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Osteoarticular Infections Following Open or Penetrating Trauma in Children in the Post-Community-Acquired Methicillin-Resistant *Staphylococcus aureus* Era: The Impact of *Enterobacter cloacae*

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Abstract

Background—Most cases of pediatric osteoarticular infections (OAI) are hematogenous in nature and caused by *Staphylococcus aureus*. OAI in children can also occur through direct inoculation of microorganisms secondary to penetrating or open trauma. No studies in the US have evaluated the microbiology or outcomes of trauma-related OAI (TROAI) in children in the era of community-acquired MRSA (CA-MRSA).

Methods—Cases were identified from the inpatient infectious diseases consultation database at Texas Children's Hospital from Jan 2011–Dec 2016. TROAI cases were those in which OAI developed following a clear history of penetrating trauma, open fracture, crush injury or traumatic amputation. Only cases with radiographic evidence of bone abscess, gross appearance of infection at time of surgery and/or positive cultures from bone or joint were included. Complications included recurrence of infection, pathologic fracture or chronic osteomyelitis.

Results—During the study period, 692 consultations for OAI were performed, with 34 meeting inclusion criteria. In 68% at least one organism was isolated and the most commonly isolated organisms were *S. aureus* (32% overall, 21% MRSA) and *Enterobacter cloacae* (24%). Polymicrobial infections occurred in 38% of patients. 85% of patients had at least one surgical procedure and 38% underwent 2 procedures. 82% of patients were discharged on oral therapy. Complications developed in 15% of patients and were more commonly associated with *E. cloacae* (80% vs. 14%, $p=0.007$) and fungi ($p=0.03$).

Conclusion—TROAI are relatively uncommon in children but cause significant morbidity. While MRSA contributes substantially to TROAI, the highly diverse microbiology emphasizes the importance of obtaining cultures for microbiologic diagnosis and management. Clinicians should be aware of the frequency of *E. cloacae* in TROAI and its high risk for sequelae.

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Keywords

Osteomyelitis; trauma; direct inoculation; *Staphylococcus aureus*; *Enterobacter cloacae*

Background

Osteoarticular infections (OAI), comprising both septic arthritis and osteomyelitis, cause substantial morbidity in children. OAIs occur most commonly as a consequence of hematogenous dissemination of microorganisms with *Staphylococcus aureus* being the most common cause, accounting for over 80% of culture positive cases.^{1–3} Given the high frequency of *S. aureus*, empiric therapy is typically targeted towards gram-positive pathogens with data suggesting that even culture-negative cases respond well to such therapy.⁴

With the widespread dissemination of community-acquired methicillin-resistant *S. aureus* (CA-MRSA) in the early 2000s, the spectrum of disease severity expanded among acute hematogenous OAI with consequent necessary changes in therapy. While the prevalence of invasive CA-MRSA is declining in some centers,⁵ it still contributes substantially to hematogenous OAI in children. Furthermore, many regions have experienced an increase in the proportion of CA-MRSA isolates that are resistant to clindamycin,⁶ limiting options for treatment.

OAI can also occur through direct inoculation of microorganism into tissues as a consequence of penetrating or open trauma. Bone infection following direct inoculation, while clearly having different pathogenesis than hematogenous disease, is considered a form of osteomyelitis in North American literature;⁷ by contrast the term osteitis is used in many European publications.⁸ In North American literature, however, the term osteitis most often refers to inflammation of bone secondary to a non-bacterial etiology⁹ or syphilis.¹⁰ For purposes of simplicity, we will refer to this entity as trauma related OAI (TROAI) to encompass infection of a bone and/or joint secondary to inoculation of microorganisms from penetrating or open trauma. Following trauma involving direct inoculation into or exposure of bone or synovium, the risk of infection is high. In resource limited settings, infection complicates as many as 44% of open fractures.¹¹ The frequency of TROAI complicating puncture wounds among patients seeking medical care has ranged from 2–60% with variability by specific type of injury.^{12–14} In such scenarios, infection may be secondary to inoculation with skin flora, organisms colonizing the penetrating object or those intrinsic to the environment (soil or vegetable matter) and as such the potential etiologic agents are far more diverse than in hematogenous disease.^{7, 15} Few studies have examined such infections as a whole in children, however, with most literature on this subject restricted to penetrating trauma of the foot and emphasizing the predominance of *Pseudomonas* spp. with or without staphylococci.^{12, 16} Furthermore, many series are restricted to very specific injuries or examine bone/joint infections in the context of all infections following trauma.¹²

