Musculoskeletal Infections in Children

Basic Treatment Principles and Recent Advancements

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“Most bacterial infections of childhood are easily diagnosed, readily treated, and have good outcomes. By contrast suppurative infections of the skeletal system still present challenges, since these illnesses are often difficult to recognize and localize early in the course of illness and many are difficult to manage medically and surgically. In spite of our best efforts, a substantial portion of those treated are left with disabling sequelae.”

Sepsis accounts for 200,000 deaths each year in the United States. One in 5000 children under the age of thirteen years will have osteomyelitis, and about twice as many will have septic arthritis (Fig. 1). The outcome is poor in 27% of patients with septic arthritis and in nearly 40% of those with involvement of the hip.

Unique to the infectious process is the fact that the disease actually changes over time. The incidence of infections, especially gram-positive infections, is rising. Fortunately, physicians are getting better at diagnosis and treatment.

Prior to antibiotic treatment, the mortality rate associated with infection was close to 50%; now it is <1%. The Haemophilus influenzae Type-B vaccination has essentially eliminated septic arthritis due to this organism in immunized patients. New techniques for diagnosis, such as the use of polymerase chain reaction for the detection of bacterial pathogens or ultrasonography, may help us to make the diagnosis more quickly.

The purpose of this article is to update orthopaedic surgeons about the treatment principles and recent advancements in the management of musculoskeletal infections in children. It is divided into three sections: infections of bone, joints, and soft tissue. Each section reviews the etiology, diagnosis, and treatment.

Acute Hematogenous Osteomyelitis

Acute hematogenous osteomyelitis in children is an inflammation of bone caused by bacteria that reach the bone through a hematogenous route. No consistent peak incidence in a specific age group has been reported in the literature, although the infection usually occurs in the first decade of life. During the years after the introduction of penicillin (1944 through 1950), the incidence of osteomyelitis decreased. Then, after 1950, the incidence increased with the development of antibiotic-resistant organisms. During the past fifteen years, there has been little change in the number of cases per year.

Etiology

Typically, acute hematogenous osteomyelitis in children begins in the metaphyseal venous sinus, where there are...
vascular loops and terminal branches with low oxygen tension and inhibited phagocytosis that is conducive to bacterial growth. The initial bacteremia may occur from a daily event such as tooth brushing, which results in bacteremia 25% of the time5, or it may be related to another cause such as trauma or decreased host resistance. Trauma may play a role in up to 30% of the cases of acute hematogenous osteomyelitis. Studies of a rabbit model showed that trauma increased the chance of acute hematogenous osteomyelitis when there was concurrent bacteremia (Fig. 2)6,7.

Thrombosis of the venous sinus and nutrient artery can occur with bacterial proliferation and result in a loss of medullary blood supply, slowing mobilization of infection-fighting cells. By seventy-two hours, inflammatory processes are well developed, and an exudate forms that can exit the bone through the porous cortex of the metaphysis. In some locations, such as the proximal part of the femur, the metaphysis may be within the joint capsule and result in the coexistence of septic arthritis and osteomyelitis. If the elevated periosteum remains viable, it will produce new bone and, over time, an involucrum will form; the adjoining cortex can become nonviable and become a sequestrum. Acute hematogenous osteomyelitis in children is more common in the lower extremity and tends to affect the most rapidly growing ends of the long bones, such as the distal part of the femur and proximal part of the tibia.

**Diagnosis**

The diagnosis of acute hematogenous osteomyelitis in children is difficult and is still often made late. The most important factors in making the diagnosis are the clinical findings, and a high index of suspicion on the part of the clinician is essential. Unexplained bone pain with fever means osteomyelitis until proven otherwise.

The onset of acute hematogenous osteomyelitis is usually sudden, and 30% to 50% of patients with the disease have had a recent or have a concurrent nonmuscular infection. Often, these infants and children appear systemically ill, with localization of the cardinal signs of infection: swelling, redness, warmth, and pain. The patient may have findings of an adjacent sympathetic joint effusion, with joint irritability and a limited range of motion or even pseudoparalysis.

An elevated white blood-cell count and erythrocyte sedimentation rate are seen in the majority of these children, but these tests are not as reliable in the neonate. Blood cultures are positive in 30% to 50% of infants and children. Radiographs do not show osseous changes for seven to ten days. Deep soft-tissue swelling is the key finding early in the process.

Magnetic resonance imaging is the best imaging modality for the diagnosis of acute hematogenous osteomyelitis and is especially useful in the axial skeleton10; it is better able to differentiate abnormal bone marrow involvement than are bone scans, computer tomography scans, or radiographs11. However, magnetic resonance imaging lacks the specificity to demonstrate whether the abnormal changes are due to osteomyelitis12.

Another imaging study that may be helpful is the technetium-99m di-phosphonate bone scan, a three-phase scan that usually demonstrates increased uptake as a result of alteration in the physiology of involved bone13. An abnormal technetium bone scan is nonspecific and may yield false-positive results associated with trauma or tumors. There is a 4% to 20% rate of false-negative results (a lack of increased uptake despite the presence of acute hematogenous osteomyelitis), which may be seen with osteonecrosis or in very early cases. A bone scan is best used to identify multiple or difficult locations (the spine and pelvis).

