

Pediatric Bone and Joint Infection Guidelines

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Abstract

Problem & Purpose: Antimicrobial stewardship guidelines are a Joint Commission requirement to address the Centers for Disease Control and Prevention's call to reduce unnecessary and potentially harmful antibiotics. Pediatric bone and joint infections are traditionally treated with lengthy intravenous antibiotic courses, but evidence shows earlier transition to oral therapy is safe and reduces antibiotic exposure. In the absence of hospital-wide clinical guidelines at an urban academic institution, provider guidance is needed to minimize antibiotic exposure in this population. The purpose of this project is to implement two institution-specific pediatric guidelines for osteomyelitis and septic arthritis with a diagnostic order set and targeted provider education. **Methods:** The project lead wrote guidelines and order sets based on evidence review, the institution's protocols and resources, and input from infectious disease, orthopedics, radiology, emergency medicine, microbiology, pharmacy, and advanced nursing. Guideline virtual education for all pediatric providers was provided synchronously and asynchronously. The project was implemented over a 15-week period. Inclusion criteria are acute hematogenous infections in ages one month to 18 years. NICU patients or those with major trauma or other medical history that increases risk for infection such as bone disease, open fractures, existing hardware, or previous surgeries are excluded. Prospective chart reviews and real-time provider education were conducted for all eligible patients. Data collected includes guideline compliance, order set use, and safety outcomes. **Results:** The guidelines were published on the institution's stewardship website and mobile application. Two eligible patients have been identified. Management of one patient followed the guidelines. The other transferred from another hospital and empiric antibiotic choices were not consistent with the guidelines; subsequent care has been. **Conclusions:** A team and multidisciplinary approach successfully implemented new stewardship

guidelines. Findings suggest an institution-wide guideline with targeted education is an effective way to ensure more streamlined care for pediatric patients with bone or joint infections and may reduce antibiotic exposure.

Pediatric Bone and Joint Infection Guidelines

The United States Centers for Disease Control and Prevention (CDC) estimates that up to 50% of the antibiotics prescribed are unnecessary—antibiotic stewardship programs strive to reduce that number as overuse is linked to increasing resistance and chronic morbidity (CDC, 2021). One area of focus is bone and joint infections (osteomyelitis and septic arthritis) in children, which traditionally are treated with six to eight weeks of intravenous (IV) antibiotics. Evidence over the past decade shows that most patients can be safely treated with a shorter course and earlier transition to oral therapy. The Infectious Disease Society of America (IDSA) published 2021 guidelines for this population based on a growing body of evidence showing safe management with narrower empiric antibiotics, shorter IV therapy, and shorter overall treatment courses—all of which reduce antibiotic exposure in this population (Woods et al., 2021).

Bone and joint infections—osteoarticular infections (OAI)—are uncommon in pediatrics. The incidence of pediatric acute osteomyelitis is between 1.2 and 13 cases per 100,000 children yearly and the incidence of pediatric septic arthritis is estimated between four to 10 per 100,000 children yearly (Montgomery & Epps, 2017; Woods et al., 2021). At a large, urban, academic pediatric hospital, there were four pediatric patients admitted for osteomyelitis in 2018. Two were discharged home with IV antibiotics, a challenge for both caregiver and patient. One patient was readmitted due to a bacterial line-associated bloodstream infection. In this pediatric inpatient setting, there were no antibiotic stewardship guidelines or an electronic medical record order sets for pediatric bone infections (an outdated septic arthritis order set did exist). There is no standard for empiric antibiotics when patients present to the emergency department. An immediate pediatric infectious disease (PID) consult is not standard practice at this institution, and some plans are created based on suboptimal information.

The root of this problem is complex and outlined in detail in the fishbone diagram (Figure 1). Patients are often started on broad-spectrum IV antibiotics, and some continued after discharge. Some cases require prolonged IV treatment, but there is no mechanism encouraging providers to consider early transition to oral therapy. The PID team is responsible for discussing early oral transition but does not have guidelines to refer to for support. If early transition can be done while the patient is admitted, the team has time to monitor the child's tolerance of oral antibiotics and assist parents with initial challenges. Additionally, the emergency department septic arthritis order set needed updating. A quality improvement (QI) project was implemented to encourage early consults, appropriate diagnostics, and narrower empiric antibiotic therapy. This was achieved by creating an evidence-based clinical management guidelines and new diagnostic order set accompanied by provider education.

Available Knowledge

The available evidence for this population is limited but consistent and shows several areas within the management of bone and joint infections where antibiotics can safely be used more judiciously. Using the Johns Hopkins Evidence-Based Practice Model (2022), this review included two level II studies, three level III studies, and one level IV paper (see Tables 1 and 2 for grading and levels). The IDSA (2021) recommends basing empiric antibiotic choices on local antibiograms, which show the local prevalence of pathogenic bacteria and their antibiotic susceptibilities. Specifically, if methicillin-resistant *Staphylococcus aureus* (MRSA) rates are less than 20% of *Staphylococcal* infections, then it may not be prudent to include vancomycin as a routine empiric choice (Woods et al., 2021). Another aspect is the duration of IV therapy; no consensus exists for when to transition from IV to oral antibiotics. The new guidelines encourage early transition based on clinical improvement and reduction in inflammatory markers, such as

C-reactive protein (CRP). Evidence indicates that transitioning to oral treatment is safe (e.g., no increased treatment failures, readmissions, or orthopedic complications) for patients with an uncomplicated course, a rapidly declining CRP, and clinical improvement (Chou & Mahadev, 2016; Keren et al., 2015; McNeil et al., 2017). Earlier transition to oral treatment reduces the number of children discharged with peripherally inserted central line catheters (PICCs), thus reducing line-associated complications. These interventions do not have any associated safety risks or poor clinical outcomes. These conclusions were consistent across

Rationale

The Knowledge-to-Action (KTA) framework directs this QI project (see Figure 2) (Graham et al., 2006). KTA is simple and can be tailored for most types of healthcare QI projects. KTA highlights the use of existing knowledge—in this case the IDSA’s 2021 guidelines—and leads teams through the cycle of identifying problem areas and barriers, tailoring and implementing that knowledge to the institution, and monitoring and evaluating the outcomes to identify additional problems. KTA assumes projects discover new problems as they progress and has a built-in cycle for identifying and addressing them, thus building sustainability. Sustainability ensures clinicians provide the most updated care for bone and joint infection patients, whose incidence is relatively low and infrequent. Since this QI project is part of a larger antibiotic stewardship effort, the process for monitoring and evaluating patient outcomes is already established within the pharmacy department and adding new measures is not cumbersome.

Methods

The QI project-lead (PL) is a Doctor of Nursing Practice student who initiated and facilitated all activities of the project. A PID attending physician served as the clinical site

representative and local expert. Other team members included members of pharmacy (pediatric pharmacist and an adult antimicrobial stewardship pharmacist), a pediatric orthopedic surgeon, a pediatric radiologist, emergency medicine pediatrician, and pediatric emergency pharmacist. The Joint Commission (2016) requires pediatric hospitals to have pediatric-specific stewardship guidelines for major systems and the PID team has not had available staff to complete them, despite buy-in from all stakeholders. Each stewardship guideline requires a similar size team, extensive literature review, and a commitment from multiple parties. The low incidence of patients combined with their extensive exposure to broad-spectrum antibiotics result in inconsistent management, a target for antibiotic stewardship. The desired processes are shown in Figure 3.

This QI project involved (1) creation of evidence-based, institution-specific pediatric bone and joint infection clinical guidelines, (2) modification of the current septic arthritis electronic diagnostic order set to include osteomyelitis and match the new guidelines (see Appendix A), and (3) providing clinical education. Pre-implementation work by the PL included data collection and analysis via chart review of the previous five years (2017–2022) of acute hematogenous osteomyelitis and septic arthritis patients at this institution to determine trends in causative organisms and resistance pattern. Particular focus was given to *Staphylococcus aureus* isolates as these are the most common in osteoarticular infections. These data determined the empiric antibiotic choices in the guidelines. The guidelines were finalized via virtual meetings with all stakeholders. The PL presented to the entire PID team (which includes physicians, fellows, residents, a nurse practitioner, and visiting medical students) to determine consensus recommendations for empiric coverage.

Final versions of the guidelines were presented to the pediatric pharmacy and therapeutics committee and the antimicrobial subcommittee, the committees responsible for approving guidelines and publishing them on the hospital stewardship website. Final approval was given by the hospital-wide pharmacy and therapeutics committee. With all necessary approvals, the guidelines were published on a Sanford site for the hospital, a clinical resource for antibiotic stewardship and infectious disease management. The guidelines are also available on the Sanford mobile application. The order set was drafted by the PL and the pediatric emergency pharmacist based on the guidelines (see Appendix A) with support and input from two emergency medicine attendings.

All PID providers (nurse practitioner, fellows, and attendings) notified the PL of potential bone or joint infection patients. The team was notified either as a consult from the emergency department or as a consult from an outside hospital prior to transfer. The PL monitored an electronic medical record list of osteomyelitis or septic arthritis patients weekly. Any patient whose medical record carried a diagnosis of osteomyelitis or septic arthritis who presented to the hospital (emergency department or admitted) appeared in real time. This served as a double check to avoid missing eligible patients. Bi-weekly reminders were sent to the team to ensure screened patients were captured. Chart reviews were done for all screened patients and those deemed eligible were put into a secure REDCap database for data collection from their clinical course.

Education was provided at each meeting with PID and orthopedics, the main teams that drive management of bone and joint infection patients. During week six of implementation, the PL and clinical site representative delivered (virtually) specific education to the pediatric residents and medical students at their noon conference education series. An additional

asynchronous virtual presentation was created for those unable to attend. Education was also delivered in real-time when the PL is notified of an eligible patient. Once the order set is live, targeted education to the pediatric emergency providers will be delivered to ensure awareness and proper use.

