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NEURORADIOLOGY

ORIGINAL ARTICLE

Examining the current image-guided biopsy and empiric antibiotic paradigm for suspected spondylodiscitis

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PURPOSE

This study aims to identify factors associated with successful pathogen isolation via percutaneous image-guided biopsy (IGB) in suspected spondylodiscitis, compare diagnostic value between fluoroscopy and computed tomography (CT) guided IGB, evaluate the influence of empiric antibiotics prior to biopsy, and assess the impact of IGB results on clinical management and patient outcomes.

METHODS

This retrospective study examined 81 IGBs (62 CT-guided, 19 fluoroscopy-guided) performed for suspected spondylodiscitis between March 2014 and February 2025. Retrospective diagnosis was determined using a composite of biopsy microbiology, clinical criteria, and radiologic findings. Primary analyses included IGB culture yield (procedural diagnostic return), as well as sensitivity, specificity, and diagnostic accuracy. Subgroup analyses included biopsy modality and prior antibiotic administration.

RESULTS

The overall culture yield was 37.0%, with a sensitivity of 44.4% and a specificity of 88.9%. Culture yield did not differ significantly among patients who received antibiotics prior to biopsy (36.4%) and those who did not (37.8%; $P = 0.890$). Similarly, no significant difference in yield was observed between CT-guided (38.7%) and fluoroscopic IGB (31.6%; $P = 0.586$). No significant difference was observed between the coaxial devices used for either transpedicular bone biopsy ($P = 0.604$) or disc biopsy/aspiration ($P = 1.000$). Excluding tuberculosis (TB) case, 97% of cultured organisms were susceptible to the institution's standard empiric antibiotic regimen of vancomycin and ceftriaxone.

CONCLUSION

In cases of suspected spondylodiscitis, IGB demonstrated low sensitivity and rarely altered clinical management during the study. Culture yield was not significantly diminished by prior antibiotic therapy, and 97% of cultured organisms (excluding TB) were susceptible to this institution's standard empiric antibiotics. Furthermore, the relative infrequency of positive cultures suggests that empiric antibiotic initiation should not be delayed solely for the purpose of biopsy in clinically stable patients with characteristic magnetic resonance imaging findings and elevated inflammatory markers. Although the findings in this single-center retrospective study support consideration of a more selective use of IGB, further multicenter studies and meta-analyses are warranted.

CLINICAL SIGNIFICANCE

If additional larger studies corroborate these findings, this could result in a paradigm shift for the clinical management of suspected spondylodiscitis.

KEYWORDS

Antibiotics, image-guided biopsy, intervertebral disks, neuroradiology, osteomyelitis, spondylodiscitis, vertebra

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Spondylodiscitis, including vertebral osteomyelitis and discitis, is an infection of the intervertebral disc and adjacent vertebrae that often presents with non-specific symptoms and diagnostic uncertainty. The condition is associated with a wide spectrum of pathogens and most commonly results from hematogenous spread; less frequently, it arises from direct inoculation or contiguous extension.[1] The estimated annual incidence is 0.4–2.4 cases per 100,000 and has increased in recent years due to improved imaging and the rising prevalence of risk factors such as diabetes, immunosuppression, intravenous drug use, and implanted devices.[1,2] Patients often present with back pain (86% of patients), fever (60%), or neurologic deficits (34%), though these findings lack specificity.[2] Delayed diagnosis may result in vertebral deformity, paraplegia, chronic pain, or death.[1,3] Treatment of spondylodiscitis generally requires 6–8 weeks of antimicrobial therapy.

Contrast-enhanced magnetic resonance imaging (MRI) is the primary imaging modality for diagnosis, with reported sensitivity, specificity, and diagnostic accuracy > 90%.[4,5] However, early infection may mimic degenerative changes, and imaging findings alone cannot establish a microbiologic etiology.[6] Laboratory markers, including erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP), are sensitive for spondylodiscitis (approximately 90%) but lack specificity.[4] Definitive pathogen identification traditionally relies on blood cultures, open surgical biopsy, or percutaneous image-guided biopsy (IGB). Although open biopsy remains the gold standard, it is invasive and generally reserved for refractory or complicated cases.[7] Percutaneous IGB, performed under computed tomography (CT) or fluoroscopic guidance, has been utilized as a less invasive diagnostic option since its introduction in 1981.[8,9]

Main points

- Percutaneous image-guided biopsy (IGB) for suspected spondylodiscitis demonstrated low sensitivity (44%) and modest culture yield (37%), limiting its ability to reliably exclude infection when results are negative.
- Culture yield was not significantly affected by prior antibiotic administration, suggesting that empiric therapy does not need to be delayed solely to improve biopsy yield.
- In most patients (57%), biopsy results did not alter clinical management, and nearly all pathogens identified (97%, excluding tuberculosis) were susceptible to standard empiric therapy with vancomycin and ceftriaxone.
- These findings support a more selective role for IGB in suspected spondylodiscitis, reserving it for patients with atypical features, concern for uncommon pathogens, or lack of clinical improvement after empiric treatment.