Few studies exist describing the microbiology of TROAI in children since the emergence of CA-MRSA. A better understanding of the contemporary microbiology of TROAI is needed in order to guide empiric therapy given shifting antimicrobial susceptibility among

pathogens in the community. We sought to 1) describe the spectrum of etiologic agents of TROAI in children in the CA-MRSA era and 2) examine clinical outcomes associated with these infections.

Methods

The consultation database of the Texas Children's Hospital (TCH) Main Campus Infectious Diseases service was reviewed for patients with a consult for osteomyelitis or septic arthritis from January 2011– December 2016. The infectious diseases service is routinely consulted for OAI at our institution and previous comparisons of the consult database with discharge diagnosis codes have revealed a high degree of capture.¹⁷ Cases were eligible for inclusion if there was a preceding history of open or penetrating trauma at the site of OAI and 1) cultures obtained from bone or synovial fluid were positive for a pathogen and/or gram stain was positive, 2) purulence in bone/joint tissues was evident at the time of surgical exploration or 3) radiology studies revealed the presence of a subperiosteal/intraosseous abscess and/or synovial enhancement. Patients who only had microorganisms isolated from cultures at time of presentation with trauma (i.e., patients who had wound swabs sent for culture at time of presentation to emergency room after injury) were excluded unless subsequent blood, bone or synovial fluid cultures obtained at least 48 hours after injury became positive. Patients with orthopedic hardware infection without a history of trauma (such as infection of spinal instrumentation for scoliosis or femoral head fixation pins/devices for slipped capital femoral epiphysis) were excluded. The number of and type of cultures obtained were at the discretion of the attending orthopedic surgeon in consultation with infectious diseases. Molecular diagnostics, such as 16s PCR, were not routinely utilized for bone/synovial fluid samples during the study period. The identification and speciation of microorganisms was performed by the TCH clinical microbiology laboratory in the routine course of care in accordance with Clinical and Laboratory Standards Institute guidelines. The level of organism identification (i.e. genus vs. species level) was based on standardized workflows; organisms were not routinely categorized to the subspecies level. Complete medical, microbiology and laboratory reports were reviewed for all patients through August 1, 2017 or until last follow-up with infectious diseases and/or orthopedic surgery.

Definitions

Open or penetrating trauma included puncture, gunshot or stab wounds, open fractures, crush injuries, traumatic amputation, and animal/human bites. For purposes of this study, types of injuries were grouped into four categories: penetrating injuries (to include gunshot, stab, puncture and bite wounds), crush injuries (including avulsion injuries [injuries associated with forceful removal of soft tissue and exposure of underlying bone] and comminuted fractures without extrusion of bone through the skin), open fractures and amputations. Patients could have more than one of these four categories of injury. Organic foreign bodies included soil, gravel, plant matter (i.e., leaves, grass, twigs, wood fragments, etc.) and animal matter (i.e., teeth, fish fins, hair, etc.). Orthopedic complications included chronic osteomyelitis, limb length discrepancy, angular deformity, growth arrest, pathologic fracture or readmission for recurrence of signs/symptoms of TROAI (such as drainage, pain, swelling or erythema of the involved bone/joint).¹⁸

Statistics

The number of total hospital admissions during the study period was obtained from TCH administrative data and used to calculate TROAI incidence in terms of cases/10,000 admissions. In comparisons of clinical features across organisms, patients were grouped into the following categories: those with 1) Gram-positive organisms only, 2) Gram-negative organisms only, 3) mixed Gram-negative and -positive organisms, 4) mycobacteria with/without typical bacteria, 5) fungi with/without typical bacteria, 6) combination of mycobacteria, fungi and typical bacteria and 7) culture negative infection. Such comparisons allowed for individual patients to only be examined once. Dichotomous variables were compared with Fisher's exact test and continuous variable with the parametric Wilcoxon rank-sum or Kruskal-Wallis tests as appropriate; these tests were chosen given the anticipated small number of patients and the potential for skewed data when examining continuous variables. Two-tailed p values <0.05 were considered statistically significant. All statistical analyses were performed using STATA ver. 13 (STATA Corp, College Station, TX).