Early studies showed that technetium scans were unreliable for infants and neonates, as they detected only 50% of foci12,13, but high-resolution techniques have improved the sensitivity14. Use of technetium scans in neonates is particularly helpful, especially for finding multiple sites of infection. Bone scans (or other diagnostic imaging) should not delay treatment, and aspiration does not produce false-positive results15. If needed, the accuracy of technetium scans can be increased by repeating the scan in forty-eight to seventy-two hours16.

With osteomyelitis, there is an almost immediate increase in uptake on gallium-67-citrate-labeled-leukocyte bone scans17. These scans are performed less frequently, primarily because they are more expensive, are associated with more radiation exposure, and take longer to complete (forty-eight to seventy-two hours). The accuracy of early diagnosis may be increased by following a negative
with the focus on identifying the organism or organisms and their sensitivities, use of the correct antimicrobial treatment and delivery in sufficient concentrations to kill the organism, and surgical debridement if the infection is refractory to medical treatment or if an abscess is identified.

*Staphylococcus aureus* is still the predominant organism, with the prevalence ranging from 60% to 90%,

followed by *Streptococcus* species (prevalence, 20% to 50%) (Table I). The rate of *Streptococcus* osteomyelitis has increased in infants; this represents an increase in the incidence of *Group-B Streptococcus* in neonatal sepsis.

Gram-negative organisms account for <5% of the cases, with *Haemophilus influenzae* formerly being the predominant gram-negative organism. *Salmonella* should always be considered in the differential diagnosis of children with sickle cell disease.

Traditionally, intravenous antibiotics have been administered for approximately three weeks prior to switching to oral treatment, but if there is a prompt response to the intravenous antibiotics, then oral medication can be initiated at five to seven days. Ten percent of infants and children do not respond to oral medication and need continued intravenous antibiotic treatment. Typically, the prerequisites for switching to oral medications have been identification of the organism, determination of antibiotic sensitivities and susceptibilities, and confirmation of bactericidal antibiotic levels.

Currently, the clinical response to treatment as well as laboratory values (usually the C-reactive protein level) is used to determine whether switching to oral medications is appropriate. The C-reactive protein level rises faster and returns to normal more quickly than does the erythrocyte sedimentation rate and is the laboratory indicator of choice when following infants and children being treated for osteomyelitis. Historically, the total duration of treatment has been as long as six weeks, but now a shorter duration of antibiotic therapy may be adequate. However, there is no established duration, which depends on clinical characteristics such as the site of the infection, amount of destruction, treatment, and response to treatment. For example, a child with femoral osteomyelitis who has considerable destruction of the femur may need eight to twelve weeks of treatment, whereas a child with early metacarpal osteomyelitis may need only fourteen to twenty-one days and a neonate may need only seven days.

Most children with an age of more than one year and a duration of symptoms of less than forty-eight hours respond to antibiotic treatment alone (without surgery). If a child does not respond to antibiotics within thirty-six hours, surgical débridement should be considered.

The primary role of surgery is to evacuate purulent material. If the pus accumulates under the periostea for any length of time, the periostea can be destroyed. The periostea may serve as the only source of osteogenic regeneration of the dead bone. If the bone does not regenerate, a permanent defect may result. Surgery is also very effective in removing sequestra to clear up chronic infections. An appropriate aphorism is: “Antibiotics save the life; surgery saves the bone.”

The surgical technique for patients with established osteomyelitis includes periosteal incision and removal of all exudate and necrotic bone. The role of drilling the cortex is somewhat
controversial. If suction irrigation tubes are used, they should be removed by forty-eight hours. Placement of long-term intravenous access with the patient under the same anesthetic should be considered.

Other, Unique Forms of Osteomyelitis

Several unique forms of osteomyelitis can occur in children. These include neonatal osteomyelitis, subacute hematogenous osteomyelitis, and chronic recurrent multifocal osteomyelitis. It is important to understand the characteristics of these disorders and how they differ from the more common acute hematogenous osteomyelitis.

Neonatal osteomyelitis differs from acute hematogenous osteomyelitis in four ways: (1) the musculoskeletal anatomy of the neonate is unique, and an infection ultimately affects growth of the physis and/or enters the joint in 76% of cases; (2) the organism that causes the infection may differ from that seen with acute hematogenous osteomyelitis; (3) multiple sites are commonly involved (40% of cases); and (4) infants have an immature immune system, and therefore diagnosis can be difficult.

Neonates and young infants with osteomyelitis have a unique anatomy that differs from that of older children with acute hematogenous osteomyelitis (Fig. 3). For example, before the epiphyseal ossification centers form in the proximal part of the femur, metaphyseal vessels penetrate directly into the cartilaginous precursor. Infection can destroy these fragile growth centers and enter the hip joint directly. Transphyseal vessels persist for up to twelve to eighteen months. In older children, the physis serves as a mechanical barrier to infection, but in infants, the osseous architecture is more fragile and is very easily injured. The morbidity rate is higher (up to 76%) for neonates.

*S. aureus* is the most common organism in neonates and infants with osteomyelitis, especially in cases associated with invasive procedures. Other organisms are not uncommon and include Group B *Streptococcus*, gram-negative organisms (in 10% to 15% of cases), and *Candida albicans*. Staphylococcal infections, which are associated with less purulent exudate, tend to be associated with less morbidity and fewer clinical symptoms. The diagnosis of these infections is often delayed.