Staphylococcus aureus is the most common causative pathogen of spondylodiscitis in the United States, accounting for nearly half of all cases;[2,4] *Mycobacterium tuberculosis* is the most common pathogen worldwide.[10] Fungal cases represent rare non-bacterial sources of spondylodiscitis typically confined to endemic regions, including *Coccidioides* species in the American Southwest desert region.[11]

For the diagnosis of spondylodiscitis, the 2015 Infectious Diseases Society of America guidelines recommend percutaneous IGB when initial cultures are negative and advise withholding empiric antibiotics until after IGB to optimize culture yield.[8] Under these guidelines, empiric treatment is not recommended before biopsy unless there are clinical signs of life-threatening sepsis or neurological complications, with targeted antibiotic therapy initiated only upon pathogen identification via culture. However, emerging literature challenges this paradigm.[12] Specifically, recent studies suggest that prior antibiotic administration may not significantly reduce IGB yield.[10,13] A 2025 multicenter retrospective analysis similarly reported no impact of antibiotic exposure (< 6 weeks) on culture positivity.[14] Additionally, systematic reviews demonstrate substantial heterogeneity in IGB yield, with reported averages ranging from 33% to 48%.[13,15]

Despite widespread use, uncertainty persists regarding the true diagnostic performance of IGB for suspected infection, the comparative value of CT vs. fluoroscopy-guided techniques, and the extent to which biopsy results meaningfully alter clinical management. Literature directly linking diagnostic performance metrics to downstream treatment decisions remains limited.[16] Whereas culture yield reflects the procedural ability to obtain a microbiologic diagnosis, sensitivity and specificity depend on the reference standard used to define true infection status. In practice, the final diagnosis is often clinical rather than microbiologic, partially as a function of low IGB culture yield. This distinction has important implications for interpreting the clinical utility of IGB.

This study aims to (1) evaluate the diagnostic yield, sensitivity, and specificity of percutaneous IGB in suspected spondylodiscitis, (2) assess the impact of biopsy modality and prior antibiotic exposure on culture positivity, and (3) determine the clinical impact of IGB results on patient management. The authors hypothesize that antibiotic exposure and biopsy modality do not significantly affect diagnostic yield and that IGB results seldom alter treatment when empiric antibiotics are initiated based on clinical and MRI findings. With recent studies suggesting substantial increases in the incidence of spinal infection over the past decade and calling for implementation of an appropriate diagnostic algorithm, further investigation is crucial.[17] Ultimately, this study seeks to improve patient care by providing supplementary data to a growing body of evidence that could lead to an update of current IGB practices.

Methods

Data collection

This single-center retrospective study evaluated all image-guided percutaneous IGBs performed for suspected spondylodiscitis at a quaternary academic medical center between March 2014 and February 2025. University of Minnesota Institutional Review Board approval was obtained from the academic institution (study number: 00011154, date: January 10, 2020, "Imaging-guided biopsy/aspiration of the spinal osteomyelitis/discitis"); patient consent was not required given the nature of the study. In accordance with institutional guidelines, electronic medical records were reviewed for each case, and all IGBs meeting the inclusion criteria completed during the specified time range were included consecutively to minimize selection bias. Inclusion criteria included (1) documented clinical suspicion of spondylodiscitis as the primary indication for IGB and (2) submission of an adequate biopsy sample for microbiologic culture. Cases were excluded if the IGB was performed for an indication other than suspicion of spondylodiscitis or if the tissue/aspirate sample was insufficient for analysis (Figure 1). Sample adequacy was determined by the onsite hospital pathology service.

Patient electronic medical records for IGBs meeting inclusion criteria were retrospectively reviewed for demographic information (age and sex of patient), clinical features (back pain, fever, and neurologic deficits), laboratory markers (CRP and ESR), MRI features of spondylodiscitis, type and duration of pre- and post-biopsy antibiotics (if any), blood culture results if completed (culture

positivity and microbiology), biopsy details (biopsy approach, modality of image-guidance, and level of vertebra/disc biopsied), biopsy results (culture positivity, microbiology, and histopathology), and long-term clinical improvement (or lack thereof).

Magnetic resonance imaging review

For all included cases, MRIs were systematically reviewed for features of spondylodiscitis by multiple in-house board-certified neuroradiologists prior to biopsy. The diagnosis of spondylodiscitis/vertebral osteomyelitis on MRI was based on each interpreting neuroradiologist's overall clinical impression of the images. Criteria for a positive finding included a combination of the following MRI features: T1 hypointensity and T2 hyperintensity in the disc; enhancement in adjacent vertebral endplates and/or the contiguous vertebral bodies; T2 hyperintensity and enhancement of surrounding paravertebral soft tissues; epidural thickening and enhancement centered at the suspected level; "psoas sign" with T2 hyperintensity involving the psoas muscle; absent "claw sign"; and restricted diffusion within the disc ± epidural and/or paraspinal tissues (Figure 2).