Ongoing assessment will be carried out by pediatric pharmacy (who monitor antibiotic use) and the PID team. Typically, there are around 5 patients yearly in this population and monitoring these measures should not add undue challenge. The PID team has a nurse practitioner and usually one or two fellows who will follow up on patients and ensure adherence to the guideline and use of the order set. If new issues arise as the order set is used, the PID team and emergency medicine will follow up with clinical informatics for modifications.

To evaluate the effectiveness of this QI project, several outcomes were analyzed to compare pre-implementation data with data collected during implementation (see Table 3). Two were structure goals: (1) creation and implementation of two new clinical guidelines for osteomyelitis and septic arthritis and (2) a corresponding diagnostic order set for the electronic medical record. Two were process goals: (1) order set use and (2) education dissemination to providers. Outcome goals of interest included empiric antibiotic choices, microbiology data, transition to oral therapy, and discharge course. Safety events such as readmissions, treatment failures, or subsequent orthopedic complications were also monitored. Data collection for outcome goals occurred over 15 weeks when eligible patients were admitted for osteomyelitis or septic arthritis. Chart review was completed by the PL. Compliance with guidelines was determined with consideration of the clinical context and the patient's medical course.

All pediatric patients qualify as a vulnerable research population and ethical considerations are key. This project obtained Institutional Review Board approval and was

designated as non-human subject research. All patients affected by this QI project received the same standard of care and were included only based on their diagnosis and no other characteristics. Patients were excluded based on clinical factors such as pertinent chronic morbidity, age, trauma-related or surgical device-related infections—the same criteria that the IDSA guidelines use. Patient information was sent via secure email or text; it was shared only between the providers and the PL. Patient chart review was done by the PL only via the hospital's secure virtual private network and was deidentified for analysis.

Results

In the pre-implementation chart review, 306 chart encounters were identified from 2017-2022; 32 patients met inclusion criteria for OAI and 4 of those had a diagnosis of both osteomyelitis and septic arthritis. Twenty-four patients had osteomyelitis (with or without arthritis) and were aged 5 months to 18 years with an average age of 8 years. Half were male (50%). Fever was present in 82%. There were 12 patients with non-Lyme septic arthritis (with or without osteomyelitis) were identified, aged 1 month to 15 years with an average age of 7 years. Fifty-five percent were female. Fever was present in 72%. About half were transferred from an outside facility in both groups.

Of the 32 patients with either osteomyelitis, septic arthritis, or both, 24 (75%) had positive cultures. The most common causative organism was MSSA which was found in 15/24 (62%) of the patients; 12 in the osteomyelitis group and 4 in the septic arthritis group. MRSA was recovered in 5/24 (20%) patients, all of whom had osteomyelitis and 3 of whom also had septic arthritis (see Figure 5). In addition to the QI project institution's data, data from 3 regional pediatric hospitals was obtained to compare rates of MSSA vs MRSA in pediatric OAIs (see Table 4) and the rates were very similar. Clindamycin susceptibility among the *Staphylococcus*

aureus isolates was 20/22 (90%); there were 2 resistant MSSA isolates. All but three osteomyelitis patients and one septic arthritis patient received anti-MRSA empiric coverage (vancomycin or clindamycin). Twenty-five patients (78%) were discharged on oral therapy. Of the seven that went home with IV therapy, three patients had complications related to the IV access (thrombophlebitis, catheter-associated bloodstream infection).

Implementation results were collected from August 29, 2022, through December 17, 2022. The first structure goal was met 100%: two new clinical guidelines have been approved and published for osteomyelitis and septic arthritis. At the pediatric pharmacy and therapeutics meeting, eighteen committee members of 35 invitees (51%) attended, which is the average number of attendees. At the Antibiotic Stewardship committee meeting, about 75% (18 members and six guests) attended. At the hospital-wide pharmacy and therapeutics meeting, 13 of 24 (54%) voting members attended as well as 12 guests. This was typical attendance and adequate to generate discussion and approve the new guidelines. This was a successful implementation of hospital clinical guidelines. The second structure goal was also achieved: the order set is in production. For the resident provider education session, 17 of 58 (29%) were in attendance which is typical for this conference. An asynchronous virtual presentation was distributed to reach more providers. Once the order set is live, targeted education will be offered virtually for emergency department providers both synchronously and asynchronously.

Two eligible patients were admitted during the implementation period, one for osteomyelitis and one for septic arthritis (see Table 5). Timing of the PID consult and choice of empiric antibiotics for these patients were 100% compliant with the new guidelines (see Figure 4). Both were empirically started on an anti-MRSA agent. The patient with osteomyelitis grew MRSA from her cultures. Her course was complicated by pulmonary septic emboli requiring IV

therapy post discharge at a step down facility, but care was compliant with the guideline. The patient with septic arthritis was transferred from an outside hospital where empiric antibiotics were started, which differed slightly from the new guidelines (ceftriaxone was started rather than cefazolin). This does not affect compliance as the decision was made at an outside institution. This patient's care was otherwise aligned with the guidelines, and he was discharged on oral therapy; his cultures grew MSSA. No safety outcomes were identified with either patient.

Discussion

This QI project significantly moved the hospital's pediatric antibiotic stewardship program forward. The development process engaged many different disciplines to build a collaborative set of guidelines and an order set. The early and sustained collaboration between multiple departments across the hospital increases the likelihood of uptake. This QI project also built and fostered relationships that will make subsequent guideline development more feasible. This QI project also created an opportunity to corroborate data with three other regional institutions and revealed that similar rates of MSSA and MRSA are seen across four pediatric hospitals. Given the small sample size of the pre- and implementation data, the agreement of regional data increased the team's confidence in empiric antibiotic choices for the guidelines.

Direct comparison of the 5-year review data and that collected during implementation is limited given the very small sample size. Both patients had anti-MRSA empiric coverage, a higher percentage than the pre-implementation data. One had MSSA and one had MRSA—this is consistent with the literature showing that *Staphylococcus aureus* is the most common cause of OAIs. Another limit was the extended development period (1 year) given scheduling challenges of all the different disciplines and departments involved. The final limitation is that while the

order set remains in production, it was not live during the implementation period. The project could not measure order set use for the two eligible patients.

Conclusion

This QI project demonstrated a successful development process and implementation of two related pediatric clinical guidelines for the institution's antibiotic stewardship program. Collaboration was key and ensured support of the new guidelines. This QI project will lead to consistent care in this population at this institution. It offers an opportunity to provide additional evidence on whether anti-MRSA empiric coverage is necessary for OAI patients, whether early transition to oral therapy will continue to result in full recovery for non-complex patients, and whether a diagnostic order set will improve guideline adherence. The order set, if used regularly, should ensure sustainability of the project but will require provider education once it is live. Success of this project demonstrates that other stewardship guidelines can be created and implemented via a similar process at this institution. Further QI study such as this would increase the available knowledge of bone and joint infections in children and how antibiotic therapy can be safely reduced without compromising clinical outcomes.

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Table 1

Evidence Review Table

Alhinai, Z., Elahi, M., Park, S., Foo, B., Lee, B., Chapin, K., Koster, M., Sánchez, P. J. & Michelow, I. C. (2020). Prediction of adverse outcomes in pediatric acute hematogenous osteomyelitis. <i>Clinical Infectious Diseases</i> , 71(1 November), e454–e464. https://doi.org/10.1093/cid/ciaa211					Level III Quality A
Purpose/Hypothesis	Type of evidence Research Design	Sample – Population, Size, Setting	Intervention/ Procedures	Primary Outcome/Measures	Results/Conclusions
<p>“The objective of this study was to develop scoring systems that could accurately identify children with acute hematogenous osteomyelitis (AHO) within 96 hours of admission who were at high risk of developing acute or chronic complications. We reasoned that early identification of such patients could potentially improve outcomes by indicating the need for high-resolution diagnostic imaging, an extended course of parenteral antibiotics, surgical interventions, and anticipatory counseling.”</p>	<p>Retrospective cohort study from two pediatric hospitals.</p>	<p>Sampling Technique: Purposive sampling</p> <p># Eligible: 983 skeletal infections</p> <p># Accepted: 261 met eligibility criteria of acute hematogenous infection without prior trauma or surgery or chronic condition (201 had osteomyelitis alone, 60 had osteomyelitis associated with suppurative arthritis)</p> <p># Control: none</p> <p># Intervention: 261 patients received standard care</p> <p>Power analysis: Not done</p> <p>Group Homogeneity: Median age was 9 years, male to female ratio was 1.6:1. All children had preceding or current fever and</p>	<p>Control protocol: none</p> <p>Intervention protocol: Standard care which includes empiric IV antibiotics according to provider discretion in consult with infectious disease specialist, diagnostic imaging as indicated (usually MRI), surgery if indicated by orthopedic surgeon, pain control, and inflammatory marker monitoring.</p> <p>Intervention fidelity (describe the protocol): The purpose of this study was to retrospectively create two composite scores (“A-SCORE” for acute score and “C-SCORE” for chronic score) based on several</p>	<p>Dependent Variable (DV): Predictability of a composite score based on factors within the first 96 hours of admission for long- and short-term adverse outcomes through the end of treatment</p> <p>Measurement tool (reliability), time, procedure: No single tool was used. Adverse events included treatment failure with persisting symptoms and/or signs resulting in readmission or change of antibiotics within 6 weeks of diagnosis, PICC complications (major or minor), and chronic morbidity.</p>	<p>Statistical results: Five covariates independently predicted an acute complicated course (P = 0.99)</p> <ol style="list-style-type: none"> 1. Bone abscess (OR, 2.3 [95% CI, 1.0–5.2]) 2. Fever > 48 hours (OR, 2.7 [95% CI, 1.2–6.0]) 3. Associated suppurative arthritis (OR, 4.6 [95% CI, 1.3–7.5]) 4. Disseminated disease (OR, 4.6 [95% CI, 1.5–14.3]) 5. Delayed source control (OR, 5.1 [95% CI, 1.4–19.0]) <p>The A-SCORE has a max score of 15.</p> <p>Three variables independently predicted chronic morbidity:</p> <ol style="list-style-type: none"> 1. CRP ≥ 100 mg/L at 2–4 days after admission (OR, 2.7 [95% CI, 1.0–7.3]) 2. Disseminated disease (OR, 3.3 [95% CI, 1.1–10.0]) 3. Bone debridement (OR, 6.7 [95% CI 2.1–21.0])