Neonates with osteomyelitis have an immature immune system, are less able to produce an inflammatory response, and are susceptible to organisms that are less virulent in older children and adults. The temperature and white blood-cell count of neonates with osteomyelitis may be normal, and there may be few findings on physical examination or imaging (including false-negative bone scans). Often, these factors delay the diagnosis.

In general, the characteristics of neonatal osteomyelitis vary depending on whether the infection was acquired in the hospital or community. When neonatal osteomyelitis is acquired in the hospital, it is often caused by invasive monitoring devices such as umbilical catheters, fetal monitors, or heel puncture instruments. Neonates more often have multiple sites of infection, and bone scans are often helpful in identifying the multiple locations. Neonates who acquire osteomyelitis after discharge from the hospital are normally not ill and more often have normal development and feeding habits. In these infants, the organism is more commonly Group B *Streptococcus* and the osteomyelitis more commonly affects a single site.

Subacute hematogenous osteomyelitis differs from acute hematogenous osteomyelitis in that the child is typically less symptomatic, with less pain and often no fever. Many children (30% to 40%) have had a trial of antibiotics. The results of laboratory assessments (including blood and tissue cultures) are more commonly normal. Unlike radiographs of patients with acute hematogenous osteomyelitis, radiographs of patients with subacute hematogenous osteomyelitis usually show
changes (Fig. 4). Nearly all cases are due to *Staphylococcus aureus*, but recently some streptococcal infections have been identified. The most important aspect of treating children and adolescents with subacute hematogenous osteomyelitis is ruling out tumors. In addition to cultures of involved tissue, a biopsy is needed, and this is the classic situation for which the mantra “culture all biopsies, and biopsy all cultures” is applied. Treatment consists of administration of appropriate antibiotics and, when the osteomyelitis is chronic (with symptoms for more than one month), débridement and removal of any sequestrum may be required.

Subacute hematogenous osteomyelitis can also occur in the epiphyses of the long bones. Radiographs usually demonstrate a well-defined lesion, possibly with a sclerotic rim, and chondroblastoma should be considered in the differential diagnosis. Usually, the nidus of epiphyseal osteomyelitis heals with appropriate antibiotic treatment. Physal damage and involvement of the articular surface are uncommon.

Chronic recurrent multifocal osteomyelitis differs from acute hematogenous osteomyelitis in that there is an insidious onset of bone pain and tenderness. Most often, patients with chronic recurrent multifocal osteomyelitis present with only one site of involvement, although other sites develop with time. Chronic recurrent multifocal osteomyelitis may be confused with pyogenic osteomyelitis, but typically no organisms are isolated with the former. Furthermore, chronic recurrent multifocal osteomyelitis does not typically respond to antibiotic treatment. SAPHO syndrome (synovitis, acne, pustulosis, hyperostosis, osteitis) is not uncommon in children who present with manifestations that are similar to those of chronic recurrent multifocal osteomyelitis as well as with skin lesions, most commonly palmoplantar pustulosis. Radiographs of patients with chronic recurrent multifocal osteomyelitis often demonstrate eccentric metaphyseal sclerotic lucencies; bone scintigraphy may help to identify additional lesions. Treatment consists of nonsteroidal anti-inflammatory drugs and management of the symptoms. In one series of twelve patients with chronic recurrent multifocal osteomyelitis, five patients had a limb-length inequality of >1.5 cm, and other orthopaedic deformities may occur. The long-term outcome of treatment of chronic recurrent multifocal osteomyelitis is generally good, although recurrence is common. As many as 26% of patients have active disease at the time of long-term follow-up. Few patients have functional limitations, even without complete resolution of symptoms.

### Acute Hematogenous Osteomyelitis in Unusual or Difficult-to-Diagnose Locations

Acute hematogenous osteomyelitis usually occurs in the metaphyses of long bones, but it can also develop in unusual locations, such as the epiphysis, the pelvis, the calcaneus, the talus, and the metatarsals.

Historically, the diagnosis of pelvic and sacroiliac joint infection has been delayed, but newer imaging modalities have made the diagnosis easier. The physical examination findings are variable and may include a positive FABER test (pain with flexion, abduction, and external [lateral] rotation of the hip). Pain may also occur with lateral compression/distraction of the iliac wings and with straight-leg raising or hyperextension of the hip (Gaenslen sign). The child may have direct tenderness over the sacroiliac joint or may refuse to stand on the limb.

Evaluation should include routine laboratory studies, such as a white blood-cell count and measurement of the erythrocyte sedimentation rate. It is also important to rule out other causes for the symptoms, such as noninflammatory arthritis. About half of the patients have positive blood cultures. Stool and urine can also be obtained if the diagnosis is still in question.

Radiographs of the area in question and a bone scan may be helpful, but the findings can be negative early in the disease course, and magnetic resonance imaging is the most accurate modality for evaluation. Computer tomography-guided biopsy may be needed to rule out a psoas abscess.

