Open Forum Infectious Diseases

MAJOR ARTICLE

Factors Impacting the Yield of Image-Guided Biopsy in Native Vertebral Osteomyelitis: A 10-Year Retrospective Study

Julian B. Maamari,[1] Aaron J. Tande,[1] Don Bambino Geno Tai,[1,2] Felix E. Diehn,[3] Courtney Ross,[3] Brian Lahr,[4] Gina A. Suh,[1] and Elie F. Berbari[1]

[1]Division of Public Health, Infectious Diseases, and Occupational Medicine, Mayo Clinic, Minneapolis, Minnesota, USA, [2]Division of Infectious Diseases and International Medicine, University of Minnesota, Minneapolis, Minnesota, USA, [3]Department of Radiology, Mayo Clinic, Minneapolis, Minnesota, USA, and [4]Department of Quantitative Health Sciences, Mayo Clinic, Minneapolis, Minnesota, USA

Background. Image-guided biopsies in patients with suspected native vertebral osteomyelitis (NVO) are recommended to establish the microbiological diagnosis and guide antibiotic therapy. Despite recent advances, the microbiological yield of this procedure remains between 48% and 52%. A better understanding of factors associated with this low yield may lead to improved microbiological diagnosis.

Methods. We retrospectively identified patients with suspected NVO undergoing image-guided biopsies from January 2011 to June 2021 at our institution. Two hundred nine patients undergoing 248 percutaneous biopsies were included. Demographic data, biopsy and microbiologic techniques, clinical characteristics, and antibiotic use were collected. Multivariable logistic regression analysis was conducted to determine factors associated with microbiological yield.

Results. A total of 110 of 209 (52.6%) initial image-guided biopsies revealed positive microbiological results. This number increased to 121 of 209 (57.9%) when repeat image-guided biopsies were included. In multivariable analysis, aspiration of fluid was associated with a 3-fold increased odds of yielding a positive result (odds ratio [OR], 3.13; 95% confidence interval [CI], 1.39–7.04; $P = .006$), whereas prior antibiotic use was associated with a 3-fold decreased yield (OR, 0.32; 95% CI, .16–.65; $P = .002$). A univariate subgroup analysis revealed a significant association between the length of the antibiotic-free period and microbiological yield, with the lowest rates of pathogen detection at 0–3 days and higher rates as duration increased ($P = .017$).

Conclusions. Prior antibiotic use in patients with suspected NVO was associated with a decrease in the microbiological yield of image-guided biopsies. An antibiotic-free period of at least 4 days is suggested to maximize yield. Successful fluid aspiration during the procedure also increases microbiological yield.

Keywords. antibiotics; image-guided biopsy; microbiological yield; spondylodiscitis; vertebral osteomyelitis.

The incidence of native vertebral osteomyelitis (NVO) has been increasing in recent years due to a rapidly aging population, as well as other demographic and iatrogenic factors [1, 2]. Most cases of NVO result from hematogenous seeding of the endplate adjacent to the disc space from a distant infectious focus. Native vertebral osteomyelitis is associated with a mortality rate of up to 11% in contemporary cohorts. It also carries a significant risk of complications and sequalae if treatment is delayed [3]. Optimal treatment requires the microbiologic identification of the offending microorganism. Blood cultures may isolate the organism in up to half of cases, which could preclude the need for a biopsy [4]. However, many patients will require an image-guided or an open spinal biopsy to identify the pathogen [4].

Image guidance typically involves either computed tomography (CT) or fluoroscopic guidance and is less invasive than an open surgical approach. Unfortunately, the yield of image-guided biopsy is lower than an open biopsy (48% vs 76%) [5]. There is also a significant variability in the accuracy of image-guided biopsy [6, 7]. Factors that may influence the yield include prior antimicrobial therapy, needle size, presence of fluid collections, and performing a repeat percutaneous biopsy [8–10]. Most cohorts that have attempted to study those variables have been relatively small and yielded conflicting results regarding the effect of certain factors such as antibiotic exposure [9, 11, 12]. We herein conducted a large cohort study to evaluate the impact of various factors that affect the microbiological yield of image-guided biopsies among patients with suspected

Received 23 September 2022; editorial decision 04 November 2022; accepted 04 November 2022; published online 16 December 2022

Correspondence: Elie F. Berbari, MD, Division of Infectious Diseases, Department of Medicine, Mayo Clinic College of Medicine, 200 1st St. SW, Rochester, MN 55905 (berbari.elie@mayo.edu).

