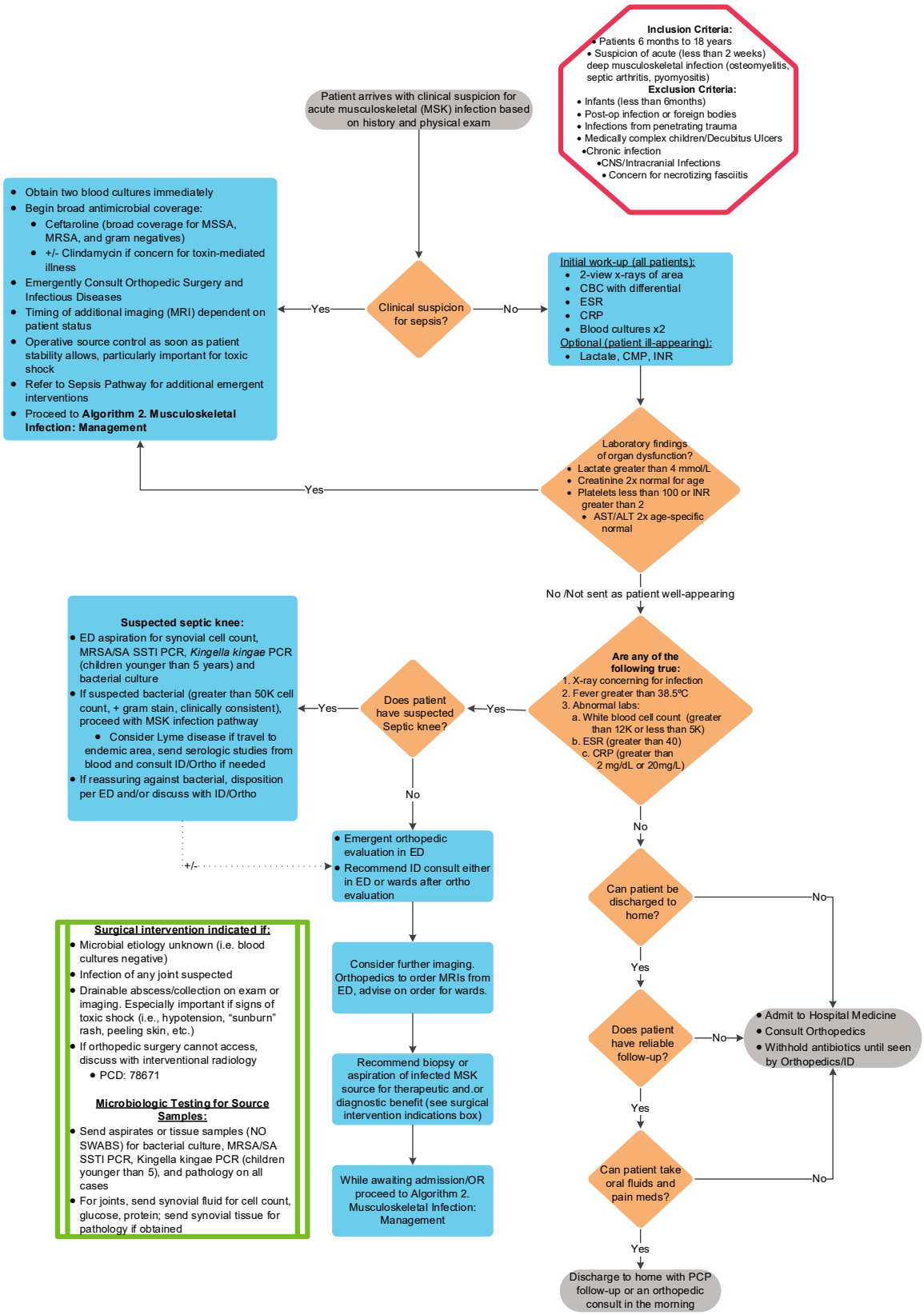
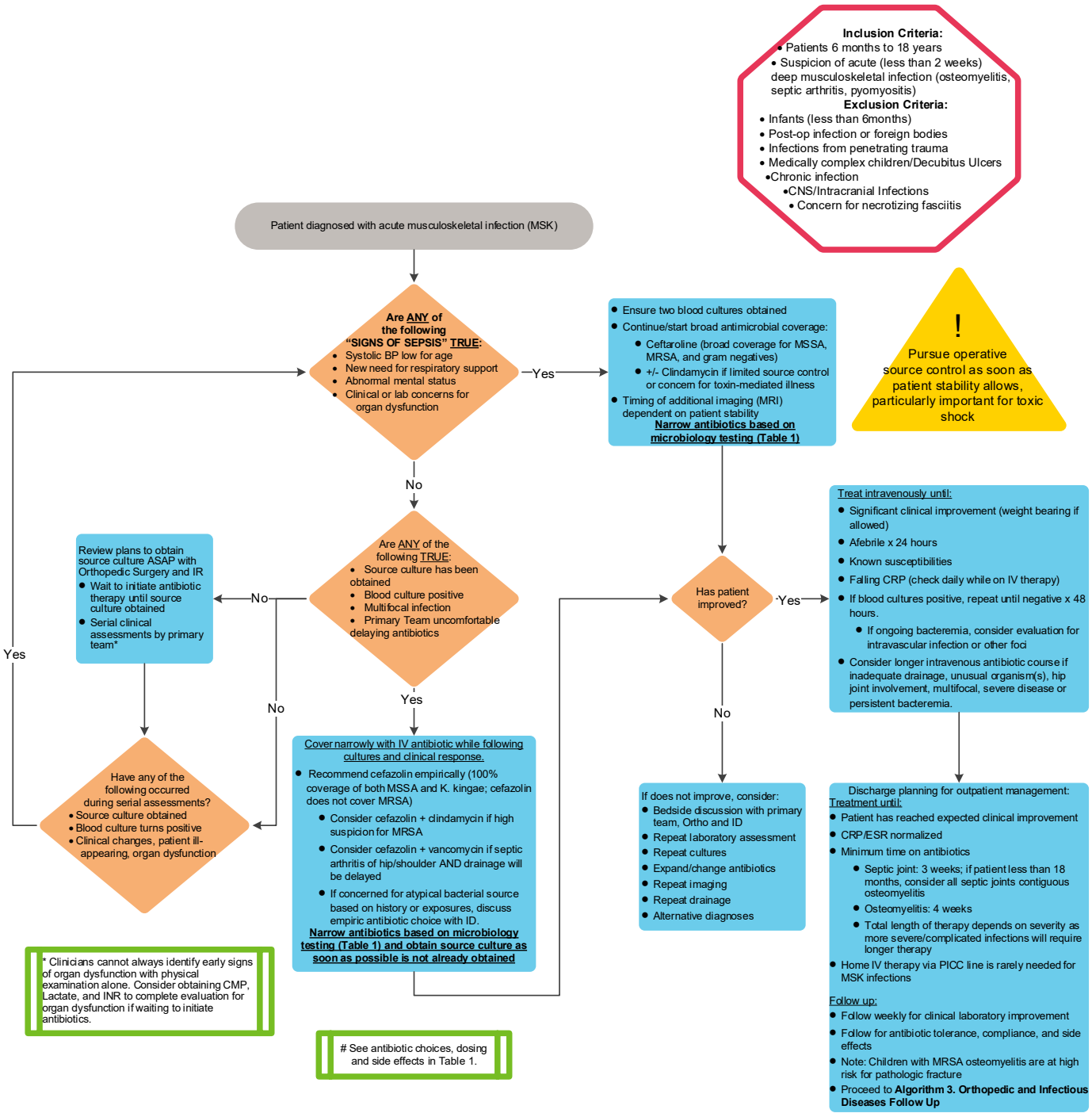
Children's Hospital Colorado

