Global Spine Journal
2026, Vol. 16(3S) 14S-26S
© The Author(s) 2026
Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/21925682261442201
journals.sagepub.com/home/gsj

Methodological Framework for Global Expert Consensus on Musculoskeletal Infection: Establishing the ICM 2025 Recommendations

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

Abstract

Study Design: Multiphase methodological framework for international consensus development.

Objective: This study describes the structured methodology adopted by the International Consensus Meeting on Infection - ICM 2025 (Spine Section) to formulate globally endorsed recommendations in musculoskeletal infection. The initiative aimed to standardise best practices in prevention, diagnosis, and management through a collaborative, evidence-driven process.

Methods: The consensus was developed through an 11-phase process spanning over 2 years, involving more than 100 global experts in orthopaedic infection. Phases included expert selection, question generation and ranking, systematic evaluation, literature synthesis, inter-delegate discussions, and a final face-to-face meeting. Recommendation statements were refined via iterative feedback and consensus-building techniques, including asynchronous dialogue and voting thresholds. Delegates were selected based on academic merit and regional representation, ensuring a diverse and multidisciplinary panel. Structured timelines ensured transparency and accountability across all phases.

Results: The outcome was a series of actionable, context-sensitive recommendations, reflecting high-level agreement across diverse healthcare settings. The methodology facilitated consensus on complex infection scenarios where definitive evidence was lacking, incorporating expert judgment and current literature.

Conclusion: The ICM 2025 (Spine Section) framework demonstrates a robust model for consensus development in orthopaedic surgery. Its transparent and scalable design ensures reproducibility for future topics requiring global guidance. This methodology sets a precedent for collaborative guideline generation in musculoskeletal care.

Keywords

international consensus meeting (ICM), musculoskeletal infection, orthopaedic guidelines, expert consensus, multiphase methodology, evidence-based recommendations, global collaboration

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

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

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

Introduction

Musculoskeletal infections, encompassing a spectrum of conditions from postoperative site infections to complex spinal pathologies, remain a persistent challenge in orthopaedic surgery.[1] Their rising incidence globally, coupled with wide clinical variability in presentation and progression, has exposed the limitations of standardised treatment protocols.[2] Among these, spinal infections, particularly tuberculous and pyogenic spondylodiscitis are fraught with diagnostic ambiguities, therapeutic controversies, and considerable risk of neurological morbidity and functional impairment.[3,4] Despite advancements in imaging modalities, microbiological diagnostics, and surgical technology, orthopaedic practitioners often face dilemmas that are under-supported by definitive evidence, highlighting the need for globally unified recommendations rooted in both science and expert experience.

Recognising this critical gap, the International Consensus Meeting on Infection ICM 2025 (Spine Section) was founded with the mission of orchestrating a collaborative framework through which leading experts in orthopaedic infection could converge, deliberate, and generate actionable, evidence-informed recommendations. The ICM 2025 (spine section) model aims synthesise prevailing literature but also to create a reproducible structure for global consensus development that accommodates geographic diversity, clinical nuance, and multidisciplinary insights.

The Infection ICM 2025 (Spine Section) meeting held in Istanbul represented a landmark initiative, bringing together more than 100 orthopaedic surgeons, infectious disease specialists, microbiologists, spine surgeons, and researchers from all over the world. Compared to prior ICM consensus efforts (eg, 2018), the 2025 process introduced several methodological advances, including centralised literature screening, refined consensus grading thresholds, and broader global participation spanning 33 countries. These innovations improved transparency, reproducibility, and implementability of recommendations. Further, the earlier ICM work in 2018 was non-specific or mostly on an arthroplasty background, and the current work is exclusively on spine infections, which makes it more relevant to the spine surgeons to aid in clinical practice decisions related to spinal infections. The central theme of this iteration focused on spinal infections, specifically tuberculous and pyogenic spondylodiscitis, owing to their distinct pathogenetic pathways, contrasting epidemiological burdens, and clinical decision-making complexity. Tuberculous spondylodiscitis remains endemic in several regions, yet lacks uniform guidelines on diagnosis and therapeutic duration.[3,5] Pyogenic infections, while more frequently encountered in developed healthcare systems, suffer from diagnostic delays, empirical treatment practices, and surgical controversies.[4,6] The dual-pathogen framework of this consensus allowed for parallel development of recommendations while respecting the unique considerations each domain presents.

To ensure transparency, reproducibility, and academic rigour, the ICM 2025 (Spine Section) adopted a multiphase methodology that spanned over 2 years and included a series of structured processes. Each phase was time-bound, with clear objectives and deliverables, facilitating accountability and ensuring broad participation. By structuring the work into these well-defined phases, the ICM 2025 (Spine Section) ensured the outcome of this effort is of practical usability for clinicians worldwide. Each recommendation carries not just the weight of evidence but the collective judgment of an internationally representative expert group. This paper seeks to document the full methodology behind the ICM 2025 (Spine Section) meeting from inception to final consensus with the intention of enabling reproducibility for future disease domains. This ICM 2025 (Spine Section) framework provides a scalable template for future consensus efforts in musculoskeletal care, aligning academic rigour with clinical realities across diverse healthcare landscapes.

Methodological Overview

ICM 2025 (Spine Section) Consensus

The ICM 2025 (Spine Section) was convened under the leadership of Prof. S. Rajasekaran (India), as delegated by the central ICM committee. The initiative aimed to develop globally applicable, evidence-informed recommendations addressing 2 key domains: tuberculous and pyogenic spondylodiscitis. A rigorous 11-phase methodology was employed to ensure transparency, inclusiveness, and academic rigour as shown in Figure 1.

