Historically, bone and joint infections have been described in grim terms. *Aids to Surgery*, written in 1919, notes that “acute infective osteomyelitis … is a very fatal disease.” With septic arthritis, “the patient becomes exhausted from toxæmia or pyæmia,” and “ankylosis is the usual most favourable termination.” Advances in diagnostic methods, antibiotic therapy, and surgical techniques have resulted in better patient outcomes. In the case of osteomyelitis, treatment with antibiotics and limb salvage protocols is successful in more than 90% of patients with chronic osteomyelitis despite the increase in the number of patients with multiple comorbidities that affect wound healing. However, new challenges are being unveiled. The types of infections that are encountered today are evolving. Host immunity is decreased in many populations, leading to the complexity of the management of bone and joint infections that has never before been encountered. Emergency physicians must consider many subsets of patients who are at increased risk of infection, including injection drug users, patients with acquired immunodeficiency syndrome (AIDS), postsurgical patients, and patients with iatrogenic immune suppression. The emphasis of modern management of bone and joint infections has shifted from prevention of sepsis and death to prompt diagnosis, initiation of treatment, and avoidance of the complications and morbidity associated with chronic bone or joint infections.

The overall occurrence of bone and joint infections appears to have remained constant during the past three decades. The incidence of bone infections in hospitalized patients is approximately 1%. In the United States, the incidence of osteomyelitis in children younger than 13 years is 1 in 5000, whereas the incidence of septic arthritis ranges from 5.5 to 12 per 100,000 individuals. Globally, epidemiologic data for community-acquired bone and joint infections in adults vary significantly, with an overall higher incidence in patients of a lower socioeconomic class in developing countries. However, in the United States, there is no correlation between socioeconomic factors or race and the incidence of bone and joint infections. Both bone and joint infections show a bimodal age distribution, occurring most commonly in people younger than 20 years or older than 50 years. In children, bone and joint infections usually occur in previously healthy individuals, and boys have a slightly increased susceptibility to bone infections. In adults, risk factors can usually be identified in patients who present with either bone or joint infection.

Orthopedic infections can be classified according to the site of involvement and include osseous (osteomyelitis), articular (septic or suppurrative arthritis), bursal (septic bursitis), subcutaneous (cellulitis or abscess), muscular (infectious myositis or abscess), and tendinous (infectious tendinitis or tenosynovitis) varieties. The word osteomyelitis literally means inflammation of the marrow of the bone, but the term is loosely used to refer to infection in any part of the bone.

Infectious processes can also be categorized by their onset and are generally designated acute, subacute, or chronic. An acute infection is one that lasts less than 2 weeks; a subacute infection is one that lasts 2 to 6 weeks; and chronic infections are those that last longer than 6 weeks. Chronic osteomyelitis is generally defined as a bone infection that fails to respond to a normal course of antibiotic therapy. On histologic examination, chronic osteomyelitis is diagnosed when areas of necrotic bone are identified.

Septic arthritis is defined as an infection of a joint by bacterial or fungal organisms. Bacterial arthritis is sometimes called pyogenic or suppurrative arthritis. Reactive arthritis is more common than bacterial arthritis. It is a sterile, secondary inflammation of a joint with no identifiable infecting microorganisms within the synovial fluid. Commonly, reactive arthritis occurs after a systemic infection with a virus, but it can also develop after group A streptococcal infection.

There are many classification systems for osteomyelitis based on the condition of the host, functional impairment caused by the disease, site of involvement, and extent of bone necrosis. For the emergency physician, the most practical way to classify osteomyelitis is as hematogenous osteomyelitis, which is more common, and osteomyelitis secondary to a contiguous focus of infection. Osteomyelitis from a contiguous focus is further subdivided on the basis of the presence or absence of vascular insufficiency. Vascular insufficiency is often secondary to trauma, surgery, or insertion of hardware into the bone, including a prosthetic joint. Recognition of the etiologic mechanism of osteomyelitis assists in the interpretation of diagnostic imaging examinations and helps guide management, including antibiotic therapy and surgical intervention.

Septic arthritis usually results from hematogenous migration of bacteria into the joint, although it can be caused by direct inoculation of bacteria from trauma or joint aspiration or infected foreign material, such as a prosthesis. In some cases septic arthritis may occur concomitantly with osteomyelitis, with infection spreading from bone to joint, and vice versa.

**PRINCIPLES OF DISEASE**

On the basis of cross-sectional histology, bone tissue can be classified as compact or spongy. Compact bone is dense and without cavities. It forms the shell of most bones and surrounds the trabecular core in the center. It consists of haversian systems, which are made up of concentric rings of osteocytes that synthesize and maintain the bone matrix. The central haversian canals run parallel to the long axis of the bone and contain the blood supply and reticular connective tissue for the haversian system. Spongy bone,
Osteomyelitis is an infection of the bone and the medullary cavity. Bone is resistant to infection unless it is subjected to trauma, a large inoculum of blood-borne or external microorganisms, or a foreign body. With hematogenous inoculation, the metaphysis is usually the first to be infected because of the slow flow of blood in the sinusoidal blood vessels. Acute inflammatory cells migrate to the area, causing edema, vascular congestion, and small-vessel thrombosis. Acutely, inflammatory fluid spreads into the haversian and vascular channels, raising the intraosseous pressure and compromising blood flow to the bone. Infection may proceed laterally through Volkmann's canals, which are small channels that run perpendicularly to the haversian system, and reach the subperiosteal space. Eventually, blood supply to both the medullary canal and the periosteum is compromised, leading to areas of necrotic bone called sequestra. The presence of necrotic bone is the hallmark of chronic osteomyelitis. Often, the body will try to create new bone around the areas of necrosis. This is called an involucrum. Because there is significantly reduced blood supply to this necrotic bone tissue, bacterial infection is difficult to eradicate with medication alone. Chronic osteomyelitis often requires a combination of surgical débridement and antibiotic therapy.

The variation of the blood flow at the metaphysial-epiphyseal junction results in the variety of pathologic features of hematogenous osteomyelitis among the different age groups. Also contributing to this are the differences in vascular anatomy as the skeleton ages. In neonates and infants, arterial vessels from the metaphysis perforate the epiphyseal growth plate and terminate in the epiphysis in venous sinusoids. This communication allows osteomyelitis...
to advance readily from the metaphysis to the epiphysis and adjacent joint space, leading to septic arthritis.

Cortical bone in neonates and infants is thin and loosely attached to the underlying bone. It is composed primarily of woven bone that allows the release of pressure caused by the infection and also permits rapid spread of the infection into the subperiosteum. Because of these structural characteristics of bone in neonates and infants, pressure-related cortical infarction does not usually occur and sequestra are not created. Infection remains trapped in the subperiosteal region and eventually leads to subperiosteal abscess formation. The periosteum is stimulated and vigorous formation of new periosteum occurs, creating an involucrum.

After the first year of life, there is no longer a vascular connection between the metaphysis and epiphysis. The metaphyseal arteries end in loops that abut the growth plate. The epiphyseal growth plate is avascular and inhibits the spread of infection to the epiphysis and joint. Instead of spreading to the joint space, the infection usually spreads laterally through Volkman’s canals, breaks through the cortex, and lifts the loose periosteum to form a subperiosteal abscess. In the adult, after the closure of the epiphyseal plate and resorption of the growth plate, anastomoses form between the metaphyseal and epiphyseal blood vessels, and infection can once again spread from the metaphysis to the epiphysis and eventually into the synovium and joint space. In addition, the periosteum is firmly attached to the underlying bone, limiting subperiosteal abscess formation. Decreased osteoblastic activity in adults limits involucrum formation. However, infection can erode through the periosteum, forming a draining sinus track with more extensive longitudinal diaphyseal spread. Devascularized weakened bone is prone to pathologic fractures. If osteomyelitis proceeds unchecked, ischemic segments of bone may detach from surrounding bone. These separated sections are called sequestra and occur only in advanced or chronic osteomyelitis. The sequestrum can migrate outward from the medullary space through a cortical opening (cloaca) and then to the skin surface through a fistula. Bone infection may also progress into the adjacent soft tissues with abscess formation.

Hematogenous osteomyelitis develops when blood-borne bacteria are deposited in bone. This is most common in prepubertal children and patients older than 65 years. This is also the primary mode of infection in vertebral osteomyelitis. A number of local and humoral factors play a role in determining whether bacteria progress to significant skeletal infection. These include the virulence of the infecting organism; the underlying immune status of the host; and the type, location, and vascularity of the bone.

Some sites in the skeletal system are more likely to become colonized by bacteria. Bones containing slow-moving venous systems or venous sinusoids, such as the metaphyses of long bones and the vertebral bodies, have increased susceptibility to hematogenous osteomyelitis. In the metaphysis, a relative lack of phagocytic cells in the venous capillaries and sinusoids may further predispose to infection. In the synovial membrane, the existence of a deep venous plexus that also has sluggish blood flow may invite deposition of bacteria.

Bacteria congregate in a highly structured community, the biofilm, which plays an important role in the pathogenesis of septic arthritis and osteomyelitis. In the biofilm community, bacteria communicate with each other through cell–cell signals and adhere to both inert and living surfaces. Bacterial cells can be released from the biofilm and revert to the individual planktonic state. The biofilm community is more resistant than its planktonic counterparts to the host immune response and antibiotics. First, there is a protective layer on the biofilm, the biofilm matrix, that is difficult to penetrate. Second, the biofilm secretes catalase, which protects the community from hydrogen peroxide, which is used by neutrophils to kill bacteria. Finally, the community is protected by its metabolic variability. Within the biofilm, the bacteria are at varying stages of metabolism; some are active, some are slow growing, and some are dormant. Antibiotics target metabolically active bacteria, such as those in the planktonic state, but bacteria in other stages in the biofilm community may be more resistant to the effects of antibiotics. When bacterial infections form biofilms in bone, in joints, or on artificial implanted devices, fewer free bacteria are available to be aspirated. This helps explain why Gram’s stains of aspirated synovial fluid in a suspected septic joint are often negative because Gram’s stain will identify only planktonic bacteria. It also helps explain why a definitive diagnosis is made only by a culture of the synovial fluid aspirate or synovial tissue. Biofilm formation is one of the reasons that optimal treatment of a septic joint, especially of prosthetic joints, involves complete surgical debridement.