MUSCULOSKELETAL (MSK) INFECTION

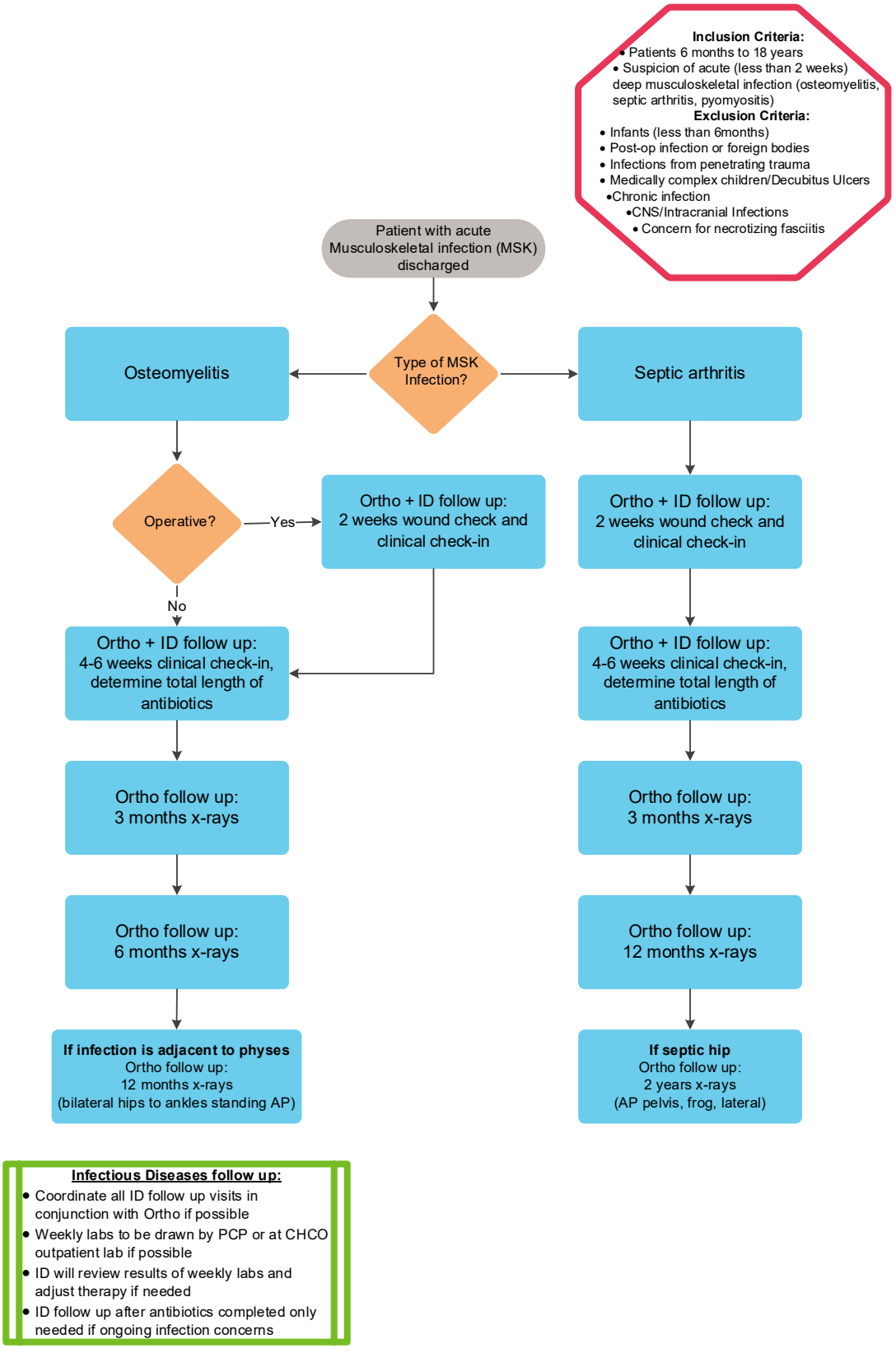
Algorithm 1. Musculoskeletal Infection: Diagnostic