Phase I: Delegate Identification

A preliminary list of international spine experts comprising key opinion leaders, researchers, and clinicians was curated using academic databases and guidance from regional representatives. The selection emphasised geographic diversity and scholarly credibility. Eligibility criteria included peer-reviewed publications in spinal infection, a minimum of 5 years of clinical experience, and representation across geographic regions and disciplines (spine surgery, infectious disease, microbiology, radiology). Conflicts of interest were declared at the outset, and delegates with relevant conflicts were recused from voting on affected questions.

Phase II: Invitation & Commitment Confirmation

The spine section leadership sent formal invitations to shortlisted experts. Delegates were informed about the scope of engagement, including responsibilities for evidence synthesis and compulsory participation in the face-to-face consensus meeting in Istanbul.

Phase III: Clinical Question Collection

Participating delegates were requested to submit up to 10 clinically relevant questions on spinal infections

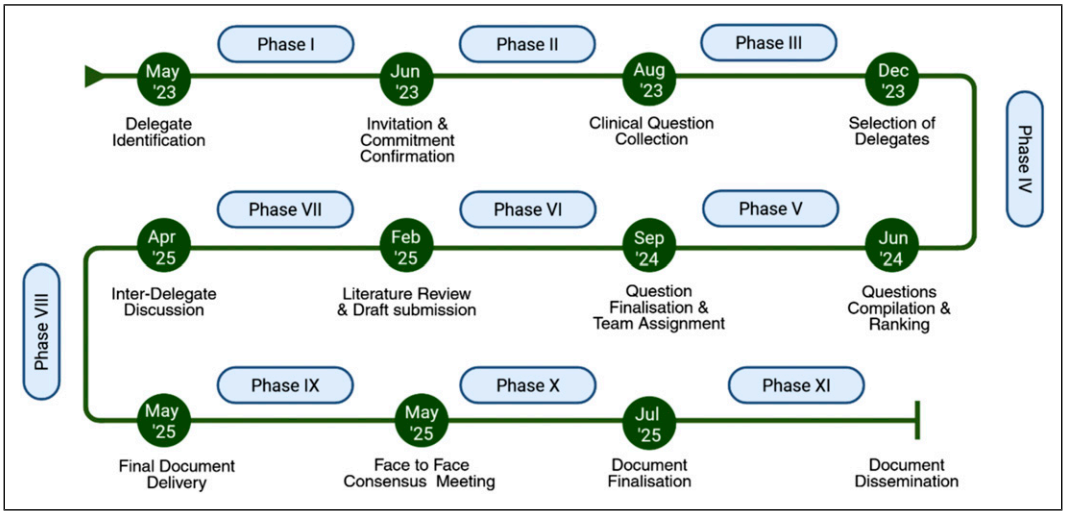


Figure 1. Phases of events followed in ICM 2025 (Spine Section)

encompassing both tuberculous and pyogenic spondylodiscitis that they believed required evidence-based guidance. These questions reflected areas of practical uncertainty in global spine care.

Phase IV: Compilation & Ranking of Questions

All submitted questions were compiled, de-duplicated, and structured into a unified list. This consolidated list was circulated among delegates for ranking. Questions were ranked using a standardised scoring instrument (scale 1-10) based on clinical relevance, feasibility, and impact. Tie-breaking was resolved by median score and, if needed, discussion within the core committee.

Phase V: Finalisation of Questions & Thematic Segregation

Questions receiving higher rankings were shortlisted. These were refined for clarity, reformulated using PICO principles, and organised into thematic domains. The resulting structure formed the backbone for both the Tuberculous and Pyogenic Spondylodiscitis sections.

Phase VI: Open Call for Collaboration

An open invitation was extended to delegates for participation in the evaluation of specific questions. Experts could opt to serve as either liaisons responsible for coordinating collaborators and finalising the recommendation draft or as collaborators who would engage in literature review and discussion under each question. Each question was supported by 1 liaison and 3-5 collaborators. Experts were limited to a maximum of 3 questions to ensure focused contribution.

Phase VII: Team Formation & Assignment

Following expert preferences and strategic allocation, teams were assigned to each question. This established the functional working groups responsible for conducting evidence synthesis and recommendation drafting.

Phase VIII: Literature Review & Data Synthesis

Under the oversight of the ICM 2025 (Spine Section) core committee, each team conducted a systematic search of databases including PubMed, Scopus, Web of Science, and https://ClinicalTrials.gov. Searches were limited to studies published from inception till December 31, 2024 and available in English or with available translations. Grey literature was considered, if peer-reviewed or indexed. Each question was formatted into the PICO structure, and a centralised uniform literature search was made by the ICM 2025 (Spine Section) core committee in February 2025. The search records under each question were managed using the Rayyan platform[7] for centralised screening. Each question with the allotted liaison and the team of collaborators was invited to their respective questions by the ICM Spine core committee to proceed with the screening process. The screening process consisted of deduplication, title and abstract screening, followed by full-text screening to identify the relevant studies for further analysis. Reviews adhered to PRISMA guidelines. Inclusion criteria comprised peer-reviewed clinical studies, systematic reviews, and meta-analyses addressing spinal infection. Exclusion criteria included case reports, non-English publications without translation, and studies lacking extractable data. Risk-of-bias was assessed using appropriate tools per study design (eg, Cochrane RoB2 for RCTs, Newcastle-Ottawa Scale for observational studies), and QUADAS-2 for diagnostic accuracy studies. Where sufficient homogeneous data existed, meta-analyses were performed; otherwise, synthesis

was narrative. Disagreements during evidence appraisal were resolved through structured team discussion, with the liaison adjudicating and escalation to the ICM 2025 (Spine Section) core committee if consensus was not reached.

