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Research article

Percutaneous CT guided bone biopsy for suspected osteomyelitis: Diagnostic yield and impact on patient's treatment change and recovery

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ABSTRACT

Aim: To evaluate the utility of percutaneous CT guided bone biopsy (PCBB) for suspected osteomyelitis (OM) and its eventual impact on patient management and recovery.

Material and methods: Patients who received a PCBB for suspected osteomyelitis from years 2012-2018. Patient demographics, lesion location, ulcer grade, signs of toxemia, serology, wound and blood cultures, bone biopsy and cross-sectional imaging results were recorded. Diagnostic yield of the bone biopsy and its role in influencing the final treatment plan and patient recovery were evaluated. Chi-square test was used. P-value less than 0.05 was considered statistically significant.

Results: 115 patients with mean age 50.86 ± 14.49 years were included. The common locations were sacrum/ischium (49/115, 43%) and spine (35/115, 30%). Clinically, 40/115 (35%) had toxemia and 67/115 (58%) had ulcers. Per serology, 17/111 (15%), 95/106 (90%), and 86/98 (88%) had an elevated WBC, CRP, and sedimentation rate, respectively. 22/91 (24%) had a positive blood culture and all 23/23 had a positive wound culture. On imaging, definitive and possible OM were reported in 84.1% and 14.2%, respectively, with 1.8% as no OM. Only 24/115 (21%) had a positive bone biopsy culture and only 10/24 (42%) total positive bone cultures impacted the treatment plan. There was no significant effect of antibiotics on the diagnostic yield of culture ($p = 0.08$). No statistical significance was found when comparing treatment change based on bone culture results versus all other factors combined ($p = 0.33$), or when comparing clinical improvement with and without positive bone cultures ($p = 0.12$).

Conclusion: Despite positive cross-sectional imaging findings of OM, bone biopsy yield of positive culture is low, and it leads to a small impact in changing the treatment plan or altering the course of patient recovery.

1. Introduction

Osteomyelitis (OM) is a serious and recalcitrant infection of the bone that affects 10 out of every 100,000 people [1]. It is often caused by contiguous soft tissue infection and/or ulceration with direct inoculation of a pathogen, or via hematogenous spread of microorganisms and thus, often follows other co-morbidities or injuries [2,3]. As such, management protocols vary between cases and institutions, which create inefficiencies in the diagnostic workup and may decrease the effectiveness of treatment for OM [4]. This can be problematic for the affected patients because if inadequately treated, an acute case of OM becomes chronic, which accompanied by significant complications such as bone fractures, septic arthritis, cellulitis, septicemia, and osteonecrosis [2]. Standard treatment involves intravenous antibiotic therapy, preferably in the hospital setting, guided by culture results if possible, or empiric antibiotic therapy if the pathogen is unknown or cannot be retrieved [2]. It is then followed by outpatient parenteral antimicrobial therapy, often lasting about 6 weeks [5,6]. However, if treatment of acute OM fails, progression to chronic OM is notoriously associated with poorer treatment outcomes due to the usual presence of other co-morbidities affecting immune response, low antibiotic penetrance into the bone from osteonecrosis, and formation of bacterial biofilms [7,8]. Hence, surgical debridement may be required. However, despite surgical debridement and antibiotic therapy, the recurrence rate of chronic OM is still 30% at 12 months [9]. Thus, it is vital to analyze the current diagnostic and treatment practices to detect inefficiencies, and outline strategies to optimize the management algorithm.

The diagnosis of OM is usually based on a combination of factors including clinical signs and symptoms of local hyperemia, swelling, ulcer and toxemia, white cell count, serology, imaging, and culture