The types of subacute osteomyelitis. Type I indicates lucency; type II, metaphyseal with loss of cortical bone; type III, diaphyseal; type IV, onion-skinning; type V, epiphyseal; and type VI, spine.
Aspiration can be performed when the diagnosis is uncertain and when the patient does not respond to more conservative therapy. A bone biopsy can be considered when aspiration does not yield fluid. *Staphylococcus aureus* is the most common organism with involvement of the sacroiliac joint. Treatment is initiated with antibiotics, which is sufficient in most cases. If an abscess is identified, surgical drainage should be considered.

Acute hematogenous osteomyelitis of the calcaneus can also be difficult to diagnose. While foot puncture wounds are common, true calcaneal osteomyelitis is uncommon. Radiographically, there is very little periosteal bone reaction. Most cases respond to antibiotics with or without curettage.

Subacute osteomyelitis of the talus and metatarsals has been reported. Usually, no systemic signs are reported, so there is often a delay of several months in the diagnosis. Radiographic changes are slow to develop, but radiographs show a lytic lesion. The organism is usually coagulase-negative *Staphylococcus*. Treatment consists of surgical curettage, antibiotics, and rest.

It is important to remember that a number of bone tumors can simulate subacute and chronic osteomyelitis. The most common is Ewing sarcoma, but eosinophilic granuloma and leukemia can also present in a fashion that is similar to that of osteomyelitis and they should be included in the differential diagnosis. Thirty percent of children with leukemia present with bone pain.

### Septic Arthritis

Septic arthritis in children can occur in any joint, but the most common and most devastating location is the hip. This section describes the etiology, diagnosis, and treatment of septic arthritis in children, with a focus on the hip.

#### Etiology

Septic arthritis can occur from primary seeding of the synovial membrane, secondarily from infection in the adjacent metaphyseal bone or directly from infection in the adjoining epiphysis. In the hip, shoulder, ankle, and elbow, the joint capsule overlaps a portion of the adjoining metaphysis, and if a focus of osteomyelitis breaks through the soft metaphyseal bone, it can directly seed the joint and lead to concurrent septic arthritis. Additionally, in the hip, vessels cross the epiphysis until the age of approximately eighteen months, and this provides a direct route for infection to spread from the metaphysis to the hip joint.

### Diagnosis

The diagnosis of septic arthritis is based on the clinical findings. Typically, the disease has an acute onset in which the child is irritable, febrile, and anorexic. When the infection is in the lower extremity, the child limps or refuses to bear weight. There is severe pain with attempted passive motion of the hip joint. When the hip is affected, the child typically holds that joint in a position of flexion, abduction, and external rotation that is characteristic of the intracapsular pressure increase. Swelling of the anterior aspect of the thigh is a late sign. Neonates may display only anorexia, irritability, and lethargy and may not move the affected limb (psuedoparalysis).

Laboratory tests include peripheral blood studies, which typically demonstrate a white blood-cell count of \(>12,000/\text{mm}^3\) \((>12.0 \times 10^3/\text{L})\), with 40% to 60% polymorphonuclear leukocytes, and an erythrocyte sedimentation rate of \(>50\) mm/hr. Blood cultures are positive in 30% to 50% of cases. The C-reactive protein level is a very good indicator of disease progression, although it is nonspecific. It is elevated in 90% of children with musculoskeletal infection at the time of admission, it peaks two days following admission, and it quickly returns to normal after treatment. Measurement of the C-reactive protein level may also be helpful in the identification of septic arthritis in children with underlying acute hematogenous osteomyelitis.

Joint aspiration is essential for the diagnosis and typically reveals a white blood-cell count of \(>50,000/\text{mm}^3\) \((>50.0 \times 10^3/\text{L})\), with 75% polymorphonuclear leukocytes, but 34% of patients have white blood-cell counts of \(<25,000/\text{mm}^3\) \((<25.0 \times 10^3/\text{L})\). Gram stains of the aspirate are positive in 30% to 50% of cases, and cultures of the aspirate are positive in 50% to 80%. Synovial protein levels that are 40 mg/dL (400 mg/L) and are less than the serum protein levels are consistent with septic arthritis. Lac-tate levels are typically elevated in the joint fluid in patients with septic arthritis (except in those with gonococcal infection), and the glucose level in the aspirate is lower than the level in the serum. On direct examination, the aspirate may demonstrate gross pus and the result of the mucin (string) test is poor when infection is present.

Transient synovitis is not uncommon in children, and the primary differential diagnosis is between it and septic arthritis in the hip. With both disorders, young children may present with substantial pain, which can cause crying and can limit motion of the hip dramatically. Also, with both disorders, the child may be carried in or may limp and tends to sit or lie with the lower limb held in flexion and in external rotation. The differential diagnosis between these two disorders is extremely important and can be difficult. Treatment varies dramatically, from open arthroscopy for septic arthritis to simple observation and nonsteroidal anti-inflammatory drugs for transient synovitis. To help examiners make this diagnosis more accurately, Kocher et al. developed four clinical criteria to aid in the assessment of a child with a painful hip; these criteria include non-weight-bearing, an erythrocyte sedimentation rate of \(>40\) mm/hr, fever,
and a white blood-cell count of >12,000 mm$^3$ (>12.0 × 10$^9$/L). In their study, when all four of the criteria were met, there was a 99% chance that the child had septic arthritis. There was a 93% chance of septic arthritis when three of the four criteria were met, a 70% chance when two criteria were met, and a 3% chance when only one was met. When this paradigm was applied to different populations, the probability of septic arthritis dropped to about 90% when all four predictors were present and 70% when three of the four were present. Despite this decreased sensitivity, the clinical factors identified by Kocher are excellent predictors to help guide the differential diagnosis and subsequent treatment.