Phase IX: Online Discussion & Document Posting

Draft documents and recommendations were uploaded to the ICM website for review. Inter-delegate discussions occurred asynchronously to refine recommendations, address conflicts, and build preliminary consensus ahead of the final meeting. Disagreements during asynchronous phases were resolved through structured moderation with defined timelines. Sensitivity analyses were performed by excluding low-attendance votes to confirm robustness of consensus outcomes.

Phase X: Face-to-Face Consensus Meeting

The consensus meeting was held in Istanbul, where all team members convened physically. Sessions were moderated by ICM 2025 (Spine Section) leadership and involved presentation of evidence summaries, structured discussion, and formal consensus voting on each recommendation. Agreement thresholds were predefined and applied consistently. Consensus grading utilised a categorical voting framework with the following thresholds: unanimous consensus: ≥90% agreement; strong consensus: 75%-89% agreement; moderate consensus: 60%-74% agreement; weak consensus (50%-59%), and no consensus (<50%). Evidence strength was concurrently graded as recommended by the GRADE working group into strong, moderate, low and very low as found appropriate.[8] Voting was conducted using an electronic device uniquely coded to each participant, ensuring anonymity and accurate recording of responses. Votes were cast immediately after presentation of the literature evidence and draft recommendations. Conflicts of interest were declared prior to participation, and delegates with relevant conflicts were recused from voting on those specific questions. Dominance bias was mitigated through structured moderation, equal opportunity for input, and reliance on electronic anonymous voting rather than verbal or visible voting methods. Regional practice variations were balanced by diverse geographic representation and equal weighting of all votes within the predefined consensus thresholds. Abstentions and non-responses were excluded from denominators. Quorum was defined as ≥80% of delegates present. Two independent raters graded evidence per question using GRADE principles.[8] Disagreements were adjudicated by the liaison, with escalation to the core committee if unresolved. Adaptations were applied where direct evidence was limited, ensuring transparency in grading.

Phase XI: Finalisation & Dissemination

The consolidated recommendations, reflecting broad expert agreement and evidence alignment were finalised into a unified document. This was prepared for clinical dissemination and future integration into guidelines, educational programs, and research platforms.

Results

In total, 72 clinically relevant questions were evaluated across 2 thematic domains: Tuberculous Spondylodiscitis (36 questions) and Pyogenic Spondylodiscitis (36 questions), within the ICM 2025 (Spine Section) framework, as shown in Tables 1 and 2, respectively. These were distributed across major clinical domains, including Screening & Initial Evaluation (12 questions), Imaging (10 questions), Microbiology & Histopathology (14 questions), Anti-Tuberculous/Antibiotic Therapy (12 questions), Response Monitoring (6 questions), Surgical Indications (10 questions), Surgical Techniques (5 questions), and Surgical Adjuncts (3 questions). For ease of interpretation, consensus levels are categorised as Unanimous (≥90%), Strong (75%-89%), Moderate (60%-74%), Weak Consensus (50%-59%), and No Consensus (<50%). Evidence strength is graded as Very Low, Low, Moderate, or High, following GRADE principles.[8] A domain-level summary is provided below to highlight the distribution of questions across screening, imaging, microbiology, therapy, and surgical domains. Of the 72 consensus items, 61 (85%) reached unanimous consensus (≥90% agreement), 7 (10%) achieved strong consensus (75%-89%), and 4 (5%) demonstrated moderate or weak consensus (<75%), reflecting areas of ongoing debate and the need for further research. Abstentions were excluded from denominators. A domain-level heatmap summarising consensus percentages by topic (screening, imaging, microbiology, therapy, surgery) is provided in Figure 2A and B for tuberculous and pyogenic spondylodiscitis, respectively. This domain-level overview highlights the breadth of topics addressed and the high level of agreement achieved across most clinical decision points. Each question was collaboratively addressed by a multidisciplinary international panel involving 132 experts across 33 countries, as shown in Figure 3. Contributors included spine surgeons, infectious disease specialists, microbiologists, radiologists, and evidence synthesis methodologists, ensuring a broad spectrum of global expertise and clinical applicability.

For every question, consensus statements were developed through structured literature review, iterative drafting, and graded voting using predefined thresholds. The recommendations spanned multiple domains, including screening and initial evaluation, imaging, microbiological workup, therapy planning, surgical techniques, and adjunctive strategies. Notably, specific topics, such as the timing and indication for surgical intervention in TB with neurological deficits, or the value of biopsy in culture-negative pyogenic infections, elicited uniform expert agreement supported by qualitative evidence grading. Evidence strength was concurrently graded based on literature quality and availability, with the majority of statements classified as a low to moderate level of evidence

Table 1. List of Questions Analysed in Tubercular Spondylodiscitis, With the Authors' Team That Analysed It, Along With Their Final Literature-based Recommendations and Expert Consensus Grading

