with bone graft enhances healing in infective spondylodiscitis. Concerns about impaired fusion persist, and current data are insufficient to recommend routine use of vancomycin-graft combinations.

Question 7.2: Is there a role for local antibiotic cement bead application in improving outcomes after debridement in pyogenic spondylodiscitis?

Authors: Harvinder Singh Chhabra, Dilip Chand Raja Soundararajan, Ajoy Prasad Shetty, Naresh Babu J

Recommendation: When used alongside thorough debridement and systemic antibiotics, local antibiotic cement beads reduce spinal surgical site infection recurrence.

Level of Evidence: Moderate.
Delegate Vote: Agree – 60.6% | Disagree – 12.1% | Abstain – 27.3% (Moderate Consensus).

Rationale: A systematic review was conducted using PubMed, Scopus, Web of Science, and the related databases

to identify 254 records. Of these, 42 duplicates were removed, and eligible records were screened to evaluate the role of local antibiotic cement bead application in improving outcomes after debridement in pyogenic spondylodiscitis. The aim was to determine whether cement beads enhance infection control, reduce recurrence, and improve healing compared to systemic antibiotics alone.

Surgical site infection (SSI) is a significant complication following spine surgery, with reported prevalence ranging from 1% to 10% depending on patient comorbidities, surgical technique, and instrumentation. Deep infections are particularly devastating, leading to hardware failure, multiple revision surgeries, prolonged hospitalisation, and even mortality. Risk factors include prolonged operative time, blood loss, revision procedures, diabetes, smoking, obesity, and immunosuppression.

Polymethyl methacrylate (PMMA) remains the most commonly used carrier for antibiotic beads, though newer bioabsorbable materials such as calcium sulfate and calcium phosphate have been developed. Calcium sulfate provides rapid antibiotic elution, while calcium phosphate offers more potent mechanical properties.[225] A key limitation of PMMA is that retained beads can act as a nidus for bacterial growth, with studies showing low-level antibiotic release for up to 5 years, potentially contributing to multidrug resistance.[226] Bioabsorbable carriers such as hydrogels, ceramics, and fibrin-coated beads avoid the need for removal but have shorter elution durations.[227]

Release kinetics depend on solubility, porosity, diffusivity, and bead diameter.[228] Vancomycin, teicoplanin, daptomycin, and tobramycin are among the most effective antibiotics used, though heat stability must be considered when selecting agents for PMMA. Prospective studies have demonstrated that antibiotic-loaded beads achieve high local concentrations at the infection site, surpassing systemic therapy alone, while minimising systemic toxicity. This targeted approach reduces microbial load and enhances healing.[228]

Clinical evidence supports their adjunctive role. Viswanathan et al[226] reported reduced recurrence rates in vertebral osteomyelitis and discitis with local antibiotic beads, while Edelstein[229] and Savas[230] highlighted their effectiveness when combined with thorough debridement, systemic antibiotics, and wound care. However, complications such as nephrotoxicity, neurotoxicity, drug fever, and superadded infections have been reported, particularly with PMMA beads left in situ. Bioabsorbable carriers mitigate these risks but may require further validation.

In summary, local antibiotic cement beads provide high local antibiotic concentrations, reduce recurrence rates, and support healing when used alongside systemic therapy and meticulous debridement. PMMA remains widely used but carries risks of bacterial colonisation and prolonged low-level elution, while bioabsorbable alternatives offer promising safety advantages. Their use should be individualised, guided by infection severity, pathogen sensitivity, and patient comorbidities, with careful monitoring for potential complications.

Question 7.3: Does osteoporosis influence the outcomes after surgical fixation, and can cement-augmented screws be used in the presence of pyogenic spinal infections for better implant purchase?

Authors: Sebastian F Bigdon, Muzahem M Taha, Tadatsugu Morimoto, Stefano Conti, Hirohito Hirata

Recommendation: Osteoporosis highly influences surgical fixation outcomes in pyogenic spinal infections, necessitating careful preoperative planning. The current literature does not show sufficient evidence to support the use of cement-augmented pedicle screws in pyogenic spondylodiscitis.

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 the related databases to identify 1401 records. Of these, 175 duplicates were removed, and eligible records were screened to evaluate the impact of osteoporosis on surgical fixation outcomes in pyogenic spinal infections, as well as the potential role of cement-augmented pedicle screws in improving implant purchase. The aim was to clarify whether augmentation strategies can safely and effectively be applied in this setting.

Pyogenic spinal infections are increasingly encountered in patients presenting with back pain or neurological deficits. While conservative treatment with bed rest and long-term antibiotics remains the standard of care, surgery becomes mandatory in cases of spinal instability, epidural abscess, intolerable pain, or failure of medical therapy. Osteoporosis, particularly prevalent in patients between 50 and 70 years of age, complicates surgical management by reducing bone quality and increasing the risk of fixation failure. Several studies have demonstrated adverse outcomes associated with osteoporosis, including catastrophic implant failure. Gupta et al[231] reported a higher risk of revision surgery in osteoporotic patients, while Bejerke et al[232] found a direct correlation between osteoporosis and implant-related complications.

Cement augmentation of pedicle screws using polymethyl methacrylate (PMMA) has been shown to increase pullout strength by 1.5-2 times compared to non-cemented screws. It has been validated in degenerative, deformity, and oncological settings.[233] However, very few studies have investigated its safety and utility in spinal infections. Gao and Yang[234] reported favorable outcomes with cement-augmented screws in elderly patients with spinal tuberculosis and concomitant osteoporosis, suggesting potential utility in infectious settings. Yet, no studies have specifically addressed their use in pyogenic spondylodiscitis.