Imaging may assist in the diagnosis. Plain radiography can reveal subtle signs early in the disease process (capsular distention and joint space widening) and metaphyseal lucency later in the course. Technetium bone scans may show decreased uptake (“cold”) early in the disease process and increased uptake (“hot”) later, as a result of a hyperemic response. Gallium and indium-labeled-"hot") later, as a result of a hyperemic uptake to the disease process and increased uptake (“cold”) early in the disease process (capsular distention and joint space widening) and metaphyseal lucency later in the course. Technetium bone scans may show decreased uptake (“cold”) early in the disease process and increased uptake (“hot”) later, as a result of a hyperemic response. Gallium and indium-labeled-leukocyte scans may be helpful in the diagnosis of atypical cases, but, as mentioned in the previous section, they are difficult to perform and take forty-eight to seventy-two hours to complete.

Ultrasonography is quick and painless and imparts no ionizing radiation. It can detect an effusion in 100% of cases, with a criterion being a capsule-to-bone distance that is >2 mm wider than the distance on the contralateral side. This finding is specific for septic arthritis, but the absence of an effusion makes septic arthritis unlikely. Ultrasonography is also a useful tool for guiding aspiration and confirming needle location.

**Treatment**

Septic arthritis is a true emergency, and treatment often involves the emergency department as well as the radiology and orthopaedic departments. It is therefore important to have an established algorithm for treatment. Any evaluation of a painful hip must rule out the possibility of septic arthritis, and, if septic arthritis is suspected, it must be treated emergently. When concomitant osteomyelitis is suspected, aspiration of the proximal part of the femur should be considered at the time of hip joint aspiration.

The cornerstone of treatment is surgical drainage and irrigation of the hip joint with appropriate constitutional support, including hydration and antibiotics. A capsular window should be removed to ensure continued drainage, and a drain should be left in place until the volume of the drainage decreases. Arthroscopic treatment of septic arthritis was reported to have an excellent result in ten patients at the time of a five-year follow-up. If surgery is not followed by a rapid reversal of clinical symptoms and normalization of vital signs, reexploration should be considered.

The antibiotic regimen should be started immediately after aspiration. It should initially be based on the suspected organism and later tailored to the culture results. Intravenous antibiotic therapy should be continued until constitutional signs improve. Switching to oral antibiotics may be considered if no concurrent osteomyelitis is present. Recently, there has been a trend toward decreasing the period of parenteral antibiotic treatment. When there is concurrent osteomyelitis, intravenous antibiotic therapy should be continued as described in the preceding section.

The causative organisms vary depending primarily on the age of the patient. Group-B Streptococcus is most common in healthy neonates (birth to less than twenty-eight days old), and *Staphylococcus aureus* is most common in high-risk neonates. Gram-negative bacilli must also be considered as possible organisms. Recommended antibiotic treatment includes oxacillin or cefotaxime, with the addition of gentamicin for a high-risk neonate (Table II).

**Staphylococcus aureus** is the most common organism in infants and children up to three years of age. Infection with *Haemophilus influenzae* type B is occurring much less frequently, and it is virtually nonexistent in children immunized with the *Haemophilus influenzae* type-B vaccine. However, 20% to 30% of children diagnosed with *Haemophilus influenzae* type-B septic arthritis have concomitant meningitis. *Kingella kingae* infection is being recognized more frequently, primarily in healthy children under four years of age, and it is often associated with an upper respiratory infection. To identify this organism, the culture must be performed in a BACTEC bottle (Becton Dickinson Diagnostic Instrument Systems, Sparks, Maryland) and needs to be observed for fourteen days. This culture technique is 87% sensitive for detecting *Kingella kingae*. Recommended antibiotics for patients who are twenty-eight days to three years of age include cefotaxime or ceftriaxone and penicillin for *Kingella kingae* infection.

*Staphylococcus aureus* infection is still common in older children and adolescents, but other organisms such as *Neisseria gonorrhoeae* and *Borrelia burgdorferi* (Lyme disease) must be considered. The recommended antibi-
otic for *Staphylococcus aureus* infection is oxacillin.

Gonococcal arthritis is usually found in sexually active teenagers or is transmitted to newborns from their mothers during birth. It is associated with a rash, tenosynovitis, and migratory polyarthritis. The knee is the most commonly affected joint. Often, children with gonococcal disease have been sexually abused.

The diagnosis of gonococcal arthritis is confirmed by culture, which needs to be performed under special conditions (warm, with a low CO₂ level, and in special culture media [sterile specimens on chocolate blood agar and nonsterile specimens on Thayer-Martin agar]). Treatment is initiated with antibiotics. There is a growing resistance to penicillin and, therefore, a third-generation cephalosporin should be used for the initial treatment. Open drainage is indicated for septic arthritis of the hip, whereas repeated aspirations have been successful for the treatment of other infected joints, such as the knee.