Domain	Question title	Authors	Recommendation statement	Evidence level	Consensus level (%)	Category
Screening & initial evaluation	HIV testing in spinal TB	S Muthu, V Krishnan, J Scherer, R Tangente	Routine HIV screening should be standard for spinal TB diagnosis	Low	98	Unanimous
	Role of constitutional symptoms	V Menon, S Muthu, G Gurusamy	Symptoms are significant but not definitive for diagnosis	Low	100	Unanimous
	ESR, CRP, immune tests in diagnosis	R Kanna, K Izawa, J Scherer	Supportive role but not confirmatory	Low	100	Unanimous
	Value of radiographs/CT with MRI	J Scherer, R Amritanand, A Jaiswal, N Taboada, J Montoya	No added diagnostic value beyond MRI	Low	98.1	Unanimous
	Chest X-ray for ruling out other foci	B Garg, S Park, N Mehta, N Taboada	Chest radiography is recommended for all spinal TB cases	Low	100	Unanimous
	Differences in natural history by age group	S Rajasekaran, N Nagoshi, S Srivastava, M Venkatesan, G Gurusamy	Differences exist based on spine flexibility and immune status	Low	91.7	Unanimous
Imaging	MRI differentiation of TB vs pyogenic	P Bhari Thippeswamy, J Montoya, M Ito, S Muthu, A Choudhury, V Krishnan, M Ali	MRI cannot reliably distinguish TB from pyogenic	Low	94.6	Unanimous
	Prognostic imaging features in TB	S Zwingenberger, K Nagata, P Bhari Thippeswamy, J Emmerich	Yes, radiological features aid prognosis	Low	92.9	Unanimous
	Radiological healing – is MRI sufficient?	A Bosco, S Srivastava, A Joaquim, T Sakai	MRI is adequate on a case-by-case basis; CT/X-ray add little to it	Very low	77.5	Strong
	Persistent MRI abnormality vs surgery indication	N Babu, A Joaquim, A Nene, T Muzahem	MRI abnormality alone is not an indication for surgery	Moderate	100	Unanimous

(continued)

Table 1. (continued)

Domain	Question title	Authors	Recommendation statement	Evidence level	Consensus level (%)	Category
Microbiology & histopathology	Is a biopsy needed with typical MRI features?	G Vijay Kumar, R Tangente	Biopsy is advisable in all cases, even with typical imaging	Moderate	98.1	Unanimous
	Can treatment begin without a spinal biopsy?	S Basu, S Akon, H Inoue, N Shamie, A Ghosh, V Hanasoge	Site-specific biopsy is still recommended despite systemic TB	Low	98.1	Unanimous
	Window period needed before biopsy?	K Chaudhary, K Izawa, J Montoya	No evidence supporting interruption of therapy before biopsy	Very low	100	Unanimous
	Comparative value of diagnostic tests	S Muthu, V Krishnan, G Gurusamy	A combination of GeneXpert, histopathology, and culture is recommended	Low	86.5	Strong
	Pyogenic and fungal culture recommendations (split)	S Park, J Aithala, J Montoya	Pyogenic culture for all patients	Moderate	100	Unanimous
	Fungal culture in spinal TB	S Park, J Aithala, J Montoya	Fungal culture in immunocompromised or selective patients	Moderate	71.2	Moderate
	Empirical ATT in inconclusive biopsy	H Chhabra, S Ganesan, S Muthu, J Emmerich, S Park, S Jonayed	Repeat biopsy with molecular diagnostics recommended	Low	100	Unanimous
	Management of non-responders to ATT	A Jain, B Bijukachhe, K Izawa	Repeat biopsy to confirm diagnosis and resistance is necessary	Moderate	100	Unanimous
ATT	Duration of ATT in responders	R Dunn, B Ndeleva, H Chhabra, S Rajasekaran	Six-month regimen is increasingly supported	Moderate	58.7	Weak
	Value of neoadjuvant chemotherapy	F Zhu, V Kumar Gomatam, K Yamada, S Rajasekaran	Preoperative chemo is helpful for infection control	Low	55.6	Weak
	Restarting ATT after treatment interruption	R Kanna, A Bosco, T Endo	Restart therapy from the intensive phase, referencing pulmonary TB protocols.	Very low	86.4	Strong
	Duration for surgical vs conservative management	J Cheung, C Chiu, G Vijay Kumar, A Shetty	Duration should be the same for both conservative and surgical cases	Moderate	92.9	Unanimous
	Preoperative ATT for healed post-TB kyphosis surgery	Y Hai, S Aiyer, K Yamada	No evidence supporting ATT before corrective surgery in healed kyphosis	Very low	100	Unanimous
Response monitoring	Best methods to assess treatment response	R Dunn, G Dhakal, S Rajasekaran, A Vlok	Multifactorial approach—clinical, radiographic, and optional MRI	Low	84.1	Strong
	Prediction of final deformity with conservative management	S Basu, S Rajasekaran, H Inoue, M El-Sharkawi, V Hanasoge, A Ghosh	Prediction is possible, but evidence is limited	Low	56.8	Weak
	Need for bed rest and role of ambulatory chemotherapy	A Joaquim, T Endo	Bed rest not needed; ambulatory chemo preferred	Moderate	100	Unanimous
	Effect of braces on pain and deformity	S Muthu, G Kalanjiyam, S Zwingenberger, S Kato, S Shinsuke	Helps with pain relief, but has no impact on deformity or collapse	Very low	42.9	No

(continued)

Table 1. (continued)

