MAJOR ARTICLE

The Impact of Prebiopsy Antibiotics on Pathogen Recovery in Hematogenous Vertebral Osteomyelitis

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Background. Biopsy specimens are often obtained in the evaluation of hematogenous vertebral osteomyelitis. The effect of prebiopsy antibiotic exposure on pathogen recovery is unknown.

Methods. We conducted a retrospective cohort study of adult inpatients with hematogenous vertebral osteomyelitis at a tertiary care hospital from 1 January 2003 through 31 July 2007. Antibiotic exposure within 14 days before biopsy was evaluated.

Results. Of 150 patients with hematogenous vertebral osteomyelitis, 92 (61%) underwent a biopsy (60 [65%] needle and 32 [35%] open biopsies). The median time from admission to biopsy was 3 days (range, 0–69 days). Patients who underwent biopsy were more likely to have weakness (53 [58%] biopsy vs 15 [26%] no biopsy; $P < .001$) and sensory loss (27 [29%] vs 6 [10%]; $P = .006$), but were less likely to have a positive blood culture result (28 [30%] vs 30 [52%]; $P = .01$). Pathogens were recovered in 61 patients (66%). Open biopsy had a higher yield than needle biopsy (29 [91%] of 32 vs 32 [53%] of 60; $P < .001$). Sixty patients (65%) who had biopsies performed received antibiotics ⩽14 days before the procedure (median duration, 4 days; range, 1–37 days). Open biopsy predicted positive biopsy culture results (adjusted odds ratio, 8.4; 95% confidence interval, 2.2–31.8), but there was no association of prebiopsy antibiotics with culture results (adjusted odds ratio, 2.3; 95% confidence interval, 0.8–6.2).

Conclusions. A pathogen was recovered from 61 (66%) of 92 patients who had biopsies performed in this cohort of hematogenous vertebral osteomyelitis. Open biopsies had a higher microbiological yield than did needle biopsies. Antibiotic exposure before biopsy did not negatively impact pathogen recovery and should not be the sole reason for foregoing biopsies.

Identification of a causative pathogen is important in the treatment of hematogenous vertebral osteomyelitis and discitis; however, blood culture results are positive in only 20–78% of cases [1, 2]. Because of the low rates of bacteremia, bone biopsy is often required to determine the causal pathogen. Percutaneous needle biopsy is usually performed when a specimen is needed for diagnosis and surgery is not otherwise indicated [3]. Patients with vertebral osteomyelitis frequently receive antimicrobial therapy before biopsy. Prebiopsy antibiotic exposure may cause clinicians to forego a biopsy because of concerns that antibiotics will reduce the likelihood of getting positive culture results from the biopsy specimens. Empirical antibiotic treatment without adequate cultures may lead to unnecessary, prolonged broad-spectrum antibiotic use. Conversely, withholding antibiotics before a biopsy can be scheduled may cause delays in initiating appropriate therapy [4].

There are limited data on the yield of bone biopsies in vertebral osteomyelitis and the effect of prebiopsy antibiotics on pathogen recovery. Several studies suggest that the diagnostic yield of biopsy may be diminished in cases of vertebral osteomyelitis with antecedent antibiotic use [3, 5, 6]. These studies are either small in size, unclear in the duration or spectrum of antibiotic

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exposure, or include patients with postoperative spinal infections [7], which are caused by a distinct set of pathogens.

We conducted a retrospective review of patients who received a diagnosis of hematogenous vertebral osteomyelitis at our institution to better understand the effect of prebiopsy antibiotic use on microbiological yield.

METHODS

Setting

Barnes-Jewish Hospital (BJH), a 1250-bed teaching hospital, is the largest hospital in Missouri, and has a referral base that includes the Saint Louis metropolitan area, eastern Missouri, and western Illinois.

Study Design

We performed a retrospective cohort study of hospitalized patients admitted from 1 January 2003 through 31 July 2007, who received a diagnosis of hematogenous vertebral osteomyelitis. We used the BJH Medical Informatics database to identify all discharges with *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) codes for epidural abscess (324.1 and 324.9), osteomyelitis of the spine or unspecified site (730.28, 730.08, 730.2, and 730.00), and discitis (722.90, 722.91, 722.92, and 722.93). Discharges containing these ICD-9-CM codes were then reviewed by one of the authors (KPB) to determine whether they met study criteria defined below. The study was approved by the Washington University Human Research Protection Office.