Algorithm 2. Musculoskeletal Infection: Management



Algorithm 3. Musculoskeletal Infection: Orthopedic and Infectious Diseases Follow-up



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TARGET POPULATION

Inclusion Criteria

- 6 months to 18 years
- Suspicion of acute (less than 2 weeks) deep musculoskeletal infection; osteomyelitis, septic arthritis, pyomyositis

Exclusion Criteria

- Postoperative infection or foreign bodies (including indwelling orthopedic hardware)
- Infections from penetrating trauma
- Chronic infection
- Infants (less than 6 months), as they may have: 1) other pathogens, 2) multifocal disease, and 3) poor oral antibiotic absorption
- Medically complex children (e.g. immunocompromised, significant neurologic deficits, decubitus/pressure ulcers, etc)
- CNS/Intracranial Infections

KEY TREATMENT PRINCIPLES

Indicated:

- Laboratory workup including complete blood count (CBC) with differential, C-reactive protein (CRP), erythrocyte sedimentation rate (ESR), and blood cultures[1-7]
- Radiographic imaging[1, 2, 5, 7]
- Source culture prior to antibiotics in well-appearing patients[1, 2, 5, 6, 8-10]

Not routinely indicated:

- Antibiotics prior to source culture for well-appearing children with negative blood cultures
- PICC/central line placement

CLINICAL ASSESSMENT

1. Vital signs on admission
2. Observation and/or history for:
    - Limited used or immobility of extremity or spine
    - Gait disturbance/Limp
    - Inability to bear weight
    - Pain
    - Fever greater than 38.5ºC
    - Travel and exposures
    - Clinical signs of sepsis
3. Physical examination for the presence of:
    - Limited range of motion
    - Tenderness
    - Swelling
    - Warmth at site
    - Erythema
    - Psoas sign
    - Fever
    - Inadequate perfusion or organ dysfunction

INITIAL EVALUATION AND LABS

1. Complete blood count (CBC) with differential, C-reactive protein (CRP), Erythrocyte sedimentation rate (ESR), Blood culture x 2 (per Children's Hospital Colorado protocol)
2. If patient is ill-appearing, obtain Lactate, CMP, and INR to evaluate for organ dysfunction per sepsis pathway [11-13]
3. If knee/elbow: Arthrocentesis, interpretation and disposition in ED. Arthrocentesis may be performed by ED or Orthopedics (if ED physician, consider Ortho consult prior to arthrocentesis)

- If suspected bacterial (≥50,000 WBC count, + Gram stain, +MRSA/SA SSTI PCR, or presentation clinically consistent), proceed with MSK Clinical Pathway [14, 15]
- If travel/cell count supports, consider Lyme disease (send serology) and consult Orthopedics/Infectious Diseases if needed

4. Suspected deep-seated bone or joints (e.g. shoulder, hip): Obtain labs/imaging; consult Orthopedics

INITIAL IMAGING STUDIES

- **Plain radiographs (all patients):** Radiographs can be insensitive for the evaluation of acute soft tissue and osseous infection, as changes on x-ray are often a late finding with MSK infections. However, if infectious changes seen may avoid further imaging. Soft tissue swelling, though nonspecific, may be an early finding of MSK infection.[5-7, 9, 16]
- **Ultrasound:** Hip and/or knee ultrasound may be helpful in the setting of equivocal physical exam findings for joint effusion. Consider ordering if a negative ultrasound would avoid further imaging and/or aspiration. [1, 6, 7]

Additional Imaging as directed by ORTHOPEDIC CONSULTANT AND RADIOLOGY

- **MRI: The orthopedic team is to place all MRI orders in EPIC from the ED.** MRI should not be ordered until Orthopedics has evaluated patient. This is to assure the correct exam is ordered in the appropriate time frame.

MRI ordering process:

Anschutz Medical Campus MRI Process

Patients needing EMERGENT exam:

- 7am - 10pm: Call lead MRI tech directly (7-8648) to schedule a sedated or non-sedated exam.
- 10pm - 7am: If an MRI cannot wait for earliest sedated or non-sedated slot, please have Orthopedic attending call the CT tech (7-8645), who will call the on-call radiologist to approve calling in an MRI tech to perform an emergent exam. If exam will need sedation, please have Orthopedic attending call on-call anesthesiologist (7-8339) to coordinate.

Patients needing URGENT (not critical/emergent) exam:

- 7am - 10pm: Call lead MRI tech directly (7-8648) to schedule a sedated or non-sedated exam, goal is to perform MRI within 10 hours.
- After 10pm NON-SEDATED patient: Please have Orthopedic provider call CT Tech (7-8645), who will schedule and place patient in a 6:30am slot (Weekdays) or earliest slot available (Weekends/Holidays).
- After 10pm SEDATED patient: Please have Orthopedic provider call CT Tech (7-8645), who will schedule and place patient in a 7:30am slot (Weekdays) or the earliest sedated slot available (Weekends/Holidays).
    - Weekdays: Anesthesiology will accommodate sedated MRI add-on by sending swing shift anesthesiologist if necessary.
    - Weekends/Holidays: If sedated MRI is outside 10 hour goal, Orthopedic attending should call anesthesia to find first available anesthesiologist.