Results

During the study period, 692 consultations for OAI were performed with 34 meeting inclusion criteria. There were 115,721 hospital admissions at TCH Main Campus during the study period with TROAI accounting for 2.9 patients/10,000 hospital admissions. The median patient age was 8.2 years (interquartile range (IQR): 4.2–9.6 years) and 22 (64.7%) were of male gender (Table 1). Twenty-two patients had isolated bone infection (64.7%), one had an isolated joint infection (2.9%) and eleven (32.4%) had infection of both bone and joint. The median time from trauma until presentation with symptoms was 11 days (IQR: 4–11 days). Twenty-two patients had blood cultures obtained, none of which were positive. Twenty-nine patients (85.3%) underwent a surgical procedure and 13 (38.2%) underwent multiple surgical procedures. Five patients had imaging suggestive of OAI along with local signs/symptoms of inflammation but did not undergo surgical exploration. Eleven patients required placement of orthopedic hardware (32.4%) as a consequence of injury and/or infection. The most commonly affected bones were the tarsals/metatarsals (41.2%) followed by the carpals/metacarpals (20.6%); the most commonly affected joints were the knee (14.7%) and metatarsophalangeal (MTP) joint (11.8%). The most common form of trauma was penetrating trauma (58.8%) followed by open fractures (26.5%, Supplemental Table 1).

Microbiology

In 67.7% of cases a pathogen was identified (Figure 1A and B). The most commonly identified pathogen was *Staphylococcus aureus* (11/34, 32.3%) of which 7/11 were MRSA (63.6%). Clindamycin resistance was noted in 4/11 isolates (36.4%) and 3/7 MRSA isolates (42.8%). The second most commonly isolated organism was *Enterobacter cloacae* (8/34, 23.5%) followed by assorted fungi (17.6%). Twelve different species of fungi were isolated from six patients, the most common of which were *Fusarium* and *Curvularia* species (n=2 each). *Pseudomonas* and *Mycobacteria* spp. were each isolated in 3 cases (8.8%); 38.2% of all cases were polymicrobial. Among polymicrobial cases, the median number of species isolated per patient was 3 (IQR: 2–6). In three cases, *E. cloacae* was co-isolated along with

MRSA; overall *E. cloacae* was a component of polymicrobial infections in 7/8 cases (87.5%). *E. cloacae* isolates exhibited *in vitro* susceptibility to most antimicrobial agents tested (Supplemental Table 2).

Polymicrobial, monomicrobial and culture negative infections were compared (Table 2). Polymicrobial infections were more often associated with fever on presentation as well as a higher C-reactive protein (CRP) on admission and were less often associated with foot/ankle injuries than either monomicrobial infections or culture negative infections. In addition, polymicrobial infections were associated with retained foreign bodies, a higher median number of surgical procedures per patient (3 vs. 1, $p=0.02$) and a longer duration of hospital admission ($p=0.001$).

The isolation of a gram-negative pathogen or mycobacteria alone was associated with a longer time from trauma to presentation with infection compared with other organisms ($p=0.02$, Table 3). The isolation of fungi and/or mycobacteria was associated with a greater number of surgical procedures as well as a longer length of hospital stay. In addition, infections involving fungi were more often associated with the presence of retained foreign bodies, specifically organic foreign bodies, than other infections. There was no statistically significant relationship between categories of trauma and infectious etiologies.