		bone pain at time of admission. All received parenteral antibiotics on admission. Organisms were identified in 73%. Lower extremity infections made up 62%. Adjusted analyses were done to account for the heterogenous use of PICCs among the cohorts from each site.	factors at or within 96 of admission and test if that score could predict adverse events. The two new scores were also compared to other scores seen in the literature or used in practice (including comparison to ESR and CRP as predictors of adverse events). Investigators at each site systematically reviewed the medical records to collect data. This study was IRB-approved at each hospital.		<p>The C-SCORE has a max score of 4.</p> <p>Both scores performed better than other scores, CRP, or ESR at predicting adverse events. A-SCORE had sensitivity of 74%, specificity of 78%, PPV 52%, and NPV 91%. C-SCORE has a sensitivity of 63%, specificity of 89%, PPV 42%, NPV 95%.</p> <p>Clinical Significance: The high NPVs for both scores is significant. Even if the scores are not formally calculated, when a patient does not have any of the above factors within the first 96 hours, they are not likely to have an adverse event.</p> <p>Conclusions: These cannot be used as single predictors and should not be used to make decisions alone, but it does support other literature indicating that the absence of these variables correlates with a milder disease course.</p>
<p>Chou, A. & Mahadev, A. (2016). The use of c-reactive protein as a guide for transitioning to oral antibiotics in pediatric osteoarticular Infections. <i>Journal of Pediatric Orthopedics</i>, 36(2), 173–177. https://doi.org/10.1097/BPO.0000000000000427</p>					<p>Level III Quality B</p>
Purpose/ Hypothesis	Type of evidence Research Design	Sample – Population, Size, Setting	Intervention/ Procedures	Primary Outcome/Measures	Results/Conclusions

<p>“We aimed to determine if a 50% decline in CRP levels could supplement clinical improvement in determining when to transition to oral antibiotics.”</p>	<p>Retrospective case series from single institution.</p>	<p>Sampling Technique: Purposive sampling</p> <p># Eligible: Not stated # Accepted: 37 total, 24 with osteomyelitis, 11 with septic arthritis, 2 with both # Control: none # Intervention: oral antibiotic transition at 4 days if CRP had reduced by 50%</p> <p>Power analysis: None</p> <p>Group Homogeneity: average age 9.14 years, range 6 weeks to 18 years; 56.75% male; 94.59% underwent surgery.</p>	<p>Control protocol: None within the study; comparison is standard care which typically involves normalization of CRP before transition to oral antibiotics.</p> <p>Intervention protocol: All patients who demonstrated a decline in their CRP of 50% or more by day 4 of admission were transitioned to oral antibiotics. They were then discharged to complete 6 weeks of total treatment.</p> <p>Intervention fidelity (describe the protocol): The study procedure included clinical data and case note reviews of patients from 2007–2013. All patients were eligible if they had an ICD-9 code for osteomyelitis and/or septic arthritis. Outpatient notes were reviewed up to 18 months after discharge for complications. This study was IRB-approved.</p>	<p>DV: 50% reduction in CRP within 4 days.</p> <p>Measurement tool (reliability), time, procedure: CRP is a commonly used serum marker of general inflammation. It has a half-life of 19 hours and is usually elevated in acute episodes of inflammation like acute infection. For this study, it was measured every 4 days while the patient was admitted.</p>	<p>Statistical results:</p> <ul style="list-style-type: none"> - Average peak CRP was 156.91 mg/L (+/-97.8) - Average CRP at oral conversion was 24.94 mg/L (+/- 22.36) - 91% of patients had 50% decline in CRP in 4 days - 94% had uncomplicated outcomes <p>Clinical Significance: This study showed that in this population, patients can be safely transitioned to oral antibiotics before their CRP is normalized. They did not exclude culture-negative cases (unlike other similar studies), which can be a significant number of cases. Only two patients had complicated outcomes.</p> <p>Conclusions: If the patient is clinically improving and their CRP has at least halved by day 4, it is reasonable to consider transitioning from IV to oral antibiotics if an equivalent exists.</p>
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<p>Keren, R., Shah, S. S., Srivastava, R., Rangel, S., Bendel-Stenzel, M., Harik, N., Hartley, J., Lopez, M., Seguias, L., Tieder, J., Bryan, M., Gong, W., Hall, M., Localio, R., Luan, X., deBerardinis, R., & Parker, A. (2015). Comparative effectiveness of intravenous vs oral antibiotics for postdischarge treatment of acute osteomyelitis in children. <i>JAMA Pediatrics</i>, 169(2), 120. https://doi.org/10.1001/jamapediatrics.2014.2822</p>					<p>Level II Quality B</p>
Purpose/ Hypothesis	Type of evidence Research Design	Sample – Population, Size, Setting	Intervention/ Procedures	Primary Outcome/Measures	Results/Conclusions
<p>“We sought to compare the effectiveness of oral antibiotics with intravenous (IV) antibiotics delivered via a PICC in children who received prolonged home antibiotic therapy after hospitalization for osteomyelitis. We tested the following hypotheses: (1) children who receive oral antibiotic therapy at home would not have more treatment failures than comparable children who receive IV antibiotic therapy at home; and (2) children receiving IV antibiotic therapy at home would have more emergency department (ED) visits and hospitalizations owing to</p>	<p>Retrospective cohort study conducted across 36 children’s hospitals, medical chart review.</p>	<p>Sampling Technique: Purposive sample from data across 36 children’s hospitals within a national database and additional data from those individual hospitals over 4 years</p> <p># Eligible: 8555 children 2 months to 18 years old with an ICD-9 discharge code for acute osteomyelitis or unspecified osteomyelitis.</p> <p># Accepted: 2060; all children who could not take oral medications for a medical reason (or could only take tube-fed oral medications were excluded. Medically fragile patients were also excluded, as well as any AHO associated with orthopedic hardware, bone fractures, chronic osteomyelitis, or infections in the head, face, or orbits.</p>	<p>Control protocol: Children received IV antibiotics via PICC at home after discharged, managed by parents or caregiver.</p> <p>Intervention protocol: Children transitioned to PO antibiotics in the hospital and discharged on the same medications, given by the parent or caregiver.</p> <p>Intervention fidelity (describe the protocol): The authors used data from the Pediatric Health Information System (PHIS) and supplemented that data with local hospital physicians and trained research assistants to do detailed reviews of the medical records for eligibility confirmation; antibiotic choice,</p>	<p>DV: Treatment failure defined as revisit to the ED or readmission to the hospital for a change in prescribed antibiotic or its dosage, prolonged therapy courses, conversion from oral back to IV route, additional abscess drainage, debridement of necrotic bone, bone biopsy, drainage of an abscess of the skin or muscle, arthrocentesis, or diagnosis of pathologic fracture.</p> <p>Measurement tool (reliability), time, procedure: Similar to the measures for intervention fidelity. After the two investigators independently reviewed the codes and identified patients from the PHIS, local hospitals reviewed their own patient’s medical record using trained physicians and</p>	<p>Statistical results: The total cohort included 2060 children from 36 hospitals, evenly divided between PICC and oral routes at discharge. No relationship was seen between route and hospital or volume of cases. In the unmatched analysis, 5% of the oral group and 6% of the PICC group had treatment failure. In the matched analysis, the oral therapy group did not have more treatment failures than the PICC group (across hospital risk difference of 0.3% [95% CI, -0.1%–2.5%] and within-hospital risk difference of 0.6% [95% CI, -0.2% –3.0%]). The negative lower bound demonstrates a non-significant difference in treatment failure risk between the two groups, thus supporting the hypothesis. Adverse drug reactions were higher in the PICC group and 15% had a PICC complication requiring an ED visit, rehospitalization, or both.</p> <p>Clinical Significance: There were no increased safety</p>

<p>complications with their PICC line.”</p>		<p># Control: 1055 received antibiotics via PICC upon discharge # Intervention: 1005 received oral antibiotics upon discharge</p> <p>Power analysis: None described</p> <p>Group Homogeneity: This was achieved through propensity score-based full matching between the PICC and oral groups. Patients were matched based on age, race, insurance, length of hospital stay in days, location of the infection, and surgical procedure (arthrocentesis or wash out etc.).</p>	<p>route, and duration at time of discharge; review of all ED visits and hospitalizations for treatment failure, adverse reactions, or PICC complications; and find culture data. Two investigators independently reviewed the codes for diagnosis and procedures. Matching within hospitals or hospital systems mimicked a stratified randomized clinical trial by comparing patients with similar characteristics treated at the same institution. This study was IRB-approved.</p>	<p>research assistants to obtain the outcome data.</p>	<p>issues in those who were transitioned early to oral medication. While this does not show that it is always appropriate to transition early, this study does show that in non-complex cases, patients are likely to do just as well finishing with oral antibiotics as IV.</p> <p>Conclusions: The results support oral antibiotics as an appropriate treatment for many cases.</p>
<p>McNeil, J. C., Kaplan, S. L., & Vallejo, J. G. (2017). The influence of the route of antibiotic administration, methicillin susceptibility, vancomycin duration and serum trough concentration on outcomes of pediatric <i>Staphylococcus aureus</i> bacteremic osteoarticular infection. <i>Pediatric Infectious Disease Journal</i>, 36(6), 572–577. https://doi.org/10.1097/INF.0000000000001503</p>					<p>Level II Quality C</p>
<p>Purpose/ Hypothesis</p>	<p>Type of evidence Research Design</p>	<p>Sample – Population, Size, Setting</p>	<p>Intervention/ Procedures</p>	<p>Primary Outcome/Measures</p>	<p>Results/Conclusions</p>
<p>“The primary goals of this study were to (1) determine the impact of positive blood culture on short- and long-term clinical outcomes, (2) determine the impact of discharge on oral</p>	<p>Single hospital and clinic system retrospective cohort study, medical chart review.</p>	<p>Sampling Technique: Purposive sample from data from a large academic children’s hospital and 52 primary care clinics over 4 years</p> <p># Eligible: Pediatric patients with acute</p>	<p>Control: Children received IV antibiotics in the hospital and were discharged on IV antibiotics either to be managed at home (OPAT) or in a subacute facility (CHIT).</p>	<p>DV (of interest): Orthopedic complications following discharge from the hospital (either to home or a subacute facility)</p>	<p>Statistical results: Of the 102 patients, one third (34%) had infections due to MRSA. Those with MRSA infections had longer duration of fever, bacteremia, and hospital length of stay. They were more likely to require multiple surgical interventions and less</p>

