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Operative Techniques in
Orthopaedics

Treating Orthopaedic Infections in Pediatric Patients

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Pediatric musculoskeletal infections represent a wide spectrum of diseases and pose a treatment challenge for the orthopaedic surgeon. Prompt and accurate diagnosis and treatment are of utmost importance to prevent long-term sequelae and often require a multidisciplinary approach. *Staphylococcus aureus* is still reported as the most common causative organism of infection, with an increase in the number of methicillin-resistant *S. aureus* infections in more recent years. Treatment consists of a combination of surgical debridement and antibiotics. Close follow-up is required, as up to 6% of all infected children still suffer from permanent sequela.
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Introduction

The treatment of orthopaedic infections in children remains a challenge as bacteriology continues to evolve. In the past, the mortality rate of pediatric osteomyelitis ranged between 20% and 50%, which has significantly decreased with the introduction of improved antibiotics. Morbidity still poses significant challenges to the pediatric orthopaedic surgeon as 6% of all children with musculoskeletal infections still suffer from permanent sequelae of delayed diagnosis and inadequate treatment.[1,2] The annual incidence of septic arthritis and acute hematogenous osteomyelitis is 1 per 10,000 children younger than 12 years of age.[3] This incidence varies widely in different geographic regions of the world, where the incidence is low in developed regions and the incidence is high in developing countries (5-20 of 100,000). Of 1000 infant intensive care unit (ICU) admissions, 1-3 infants are diagnosed with neonatal osteomyelitis. In older children, 50% of all cases of acute osteomyelitis are found in children younger than 5 years of age.[2] Osteomyelitis can be found in 17%-33% pediatric musculoskeletal infections and typically occurs in the epiphyseal or metaphyseal and epiphyseal-equivalent regions in infants and the metaphyseal and metaphyseal-equivalent regions after infancy.[4-6] Septic arthritis mostly manifests in the hip and knee; however, infection of the ankle, elbow, shoulder, sacroiliac, and metatarsophalangeal joints have been described, as well.[7] Approximately, 10%-16% of all septic arthritis cases are secondary to osteomyelitis.[2]

This article describes the diagnosis and treatment of the most 2 common pediatric infections—osteomyelitis and septic arthritis. Specifically, bacteriology, diagnosis, antibiotic, and operative treatment would be discussed.

Bacteriology

Staphylococcus aureus is the overall leading bacterial cause of infection. Based on the patient's age, certain bacterial organisms are more common and therefore specific antibiotic treatment can be initially guided by these common organisms (Table). Typically, patients are infected with methicillin-sensitive *S. aureus* (MSSA), but the number of infections with methicillin-resistant *S. aureus* (MRSA) has constantly increased over the past few years leaving orthopaedic surgeons with bigger challenges in treatment.[7-12] *Hemophilus influenza* has been found to affect joints rather than bones and *Salmonella* is a main pathogen in patients with sickle cell disease. *Kingella*

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Table Overview of the Most Common Pathogens by Age Group and Specific Antibiotic Treatment

Age	Common Organisms	Antibiotic	Dose, mg/kg	Route	Frequency
Neonatal <1 mo	Streptococcus sp., Gram-negative organisms	Ampicillin-sulbactam	150	IV	Q6 h
		Gentamycin	2	IV	Q8 h
Neonatal 1-3 mo		Vancomycin	15	IV	Q6 h
		Ceftriaxone	100	IV	Q24 h
Infants	*Staphylococcus aureus*	Clindamycin	10	IV	Q6 h
	Haemophilus influenza	Clindamycin	8	Oral	Q8 h
Children	*Staphylococcus aureus* Salmonella	Vancomycin	15	IV	Q6 h
Adolescents	*Staphylococcus aureus* *Nesseria gonorrhea*	Rifampin	10	IV or oral	Q24 h

IV, intravenous.

kingae has also become more prevalent in children younger than 4 years of age, but is associated with a milder disease course with a mild-to-moderate radiographic and biological inflammatory response.[13-15]