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results [8,10]. Leukocytosis, increased erythrocyte sedimentation rate (ESR), and C-reactive protein (CRP) levels indicate inflammation and hence, a consistently normal ESR and CRP level can rule out OM [10]. CRP is elevated more so in soft tissue inflammations and elevated ESR > 70-75 is suggested as an accurate predictor of OM. Presence of cortical erosion at the site of ulceration is an accurate sign of OM. The most commonly used imaging modality to assess OM following radiographic screening is an MRI due to its high sensitivity (91%) and specificity (82%) for OM; however in some cases, CT or leukocyte scintigraphy may also be used [8]. Nevertheless, despite the high sensitivity of MRI, bone biopsies are still considered the gold standard for an OM diagnosis [11]. In a recent study by Garg et.al [12], among the 84 bone biopsies of the vertebrae for suspected OM, the yield rate for confirming OM and microorganisms was 41% and 19%, respectively with different micro-organisms than blood or urine cultures identified in only 9.5% cases. The impact of these results on patient management was however not reported and the study was limited to spine biopsy. Despite such observations, there are often pressing circumstances where interventional and/or musculoskeletal radiologists are asked to perform bone biopsy by the referring teams and consulting infectious disease physicians. Many reasons are cited for these urgent requests, such as, to provide early accurate treatment, and to mitigate the possibilities of drug resistance, and reduce patient morbidity from empiric treatments. Bone biopsies are however, also associated with increased costs, patient discomfort and sedation, and increased labor.

To systematically address the role of CT guided biopsy for suspected OM, we performed an institutional audit of all bone biopsies of various body sites performed during a specific period by our radiologists. We evaluated the clinical findings, serology, pathology and microbiology results, imaging results, as well as the effect of bone biopsy results on the patient management and outcomes. It was hypothesized that bone biopsy culture yield is low despite high MRI positivity rate, and it will have a low impact on the final treatment plan and patient recovery.

2. Methods

The study was performed in compliance with HIPAA regulations and was approved by the institutional review board. Informed consent was waived due to the retrospective nature of the study.

2.1. Patient population

A search of all adult patients (18–100 years old) who had undergone a CT guided bone biopsy due to suspected osteomyelitis from January 2012 through February 2018 was performed using the clinical PACS. All reports for exam description CT BONE BIOPSY were compiled from this date range yielding 823 studies. A musculoskeletal (MSK) radiology fellow evaluated the records and then included only procedures performed with an indication of “infection” or “osteomyelitis”, 122 of the 823 original studies. 4 of these were subsequently excluded due to incorrect categorization of the procedure. 2 were excluded due to incomplete study, and 1 was excluded due to restricted records. Ultimately, 115 consecutive biopsies from 115 patients were included in the final study sample (See Fig. 1).

2.2. Data collection

The data was collected by extensive chart reviews by three observers in consensus, a medical student, MSK radiology fellow and a senior MSK fellowship trained attending. The recorded data included patient demographics, clinical signs and symptoms, serology, culture results, imaging findings, biopsy and microbiology results, impact on treatment plan, and patient outcomes. Only data relating to a single OM event which required a bone biopsy were collected and analyzed. Demographic data included gender, age, and inpatient or outpatient status. Clinical signs and symptoms included signs of toxemia (fever, chills, night sweats, and sepsis) and the presence of wounds or ulcers near the suspected OM. Serology results analyzed were white blood cell count, CRP and ESR. Results were then reported as elevated or normal according to the established institutional laboratory reference ranges. Next, blood and wound cultures were reviewed and if positive, the organisms isolated, and their antibiotic sensitivities were recorded.

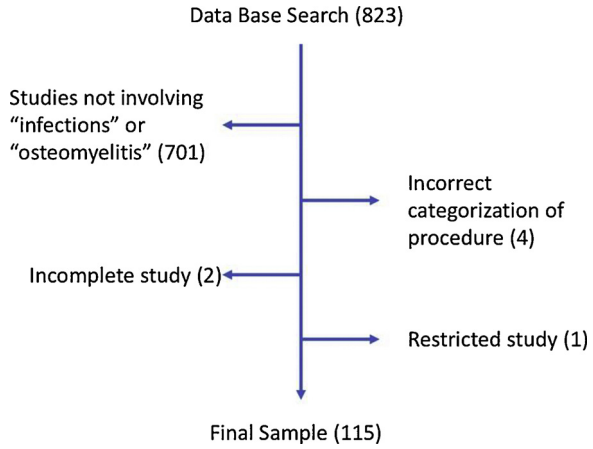

Fig. 1. A final sample size of N = 115 was obtained from a data base search.