<p>antibiotics versus outpatient parenteral antibiotic therapy (OPAT) or complete hospital IV therapy (CHIT) on the development of orthopedic complications, and (3) assess the impact of length of vancomycin therapy and vancomycin serum troughs on the clinical outcomes of MRSA BOAI.”</p>		<p>hematogenous osteomyelitis and/or septic arthritis with culture-confirmed <i>S. aureus</i> infection. 192 patients were eligible, 62 cases were excluded because only the bone culture was positive, 19 cases were excluded because only the synovial fluid culture was positive, and 9 cases were excluded because both bone and synovial fluid were positive (but not blood). # Accepted: 102 had positive blood cultures with or without other positive cultures from bone or synovial fluid. Patients with symptoms >28 days, open or penetrating trauma, orthopedic hardware, or otherwise post-operation were excluded. # Control: 76 patients were discharged on IV therapy either at home as OPAT (68) or in a subacute facility on CHIT (8) # Intervention: 26 patients were discharged to home on oral therapy</p>	<p>Intervention: Children were given empiric IV antibiotics and transitioned to oral antibiotics in the hospital and discharged home on oral antibiotics.</p> <p>Intervention fidelity (describe the protocol): The inpatient infectious disease service consult database was reviewed for patients with a diagnosis of AHO or septic arthritis. Fifteen board certified pediatric infectious disease physicians staffed the service during the study and were routinely conferred with. All records were reviewed for orthopedic complications up to 6 months following the study period. All patients had to be initially hospitalized and discharged within the study period. This study was IRB-approved.</p>	<p>Measurement tool (reliability), time, procedure: Their definition for orthopedic complications included the long-term complications of chronic osteomyelitis (as diagnosed by a pediatric infectious disease specialist at follow up), limb length discrepancy or growth arrest, deformities, dislocations, avascular necrosis, or pathologic fractures.</p>	<p>likely discharged on oral therapy. Of the 26 patients discharged on oral therapy, they received one week of IV antibiotics before transitioning to oral. There were no significant differences between the two groups in risk of developing long-term orthopedic complications: 11% in the oral group and 18.4% in the OPAT/CHIT group with $P = 0.55$. One patient on OPAT was re-hospitalized for bacteremia.</p> <p>Clinical Significance: MRSA increases the risk for complications generally but does not prohibit transition to oral antibiotics. No safety issues were identified in those who were transitioned to oral medications, which supports a provider’s decision to transition based on clinical judgement.</p> <p>Conclusions: This evidence supports the hypothesis that the route of therapy after discharge does not increase the risk for orthopedic complications, even in a population with 1/3 MRSA+ patients.</p>
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		<p>Power analysis: To achieve 80% power in seeing 50% difference in rates of orthopedic complications between these groups with $\alpha = 0.05$, a total sample size of 1498 is needed. If a higher baseline rate of orthopedic complications of 20% is assumed, total sample size needed is 398 to see a 50% reduction in complication rates.</p> <p>Group Homogeneity: Demographic data were similar between the two groups. Clinically, there were differences between the two groups that may confound the results. These differences reveal the association between sicker patients and the decision to discharge on OPAT/CHIT.</p>			
<p>Ratnayake, K., Davis, A. J., Brown, L. & Young, T. P. (2015). Pediatric acute osteomyelitis in the postvaccine, methicillin-resistant <i>Staphylococcus aureus</i> era. <i>American Journal of Emergency Medicine</i>, 33(10), 1420–1424. https://doi.org/10.1016/j.ajem.2015.07.011</p>					<p>Level III Quality C</p>
Purpose/ Hypothesis	Type of evidence Research Design	Sample – Population, Size, Setting	Intervention/ Procedures	Primary Outcome/Measures	Results/Conclusions
<p>“Our objective was to examine cases of acute culture- and/or imaging-proven</p>	<p>Retrospective descriptive study based on medical record review; only</p>	<p>Sampling Technique: Purposive sampling from pediatric</p>	<p>Control: none Intervention: Standard care was</p>	<p>DV (of interest): Rate of MRSA infections was primary outcome of interest. Others</p>	<p>Statistical results: Most common pathogen was MSSA (47%), followed by community-acquired MRSA</p>

<p>osteomyelitis involving healthy prepubescent children seen in our pediatric emergency department. Our primary aim was to determine the rate of MRSA infection in cases of pediatric osteomyelitis. Our secondary aims were to determine organism susceptibilities for MRSA osteomyelitis, to describe site of involvement and rate of complications of osteomyelitis, to determine whether complications were associated with antibiotic discordance or time to antibiotic administration, and to evaluate the yield of operative cultures when antibiotics had already been administered.”</p>	<p>included patients 12 years and younger (versus other studies listed which all included 18 years and younger).</p>	<p>emergency room patients. # Eligible: 194 had ICD-9 code for osteomyelitis; 102 patients met exclusion criteria (chronic infection, chronic conditions, post-surgical, etc.) # Accepted: 67 patients met exclusion criteria and had positive evaluation for osteomyelitis # Control: none # Intervention: 67 patients received standard care Power analysis: None Group Homogeneity: Median age was 5 years old (range 1 month to 10 years), 60% male, all subjects either had positive imaging or positive surgical culture for osteomyelitis.</p>	<p>provided for all patients and specific outcomes were measured. Intervention fidelity (describe the protocol): They used a standardized data collection form with a trained data abstractor.</p>	<p>included organism susceptibility, site involved, rate of complications according to antibiotic timing, yield of surgical cultures post antibiotic administration. Measurement tool (reliability), time, procedure: Each outcome was measured based on its presence in the patient’s medical record.</p>	<p>(38%). The other organisms all made up 5% or less of cases. Conversely, the most common pathogen recovered from blood culture was MRSA (52%), then MSSA (39%). Of the 12 recovered MRSA isolates, 2 were clindamycin-resistant; all were susceptible to vancomycin and trimethoprim-sulfamethoxazole. Most common site was the femur. Sixty-nine percent had local complications (i.e. abscess, myositis, fasciitis). In cases requiring surgical intervention, 84% still yielded positive culture; operative culture was positive in 80% (4 of 5) in cases when antibiotics was delayed. Clinical Significance: In this community, MSSA and MRSA rates were nearly equal. Antibiotics prior to surgical intervention/culture did not affect the positivity rate—antibiotics should not be delayed for surgical intervention. Vancomycin (IV) is a reasonable empiric choice in this population; trimethoprim-sulfamethoxazole is a reasonable oral option to complete treatment if the organism is susceptible.</p>
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					<p>Conclusions: This descriptive study supports a growing body of evidence that MRSA is an increasing cause of pediatric osteomyelitis and corroborates other findings of community clindamycin-resistant strains. This study’s population also had a higher rate of complications requiring surgical intervention, but cultures were unaffected when antibiotics were administered prior.</p>
<p>Woods, C. R., Bradley, J. S., Chatterjee, A., Copley, L. A., Robinson, J., Kronman, M. P., Arrieta, A., Fowler, S. L., Harrison, C., Carrillo-Marquez, M. A., Arnold, S. R., Eppes, S. C., Stadler, L. P., Allen, C. H., Mazur, L. J., Creech, C. B., Shah, S. S., Zaoutis, T., Feldman, D. S., & Lavergne, V. (2021). Clinical practice guideline by the pediatric infectious diseases society and the Infectious Diseases Society of America: 2021 Guideline on Diagnosis and Management of Acute Hematogenous osteomyelitis in pediatrics. <i>Journal of the Pediatric Infectious Diseases Society</i> (Vol. 10, Issue 8, pp. 801–844). Oxford University Press. https://doi.org/10.1093/jpids/piab027</p>					<p>Level IV Quality A</p>
Purpose/ Hypothesis	Type of evidence Research Design	Sample – Population, Size, Setting	Intervention/ Procedures	Primary Outcome/Measures	Results/Conclusions
<p>“This clinical practice guideline for the diagnosis and treatment of AHO in children was developed by a multidisciplinary panel representing Pediatric Infectious Diseases Society (PIDS) and the Infectious Diseases Society of America (IDSA). This guideline is intended for use by healthcare professionals who</p>	<p>Clinical practice guideline (CPG) with recommendations based on a systematic selection, meta-analyses, and evaluation of available literature with standardized methodology for rating certainty of evidence and strength of recommendation (same process used in all IDSA and</p>	<p>Search Strategy: Multiple database searching with key words # Screened: 10,260 articles # Eligible: 577 articles # Excluded: 522 articles # Included: 55 articles # Included for transition to oral antibiotics section: 4 articles</p>	<p>Control: Varied based on dependent variable (clinical topic of focus). For this focus, the control was the traditional method of care to discharge the patient home on IV therapy via a PICC line. Intervention: Interventions varied by topic. For this focus, the intervention of comparison is</p>	<p>DV: Multiple variables were included according to specific practice problems. 1. Noninvasive diagnostic lab tests 2. Imaging studies 3. Role of invasive procedures 4. Timing of antibiotic initiation 5. Empiric antibiotic selection 6. Invasive therapeutic procedures</p>	<p>Statistical results: Relative Risk with 91% CIs were calculated for 4 outcomes related to the clinical topic of focus: treatment failure, catheter-related complications, re-hospitalization within 6 months, and adverse drug reactions. The authors pooled the 4 included study’s data to answer whether the risk of each outcome was affected by transitioning to oral therapy. Treatment failure had a RR of 0.79 (95% CI, 0.60–1.02), catheter-related complications was not estimable,</p>