Puncture Wounds of the Foot

Eleven cases of TROAI (32.4%) were associated with penetrating trauma to the foot. The median time from trauma to presentation with symptoms was 15 days (IQR: 3–34 days). Osteochondritis¹⁶ was present in all cases and four patients had concomitant septic joint (ankle or MTP joints). The most commonly isolated organism was *S. aureus* (3/11, 27.3%, MRSA $n=1$). Two cases were polymicrobial (18.2%) and in an additional two cases mycobacteria were isolated in pure culture. *Pseudomonas aeruginosa* was isolated in a single case and no etiology was identified in three cases (27.3%). Four cases (4/11, 36.4%) were associated with penetration of a sharp object through a shoe or sandal.

Repeat Surgical Procedures and Long Term Outcomes

Among the thirteen patients requiring ≥ 2 surgical procedures, the median number of procedures per patients was 3 (IQR: 2–4); one patient underwent as many as 7 surgical debridement procedures during the index hospitalization. Patients undergoing ≥ 2 surgeries were more likely to have polymicrobial infection (10/13, 76.9%, vs. 3/21, 14.3%, $p=0.001$), fungi (5/13, 38.5%, vs. 0/21, $p=0.005$) or mycobacteria isolated in culture (3/13, 23.1%, vs. 0, $p=0.048$), any organism isolated (13/13, 100% vs. 10/21, 47.6%, $p=0.002$) and a greater number of species isolated in culture (median 3 [IQR: 1–6] vs. 1 [IQR: 1–2], $p=0.05$) than patients who underwent 1 surgical procedure.

Five patients developed long term orthopedic complications (14.7%) of which four (80%) required a second hospital admission and additional surgical procedures within the subsequent calendar year. Two patients (both of whom had open fractures) experienced nonunion. The development of orthopedic complications was associated with the isolation of fungi and *E. cloacae* as well as a greater number of surgical procedures during the index admission (Table 4). A higher proportion of patients with infections involving *E. cloacae*

(with or without co-pathogens) developed orthopedic complications (4/8, 50%) than infections from other organisms (1/15, 6.7%) or culture negative cases (0/11, $p=0.008$).

Treatment

The most commonly used empiric antimicrobials were clindamycin (17/34, 50%) and vancomycin (13/34, 38.2%); eighteen patients (52.9%) received combination therapy empirically, most frequently clindamycin or vancomycin with a third generation cephalosporin (8/18, 44.4%). Among 23 patients with culture positive infections, empiric antimicrobials provided inadequate coverage for identified pathogens in thirteen cases (56.5%). Twenty-eight patients were discharged on oral antimicrobials after a median of 4 days of intravenous therapy (IQR: 3–6 days). The median duration of total therapy among such patients was 34 days (IQR: 28–90 days). Five patients (14.7%) were discharged on outpatient parenteral antimicrobial therapy (OPAT) and one patient completed all therapy parenterally as an inpatient. Patients discharged on OPAT were more likely to have polymicrobial infections than those discharged on oral therapy (4/5, 80%, vs. 8/28, 28.6%, $p=0.047$); there were no other statistically significant differences between these groups. The most commonly utilized oral antimicrobials were clindamycin ($n=10$), ciprofloxacin ($n=6$) and trimethoprim-sulfamethoxazole ($n=5$). Nineteen patients discharged on oral therapy received a single agent (19/28, 67.9%) while nine received 2 antimicrobials (32.1%). Three patients with fungal TROAI were discharged on oral therapy; two patients received posaconazole and one received voriconazole. Among patients with *E. cloacae* treated with oral therapy, 2/5 received trimethoprim sulfamethoxazole and one patient each received cefpodoxime, levofloxacin and amoxicillin-clavulanate. The patient with *E. cloacae* treated with amoxicillin-clavulanate developed experienced nonunion of an open fracture.