Inclusion and Exclusion Criteria

Hospitalized patients ⩾18 years of age who presented with hematogenous vertebral osteomyelitis or developed this infection in the hospital were included. Vertebral osteomyelitis was defined by radiographic changes. MRI changes consistent with osteomyelitis and discitis included decreased signal intensity in the vertebral body and disk and loss of end plate definition on T1-weighted images, and increased signal intensity of the disk and vertebral body on T2-weighted images. Patients with contiguous osteomyelitis due to decubitus ulcers, trauma, or a surgical site infection (defined as infection within 1 year of surgery) were excluded. Stage I decubitus ulcers were not considered as a reason for exclusion.

Data Collection

We reviewed medical records for all the patients meeting study inclusion criteria. Medical records were reviewed for demographic information, comorbidities, antibiotic history, presenting symptoms, vital signs and physical examination findings, diagnostic procedures, microbiology, and medical and surgical treatment. Laboratory and temperature data within 24 h after admission were collected. Antibiotic history was derived from multiple sources, including patients' reported home medications, documentation from outside hospital transfers, and pharmacy records from our institution.

Definitions

Renal insufficiency was defined as a serum creatinine level ⩾2 mg/dL. Open biopsy was defined as biopsy performed in the operating room and requiring skin and soft-tissue incision with direct visualization of the spine. Antibiotic exposure was defined as any antibiotic given within the 2-week period before the bone biopsy. "Prebiopsy antibiotic match" was defined as empirical antibiotic treatment given before obtaining the biopsy specimen that subsequently was found to match the susceptibilities of the pathogens recovered from the bone biopsy culture. The term "biopsy specimen" is used to describe any vertebral bone and/or disk and/or epidural specimens. For needle biopsies, either cutting needles (eg, Jamshidi needle) were used if the goal was to obtain tissue specimens (n = 41) or aspiration needles if the disk space or an abscess space were sampled (n = 19). For coagulase-negative staphylococci or other possible skin contaminants to be considered to be a true pathogen, they had to be isolated from a sterilely obtained bone biopsy specimen and/or ⩾2 blood culture specimens drawn on separate occasions. We also did a subanalysis in which only coagulase-negative staphylococci isolated from both bone and blood culture specimens were considered. Renal insufficiency was defined as a serum creatinine level ⩾ 2 mg/dL.

Statistical Analysis

Data entry was performed using Microsoft Access and Excel, and data analysis was performed using SPSS, version 17 (SPSS). Univariate comparisons among categorical variables were performed using the χ^2 test or Fisher's exact test as appropriate. Comparisons among continuous independent variables were performed using Student's t test or the Mann–Whitney U test, as appropriate. A 2-sided P value of $<.05$ was considered to be statistically significant. We considered variables with statistical significance of $P < .1$ in a univariate analysis for inclusion in a forward stepwise multivariate logistic regression model comparing patients with positive biopsy culture results with those with negative biopsy culture results. Prebiopsy antibiotic exposure was forced into the model, with other variables retained in the final model, based on a statistical significance of $P < .05$.

RESULTS

Hospital Management of Hematogenous Vertebral Osteomyelitis

Of 475 patients admitted from 1 January 2003 through 31 July 2007 with the ICD-9-CM codes of interest, 150 patients met study criteria. Sixty (40%) of 150 patients were admitted initially to an outside hospital and were then transferred to BJH for care.

Ninety-two patients had a biopsy procedure performed, all of which were performed at BJH (Table 1). Of these patients, 60

(65%) had a percutaneous needle biopsy and 32 (35%) had an open biopsy performed. The median time from admission to biopsy was 3 days (range, 0–69 days). Sixty (65%) of 92 patients received antibiotics in the 14 days before biopsy. Among these patients, the median duration of prebiopsy antibiotics received was 4 days (range, 1–37 days). The most frequently used empirical antibiotic regimens in patients with culture-positive biopsy specimens were vancomycin alone and vancomycin with a third-generation cephalosporin (Table 2).