All patients had underwent MRI, CT, or leukocyte scintigraphy for suspected OM evaluation. The reports previously generated as part of standard of care were categorized as ‘definitive OM’, ‘no OM’, and ‘possible OM’. Blinded to the final biopsy results, all ‘possible OM’ case images were re-reviewed by an expert fellowship trained MSK radiologist were attempted to stratify the cases into ‘definitive OM-(sinus tract abut the cortical margin with loss of cortical density or hypointensity, intra-osseous abscess, confluent loss of marrow hyperintensity on T1W images with enhancement in post-contrast cases)’ or ‘no OM- (no bone marrow edema on fat suppressed fluid sensitive sequences)’ since the terminology can vary among radiology reports. The cases which couldn’t be stratified into ‘definitive OM’ or ‘no OM’, were finally kept as ‘possible OM- (bone marrow edema or mild enhancement with no definite loss of cortex or loss of marrow hyperintensity on T1W images)’. All bone biopsies were done under CT guidance using an 11 G needle and core and/or aspirate bone samples were obtained. The cores were obtained using co-axial technique targeting the imaging abnormality, avoiding the ulcerated area, if present; and the cores varied from 2 to 3 in each case. If a collection was encountered adjacent to the bone lesion, it was partly aspirated. No drains were placed. All samples of cores and aspirates were sent in a sterile cup to pathology and microbiology. The histology from the cores were read by multiple pathologists in the pathology department with no specific infectious disease expertise, which is the standard practice in our tertiary care institution. Data gathered from the biopsies included location, yield of culture, organisms isolated and their antibiotic sensitivities, and interpretation of tissue pathology. For reference, the amount of days between serology, culture, and imaging studies, and the bone biopsy were also recorded and averaged.

Finally, changes in the patient diagnosis and treatment were recorded after interpretation of the physician’s assessment and plan. A change in diagnosis was defined as initial suspicion of OM but upon further workup, the patient was found to definitively not have OM and/or another illness. A change in treatment plan was defined as a change from the standard in-patient antibiotic regimen (vancomycin and zosyn) or out-patient regimen (varied per physician due to specific cause, certain clinical features, past medical history, pathogen antibiotic sensitivities, and other co-morbidities). Lastly, follow-up notes within a 3-month period after the biopsy were analyzed and interpreted as a positive improvement, worsening, or no improvement. An improvement constituted improved wound appearance, clinical

symptoms, and serology. Worsening was defined as spread of infection and/or death related to infection. No improvement was defined as status quo with persistent wound and toxemia symptoms.

Descriptive and analytic statistics were performed by an expert statistician. The data was stored on Microsoft 2010 excel worksheet, expressed as summaries and percentages. Chi-square test was used. P-value less than 0.05 was considered statistically significant.

3. Results

3.1. Patient population

A total of 115 patients, ages 21 to 80 years old (mean ± SD = 50.86 ± 14.49 years) were included in this study. There were 81 males and 34 females (ratio of 2.4:1). Most patients were treated for their OM in the in-patient setting (100/115, 87%). Upon admission or initial clinical visit, 40/115 (34.8%) patients presented with symptoms of toxemia (fever, chills, night sweats, sepsis). The remaining 75 patients presented with more localized symptoms, such as local erythema, bone pain, wound discharge, foul odor from wound, non-healing wound(s), and/or local edema. In some cases, patients also presented with symptoms related to other co-morbidities, which will not be analyzed in this study. 67/115 patients (58.3%) also had one or more wounds or ulcers on their body. In cases where wound grading was reported, it was found that 49/50 wounds (98%) were high grade (Grade III/IV). For remaining 48 patients without wounds or ulcers, 31 of them (64.5%) had a chief complaint of neck or back pain. Table 1 summarizes the demographic and initial clinical characteristics of the patient sample.

3.2. Serology, cultures, imaging

On serology, the WBC, CRP, and ESR were recorded and analyzed for their correlation with an OM diagnosis. The average value for the WBC was 7.5 × 10^9/L with a normal reference range of 4–11 × 10^9/L and 3.9–10.7 × 10^9/L at the two University hospitals. The WBC was elevated in only 17/111 (15.3%) reported cases. The average value for the CRP was 8.16 mg/dL with a normal reference range of < 0.05 mg/dL. The CRP was elevated in 95/106 (90%) of reported cases. The average value for the ESR was 64.01 mm/hr with a normal reference range of 0–20 mm/h and 0–10 mm/hr at the two hospitals. The ESR was elevated in 86/98 (87.8%) reported cases. The WBC, CRP, and ESR were each measured an average of 4.1, 6.3, and 8.2 days, respectively before the bone biopsy. To identify possible pathogens associated with the OM, blood and wound cultures were taken. Out of 91 reported blood cultures taken, 22 (24.2%) were positive for at least one organism. The most common organism found in blood cultures was coagulase negative staphylococcus (6/22; 23.7%) followed by staphylococcus aureus (4/22; 18.2%). Out of 23 reported wound cultures taken, all cultures grew at least one organism. The most common organism was staphylococcus aureus (9/23; 39.1%) followed by escherichia coli (6/23; 26%). Blood and wound cultures were done an average of 6 and 11.1 days before the bone biopsy, respectively. Out of the 113 cases where imaging was done to assess for OM, the most common imaging modality used was MRI (98/113; 87%) followed by CT (8/113; 7%), and leukocyte scintigraphy (7/113; 6.2%). Upon image interpretation, 95 out of 113 had definite OM (84.1%), 16 out of 113 had possible OM (14.2%), and 2 out of 113 did not have OM (1.8%). The images were taken an average of 8.5 days before the bone biopsy. Table 2 summarizes the results obtained from pre-bone biopsy workup.