<p>care for children with AHO, including specialists in pediatric infectious diseases, orthopedics, emergency care physicians, hospitalists, and any clinicians and healthcare providers caring for these patients.”</p>	<p>PIDS guidelines). Authored by panel of experts specializing in pediatrics and infectious disease.</p>	<p>PRISMA Criteria: Detailed decision making for both inclusion/exclusion criteria, quality and strength determinations. Included supplemental materials that include all evidence table reviews for each section of the guideline. Meta-analysis of pooled data done for each section of guideline. Extensive review included strengths and limitations of each study included.</p> <p>Power analysis: not applicable</p>	<p>discharging the patient home on oral therapy.</p> <p>Intervention fidelity (describe the protocol): See PRISMA Criteria.</p>	<ol style="list-style-type: none"> 7. Surgical-site antimicrobials 8. Selecting definitive parenteral and oral therapy 9. Clinical and lab criteria for assessing treatment response 10. IV therapy transition to oral 11. Duration of treatment for <i>S. aureus</i> infection 12. End-of-therapy studies 13. Treatment failure 14. Long-term follow up <p>Measurement tool (reliability), time, procedure: Varied based on clinical topic of focus. For this focus, the definitions were the same as those found in each of the 4 articles included.</p>	<p>rehospitalization had a RR of 0.43 (95% CI, 0.23–0.79), and adverse drug reaction had a RR of 0.49 (0.27–0.88). Forest plots using <i>t</i>-tests and chi-squares for all 4 outcomes were also created with significant differences found in catheter-related complications, rehospitalization, and adverse drug reactions. Despite the limitations of the articles in their systematic review for this area of focus, the authors <i>strongly</i> recommend switching to oral therapy when the patient has responded to IV therapy and there is an equivalent oral agent available and well tolerated.</p> <p>Clinical Significance: This guideline is extensive and gives providers specific recommendations based on specific patient parameters and helps guide decision-making based on pooled evidence (ranging from high to low quality). They calculated pooled odds ratios when appropriate and made recommendations based on all available evidence. The first section of the guideline is the most usable section for the clinical setting. It lists out each recommendation clearly and indicates how strongly it</p>
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					<p>is recommended and quality of evidence on which it is based. They are ordered by clinical process.</p> <p>Conclusions: The guideline encourages early transition to oral medications when the patient is clinically improving (among many other recommendations).</p>
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AHO: acute hematogenous osteomyelitis; IV: intravenous; PICC: peripherally inserted catheter; MRI: magnetic resonance imaging; ESR: erythrocyte sedimentation rate; CRP: c-reactive protein; OR: odds ratio; CI: confidence interval; PPV: positive predictive value; NPV: negative predictive value; ICD: International Classification of Diseases; IRB: internal review board; OPAT: outpatient parenteral antibiotic therapy; CHIT: complete hospital intravenous (IV) therapy; MRSA: Methicillin-resistant Staphylococcus aureus; MSSA: methicillin-sensitive Staphylococcus aureus; BOAI: bacteremic osteoarticular infection; PO: oral route

Table 2

Synthesis Table

Evidence Based Practice Question (PICO): Does implementing clinical practice guidelines with an electronic health record (EHR) order set for pediatric bone or joint infections reduce the number of patients discharged on parenteral antimicrobials compared to the five years prior to the intervention?			
Level of Evidence	# of Studies	Summary of Findings	Overall Quality
II	2	Keren et al. (2015) found no significant difference in treatment failure rates between pediatric patients discharged home on oral antibiotics and those discharged on IV antibiotics given via PICC. They found an increased risk for adverse drug events, PICC line complications, ED visits and rehospitalization among the PICC group.	B, this study’s retrospective design with propensity score-based matching creates artificial (statistical) control. It is quasi-experimental. The results are definitive and consistent within the article as well as consistent with other literature. The study is limited by its design but attempts to address confounding across multiple arenas.
		McNeil et al. (2017) found no statistically significant difference in likelihood to develop long-term orthopedic complications between those discharged on oral therapy and those discharged on home IV therapy in patients with culture-confirmed <i>Staph. aureus</i> AHO.	C, this study is underpowered for identifying orthopedic complications between the two study groups. It likely includes bias based on its design—it identifies the association between sicker children and going home with a PICC. The results are consistent with other studies, and it did not identify any safety data (i.e. clear negative consequences from the intervention). Despite limitations, this study does demonstrate that, for some patients, oral therapy is a safe option.
III	3	Alhinai et al. (2020) found 5 clinical factors independently predicted acute complications from osteomyelitis (together a composite “A-SCORE”) and 3 clinical factors independently predicted chronic complications (together a composite “C-SCORE”). The clinical factors included abscess, fever >48 hours, disseminated disease, delayed source control, prolonged elevated CRP, and bone debridement. The absence of all factors reliably and significantly predicted a mild course without complication (NPV >90% for each score).	A, this study aimed to find safety issues within a large cohort (no control in the design) and while the scoring tools had only semi-reliable sensitivity, specificity, and PPV, they had very high NPV which is extremely useful clinically and generalizable. These results are supported in other literature and are consistent with the IDSA guidelines that were published the following year.
		Chou & Mahadev (2016) found that transitioning to oral antibiotics in patients whose CRPs decreased by at least 50% within the first 4 days of admission is safe; 94% of this	B, this study had a small sample size but very consistent results. The results are generalizable to similar populations and uphold older studies examining CRP as a predictor in bone and joint infection outcomes.

		<p>cohort had uncomplicated outcomes. This study included patients with culture-negative osteomyelitis (diagnosis confirmed by imaging).</p> <p>Ratnayake et al. (2015) found that MRSA osteomyelitis cases were increasing in their cohort of patients, but all were susceptible to vancomycin and trimethoprim-sulfamethoxazole. Their cohort also had higher rates of complications than previously described, which correlates to MRSA infections.</p>	<p>C, this study is descriptive in nature and its results are not necessarily generalizable to other populations as community-acquired MRSA rates and strains vary widely. It is consistent with other literature that shows that MRSA infections tend to have higher rates of complications (namely abscesses requiring surgical intervention) but that final outcomes with standard treatment are about as favorable as non-MRSA infections.</p>
IV	1	<p>Woods et al. (2021) support the transition from IV to oral antibiotics based on the patient’s improvement on IV therapy and recommends that patients be discharged on oral when an equivalent antibiotic exists and is tolerated. Fourteen recommendations are given in total that range from diagnosis to management to follow up.</p>	<p>A, this CPG had well-defined processes for choosing, evaluating, and rating the evidence used for each clinical question. Despite a lack of RCTs available (which are not feasible in this population), expertise was clearly evident in all recommendations. Great care was taken to explain the conditions of each clinical recommendation and included detailed rationales and admissions of low evidence. PRISMA Criteria were fully met.</p>

A (High quality): Consistent, generalizable results; sufficient sample size for the study design; adequate control; definitive conclusions; recommendations consistent with the study’s findings and include thorough reference to scientific evidence

B (Good quality): Reasonably consistent results; sufficient sample size for the study design; some control; fairly definitive conclusions; reasonably consistent recommendations based on fairly comprehensive literature review that includes some reference to scientific evidence

C (Low quality): Little evidence with inconsistent results; insufficient sample size for the study design; conclusions cannot be drawn.

Johns Hopkins Evidence-Based Practice Model for Nursing and Healthcare Professionals. (2022). “Research Evidence Appraisal Tool.”

Table 3

Goals and Measurements

Project Goals	Measure Pre-Implementation	Measure During Implementation
Structure Goal(s)		
1. Create an institution-specific antibiotic stewardship guideline for pediatric bone and joint infections accessible to all pediatric providers by September 6, 2022.	Presence of guideline in the UMMC Sanford App and website	Presence of guideline in the UMMC Sanford App and website
2. Change the EMR to include a pediatric Epic order set and checklist for bone and joint infections identified in the pediatric emergency department, medical-surgical floor, or intensive care units by September 6, 2022.	Presence of pediatric bone and joint infection order set available in the EMR	Presence of pediatric bone and joint infection order set available in the EMR
Process Goal(s)		
1. 100% use of the pediatric order set by providers for all eligible patients with suspicion for bone and/or joint infection after the implementation period.	Numerator: # of patients with a diagnosis of osteomyelitis or septic joint Denominator: # of patients with a diagnosis of osteomyelitis or septic joint	Numerator: # of patients with a diagnosis of osteomyelitis or septic joint whose EMR shows use of the order set at least once during admission Denominator: # of patients with a diagnosis of osteomyelitis or septic joint
2. 80% attendance of all pediatric medical learners (includes medical students, residents, fellows, nurse practitioners, and attendings) to education session for roll out of the guidelines and order set	# average number of attendees to pediatric education sessions over the past year	# of attendees to the education session for this guideline and order set roll out