PMMA has been explored for anterior column reconstruction in pyogenic infections. Deml et al[235] demonstrated

the safety and efficacy of PMMA in intervertebral spaces for 73 patients with pyogenic spondylodiscitis. At the same time, Banse et al[171] reported positive outcomes using antibiotic-impregnated PMMA for anterior reconstruction. Isolated case reports, such as those by Soei Asuka,[236] describe successful use of cement-augmented pedicle screws with titanium mesh cages in elderly patients with pyogenic spondylitis and osteoporosis. However, these remain anecdotal, with small sample sizes and no long-term follow-up.

Concerns persist regarding the use of cement augmentation in pyogenic infections. Potential risks include difficulty eradicating infection, PMMA leakage, and the possibility of cement acting as a nidus for persistent bacterial colonization. While PMMA has demonstrated utility in reconstruction, its role in pedicle screw augmentation for pyogenic spondylodiscitis remains unproven.

In summary, osteoporosis significantly influences surgical fixation outcomes in pyogenic spinal infections, increasing the risk of implant failure and revision surgery. Cement augmentation of pedicle screws has demonstrated biomechanical advantages in other spinal conditions, but current evidence is insufficient to support its routine use in pyogenic spondylodiscitis. Further prospective studies are needed to establish safety, efficacy, and long-term outcomes before cement augmentation can be recommended in this setting.

Question 7.4: Do vacuum-assisted closure devices have a role in the treatment of spinal infections post debridement?

Authors: Tan Jiong Hao Jonathan, Ahmet Alanay, Shree Kumar Dinesh, Jonathan Koh Ern Juan, Koji Yamada, Nelson Astur, Natsumi Saka, Takeo Furuya

Recommendation: Available literature shows that there is a role and safety in the usage of vacuum-assisted closure in the treatment of spinal infections post debridement, but further validation is necessary.

Level of Evidence: Low.

Delegate Vote: Agree – 93.8% | Disagree – 3.1% | Abstain – 3.1% (Unanimous Consensus).

Rationale: A systematic review was conducted to study the role of vacuum-assisted closure (VAC) devices following debridement of spinal infections. PubMed, Web of Science, ClinicalTrials.gov, and Scopus were searched from inception until December 1, 2024, for original articles reporting VAC use in this context. Studies were included if they compared VAC combined with other wound management techniques vs alternative wound management strategies alone. Non-English publications, case reports, reviews, registry-based studies, and studies on tubercular spondylodiscitis were excluded. Of 496 records screened, 107 duplicates were removed, 49 underwent full-text review, and 5 retrospective studies met the inclusion criteria. These provided level IV evidence, comparing VAC to other wound management techniques in adult patients with deep surgical site infections after spinal surgery. Outcomes assessed included number of procedures, implant retention, recurrence of disease, hospitalization duration, and cost.

Negative pressure wound therapy with VAC devices has shown promise by improving local blood flow, promoting granulation tissue, and creating a favourable microenvironment for healing in spinal infection.

Comparative studies provide mixed results. Wang et al[237] found that VAC significantly reduced recurrence, implant removal, and hospital stay compared to standard debridement with drains. Li et al[238] reported fewer procedures and shorter hospital stays with VAC in cervical spine infections, though recurrence and implant removal rates were similar. Yuan et al[239] and Zeng et al[240] compared VAC with continuous irrigation suction systems (CISS), finding no significant differences in recurrence or implant removal. However, CISS was associated with lower costs and fewer reoperations. Shi et al[241] showed that combining superficial VAC with CISS reduced reoperations and hospital stay, but increased costs.

A pooled analysis demonstrated that VAC significantly reduced hospital stay compared to standard debridement and drains. Still, no consistent differences were observed in recurrence or implant removal when compared to CISS or other methods.[242] Evidence in pediatric patients and in primary spinal infections is limited. While case series suggest VAC can be safely used even with exposed dura, no definitive recommendations can be made.

Overall, the available literature suggests that VAC therapy is safe and may reduce hospital stay and recurrence in selected patients with deep spinal infections post debridement. However, the evidence is limited by small sample sizes, retrospective design, heterogeneous outcomes, and methodological weaknesses. Further prospective studies are required to validate its role and establish standardised protocols.

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, and while PRISMA guidelines were followed with search strategies provided in supplementary material, 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. Finally, surrogate markers such as CRP and ESR were used to guide treatment response without validated correlation to definitive

outcomes. 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 PSI. Despite the heterogeneity and generally low to moderate levels of evidence, several consistent principles emerge.

The importance of accurate diagnosis, timely initiation of culture-directed antibiotics, and individualised decision-making regarding surgical intervention was emphasised. Surgical indications are driven by instability, deformity, neurological compromise, and failure of conservative therapy, with fixation strategies tailored to the extent of vertebral destruction. Grafting criteria recommend non-structural grafts for <50% vertebral height loss and structural grafts or cages for larger defects. Instrumentation levels should be individualized, ranging from monosegmental fixation in moderate cases to extended constructs in severe destruction or osteoporosis. Intraoperative complications such as dural tears require prompt watertight repair, monitoring, and tailored antibiotics. Minimally invasive and staged approaches, including endoscopic debridement and damage-control strategies, may be considered in selected cases, while repeat debridement is indicated in persistent infection. Adjuncts such as local vancomycin powder and antibiotic cement beads may reduce recurrence, though evidence remains limited; osteoporosis significantly influences fixation outcomes, but cement-augmented screws lack validation in PSI; and vacuum-assisted closure devices appear safe and effective but require further study.

In summary, meticulous debridement, systemic antibiotics, and individualised fixation remain the cornerstones of PSI surgical management. Adjunctive measures show promise but should be considered complementary. Future multicenter prospective studies are essential to establish standardised, evidence-based protocols that optimise infection control, stability, and patient outcomes.

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Supplemental Material

Supplemental material for this article is available online.

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