Colorado Springs Hospital MRI Process

Patients needing EMERGENT exam:

- 7am - 7pm: Call lead MRI tech directly (5-6350) to schedule a sedated or non-sedated exam.
- 7pm - 7am: If an MRI cannot wait for earliest sedated or non-sedated slot, please have Orthopedic attending call the CT tech (5-6360), who will call the on-call radiologist to approve calling in an MRI tech to perform an emergent exam. If exam will need sedation, please have Orthopedic attending call on-call anesthesiologist (5-6824) to coordinate.

Patients needing URGENT (not critical/emergent) exam:

- 7am - 7pm: Call lead MRI tech directly (5-6350) to schedule a sedated or non-sedated exam, goal is to perform MRI within 10 hours.
- After 7pm & Holidays: Please have Orthopedic provider call CT Tech (5-6360), who will coordinate with on-call MRI tech and anesthesiology (if sedated exam) to schedule patient for the earliest available time.

ADMISSION CRITERIA

- Admit all patients with suspected and confirmed acute musculoskeletal infections unless indicated otherwise by Pediatric Orthopedics or ID.
- If a patient with suspected or confirmed MSK infection presents to South/North Campus ED and will require inpatient admission, please consult orthopedic surgery and infectious disease to review clinical scenario and discuss best location for patient admission. Efforts should be made to obtain MRI (if needed) at South/North Campus if this can be obtained without a delay in care.

PROCEDURES | INTERVENTIONS (Emergency Department/Operating Room/Interventional Radiology)

Recommend biopsy/aspiration to establish microbial etiology, for therapeutic benefit (to prevent rupture into contiguous joint, for example) and for abscess discovery. Send ASPIRATE of pus or fluid (NOT A SWAB) for Gram stain and bacterial culture, MRSA/SA SSTI PCR, *Kingella kingae* PCR (if patient < 5 yo), and tissue/synovium for pathology if possible. If joint fluid, send for bacterial culture, Gram stain, MRSA/SA SSTI, *Kingella kingae* PCR (if patient < 5 yo), cell count with differential, and fluid to hold. If unusual case or exposures, consult Infectious Diseases for further testing/culturing recommendations.[2, 5-7, 9, 17-19]

CONSULTATIONS TO CONSIDER

Seek primary attending's approval prior to consulting specialist; primary team to coordinate consult communication.

Orthopedics

Orthopedics prefers to be consulted on all confirmed and probable musculoskeletal infections as soon as suspected, and prior to advanced imaging, as orthopedics can facilitate and will order timely MRI.

Infectious Disease

Infectious Diseases prefers to be consulted on all confirmed and probable musculoskeletal infections as soon as suspected, particularly if ID to follow as an outpatient or upon unit transfer.

Rheumatology

- Polyarthritis
- Suspicion or history of juvenile idiopathic arthritis (JIA), systemic lupus erythematosus (SLE), rheumatic fever, post-strep arthritis or psoriasis
- Chronic joint effusion

INITIAL THERAPIES | EMERGENCY DEPARTMENT AND INPATIENT UNIT

1. Pain control administered per Emergency Department/primary team.
2. Source culture should be obtained prior to starting antibiotics (unless blood culture positive, multifocal infection, patient ill-appearing, lab findings of end organ dysfunction, or clinical concern for sepsis). Goal is source culture by end of day after admission in orthopedic surgery room if needed.[1, 2, 5, 6, 8-10]

3. **Patients without signs of sepsis**: Cover narrowly with IV agent while following cultures and clinical response. If concerned for atypical bacterial source based on history or exposures, discuss empiric antibiotic choice with ID.
   - **Recommend cefazolin empirically** (100% coverage of both MSSA and *K. kingae).*[2, 18, 20-23]
   - Consider cefazolin + clindamycin if high suspicion for MRSA (prior history of MRSA infection, family history, etc.). Per internal data for MSK infections from 2014-2018, 81% of identified pathogens are *S. aureus*, the majority of which are MSSA (86%). Clindamycin resistance was seen in 16% of MSSA isolates and 7% of MRSA isolates from patients with MSK infections.
   - If patient has septic arthritis of hip or shoulder AND drainage will be delayed >12 hours, consider cefazolin + vancomycin for empiric MRSA coverage while cultures/PCR testing pending.
4. **Patients with clinical concern for sepsis:** Do not delay antimicrobials, cover broadly immediately with IV agent after obtaining blood cultures.
   - **Recommend ceftaroline empirically** (broad coverage for MSSA, MRSA, and Gram negative coverage)[24-26]
   - Consider adding clindamycin if limited source control or concern for toxin-mediated illness such as toxic shock syndrome[27-31]
5. Narrow antibiotics based on microbiology testing as follows:
   - Once bacterial species is identified by rapid diagnostics or culture, but final susceptibilities pending
     - MSSA or *K. kingae*: Cefazolin (covers 100% of MSSA and *K. kingae*)[23]
     - MRSA: Ceftaroline until clindamycin susceptibility/resistance known.
       - Alternative MRSA IV antibiotics include vancomycin and daptomycin (do not use daptomycin if concern for lung infection).
     - *Streptococcus pyogenes*: Cefazolin or ampicillin (both cover 100% *S. pyogenes*)[23]
   - Once final susceptibilities available:
     - MSSA: Cefazolin or clindamycin if susceptible
     - MRSA-Clindamycin Susceptible: Can transition to clindamycin pending clinical improvement after discussion with ID.
     - MRSA-Clindamycin Resistant: Options include ceftaroline, vancomycin, daptomycin, linezolid, and trimethoprim-sulfamethoxazole among others. Decision for MRSA antimicrobial should be made in consultation with ID.
6. Additional information on antibiotics, dosing, and monitoring is available in Table 1.