In joints, the synovium lacks a basement membrane, allowing bacteria to penetrate and to bind to articular cartilage, bone, and even prosthetic devices. Bacteria such as Staphylococcus aureus, the most common cause of both hematogenous and contiguous osteomyelitis, have developed mechanisms to increase bone adherence, to increase proteolytic activity, and to increase resistance to host defense mechanisms. In the early stages of osteomyelitis or septic arthritis, S. aureus expresses microbial surface proteins called adhesins that help form biofilms by binding to a glycoprotein called fibrinogen found in bone and synovium and that can also coat prostheses. Finally, S. aureus can surmount host defense mechanisms at both the cellular and matrix levels. For example, S. aureus can increase expression of protein A. This interferes with the opsonization and phagocytosis of S. aureus, leading to an increase in virulence.

Biomaterials, including the metal and plastic components of prosthetic joints, acrylic bone cement, devascularized bone graft, and synthetic bone substitutes, cause local immune impairment and allow nonpathogenic skin flora, such as coagulase-negative staphylococci, to become significant pathogens. Proteolytic enzymes that are present in noninfected joints are normally inhibited; however, this inhibition is lost in the face of infection, enabling the invading bacteria to persist.

The humoral immune response to bone or joint infection is usually well developed by the time that the infection is clinically apparent. B lymphocytes sense bacterial antigens and release antibodies, and antigen–antibody complex is formed at the site of infection. Through the complement cascade, bacteria are destroyed by neutrophils or macrophages. As with other infections, bacterial toxins may be destroyed directly by bound antibody.

Tissue injury in bone and joint infections can occur by several different mechanisms. Direct tissue destruction by invasive bacteria is the initial insult. After this, the inflammatory response can produce microabscesses and edema in infected tissues and subsequent vascular occlusion and ischemic necrosis. This is especially damaging to the venous capillaries of the metaphysis, where no collateral blood vessels exist to compensate for ischemic injury. If immune complexes become embedded in the bone or cartilage matrix, a prolonged inflammatory response can occur even after the primary infection has been cleared. This prolonged inflammation is particularly a problem in joints. This results in rapid destruction of articular cartilage. A final type of tissue injury caused by infection is abnormal synthesis of bone or joint matrix and cells. Abnormally synthesized bone or cartilage may be structurally unsound and function poorly.

Hematogenous spread of bacteria causes almost all cases of osteomyelitis in children and in the subset of adults who have vertebral osteomyelitis. In children, hematogenous osteomyelitis usually starts in the medullary portion of long bones and progresses outward to involve the surrounding structures. However, in the appendicular skeleton of adults, osteomyelitis occurs more
commonly by either spread of the pathogens from a contiguous source of infection or direct implantation. The direction of contamination for contiguous focus osteomyelitis is from the soft tissues inward into the bone, by dissemination through the haversian and Volkmann’s canals and toward the bone marrow. The most common sites of contiguous focus osteomyelitis are in the foot and hand. Other common sites affected by this mechanism are the skull, maxilla, and mandible. Head and neck osteomyelitis is usually caused by sinus disease and odontogenic infections.

Infections from direct implantation of bacteria are caused by deep puncture wounds and tend to occur in the hands and feet. Human and animal bites are another cause of infections that can result in osteomyelitis and septic arthritis. Although cats account for only 10% of animal bites, significant infection results from 20 to 50% of cat bites versus only 5% of dog bites because of the morphology of feline teeth. Most human bite injuries are related to fistfights and contamination of the metacarpophalangeal joints and metacarpals, with infection due to oral flora. Direct implantation of pathogens is also common with open fractures and can also occur during surgical instrumentation. Artificial joints and other implanted surgical materials can serve as sites for colonization of bacteria and formation of biofilms.

Septic arthritis is usually a consequence of hematogenous spread unless there is direct injection of bacteria into the joint. The lack of a basement membrane makes the highly vascular synovium vulnerable to bacterial seeding. Infection occurs first in the synovium, spreads into joint fluid, and finally affects the articular cartilage. Bacterial enzymes and toxins directly damage cartilage. The synovial membrane responds to infection by increasing synovial fluid production, resulting in a large joint effusion. Septic arthritis is a closed space infection; increasing pressure in the joint contributes to a decreased rate of exchange of solutes across the synovial lining and synovial blood flow can be reduced by the increased pressure, resulting in ischemic damage to cartilage. Even a small bacterial load in the joint space elicits a profound and persistent inflammatory and immune response. Bacteria can be cleared from the joint, resulting in a sterile-appearing inflammatory response. In animal models, the injection of isolated bacterial DNA into joints can produce a marked inflammatory arthritis.

In response to infection, synovial cells and polymorphonuclear leukocytes release lysosomal enzymes into joint fluid. These enzymes contain collagenase and elastase, both of which can degrade cartilage. Cytokines also seem to play a key role in the release of metalloproteinases and other harmful enzymes. The most pathologic aspect of septic arthritis is the destruction of articular cartilage, which creates a painful joint with limited motion. Once it is destroyed, hyaline (articular) cartilage is not replaced. Other structures that are enclosed within or adjacent to the synovium, such as bursae, tendons, and bone, may become damaged in septic arthritis.

**ETIOLOGY AND MICROBIOLOGY OF BONE AND JOINT INFECTIONS**

The pathogenic organisms in osteomyelitis are numerous, and Gram-positive organisms are responsible for most types of osteomyelitis. Even though Gram-negative organisms account for 43% of cases of community-acquired bacteremia, they result in only about 10% of septic arthritis cases. Trauma predisposes patients to osteomyelitis by environmental pathogens. Patients who are wounded or sustain open fractures in fresh water are susceptible to infections with the Gram-negative bacillus *Aeromonas hydrophila*. People who are bitten by animals, particularly dogs and cats, are at risk for development of osteomyelitis from *Pasteurella multocida*. Osteomyelitis caused from human bites is most common in the hand and involves human oral flora, such as *Streptococcus anginosus*, *Fusobacterium nucleatum*, and *Eikenella* species. In the population of injection drug users, *S. aureus* is the most likely cause of infection, followed by *Pseudomonas species*. *Pseudomonas aeruginosa* is also an important cause of osteomyelitis in puncture wounds, in postsurgical wounds, and in patients with sickle cell anemia.

Certain underlying disease states predispose a patient to acquire bone and joint infections. These conditions include diabetes mellitus, sickle cell disease, AIDS, alcoholism and injection drug use, chronic corticosteroid use, preexisting joint disease (especially rheumatoid arthritis), and other immunosuppressed states. Another subset of patients who are susceptible to bone and joint infections are postsurgical patients, especially those who have implanted prosthetic devices (Table 136-1).

Although most bone and joint infections are bacterial, viruses, fungi, and parasites may be the responsible pathogens. The microbiology of osteomyelitis and septic arthritis is a function of several host and environmental factors. As has been described, age is an important variable in determining the type of bacteria that cause bone and joint infections. A patient’s living environment also has some role in determining the incidence of bone and joint infections. For example, people living in crowded conditions where tuberculosis is prevalent are at increased risk for tubercular bone and joint infections. Elder patients in hospitals and institutions may be more susceptible to infections with Gram-negative bacteria. A summary of the organisms that cause osteomyelitis and septic arthritis is given in Table 136-2. The following points deserve special mention:

- In all age groups except neonates, *S. aureus* is the leading cause of osteomyelitis. It also accounts for more cases of septic arthritis than any other bacterium. In neonates, group B

---

**Table 136-1 Microbiology of Bacterial Septic Arthritis as Related to Age of the Patient**

<table>
<thead>
<tr>
<th>ORGANISM</th>
<th>CHILD*</th>
<th>YOUNG ADULT ENGAGING IN HIGH-RISK SEXUAL BEHAVIOR</th>
<th>ADULT</th>
<th>ELDERLY ADULT</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Staphylococcus aureus</em></td>
<td>10-20%</td>
<td>15-20%</td>
<td>60-70%</td>
<td>45-65%</td>
</tr>
<tr>
<td><em>Streptococcus</em> species</td>
<td>5-10%</td>
<td>1-5%</td>
<td>15-20%</td>
<td>10-15%</td>
</tr>
<tr>
<td>Gram-negative bacterium</td>
<td>1-5%</td>
<td>Rare</td>
<td>10-15%</td>
<td>15-35%</td>
</tr>
<tr>
<td><em>Haemophilus influenza</em></td>
<td>Rare†</td>
<td>Rare†</td>
<td>Rare†</td>
<td>Rare†</td>
</tr>
<tr>
<td><em>Neisseria gonorrhoeae</em></td>
<td>1-5%</td>
<td>60-80%</td>
<td>1-5%</td>
<td>Rare</td>
</tr>
</tbody>
</table>


*Ages 6 months to 5 years.
†With widespread immunization.*
Table 136-2  Microbiology and Initial (Empirical) Antibiotic Treatment of Bone and Joint Infection