Table 1
Baseline Population Characteristics.

Parameter	Frequency (%)
Patients (n = 115)	
Male	81 (70.4)
Female	34 (29.6
In-patient	100 (86.9)
Outpatient	15 (13.1)
Clinical s/s (n = 115)	
Toxemia	40 (34.8)
Wound/Ulcer Present	67(58.3)
High Grade	49/50 (98)
No Wound/Ulcer	48 (41.7)
Neck/Back Pain	31 (64.5)

Table 2
Pre-Bone Biopsy Workup Results.

Parameter	Frequency (%)
Serology	
Elevated WBC	17/111 (15.3)
Elevated CRP	95/106 (90)
Elevated ESR	86/98 (86.8)
Culture	
Positive blood cultures	22/91 (24.2)
Coagulase negative staphylococcus	6/22 (23.7)
Staphylococcus aureus	4/22 (18.7)
Positive wound cultures	23/23 (100)
Staphylococcus aureus	9/23 (39.1)
Escherichia coli	6/23 (26)
Imaging	
Definite OM	95/113 (84.1)
Possible OM	16/113 (14.2)
Negative OM	2/113 (1.8)

3.3. Bone biopsy, cultures, and histology

The most common bone biopsy site was the sacrum/ischium (49/115, 43%), followed by the spine (35/115, 30%), extremities (32/115, 28%), and the chest wall (2/115, 1.7%). Regarding the localizations of the lesions at the extremities and spine, the specific sites were-

extremities: calcaneus, ankle, femoral head, proximal radius, distal tibia, fibula, tibial stump, femur, elbow, and greater trochanter; *spine*: ranging from C4-L5.

Figs. 2c, 3c and f show CT images of the bone biopsies. In anticipation for a bone biopsy, antibiotics were held in 70/115 cases (61%). Upon culture of the biopsy sample, only 24/115 (21%) had a positive culture of which 19/24 (91%) contained organisms not shown in blood or wound cultures. The most common organism grown in culture was Staphylococcus aureus (7/24; 29.2%) followed by E. coli (3/24; 12.5%). Other organisms included diphtheroids, enterococcus species, proteus mirabilis, streptococcus species, staphylococcus epidermidis, pseudomonas aeruginosa, C. perfringens, bacteroides fragilis, P. acnes, and candida. When clustered among different locations, the positive and negative cultures were seen in spine (8/115, 7.0% and 28/115, 24.3%), ischium (9/115, 7.8% and 39/115, 33.9%), extremities (7/115, 6.1% and 22/115, 19.1%), and chest wall (0/115, 0% and 2/115, 1.7%), respectively.

Per tissue histology findings, 12/36 (33.3%) showed no evidence of OM, 11/36 (30.6%) showed evidence of inflammation or OM, and 13/36 (36.1%) were inconclusive. Out of the 12 cases that reported no evidence of OM, 6 (50%) turned out to be false negatives, and the patients were still treated for OM. Table 3 summarizes the data analyzed for bone biopsies. Figs. 2 and 3 show MRI imaging and CT guided bone biopsies of positive and negative bone biopsy culture cases, respectively.

Among the 115 patients, 70/115 with no antibiotic exposure had positive cultures in 14/70, and negative cultures in 56/70. In the remaining 45/115 patients on antibiotics, positive cultures were seen in 10/45 and negative cultures in 35/45 (p = 0.08, Chi square test).