Compared with patients who did not have biopsies performed, individuals who underwent a biopsy were more likely to have symptoms of subjective weakness (53 [58%] of 92 with biopsy vs 15 [26%] of 58 without biopsy; $P < .001$) and subjective sensory loss (27 [29%] of 92 vs 6 [10%] of 58; $P = .006$], as well as decreased motor strength (59 [66%] of 89 vs 21 [39%] of 54; $P = .001$] and objective sensory deficits (35 [39%] of 89 vs 12 [23%] of 54; $P = .04$) during examination. A radiological diagnosis of an epidural abscess had been made more often in patients who subsequently underwent biopsy, but this comparison did not reach statistical significance [40 [44%] of 92 vs 16 [28%] of 58; $P = .05$). Patients who did not have a biopsy performed were more likely to have a positive blood culture result than were patients who had a biopsy performed (30 [52%] of 58 vs 28 [30%] of 92; $P = .01$]. Transfer from an outside hospital, demographic characteristics, comorbidities (including diabetes), and clinical and laboratory presentation other than the aforementioned characteristics did not differ significantly between patients who did or did not have a biopsy performed (data not shown).

Sixty-one (66%) of 92 patients who underwent biopsy had a positive culture result. All positive biopsy specimens yielded a single pathogen, except one culture, which grew both *Haemophilus parainfluenzae* and coagulase-negative staphylococci and one with methicillin-susceptible *Staphylococcus aureus* and unidentified gram-negative bacteria. Gram-positive bacteria were predominantly recovered, including methicillin-susceptible *S. aureus* (18.5% of 92), methicillin-resistant *S. aureus* (16.3%), coagulase-negative staphylococci (9.8%), and *Streptococcus* species (7.6%) (Table 1). There were 10 cases (10.9%) of gram-negative bacteria. There was a single case in which anaerobic bacteria, *Propionibacterium acnes*, was isolated. No mycobacteria or fungi were isolated from any biopsy cultures.

Needle Biopsy versus Open Biopsy

There were no statistically significant differences in demographic characteristics between patients undergoing a percutaneous needle biopsy and those undergoing open biopsy (Table 1). All open biopsies were performed as part of a primary surgical procedure (ie, laminectomy, fusion, and/or corpectomy). Transfer from an outside hospital was more frequent in those patients who had open biopsy performed ($P = .005$). Chronic renal insufficiency was more frequent in patients with needle biopsy ($P = .006$). Fever ($P < .001$), subjective sensory loss ($P < .001$), weakness ($P = .01$), and pre-existing paralysis at admission ($P < .001$) were more frequent among patients who underwent an open biopsy. One hundred forty-three patients had a complete, documented neurological exam performed at admission. Impaired motor strength ($P = .01$), sensory deficit ($P = .03$), decreased rectal tone ($P = .01$), and a positive Babinski sign ($P = .003$) were all more frequent in patients undergoing open biopsy. The maximum body temperature ($P = .01$), white blood cell count ($P = .001$), and serum CRP level ($P = .02$) were all significantly higher in the group of patients undergoing open biopsy (Table 1).

Culture samples obtained via open biopsies were more likely to yield organisms than were culture samples obtained percutaneously (29 [91%] vs 32 [53%]; $P < .001$).

Microbiological Yield of Biopsy Specimens and Previous Antibiotic Exposure

Among the 92 patients who underwent biopsies, 60 (65%) were started on empirical antibiotics before the procedure. Forty-three (72%) of these 60 patients had positive culture results, with 38 empirical regimens matching the pathogens later recovered. An additional 18 positive culture samples were obtained from 32 patients who had no prior antibiotic exposure. The yield of biopsies was not lower in patients with antibiotic exposure (43 [72%] of 60 with prebiopsy antibiotics vs 18 [56%] of 32 with no antibiotics; $P = .1$]. Patients who were treated with antibiotics before the biopsy was performed were more likely to present with subjective weakness ($P = .02$), fever ($P = .04$), and a higher temperature ($P = .001$) and higher peripheral white blood cell count ($P = .006$) than were patients who had no prior antibiotic exposure.

Twenty-one (66%) of 32 patients who had open biopsy performed had previous antibiotic exposure, compared with 39 (65%) of 60 patients who had needle biopsy performed ($P = 1.0$). Among those with antibiotic exposure, 20 patients with open biopsy (20 [95%] of 21) and 23 patients with needle biopsy (23 [59%] of 39) had positive culture results ($P = .003$). Among the patients with no antibiotic exposure, 9 (82%) of 11 in the open biopsy group and 9 (43%) of 21 in the needle biopsy group had positive culture results ($P = .06$). Among the 43 pretreated patients who had a positive biopsy culture result, 18 (90%) of 20 patients who underwent open biopsy were pretreated with an antibiotic that matched susceptibilities for the organism that was later recovered, compared with 20 (87%) of 23 patients in the percutaneous needle biopsy group ($P = 1.0$).