Microbiology Testing Process

Identifying a bacterial etiology allows for targeted antimicrobial therapy that is both more effective and less likely to cause avoidable adverse events. [2, 9, 10]

Specimen types

Recommend obtaining two blood cultures on admission (per CHCO protocol). Unless likely bacterial source already identified via blood culture, recommend obtaining source samples from infected area(s), such as aspirates or tissue biopsies of bone, synovial fluid, and abscesses/fluid collections. Among MSK infections at CHCO from 2014-2018, 75% of MSK patients had a pathogen identified (24% blood culture, 28% source culture, 23% both). Identifying the causative bacterial pathogen decreases broad spectrum antibiotic exposure leading to fewer adverse events, decreased days of therapy, decreased PICC line placement, and improved outcomes with simplified management decisions.[8, 32]

Microbiologic Testing Process

Blood Cultures: Once bacterial growth in incubated blood cultures bottles is sufficient, Biofire® FilmArray® Blood Culture Identification (BCID) is performed. BCID is a multiplex PCR and includes targets for pathogens commonly found in MSK infections (MSSA, MRSA, Group A *Streptococcus pyogenes*, *Streptococcus pneumoniae*, etc). Turn-around time for BCID results is ~90 minutes from time of bacterial growth in specimen sample. For patients with *Staphylococcus aureus* identified via blood culture at CHCO, median time to blood culture growth is 19 hours. Final bacterial culture results and antimicrobial susceptibilities are typically completed 2-3 days after collection.[33, 34]

Source Cultures: Recommend bacterial cultures for all source specimens. Aspirates of source samples can also be inoculated into standard blood culture bottles for "broth-enriched" cultures. If sufficient bacterial growth is reached on broth-enriched source cultures, BCID testing can be performed to identify the same targets as blood culture specimens. Yield from fungal and mycobacterial cultures from MSK source specimens is very low. No fungal/mycobacterial culture at CHCO between 2014-2018 identified a causative pathogen from any patient with acute MSK infections. Fungal and mycobacterial cultures from MSK sources should not routinely be sent unless high suspicion based on clinical and exposure history. Rapid diagnostic testing is also available directly on source specimens as described below and may be performed immediately after source specimen collection, they do not need to be incubated prior to testing. Rapid diagnostic testing for source samples includes:

- **MRSA/SA SSTI PCR (Cepheid®):** Rapid direct-from-source testing to identify MSSA or MRSA from bone, joint, or deep abscess samples. Turn-around time of ~90 minutes from time of sample receipt in lab. [14, 15]
- ***Kingella kingae* PCR:** Recommended for patients < 5 yo. Rapid direct-from-source testing to identify *Kingella kingae* from bone, joint, or deep abscess samples. Turn-around time <24 hours from time of sample collection. [14, 17, 18]

Note: For both BCID and MRSA/SA SSTI PCR, if *Staphylococcus aureus* is identified but MRSA is not identified, recommend targeting antimicrobial therapy for presumptive MSSA infection as described in Table 1 while bacterial culture results pending.

CHANGE TO ORAL ANTIBIOTICS | DISCHARGE CRITERIA

- Treat intravenously and inpatient until: [2, 7, 35-43]
  - Clinically substantially improved (weight bearing if allowed, improved motion of infected joint, well-appearing)
  - Afebrile x 24 hours
  - Known susceptibilities identify an effective oral antimicrobial
  - Falling CRP
- If blood cultures positive, repeat daily after initiation of antibiotics until negative x 48 hours; if persistent bacteremia, consider evaluation for intravascular infection (e.g. septic thrombophlebitis adjacent to MSK infection or infective endocarditis) and/or other infectious foci and treat with longer course of intravenous antibiotics.[44]
- If patient develops respiratory symptoms (chest pain, cough, shortness of breath, hypoxia), recommend evaluation for septic pulmonary emboli due to intravascular infection (e.g. septic thrombophlebitis adjacent to MSK infection or infective endocarditis).
- Also consider longer course of intravenous treatment if: adequate drainage not achieved, unusual organism(s), hip joint involvement, multifocal disease, unusually severe disease, concern for poor oral absorption or adherence.

If condition does not improve, consider:

- Bedside discussion with Primary Team, Orthopedic Surgery, and Infectious Diseases to re-evaluate plan
- Repeat laboratory assessment
- Repeat cultures
- Expand/change antibiotics
- Repeat imaging [45]
- Repeat drainage
- Alternate diagnoses

DISCHARGE PLANNING AND FOLLOW-UP

1. Assure family understands importance of compliance, can purchase medications, and understands possible side effects of antibiotics (Table 1). Arrange home IV therapy if indicated, though rarely is home IV therapy required for MSK infections.
2. Treat until:
    - Patient has reached expected clinical improvement for condition
    - ESR/CRP normal
    - Minimum total time on antibiotics: [37, 39-41, 46]
        - Septic joint: 3 weeks; if less than 18 months, consider all septic joints contiguous osteomyelitis
        - Osteomyelitis: 4 weeks
        - Length of therapy depends on severity, and some infections will require longer therapy
3. Infectious diseases or primary care follow up; coordinate ID follow up visits with Ortho if possible (Algorithm 3)
    - Follow each 1-2 weeks as needed for:
        - Continued clinical improvement
        - Antibiotic tolerance/compliance
        - Improving ESR/CRP
        - Laboratory indications of antibiotic side effects (obtain baseline and follow up labs per Table 1)
4. Orthopedic follow up (Algorithm 3)
    - Surgical patients and those with joint involvement should follow up at two weeks post operatively, all other patients should follow up at 4-6 weeks with option for imaging
    - Obtain baseline plain radiograph at three months
    - Remaining follow up after three months will be determined at discretion of orthopedics
    - Note children with MRSA osteomyelitis are at high risk for pathologic fracture, children with hip infection are at risk for avascular necrosis [47]