<table>
<thead>
<tr>
<th>AGE GROUP</th>
<th>Common Organisms</th>
<th>Antibiotic Regimen</th>
<th>Common Organisms</th>
<th>Antibiotic Regimen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neonate to &lt;3 months</td>
<td><em>Staphylococcus aureus</em> Group B streptococcus Enterobacteriaceae Gram-negative rods</td>
<td>Ceph 3</td>
<td><em>Staphylococcus aureus</em> Group B streptococcus Enterobacteriaceae</td>
<td>PRP + Ceph 3</td>
</tr>
<tr>
<td>3 months to 14 years</td>
<td><em>Staphylococcus aureus</em> Group A streptococcus <em>Haemophilus influenzae</em></td>
<td>PRP + Ceph 3</td>
<td>Mr <em>Staphylococcus aureus</em> Group A streptococcus <em>Streptococcus pneumoniae</em> <em>Haemophilus influenzae</em></td>
<td>PRP + Ceph 3</td>
</tr>
<tr>
<td>14 years to adult</td>
<td><em>Staphylococcus aureus</em></td>
<td>PRP</td>
<td><em>Staphylococcus aureus</em> Streptococcal sp. Enterobacteriaceae</td>
<td>PRP or Ceph 3</td>
</tr>
</tbody>
</table>

Infection Subsets

<table>
<thead>
<tr>
<th>Infection Subset</th>
<th>Common Organisms</th>
<th>Antibiotic Regimen</th>
<th>Common Organisms</th>
<th>Antibiotic Regimen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sexually active adolescents or adults with acute arthritis</td>
<td><em>Staphylococcus aureus</em> Enterobacteriaceae Anaerobic bacteria</td>
<td>PRP + FLQ + metronidazole</td>
<td><em>Staphylococcus aureus</em> <em>Staphylococcus epidermidis</em> <em>Pseudomonas aeruginosa</em></td>
<td>Vancomycin + FLQ</td>
</tr>
<tr>
<td>Chronic osteomyelitis and diabetic foot infections</td>
<td><em>Staphylococcus aureus</em> Enterobacteriaceae Anaerobic bacteria</td>
<td>Vancomycin + FLQ</td>
<td><em>Staphylococcus aureus</em> <em>Staphylococcus epidermidis</em> <em>Pseudomonas aeruginosa</em></td>
<td>Vancomycin + FLQ</td>
</tr>
<tr>
<td>Infected orthopedic joint prosthesis</td>
<td><em>Staphylococcus aureus</em> <em>Staphylococcus epidermidis</em> <em>Pseudomonas aeruginosa</em></td>
<td>Vancomycin + FLQ</td>
<td><em>Staphylococcus aureus</em> <em>Staphylococcus epidermidis</em> <em>Pseudomonas aeruginosa</em></td>
<td>Vancomycin + FLQ</td>
</tr>
<tr>
<td>Sickle cell disease</td>
<td><em>Staphylococcus aureus</em> <em>Salmonella sp.</em></td>
<td>PRP + Ceph 3</td>
<td><em>Staphylococcus aureus</em> <em>Salmonella sp.</em></td>
<td>PRP + Ceph 3</td>
</tr>
<tr>
<td>Injection drug abuse</td>
<td><em>Staphylococcus aureus</em> <em>Pseudomonas aeruginosa</em> Enterobacteriaceae</td>
<td>Ceph 3 + aminoglycoside</td>
<td><em>Pseudomonas aeruginosa</em> <em>Staphylococcus aureus</em> Enterobacteriaceae</td>
<td>PRP + APAG or FLQ</td>
</tr>
<tr>
<td>Plantar puncture wound</td>
<td><em>Pseudomonas aeruginosa</em></td>
<td>AP Ceph</td>
<td><em>Pseudomonas aeruginosa</em></td>
<td>AP Ceph</td>
</tr>
<tr>
<td>Human or animal bites</td>
<td><em>Eikenella corrodens</em> <em>Pasteurella multocida</em></td>
<td>Penicillin ± AC</td>
<td><em>Eikenella corrodens</em> <em>Pasteurella multocida</em></td>
<td>Penicillin ± AC</td>
</tr>
</tbody>
</table>

* Concurrent treatment of *Chlamydia trachomatis* infection should be given to patients with suspected *N. gonorrhoeae* septic arthritis. 
  Alt. alternative antibiotics; APAG, antipseudomonal aminoglycoside; AP Ceph, antipseudomonal cephalosporin (cefazidime or cefepime); Ceph 3, third-generation cephalosporin (e.g., ceftriaxone, cefotaxime, cefamandole, ceftizoxime, ceftazidime, cefazolin, moxalactam); FLQ, fluoroquinolone; MRSA, methicillin-resistant *S. aureus*; PRP, penicillinase-resistant penicillin (oxacillin, nafcillin, methicillin, amoxicillin-clavulanate [AC]); TS, trimethoprim-sulfamethoxazole.

---

**Streptococci, Escherichia coli and other Gram-negative coliforms, and *Staphylococcus epidermidis* are the most common pathogens responsible for bone and joint infections.**

- Since the introduction of the vaccine, *Haemophilus influenzae* type b, once a common cause of septic arthritis and osteomyelitis in children younger than 2 years, has essentially disappeared as a pathogen among vaccinated children.

  - Another Gram-negative coccobacillus within the Neisseriaceae family, *Kingella kingae*, in being encountered with increasing frequency. *K. kingae* can be part of the normal flora of the nasopharynx; like *H. influenzae*, it can be spread hematogenously to bones and joints. It is a fastidious organism and may be mistaken for *Haemophilus* or *Neisseria* species.

  - *P. aeruginosa* has been reported as a cause of cervical spine osteomyelitis in injection drug users and lumbar spine osteomyelitis in patients with urinary catheters in place for long times. *Pseudomonas* colonizes the rubber and plastic inserts in footwear and is therefore seen in soft tissue infections and osteomyelitis of the foot after a puncture wound.

- In elders and in patients with diabetes, Gram-negative bacteria account for a higher percentage of cases of bone and joint infections.

- Methicillin-resistant *S. aureus* (MRSA), methicillin-resistant *S. epidermidis*, and vancomycin-resistant enterococci have emerged as a significant microbiologic problem in the past decade. Multiresistant enterococci pose the greatest potential danger in that no currently available antibiotic regimen is reliably bactericidal against such organisms.

  - A typical case of hematogenous osteomyelitis or septic arthritis is caused by a single strain of bacterium, although polymicrobial infection occurs 36 to 50% of the time and is more likely to occur in diabetic foot osteomyelitis, post-traumatic osteomyelitis, and chronic septic arthritis or osteomyelitis. Anaerobic bacteria can complicate polymicrobial infection and may be present in bone and joint infections more often than is commonly recognized because standard culture techniques may be inadequate for isolation of anaerobic bacteria. This is especially important in chronic
osteomyelitis, in which anaerobic bacteria may be present in up to 40% of cases.

Mycobacterium tuberculosis may infect bones and joints, most commonly in the axial skeleton. The two most common forms of skeletal infection are vertebral osteomyelitis (Pott’s disease) and tubercular arthritis. The spine is affected in half of cases of tubercular skeletal infection. The arthritis of tuberculosis is a chronic, low-grade inflammatory process that resembles rheumatoid arthritis more than acute septic arthritis.1

The prevalence of fungal bone and joint infections is increasing because of the rise in the number of patients with risk factors. Host factors that predispose to fungal infections include immobility, mucositis, use of antibiotics, radiation therapy, immunosuppressive agents, admission to an intensive care unit, malnutrition, and hematopoietic stem cell transplantation.12 Fungal infection is also a complication of catheter-related fungemia, the use of injection drugs contaminated by Candida species, and prolonged neutropenia. Candida osteomyelitis occurs through hematogenous spread or as a postoperative wound infection. Fungal bone infection is indolent and may go through periods of activity and remission.12 Aspergillus has been reported to cause osteomyelitis in vertebrae, hip prostheses, and ribs. In adults, the infection is hematogenous. In children, Aspergillus osteomyelitis is most common in those with prior granulomatous disease and spreads from a primary pulmonary infection. Blastomyces and Cryptococcus are two other fungi that may become disseminated and infect the skeleton. Treatment of these infections is difficult, especially because of emerging pathogens that are resistant to common antifungal agents, and therapy needs to be individualized against the specific organism.

Patients with human immunodeficiency virus (HIV) infection and AIDS are predisposed to a variety of common and opportunistic pathogens. Although S. aureus is still the most likely cause of bone and joint infections in patients with AIDS, fungal and other atypical organisms should be considered. One unusual but particularly characteristic form of osteomyelitis in HIV-positive patients is bacillary angiomatosis. This infection is caused by a Gram-negative rickettsia-like organism that frequently causes osteolytic bone lesions.

OSTEOMYELITIS

Clinical Features

History and Physical Examination

The symptoms and signs of osteomyelitis in adults are predictable, although not always present. Patients with osteomyelitis often present with fever and rigors and may appear toxic. Fever appears to be present more commonly in children. Systemic complaints of headache, fatigue, malaise, and anorexia are often reported. However, these findings are inconsistently present and are less likely with chronic osteomyelitis. In children with lower extremity osteomyelitis, a sudden limp or inability to bear weight, localized warmth, swelling, and erythema may be reported. A careful review of the patient’s past medical history is especially important to identify risk factors that may predispose to bone infection.

The physical examination findings of osteomyelitis are fairly specific. The predominant symptom of osteomyelitis is pain over the affected bone. Palpation of the involved bone usually elicits point tenderness over the infected segment. Palpable warmth and soft tissue swelling with erythema may be present, but these findings are variable. In chronic advanced osteomyelitis, the involucrum or sequestrum may be palpated, and sinus tracks that drain through the skin may be noted. Because osteomyelitis has a propensity to occur in the metaphyses of long bones, it is often difficult to distinguish infection in bone from infection in the neighboring joint. A “sympathetic” effusion in the adjacent joint may develop in some patients with osteomyelitis even when the joint is not infected.