Outcome Goal(s)		
1. No change in safety outcomes (PICC complications, ortho complications, readmission, etc.) identified in pediatric bone and/or joint infection patients after implementation compared to before implementation	<p>Numerator: # of pediatric bone and/or joint infection patients seen at UMMC from 2016–2021 who had a safety outcome identified</p> <p>Denominator: # of pediatric bone and/or joint infection patients seen at UMMC from 2016–2021</p>	<p>Numerator: # of pediatric bone and/or joint infection patients seen at UMMC after implementation in fall 2022 who had a safety outcome identified</p> <p>Denominator: # of pediatric bone and/or joint infection patients seen at UMMC after fall 2022</p>
2. 20% decrease in the number of the pediatric bone and/or joint infection patients who receive > 96 hours (4 days) of IV antibiotic therapy despite a 50% decline in CRP within 96 hours in the post-implementation period	<p>Numerator: # of pediatric bone and/or joint infection patients seen at UMMC from 2016–2021 who received > 96 hours of IV antibiotic therapy despite a 50% decline in CRP within 96 hours</p> <p>Denominator: # of pediatric bone and/or joint infection patients seen at UMMC from 2016–2021</p>	<p>Numerator: # of pediatric bone and/or joint infection patients seen at UMMC after implementation in fall 2022 who received > 96 hours of IV antibiotic therapy despite a 50% decline in CRP within 96 hours</p> <p>Denominator: # of pediatric bone and/or joint infection patients seen at UMMC after fall 2022</p>
3. 20% decrease in the number of pediatric bone and/or joint infection patients who receive empiric IV vancomycin but were hemodynamically stable at presentation in the post-intervention period	<p>Numerator: # of pediatric bone and/or joint infection patients seen at UMMC from 2016–2021 who receive empiric IV vancomycin but were hemodynamically stable at presentation</p> <p>Denominator: # of pediatric bone and/or joint infection patients seen at UMMC from 2016–2021</p>	<p>Numerator: # of pediatric bone and/or joint infection patients seen at UMMC after implementation in fall 2022 who receive empiric IV vancomycin but were hemodynamically stable at presentation</p> <p>Denominator: # of pediatric bone and/or joint infection patients seen at UMMC after fall 2022</p>

Note: “pediatric bone and/or joint infection patients” refers to a population age 1–17 years old (NICU patients are excluded regardless of age) who are diagnosed with an acute hematogenous osteoarticular infection without a prior risk factor for complications such as implanted hardware, post-surgical patients, moderate to severe chronic co-morbidities, or chronic osteoarticular infection history.

Table 4*Regional MSSA vs MRSA data*

Institution	Related MSSA and MRSA data
Johns Hopkins Children's Hospital	MSSA vs MRSA rates were similar, ~25% MRSA vs 75% MSSA over a 5-year period*
Children's National	Review of 2010–2019 OAI MSSA and MRSA data: MSSA: 60/79 (76%) MRSA: 19/79 (24%) Clindamycin susceptibility: 69/79 (87%)
Children's Hospital of Philadelphia	2012–2022 Antibiogram data: Blood: MSSA 311/420 (74%) MRSA 109/420 (25/9%) Clindamycin susceptibility 82% Wound: MSSA 8,676/12,688 (68%) MRSA 4,012/12,688 (31%) Clindamycin susceptibility 80%

*Specific data were not available as this paper has not yet been published

Table 5*Screened, Ineligible, and Eligible Patients*

Implementation Week	Screened	Ineligible	Eligible
Week One	1	1	0
Week Two	0	0	0
Week Three	1	1	0
Week Four	0	0	0
Week Five	0	0	0
Week Six	1	0	1
Week Seven	0	0	0
Week Eight	0	0	0
Week Nine	0	0	0
Week Ten	0	0	0
Week Eleven	1	0	1
Week Twelve	0	0	0
Week Thirteen	0	0	0
Week Fourteen	0	0	0
Week Fifteen	0	0	0
Total	4	2	2