PARENT | CAREGIVER EDUCATION

It is suggested that parent/caregiver education contain the following information:

- Education on obtaining and taking antibiotics
- Pain control measures
- Return precautions and contact information for orthopedics and infectious diseases
- Education regarding antibiotic side effects
- PICC line training and education (including risk of infection) if applicable

TABLE 1. Antibiotics and Monitoring for Patients with Musculoskeletal Infections
(Other antibiotics may be indicated based on culture results)

Intravenous Antimicrobials

	Cefazolin	Clindamycin [a]	Ampicillin	Ceftriaxone	Ceftaroline [b]	Vancomycin [c]
Daily Amount	100-150 mg/kg/day divided Q8H	30-40 mg/kg/day divided Q8H	200 mg/kg/day divided Q6H	100 mg/kg/day Q24H	45 mg/kg/day divided Q8H	60-80 mg/kg/day divided Q6H
CHCO Total Daily Maximum Dosing for MSK Infection	6000 mg divided Q8H [d]	2700 mg divided Q8H	8000mg divided Q6H [e]	2000 mg Q24H	1800 mg divided Q8H	6000 mg divided Q8H [c]
Organism						
MSSA	+	+/- [a]		f	+	+
MRSA		+/- [a]			+	+
S. pyogenes (Group A strep)	+	+	+	+	+	+
S. pneumoniae	+	+/-	+	+	+	+
Kingella kingae [g]	+		+/-	+	+	
Labs						
Monitor for infection resolution and side effects	CBC w/ diff, CRP or ESR, BUN, Cr [h]					CBC w/ diff, CRP or ESR, BUN, Cr, vancomycin levels [h]

Oral Antimicrobials
(Once patient has met criteria for transition to oral antimicrobial therapy, see Algorithm 2)

	Cephalexin	Clindamycin [a]	Amoxicillin
Daily amount	100-150 mg/kg/day divided QID	30-40 mg/kg/day divided TID	90 mg/kg/day divided TID
CHCO Total Daily Maximum Dosing for MSK Infection	4000 mg divided QID	1800 mg divided TID	3000 mg divided TID
Organism			
MSSA	+	+/- [a]	
MRSA		+/- [a]	
S. pyogenes (Group A strep)	+	+	+
S. pneumoniae	+	+/-	+
Kingella kingae [g]	+		+/-
Labs			
Monitor for infection resolution and side effects	CBC w/ diff, CRP or ESR, BUN, Cr [h]		

[a] Oral bioavailability for clindamycin is >90%. The use of clindamycin for MRSA depends on local susceptibility patterns and susceptibility testing (if available). It is important that the microbiology lab perform a "D-test" or equivalent for inducible clindamycin resistance. At Children's Hospital Colorado, D-test is routinely performed, and among MSK patients 16% of MSSA and 7% or MRSA isolates are resistant to clindamycin. If patient is <5 years, clindamycin does not routinely cover *K. kingae*.
[b] Consultation with ID strongly encouraged prior to initiating ceftaroline for any non-critically ill patient.
[c] Vancomycin can be given by continuous infusion; discuss with pharmacy. Adjust dose with levels.
[d] For severe cases, may use cefazolin 8000mg divided Q6H.
[e] For severe cases, may use ampicillin 12000mg divided Q4H.
[f] While ceftriaxone has activity against MSSA, anti-staphylococcal penicillins (such as nafcillin) or first generation cephalosporins (such as cefazolin) are preferred therapy.
[g] *Kingella kingae* can cause bone and joint infection in patients from 6 months to 5 years of age but is difficult to culture. PCR-based testing can increase yield for *K. kingae* identification. *K. kingae* predominantly causes septic arthritis but can also cause isolated osteomyelitis and tenosynovitis; it generally has a milder presentation than *S. aureus*. Unless microbial cause is known, *K. kingae* should be empirically covered in children <5 years.
[h] All patients on antibiotics for MSK infection should be followed with a weekly CBC with differential, CRP or ESR, and BUN/Cr. There are additional labs specific to the antibiotic, for example: urinalysis to screen for interstitial nephritis. Clinically, patients should be followed for signs of allergy such as rash, diarrhea (any antibiotic can cause *Clostridioides difficile* colitis), fevers (severe allergy, line infection, recurrent infection), compliance, and other complaints. All antibiotics can cause anaphylaxis. Side effects listed are most common and do not represent all side effects.
Please consult ID for additional antimicrobial options such as daptomycin, doxycycline, trimethoprim-sulfamethoxazole, or linezolid