MRSA infections have emerged as commonplace in our hospital systems, and pediatric hospitals have seen a steady increase in the number of MRSA infections each year.[9,10] This is of utmost concern to the pediatric orthopaedic surgeon, as MRSA infections cause more local soft tissue destruction, spread more rapidly, and have a higher mortality rate compared with MSSA infections.[9,16] In addition, patients with MRSA infections have higher rates of complications such as deep vein thrombosis, septic emboli, require increased length of inpatient hospitalization, and have higher rates of abscesses and subperiosteal infections requiring surgical intervention.[9,16-18] Clinically, children affected by MRSA may present with a higher fever than those affected by MSSA, and can cause greater increase in acute-phase reactants (C-reactive protein [CRP], erythrocyte sedimentation rate [ESR], and white blood cell [WBC]) compared to other bacteria.[19] MRSA achieves its resistance to methicillin through the mecA gene that encodes penicillin-binding protein 2a that has a low affinity for β-lactam antibiotics. Consequently, antibiotics are unable to bind to the cell wall.[20] In addition, community-acquired MRSA can produce Panton-Valentine Leukocidin in 66%-100% of MRSA strains and can cause rapid local soft tissue destruction.[21] Panton-Valentine Leukocidin gene causes rapid tissue necrosis and likely accounts for most of the infections that progress to abscess formation in patients with MRSA infections.[22] Close inpatient observation of patients with suspected musculoskeletal MRSA infections is necessary secondary to the potential rapid progression of declining clinical status.

The vast majority of musculoskeletal infections are of hematogenous origin, and it is the main cause of bacterial seeding in septic arthritis. Once the bacteria spread, they can lodge in the vascularized synovium. In patients younger than 18 months, infections in the joint and metaphysis often arise from transphyseal blood vessels that allow free communication through the physeal plate.[7,8] Septic arthritis is mainly found in the hip and knee and is usually caused by *Staphylococcus*. It is considered a surgical emergency, especially in children, as untreated infections can lead to cartilage destruction and subsequent irreversible degenerative changes with risk of functional debilitation, avascular necrosis, sepsis, and death.[23-27] Timely and correct diagnosis is of utmost importance and antibiotic treatment should be appropriately administered based on the presenting organism.

Diagnosis

Accurate diagnosis of musculoskeletal infections poses a challenge, especially in young children. This is because of the fact that it is difficult for these patients to give an adequate history or describe symptoms. A total of 15%-30% of patients have a history of preceding trauma that can cause infection from direct contamination by penetrating trauma.[21,28-30] The role of closed injuries in the development of hematogenous osteomyelitis is still unclear, however, experimental studies suggest that impaired tissue has a lower threshold for resisting bacterial seeding.[31-33] The diagnosis of infection is based on clinical presentation, laboratory values, and imaging.

Clinical Presentation

Children who walk with a limp or present with the inability to bear weight demonstrate some of the classic physical examination findings of pediatric cases of musculoskeletal infection. In addition, children may present with fever and malaise, and occasionally tenderness, erythema, and swelling. Pertinent history may include recent trauma or infection. However, one has to take into consideration that osteomyelitits can present without a systemic inflammatory response and only mild clinical symptoms may be present, as seen with a Brodie abscess in chronic osteomyelitis.

In children with septic arthritis, movement of the affected joint may cause severe pain. In patients with septic arthritis of the hip, they often present with the hip in a position of flexion, abduction, and external rotation to maximize the hip capsular volume, which places them in the position of maximal comfort. Kocher et al established an evidence-based algorithm that is based on 4 independent clinical factors, including fever (temperature $>38.5^{\circ}C$), inability to bear weight on the affected extremity, ESR of 40 mL/h or more, and a serum WBC greater than 12,000 cells/mL. If all 4 predictors are present, the likelihood of septic arthritis is close to 100%.[34] Normally, CRP is also part of the infectious workup and a