Open Forum Infectious Diseases®

https://doi.org/10.1093/ofid/ofac616

NVO. We aimed to determine the optimal duration of withholding antibiotics before biopsy.

METHODS

We performed a retrospective review of patients who underwent CT or fluoroscopically guided biopsies between January 1, 2011 and June 30, 2021 at our institution. An initial list of patients was curated from the Department of Radiology database ($n = 1555$) and all cases were reviewed using the electronic medical record. We included patients age 18 years or older with suspected NVO. We excluded patients younger than 18 years old ($n = 20$), patients who declined research authorization ($n = 23$), and patients with spinal hardware ($n = 39$). We also excluded cases in which biopsy revealed an alternative diagnosis or was performed for another indication such as malignancy ($n = 1098$). Study data were collected and managed using REDCap electronic data capture tools [13]. Patients with positive blood cultures were not excluded if they underwent biopsy. Only patients who underwent the image-guided biopsy at our center were included. We focused on data collected at the first biopsy per patient in our primary analysis, although data from repeat biopsies were also collected and included in secondary analyses. Our Institutional Review Board (IRB) classified the study as exempt research (IRB 21-005624).

Definitions

Native vertebral osteomyelitis was diagnosed through clinical judgment by providers with histological, microbiological, or imaging confirmation. Antibiotic exposure was defined as any receipt of antibiotics in the preceding 28 days before biopsy. A positive yield was defined as an organism clinically determined to be the cause of the underlying NVO. Organisms determined by treating providers as clinically insignificant and were not treated with antibiotics were considered negative yield.

Biopsy Techniques

The biopsies were performed by neuroradiologists subspecializing in procedural neuroradiology. Either fluoroscopy or CT was used as the guidance modality in each case. The regions most compatible with active infection on imaging were sampled. Although each individual patient scenario is unique, common approaches included the following: (1) when preprocedure imaging (typically magnetic resonance imaging) suggested infection of adjacent subendplate regions and/or the intervening disc space, a caudal to cranial transpedicular approach was typically used under fluoroscopy; (2) when preprocedure imaging suggested that the disc space was extensively involved including with probable purulent fluid, a disc space approach was typically used under either fluoroscopy or CT; (3) when preprocedure imaging demonstrated paraspinal fluid collections, these were typically sampled under CT-guidance [14]. The types and gauges of needles used varied by route of sampling and by practitioner preference. However, when an osseous biopsy is performed, commonly relatively large caliber (13- or 14-gauge) sampling needles were used. If imaging suggested purulent fluid was present, such as in a disc space, the paraspinal region, or a facet joint, attempts were made to aspirate these regions. Note that epidural abscesses are typically not accessible to percutaneous sampling.

Culture Techniques

Tissue specimens were homogenized using a stomacher (Seward Inc., Port St. Lucie, FL). Before March 2016, the homogenates were inoculated onto sheep-blood and chocolate agar, incubated aerobically at 35°C in 5% CO_2 for 5 days, and onto CDC anaerobic blood agar and into a prereduced thioglycollate broth, incubated anaerobically for 14 days. From April 2016 onwards, homogenates were inoculated into blood culture bottles (BD BACTEC Plus Aerobic/F medium and BD BACTEC Lytic/10 Anaerobic/F medium) and incubated on the BACTEC 9240/FX instruments (BD Diagnostic Systems) for 14 days. Bone specimens were processed through a grinder with brain-heart infusion broth. Grounded bone specimens were inoculated into agar plates.