Domain	Question title	Authors	Recommendation statement	Evidence level	Consensus level (%)	Category
Surgical indications	Radiological criteria and scoring for instability	M Venkatesan, C Chan, Y Pithwa, R Tangente, M Subbiah	Multiple parameters defined; scoring systems are beneficial	Low/Very low	68.3-75.6	Moderate – Strong
	Neurological deficit as an indication for surgery	A Aly, E Laos, B Ndeleva, A Mamun, K Ramachandran, S Rajasekaran	Surgical decompression advised for deficit, instability, or deformity	Very low	97.5	Unanimous
	Use of corticosteroids in TB with neurological deficit	S Srivastava, J Dalton, Komang, S Muthu, Gregory	Not recommended due to limited safety data	Very low	95	Unanimous
	Time to wait before surgery in TB with a deficit	E Laos, J Aithala, M Valacco	Severe cases: Early surgery; mild: 4-week reassessment	Very low	94.7	Unanimous
	Drainage protocols for psoas abscess	S Aiyer, J Dalton, C Menezes, G Schroeder, N Shamie	Not all need drainage; symptomatic cases may be image-guided	Low	100	Unanimous
Surgical techniques	Role of endoscopic/ transpedicular debridement	S Ganesan, N Babu	Suitable in selected cases with a stable spine and a small lesion	Moderate	82.6	Strong
	Indications for anterior surgery	P Phedy, R Dunn, A Hidayat, B Lay, K Irianto, S Katsumi	Primarily posterior approach is preferred; the anterior needed in specific thoracolumbar cases	Low	93.3	Unanimous
	Kyphosis threshold for fixation and reconstruction	Y Pithwa, B Benny, P Phe, A Hidayath, F Zhou	Pediatric: >30°; Adults: >40° kyphosis threshold	Moderate	77.8	Strong
	Indications for posterior-only stabilisation/shortening/ anterior reconstruction	A Nene, SV Anand, M El-Sharkawi, B Lay, P Phedy, S Conti, G Gurusamy	Posterior stabilization for minimal destruction; shortening for moderate VBL; anterior reconstruction needed if VBL >0.5 or deformity >30°	Moderate	97.8	Unanimous
	Preference for graft types vs titanium cage	J Aithala, B Garg, A Nene, D Chand Raja, K Irianto	No preferred graft type; titanium cage favoured for significant defects; local bone grafts suitable for minor defects due to shorter operative time and reduced blood loss	Low	60	Moderate

ATT – Anti-Tubercular Treatment; CRP – C-Reactive Protein; CT – Computed Tomography; ESR – Erythrocyte Sedimentation Rate; MRI – Magnetic Resonance Imaging; TB – Tuberculosis; VAC – Vacuum-Assisted Closure; VBL – Vertebral Body Loss.

Table 2. List of Questions Analysed in Pyogenic Spondylodiscitis With the Authors' Team That Analysed It, Along With Their Final Literature-Based Recommendations and Expert Consensus Grading

Domain	Question title	Authors	Recommendation summary	Evidence level	Consensus level (%)	Category
Diagnosis	Role of albumin/pre-albumin in outcome prediction	J Núñez, H Amin Mohamad, D Hao, K Tamai	Albumin <3.5 g/dL linked to poor outcomes and complications	Moderate	100	Unanimous
	Utility of lab tests (ESR, CRP, Procalcitonin)	J Dalton, Y Kawaguchi, J Nuñez, D Hao, H Nagashima, K Ramachandran, G Gurusamy, A Vaccaro	ESR and CRP are useful; next-gen markers are promising but remain unvalidated	Moderate	91.7	Unanimous
	Modic changes and subclinical infection	S Rajasekaran, G Gurusamy, M El-Sharkawi, M Amin, K Watanabe, E Acaroğlu, A Alanay	Literature suggests a possible link; causality is unproven	Low	66	Moderate
	Differentiating Modic changes from pyogenic infection via MRI	M Teli, H Nagashima, T Kaito, S Rajasekaran, G Gurusamy	Not possible; multimodal imaging needed (CT, FDG-PET)	Low	93.9	Unanimous
	Classification systems for pyogenic infection	N von der Hoeh, R Kanna, JH Cho, C Thomé	No validated system; Pola and SITE scores are promising but need validation.	Moderate	86.3	Strong
	Imaging predictors of deformity and instability	JH Cho, Z Mohd, R Yurac, E Acaroğlu, T Sakai	Junctional level, collapse >50%, kyphosis >30°, bilateral involvement key predictors	Moderate	78.4	Strong
Biopsy & microbiology	Waiting for blood cultures before biopsy	A Demetriades, M Teli, H Arima, K Ramachandran	Blood cultures first; biopsy only if cultures are negative or atypical	Moderate	72	Moderate
	Empirical antibiotics in early vertebral oedema without destruction	R Maximilian, R Chapa, H Imabayashi, K Ramachandran, G Gurusamy	Empirical treatment not supported — strong consensus against it	Low	74.5	Disagree – Moderate
	Optimal biopsy technique	S Muthu, CK Chiu, R Yurac	Use large core needles and target soft tissue/ paravertebral fluid where possible.	Low	100	Unanimous
	Drainage of pyogenic psoas abscess	M Kimani, S Zwingenberger, H Imabayashi	Not all require drainage; it depends on size and risk factors	Low	98	Unanimous
	Avoiding biopsy with recent systemic infection	K Chaudhary, H Funao	A biopsy is still needed even with a known pathogen from systemic infection.	Low	100	Unanimous
	Management after an inconclusive biopsy	D Chand Raja, H Chikuda, H Nagashima, S Muthu	Repeat needle biopsy; open biopsy if needed; empirical antibiotics based on regional profile.	Low	90.6	Unanimous
	Role of Next-Gen Sequencing	S Rajasekaran, K Watanabe, K Ramachandran, G Gurusamy	NGS is useful in culture-negative cases	Moderate	90.9	Unanimous

(continued)

Table 2. (continued)