Diagnostic Strategies

Laboratory Data and Diagnostic Imaging

Imaging remains the cornerstone of the initial evaluation process, but bone biopsy and culture are the “gold standard” and definitive tests to confirm the diagnosis and to guide treatment of osteomyelitis.

Laboratory data are not specific and can only suggest the diagnosis of osteomyelitis. In acute osteomyelitis, the white blood cell (WBC) count is often although not always elevated; typical values range from normal to 15,000/mm³. The WBC count is often normal in chronic osteomyelitis. The erythrocyte sedimentation rate (ESR), a nonspecific measure of inflammation, is more helpful than the WBC count. The ESR represents the rate at which red blood cells fall when anticoagulated blood is placed in an upright tube. When an inflammatory process is present, the high proportion of fibrinogen in the blood causes the red blood cells to form stacks, called rouleaux, which settle faster. This is a sensitive marker for bone infection, and many series report elevated ESRs in patients who have confirmed osteomyelitis. In children, an elevated ESR or C-reactive protein (CRP) level is seen in all cases of osteoarticular infection, and the sensitivity of use of both the ESR and the CRP value is 98%. In the evaluation of a diabetic foot infection, an ESR greater than 70 mm/hr predicts the presence of an underlying bone infection.13 An elevated ESR in the presence of appropriate physical findings should lead one to suspect osteomyelitis, but a normal or slightly elevated ESR does not eliminate the diagnosis. Other inflammatory conditions, such as cellulitis, can cause an elevated ESR, although the degree of elevation of the ESR is often higher with osteomyelitis.

CRP, another nonspecific marker of inflammation produced by the liver and by adipocytes in response to interleukin-6, also plays a role in the evaluation of patients with bone infections. The CRP value increases within the first 24 hours of infection, peaks within approximately 48 hours, and is usually normal within 1 week of therapy. In children presenting with osteomyelitis, it has been shown that the ESR is elevated in 92%, the CRP level is elevated in 98%, and the WBC count is elevated in 35%.

The ESR and CRP blood tests have a high positive predictive value, and elevated values should increase suspicion for this diagnosis. However, normal values of these nonspecific inflammatory markers cannot be used to rule out the diagnosis of osteomyelitis. The CRP may be a better early indicator of disease, but the ESR is most valuable in following response to treatment.16 Typically, the ESR falls steadily as osteomyelitis resolves and increases should it recur.

Because conventional radiography is readily available, relatively inexpensive, and useful in differentiation of infection from trauma and tumors, it remains the initial imaging test of choice for suspected osteomyelitis. In addition, plain radiography is often a helpful adjunct to secondary imaging studies. Unfortunately, radiographic evidence of osteomyelitis lags behind the clinical picture, and less than one third of patients have abnormalities on plain radiographs in the first 7 to 10 days after the onset of symptoms. The characteristic early findings on the plain radiograph in osteomyelitis are lucent lytic areas of cortical bone destruction (Fig. 136-2). However, lucency is not detected on radiographs until approximately 50% of bone mineral is lost, and this often takes up to 2 weeks from the onset of infection. Although these findings are often difficult to identify on plain radiographs, soft tissue edema, deep soft tissue swelling, distorted fascial planes, and altered fat interfaces may be present within 3 to 5 days from the
onset of infection and can serve as a clue to osteomyelitis in the underly-
ing bone. Periosteal reaction is another early sign. It may appear on radiographs as hypertrophy or elevation of the periost-
teum creating an involucrum (Fig. 136-3). Because of the thinner periosteum, these early periosteal changes are seen in radiographs in children more commonly than in adults. In advanced disease, the lytic lesions are surrounded by dense, sclerotic bone, and sequestra may be noted. By 28 days from the onset of osteomyel-
itis, 90% of the plain radiographs are abnormal.17

Radionuclide skeletal scintigraphy (bone scanning) is more sen-
tive than plain radiography in the early diagnosis of osteomyel-
itis and is especially useful in the presence of prosthetics or other hardware. Radionuclide scans can detect osteomyelitis within 48 to 72 hours after the onset of infection. A radioactive tracer is injected into the bloodstream and given time to bind or to accumulate in body tissues, after which a camera is used to sense released radioactivity. An image is created that is evaluated for increase or decrease in expected uptake of the radionuclide. In the past decade there has been a movement away from skeletal scintigraphy in diagnosis of osteomyelitis. There is a significant radiation burden associated with scintigraphy, and recent recom-
mendations are that children thought to have acute osteomyelitis should have magnetic resonance imaging (MRI) rather than a bone scan.18

Computed tomography (CT) may be useful in the diagnosis of osteomyelitis. The bony cortex is particularly well seen on CT, and involucrum and sequestrum formation is easily identified. Non-
long bones like the sternum, vertebrae, pelvic bones, and calcaneus are far better imaged with a CT scan than with plain radiographs. CT is most commonly used to detect and to define areas of

Figure 136-2. Radiographic progression of acute osteomyelitis. A, Soft tissue swelling at both the medial and lateral aspects of the ankle with a moderately sized effusion (August 2, 2006). B, Large ankle effusion with extensive soft tissue swelling. There is complete loss of the tibiotalar joint space as well as widening of the medial joint space, suggesting chondrolysis. There are lucent areas in the distal tibia and fibula, suggestive of hyperemia, and the talus is diffusely sclerotic (September 11, 2006). C, Increased erosion of the medial aspect of the talar dome with increased joint effusion (October 12, 2006). D, Talar bone destruction with demineralization involving all of the osseous structures. There is also a small joint effusion (January 2, 2007). E, Avascular necrosis of the talus as well as destruction of the articular surfaces of the tibia and talus is present, consistent with chronic osteomyelitis. There is diffuse osteopenia as well as loose bodies within the joint (April 19, 2007). F, There is continued irregularity of the articular surface of the tibia as well as collapse of the talus. Loose bodies are still present within the joint, and there is a persistent joint effusion and soft tissue swelling (June 14, 2007). (Courtesy Thomas Egglin, MD, Department of Diagnostic Imaging, Rhode Island Hospital, Brown University.)
possible infection in bones with complex anatomy that is difficult to visualize on plain radiographs and bone scans. Osteomyelitis appears as rarefaction, or lucent areas, on the CT scan images (Fig. 136-4). Gas may be seen in bony abscess cavities. The limitation of CT for early diagnosis of osteomyelitis is the same as that for plain radiography in that the disease must be present for more than a week for changes to be apparent. An important role of a CT scan in osteomyelitis is to help localize bone lesions that have been found with other imaging modalities. The CT scan can guide the surgeon in debridement and resection of infected bone and in choosing a site for diagnostic biopsy.17

The use of bone scans and CT for detection of osteomyelitis in the emergency department (ED) is decreasing as the availability and image quality of MRI improves while its cost decreases. The anatomic resolution of MRI is far superior to that of bone scans and plain radiographs. MRI findings are often evident before an abnormality is detected by skeletal scintigraphy, plain radiography, or CT because of the earlier detection of bone marrow involvement. MRI can reveal edema and the destruction of the medulla as well as any periosteal reaction, cortical destruction, articular damage, and soft tissue involvement, even when conventional radiographs are still normal. Whereas the presence of ferromagnetic material is a contraindication to MRI, most materials used in orthopedic surgery, such as titanium and chrome cobalt, do not interfere with this imaging modality. One drawback to MRI is the presence of metal in bone, especially prosthetic joints. Metal may cause distortion of the signal in the area adjacent to a joint prosthesis, but this does not exclude MRI in this group of patients.17 MRI uses a combination of spin echo T1-weighted and T2-weighted images, short tau inversion recovery (STIR) images, and fat-suppressed T2-weighted images. Osteomyelitis produces a diminished intensity of the normal marrow signal on T1-weighted images and a normal or increased signal on T2-weighted images (Fig. 136-5).

Administration of gadolinium as a contrast agent enhances the interface between normal and abnormal marrow and helps distinguish devitalized from normally perfused bone. Gadolinium becomes localized in areas of increased vascularity and blood flow and also helps distinguish soft tissue infections such as abscesses and cellulitis from osteomyelitis. Whereas contrast agents increase reader confidence in the diagnosis of osteomyelitis, they do not increase the sensitivity or specificity of the diagnosis of osteomyelitis.17 Soft tissue swelling and edema are best detected with fat-suppressed images, in which the resolution is much greater with MRI than with plain radiographs or CT scan. MRI also allows better visualization of subtle bone cortical changes, periosteal reaction, soft tissue edema, abscesses, and sinus tracks.

When it is done with STIR images, MRI has a 100% negative predictive value, and osteomyelitis can be essentially excluded in the presence of a normal MRI study.17 STIR images have a very low signal from fat, like fat-suppressed images, but still obtain a strong signal from water. The sensitivity of MRI is reported to be between 88 and 100%, with a specificity of 75 to 100%.17 MRI with gadolinium contrast enhancement has been demonstrated to have higher sensitivity and specificity than radionuclide bone scans in the diagnosis of vertebral osteomyelitis (Fig. 136-6).

The differential diagnoses for the magnetic resonance findings in acute osteomyelitis are trauma, noninfectious inflammatory and metabolic lesions, histiocytosis, tumors, and cancer. In cases in which a surgical procedure will be done to obtain a microbiologic diagnosis or is needed to treat osteomyelitis, MRI has obvious advantages over a radionuclide bone scan in detailing the anatomy for the surgeon.

Microbiologic Diagnosis

The most direct and often the most effective way to definitively diagnose osteomyelitis is to obtain infected bone by needle aspiration or surgical resection. Culture specimens from this bone will help guide antimicrobial therapy. Culture of draining fistulas or sinus tracks is not an acceptable substitute because the organisms cultured from these sites are often different from those in the underlying infected bone. Because osteomyelitis may be polymicrobial or due to unusual microorganisms, especially in immunocompromised patients, cultures for fungal and anaerobic organisms should be performed.