Statistical Analysis

Descriptive statistics were presented as count and percentage for categorical variables and as median and interquartile range (IQR) for continuous variables. To test unadjusted associations between potential risk factors and pathogen detection, Pearson χ^2 or Wilcoxon rank-sum tests were used, as appropriate. A multivariable logistic regression analysis was conducted to examine independent associations of prespecified risk factors with pathogen detection. Continuous variables were modeled with 3-knot restricted cubic splines to allow for nonlinear associations. Odds ratios (ORs) were used to quantify the relative increase in odds of pathogen detection for an IQR increase in the input variable or for each level of the variable compared with a reference level. Missing data on covariates were handled with multiple imputation such that the missing values were predicted using all observed information on the outcome and the other covariates in the model and averaged over 20 separate draws. Statistical analysis was conducted using R programming language, version 4.0.3 (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

A total of 209 patients were diagnosed with NVO and underwent 248 image-guided biopsies. The median age at the time of biopsy was 66 years old (IQR, 55.5–74.6) and 60.8% were male. Demographics and clinical presentation are outlined in Table 1. Data on imaging, procedural details, and specifics of

Table 1. Patient Characteristics

Characteristic	N	Overall (N = 209)
Age, years	209	66.1 (55.5–74.6)
Sex, male	209	127 (60.8%)
Race, White persons	206	194 (94.2%)
Comorbidities	209	…
Diabetes mellitus	…	65 (31.1%)
Malignancy	…	37 (17.7%)
Prior spinal radiation	…	7 (3.3%)
Prior spinal surgery	…	53 (25.4%)
Immunosuppression	…	51 (24.4%)
Spinal injections within 6 months	209	21 (10.0%)
Presence of back pain	209	201 (96.2%)
Duration of back pain (days)	200	44.5 (22.0–88.2)
Presence of fever at any point before the biopsy	209	42 (20.1%)
Presence of chills at any point before biopsy	209	23 (11.0%)
Any neurologic sequelae	209	37 (17.7%)
Maximum CRP (mg/L)	194	46.8 (17.4–103.7)
Maximum ESR (mm/h)	183	56.0 (30.0–87.0)
Maximum total serum WBC	208	8.9 (7.0–11.1)

Abbreviations: CRP, C-reactive protein; ESR, erythrocyte sedimentation rate; WBC, white blood cells.

NOTES: N is the number of patients with available information for each variable. Categorical variables are presented as number (percentage) and continuous variables are reported as median (quartile 1 to quartile 3).

Table 2. Imaging, Biopsy, and Culture Techniques

Characteristic	N	Overall (N = 209)
Degree of NVO suspicion on imaging	209	…
Low	…	17 (8.1%)
Moderate	…	38 (18.2%)
High	…	154 (73.7%)
Site/level of NVO	209	…
Cervical	…	5 (2.4%)
Thoracic	…	46 (22.0%)
Lumbosacral	…	108 (51.7%)
Multifocal	…	50 (23.9%)
Epidural abscess or collection	209	39 (18.7%)
Paraspinal abscess or collection	209	40 (19.1%)
CT versus fluoroscopy guidance: CT	209	58 (27.8%)
Use of antibiotics in the 28 days before procedure	209	130 (62.2%)
Duration of antibiotics (days) before procedure	130	10.0 (3.0–35.8)
Number of antibiotics used	209	1.0 (.0–2.0)
Number of specimens taken	178	4.0 (3.0–5.0)
Needle gauge used	209	14 (13.0–14.0)
Successful fluid aspiration	209	63 (30.1%)
Volume of aspirate taken (mL)	49	3.0 (1.0–5.0)
Pathogen detection (1st biopsy)	209	110 (52.6%)
Result of PCR: Positive	36	10 (27.8%)
Pathogen detected by blood culture bottles	82	40 (48.8%)
Pathogen detected by regular cultures	171	67 (39.2%)
Pathogen detected by fungal cultures	197	6 (3.0%)
Pathogen detected by mycobacterial cultures	173	2 (1.2%)
Pathogen detected by anaerobic cultures	171	14 (8.2%)
Pathology report: NVO	209	31 (14.8%)

Abbreviations: CT, computed tomography; NVO, native vertebral osteomyelitis; PCR, polymerase chain reaction.

NOTES: N is the number of patients with available information for each variable. Categorical variables are presented as number (percentage) and continuous variables are reported as median (quartile 1 to quartile 3).

recent antibiotic exposure are reported in Table 2. One hundred thirty patients (62.2%) had antibiotic exposure with antibiotic-free period ranging from 0 to 27 days. Eighty-seven of these patients (66.9%) received antibiotics up to the same day of biopsy and 43 (33.1%) had their antibiotics stopped earlier. The remaining 79 patients (37.8%) did not have antibiotic exposure. Initial biopsies were positive in 110 patients (52.6%). Repeat biopsies were performed in 39 patients and were positive in 14 (35.9%), including 11 who were initially negative and 3 whose initial biopsies became positive after the repeat biopsy was completed. Therefore, the cumulative positive yield among all patients in the study was 57.9% (121 of 209). A third biopsy was performed in one patient and did not reveal any organism. The results of the various culture and molecular techniques used are detailed in Table 2. Gram-positive organisms represented 87.1% of detected cases as is shown in Table 3.