Domain	Question title	Authors	Recommendation summary	Evidence level	Consensus level (%)	Category
Antibiotic management	Mono vs combination therapy	C Menezes, V Menon, et al	Tailored to the pathogen; no blanket recommendation	Low	94.3	Unanimous
	Duration/regimen structure	CYW Chan, H Ueda, et al	≥6 weeks total; route and dosage per sensitivity	Low	79.2	Strong
	Definition of treatment failure	J Cheung, H Arima, K Watanabe	Clinical worsening/new deficit triggering surgery	Low	100	Unanimous
	Managing failure of initial treatment	V Menon, R Soh, et al	Reassess diagnosis with repeat biopsy/cultures/ imaging; surgery if necessary.	Low	100	Unanimous
	Preferred empirical antibiotics	S Muthu, SV Anand, et al	Choice should be based on host, epidemiologic risk, and local susceptibility trends.	Low	100	Unanimous
	Managing culture-negative cases	SV Anand, AP Shetty, et al	Combination therapy preferred; multidisciplinary input recommended	Low	80.8	Strong
	When to stop antibiotics and the need for follow-up	J Schmirler, R Amritanand, et al	Stop after ≥6 weeks with clinical and marker improvement; follow-up for ≥1 year if high risk	Low	87.9%-100	Mixed consensus
Monitoring	Role and frequency of MRI in follow-up	P Bhari Thippeswamy, A Demetriades, et al	MRI only if no clinical improvement; individualised frequency	Very low	100	Unanimous
	MRI progression in stable patients -surgical indication?	Y Hai, Harikrishna	MRI progression alone is not sufficient; clinical symptoms guide surgical decision	Low	98.1	Unanimous
	Impact of infection morphology on treatment decisions	J Dalton, K Watanabe, et al	Morphology affects strategy; specific approaches are defined for discitis, spondylodiscitis, epidural abscess, and posterior infection.	Low	68.9–100	Mixed consensus
	Epidural abscess with deficit - need for emergency surgery	A Aly, M Kimani, et al	Surgery is needed if a neurological deficit is present	Very low	80	Strong
Surgical indications	Indications for spinal instrumentation	S Bigdon, N Hoeh, et al	Instability, deficit, failure of therapy, deformity - instrumentation improves outcomes	Moderate	97.3	Unanimous
	Indications for anterior reconstruction vs posterior only	Z Kalfopulos, S Bigdon, et al	Anterior preferred with severe anterior damage; outcomes evidence conflicting.	Moderate	83.8	Strong
	Graft type vs cage choice	S Ganesan, A Bosco, L Rocha	<50% height loss: bone grafts; >50% or severe loss: structural grafts or cage	Low	100	Unanimous
	Levels of instrumentation needed	R Chapa, J Cheung, et al	Should be individualised based on vertebral destruction and osteoporosis	Low	100	Unanimous
	Managing incidental dural tear during debridement	J Schmirler, J Dalton, et al	Primary repair followed by tailored antibiotics and monitoring	Very low	86.1	Strong
	Endoscopic transforaminal debridement	C Menezes, J Nuñez, et al	Safe and effective for localised early-stage infection	Low	100	Unanimous
	Damage control surgery in septic patients	S Basu, S Rajasekaran, et al	Minimally invasive debridement with or without stabilisation is reasonable	Low	87.1	Strong
	Indications for repeat surgical debridement	J Schmirler, M Teli, et al	Persistent drainage, abscess, wound issues, and necrosis dictate the need for repeat surgery	Low	100	Unanimous

(continued)

Table 2. (continued)

Domain	Question title	Authors	Recommendation summary	Evidence level	Consensus level (%)	Category
Surgical adjuncts	Role of local vancomycin powder post-debridement	R Soh, S Bigdon, J Tan, M Venkatesan, K Tamai, Y Kawaguchi	Safe and well-tolerated; efficacy not supported by substantial evidence	Moderate	87.9	Strong
	Vancomycin powder mixed with bone grafts	R Soh, S Bigdon, J Tan, M Venkatesan, K Tamai, Y Kawaguchi	No supporting evidence for enhanced healing when mixed with grafts	Moderate	90.9	Unanimous
	Role of antibiotic cement beads	H Chhabra, D Chand Raja, AP Shetty, J Naresh Babu	May reduce recurrence when combined with systemic antibiotics and thorough debridement	Moderate	60.6	Moderate
	Influence of osteoporosis and role of cement-augmented screws	S Bigdon, M Taha, T Morimoto, S Conti, Hirata	Osteoporosis impacts outcomes; insufficient evidence for cement augmentation	Low	100	Unanimous
	Vacuum-assisted closure devices post-debridement	J Tan, A Alaynay, D S Kumar, J Koh, K Yamada, N Astur, S Natsumi, T Furuya	VAC therapy appears safe and potentially useful; further validation needed	Low	93.8	Unanimous

CRP – C-Reactive Protein; CT – Computed Tomography; ESR – Erythrocyte Sedimentation Rate; IL-15 – Interleukin-15; MRI – Magnetic Resonance Imaging; NGS – Next-Generation Sequencing; PET – Positron Emission Tomography; TB – Tuberculosis; VAC – Vacuum-Assisted Closure.