REFERENCES

1. Donaldson N, Sanders J, Child J, Parker S. Acute Hematogenous Bacterial Osteoarticular Infections in Children. Pediatr Rev. 2020;41(3):120-36.
2. Thomsen I, Creech CB. Advances in the diagnosis and management of pediatric osteomyelitis. Curr Infect Dis Rep. 2011;13(5):451-60.
3. Paakkonen M, Kallio MJ, Kallio PE, Peltola H. Sensitivity of erythrocyte sedimentation rate and C-reactive protein in childhood bone and joint infections. Clin Orthop Relat Res. 2010;468(3):861-6.
4. Arnold JC, Cannavino CR, Ross MK, Westley B, Miller TC, Riffenburgh RH, et al. Acute bacterial osteoarticular infections: eight-year analysis of C-reactive protein for oral step-down therapy. Pediatrics. 2012;130(4):e821-8.
5. Peltola H, Paakkonen M. Acute osteomyelitis in children. The New England journal of medicine. 2014;370(4):352-60.
6. Arnold JC, Bradley JS. Osteoarticular Infections in Children. Infectious disease clinics of North America. 2015;29(3):557-74.
7. Copley LA. Pediatric musculoskeletal infection: trends and antibiotic recommendations. The Journal of the American Academy of Orthopaedic Surgeons. 2009;17(10):618-26.
8. Spruiell MD, Searns JB, Heare TC, Roberts JL, Wylie E, Pyle L, et al. Clinical Care Guideline for Improving Pediatric Acute Musculoskeletal Infection Outcomes. Journal of the Pediatric Infectious Diseases Society. 2017.
9. Wheeler AM, Heizer HR, Todd JK. Influence of Culture Results on Management and Outcome of Pediatric Osteomyelitis and/or Septic Arthritis. Journal of the Pediatric Infectious Diseases Society. 2012;1(2):152-6.
10. McNeil JC, Forbes AR, Vallejo JG, Flores AR, Hulten KG, Mason EO, et al. Role of Operative or Interventional Radiology-Guided Cultures for Osteomyelitis. Pediatrics. 2016;137(5).
11. Slatnick LR, Thornhill D, Deakyne Davies SJ, Ford JB, Scott HF, Manco-Johnson MJ, et al. Disseminated Intravascular Coagulation Is an Independent Predictor of Adverse Outcomes in Children in the Emergency Department with Suspected Sepsis. J Pediatr. 2020;225:198-206 e2.
12. Fitzgerald JC, Basu RK, Akcan-Arikan A, Izquierdo LM, Pineres Olave BE, Hassinger AB, et al. Acute Kidney Injury in Pediatric Severe Sepsis: An Independent Risk Factor for Death and New Disability. Crit Care Med. 2016;44(12):2241-50.
13. Scott HF, Donoghue AJ, Gaieski DF, Marchese RF, Mistry RD. The utility of early lactate testing in undifferentiated pediatric systemic inflammatory response syndrome. Acad Emerg Med. 2012;19(11):1276-80.
14. Searns JB, Robinson CC, Wei Q, Yuan J, Hamilton S, Pretty K, et al. Validation of a novel molecular diagnostic panel for pediatric musculoskeletal infections: Integration of the Cepheid Xpert MRSA/SA SSTI and laboratory-developed real-time PCR assays for clindamycin resistance genes and Kingella kingae detection. J Microbiol Methods. 2019;156:60-7.
15. Searns JB, Gralla J, Parker SK, Dominguez SR. Potential Clinical Effects of a Novel Rapid Diagnostic Panel for Pediatric Musculoskeletal Infections. Journal of the Pediatric Infectious Diseases Society. 2019.
16. Jaramillo D, Dormans JP, Delgado J, Laor T, St Geme JW, 3rd. Hematogenous Osteomyelitis in Infants and Children: Imaging of a Changing Disease. Radiology. 2017;283(3):629-43.
17. Verdier I, Gayet-Ageron A, Ploton C, Taylor P, Benito Y, Freydiere AM, et al. Contribution of a broad range polymerase chain reaction to the diagnosis of osteoarticular infections caused by Kingella kingae: description of twenty-four recent pediatric diagnoses. The Pediatric infectious disease journal. 2005;24(8):692-6.
18. Yagupsky P, Dagan R. Kingella kingae: an emerging cause of invasive infections in young children. Clinical infectious diseases : an official publication of the Infectious Diseases Society of America. 1997;24(5):860-6.
19. Arnold SR, Elias D, Buckingham SC, Thomas ED, Novais E, Arkader A, et al. Changing patterns of acute hematogenous osteomyelitis and septic arthritis: emergence of community-associated methicillin-resistant Staphylococcus aureus. Journal of pediatric orthopedics. 2006;26(6):703-8.
20. Basmaci R, Ilharreborde B, Lorrot M, Bidet P, Bingen E, Bonacorsi S. Predictive score to discriminate Kingella kingae from Staphylococcus aureus arthritis in France. The Pediatric infectious disease journal. 2011;30(12):1120-1; author reply 1-2.
21. Basmaci R, Lorrot M, Bidet P, Doit C, Vitoux C, Pennecot G, et al. Comparison of clinical and biologic features of Kingella kingae and Staphylococcus aureus arthritis at initial evaluation. The Pediatric infectious disease journal. 2011;30(10):902-4.