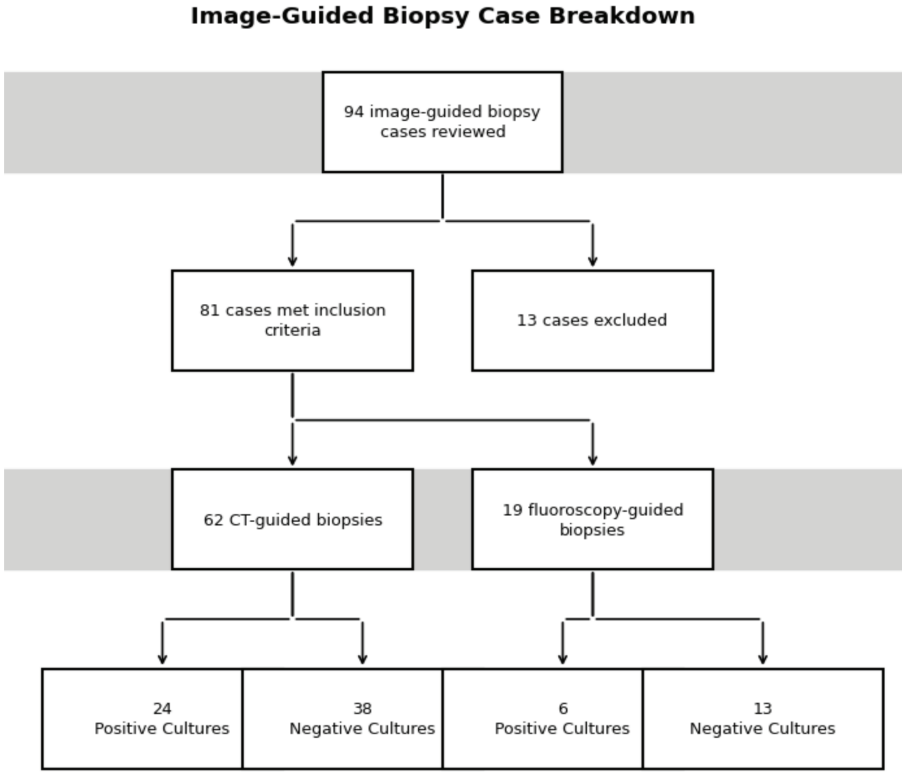

Figure 1. Flowchart demonstrating final case selection for retrospective electronic health record review, with corresponding yield of computed tomography- and fluoroscopy-guided biopsies. Examples of excluded cases were biopsy for an indication other than suspected spondylodiscitis and insufficient tissue/aspirate sample.

Biopsy technique

All IGBs were completed by neuroradiologists under CT or fluoroscopic guidance. Modality selection was based on radiologist preference and equipment availability, with CT generally preferred for deep, anatomically complex targets. The biopsy approach (e.g., transpedicular, posterolateral) and site of insertion were determined by the practitioner based on lesion location and surrounding anatomy. Biopsies consisted of vertebral bone core samples, disc space needle biopsy or aspirate, or both bone and disc samples. Specimens were taken for microbial culture. Core biopsies for histopathological evaluation were collected only if deemed clinically useful to rule out malignancy. Transpedicular vertebral bone biopsies were performed with either a coaxial electric drill (13/15 or 11/13 gauge), a coaxial manual drill (13/14 gauge), or a mallet-driven coaxial biopsy system (14/15 gauge). Intervertebral disc biopsies were performed with either a coaxial slotted needle biopsy system (17/18 gauge) or via aspiration with a spinal needle (after stylet removal) within the disc (18, 20, or 22 gauge). The diagnostic performance of each system is summarized in Table 1. Imaging for each biopsy was retrospectively reviewed by two in-house board-certified neuroradiologists to ensure appropriate device position for the biopsy.

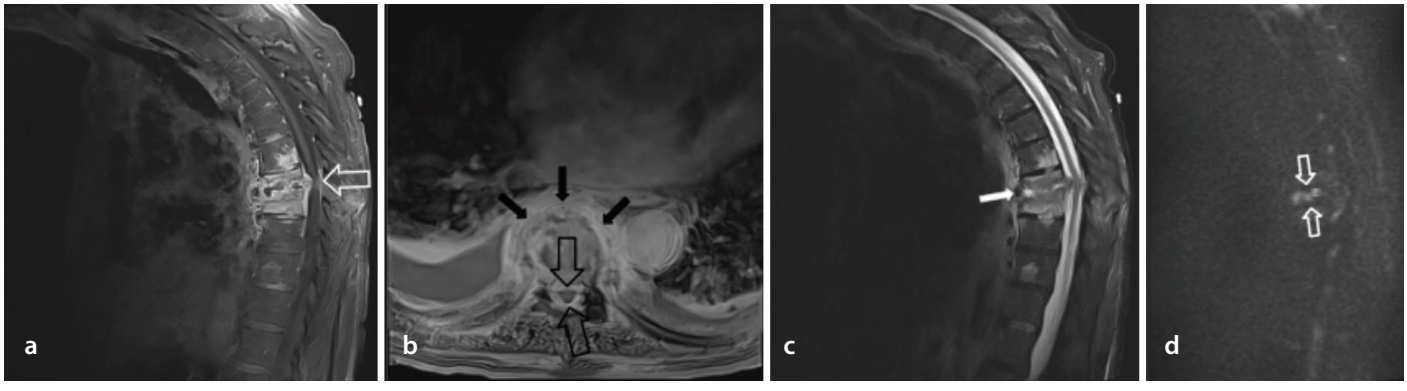

Figure 2. Magnetic resonance imaging features of spondylodiscitis. **(a)** Sagittal post-contrast fat-saturated T1-weighted image of the thoracic spine showing endplate erosions, diffuse enhancement throughout the adjacent vertebral bodies, peripheral enhancement around the infected disc material, epidural thickening, and enhancement (white-outlined arrow). **(b)** Axial fat-saturated post-contrast T1-weighted image of the thoracic spine showing paravertebral soft tissue thickening and enhancement (solid black arrows), and epidural thickening and enhancement (black-outlined arrows). **(c)** Sagittal short tau inversion recovery image of the thoracic spine showing fluid signal in the disc (solid white arrow). **(d)** Sagittal diffusion weighted image (DWI) of the thoracic spine showing restricted diffusion in the disc and endplates (white-outlined arrows) (not the "claw sign," which demonstrates increased signal on DWI in the endplates but not in the disc). There is corresponding hypointense signal on the apparent diffusion coefficient map (not included).