Unadjusted analysis conducted on the results of the first biopsy revealed a significant association between positive yield and antibiotic exposure, successful fluid aspiration, and elevated levels of C-reactive protein (CRP)/erythrocyte sedimentation rate (ESR). Although using blood culture bottles (BCBs) for specimen incubation had a positivity rate of 48.8%, the yield was not significantly higher than with agar/broth techniques ($P = .052$) in the unadjusted analysis as shown in Table 4.

Among patients with antibiotic exposure ($n = 130$), positive yield was significantly higher with a longer duration of antibiotic-free period before the biopsy. To further depict the association between the length of the antibiotic-free period and the yield, a prediction curve for duration was plotted after fitting a univariate logistic regression model with a spline function (Figure 1). The curve suggests that withholding antibiotics for 0–3 days corresponded to rates of pathogen detection <50%, and that withholding antibiotics for additional days

Table 3. Pathogens Detected

Pathogen	First Biopsy (N = 110)	Total Biopsies (N = 124)
Staphylococcus aureus	22 (20.0%)	24 (19.4%)
Coagulase-negative Staphylococci	29 (26.4%)	33 (26.6%)
Streptococci	11 (10.0%)	11 (8.9%)
Gram-negative rods	8 (7.3%)	9 (7.3%)
Mycobacteria	2 (1.8%)	2 (1.6%)
Anaerobes	3 (2.7%)	3 (2.4%)
Fungi[a]	7 (6.4%)	8 (6.5%)
Other Gram-positive[b]	28 (25.5%)	32 (25.8%)
Hyphomicrobium	0 (0%)	1 (0.8%)
Ureaplasma urealyticum	0 (0%)	1 (0.8%)

[a] *Candida albicans, Nakaseomyces glabrata, Blastomyces, Coccidioides.*

[b] *Cutibacterium acnes, Trueperella pyogenes, Parvimonas micra, Corynebacterium striatum.*

Table 4. Unadjusted Outcome Analysis for Pathogen Detection

Characteristic	N	No Pathogen Detected (N = 99)	Pathogen Detected (N = 110)	*P* Value
Degree of suspicion of NVO on imaging	209	…	…	.342[a]
Low	…	9 (9.1%)	8 (7.3%)	
Mild–moderate	…	14 (14.1%)	24 (21.8%)	
High	…	76 (76.8%)	78 (70.9%)	
Prior use of antibiotics	209	70 (70.7%)	60 (54.5%)	.016[a]
Time from stopping abx to biopsy, days	130	0.0 (0.0–1.0)	0.0 (0.0–7.2)	.017[b]
> 0 days	…	19/70 (27.1%)	24/60 (40.0%)	
≥ 3 days	…	9/70 (12.9%)	22/60 (33.9%)	
≥ 7 days	…	3/70 (4.3%)	16/60 (26.7%)	
Number of specimens taken	178	4.5 (3.0–5.8)	4.0 (3.0–5.0)	.249[b]
Successful fluid aspiration	209	19 (19.2%)	44 (40.0%)	.001[a]
Inoculation into blood culture bottles	209	32 (32.3%)	50 (45.5%)	.052[a]
Maximum C-reactive protein	194	31.8 (12.3–67.8)	63.7 (19.8–126.3)	<.001[b]
Maximum ESR preprocedure	183	45.0 (23.0–76.5)	67.0 (37.8–93.5)	.001[b]
Multilevel NVO	209	27 (27.3%)	23 (20.9%)	.282[a]
Presence of epidural or paraspinal collection	209	30 (30.3%)	37 (33.6%)	.606[a]
Presence of fever	209	18 (18.2%)	24 (21.8%)	.512[a]
Needle gauge used	209	14.0 (13.0–14.0)	14.0 (13.0–14.0)	.908[b]
CT or fluoroscopy guidance: CT	209	28 (28.3%)	30 (27.3%)	.871[a]

Abbreviations: abx, antibiotics; CT, computed tomography; ESR, erythrocyte sedimentation rate; NVO, native vertebral osteomyelitis.