Lyme disease is caused by the spirochete *Borrelia burgdorferi*, carried by the deer tick. It is typically described as occurring in three stages: Stage I is a localized infection (erythema migrans), Stage II is early disseminated disease (myocarditis and/or Bell palsy), and Stage III is persistent infection (arthritis). However, the clinical manifestations can be variable, and only 40% of those presenting with Lyme disease have classic Lyme arthritis. Lyme arthritis often presents as an episodic synovitis affecting one to four joints, with asymptomatic intervals, and it is considered to be a great mimicker in that the presentation can be similar to that of other forms of chronic or even acute arthritis.

The laboratory diagnosis of Lyme disease is made with the use of the ELISA (enzyme-linked immunosorbent assay) test, which is sensitive but not specific; therefore, when the test is negative, no further diagnostic evaluation is needed. However, when it is positive, a Western blot test is needed to confirm the diagnosis. Other laboratory tests, such as the antinuclear antibody, may also be positive (in up to 30% of cases).

Treatment consists of appropriate antibiotics, which reportedly have been associated with few long-term problems in children. Surgical intervention is rarely needed, although synovectomy has been performed for chronic arthritis of the knee.

Several factors place a child with septic arthritis at risk for a poor result. These include prematurity, an age of less than six months, a delay in treatment of more than four days, concurrent osteomyelitis of the femur, and septic dislocation of the hip joint.

Sequelae of septic arthritis of the hip are common, with poor results oc-

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Fig. 5-A

Follow-up hip radiographs of a patient after delayed treatment of septic arthritis, demonstrating nearly complete destruction of the hip.

Fig. 5-B
Curing in as many as 40% of children (Table III) (Figs. 5-A and 5-B). Long-term follow-up is critical to identify these possible sequelae. When deciding on treatment options, the physician must consider not only the insult to the hip joint but future growth disturbances and the limb-length inequality or trochanteric overgrowth that may occur. Appropriately timed epiphysiodesis of the contralateral limb may be more appropriate than lengthening of the affected limb, especially with a dysplastic hip joint. Performance of ipsilateral epiphysiodesis of the greater trochanter, in an attempt to maintain the proximal femoral anatomy (the articular trochanteric distance) as close to normal as possible, should be considered66. For the more severely dysplastic hip, other treatment options, such as bone-grafting for a pseudarthrosis of the femoral neck or a valgus osteotomy of the proximal part of the femur, may be indicated. Arthrodesis or hip joint arthroplasty may be indicated for a painful hip with severe osteoarthrosis78-79.

**Infections of the Soft Tissues**

Infections of the soft tissues are common in children and are usually easily treated, with few residual long-term problems. However, a few soft-tissue infections are not so easily managed, and prompt diagnosis and appropriate treatment are needed. Some of these infections are life-threatening, and many commonly occur in the upper extremity. The focus of this section is to provide a brief overview of these soft-tissue infections.

**Cellulitis**

Cellulitis is a common, diffuse inflammation with hyperemia, leukocyte inflammation, and edema but without abscess formation. It is most frequently caused by Streptococcus (Group-A β-hemolytic) and *Staphylococcus aureus*. Treatment includes a trial of oral antibiotics, but intravenous antibiotics may be necessary for resolution of more severe cases or those resistant to oral antibiotics. If an abscess forms, prompt surgical drainage is also indicated.

One of the most common ways in which cellulitis develops is through a puncture wound of the foot, with such injuries responsible for 0.8% of visits to the emergency department by children. Although the most common manifestation of a puncture wound of the foot is cellulitis, usually caused by *Staphylococcus aureus*, a deep infection or another complication will develop in 5% to 10% of patients70-72. Puncture wounds may be associated with Pseudomonas, especially if the puncturing object passes through an athletic shoe. Pseudomonas is part of the normal skin flora and grows well in the moist environment of the shoe. It does not incite much of an inflammatory response, but it has a propensity to infect cartilage73.

Treatment depends on whether the puncture wound is deep or superficial, whether a foreign body is present, whether there is evidence of articular or osseous injury, and the initial response to antibiotic treatment. When there is a superficial puncture wound, superficial debridement should be performed in the emergency department and evidence of a foreign body should be sought. Tetanus toxoid should be administered if indicated. A deep puncture wound should be managed with exploration and debridement in the emergency room, and the wound should be left open. When a foreign body is present, the bone or joint is penetrated, or there are signs of infection at three to five days after the injury, appropriate antibiotics should be used. If the patient does not respond to antibiotic treatment, formal surgical debridement followed by three weeks of culture-specific intravenous antibiotics should be considered, especially when there is a possibility of osteomyelitis73-76.

**Necrotizing Fasciitis**

Necrotizing fasciitis is a life and limb-threatening event. Although it is uncommon in children, familiarity with this disorder is crucial because of the deceivingly benign presentation of the infection and the devastating consequences of a missed or delayed diagnosis77. The orthopaedic surgeon is typically consulted when the disorder involves an extremity, which is a common location (especially the lower extremity, which is involved in 70% of cases). Necrotizing fasciitis can occur after major or minor trauma or postoperatively.