Table 1. Diagnostic performance of biopsy/aspiration systems by device type

Device	Gauge	Total cases	TP	TN	FP	FN	SN (%)	SP (%)	Culture yield (%)	95% CI (yield)
Electric drill system	13/15G, 11/13G	21	4	6	0	11	27.3	100.0	19.0	(5.4–41.9)
Manual drill system	13/14G	9	5	1	1	2	71.4	50.0	66.7	(29.9–92.5)
Mallet-driven system	14/15G	33	14	6	1	12	54	85.7	42.4	(25.5–60.8)
Slotted needle biopsy system	17/18G	11	3	3	0	5	37.5	100.0	27.3	(6.0–61.0)
22G spinal needle	22G	3	1	1	0	1	50.0	100.0	33.3	—
20G spinal needle	20G	2	1	0	0	1	50.0	—	50.0	—
18G spinal needle	18G	2	0	0	0	2	0.0	—	0.0	—

G, gauge; TP, true positive; TN, true negative; FP, false positive; FN, false negative; SN, sensitivity; SP, specificity; CI, confidence interval.

Determination of diagnostic utility and composite diagnostic reference standard

Two complementary measures of diagnostic performance were evaluated: (1) culture yield, defined as the proportion of biopsies resulting in organism identification, and (2) test characteristics (sensitivity, specificity, and predictive values) calculated using a retrospective composite clinical diagnosis as the reference standard. Culture yield reflects the procedural ability of IGB to obtain a microbiologic diagnosis, whereas sensitivity and specificity reflect the ability of IGB culture results to correctly classify patients as having or not having an infection based on their overall clinical course.

For each case, the complete clinical workup, treatment course, and long-term patient outcome were reviewed to establish the retrospective clinical diagnosis. This retrospective clinical diagnosis was used to approximate true disease status, which served as a composite reference standard against which microbiologic results could be assessed. This reference standard incorporated all available microbiology, blood culture results, imaging findings, clinical presentation, and response to therapy.

Clinical improvement was defined as documentation by the treating clinical team (e.g., infectious disease, primary service) of normalization or downward trend in inflammatory markers, stabilization of vital signs, and/or improvement in symptoms, such as pain or neurologic deficits, with or without radiologic improvement.

Using this composite diagnostic reference standard, each IGB result was classified as true positive, false positive, true negative, or false negative according to predefined criteria (Table 2). False negatives were defined as negative biopsy cultures in patients ultimately determined to have spondylodiscitis based on the composite reference standard. These included patients demonstrating clinical and/or radiologic improvement following antimicrobial therapy. False positives were defined as positive cultures deemed to be contaminants or clinically insignificant based on longitudinal clinical course. Antibiotic administration, including timing relative to biopsy and subsequent modifications in therapy, was recorded for each case. In true negative and false positive cases, an alternative diagnosis was determined to be more likely by the treating clinical teams based on additional workup and follow-up.

Statistical analysis

The primary outcomes analyzed in this study include (1) culture yield (proportion of IGBs with positive cultures); (2) diagnostic performance metrics [sensitivity, specificity, diagnostic accuracy, and diagnostic odds ratio (OR) calculated using the composite reference standard as the final diagnosis]; and (3) concordance between IGB and peripheral blood culture results. Categorical variables, including antibiotic exposure and imaging modality, were compared using the chi-square or Fisher's exact tests. Blood culture yield in the setting of suspected spondylodiscitis was also assessed, and further chi-square analysis examined the relationship between blood culture results and IGB culture results. The 95% confidence intervals (CIs) were calculated for all diagnostic metrics.

A multivariable logistic regression model was employed to identify potential independent predictors of positive IGB results. Variables analyzed in the model were selected based on prior literature and clinical relevance, including sex, age, inflammatory markers, presence of fever, back pain, neurologic symptoms, diabetes, and transplant status. A formal sample size calculation was not performed a priori given the retrospective nature of the study, although post-hoc power considerations are included in the study's Discussion section.

Results

Sample selection

Upon initial chart review, all 94 IGBs performed by radiology for possible spondylodiscitis at this institution during the specified timeframe were reviewed and evaluated against the inclusion criteria. All cases meeting the inclusion criteria were consecutively included to minimize sampling bias. Six IGB cases were excluded based on a primary indication other than spondylodiscitis (e.g., malignancy), 5 cases were excluded due to inadequate sample for culture, and 2 cases were excluded because soft tissue samples were obtained instead of vertebral bone or disc. The technical success rate, defined as the procurement of adequate tissue or aspirate for microbiologic analysis, was 94.7%

Table 2. Definitions of image-guided biopsy diagnostic categories

True positive	Positive IGB culture with clinical improvement following targeted antibiotics or concordant culture (blood, etc.) from another site
False positive	Positive IGB culture deemed spurious or contaminated by the infectious disease service or with clinical improvement without antibiotics
True negative	Negative IGB culture with no antibiotic administration and clinical condition improved or remained stable
False negative	Negative IGB culture with subsequent clinical improvement (symptoms and/or imaging) after empiric antibiotic therapy

IGB, image-guided biopsy.

(89/94). Eighty-one cases (n = 81) ultimately met the inclusion criteria of (1) suspicion of spondylodiscitis as primary indication for IGB and (2) adequate sample of vertebral bone or disc submitted for culture. No major procedure-related complications were observed.

Overall yield, pathogens, and symptoms

Of the 81 cases reviewed, 30 cultures were positive, with an overall yield of 37.0% (30/81), consistent with recent studies reporting yield averages ranging from 33% to 48%.[13-15] The most frequently isolated pathogen was *Cutibacterium acnes* in 5 cases. Other recurrent organisms included *S. epidermidis,* methicillin-sensitive *S. aureus*, coagulase-negative *Staphylococcus*, *Escherichia coli, Pseudomonas aeruginosa,* and *M. tuberculosis* (Figure 3). Prevalent signs and symptoms reported across the 81 cases included back pain (96%; 78/81), fever (16%; 13/81), and neurologic deficits (23%; 19/81). Elevated inflammatory markers (CRP and/or ESR) were recorded in 86% of cases (70/81).