N is the number of patients with available information for each variable. Categorical variables are presented as number (percentage), and continuous variables are reported as median (quartile 1 to quartile 3) or exceedance probabilities.

[a]Pearson χ^2 test.

[b]Wilcoxon rank-sum test.

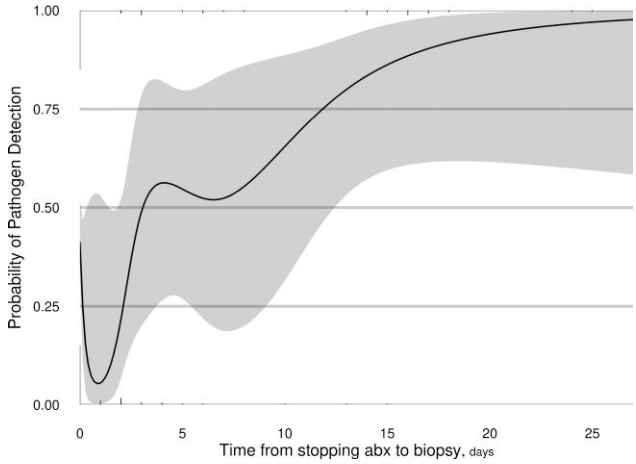

Figure 1. The curve represents the estimated relationship between the antibiotic-free period and the predicted probability of pathogen detection, as estimated by a univariate logistic regression model with time fitted flexibly with a 5-knot restricted cubic spline function. Vertical lines at the top and bottom of the plot show the distribution of interval times for patients with and without pathogen detection, respectively, with the height of these lines proportional to the frequencies of those values. abx, antibiotics.

before the biopsy demonstrated progressively higher rates of pathogen recovery.

In the multivariable logistic regression analysis, patients who had successful fluid aspiration intraoperatively with or without additional tissue biopsies had a 3-fold increased odds of positive yield (OR, 3.13; 95% confidence interval [CI], 1.39–7.04) compared to dry aspirations. Antibiotic exposure was independently associated with 3-fold lower odds of a positive yield (OR, 0.32; 95% CI, .16–.65). After adjusting for other variables in the model, CRP and ESR were no longer significantly associated with positive yield as is represented in Table 5.

DISCUSSION

The use of image-guided biopsies has long been an intuitive choice in the diagnosis of patients with NVO. Although less

Table 5. Multivariable Outcome Analysis for Pathogen Identification

Predictor	Levels[a]	Odds Ratio (95% Confidence Interval)	*P* Value
Degree of suspicion of NVO	…	…	.126
…	Low/high	0.91 (.29–2.86)	
…	Moderate/high	2.37 (1.01–5.57)	
Prior use of antibiotics	Yes/No	0.32 (.16–.65)	.002
Number of biopsies taken	5:3	1.11 (.72–1.71)	.376
Successful fluid aspiration	Yes/No	3.13 (1.39–7.04)	.006
Blood culture bottles taken	Yes/No	1.72 (.85–3.47)	.132
Maximum C-reactive protein	103.7:17.4	1.87 (.89–3.93)	.142
Maximum ESR preprocedure	87:30	2.14 (.93–4.92)	.200
Multilevel NVO	Yes/No	0.55 (.25–1.17)	.120
Presence of epidural or paraspinal collection	Yes/No	0.97 (.47–2.02)	.938
Presence of fever	Yes/No	1.18 (.50–2.77)	.705

Abbreviations: ESR, erythrocyte sedimentation rate; NVO, native vertebral osteomyelitis.

NOTES: Results are from a multivariable examination of candidate risk factors using a binary logistic regression model for pathogen detection. Missing data were imputed and continuous variables were modeled flexibly using splines.