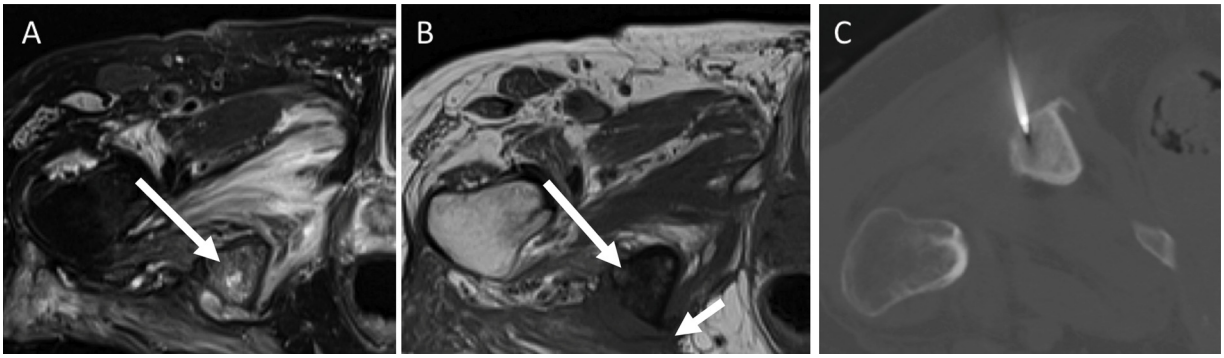

Fig. 2. 64-year-old man presented with a right ischial ulcer. (A)Axial T2FS. (B)Axial T1. MRI shows stage IV decubitus ulcer (small arrow) with definitive OM of the ischial tuberosity (large arrows) and findings of obturator internus and externus myositis. (C) Bone biopsy of right ischial tuberosity. Bone biopsy culture was positive.

3.4. Diagnosis, treatment, and recovery

The final diagnosis was modified to "No OM" in only 7 out of 115 cases (6%); however, bone biopsy results did not play a major role in changing the diagnosis in any of these cases. Instead, a combination of negative blood cultures, serology values, and clinical signs and symptoms were commonly cited to be the deciding factor to rule out OM. The treatment was altered in 58 out of 115 cases (50.4%) from their original plan of empiric antibiotics. based on 10 out of 24 positive bone cultures (42%) or 10 out of 115 attempted bone cultures (8.7%). Statistical analysis showed a p-value of 0.334 when comparing treatment change based on bone culture results versus all other factors combined. Other commonly cited reasons included the presence of other infections or co-morbidities (14/58; 24.1%), wound culture results and sensitivities (9/58; 15.5%), the absence or persistence of certain clinical signs and elevated serology results (7/58; 12.1%), blood culture results and sensitivities (7/58; 12.1%), and the past medical history (5/58; 8.6%). During follow-up, it was noted that 19/22 (79%) patients with positive bone cultures and 55/79 (70%) with negative bone cultures showed clinical improvement. A p-value of 0.116 was obtained when