Particularly in cases of hematogenous osteomyelitis, cultures of blood, urine, cerebrospinal fluid, and pus from other sites of infection can help uncover the infecting bacteria. Blood cultures in patients with acute untreated osteomyelitis are positive for the offending bacteria approximately 50% of the time.21 In children with hematogenous osteomyelitis, it is not unusual to identify the
infecting organism in other body fluid cultures in addition to blood cultures. In chronic osteomyelitis, blood cultures are almost always negative.18

The likelihood of establishing a bacteriologic diagnosis in acute osteomyelitis is 80 to 90%, but in some cases even culture of resected bone yields no organism. Possible reasons for this are poor culture techniques and inadequate preparation of recovered tissue for culture, previous antibiotic treatment, and culture specimens from necrotic ischemic regions that may be devoid of bacteria.18

The emergency physician’s diagnostic approach in suspected osteomyelitis has become simpler since MRI has largely replaced the use of radionuclide scintigraphy. The algorithm in Figure 136-7 provides a simplified approach to the diagnostic strategy in a patient with suspected osteomyelitis. A few key points should be considered with use of this algorithm:

- Radiographs lag behind the clinical picture.
- When the clinical suspicion for a diagnosis of osteomyelitis is low and the initial bone scan or MRI study is normal, it is extremely unlikely that the patient has osteomyelitis.
- In infants and children, the amount of radiation exposure with imaging techniques must be considered.18
- In easily accessible bones, aspiration of the bone is a low-risk procedure that will often help establish a microbiologic diagnosis.
- If the clinical presentation strongly suggests osteomyelitis, a lengthy diagnostic workup should not delay empirical treatment. Culture specimens of blood, urine, and other appropriate sites should be obtained and antibiotic treatment started.17
- The cost of imaging tests for osteomyelitis must be considered in deciding how to pursue the diagnosis. Expense must be weighed against the benefit of early diagnosis of osteomyelitis and the prevention of chronic osteomyelitis and the numerous surgeries and increased length of treatment associated with this diagnosis.

Clinical Subsets of Osteomyelitis

Acute hematogenous osteomyelitis (AHO) is the most common form of osteomyelitis, but it has different presentations, diagnosis,
Plain radiographs are a good initial test because abnormalities are identified within days of development of neonatal osteomyelitis and are usually abnormal by the time the disease is suspected. In the face of a normal radiograph, the next step for the clinician who suspects neonatal osteomyelitis is MRI.

Two less common forms of osteomyelitis can occur in children: subacute osteomyelitis and chronic recurrent multifocal osteomyelitis (CRMO). Subacute osteomyelitis refers to a form of osteomyelitis in children that tends to be acute, almost always arises from hematogenous seeding of bone, and can often be treated with antibiotics alone. AHO is seen in children as young as 3 months and as old as 16 years. Bacteremia is the presumed cause of bone infection. S. aureus is the most common infecting organism in children of all ages except neonates (see Tables 136-1 and 136-2). As noted before, H. influenzae is no longer a common cause of AHO. AHO has a well-established male preponderance (male-to-female ratio of 2 to 3:1) and involves long bones approximately 80% of the time. The site of infection is usually the distal metaphysis because of its increased vascularity, but up to 30% of AHO occurs in other parts of the bone. Children with AHO may have fever, chills, vomiting, dehydration, and malaise; but they usually do not appear toxic. Most children have characteristic pain and limited use of the limb and are point tender. The diagnostic evaluation for AHO is listed in Figure 136-7. Blood cultures are positive for the bacterial cause of osteomyelitis in 60% of patients with AHO. A positive blood culture and a physical examination consistent with osteomyelitis may be sufficient for a diagnosis of AHO to be made. Figures 136-2 and 136-4 show a typical radiographs of AHO.

Neonatal osteomyelitis is difficult to diagnose because of minimal systemic findings. Osteomyelitis in the neonate is more commonly seen after abnormal pregnancies or deliveries and often accompanies other acute illnesses. Multiple sites of bone involvement are found in approximately half the reported cases. Because of the unique vascular anatomy of the neonate, septic arthritis often accompanies osteomyelitis. Osteomyelitis of the flat bones, such as the facial bones, is more common among neonates than any other age group. Group B streptococcus is the leading causative bacterium in neonatal osteomyelitis, but staphylococcal species are still common. Skeletal scintigraphy is of limited value and is not a good option in diagnosis of neonatal osteomyelitis.
Vertebral Osteomyelitis

Vertebral osteomyelitis usually afflicts older adults in a manner analogous to AHO in children and appears to be increasing in frequency as the population ages and has more chronic medical diseases. Risk factors in elders include intravenous access devices and asymptomatic urinary infections. In young people, risk factors include injection drug abuse. The spine is susceptible to bacterial infection because the venous system surrounding vertebral bodies is valveless (permitting two-way flow of blood) and has transverse and longitudinal anastomoses. Bacteria that reach the spine and enter the venous plexus are more likely to aggregate and to cause infection in this slow-moving system. Infection can readily spread to adjacent vertebral bodies. Vertebral osteomyelitis most often results from hematogenous seeding, direct inoculation at the time of spinal surgery, or contiguous spread from an adjacent infection. A clear source of bacterial hematogenous seeding with positive blood cultures occurs in approximately 40% of cases of vertebral osteomyelitis. *S. aureus* (including MRSA) is the most common offending agent in vertebral osteomyelitis, followed by aerobic Gram-negative rods from urinary or gastrointestinal sources.

Only 10% of patients with vertebral osteomyelitis appear septic or toxic; the rest have a subacute presentation. The majority of patients present with insidious symptoms, leading to possible delays in diagnosis of up to 4 months. Back pain is the most common presenting symptom, seen 86% of the time. In most patients, physical examination will reveal back pain and tenderness over the spinous process. Neurologic deficits are reported in less than 38% of patients with vertebral osteomyelitis and are often an indication of an epidural abscess. Up to 60% of patients with these abscesses present without fever or leukocytosis. On laboratory testing, the ESR and CRP value are highly sensitive and are elevated in 98% and 100% of cases, respectively. Blood culture specimens should be obtained before antibiotic treatment is initiated. Rapid diagnosis and treatment of this medical emergency start with initiation of empirical antibiotics, immediate imaging, and early orthopedic involvement.

The imaging strategy for the diagnosis of vertebral osteomyelitis starts with plain radiographs, which may show disk space narrowing or destruction of the vertebral endplates or the vertebral body. Similar to osteomyelitis in other parts of the body, findings on plain radiographs are not seen until at least the second week of vertebral infection. Bone scintigraphy has been largely replaced by MRI in further imaging of suspected vertebral osteomyelitis. CT is good for defining bone destruction and is often used to assist needle aspiration of the lesion, but if osteomyelitis is still suspected or if the patient has neurologic deficits, MRI is done to look for an epidural abscess and to rule out a herniated disk. MRI has a sensitivity of 90% for vertebral osteomyelitis, with T2-weighted images proving most valuable in establishing the diagnosis. Management of spine infections is usually nonoperative, consisting of immobilization and intravenous antibiotics; surgery is considered after failed nonsurgical management.

The areas most prone to vertebral infections are the lumbar (58%), thoracic (30%), and cervical (11%) spine. Cervical spine osteomyelitis can cause a retropharyngeal abscess; lumbar spine osteomyelitis may be complicated by a psoas muscle abscess. The spinal cord may also suffer ischemic injury if the vertebral infection causes septic thrombosis or compression of local blood vessels. When osteomyelitis affects the thoracic spine, infection can spread to the chest. Paraspinal abscesses, reactive pleural effusions, and empyema have been reported and may mislead the clinician to suspect that the primary problem is not in the spine. The most dreaded complications of vertebral osteomyelitis are the spread of infection into the spinal canal, the development of an epidural abscess, and the progression of the infection to cause spinal cord injury and permanent paralysis. Fortunately, this occurs in less than 15% of cases of vertebral osteomyelitis.

The diagnostic procedure of choice for vertebral osteomyelitis is needle biopsy that can isolate the causative organism. Patients who present with a clinical picture consistent with vertebral osteomyelitis require rapid diagnostic confirmation either through imaging or by direct needle biopsy performed by a surgeon, with or without CT guidance. A delay in the definitive diagnosis of puts the patient at risk for progression of vertebral osteomyelitis to spinal cord compression. Patients who are at increased risk for paralysis include elder patients, those with cervical spine osteomyelitis, and those with serious underlying diseases, such as rheumatoid arthritis and diabetes mellitus.

Patients with vertebral osteomyelitis require antibiotic therapy that is based on the offending microorganism and its susceptibility. Even though AHO can usually be successfully treated with antibiotics alone, surgery may be required for diagnostic purposes, when there is spinal cord compression, for abscess drainage or debridement, for correction of the progressive deformity, and if the infection recurs after adequate treatment. Given evolving resistance patterns for *S. aureus*, intravenous therapy is the standard mode of treatment for Gram-positive bacteria. Diskitis is a variant of vertebral osteomyelitis. The disk is an avascular structure that depends on nutrient diffusion from adjacent blood vessels in the vertebral metaphysis and endplates. The avascular disk creates a rich environment for the bacteria to flourish. Because of the vascular anatomy, adult pyogenic diskitis coexists with vertebral osteomyelitis. In the pediatric age group, the disk has a more robust vascular supply, and isolated diskitis is more common in this population. This subacute disease is thought to be a low-grade infection (usually *Staphylococcus* species) within the disk, sometimes extending to the adjacent vertebral plate. The patient complains of back pain and may refuse to walk. Although bone scintigraphy may show increased uptake in the disk space, MRI better demonstrates the anatomy of diskitis. CT is used to guide aspiration. Cultures of the disk from needle aspiration are reported to be positive for bacteria 30 to 60% of the time, most commonly for *S. aureus*. The disease typically resolves with nonoperative treatment.