We further limited the analysis to include only coagulase-negative staphylococcal infections in which these pathogens were found both in bone biopsy and blood culture specimens (n = 3), leaving 84 patients to be examined. Twenty-one (66%)

Table 1. Comparison of 92 Patients with Hematogenous Vertebral Osteomyelitis by Biopsy Type

Variable	Total	Needle Biopsy n=60 (65%)	Open Biopsy n=32 (35%)	*P*
Demographics				
Mean age (±SD), years	57.7 (±14.5)	59.8 (±14.5)	53.8 (±14.0)	.06
Race (white)	56 (60.9)	35 (58.3)	21 (65.6)	.5
Gender (male)	49 (53.3)	30 (50.0)	19 (59.4)	.4
Median BMI(kg/m^2, range)	27.8 (13.4–80.6)	27.3 (13.4–47.0)	28.5 (19.0–80.6)	.2
Transfer from outside hospital	34 (37.0)	16 (26.7)	18 (56.3)	.005
Comorbidities				
Diabetes mellitus	37 (40.2)	27 (45.0)	10 (31.3)	.2
Chronic renal insufficiency	17 (18.5)	16 (26.7)	1 (3.1)	.006
Malignancy	7 (7.6)	6 (10.0)	1 (3.1)	.4
History of degenerative joint disease	34 (37.0)	26 (43.4)	8 (25.0)	.08
Immunosuppression	5 (5.4)	4 (6.7)	1 (3.1)	.7
Previous spinal surgery	14 (15.2)	8 (13.3)	6 (18.8)	.5
Previous spinal injury	17 (18.5)	13 (21.7)	4 (12.5)	.3
Reported symptoms				
Back pain	84 (91.3)	57 (95.0)	27 (84.4)	.1
Weakness	53 (57.6)	29 (48.3)	24 (75.0)	.01
Fever	29 (31.5)	11 (18.3)	18 (56.3)	<.001
Radicular pain	36 (39.1)	29 (48.3)	7 (22.6)	.01
Sensory loss	27 (29.3)	7 (11.9)	20 (62.5)	<.001
Weight loss	16 (17.4)	12 (20.0)	4 (12.5)	.4
Stool and/or urine incontinence	10 (10.9)	4 (6.8)	6 (18.8)	.2
Paralysis	9 (9.8)	0	9 (28.1)	<.001
Physical findings				
Decreased deep tendon reflexes	59 (64.1)	38 (64.4)	21 (70.0)	.6
Impaired motor strength	59 (64.1)	33 (56.9)	26 (83.9)	.01
Sensory deficit	35 (38.0)	18 (31.0)	17 (54.8)	.03
Decreased rectal tone (n=47)	14 (15.2)	4 (6.7)	10 (31.5)	.01
Positive Babinski's sign (n=79)	10 (10.9)	2 (3.3)	8 (25.0)	.003
Laboratory values				
Maximum temperature (°C) (median, range)	37.5 (36.6–40.7)	37.4 (36.6–40.7)	38.2 (36.7–40.0)	.01
Maximum WBC (K/mm^3) (median, range)	11.4 (4.1–50.7)	9.5 (4.1–39.5)	14.2 (5.5–50.7)	.001
ESR (mm/h) (median, range)	93 (7-140)	86 (13-140)	97 (7-134)	.1
CRP (mg/dL) (median, range)	73.7 (0.2–346.0)	39.9 (0.2–346.0)	156 (1.4–255.0)	.02
Imaging studies				
Discitis	69 (75.0)	54 (90.0)	15 (46.9)	<.001
Vertebral osteomyelitis	64 (69.6)	44 (73.3)	20 (62.5)	.3
Epidural abscess	40 (43.5)	19 (31.7)	21 (65.6)	.002
Other workup				
Infectious diseases consult	86 (94.0)	54 (90.0)	32 (100)	.09
Biopsy results				
Positive bone culture	61 (66.3)	32 (53.3)	29 (90.6)	.001
Methicillin-susceptible *Staphylococcus aureus*	17 (27.9)	6 (18.8)*	11 (37.9)*	-
Methicillin-resistant *Staphylococcus aureus*	15 (24.6)	6 (18.8)*	9 (31.0)*	-
Coagulase-negative staphylococci	9 (14.8)	8 (25.0)*	1 (3.4)*	-
Escherichia coli	4 (6.6)	2 (6.3)*	2 (6.9)*	-

NOTE. Data are no (%) of patients, unless otherwise indicated. SD, standard deviation; BMI, body-mass index; WBC, white blood cell count; ESR, erythrocyte sedimentation rate; CRP, C-reactive protein. *Percentage of positive cultures in each group.