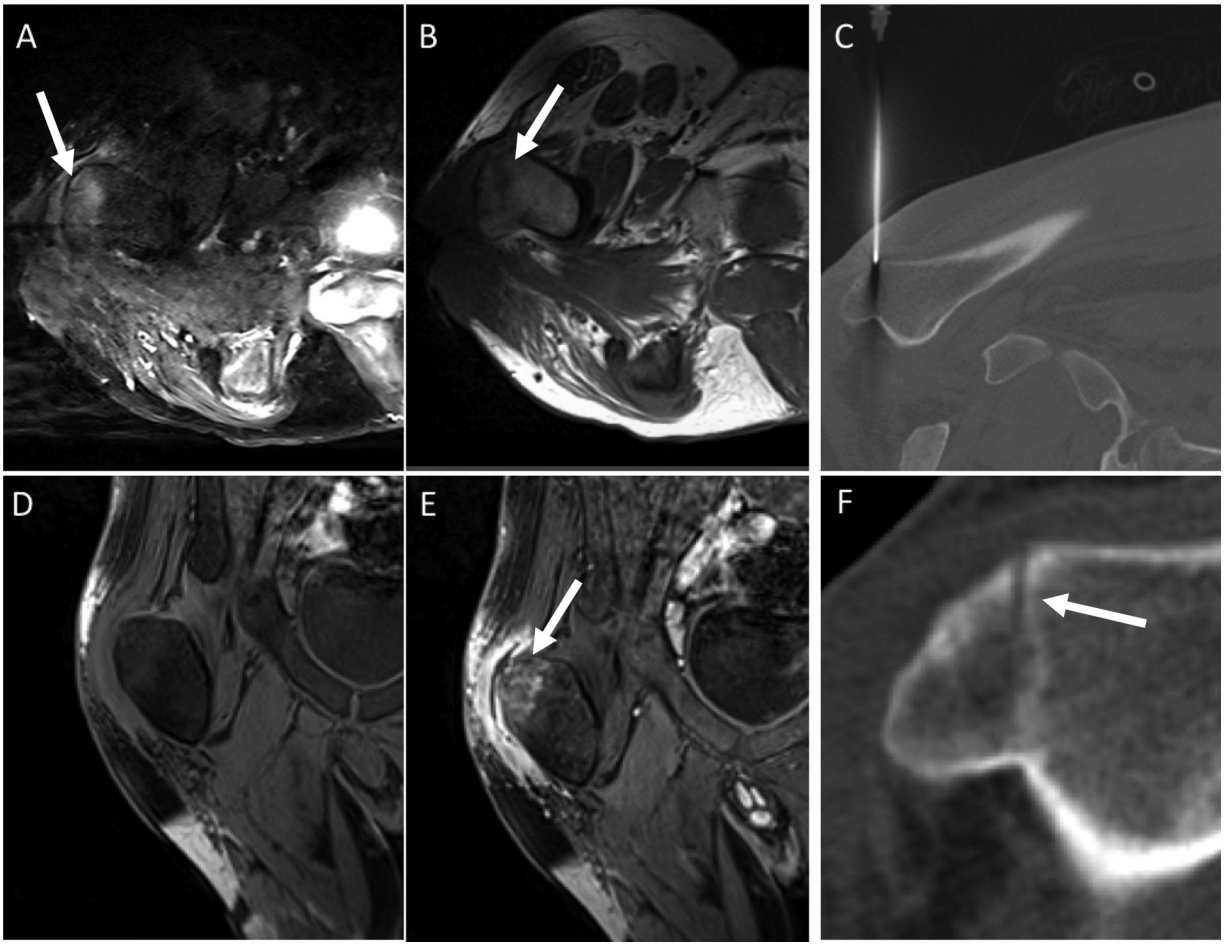

Fig. 3. 35-year-old man presented with right hip ulcer. (A)Axial T2FS. (B)Axial T1. (D) Coronal T1FS Pre-contrast. (E) Coronal T1FS Post-contrast. MRI shows decubitus ulceration with definite osteomyelitis of the right greater trochanter (arrows). (C) Bone biopsy of the right greater trochanter. (F) Bone biopsy needle tract (arrow) is shown. Bone biopsy culture was negative.

Table 3
Bone Biopsy.

Parameter	Frequency (%)
Location (n = 115)	
Sacrum/Ischium	49 (43)
Spine	35 (30)
Extremities	32 (28)
Chest wall	2 (1.7)
Results	
Positive cultures (n = 24)	24 (21)
Newly identified organism[a]	19 (91)
Staphylococcus aureus	7 (29.2)
Escherichia coli	3 (12.5)
Histology (n = 36)	
Evidence of inflammation/OM	11 (30.6)
No evidence of OM (n = 12)	12 (33)
False negative	6 (50)
Inconclusive	13 (36.1)

[a] Organism not found in other cultures.

Table 4
Diagnosis, Treatment, and Recovery.

Parameter	Frequency (%)
Final Diagnosis (n = 115)	
OM	108 (94)
No OM	7 (6)
Change in diagnosis solely due to bone biopsy	0 (0)
Treatment (n = 115)	
Altered plan (n = 58)	58 (50.4)
Co-morbidity	14 (24.1)
Bone biopsy culture	10 (17.2)
Wound culture	9 (15.5)
Clinical s/s and Elevated serology	7 (12.1)
Blood culture	7 (12.1)
PMHx	2 (3.4)
Follow-Up Improvement	
w/ positive bone biopsy culture	19/22 (72)
w/ negative bone biopsy culture	55/79 (70)

comparing clinical improvement with and without positive bone cultures. Table 4 summarizes the changes in diagnosis, treatment, and recovery resulting from the clinical workup done.