[a]Levels shown for each predictor are the 2 selected points at which the odds ratio is computed. These are the 75th percentile: 25th percentile for continuous predictors or current group: reference group for categorical predictors.

invasive and costly, this procedure is less likely to identify a pathogen than open surgery [5]. The yield microbiological yield of these biopsies has been widely variable with positive yields reported between 19% and 92% of cases [5, 15]. Our study resulted in a yield of 52.6% from the first biopsy alone, similar to the yield reported by recent meta-analyses [15]. Numerous studies have attempted to identify patient and management-related factors that affect the microbiological yield of the image-guided biopsy. Elevated inflammatory markers, such as CRP and ESR, and the aspiration of fluid, with or without tissue, during the procedure have been the factors most consistently correlated with a positive yield [16]. Other factors, such as antibiotic exposure before the biopsy, have been more controversial.

Most recent studies, including a 2017 meta-analysis, have suggested that antibiotic exposure before the procedure has a limited effect on the yield [5, 17]. Of note, many studies included a large proportion of patients with mycobacterial NVO, which may not be as susceptible to typical antibiotics used in pyogenic NVO [17]. When considering antibiotic use, numerous factors come into play, including duration and type of antibiotics used. However, the optimal antibiotic-free period before the procedure also remains a point of contention due to the scarcity of evidence. As a result, the Infectious Diseases Society of America (IDSA) supports the prevailing dogma of withholding antibiotics for 1–2 weeks when an image-guided procedure is planned [3]. In our study, 130 patients were exposed to antibiotics in the 28 days before the procedure, which was associated with a reduced microbiological yield. After these patients were evaluated according to the time between withholding antibiotics and performing a biopsy, results showed a chronologic relation between this antibiotic-free period and the positive microbiological yield of the image-guided biopsy ($P = .017$). Based on a graphical assessment, an antibiotic-free period of 0–3 days showed rates of pathogen detection lower than 50%, whereas rates increased progressively starting at approximately 4 days or longer. Therefore, we suggest an antibiotic-free period of at least 4 days if feasible to maximize the yield of image-guided biopsies. This timeframe is further justified by the need to address a patient's ongoing symptoms and the potential to develop sequalae.

Another factor that had a positive impact on microbiological yield was aspiration of fluid. This has been demonstrated before in numerous studies and is thus an established predictor of yield [16]. However, the mere presence of an epidural or paraspinal collection was not associated with an increase in yield ($P = .938$). In contrast to the antibiotic-free period, successful fluid aspiration is a factor that can be considered unmodifiable, particularly in cases where the collection is too small for aspiration or is located in an anatomically challenging position. Other potentially modifiable factors include needle choice and number of biopsies. Although studies have been conflicting, it is generally recommended that larger inner bore needles be used when feasible (at least 14-gauge) to maximize yield [18]. Our study did not find any association between gauge and yield ($P = .908$). However, a large proportion of biopsies performed in our study were done using 13- or 14-gauge needles. Another factor that may play a role but has not been well studied is the number of specimens taken during the procedure [18]. Our study did not find a significant association between the yield and the number of biopsies ($P = .249$).

Repeat biopsies have been suggested to increase the microbiological yield of the procedure while avoiding an open surgical biopsy. They are generally recommended at least 3 days after culture results from the initial procedure remain negative [3, 10]. Recent studies have suggested a minor but clinically significant increase in the sensitivity of the procedure when repeated [19]. Repeat biopsies successfully identified a pathogen in 14 of 39 cases (35.9%) in our study. This increased the incremental yield from 52.6% to 57.9% (5.3% increase). This supports the use of repeat biopsies when feasible, especially since obtaining a microbiological diagnosis has been associated with more positive outcomes [20]. It is also important to note that some patients had a repeat biopsy but later grew more insidious organisms such as *Cutibacterium acnes*. Given the increasingly recognized pathogenic role of *C acnes*, it may be prudent to consider increasing the time between the 2 biopsies [21]. Further on the technical aspect, the difference in yield between CT or fluoroscopic guidance was not found to be significant in our study ($P = .871$). Most studies also fail to find a significant difference or suggest a slight preference for fluoroscopy [22, 23]. This is in line with clinical practice patterns in radiology, at our and presumably most other institutions; that is, typically the modality that proceduralists are most comfortable with and which is most likely to provide a diagnosis based on preprocedure imaging is chosen. The slightly greater yield in the literature for fluoroscopy may in part relate to the transpedicular modified vertebroplasty approach, which can be more easily achieved on fluoroscopy than CT, and which at least in some cases allows for sampling of multiple regions (vertebral body below, disc, and vertebral body above).