Diagnostic performance of image-guided biopsy relative to composite clinical diagnosis

Using the composite reference standard diagnosis, IGB culture results were classified as true positive, true negative, false negative, or false positive. There were 28 true positive cases, 16 true negative cases, 35 false negative cases, and 2 false positive cases. IGB had a sensitivity of 44.4% (95% CI: 32.8%–56.7%) and a specificity of 88.9% (95% CI: 67.2%–96.9%) for suspected spondylodiscitis. Positive predictive value (PPV) was 93.3% (95% CI: 78.7%–98.2%) and negative predictive value (NPV) was 31.4% (95% CI: 20.3%–45.0%). The diagnostic OR was 6.40, and the diagnostic accuracy was 54.3% (95% CI: 43.5%–64.7%).

Effects of image-guided biopsy modality and antibiotics on yield

All IGBs for suspected spondylodiscitis reviewed in this study were conducted with CT (n = 62) or fluoroscopic (n = 19) guidance. The yield of IGB was 38.7% (24/62) with CT guidance and 31.6% (6/19) with fluoroscopic guidance, with no significant difference between modalities (P = 0.586). When diagnostic performance was stratified by IGB modality, CT-guided biopsies demonstrated slightly higher sensitivity of 48.9% (95% CI: 32.7%–65.2%) and specificity of 92.9% (95% CI: 66.1%–100%) compared with fluoroscopy-guided biopsies, which showed a sensitivity of 31.3% (95% CI: 8.7%–53.8%) and specificity of 75.0% (95% CI: 22.3%–100%). Furthermore, CT-guided biopsies also slightly outperformed fluoroscopy-guided biopsies in PPV (95.8% vs. 83.3%) and NPV (35.1% vs. 21.4%), as well as diagnostic accuracy (59.7% vs. 42.1%). However, these diagnostic performance metrics have wide CIs, particularly in the fluoroscopy group (Figure 4). Although CT-guided biopsies consistently—albeit only slightly—outperformed fluoroscopy-guided biopsies, these differences in diagnostic rate were not significant given the wide, overlapping CIs.

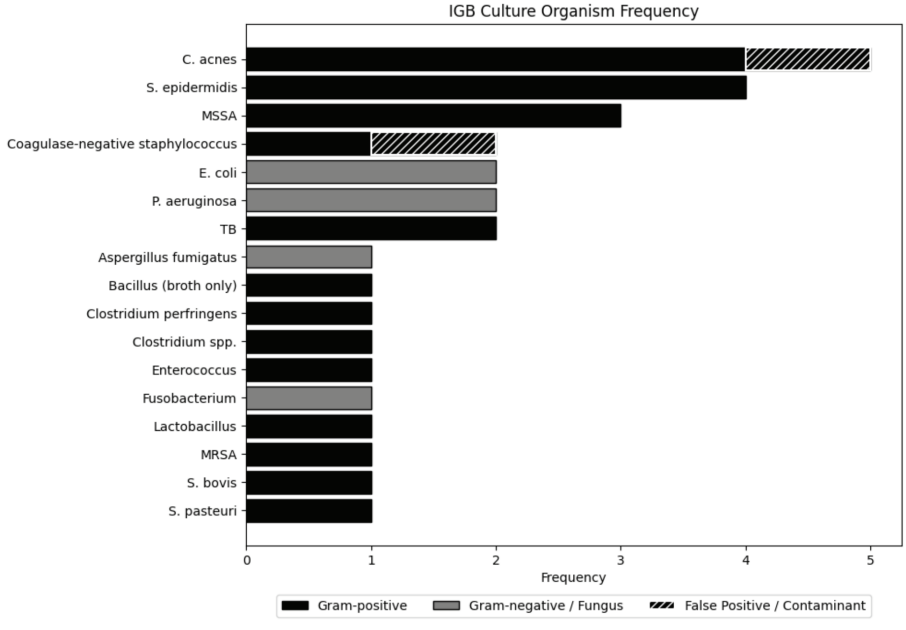

Figure 3. Organisms isolated on image-guided biopsy. IGB, image-guided biopsy; MSSA, methicillin-sensitive *Staphylococcus aureus*; TB, tuberculosis; MRSA, methicillin-resistant *S. aureus*.

Of the 81 patients in this study, 54% (44/81) received antibiotics before undergoing IGB. There was a 36.4% (16/44) yield when antibiotics were given before IGB, and a 37.8% (14/37) yield when antibiotics were not given before IGB. This difference was not statistically significant (P = 0.890), indicating that pre-procedural antibiotic administration did not significantly impact yield.

Image-guided biopsy and blood culture concordance

Blood cultures were obtained from 76 of the 81 patients in this study. Overall blood culture yield was 34.2% (26/76). The most common outcome was concordant negativity between blood and IGB cultures, seen in 42.1% (32/76) of cases. In 10.5% (8/76) of patients, both IGB and blood cultures were positive for the same organism, and 3.9% (3/76) showed discordant positive results with different organisms. Only blood cultures were positive in 19.7% (15/76) of patients, and only IGB cultures were positive in 23.7% (18/76) of patients (Figure 5). Chi-square analysis demonstrated no significant association between blood culture positivity and IGB culture positivity (P = 0.887).