4. Discussion

Osteomyelitis continues to be a serious bone condition that increases healthcare costs due to its lengthy workup and long duration of antibiotic treatment. Fortunately, the incidence of hematogenous and relapsing osteomyelitis has been declining due to the effectiveness of current antibiotics [13]. However, there is an increasing incidence of OM due to surgical procedures, predisposing chronic conditions, and wound infections, which the patient sample in this study seems to confirm. Unfortunately, it has been reportedly difficult to study OM outcomes in the past due it's heterogenous presentation, and the long period of follow-up required to assess treatment effectiveness [13]. This study shares those limitations in that cases often involved other co-morbidities or complex past medical histories that may have impacted treatment course, recovery results, and regular reporting on OM status.

In evaluating how different aspects of an OM workup contributed to a final OM diagnosis, our study showed that signs of toxemia were not a very good predictor for adult OM. This is in accordance with another study done showing signs of toxemia to be closely tied to mostly hematogenous OM, which is not a major cause of OM in adult populations [14]. The clinical findings that did correlate well with OM in this study however were the presence of ulcers, especially high grade, and persistent back/neck pain with fever. Wounds were often non-healing and accompanied by local erythema, edema, pus, strong odor, and/or drainage. For serological data, elevated values for the CRP and ESR seemed to correctly raise suspicion for OM in combination with the clinical findings, as around 90% of the patient population had elevated values. This is consistent with previous research supporting elevated CRP and ESR values in patients with OM [6,15,16]. As for the WBC, previous research has shown that it is not a reliable indicator of OM and can even be within normal limits during an infection [17]. Likewise, only 15% of patients in our sample had an elevated WBC.

Per culture data, the blood cultures exhibited a low yield rate of 24.4%. This is in accordance with previous studies where blood culture yield rate has been reported to be from 15 to 30% [18,19]. It has also been reported that bacteremia is associated with OM in 20% of cases [20]. On the other hand, wound cultures had a very high yield rate although this is probably since wound cultures were only done on infected non-healing wounds and ulcers. In the literature, staphylococcus aureus and staphylococcus epidermis are reported to be the most commonly causative organisms behind OM [21]. This is in accordance with our blood culture results and staphylococcus aureus was the most common organism in wound cultures. In addition, escherichia coli was seen in many wound cultures due to the high prevalence of sacral decubitus ulcers in our patient sample.

The most commonly biopsied site was the sacrum/ischium (n = 49, usually in patients with sacral decubitus ulcers) followed by the spine (n = 35, usually in patients with back pain). Bone biopsy cultures were only positive in 21% of cases (n = 24), with bone cultures in 2 of the cases producing organisms already present in blood or wound cultures. It is important to note that overall, the two most commonly isolated organisms from these cultures were staphylococcus aureus and escherichia coli, the same organisms that were the most commonly isolated in deep wound cultures. This correlation has also been noted in another study in patients with diabetic foot osteomyelitis [22]. The antibiotics were held in anticipation for bone biopsy in only 70 out of 115 cases. It is possible that prior antibiotic use decreases bone biopsy yield or alters the presence of cultured organisms [23–25]. However, this issue is still controversial and further definitive evidence supporting the negative impact of antibiotics on bone biopsy yield is yet to be found. We did not find it statistically significant, similar to the results shown in a recent meta-analysis by McNamara et al. that image-guided biopsy in patients without antibiotic exposure resulted in slightly higher yield at 43% (95% CI, 0.37-0.48) than those on antibiotics (32%, 95% CI- 0.22-0.43) but without statistical significance; p = 0.48 [26].

Furthermore, the histology results from the bone biopsy samples did not seem to be reliable indicators for OM. Only about 30% confirmed inflammatory process occurring in the bone sample while another 36% were inconclusive, citing an inappropriate sample or not mentioning OM at all in the final pathology report. Around 33% (12 cases) reported no signs of OM; however, half of these cases turned out to be false negatives and were eventually treated for OM with subsequent improvement. However, it seems that pathology studies were done in these cases only when the diagnosis of OM was unclear. Thus, histology results were only present in 36 of the 115 cases and due to the retrospective nature of the study, the number of pathology studies could not be controlled. Nevertheless, the opinion of the scientific community on the accuracy of histology results seems to be mixed. Whereas some studies report a high diagnostic specificity on histologic examination [27], others report histological diagnostic confirmation occurring in only up to 50% of cases [28]. Possible explanations for the low yield of bone biopsy cultures and low dependability of histology reports in this study could be patchy distribution of OM in bone, which is known to cause false negative bone biopsy results [14]. Thus, to maximize the utility of a bone biopsy for OM, one must theoretically correctly guess and biopsy the area of bone containing the causative organism. Even then, despite 22 cases having newly identified organisms on bone biopsy cultures, only 10 out of 115 cases involved a change in treatment plan based on bone biopsy culture results.