Data on culture techniques were also collected. In recent years, the use of BCBs to incubate biopsy specimen has gained some traction. Small studies have suggested good detection rates with BCBs [24]. To our knowledge, our study is the largest of its kind to examine the clinical use of BCBs for image-guided biopsies (82 patients). We found a marginal yet statistically nonsignificant association between their use and pathogen detection from univariate analysis ($P = .052$). Therefore, more studies are recommended to accurately assess the impact of BCB use.

Limitations of the study include the heterogeneity of pathogen identification techniques related to the year of diagnosis. Since the study spans 10 years, only more recent samples

were tested with BCBs (39.2%) and polymerase chain reaction (PCR) techniques (17.2%). Furthermore, in the analysis of the antibiotic-free period, the high concentration of patients taking antibiotics on the day of the biopsy resulted in an accurate estimate at that time point but less so at subsequent time points. Susceptibility to previously administered antibiotics was not examined and may have further increased the significance of the findings. When considering successfully identified organisms, it is possible to misidentify a contaminant as a pathogen. To minimize this risk, only organisms explicitly identified as pathogens and targeted with appropriate antimicrobial therapy were recognized as a positive result. Furthermore, we determined preprocedural level of suspicion based on predefined keywords extracted from radiology imaging reports, unlike certain studies that conducted specific analysis of individual images [25].

CONCLUSIONS

In patients undergoing CT or fluoroscopically guided biopsy for native vertebral osteomyelitis, successful fluid aspiration was independently associated with higher odds of pathogen detection, whereas prior use of antibiotics is associated with lower odds of detection. The antibiotic-free period suggested before obtaining the biopsy is at least 4 days. More studies are needed to elucidate the role of blood culture bottles and PCR techniques.

Acknowledgments

Author contributions. J. B. M., E. F. B., A. J. T., and D. B. G. T. had roles in study conceptualization and design. G. A. S., F. E. D., and D. B. G. T. critically reviewed design protocols. J. B. M., A. J. T., and C. R. had roles in data collection. Data entry was conducted by J. B. M. Data analysis and interpretation was done by B. L. The initial draft of the manuscript was prepared by J. B. M. All authors made substantial contributions and edits to the manuscript. All authors reviewed and approved the final version of the manuscript. The project was supervised by E. F. B.

Financial support. This work was funded by the Mayo Clinic.

Potential conflicts of interest. All authors: No reported conflicts of interest. All authors have submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest.