22. Chometon S, Benito Y, Chaker M, Boisset S, Ploton C, Berard J, et al. Specific real-time polymerase chain reaction places Kingella kingae as the most common cause of osteoarticular infections in young children. The Pediatric infectious disease journal. 2007;26(5):377-81.
23. DeRonde KJ, Girotto JE, Nicolau DP. Management of Pediatric Acute Hematogenous Osteomyelitis, Part I: Antimicrobial Stewardship Approach and Review of Therapies for Methicillin-Susceptible Staphylococcus aureus, Streptococcus pyogenes, and Kingella kingae. Pharmacotherapy. 2018;38(9):947-66.
24. DeRonde KJ, Girotto JE, Nicolau DP. Management of Pediatric Acute Hematogenous Osteomyelitis, Part II: A Focus on Methicillin-Resistant Staphylococcus aureus, Current and Emerging Therapies. Pharmacotherapy. 2018;38(10):1021-37.
25. Sharma R, Hammerschlag MR. Treatment of Methicillin-Resistant Staphylococcus aureus (MRSA) Infections in Children: a Reappraisal of Vancomycin. Curr Infect Dis Rep. 2019;21(10):37.
26. Lounsbury N, Reeber MG, Mina G, Chbib C. A Mini-Review on Ceftaroline in Bacteremia Patients with Methicillin-Resistant Staphylococcus aureus (MRSA) Infections. Antibiotics (Basel). 2019;8(1).
27. Riordan T. Human infection with Fusobacterium necrophorum (Necrobacillosis), with a focus on Lemierre's syndrome. Clinical microbiology reviews. 2007;20(4):622-59.
28. Gonzalez BE, Mon RA. Staphylococcus aureus infections in adolescents. Adolescent medicine: state of the art reviews. 2010;21(2):318-31, x.
29. Ferguson MA, Todd JK. Toxic shock syndrome associated with Staphylococcus aureus sinusitis in children. The Journal of infectious diseases. 1990;161(5):953-5.
30. Todd J, Fishaut M, Kapral F, Welch T. Toxic-shock syndrome associated with phage-group-I Staphylococci. Lancet. 1978;2(8100):1116-8.
31. Todd JK. Toxic shock syndrome - evolution of an emerging disease. Advances in experimental medicine and biology. 2011;697:175-81.
32. Rao N, Ziran BH, Lipsky BA. Treating osteomyelitis: antibiotics and surgery. Plast Reconstr Surg. 2011;127 Suppl 1:177S-87S.
33. Messacar K, Hurst AL, Child J, Campbell K, Palmer C, Hamilton S, et al. Clinical Impact and Provider Acceptability of Real-Time Antimicrobial Stewardship Decision Support for Rapid Diagnostics in Children With Positive Blood Culture Results. Journal of the Pediatric Infectious Diseases Society. 2016.
34. Altun O, Almuhayawi M, Ullberg M, Ozenci V. Clinical evaluation of the FilmArray blood culture identification panel in identification of bacteria and yeasts from positive blood culture bottles. Journal of clinical microbiology. 2013;51(12):4130-6.
35. Bachur R, Pagon Z. Success of short-course parenteral antibiotic therapy for acute osteomyelitis of childhood. Clinical pediatrics. 2007;46(1):30-5.
36. Ballock RT, Newton PO, Evans SJ, Estabrook M, Farnsworth CL, Bradley JS. A comparison of early versus late conversion from intravenous to oral therapy in the treatment of septic arthritis. Journal of pediatric orthopedics. 2009;29(6):636-42.
37. Jagodzinski NA, Kanwar R, Graham K, Bache CE. Prospective evaluation of a shortened regimen of treatment for acute osteomyelitis and septic arthritis in children. Journal of pediatric orthopedics. 2009;29(5):518-25.
38. Kocher MS, Mandiga R, Murphy JM, Goldmann D, Harper M, Sundel R, et al. A clinical practice guideline for treatment of septic arthritis in children: efficacy in improving process of care and effect on outcome of septic arthritis of the hip. The Journal of bone and joint surgery American volume. 2003;85-A(6):994-9.
39. Peltola H, Paakkonen M, Kallio P, Kallio MJ, Osteomyelitis-Septic Arthritis Study G. Short- versus long-term antimicrobial treatment for acute hematogenous osteomyelitis of childhood: prospective, randomized trial on 131 culture-positive cases. The Pediatric infectious disease journal. 2010;29(12):1123-8.
40. Syrogiannopoulos GA, Nelson JD. Duration of antimicrobial therapy for acute suppurative osteoarticular infections. Lancet. 1988;1(8575-6):37-40.
41. Weichert S, Sharland M, Clarke NM, Faust SN. Acute haematogenous osteomyelitis in children: is there any evidence for how long we should treat? Current opinion in infectious diseases. 2008;21(3):258-62.
42. Zaoutis T, Localio AR, Leckerman K, Saddlemire S, Bertoch D, Keren R. Prolonged intravenous therapy versus early transition to oral antimicrobial therapy for acute osteomyelitis in children. Pediatrics. 2009;123(2):636-42.
43. Peltola H, Unkila-Kallio L, Kallio MJ. Simplified treatment of acute staphylococcal osteomyelitis of childhood. The Finnish Study Group. Pediatrics. 1997;99(6):846-50.

44. Liu C, Bayer A, Cosgrove SE, Daum RS, Fridkin SK, Gorwitz RJ, et al. Clinical practice guidelines by the infectious diseases society of america for the treatment of methicillin-resistant Staphylococcus aureus infections in adults and children. Clinical infectious diseases : an official publication of the Infectious Diseases Society of America. 2011;52(3):e18-55.
45. Courtney PM, Flynn JM, Jaramillo D, Horn BD, Calabro K, Spiegel DA. Clinical indications for repeat MRI in children with acute hematogenous osteomyelitis. Journal of pediatric orthopedics. 2010;30(8):883-7.
46. Howard-Jones AR, Isaacs D. Systematic review of systemic antibiotic treatment for children with chronic and sub-acute pyogenic osteomyelitis. Journal of paediatrics and child health. 2010;46(12):736-41.
47. Belthur MV, Birchansky SB, Verdugo AA, Mason EO, Jr., Hulten KG, Kaplan SL, et al. Pathologic fractures in children with acute Staphylococcus aureus osteomyelitis. J Bone Joint Surg Am. 2012;94(1):34-42.

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APPROVED BY

Clinical Pathways and Measures Review Committee – November 17, 2020
Pharmacy & Therapeutics Committee – December 7, 2020

MANUAL/DEPARTMENT	Clinical Pathways/Quality
ORIGINATION DATE	April 18, 2016
LAST DATE OF REVIEW OR REVISION	December 7, 2020
COLORADO SPRINGS REVIEW BY	 Michael DiStefano, MD Chief Medical Officer, Colorado Springs
APPROVED BY	 Lalit Bajaj, MD, MPH Medical Director, Clinical Effectiveness

REVIEW | REVISION SCHEDULE

Scheduled for full review on December 7, 2024

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