Biopsy device

Regarding transpedicular bone biopsies, the coaxial drill devices listed above had a combined yield of 33.3%, a sensitivity of 40.9%, and a specificity of 87.5%. The mallet-driven coaxial biopsy device had a yield of 42.4%, a sensitivity of 52%, and a specificity of 85.7%. The comparison of yields between the two groups was not statistically significant (P = 0.604). Regarding slotted needle disc biopsy vs. aspiration, the coaxial slotted needle biopsy system had a yield of 27.3%, a sensitivity of 37.5%, and a specificity of 100%. The spinal needles with aspiration had a yield of 28.6%, a sensitivity of 33.3%, and a specificity of 100%. The comparison between the yield of these two groups also did not meet statistical significance (P = 1.000).

Multivariable logistic regression

A multivariable logistic regression analysis was performed to assess potential predictors of positive IGB culture results. Factors evaluated included sex, age, elevated inflammatory markers, fever, back pain, neurologic symptoms, diabetes, and transplant status. Of these factors, only age and elevated inflammatory markers proved to be significantly associated with positive IGB culture results (Table 3). Each year of additional age increased the odds of positive IGB culture

results (OR: 1.02; $P = 0.040$). Elevated inflammatory markers (ESR and/or CRP) were also significantly associated with positive IGB culture results (OR: 3.62; $P = 0.015$). Although fever, back pain, and neurologic deficits are classically associated with spondylodiscitis, the presence of these signs and symptoms was not a significant predictor of positive IGB culture results (Figure 6).

Impact on clinical management

Of the 81 patients undergoing IGB in this study, the antibiotic treatment plan did not change in the majority of cases after biopsy (56.8%; 46/81). Of the 46 patients with no change in treatment plan, 27 of them continued the same empiric antibiotics before and after biopsy, whereas 19 had not started antibiotics prior to biopsy and remained off antibiotics after a non-actionable biopsy result.

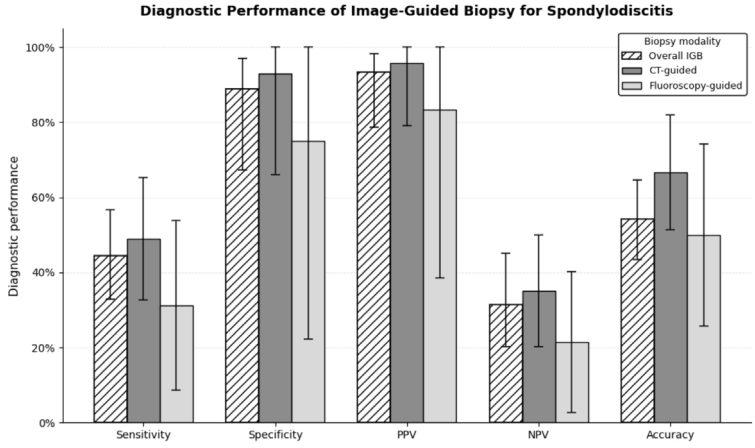

Figure 4. Diagnostic performance of image-guided biopsies by modality with 95% confidence intervals. IGB, image-guided biopsy; CT, computed tomography; PPV, positive predictive value; NPV, negative predictive value.

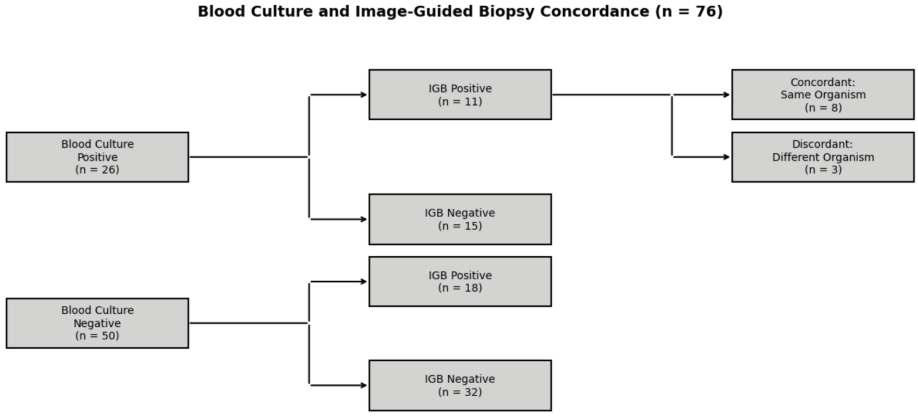

Figure 5. Flowchart illustrating concordance between blood cultures and image-guided biopsy (IGB) results among the 76 patients with available blood culture data.

Antibiotic therapy was narrowed after biopsy in 5 patients and discontinued altogether in 1 patient. Antibiotic therapy was broadened in 3 patients, all with positive cultures (Figure 7).

Antibiotic regimens were started or altered in 32.1% (26/81) of patients after biopsy. Empiric antibiotic therapy was initiated for 8 patients, and targeted antibiotic therapy was initiated for 18 patients. This institution's empiric antibiotic regimen of vancomycin and ceftriaxone would have covered the identified pathogens, excluding TB, in 97% (29/30) of patients with cultured organisms. The single exception was a patient requiring the addition of amoxicillin-clavulanate for cultured *Lactobacillus* following IGB. An additional case of methicillin-resistant *S. aureus* had been started on suboptimal antibiotics at an outside institution and required broadened antibiotics after IGB; however, it would have been adequately covered by the empiric regimen at this institution.