References

1. Issa K, Diebo BG, Faloon M, et al. The epidemiology of vertebral osteomyelitis in the United States from 1998 to 2013. Clin Spine Surg **2018**; 31:E102–8.
2. Maamari J, Tande AJ, Diehn F, Tai DBG, Berbari EF. Diagnosis of vertebral osteomyelitis. J Bone Joint Infect **2022**; 7:23–32.
3. Berbari EF, Kanj SS, Kowalski TJ, et al. 2015 Infectious Diseases Society of America (IDSA) clinical practice guidelines for the diagnosis and treatment of native vertebral osteomyelitis in adults. Clin Infect Dis **2015**; 61:e26–46.
4. Mylona E, Samarkos M, Kakalou E, Fanourgiakis P, Skoutelis A. Pyogenic vertebral osteomyelitis: a systematic review of clinical characteristics. Semin Arthritis Rheum **2009**; 39:10–7.
5. McNamara AL, Dickerson EC, Gomez-Hassan DM, Cinti SK, Srinivasan A. Yield of image-guided needle biopsy for infectious discitis: a systematic review and meta-analysis. AJNR Am J Neuroradiol **2017**; 38:2021–7.
6. Shibayama M, Nagahara M, Kawase G, Fujiwara K, Kawaguchi Y, Mizutani J. New needle biopsy technique for lumbar pyogenic spondylodiscitis. Spine (Phila Pa 1976) **2010**; 35:E1347–9.
7. Garg V, Kosmas C, Young PC, Togaru UK, Robbin MR. Computed tomography-guided percutaneous biopsy for vertebral osteomyelitis: a department's experience. Neurosurg Focus **2014**; 37:E10.
8. Husseini JS, Simeone FJ, Nelson SB, Chang CY. CT-guided discitis-osteomyelitis biopsies: needle gauge and microbiology results. Skeletal Radiol **2020**; 49:1431–9.
9. Agarwal V, Wo S, Lagemann GM, Tsay J, Delfyett WT. Image-guided percutaneous disc sampling: impact of antecedent antibiotics on yield. Clin Radiol **2016**; 71: 228–34.
10. Yeh KJ, Husseini JS, Hemke R, Nelson SB, Chang CY. CT-guided discitis-osteomyelitis biopsies with negative microbiology: how many days should we wait before repeating the biopsy?. Skeletal Radiol **2020**; 49:619–23.
11. Kim CJ, Song KH, Park WB, et al. Microbiologically and clinically diagnosed vertebral osteomyelitis: impact of prior antibiotic exposure. Antimicrob Agents Chemother **2012**; 56:2122–4.
12. Marschall J, Bhavan KP, Olsen MA, Fraser VJ, Wright NM, Warren DK. The impact of prebiopsy antibiotics on pathogen recovery in hematogenous vertebral osteomyelitis. Clin Infect Dis **2011**; 52:867–72.
13. Harris PA, Taylor R, Minor BL, et al. The REDCap consortium: building an international community of software platform partners. J Biomed Inform **2019**; 95: 103208.
14. Layton KF, Thielen KR, Wald JT. A modified vertebroplasty approach for spine biopsies. Am J Neuroradiol **2006**; 27:596–7.
15. Pupaibool J, Vasoo S, Erwin PJ, Murad MH, Berbari EF. The utility of image-guided percutaneous needle aspiration biopsy for the diagnosis of spontaneous vertebral osteomyelitis: a systematic review and meta-analysis. Spine J **2015**; 15: 122–31.
16. Ang MT, Wong GR, Wong DR, Clements W, Joseph T. Diagnostic yield of computed tomography-guided biopsy and aspiration for vertebral osteomyelitis. J Med Imaging Radiat Oncol **2019**; 63:589–95.
17. Wong H, Tarr GP, Rajpal K, Sweetman L, Doyle A. The impact of antibiotic pretreatment on diagnostic yield of CT-guided biopsy for spondylodiscitis: a multicentre retrospective study and meta-analysis. J Med Imaging Radiat Oncol **2021**; 65:146–51.
18. Husseini JS, Habibollahi S, Nelson SB, Rosenthal DI, Chang CY. Best practices: CT-guided percutaneous sampling of vertebral discitis-osteomyelitis and technical factors maximizing biopsy yield. Am J Roentgenol **2021**; 217:1057–68.
19. Weihe R, Taghlabi K, Lowrance M, et al. Culture yield in the diagnosis of native vertebral osteomyelitis: a single tertiary center retrospective case series with literature review. Open Forum Infect Dis **2022**; 9:ofac026. doi: 10.1093/ofid/ofac026.
20. Chong BS, Brereton CJ, Gordon A, Davis JS. Epidemiology, microbiological diagnosis, and clinical outcomes in pyogenic vertebral osteomyelitis: a 10-year retrospective cohort study. Open Forum Infect Dis **2018**; 5:ofy037. doi: 10.1093/ofid/ofy037.
21. Kowalski TJ, Berbari EF, Huddleston PM, Steckelberg JM, Osmon DR. Propionibacterium acnes vertebral osteomyelitis: seek and ye shall find? Clin Orthop Relat Res **2007**; 461:25–30.
22. Diffre C, Jousset C, Roux A-L, et al. Predictive factors for positive disco-vertebral biopsy culture in pyogenic vertebral osteomyelitis, and impact of fluoroscopic versus scanographic guidance. BMC Infecti Dis **2020**; 20:1–9.
23. Kim B, Lee J, Kim S, Lee G, Kang H. Diagnostic yield of fluoroscopy-guided biopsy for infectious spondylitis. American J Neuroradiol **2013**; 34:233–8.
24. Pandita N, Paul S, Yadav G, Kalia RB, Kandwal P. Evaluation of challenges in diagnosis of spontaneous subacute pyogenic spondylodiscitis in immunocompetent patients: experiences from a Tertiary Care Center. Asian Spine J **2019**; 13:621–9.
25. Brinjikji W, Everist BM, Wald JT, Lane JI, Morris JM. Association between imaging findings and microbiological findings for image-guided biopsies for spine infections. J Neurosurg Sci **2017**; 61:589–96.