Figure 1

Fishbone Diagram: Root Causes

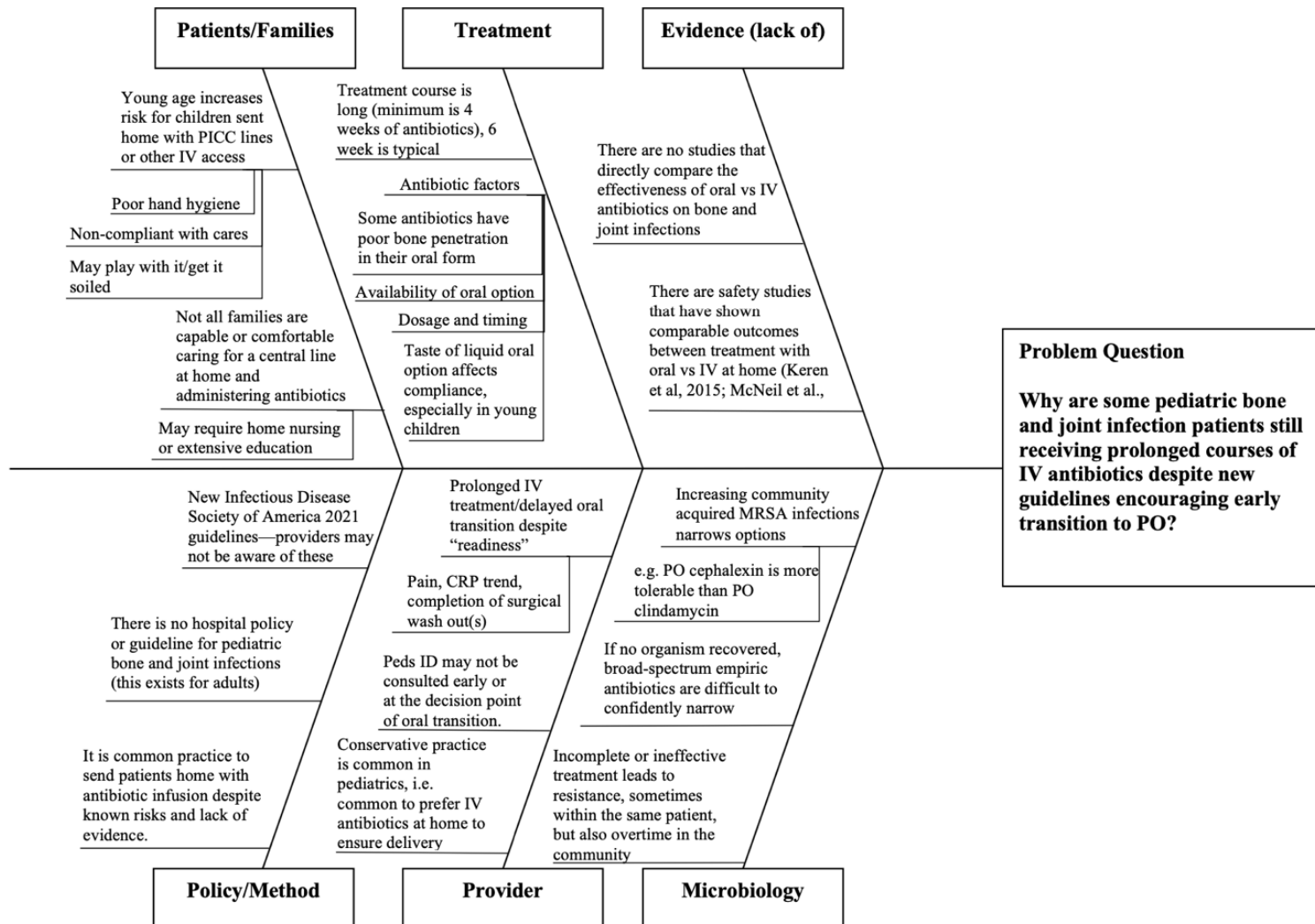


Figure 2

Framework

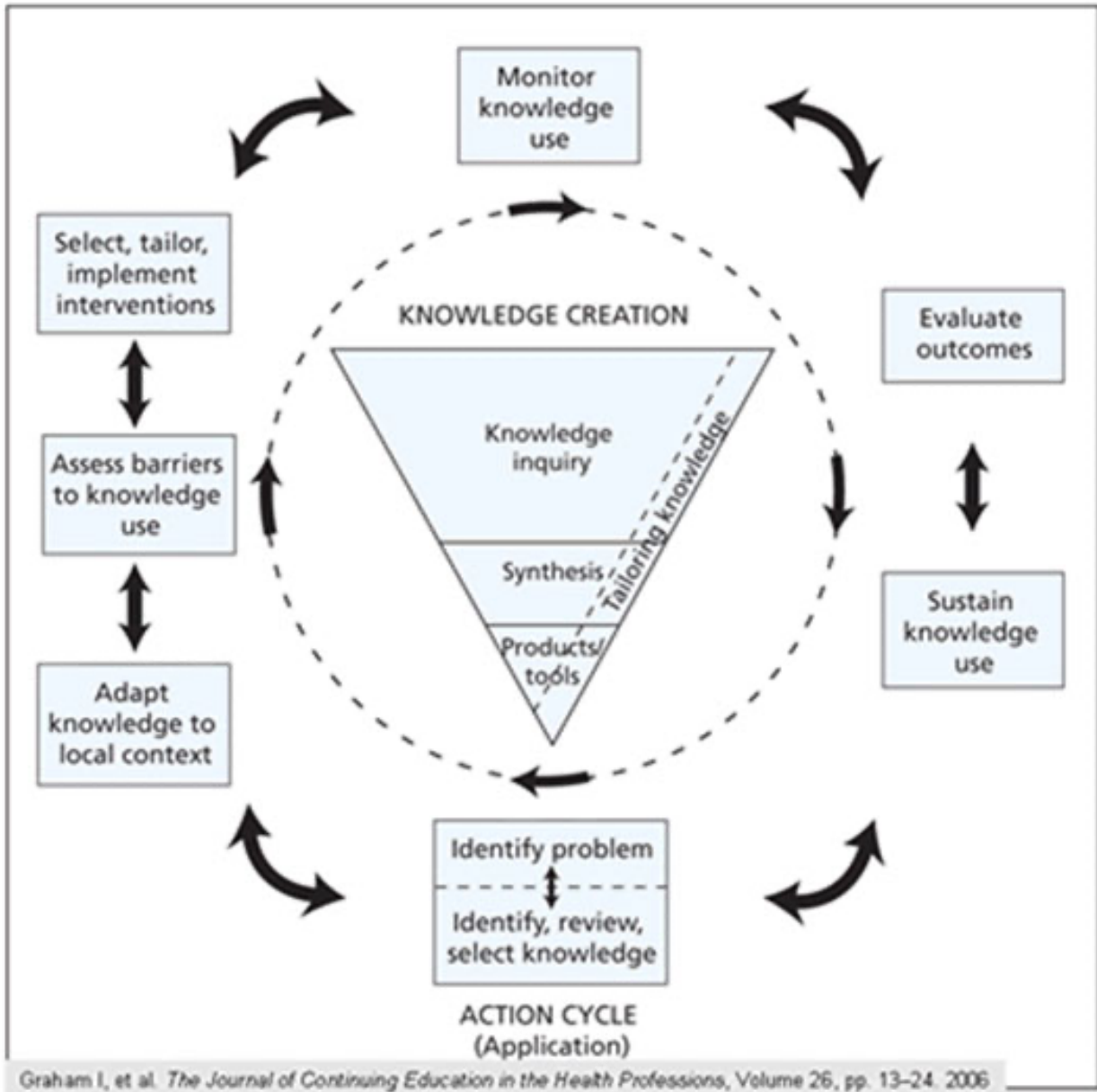
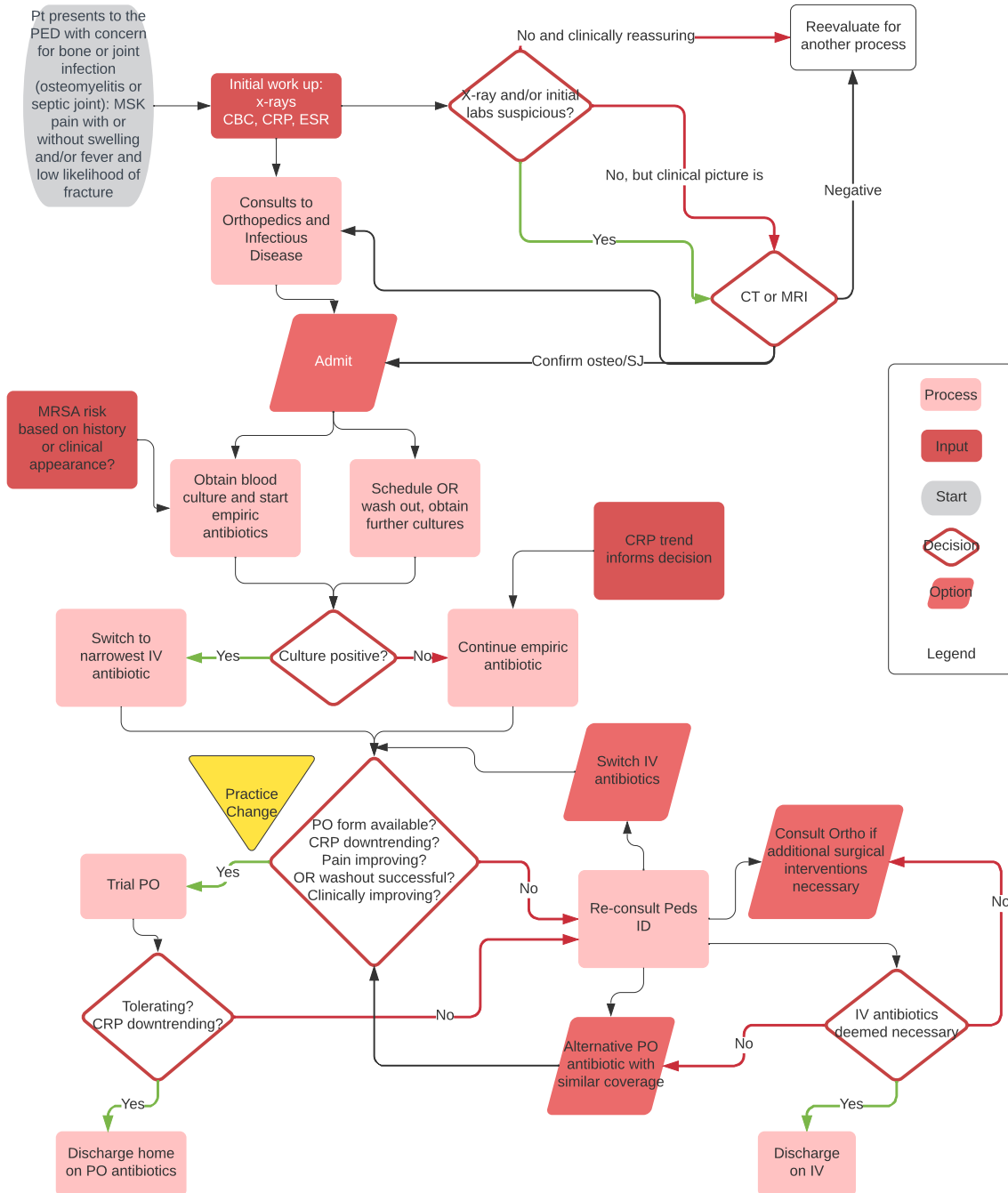


Figure 3

Desired Processes

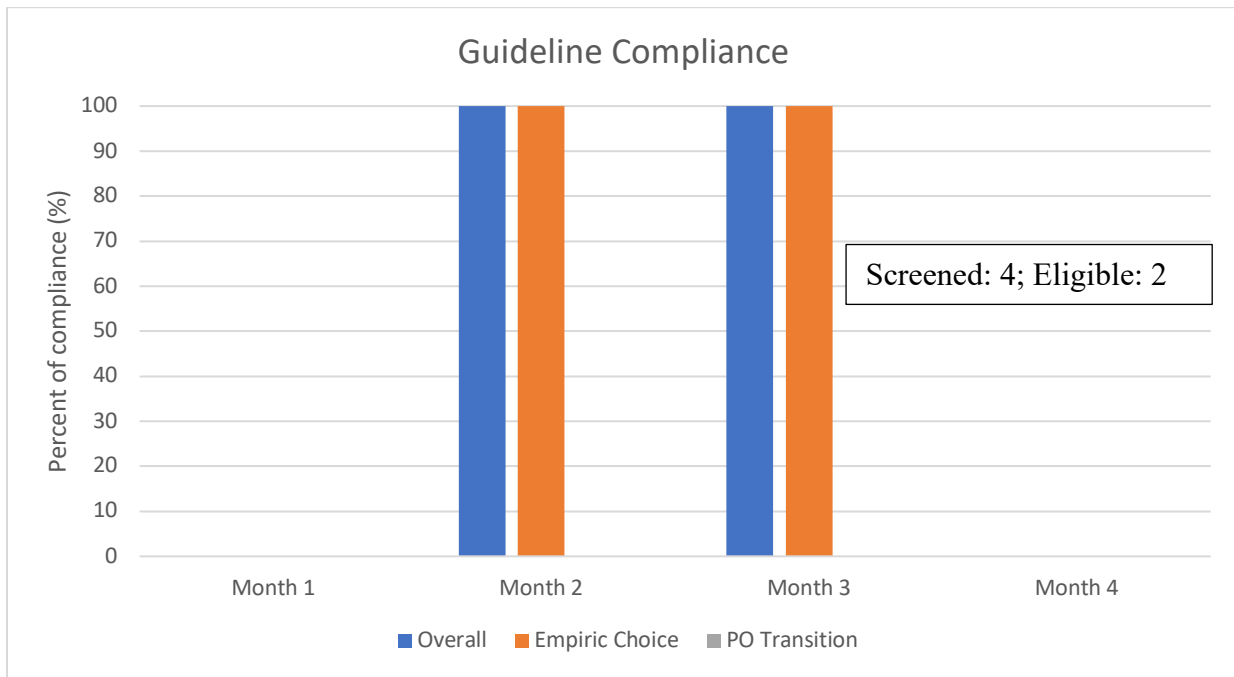


Legend

- Process (Pink rounded rectangle)
- Input (Red rounded rectangle)
- Start (Grey rounded rectangle)
- Decision (Red diamond)
- Option (Red parallelogram)