For the final diagnosis, OM was ruled out in only 7 cases. Thus, a negative bone biopsy was not regarded as a highly dependable indicator for ruling out OM as a high percentage of MRIs with OM diagnosis were present in the sample, a fairly accurate modality for the prospective diagnosis of OM. Therefore, other negative studies such as low serology, negative signs and symptoms, and negative culture results were also often cited along with a negative bone culture result as the reason to safely rule out OM [29].

About one-half (50.7%) of the original 115 cases had an altered treatment plan during their period of care due to a specified reason, of which the most commonly mentioned are listed in Table 4. Co-morbidities often affected the treatment plan by restricting antibiotic use or requiring a more potent antibiotic regimen. Culture results affected antibiotic choice based on the antibiotic sensitivity of the organisms. Meanwhile, continuation of elevated serology results or clinical signs and symptoms despite being on an antibiotic regimen and a past medical history of certain resistant or recurring organisms often altered antibiotic choice and length of treatment. The other half of the 115 cases did not feature an altered treatment plan during the encounter due to factors such as, no organisms were cultured or that cultured organisms were already covered under the standard antibiotic protocol. Upon searching available follow up notes, it was noted that the recovery rates were similar in cases that had a positive bone biopsy culture and those with a negative bone biopsy culture (about 70% in both). Such a recovery rate upon follow up is in accordance with previous studies which report OM recurrence rate of 30% [13]. Both populations reported an improvement in wound appearance, pain, and/or CRP values, which have been supported in literature to be a dependable measurement of follow-up improvement [30].

This study has some limitations. Since this study was retrospective in nature, the patient population was not randomized and not all desired data points were recorded in charts. These absent data points were left out of the final percentage calculations to accurately represent their frequency. Despite these limitations, comparability was ensured among cases by selecting only cases where bone biopsies were performed due to high suspicion of OM. We couldn't specifically address the role of bone only versus soft tissue plus bone aspiration due to incomplete details in the chart, since the latter may increase diagnostic yield as has been recently reported by Chang and Spira et al. [31,32]. Due to retrospective nature, we could not assess complications as defined by CIRSE criteria [33], however, based on chart reviews, none of the patients had any complication during the procedure which couldn't be solved within the same session. None required any additional therapy, and there was no deviation from the normal post-therapeutic course (CIRSE grade I). Finally, the study involves multiple body sites, but it is one of the larger studies till date focused specifically on bone infections and one of the few ones detailing the impact of these biopsies on patient management.

Thus, the bone biopsies performed in our study in the context of OM seemed to rarely add any additional benefit to that from previously done workup. In the 10 cases (8.7%) where it did affect the final treatment plan, half involved a de-escalation of antibiotics while the other half involved the addition of new antibiotics to cover organisms identified on bone biopsy culture. It is unfortunate that deeper wound cultures were not done as they could have identified organisms considered in this study to be "newly identified" in bone biopsy cultures. This would theoretically lower the number of cases in our study where bone biopsy results were considered high impact and could be a possible area for further study. It is important to note that the results of this study is not to say that bone biopsies are ineffective, as indeed, they show a higher impact in evaluating possible malignancies [34,35]. Thus, bone biopsies should be performed if there is a suspicion of malignancy versus OM. However, if a malignancy is not suspected, then an MRI with associated clinical symptoms and elevated serology seems to be diagnostic for OM along with wound and/or blood cultures to guide antibiotic therapy.

To conclude, despite positive cross-sectional imaging findings of OM, bone biopsy yield of positive culture is low, and it leads to a small impact in changing the treatment plan or altering the course of patient recovery.

Disclosures

AC receives royalties from Jaypee and Wolters. AC also serves as consultant with ICON Medical and Treace Medical Inc.

Conflict of interest

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome. However, we do wish to disclose that AC receives royalties from Jaypee and Wolters. AC also serves as consultant with ICON Medical and Treace 3D Medical Inc.

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