Table 2. Empiric Antibiotic Regimens in 43 Patients with Positive Biopsies

Antibiotic(s)	n (%)
Vancomycin	14 (32.6)
Vancomycin + ceftriaxone	6 (14.0)
Vancomycin + oxacillin	3 (7.0)
Ciprofloxacin	3 (7.0)
Vancomycin + cefazolin	2 (4.7)
Vancomycin + ampicillin/sulbactam	2 (4.7)
Vancomycin + ciprofloxacin	2 (4.7)
Others	11 (25.6)

NOTE. Others are (all n = 1): oxacillin; ceftriaxone; linezolid; azithromycin; cefepime + gentamicin; ampicillin/sulbactam + cefepime; vancomycin + rifampin; ciprofloxacin + rifampin; vancomycin + cefepime + amikacin; vancomycin + gentamicin + levofloxacin; vancomycin + cefepime. The data are from 43 patients who had positive needle or open biopsies despite previous antibiotic exposure; this is a subgroup of 61 culture-positive cases in our 92 biopsied patients.

of 32 who underwent open biopsy had previous antibiotic exposure, compared with 35 (67%) of 52 who underwent needle biopsy ($P = .9$). Among those with antibiotic exposure, 20 patients with open biopsy (20 [95%] of 21) and 20 with needle biopsy (20 [57%] of 35) had positive culture results ($P = .002$). Among the patients with no antibiotic exposure, 9 (82%) of 11 in the open biopsy group and 6 (35%) of 17 in the needle biopsy group had positive culture results ($P = .02$).

Positive culture results were more frequent in patients who had undergone open biopsy (29 [91%] of 32 vs needle biopsy [32 (53%) 60]; $P < .001$). Diabetes was less frequent in patients with positive culture results than in those with negative culture results (19 [31%] of 61 vs 18 [58%] of 31 with negative culture results; $P = .01$).

The multivariate regression model to predict a positive biopsy culture result among patients with hematogenous vertebral osteomyelitis found that only open biopsy (adjusted odds ratio [aOR], 8.4; 95% confidence interval [CI], 2.2–31.8; $P = .002$) was associated with a positive biopsy result. Diabetics were less likely to have positive biopsy culture results (aOR, 0.3; 95% CI, 0.1–0.9; $P = .03$). Previous antibiotic exposure, which was forced into the model (aOR, 2.3; 95% CI, 0.8–6.2; $P = .1$), was not significantly associated with negative culture results. The Hosmer–Lemeshow χ^2 was .960, and the -2 log likelihood was 95.7.

DISCUSSION

Treatment of hematogenous vertebral osteomyelitis involves extended courses of antimicrobial therapy. Pathogen-directed therapy is preferable to empirical treatment, and appropriate therapy depends on biopsy and/or blood culture results [8]. Under ideal circumstances, patients presenting with vertebral osteomyelitis would undergo a bone or disk biopsy as part of the diagnostic evaluation. However, patients may not have a diagnostic biopsy because of the perception that prebiopsy antibiotic exposure will have lowered the microbiological yield [9]. Our aim was to elucidate the role of antibiotic exposure on the results of subsequent biopsies.

CT- or fluoroscopy-guided percutaneous needle biopsy is a less invasive procedure than open biopsy for the diagnosis of vertebral pathology [10]. In our cohort, patients who had an open biopsy were more likely to have increased severity of disease or neurological compromise requiring surgical decompression or stabilization. The need for surgical intervention therefore dictated this type of biopsy, whereas needle biopsies were exclusively diagnostic. A pathogen was recovered in 53% patients having a percutaneous biopsy and in 91% having an open biopsy, with an overall yield of 66%. The yield of needle biopsies reported in the literature varies from 50% to 100% [3, 6]. Similar to our results, the diagnostic yield was higher for open biopsies [11, 12], which may be because of an increased extent of infection in patients requiring surgery (which leads to open biopsy and improved sampling) and a presumably higher bacterial load in patients with increased severity of illness.