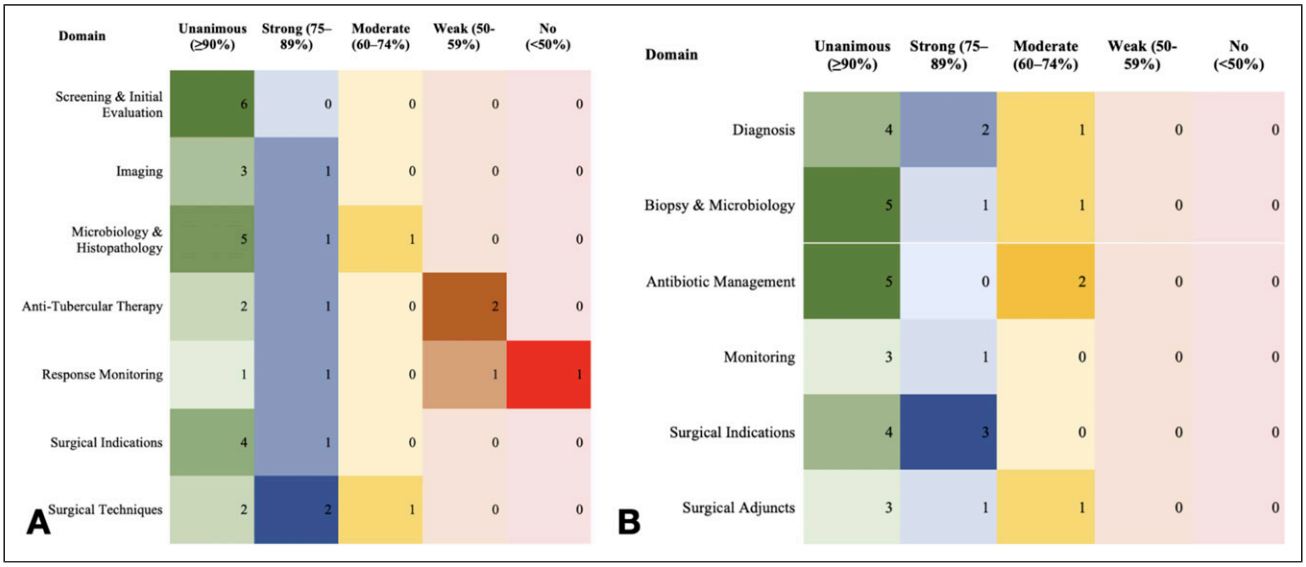


Figure 2. Heat map of consensus across various domains of (A) tubercular and (B) pyogenic spinal infection analysed

due to the inherent scarcity of high-quality studies in spinal infection domains.

Discussion

The ICM 2025 (Spine Section) initiative on spinal infection marks a transformative step in evidence-informed orthopaedic guideline development. By addressing two clinically distinct yet globally significant domains, tuberculous and pyogenic spondylodiscitis, the project demonstrated the feasibility of constructing high-value consensus recommendations through a multiphase, multinational collaboration. The rigorous methodology applied herein provided a replicable scaffold for future consensus efforts. The systematic progression from expert selection, topic generation, and team formation to structured literature review and phased consensus voting ensured intellectual diversity and methodological consistency. 132 contributors representing 33 countries participated across 72 questions, demonstrating strong engagement and geographic breadth. The thematic segregation of topics allowed granular exploration of diagnostic, therapeutic, and procedural challenges specific to each infectious entity. This manuscript

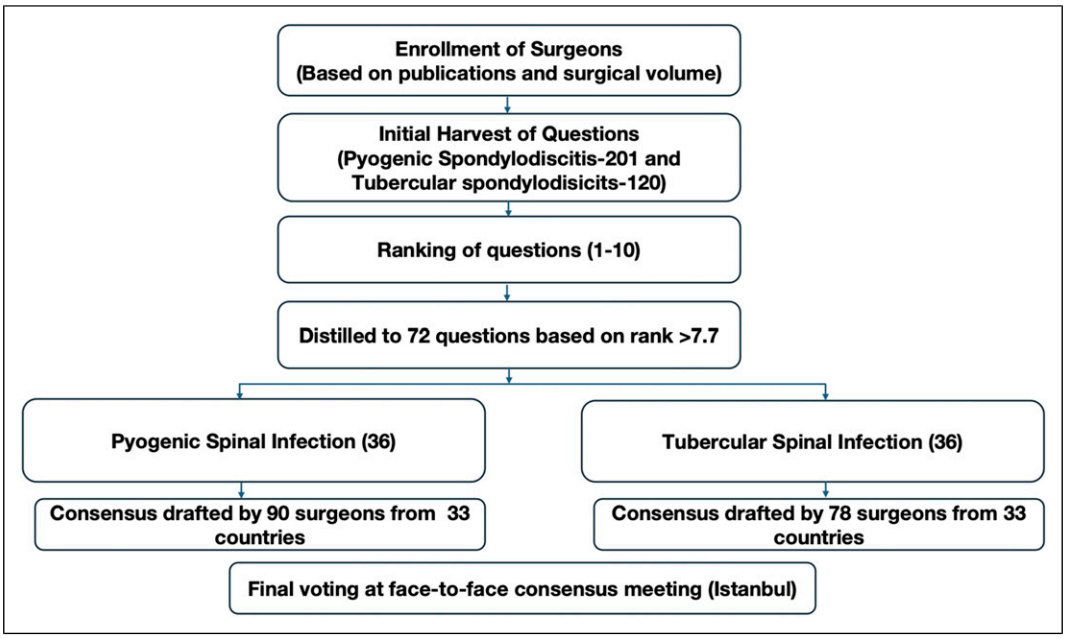


Figure 3. Recruitment and Segregation, and processing workflow of questions involved in the recommendation process

serves as the methodological keystone for the ICM 2025 (Spine Section), with linked question-specific consensus papers providing detailed evidence tables and recommendation dossiers, all published together as a focus issue.

Our findings reveal that a high proportion of consensus statements achieved unanimous or strong agreement, despite the inherently low to moderate evidence levels surrounding spinal infections. This reflects the clinical urgency of these questions. It also highlights the value of expert synthesis where definitive literature is lacking. Domains such as microbiological workup, imaging interpretation, and surgical decision-making benefited from broad alignment. For example, recommendations favouring tissue biopsy even in typical radiological TB presentations, or cautious interpretation of persistent MRI changes post-treatment, show pragmatic utility shaped by global experience. Conversely, topics involving duration of therapy, role of neo-adjuvant anti-tuberculous treatment (ATT), and postoperative use of adjuncts like vancomycin powder or Vacuum-assisted closure (VAC) devices revealed moderate or split consensus, highlighting areas where data variability or regional practice differences prevail. These nuances emphasise the need to view consensus statements not as static mandates, but as adaptable tools reflective of current expert thought and evolving evidence.