Discussion

This study contributes to a growing body of literature evaluating the clinical utility of IGB in suspected spondylodiscitis. Despite longstanding guidelines, the real-world diagnostic performance of IGB and its impact on clinical management remain limited. In this cohort of 81 patients, the overall culture yield was 37.0%, consistent with contemporary reports and reinforcing the known limitations of IGB in vertebral osteomyelitis and discitis.[12-14]

Using a composite clinical reference standard incorporating clinical, radiologic, microbiologic, and outcome data, IGB demonstrated low sensitivity (44.4%) and relatively high specificity (88.9%). Prior studies have reported similar sensitivity but often assumed near-perfect specificity.[18] By identifying false positive cases, the present study provides a more balanced and clinically applicable

Table 3. Variables analyzed as potential predictors of positive image-guided biopsy culture results

Predictor	Odds ratio	95% CI	*P* value
Sex (male)	1.05	0.43–2.57	0.910
Age	1.02	1.00–1.04	0.040
Inflammatory markers	3.62	1.29–10.1	0.015
Fever	1.33	0.52–3.43	0.550
Back pain	0.75	0.17–3.30	0.710
Neurologic symptoms	0.90	0.32–2.53	0.840
Diabetes	1.38	0.50–3.80	0.530
Transplant	0.58	0.15–2.20	0.420

CI, confidence interval.

assessment of diagnostic performance. The findings highlight two distinct limitations: IGB infrequently yields a microbiologic diagnosis, and it often fails to detect a substantial proportion of clinically confirmed infections.

CT-guided biopsy demonstrated a modest, non-significant trend toward improved diagnostic performance compared with fluoroscopy-guided biopsy. However, these differences should be interpreted cautiously given the small sample size and wide, overlapping CIs, particularly in the fluoroscopy subgroup. Advances in culture methods and image guidance, including cone-beam CT-assisted systems, may further influence diagnostic performance and warrant future study.[19]

Antibiotic administration prior to biopsy was not associated with a reduction in culture yield. Patients receiving antibiotics had similar culture positivity rates to those who did not, supporting emerging evidence that withholding empiric therapy solely to improve biopsy yield may not be necessary.[10,13] Given the risk of clinical deterioration, early empiric antibiotic initiation may be appropriate when clinical and MRI findings strongly suggest infection. Consistent with this, negative IGB results did not reliably exclude spondylodiscitis and had limited influence on treatment decisions in this cohort.

Multivariable analysis identified elevated inflammatory markers (ESR and/or CRP) and increasing age as independent predictors of positive culture results, potentially reflecting greater infection burden or chronicity. In contrast, commonly cited clinical features, such as fever, back pain, neurologic deficits, diabetes, and transplant status, were not predictive of culture positivity. Concordance between blood and biopsy cultures was low, indicating that these modalities provide complementary, but not interchangeable, diagnostic information.

In 32.1% of cases, antibiotic regimens were initiated or modified following biopsy; however, management remained unchanged in the majority of patients. Notably, excluding TB, 97% of patients with cultured organisms would have been adequately covered by this institution's standard empiric regimen of vancomycin and ceftriaxone. Although uncommon, atypical pathogens remain clinically important and should be considered in the appropriate clinical context, including relevant exposures, travel history, and immunosuppression (e.g., *Brucella* in endemic areas or fungal infections in immunocompromised patients). Adjunctive diagnostic tools, including CT, sputum culture, QuantiFERON-TB Gold for TB, and peripheral cultures, may aid in identifying such infections but do not necessarily replace spinal sampling.

Collectively, these findings support consideration of a more selective role for IGB in suspected spondylodiscitis. In this cohort, diagnostic performance was limited, the impact on management was modest, and the vast majority of pathogens were susceptible to standard empiric therapy. IGB also carries procedural risks, including nerve injury, pneumothorax, vascular injury, hematoma, and complications related to sedation or anesthesia.[20] Current guidelines recommend repeat biopsy or escalation to open surgical sampling after negative results, which may increase patient risk and cost.[13] Although alternative approaches, such as endoscopic techniques, have been explored, they remain incompletely studied.

This study does not suggest abandoning IGB, but rather potentially refining IGB use if adequate evidence is found in future multicenter studies and meta-analyses. Biopsy may be most valuable in patients who fail to improve with empiric therapy, have atypical clinical features, or have high suspicion for uncommon pathogens. In such cases, microbiologic confirmation may meaningfully guide treatment. However, in patients with characteristic MRI findings, elevated inflammatory markers, and stable clinical status, empiric therapy may be reasonably initiated without delaying for biopsy. These findings

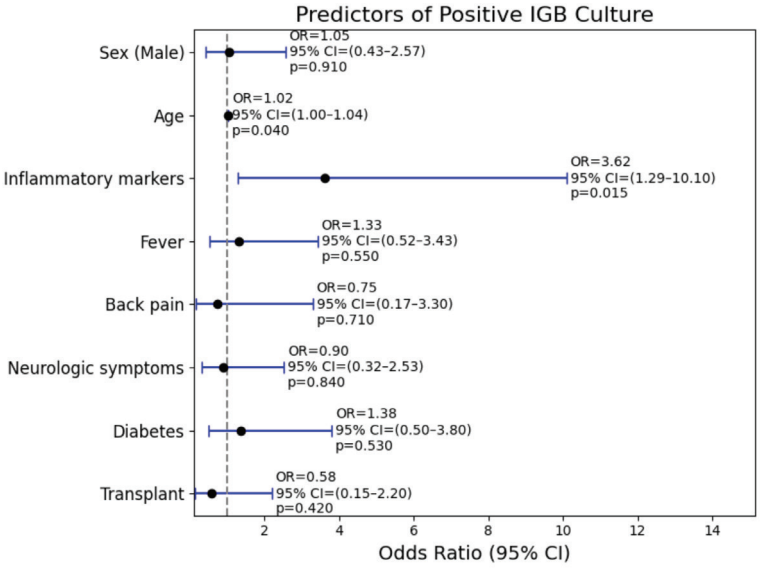

Figure 6. Multivariable logistic regression analysis of independent predictors of positive image-guided biopsy cultures in suspected spondylodiscitis. Odds ratios (OR) with 95% confidence intervals (CIs) are shown. Age and elevated inflammatory markers (erythrocyte sedimentation rate/C-reactive protein) were significantly associated with positive image-guided biopsy culture ($P < 0.05$).