Among the few studies investigating the yield of biopsies after antibiotic exposure, a retrospective analysis of CT-guided fine-needle aspirations in vertebral osteomyelitis by de Lucas et al [3] found significantly lower rates of bacterial recovery in aspirates obtained after antibiotic treatment was initiated (23% vs 60%). However, the sample size of 46 procedures was smaller than that in the present study, included contiguous-source osteomyelitis (frequently encountered in paraplegic patients with chronic decubitus ulcers), and was limited to patients with percutaneous needle biopsies. Rankine et al [5] were among the first to report decreased bacterial recovery after starting empirical treatment, but their study included even fewer patients. Another retrospective study of needle aspiration in vertebral osteomyelitis reported a 30% versus 86% yield among 10 pretreated and 7 non-pretreated patients, respectively [6]. A further study examined needle biopsy results but reported previous antibiotic exposure only for culture-negative specimens [13]. In contrast, we found that the yield of biopsy cultures was not significantly decreased in the context of previous antibiotic exposure and only 17 (28%) of 60 patients with antibiotic exposure had potentially false-negative culture results because of the empirical antibiotic treatment. The tendency in patients with previous antibiotic exposure to even have a higher microbiological yield than those in whom antibiotics were withheld may be because severely ill patients are more likely to be started on empirical treatment before undergoing biopsy. These patients may also have more severe infections. In addition to that, the fact that almost all open biopsies yielded pathogens despite antibiotic exposure points to the important role of sampling technique. We were surprised to find that diabetes was associated with

negative culture results; this could not be explained by higher rates of prebiopsy antibiotics, higher rates of positive blood culture results to guide treatment instead of a biopsy culture, or shorter duration of symptoms (data not shown). Part of the explanation might be that diabetics were somewhat more likely to have needle biopsies than open biopsies, and needle biopsies less frequently resulted in a positive culture result. Open biopsy remained the strongest predictor for positive culture results in our study, even after adjustment for prebiopsy antibiotic exposure.

In clinical practice, there has been a prevailing dogma that antibiotics should be withheld before obtainment of a biopsy specimen to improve the yield of cultures. Conversely, for those patients who have already received empirical antibiotic therapy, bone or disk biopsy is often deferred because of the anticipation that the yield will be low. Although the investigators cited above concluded that antibiotic exposure negatively impacted pathogen recovery, the match between empirical therapy and the antibiotic susceptibility of subsequently recovered organisms has never been addressed. We examined the frequency with which empirical antibiotics matched the susceptibility of recovered pathogens and found that 38 (63%) of 60 patients given empirical antibiotics (41% of all 92 patients who underwent biopsies) had been treated with an antibiotic matching susceptibilities and still grew the bacteria. It would be interesting to determine the impact of the duration of prebiopsy antibiotics on the microbiological yield; however, our numbers were too small to do this in a meaningful way. Also, the antibiotic-free window before biopsy may be more relevant to determine the impact of antibiotics but was not assessed here.

Limitations of this study include a retrospective study design, which may have resulted in missing key variables. In addition, it occurred in a single tertiary medical center, which may limit the generalizability of our results to a larger, heterogeneous population. The 14-day cutoff period for prebiopsy antimicrobial exposure is arbitrary; however, there is no established definition for what duration of exposure is relevant. It also is unclear why 17 patients with positive blood culture results underwent additional diagnostic evaluation with percutaneous needle biopsies; this is not evidence-based practice. Lastly, we did not collect long-term outcome data [14].

We have presented results from a large, retrospective cohort study on the epidemiology of hematogenous vertebral osteomyelitis and elucidated the effect of antibiotic exposure before bone or disk biopsy with respect to pathogen recovery. The results of this study argue in favor of obtaining biopsies even in the context of empirical antimicrobial pretreatment, because the yield can be expected to be at least ~50%, which will allow for tailoring of antibiotic treatment to the recovered pathogen. These findings suggest that biopsies should not be foregone solely on the basis of previous antibiotic exposure. Prospective studies and clinical trials are needed to identify best practices for diagnosing and managing hematogenous vertebral osteomyelitis.

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