Discussion

While the vast majority of OAI in children are a result of hematogenous dissemination, direct trauma may rarely be a means of microbial invasion into bone or synovial fluid. While hematogenous OAI is primarily due to gram-positive pathogens and empiric therapy may be directed as such, previous studies have shown great microbial diversity in TROAI.¹⁹ In our series an organism was identified in 67.7% of cases, comparable to that of hematogenous OAI.^{1, 2, 17} All organisms were identified by culture of bone or synovial fluid with no patients experiencing bacteremia. The single most frequently identified organism contributing to TROAI was *S. aureus*, the majority (63.6%) of which were MRSA and 36.4% were clindamycin resistant. Interestingly, a separate study of acute hematogenous OAI at our institution in an overlapping time period revealed a much lower proportion of both methicillin and clindamycin resistance among *S. aureus* isolates ($n=102$) at 34.3% and 15.6%, respectively.¹⁸ This finding may be a consequence of TROAI being secondary to environmental staphylococci rather than human colonizing strains or may simply be an artifact of the smaller sample size in the presented study.

In our series, *E. cloacae* was the second most commonly isolated organism and was associated with a longer length of hospital stay and more frequent orthopedic complications. Interestingly, the *E. cloacae* isolates obtained were susceptible to most antibiotics tested

including ceftriaxone, trimethoprim-sulfamethoxazole and fluoroquinolones. While being common commensals in the gastrointestinal and genitourinary tracts, Enterobacteriaceae are known to exist in environmental samples as well, including plant and soil matter and water sources.^{20–22} *E. cloacae* has been previously described as a prominent cause of trauma-associated infection in small case series, reflecting their presence in the environment. In a study of osteomyelitis complicating limb fractures among adolescents and adults in China, *E. cloacae* was the third most commonly isolated organism.²³ In a series of children with osteomyelitis secondary to trauma or an infected contiguous focus published in 1988,¹⁹ organisms of the genus *Enterobacter* were isolated in 3/24 (12.5%) cases, two of which occurred following an open fracture and one complicated a decubitus ulcer. In children and adults with specifically gram-negative osteomyelitis in Sao Paulo, *Enterobacter* spp. were the most common organisms identified accounting for 24.7% of isolates; a third of these cases were associated with open fractures.²⁴ A surprising finding was the relatively small number of cases secondary to *Pseudomonas* in our population. *P. aeruginosa* has been commonly reported as a prominent cause of infection complicating puncture wounds to the plantar surface of the foot.¹² *P. aeruginosa* can frequently be a colonizer in used shoes and this may serve as the source of infection for some patients.²⁵ Our findings may, in part, be explained by the relatively small proportion of foot injuries that were associated with an object penetrating a shoe (4/11 cases) as well as the small sample size. Polymicrobial infections were frequently encountered in our series accounting for 38.2% of cases. The rate of polymicrobial infection in other studies of TROAI has ranged from 22–72%.^{19, 23}

Empiric antibiotic choice for children with TROAI is a challenge for clinicians given the diversity of possible etiologies. Unfortunately we identified few clinical variables which can help distinguish TROAI secondary to one organism or group of organisms from another at time of presentation. Children with polymicrobial infections, however, were more likely to have fever at the time of presentation, CRP elevation and a shorter time since initial trauma than children with monomicrobial infection or those without an organism identified. Such findings at the time of medical evaluation may be helpful to clinicians in anticipating complications as patients with polymicrobial infection also experienced a greater need for surgical debridement, multiple debridements and a longer hospital stay. In addition, patients with infection secondary to mycobacteria presented later than most patients with infection secondary to typical bacteria species, consistent with previous work.²⁶ Similar to mycobacteria, fungi are also slow growing organisms capable of producing a subacute to chronic infection.²⁷ In our series, a greater proportion of infections including fungi were associated with crush injuries and traumatic amputations (although not statistically significant). In small series of infections following trauma associated with contamination of wounds with soil or plant matter (such as agricultural or severe motor vehicle injuries) filamentous fungi figure as prominent pathogens.^{27–31} The presence of a retained organic foreign body was common among fungal TROAI in our study population. The severity of the injuries sustained along with the fact that all cases with isolation of fungi in our series also had co-isolation of other organisms likely explains the relatively early presentation of fungal infections compared to mycobacteria infections.