As the name indicates, necrotizing fasciitis is an infectious process that involves the deep dermis and underlying fascia. It is most frequently polymicrobial, with streptococcal species being the most commonly isolated organism78.

Physical findings are often subtle initially, and the diagnosis is rarely made at the time of admission. Early in its course, necrotizing fasciitis may present as an area of unremarkable cellulitis that is usually surprisingly tender. It quickly progresses to a more painful and intense cellulitis that advances rapidly. Skin bullae and ecchymoses occur later, often well after the patient has become hemodynamically unstable. There often is a subtle etiology, such as a small laceration or relatively minor surgery. Early administration of intravenous antibiotics, often prior to the diagnosis, may mask the severity of the infection, increasing to the delay in diagnosis and treatment.

Early diagnosis is critical and can be made definitively only with a biopsy, although ultrasound, computed tomography, and magnetic resonance imaging have been used to determine if there is inflammation of the fascial layer79,80.
Disc Space Infection (Discitis)
Disc space infections often occur in children. The infection does not propagate from the Batson plexus, as previously proposed, but from arterioles that terminate in the disc. In adults, the disc is avascular; arterioles terminate in the vertebral end plate and, therefore, a primary hematogenous disc infection is not likely.

Signs and symptoms vary and tend to change with age. Seventy-five percent of children limp or will not walk. They may demonstrate the “quarter sign” (inability to bend over to pick up a quarter) and irritability when the hip is held in extension (log-roll test). Abdominal pain is not uncommon, especially in children between the ages of three and nine years (Table IV). Spine tenderness is common in older children. Pain frequently occurs at night, and children are usually not systemically ill.

Laboratory evaluation includes measurement of the erythrocyte sedimentation rate, which is elevated in 80% to 90% of children. The white blood-cell count may be elevated but frequently is normal in children. Blood and stool cultures should be performed if salmonella is suspected.

Imaging studies include radiographs, bone scans, and magnetic resonance images. Radiographs show disc space narrowing with irregularity of vertebral end plates but preservation of the vertebral body. Destruction of the vertebra may indicate osteomyelitis. These changes may not be seen for three weeks. Bone scans are helpful but not specific, and false-negative findings have been reported; therefore, the diagnosis should not be excluded on the basis of a negative bone scan. Magnetic resonance imaging is becoming the diagnostic modality of choice and may be the most sensitive imaging study.

Staphylococcus aureus is the most frequent infecting organism. Usually neither aspiration nor biopsy is needed, but if one of those procedures is used it is diagnostic in approximately 50% of children. A biopsy should be considered for atypical cases, when there is no response to treatment, or when the discitis occurs in an adolescent who is suspected of abusing drugs.

Treatment consists of antimicrobial intravenous antibiotics, and rapid improvement is usually seen in three to five days. If there is a good response, intravenous antibiotic therapy is continued for three to four weeks and then followed by oral antibiotics for another two to three weeks. The use of a prefabricated orthosis can also be considered. When there is no early response, aspiration or biopsy should be performed, followed by culture-specific antibiotic treatment.

Soft-Tissue Infections
Unique to the Hand
A felon is an infection that occurs in the digital pad of the fingertip. The pulp region is a closed compartment that is segregated into even smaller areas by multiple fibrous septa that attach the dermis to the distal phalanx. Each section contains fat globules, sweat glands, and/or terminal branches of the digital arteries that supply the distal phalanx. Obvious or inconspicuous trauma can penetrate the closed pulp space, deposit bacteria, and lead to abscess formation. Even an innocuous finger stick in the pediatric intensive care unit can lead to formation of a felon. The pus within the fingertip space creates pressure and impairs tissue perfusion. Failure to decompress the abscess can result in contiguous spread to the distal phalanx (osteomyelitis), distal interphalangeal joint (septic arthritis), or flexor tendon sheath (flexor tenosynovitis). A neglected felon may eventually lead to extrusion or osteonecrosis of the distal phalanx. Intense, throbbing pain and extreme tenderness are characteristic findings of a felon. The most common organism is Staphylococcus aureus. Treatment consists of surgi-
cal drainage and antibiotics. A high lateral incision on the less utilized side of the digit (the radial side of the thumb and small finger and the ulnar side of the index, long, and ring fingers) is preferred. A fish-mouth-type incision should be avoided because it may lead to vascular compromise of the digital pad. The neurovascular bundles must be avoided during surgical drainage.

Flexor tenosynovitis is a bacterial infection of the flexor tendon sheath. The classic signs have been identified by Kanavel as (1) a flexed resting posture, (2) tenderness over the flexor sheath, (3) fusiform swelling, and (4) pain on passive extension (Fig. 7). Early infection can be treated with a trial of intravenous antibiotics for twenty-four hours followed by reassessment. A failure to improve warrants urgent incision and drainage. A delayed diagnosis or an established infection warrants immediate incision and drainage as well.

Deep-space infections of the hand are usually the result of penetrating trauma or contiguous spread from neglected flexor tenosynovitis. The deep spaces are located dorsal to the flexor tendons and palmar to the metacarpals. A septum from the third metacarpal to the palmar skin separates the hand into a thenar and a midpalmar space (Fig. 8). The causative organism is usually Staphylococcus aureus or Streptococcus. Treatment consists of incision and drainage.