Figure 4

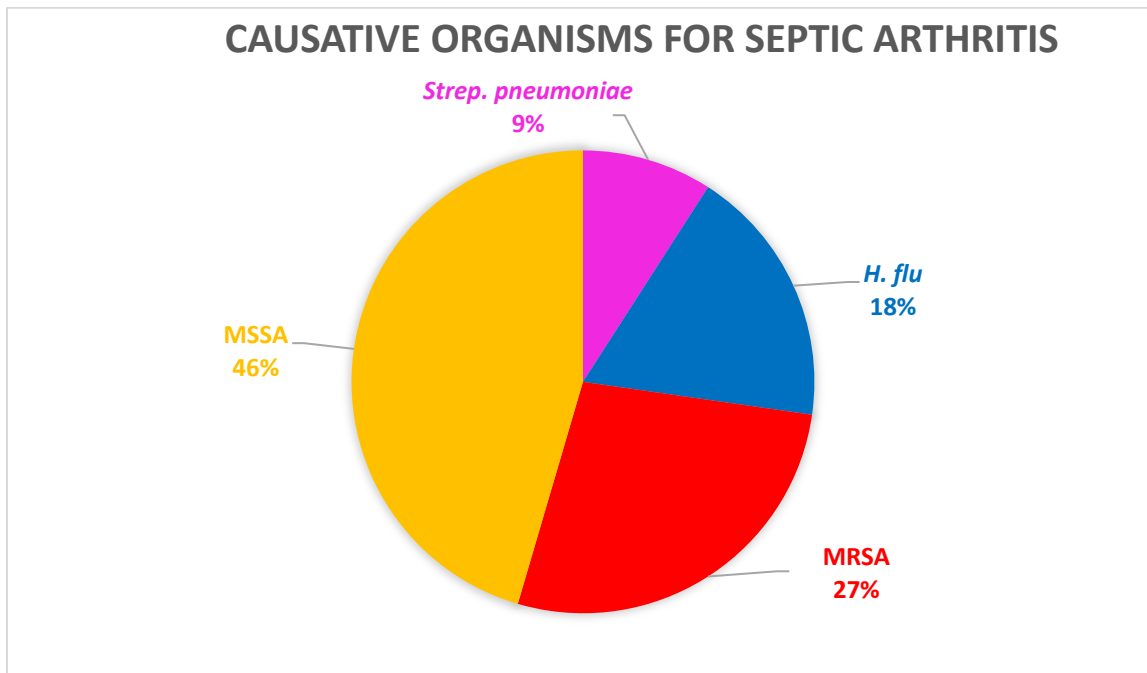
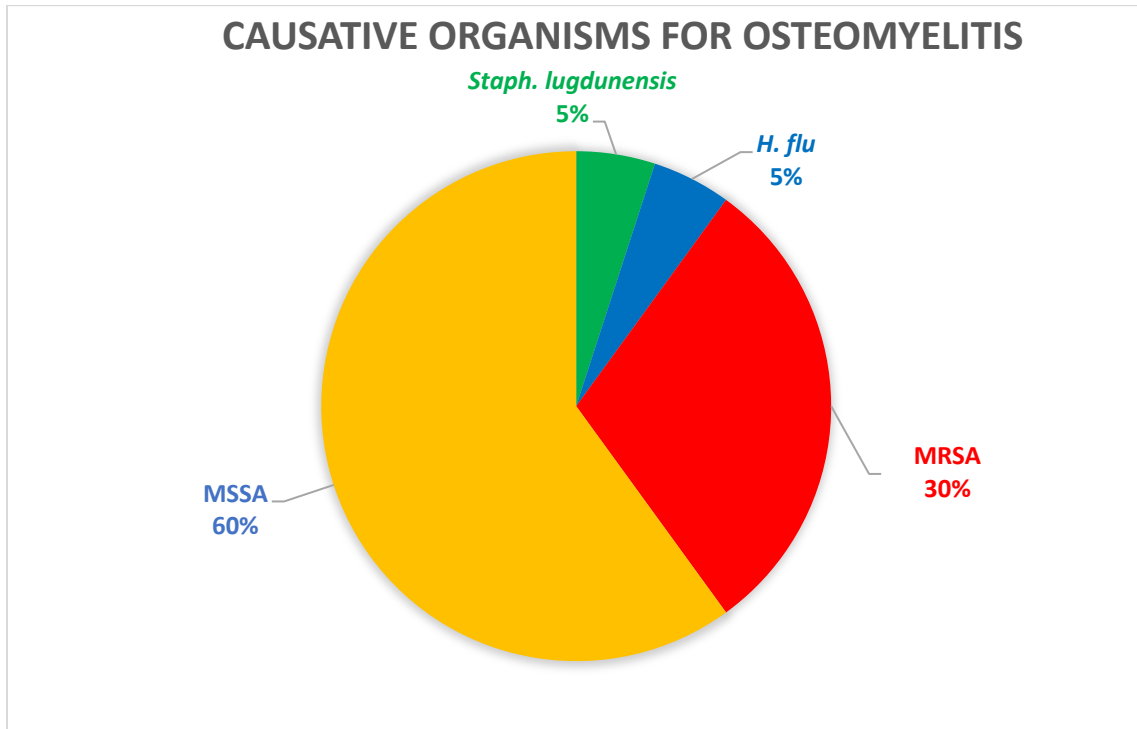
Guideline Compliance Bar Graph

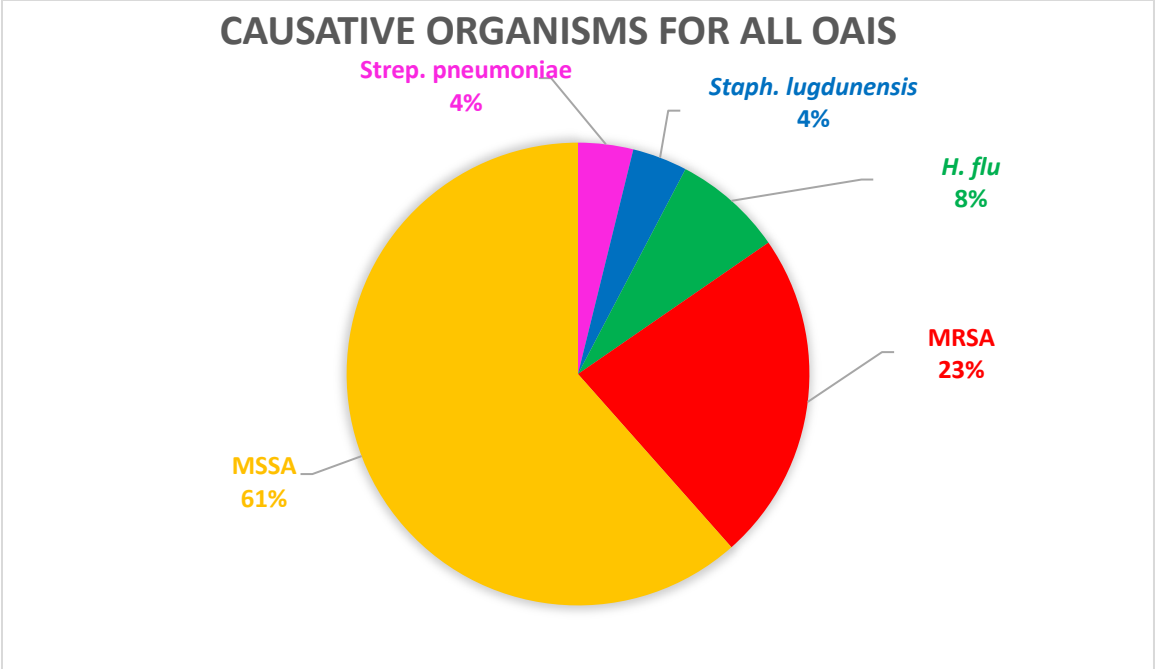


Note. PO = by mouth. In month two, there were two eligible patients, but one was transferred from an outside hospital who started the patient on empiric antibiotics that deviated from the new guidelines—this is not reflected in this graph since the decision was not made on the project’s institution. The other patient was started on antibiotics at this institution and the guidelines were followed. PO transition was not measured since data collection is not complete.

Figure 5

Causative Organism Breakdown





These charts illustrate the combined data from the 5-year review and the 2 patients seen during the implementation period.

Appendix A

Modifications of Diagnostic Order Set

Figure A1

Current Septic Arthritis Order Set

Order Sets

! Consulting Provider Contacted? No
 Team/Role for Messaging: SERVICE NOT MAPPED TO SECURE MESSAGING
 Patient Location: UMMC

▼ Labs

▼ Hematology

- CBC with Auto Diff
STAT, once, today at 2154, For 1 occurrence
- Sedimentation Rate
STAT, once, today at 2154, For 1 occurrence

▼ Chemistry

- Comprehensive Metabolic Panel
STAT, once, today at 2154, For 1 occurrence
- C Reactive Protein Quant
STAT, once, today at 2154, For 1 occurrence

▼ Microbiology

- Blood Culture
STAT, once, today at 2154, For 1 occurrence
- Body Fluid Culture
STAT

▼ Body Fluid

- Cell Count Body Fluid
STAT

▼ Imaging

▼ MR

- MR Hip W/O Con LEFT
- MR Hip W/O Con RIGHT

▼ Medications

▼ Antibiotics

- oxacillin IV (\$21/day)
33 mg/kg, 6 times daily, Intravenous, Starting 7/5/22
- ceFAZolin (ANCEF) IV (\$14/day)
33 mg/kg, every 8 hours, Intravenous
- vancomycin (VANCOGIN) IV loading dose followed by Vancomycin IV Dosed and Managed by Pharmacist Pane
- clindamycin (CLEOCIN) IV (\$9.20/day)
10 mg/kg, every 6 hours, Intravenous, Starting 7/5/22
- cefepime (MAXIPIME) IV (\$33/day)

Proposed Draft of Diagnostic Order Set

PED ED Septic Arthritis and Osteomyelitis

- General
 - Vital Signs
 - Vital signs
 - Nurse pain assessment with vital signs
 - Physician Consults
 - Consult Orthopedic Surgery UMMC (pre-selected)
 - Consult Pediatric Infectious Diseases UMMC (pre-selected)
- Labs
 - Hematology
 - CBC with Auto Diff (pre-selected)
 - Sedimentation Rate (pre-selected)
 - Chemistry
 - Comprehensive Metabolic Panel (pre-selected)
 - C Reactive Protein Quant (pre-selected)
 - Microbiology
 - Blood culture (pre-selected)
 - Body fluid culture
 - Body fluid
 - Cell count body fluid
 - *Kingella kingae* body fluid PCR (For patients < 5 years of age)
 - Serum Lyme antibody titers (EIA w/ reflex to immunoblot) and Lyme PCR of aspirated fluid
- Imaging

Consider x-ray of affected bone or joint to rule out other causes of pain (i.e. trauma)

Consider ultrasound of affected joint

Consider MR of affected bone or joint

- Medications

- Antibiotics

Obtain blood culture prior to starting antibiotics

When approved by ortho, antibiotics may be delayed until surgical specimens are obtained

If patient is between 6 months of age and 5 years old add cefazolin

If patient has history of sickle cell disease, use ceftriaxone instead of cefazolin

- Vancomycin IV loading dose, 15 mg/kg, intravenous, STAT (Pre-selected)
- Vancomycin Pharmacy to Dose Order (Pre-Selected)
- Cefazolin IV 33 mg/kg IV every 8 hours
- Ceftriaxone IV 50 mg/kg, intravenous, STAT