Approximately 15% of patients experienced long term sequelae associated with TROAI, including relapse of infection and chronic osteomyelitis. The overall rate of orthopedic

complications was comparable to that among *S. aureus* hematogenous OAI at our center but much higher than that among hematogenous OAI as a whole.^{2, 17, 18} Notably, we observed an association with orthopedic complications and fungal infection, *E. cloacae* and the need for multiple surgical procedures. To the best of our knowledge, there have been no studies suggesting an increased risk of long term orthopedic complications associated with *E. cloacae* OAI compared to other pathogens. These findings must be interpreted with caution given that the high frequency of polymicrobial infections limits the degree with which any given microorganism can be linked with outcome and that the study size precluded multivariable analyses.

There is very little data available to inform the optimal treatment of patients with *E. cloacae* bone or joint infections, with most publications discussing treatment limited to a handful of cases embedded within larger series.^{32, 33} Many experts in the field caution against the use of third-generation cephalosporins in *Enterobacter* infections in general,³⁴ given that these organisms typically possess inducible *ampC* β -lactamases, as well as potentially other β -lactamases, and the risk for failure on therapy.^{35, 36} Given sample size constraints and the variety of treatment modalities utilized, we were unable to critically evaluate the impact of different treatment regimens on the outcomes of *E. cloacae* TROAI. Furthermore, given that the vast majority of patients underwent surgical debridement of some form (85.3%), we are unable to directly assess the potential benefits of surgical intervention on long term outcomes for TROAI secondary to any organism.

There are limitations to this study in addition to those already stated. The retrospective and single center design limits the generalizability of our findings. In addition, while the total number of consultations for OAI in the study period was quite large, the number of TROAI meeting inclusion criteria was relatively small and limits conclusions that can be drawn from our data. While statistical analyses appropriate to a small sample size were utilized, given the limited number of patients, the results must be interpreted cautiously. The reliance on strict criteria for inclusion may have led to an underestimation of cases and frequency of some etiologies. These criteria helped ensure, however, that all cases were indeed OAI and not soft tissue infection or post traumatic inflammation. Finally, as not all patients underwent orthopedic procedures and all types of cultures were not obtained uniformly, this may have contributed to errors in estimating organism frequency.

In summary, while TROAI are rare in children they are associated with significant morbidity. MRSA is a substantial cause of TROAI, however, the microbiology is very diverse. *E. cloacae* is frequently identified in TROAI and is associated with negative clinical outcomes including long term complications. These data emphasize the critical role of culture in determining the etiology of these infections.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1A. Most Common Organisms Identified in TROAI Culture

Figure 1B. Combinations of Organisms Isolated

Figure 1.

Figure 1A. Most commonly identified organisms in culture of TROAI.

Individual species listed if isolated in 2 cases. Categories not mutually exclusive. Fungal organisms included *Fusarium* spp. (n=2) and *Curvularia* spp. (n=2) and one isolate each of *Trichoderma*, *Rhizopus*, *Aspergillus terreus*, *Penicillium*, *Chrysosporium*, *Acremonium*, *Arthrrium*, *Paecilomyces* and *Cladosporium*. Mycobacteria species isolated include one each of *M. chelonae*, *M. simiae* and *M. fortuitum*. Other organisms isolated once include: *Streptomyces* spp., *Nocardia* spp., *Escherichia hermannii*, *Vagococcus flavialis*, *Ochrobactrum anthropi*, *Leclercia adecarboxylata*, *Klebsiella pneumoniae*, *Micrococcus* spp., Group A streptococcus, *Pseudomonas stutzeri*, *Pasteurella multocida*, *Corynebacterium* spp., *Staphylococcus epidermidis*, *Providencia* spp. and *Serratia marcescens*.

Figure 1B. Combinations of Organisms Contributing to TROAI.