Viral hand infections usually are caused by the herpes simplex virus. Herpes infection of the nail bed and/or pulp is termed herpetic whitlow. Herpetic whitlow is one of the more common infections of toddlers’ hands. These infections are associated with oral lesions, and sucking of the digits (autoinoculation) is the mode of transmission to the hand in up to 80% of cases. Children typically present with pain, tingling, and vesicular eruptions over an erythematous base. However, young children cannot relate a tingling sensation. Involvement of multiple digits is more common in children than it is in adults. Constitutional symptoms (e.g., fever, chills, and malaise) are usually absent. The diagnosis is made on the basis of clinical examination, a Tzanck smear, and cultures (with a one to five-day incubation period). Clear vesicles that may become turbid after a few days characterize early herpetic infection (Fig. 9). The vesicles gradually undergo crusting over the next few weeks, and complete resolution occurs within two to three weeks. In children, concomitant bacterial infection by Staphylococcus aureus or Streptococcus can cause blistering dactylitis, which confuses the diagnosis. The Tzanck smear requires unroofing of a vesicle and staining the fluid in search of multinucleated giant cells. The smear identifies multinucleated giant cells only 70% of the time, and viral culture may be required for a definitive diagnosis. Successful treatment depends on a high index of suspicion. Herpetic whitlow is a self-limited process, and surgical

**ANATOMY**

![Fig. 8](image-url) Transverse section demonstrating the septum from the palmar fascia to the third metacarpal, which divides the hand into thenar and midpalmar spaces. (Reprinted, with permission, from: American Society for Surgery of the Hand. Essentials of hand surgery. Seiler JG 3rd, editor. Philadelphia: Lippincott Williams and Wilkins; 2003. p 9.)
treatment is not necessary. Antibiotic therapy is indicated only for bacterial superinfection. The virus avoids immune clearance by harboring in a latent stage within the ganglia of nerves. This shields the virus and allows recurrences. Administration of acyclovir may decrease the duration of the lesions and prevent recurrences.

Human and animal bites in children can lead to serious infection, morbidity, and even mortality. Misdiagnosis and undertreatment of human bites is still a prevailing problem. Infection can occur after nail biting (usually a paronychia), sucking a bleeding wound, sucking by a toddler, or violent tooth injury (clenched-fist injury) or bites during a fight. A clenched-fist injury is often overlooked as a minor accident, only to later result in a major infection. Considerable injury and bacterial inoculation can occur through a small puncture wound. The tooth can easily penetrate the extensor tendon, dorsal joint capsule, and metacarpal head. This passage carries bacteria into the joint and/or metacarpal head. The human mouth is a rich culture medium replete with organisms. One milliliter of saliva may contain up to 100 million organisms and forty-two different strains of bacteria. The common isolates are *Staphylococcus aureus*, *S. viridans* streptococci, *Eikenella corrodens* (in one-third of cases), and *Bacteroides* species (the most common anaerobe). Treatment begins with immediate recognition of the injury by taking a careful history and performing a physical examination. Early treatment is far superior to late intervention (including antibiotic therapy and surgical débridement). Close follow-up is mandatory to ensure a good long-term outcome.

Dogs cause the vast majority of animal bites to the hand (nine out of ten). Over one million dog-bite injuries are treated in the United States each year. More than 50% of the dog bites are inflicted on children under the age of twelve years, and about one-half of those wounds are of the hand and/or forearm. Even more frightening, approximately a dozen people die each year from dog bites in the United States, and one-third of them are infants less than twelve months of age. Similar to the human mouth, the canine oral cavity is full of organisms, including *Staphylococcus aureus*, viridans streptococci, *Pasteurella multocida*, and *Bacteroides* species. Treatment principles are similar to those for human bites and include urgent recognition and immediate débridement of all nonviable tissue. Antibiotic coverage must include *Pasteurella multocida*. The possibility of rabies is also a consideration, although rabies is rare after dog bites and surveillance of the dog for ten days is the simplest monitoring method. In contrast, wild animal bites require prophylactic treatment for rabies, as skunks and raccoons are responsible for the majority of the cases of rabies. Cat bites are less common than dog bites, although they commonly result in a deep infection (50% of the time). Cats have needle-sharp canine teeth that drive bacteria deep into tissue. A cat bite over the volar aspect of the finger frequently penetrates the flexor tendon sheath and causes flexor tenosynovitis. Typical causative organisms include *Pasteurella multocida*, *Staphylococcus aureus*, and viridans streptococci. Deep infections can occur secondary to inoculation into the flexor tendon sheath or deep spaces of the hand. Treatment consists of débridement, copious irrigation, and antibiotic coverage. Bites by other domestic animals, such as pet rabbits, hamsters, and guinea pigs, are treated in the same manner as cat bites.

**Overview**

Musculoskeletal infections in children are common. The etiology can be diverse and the presentation is often variable, making diagnosis difficult. The effects of infection in children may last well beyond the acute episode, and long-term follow-up is needed to assess for late sequelae such as angular deformities and limb-length inequality. Principles of treatment of musculoskeletal infections in children involve prevention, accurate diagnosis, and prompt intervention (including antibiotic therapy and surgical débridement). Close follow-up is mandatory to ensure a good long-term outcome.
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