Post-traumatic Osteomyelitis

Post-traumatic osteomyelitis is a form of contiguous focus osteomyelitis that results from open fractures, surgery and invasive
procedures, burns, bites, and puncture wounds. At least 10% of open fractures later develop osteomyelitis, and the tibia is the most commonly affected bone. The fracture site may be contaminated directly from the environment or iatrogenically secondary to emergency procedures or surgery. The intraoperative implantation of prosthetic devices further increases the chance of infection. Severe damage to adjacent soft tissues results in a necrotic nidus of infection that can spread to bone. Polymicrobial infection is more common with this type of osteomyelitis. The imaging of post-traumatic osteomyelitis is complicated by changes induced by surgery and new bone formation in the fracture. Imaging modalities that are best in this situation are MRI and CT.26

Osteomyelitis that is due to direct inoculation associated with joint arthroplasty may become evident within 12 weeks after the surgery. These patients generally do not report relief of their pain after the surgery. Patients who have symptoms of infection more than 12 weeks after surgery and who have postoperative improvement of their pain are considered to have a hematogenous source of infection. If either of these presentations is recognized within the first 2 weeks of onset of infectious symptoms, the prosthesis is considered salvageable. After 2 weeks, the chance of eradicating the infection without removal of the prosthesis decreases substantially.27

The most common form of postsurgical osteomyelitis is infection of a hip prosthesis, which occurs in 1 to 5% of hip replacement surgeries. Postsurgical osteomyelitis is difficult to diagnose. Fever is often absent, and the patient often presents with a painful, unstable joint on physical examination. S. aureus and S. epidermidis account for 75% of postsurgical and prosthesis-related osteomyelitis. Radiographs are often normal but may show subtle signs of bone resorption about the prosthetic components. It is difficult to distinguish mechanical from infectious loosening; joint aspiration, synovial fluid analysis, and bone biopsy performed in a sterile, operative setting are undertaken to make a firm diagnosis. Other imaging techniques, such as CT, MRI, and [18F]fluorodeoxyglucose positron emission tomography, are used but are also difficult to interpret because of scatter from the metallic components and postsurgical changes. Systemic antibiotics cannot penetrate the biofilm, and surgical removal of the prosthesis is usually the only way to cure the infection.28

Puncture wounds to the feet have approximately a 2% incidence of development of osteomyelitis. The causative organism is usually S. aureus or beta-hemolytic streptococcus. P. aeruginosa is commonly associated with plantar wounds that occur while wearing a rubber-soled shoe. Other puncture wounds are nosocomial in the form of subclavian venipuncture, fetal scalp monitors, and other invasive procedures.

Diabetic Foot Osteomyelitis

The pathologic changes induced by long-standing diabetes mellitus encourage the development of osteomyelitis. Foot infections are common in diabetics because of their compromised vascularity. The typical patient with diabetic foot osteomyelitis is older than 50 years and has advanced insulin-dependent diabetes. More than 60% of such patients have polyneuropathy, more than 50% have retinopathy, and at least 30% have concurrent cardiovascular disease. The neuropathy leads to repetitive trauma and loss of the protective barrier of the skin and subsequent foot ulcers. Once the skin has been infected and injected, the altered host defenses of diabetic patients make it easier for infection to occur and to spread. The small bones and phalanges are most often affected. Infection spreads first to the periosteum and then to the cortex and may finally disrupt medullary bone. The initial phase of foot infection in diabetic patients may exacerbate preexisting hyperglycemia. This allows bacteria to replicate at an increased rate and impairs leukocyte function, with defective chemotaxis, abnormal phagocytosis, and decreased bactericidal function. Defective antibody synthesis and decreased complement levels also exacerbate osteomyelitis in diabetics.

Local findings in diabetic foot infections consist of swelling, erythema, and sometimes pain. Indolent ulcers and frank cellulitis are seen in more than 50% of cases. Because the process is often chronic, radiographic changes may have sufficient time to develop. Mottled lytic lesions are typical, and air may be present in the soft tissues. The only reliable way for the bacteriologic diagnosis to be made is by surgical culture of the bone; however, if a wound can be probed all the way to the bone, this has an 89% positive predictive value for osteomyelitis.29 Bone biopsy for diabetic foot osteomyelitis has a reported sensitivity of 94%.30 Diabetic foot osteomyelitis is usually polymicrobial. The most common organism is S. aureus. Other common organisms include streptococci, Enterobacteriaceae, and anaerobes. Surgical treatment is often required, and severe cases commonly lead to amputation of toes or portions of the foot. However, treatment with intravenous followed by oral antibiotics can be successful in some patients. In general, patients are treated with a longer course of about 8 to 10 weeks.29

Osteomyelitis in Sickel Cell Disease

Patients with sickle cell disease are at increased risk for hematogenous infection, including osteomyelitis. Macrophage function is impaired in sickle cell patients, rendering them susceptible to infections with encapsulated organisms. AHO in children with sickle cell disease has two major differences from AHO in other children. First, infection in sickle cell disease is usually located in the diaphysis of long bones as opposed to the metaphysis as in other AHO patients. Second, although S. aureus is still the most common bacterium in children with sickle cell disease who have osteomyelitis, Salmonella species are the next most common infecting organism. Reasons for this are not completely understood, although it is postulated that microinfarcts in the bowel allow Salmonella bacteria to seed the bloodstream and become hematogenous osteomyelitis.31

The differentiation of bone infection from bone infarction in sickle cell patients is a challenge. Fever, a toxic appearance, and an elevated ESR are more commonly associated with osteomyelitis than with bone infarction. Plain radiographs are not helpful in distinguishing between the two entities. Whereas skeletal scintigraphy may help make the diagnosis, MRI is proving useful in differentiating between the two.31 Another approach is to note the response to conservative therapy; bone infarctions usually improve within 24 to 48 hours, whereas bone infection worsens.32 Antibiotic treatment of osteomyelitis in the sickle cell patient should include coverage against Salmonella with a third-generation cephalosporin.

Chronic Osteomyelitis

Most chronic bone infections occur as a complication of posttraumatic infection, surgical procedures, or diabetic foot infections. The inflammatory response to infection triggers bone resorption and cartilage destruction and ultimately leads to bone death (Fig. 136-8). The necrotic bone acts like a foreign material, providing an inanimate surface to which microorganisms adhere. Clinical signs that the infection has become chronic include the formation of sequestra and the presence of draining tracks or fistulas. Chronic infection is almost always polymicrobial and commonly involves anaerobes. Cultures of sinus tracks are not a reliable method to predict which bacteria are active in the underlying bone infection; direct biopsy of bone is the only option for accurate diagnosis of most cases of chronic osteomyelitis. Chronically established infections can be remarkably persistent or evolve
even in the face of prolonged antibiotic therapy; therefore, treatment commonly involves surgery.

Complications

In addition to the development of chronic osteomyelitis, several other complications can arise from the acute infection. The bloodstream may become seeded with bacteria or bacterial toxins, resulting in sepsis. Depending on the location of osteomyelitis, local extension of an invasive, supplicative process can lead to septic arthritis, brain abscess, meningitis, spinal cord compression, pneumonia, and empyema. In children, osteomyelitis damages the developing skeleton. If infection involves the epiphysis, permanent growth alterations can occur, resulting in a shorter or deformed extremity on the affected side. Pathologic fractures may occur through sites of osteomyelitis.

Differential Considerations

Many different processes involving bone may masquerade as osteomyelitis. Bone tumors may produce local pain and radiographic changes consistent with osteomyelitis. Tumors most likely to mimic osteomyelitis are osteoid osteomas and chondroblastomas. These produce small, round, radiolucent lesions on radiographs. Ewing’s sarcoma is a tumor of bone marrow in children that can be mistaken for osteomyelitis. Metastatic bone tumors and lymphomas should also be considered in the differential diagnosis of osteomyelitis. Trauma can also produce a clinical picture similar to osteomyelitis. In children, when trauma is common and may be occult, the evaluation for osteomyelitis may reveal a buckle fracture.

Management

Once the diagnosis of osteomyelitis is considered, the next step is to rapidly obtain culture specimens and commence treatment. The goal of therapy is to contain the infection before bone death occurs. Cure rates fall dramatically once necrotic bone is present. For osteomyelitis that is characterized by asymptomatic, hematogenous lesions coincidentally discovered during the evaluation of a patient with fever, weight loss, or bacteremia; hematogenous infection caused by sensitive microbacteria or fungi; or hematogenous vertebral osteomyelitis caused by sensitive pathogens, antibiotic treatment and medical management is usually effective.

For all other types of osteomyelitis, including contiguous focus osteomyelitis, diabetic foot infections, post-traumatic osteomyelitis, and implant-related infection, definitive care is surgical, and antibiotic treatment should be withheld until intraoperative cultures are obtained. In these cases a discussion about either infectious disease or orthopedic surgery, depending on the scenario and the available services, is appropriate, to plan or initiate surgical and medical therapy. The ideal antibiotic for treatment of osteomyelitis should be bactericidal against the offending bacteria, have low toxicity, be chemically stable at the site of infection, and be relatively inexpensive. The low pH of infected bone may limit the bactericidal action of some antibiotics, particularly the aminoglycosides. Cephalosporins and penicillins are more stable in this environment. In the ED, empirical broad-spectrum treatment of suspected osteomyelitis should be initiated with an awareness of regional resistance patterns.