Table 1

General Characteristics

	N=34 (%)
Median Age, years *	8.2 (4.2–9.6)
Male Gender	22 (64.7)
Time Since Trauma, days	11 (4–11)
Duration of Symptoms on Presentation, days	4 (2–7)
Fever on Admission	5 (14.7)
Duration of Fever After Starting Antimicrobials, days	5 (2–7)
Isolated Osteomyelitis	22 (64.7)
Isolated Septic Arthritis	1 (2.9)
Osteomyelitis with Septic Arthritis	11 (32.4)
Interventional Radiology Guided Percutaneous Drainage/Biopsy	1 (2.9)
Surgical Procedure Performed	29 (85.3)
Multiple Surgical Procedures	13 (38.2)
Number of Surgical Procedures	1 (1–3)
Positive Blood Cultures/Blood Cultures Obtained	0/22
Patients with Bone or Joint Cultures Positive/Patients with Cultures Performed	
Aerobic Culture	20/31 (64.5)
Anaerobic Culture	6/26 (23.1)
Fungal Culture	6/25 (24)
Mycobacteria Culture	3/26 (11.5)
Length of Stay, days	5 (3–11)
Treatment	
Completed All Therapy in Hospital	1 (2.9)
Discharge on Oral Antibiotics	28 (82.4)
Discharge on OPAT	5 (14.7)

* All continuous variables expressed as medians and interquartile ranges (IQR).

Table 2

Monomicrobial vs. Polymicrobial vs. Culture Negative Infections.

	Monomicrobial, n=10	Polymicrobial, n=13	No Organism Isolated, n=11	P Value
Age, years	8.3 (5.6–9.1)	6.2 (4.1–9.2)	9.3 (2.7–10.5)	0.7
Fever on Admission	0	5 (38.5)	0	0.007
Time Since Trauma, days	15 (10–60)	4 (2–10)	15.5 (3–21)	0.054
Foot/Ankle Injury	8 (80)	2 (15.4)	5 (45.4)	0.006
Type of Trauma				0.6
Traumatic Amputation	0	3 (23.1)	0	
Open Fracture	2 (20)	3 (23.1)	4 (36.4)	
Crush Injury	1 (10)	1 (7.7)	1 (9.1)	
Penetrating Injury	7 (70)	7 (53.8)	6 (54.4)	
Retained Foreign Body at Time of Admission	2 (20)	7 (53.8)	1 (9.1)	0.053
Retained Organic Foreign Body at Admission **	0	5 (38.5)	1 (9.1)	0.043
CRP on Admission, mg/dl †	0.5 (0.5–1.6)	5.2 (3.3–14)	1.15 (0.5–2.8)	0.003
ESR on Admission, mm/hr	24.5 (10–44.5)	35 (18–91)	20.5 (8.5–41)	0.3
WBC on Admission, $\times 10^3/\text{mm}^3$	7.4 (7.1–8.9)	8.6 (6.9–18)	8.8 (7.4–11.1)	0.51
Surgery Performed	9 (90)	13 (100)	6 (63.6)	0.04
Number of Surgeries, n	1 (1–2)	3 (1–4)	1 (0–1)	0.02
Length of Stay, days	5 (3–14)	11 (7–21)	3 (2–5)	0.001
Orthopedic Complications	1 (10)	4 (30.8)	0	0.1

** Organic foreign bodies included soil/gravel, plant matter (leaves, grass, twigs, etc) or animal matter.

† CRP= C-reactive protein; ESR= erythrocyte sedimentation rate; WBC = white blood cell count.

Table 3

Comparisons of Select Clinical Features With Regard to Groups of Isolated Organisms.