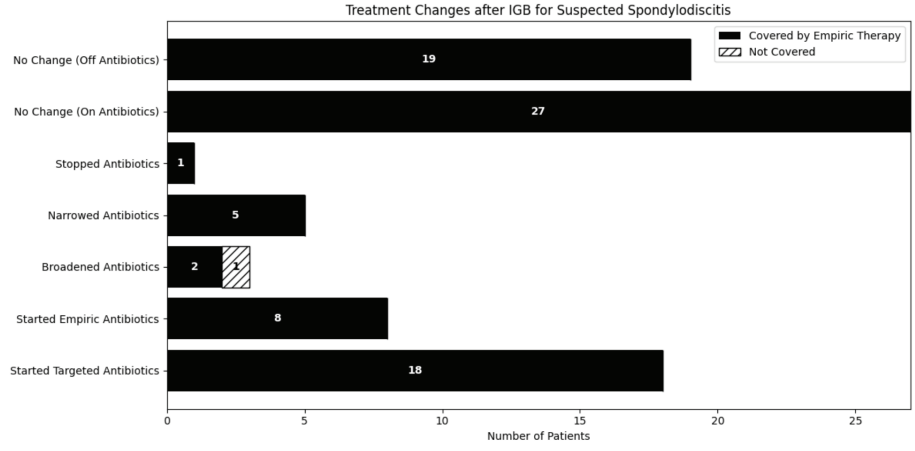

Figure 7. Clinical impact of image-guided biopsy (IGB) culture results on antibiotic management in patients with suspected spondylodiscitis (n = 81), further stratified by whether the pathogen would have been covered by empiric therapy (vancomycin and ceftriaxone).

should be interpreted cautiously given this study's retrospective, single-center design and modest sample size and should not be considered definitive evidence for changes in clinical practice. Additional multicenter studies and meta-analyses are warranted, and potential revisions to current guidelines should only be considered if there is widespread concordance with the results of this study.

Several limitations should be acknowledged. As a retrospective single-center study, the findings are subject to potential selection bias and confounders. This includes the possibility of limited heterogeneity in patient characteristics and institutional practices, which may limit generalizability and external validity. The modest sample size, particularly in subgroup analyses, reduces statistical power and contributes to wide CIs. Variability in biopsy technique, including differences in needle type, gauge, and sample volume, may have influenced culture yield and represents a source of heterogeneity. This heterogeneity may reasonably represent clinical practice but also merits further investigation. Also, given the methodological exclusion of five cases where biopsy results were insufficient, the practical yield in clinical practice may actually be lower than reported here. Furthermore, although multivariable logistic regression was performed, there may be additional unmeasured confounders affecting patient outcomes, including illness severity, timing of imaging, and pathogen virulence. Last, the use of a composite clinical reference standard introduces potential misclassification bias, particularly in cases where clinical improvement may not definitively confirm infection.

Finally, although data recency is a strength of the study, the extended study period (2014–2025) may introduce variability in imaging technology, biopsy technique, and clinical practice patterns. Some subgroup analyses were underpowered, particularly in comparisons between CT- and fluoroscopy-guided biopsy. Larger, prospective, multicenter studies are needed to validate these findings and better define the role of IGB in the diagnostic pathway.

Although additional multicenter studies and meta-analyses are needed to confirm these results, this study supports the consideration of a more selective and evidence-based approach to utilizing IGB in the diagnosis of suspected spondylodiscitis. In patients with characteristic MRI findings and high clinical suspicion for infection, empiric broad-spectrum antibiotic therapy should not be delayed for IGB, particularly when concern for atypical organisms is low. Consistent with recent literature, this study demonstrates both a low microbiologic yield and limited sensitivity of IGB for detecting clinically confirmed infection. Regardless of culture results, nearly all isolated organisms would have been adequately treated by this institution's empiric antibiotic regimen of vancomycin and ceftriaxone.

Based on these findings, empiric antibiotics may be initiated when a diagnosis of spondylodiscitis is clinically and radiographically supported. IGB may be best reserved for cases with concern for unusual pathogens (such as *M. tuberculosis*) that would not be covered by standard empiric therapy, or for patients who fail to improve after 4–6 weeks of treatment.[21,22] Such management should also account for the expected lag in imaging improvement relative to clinical response. In these rare scenarios, the high specificity of IGB has potential utility in narrowing antibiotic regimens if there is concern about adverse effects of long-term broad-spectrum antibiotic coverage.

This study does not suggest abandoning IGB, but rather refining its role in the management of spondylodiscitis. Utilizing IGB more selectively would minimize unnecessary procedural risk, reduce healthcare costs, and ultimately expedite the initiation of appropriate antibiotic treatment. Ideally, this study will prompt further, more robust multicenter studies to validate these findings and help carefully define evidence-based criteria for the role of IGB in the diagnostic algorithm for suspected spondylodiscitis.

Footnotes

Conflict of interest disclosure

The authors declared no conflicts of interest.

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