One unique strength of this initiative was the dual-pathogen format. By segmenting recommendations into Tuberculous and Pyogenic Spondylodiscitis, the process respected the divergent diagnostic algorithms, therapeutic timelines, and regional epidemiology each condition demands. This thematic bifurcation not only enabled clearer clinical applicability but may serve as a structural template for future infectious consensus formats in spine or broader orthopaedic contexts. From a methodological standpoint, the use of centralised platforms like Rayyan for literature screening, enabling real-time online communication between team members, and tiered team roles (liaison vs collaborator) has streamlined collaboration while maintaining academic rigour. The structured grading system applied categorising consensus levels and aligning recommendations with GRADE-like evidence tiers offered transparency and reproducibility, addressing a long-standing gap in many surgical guideline frameworks. It is important to note that the outputs of ICM 2025 (Spine Section) represent structured expert consensus rather than formal clinical practice guidelines. While consensus recommendations provide valuable direction in evidence-limited domains, they are inherently constrained by the quality of available literature and the reliance on expert judgment. These statements should therefore be interpreted as adaptable frameworks to guide clinical decision-making, rather than prescriptive mandates.

While the ICM 2025 (Spine Section) methodology set new standards for global orthopaedic consensus efforts, its limitations must be acknowledged. Selection bias is inherent in consensus processes, as participating experts may not fully represent all global practice environments. Evidence scarcity was particularly pronounced in tuberculous spondylodiscitis, where high-quality randomised trials are lacking, and recommendations often relied on observational data or expert judgment. In such contexts, consensus statements provide pragmatic guidance but cannot substitute for definitive evidence. The recommendations are intended to be globally relevant, but their application must be adapted to local contexts. Clinicians in resource-limited settings may face constraints in access to advanced imaging, molecular diagnostics, or surgical adjuncts. For these environments, the consensus statements should be interpreted as flexible frameworks rather than rigid mandates. Recognising the dynamic nature of evidence, the ICM 2025 (Spine Section) has committed to iterative updates. As new data emerge, particularly from ongoing multicenter studies and registries, recommendations will be re-evaluated and regraded. This update pathway ensures that the guidance remains current and responsive to evolving scientific knowledge.

The 2025 spine recommendations represent a significant evolution from earlier ICM outputs. Compared to the 2018 ICM spine section, the 2025 process introduced methodological refinements such as centralised literature screening, standardised consensus bands, and expanded global participation. Importantly, several domains were regraded based on updated evidence, making the 2025 outputs more directive in areas such as biopsy protocols, antibiotic duration, and surgical indications. Within the broader ICM 2025 (Spine Section) program, the spine section exemplifies how consensus can be both rigorous and adaptable, serving as a methodological keystone for linked question-specific papers.

Conclusion

The ICM 2025 (Spine Section) methodology for spinal infection consensus marks a significant advancement in the structured development of global orthopaedic guidelines. By deploying a rigorous, 11-phase approach from expert selection and thematic question refinement to evidence synthesis and consensus voting, the initiative established reproducible standards for collaborative recommendation generation in musculoskeletal infection. Segmenting the consensus into pathogen-specific domains, tuberculous and pyogenic spondylodiscitis, not only enhanced clinical relevance but also accommodated diagnostic and therapeutic diversity across international practice settings. The high degree of consensus achieved across 72 key questions underscores the strength of collective judgment, even when operating within evidence-limited domains.

This methodological framework balances academic integrity with pragmatic decision-making and may serve as a template for future consensus efforts across other orthopaedic subspecialties. The ICM 2025 (Spine Section) emphasis on transparency, peer participation, and structured literature evaluation reinforces its role as a credible engine for harmonising infection care globally. In documenting this process, we offer a scalable blueprint for future initiatives aiming to address ambiguity in clinical care through inclusive expert collaboration and systematic methodology. This framework is

designed to be iterative, allowing updates as new evidence emerges. Furthermore, its structured methodology can be adapted to other spine domains, such as degenerative conditions or trauma, thereby serving as a scalable model for future consensus efforts.

ORCID iDs

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

Funding

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

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

1. Al-Mulhim FA, Baragbah MA, Sadat-Ali M, Alomran AS, Azam MQ. Prevalence of surgical site infection in orthopedic surgery: a 5-year analysis. *Int Surg*. 2014;99:264-268. doi:10.9738/INTSURG-D-13-00251.1
2. Liang Z, Rong K, Gu W, et al. Surgical site infection following elective orthopaedic surgeries in geriatric patients: incidence and associated risk factors. *Int Wound J*. 2019;16:773-780. doi:10.1111/iwj.13096
3. Shanmuganathan R, Ramachandran K, Shetty AP, Kanna RM. Active tuberculosis of spine: current updates. *N Am Spine Soc J*. 2023;16:100267. doi:10.1016/j.xnsj.2023.100267
4. Kramer A, Thavarajasingam SG, Neuhoff J, et al. Epidemiological trends of pyogenic spondylodiscitis in Germany: an EANS Spine Section Study. *Sci Rep*. 2023;13:20225. doi:10.1038/s41598-023-47341-z
5. Mohanty M, Jain M, Tripathy SK, et al. Bibliometric analysis of research on spinal tuberculosis in last 5 years. *World J Virol*. 2025;14:102668. doi:10.5501/wjv.v14.i2.102668
6. Golchoub G, Hosseini I, Alamdari A, et al. Clinical and microbiological profile of spondylodiscitis: a retrospective analysis. *BMC Muscoskelet Disord*. 2025;26:515. doi:10.1186/s12891-025-08748-z
7. Ouzzani M, Hammady H, Fedorowicz Z, Elmagarmid A. Rayyan—a web and mobile app for systematic reviews. *Syst Rev*. 2016;5:210. doi:10.1186/s13643-016-0384-4
8. Atkins D, Best D, Briss PA, et al. Grading quality of evidence and strength of recommendations. *BMJ*. 2004;328:1490. doi:10.1136/bmj.328.7454.1490