	GP* Only, n=6	GN Only, n=3	GN and GP, n=6	M Only, n=2	F +/- Typical Bacteria, n=5	F + M + Typical Bacteria, n=1	No Organism Isolated, n=11	P Value
Age, years	7 (3.2–9.1)	8.1 (6.1–9.6)	5.6 (4.2–9.2)	6.9 (5.6–8.4)	8.5 (4.1–9.9)	6.21	9.34 (2.7–10.5)	0.96
Fever on Admission	1 (16.7)	0	2 (33.3)	0	2 (40)	0	0	0.21
Time Since Trauma, days	10.5 (8–33)	60 (14–60)	6 (4–10)	18.5 (16–21)	2 (2–3)	43	15.5 (3–21)	0.02
Foot/Ankle Injury	3 (50)	2 (66.7)	2 (33.3)	2 (100)	1 (20)	0	5 (45.4)	0.58
Type of Trauma								0.7
Traumatic Amputation	1 (16.7)	0	1 (16.7)	0	1 (20)	0	0	
Open Fracture	1 (16.7)	1 (33.3)	2 (33.3)	0	0	1 (100)	4 (36.4)	
Crush Injury	1 (16.7)	0	0	0	1 (20)	0	1 (9.1)	
Penetrating Injury	3 (50)	2 (66.7)	4 (66.7)	2 (100)	3 (60)	0	6 (54.5)	
Retained Foreign Body at Time of Admission	1 (16.7)	0	2 (33.3)	1 (50)	5 (100)	0	1 (9.1)	0.004
Retained Organic Foreign Body at Admission	0	0	1 (16.7)	0	4 (80)	0	1 (9.1)	0.02
CRP on Admission, mg/dl	0.5 (0.5–2.6)	0.8 (0.5–1.6)	4.6 (0.6–11.7)	1.25 (0.5–2)	14 (12.5–27.9)	3.3	1.15 (0.5–2.8)	0.04
ESR on Admission, mm/hr	10 (8–10)	51 (19–54)	30 (13–91)	38	57 (35–92)	33	20.5 (8.5–41)	0.13
WBC on Admission, $\times 10^3/\text{mm}^3$	6.9 (4.7–8.1)	7.3 (7.1–7.4)	11.8 (8.6–12.5)	9.5 (7.6–11.4)	12.9 (7.3–20.6)	6.9	8.8 (7.4–11.1)	0.44
Surgery Performed	5 (83.3)	3 (100)	6 (100)	2 (100)	5 (100)	1 (100)	7 (63.6)	0.51
Number of Surgeries, n	1 (1–2)	1 (1–1)	1.5 (1–2)	3 (2–4)	4 (3–6)	4	1 (0–1)	0.003
Duration of IV Therapy, days	3 (3–5)	4 (4–5)	8.5 (4–28)	12.5 (12–13)	25 (25–27)	42	3 (3–5)	0.01
Duration of Total Therapy, days	37.5 (21–90)	34 (25–186)	30 (28–35)	200 (186–214)	83 (44–120)	229	28 (21–34)	0.02
Discharge on Oral Antibiotics	6 (100)	3 (100)	4 (66.7)	2 (100)	3 (60)	0	10 (90.9)	0.13
Length of Stay, days	3 (3–5)	7 (5–19)	8.5 (4–11)	14 (14–14)	21 (11–27)	28	3 (2–5)	0.001
Orthopedic Complications	0	1 (33.3)	1 (16.7)	0	2 (40)	1 (100)	0	0.04

* GP = Gram Positive; GN = Gram Negative; M = Mycobacteria; F = Fungi.

Table 4

Comparison of Patients With and Without Orthopedic Complications

	Complications, n=5	No Complications, n=29	P Value
Age, years	4.2 (4.1–6.2)	8.5 (5.6–9.6)	0.1
Polymicrobial	4 (80)	8 (27.6)	0.4
Mycobacteria	1 (20)	2 (6.9)	0.48
Fungi	3 (60)	3 (10.3)	0.03
MRSA	1 (20)	6 (20.7)	1
<i>Enterobacter cloacae</i>	4 (80)	4 (13.8)	0.007
Type of Trauma			0.16
Crush Injury	1 (20)	2 (6.9)	
Penetrating Injury	1 (20)	19 (65.5)	
Open Fracture	2 (40)	7 (24.1)	
Traumatic Amputation	1 (20)	2 (6.9)	
Surgery Performed	5 (100)	24 (82.8)	1
Multiple Surgeries	4 (80)	9 (31.3)	0.06
Number of Surgeries	5 (4–6)	1 (1–2)	0.006
Duration of Total Therapy, days	180 (120–186)	33 (28–44)	0.06
Duration of IV Therapy, days	27 (4–42)	5 (3–12)	0.06
Discharge on Oral Therapy	4 (80)	24 (82.8)	1