The antibiotic of choice for osteomyelitis should be active against beta-hemolytic streptococci and staphylococci, including MRSA. Although Gram-negative organisms are uncommon pathogens, the serious consequences of inadequate treatment justify the inclusion of anti-Gram-negative coverage in the initial drug regimen. Once culture results are obtained, the antibiotic regimen can be tailored. In the case of post-traumatic osteomyelitis, appropriate initial emergency care may help prevent the disease. The proper management of open fractures in the field is to cut away surrounding clothing, to pour sterile saline or water over the exposed bone, and to cover the wound with moist sterile gauze bandages or a sterile sheet. Only in the case of severe vascular compromise to the distal limb should an open fracture site be manipulated or realigned because of the danger of introducing bacteria deeper in the wound. Because wound surface cultures in the emergency setting are not reliable in predicting future pathogens in bone infections, they need not be done as part of emergency care.

Treatment of osteomyelitis often requires a combined medical and surgical approach. This is usually true when osteomyelitis is caused by direct inoculation into bone or spreads from a contiguous focus of infection. If the area of osteomyelitis is small, aspiration or resection of the bone abscess may be both a diagnostic and therapeutic procedure. Acutely, indications for surgery include the presence of an abscess, necrosis, wound dehiscence, and failure to respond to appropriate therapy. In chronic infections, surgery is invariably required for radical cure of infection, and a team with orthopedic and infectious disease expertise may provide the best results.

AHO in children can be treated with antibiotics alone. In other situations, such as diabetic foot osteomyelitis and chronic osteomyelitis, the use of antibiotics with surgical débridement is necessary to eradicate the infection.

The first priority remains adequate treatment of *Staphylococcus* species with a penicillinase-resistant penicillin, such as oxacillin or nafcillin, or a first-generation cephalosporin. In patients with a severe penicillin allergy, vancomycin is an acceptable alternative; however, cure rates with vancomycin are inferior to those with nafcillin or cefazolin. Vancomycin should be reserved for those patients with a real type I penicillin allergy. Nonenterococcal streptococci are usually sensitive to antibiotics used to combat staphylococci. Gram-negative bacteria, including Enterobacteriaceae, *E. coli*, *Proteus mirabilis*, and *Serratia marcescens*, are rare causes of osteomyelitis. Third-generation cephalosporins, aminoglycosides, imipenem–cilastatin, and ampicillin are the usual choices for broad Gram-negative coverage. Beyond this initial
broad-spectrum therapy, treatment for anaerobic bacteria, *Pseudomonas*, and fungal organisms should be based on clinical suspicion.

The incidence of antibiotic resistance is increasing. Resistance to both penicillin-resistant penicillins (oxacillin and nafcillin) and fluoroquinolones by staphylococci, vancomycin by enterococci, and imipenem by pseudomonas has been reported. Therefore, if the bacterium is identified or known in the emergency setting, it is important to select the most specific antimicrobial agent on the basis of regional resistance patterns. 18

The increase in antimicrobial resistance highlights the need for new antibiotics to expand therapeutic options. Second-generation fluoroquinolones, such as ciprofloxacin and lomefloxacin, and third-generation agents, such as levofloxacin, offer excellent bone and joint penetration and are active against a broad spectrum of Gram-positive and Gram-negative organisms. Because the blood concentrations of orally and parenterally administered drugs are similar, development of oral treatment protocols for osteomyelitis is pursued after an initial course of parenteral antibiotics. Successful treatment of osteomyelitis correlates best with serum levels of the antibiotic, not the route of administration. The standard recommendation is that the antibiotic used should achieve a serum level eight times greater than its minimum inhibitory concentration. If the serum concentration of an antibiotic is bactericidal, bactericidal levels in bone will almost always be present. 30 Table 136-2 lists common treatment regimens for the variety of bacteria that cause osteomyelitis. The standard recommendation is parenteral antibiotics for 4 to 6 weeks and then an oral course of antibiotics.

Treatment of chronic osteomyelitis is a difficult surgical problem. Instillation of antibiotic-containing beads into infected bone can help eradicate the infection so that bone grafts can be successfully used in chronic osteomyelitis. Hyperbaric oxygen therapy is reported to be effective in treatment of chronic osteomyelitis in noncontrolled clinical case series and may work best in diabetic foot osteomyelitis, although other scenarios are being explored. 36-38

**Disposition of the Patient with Osteomyelitis**

Patients with osteomyelitis are admitted for intravenous antibiotic treatment. A subset of these patients will also need operative débridement. Oral antibiotics that have the same bioavailability as their intravenous forms can be used, and some studies have demonstrated good results with outpatient treatment of osteomyelitis. After steady-state serum antibiotic levels have been achieved, patients can receive outpatient intravenous antibiotic therapy.

**SEPTIC ARTHRITIS**

**Clinical Features**

Septic arthritis is an orthopedic emergency, and the incidence appears to be increasing. Even with prompt recognition and appropriate care with antibiotics and joint decompression, septic arthritis leads to a loss of function in 25 to 50% of patients. 39 In the United States, the incidence of septic arthritis in native joints ranges from 2 to 10 per 100,000; in patients with rheumatoid arthritis, the incidence jumps to 30 to 70 per 100,000. 40

Septic arthritis most commonly results from hematogenous migration of bacteria into a joint. Like osteomyelitis, septic arthritis may also result from spread from a contiguous focus of infection or by direct inoculation of bacteria. Direct inoculation can result from penetrating trauma or iatrogenically as a consequence of invasion of the synovium, such as during joint aspiration or injection. Because the synovial membrane extends beyond the epiphysis and attaches to the metaphysis in the knee, hip, and shoulder joints, infection can easily spread from the metaphysis of the femur or humerus into the joint. This explains why septic arthritis may occur concomitantly with osteomyelitis, with infection spreading from bone to joint, and osteomyelitis may also be the result of septic arthritis. The most commonly isolated organism is *S. aureus*, but joint fluid Gram's stain has a 45 to 71% false-negative rate. 41 It is almost always a monarticular process; polyarticular involvement is present in less than 10% of pediatric cases and less than 20% of adult cases.

Septic arthritis is most likely to occur in the joints of the lower extremity. In infants and children, the knee and hip are most often infected. In adults, the knee is the site of septic arthritis 50% of the time, followed by the hip (25%) and shoulder (15%).

**History and Physical Examination**

Septic arthritis is usually more acute in onset than osteomyelitis. The predominant symptom of septic arthritis is joint pain, exacerbated with range of motion. Many children who have septic arthritis will not use the involved limb at all. 42 If the hip is infected, the patient may present with referred pain to the thigh or knee. Immunosuppressed patients, especially those receiving corticosteroids, may have septic arthritis with minimal joint pain. It is important in obtaining the patient's history to ascertain predisposing factors for septic arthritis. These include underlying joint disease, such as osteoarthritis, gout, rheumatoid arthritis, or joint surgery, and the presence of other conditions, such as chronic systemic diseases, immune deficiency, prolonged steroid use, or a history of injection drug use. In these patients, a careful history may help differentiate chronic joint pain from the acute pain associated with septic arthritis. More than 80% of children and 40% of adults with septic arthritis have a fever on presentation; however, constitutional symptoms such as weakness, malaise, anorexia, nausea, and diffuse myalgias are inconsistently reported.

On physical examination, tachycardia and hypotension may indicate a generalized septic process. Examination of the skin, nose, ears, and pharynx may reveal a focus of infection. In the neonate or infant, there may be “pseudoparalysis” of the affected limb. This can be mistaken for a neurologic problem; however, an isolated true paralysis is far less common than septic arthritis. The inability of a child to bear weight on a lower extremity or to spontaneously move any joint should be considered a sign of septic arthritis, and it should remain on the differential until it is adequately ruled out. 42

In the older child and adult, signs may be more localized. The extremity will usually be held motionless in the position of greatest comfort, which is slight flexion. Palpation of the septic joint will cause exquisite pain, and any maneuver that stretches the synovium, such as flexion and extension, will cause severe pain. The cardinal signs of inflammation—swelling, erythema, and warmth—are commonly found in the infected joint. Joint pain is 80 to 100% sensitive for septic arthritis, and tenderness is 100% sensitive. 43 Periarticular processes such as bursitis, tendinitis, and cellulitis may produce erythema, warmth, and tenderness, but these processes can usually be differentiated from septic arthritis. Palpation of the joint line and maneuvers that stress the synovium and joint are not usually painful in cellulitis. Periarticular processes also do not commonly produce an effusion. In general, the triad of fever (seen in 45 to 60% of cases), pain (seen in 75% of cases), and impaired range of motion suggests septic arthritis. One caveat with the physical examination is that an increasing number of patients are receiving chronic immunosuppressive drugs, and in these patients the classic history and examination findings may be significantly less dramatic than in their immunocompetent counterparts.
Diagnosis Strategies

Joint Aspiration and Joint Fluid Analysis

Blood tests are not consistently helpful in making a diagnosis of septic arthritis. The ESR is elevated in approximately 90% of cases and along with the CRP level can be used to help diagnose the infection and to track resolution. When low thresholds are used in the ED, the sensitivity of ESR is reported to be 98% with a cutoff of ≥20 mm/hr, and the sensitivity of CRP is 92% with a threshold of ≥20 mg/L. Li demonstrated a sensitivity of 96% for an ESR of greater than 30 mm/hr. Procalcitonin is another possible serum marker for septic arthritis, but it is also a nonspecific marker of inflammation and is not likely to provide a definitive diagnosis. Two sets of blood culture specimens should be obtained; however, blood cultures reveal the infecting organism in only 25 to 50% of cases. Serum leukocytosis is both nonspecific and nonsensitive for diagnosis of septic arthritis. Traditionally, a serum WBC count of more than 10,000 cells/mm³ may suggest a systemic illness but is present in only 50% of patients with septic arthritis, and many sterile inflammatory processes create a similar leukocytosis. Cultures of infectious foci, such as the throat, cervix, and urine, may demonstrate the bacteria responsible for septic arthritis.

The diagnosis of septic arthritis requires joint fluid for culture and analysis. It is fortunate that the knee joint is both the most likely to be infected and the easiest to aspirate. Other joints, such as the hip, are more difficult to aspirate, and aspiration usually requires orthopedic surgical consultation. Ultrasonography and fluoroscopy to guide aspiration are adjunct modalities used to obtain fluid from the joint and may be useful in detection of early, less obvious intra-articular fluid collections. However, the absence of sonographic fluid does not rule out septic arthritis as the cause of joint pain. Septic technique should always be practiced; however, the risk of introducing infection into a joint during intra-articular aspiration or injection has been reported to be between 1 in 2000 and 1 in 15,000 injections and seems to be related to the number of precautions taken to avoid it.

Because joint fluid analysis is not done as often as other diagnostic tests in the ED, a joint fluid protocol is useful to ensure that all necessary tests are prepared and ordered properly. Joint fluid cultures must be inoculated as soon as possible after the fluid is obtained. The laboratory should include special media to test for fastidious organisms such as Neisseria gonorrhoeae. Anaerobic and fungal organisms are cultured in patients with risk factors for these infections.

One method that may increase the yield in isolation of bacteria from joint fluid is to inoculate blood culture bottles with joint fluid immediately after joint aspiration. This allows some bacteria, which would normally die before being inoculated on culture media in the laboratory, to survive and grow in the blood culture bottle (brain-heart infusion broth). Synovial Gram's stain results in clinically suspected septic arthritis are negative about a third of the time, probably because the bacteria are usually not in the planktonic state in a joint. This may also be due to an inadequate joint fluid sample, poor culture techniques, presence of fastidious organisms, or misdiagnosis of the joint inflammation. In addition, leukocytes may have cleared bacteria from the joint space; however, the bacteria may still persist in the synovial membrane and may be detected by a synovial biopsy.

The definitive test to determine bacterial arthritis is synovial culture. Other tests of the synovial fluid are commonly performed, but many studies have refuted the efficacy of these additional tests. Gram's stain, synovial WBC count and differential, percentage of polymorphuclear cells, and joint fluid glucose level have traditionally been used to differentiate bacterial arthritis from other joint diseases. The primary reason for the decreasing utility of these common joint fluid tests is the number of patients who have a chronically activated or suppressed immune response in the infected joint. Traditionally, a synovial fluid leukocyte count of more than 50,000 cells/mm³ with a predominance of polymorphuclear leukocytes was used to define septic arthritis, but other processes can produce similar cell counts, and up to 30% of patients with septic arthritis have been documented to have counts below 50,000 cells/mm³.

Many other studies support the idea that a specific range of elevation of the synovial fluid leukocyte count can be reliably used to diagnose septic arthritis. One large study found that for a synovial fluid WBC count higher than 17,500 cells/mm³, the sensitivity was 83% and the specificity was 67%. The positive likelihood ratio at this level was 2.5, with a negative likelihood ratio of 0.25. Another study showed likelihood ratios of 0.32, 2.9, 7.7, and 28 with synovial fluid leukocyte counts of less than 25,000 cells/mm³, more than 25,000 cells/mm³, more than 50,000 cells/mm³, and more than 100,000 cells/mm³, respectively. A synovial fluid leukocyte differential count with at least 90% neutrophils suggests septic arthritis with a likelihood ratio of 3.4; a count of less than 90% decreases the likelihood ratio to 3.4. There is mounting evidence that one cannot rely solely on the synovial fluid leukocyte count either to exclude or to include the diagnosis of septic arthritis and that this value should be used with the clinical, radiographic, and laboratory findings to help guide therapy as Gram's stain and culture results become available.

The examination of synovial fluid under polarizing microscopy for the presence of crystals may be useful in differentiation of inflammatory from noninflammatory joint disease but is not helpful in the separation of infectious inflammatory joint disease from noninfectious inflammatory joint disease as the two often coexist. The identification of crystals should not deter the physician from continuing to search for an infectious etiology of joint pain.

When only a small volume of synovial fluid is recovered from a joint aspiration, the following tests should be performed. The single most important test is a bacterial culture. Culture of the synovial fluid or of synovial tissue itself (obtained by arthrotomy) is the only definitive method for diagnosis of infective arthritis. If extra fluid is available after a culture specimen is obtained, it can be used to obtain Gram's stain and smear and then a cell count and crystal analysis. A positive result of Gram's stain can be used to guide antibiotic treatment; however, empirical treatment should not be delayed if the result is negative as Gram's stain is less than 60% sensitive for detection of bacteria in synovial fluid.

Plain radiography is not an effective tool for the early evaluation of septic arthritis but may detect surrounding osteomyelitis. In most joints, the small areas of attachment of the synovial membrane to bone are devoid of cartilage. These “bare areas” at the margins of the joint appear as lucencies or erosions early in the course of septic arthritis. Bone beneath the articular cartilage may start to erode 1 to 3 weeks into the disease. Air in the joint may be a sign of infection with gas-forming organisms, but it may be the result of a previous joint aspiration. In patients with existing joint disease, radiographs provide minimal assistance in diagnosis of septic arthritis.

Ultrasonography is a useful modality to detect a joint effusion in suspected septic arthritis and to assist in joint aspiration, particularly of the hip (Fig. 136-9). When synovial fluid aspiration from the hip is attempted under fluoroscopy, a small amount of contrast material should be injected into the joint to confirm that the needle has entered the intra-articular space. CT provides better anatomic images of the joint, and MRI is most useful in visualization of the detailed anatomy of joints and can determine if septic arthritis is complicated by concurrent osteomyelitis. Diagnosis of an effusion on a CT or MRI study is done cautiously. Three of these modalities can identify joint fluid, but a volumetric analysis cannot be done to assess the amount of fluid.
In a three-phase 99mTc scan, all three phases will be “hot” with symmetrical areas of increased uptake on both sides of the joint. Other imaging techniques. In septic arthritis, scintigraphy shows scintigraphy is in detection of septic arthritis earlier than with arthritis, but its use is decreasing. The main advantage of skeletal involvement the joint itself and those that are systemic. The introduction of bacterial DNA into a joint triggers a profound immune response that leads to destruction of the articular cartilage. Bacteria, host synovial cells, chondrocytes, neutrophils, and macrophages all release enzymes and inflammatory chemicals such as collagenase, elastase, hyaluronidase, lipase, and lipoproteinase that may be destructive to the joint. Damaged articular cartilage has limited repair capacity, and a common result of articular cartilage destruction is arthritis or ankylosis, which results in a stiff, immobile joint.

Children are at great risk for epiphyseal damage if the infection extends through subchondral bone. This can result in impaired growth and limb-length discrepancy. Other tissues adjacent to the joint can be invaded. Bursae, tendons, ligaments, and muscles can be destroyed by the suppurative process. Sinus tracks may lead the infection out through the skin. In the hip, the pressure and edema of a septic synovial effusion can occlude blood supply, resulting in avascular necrosis of the femoral head, especially in neonates.

Systemic complications from septic arthritis are less common than joint damage, but the hematogenous spread of bacteria from an infected joint can produce sepsis, septic shock, and death. Seeding of other sites with bacteria is also a possibility, and this can produce endocarditis, pneumonia, and abscesses.

Clinical Subsets of Septic Arthritis

Bites

Human mouth flora is polymicrobial with aerobic organisms, such as Staphylococcus; oral Gram-negative rods, such as Eikenella corrodens; and anaerobes, such as Fusobacterium. Therefore, human bites that lead to bone and joint infections can be difficult to treat. Similarly, animal bites also lead to a polymicrobial infection, with Pasteurella multocida an important additional organism. Antibiotics should be empirically started, but treatment also requires drainage and debridement.

Septic Arthritis in Infants and Children

Septic arthritis is more common in children than in adults, and the incidence of septic arthritis is twice that of osteomyelitis in children. Of pediatric cases, two thirds occur in children younger than 2 years, and boys are affected twice as often as girls are. The bacterial etiologic agent of septic arthritis varies with age. In the post–H. influenzae vaccine era, overall, S. aureus (methicillin sensitive more than methicillin resistant) is the most common infecting organism in all pediatric and adult age groups, followed by group A streptococci and Streptococcus pneumoniae. In neonates, group B streptococci, S. aureus, and Gram-negative enteric bacilli are usual pathogens. Candida albicans should also be considered in neonates and premature infants. Kingella kingae is an emerging important cause of septic arthritis and osteomyelitis in children younger than 2 years. In children between 3 months and 5 years, concomitant respiratory infection or otitis media is often present. Prior trauma or skin infection may be more common with staphylococcal septic arthritis.

Even with full culture of joint fluid and blood, a causative organism is not discovered in up to 30% of cases of septic arthritis in children. Prior antibiotic treatment in children decreases the yield on synovial fluid cultures from 80 to 38%. In the pediatric population, the hip and knee have equal rates of infection, each accounting for about one third of infections. If the hip joint is infected, delays to diagnosis lead to higher complication rates, and permanent joint damage is more likely. This is especially true in infants, particularly those who have coexisting septic arthritis and osteomyelitis. Hematogenous osteomyelitis is often associated with septic arthritis of the hip in children. Concurrent osteomyelitis is present in 20% of infants and in almost half of all neonates with septic arthritis.

The Kocher criteria can be used to help identify those children with septic arthritis of the hip. However, the sensitivity of the algorithm has been challenged, and it should be used cautiously. The four criteria are fever (temperature ≥38.5°C), non-weightbearing on the affected side, ESR greater than 40 mm/hr, and peripheral blood WBC count of more than 12,000 cells/mm³ (Table 136-3). Laboratory work, including complete blood count, ESR, and CRP level, are part of the routine evaluation of the limping child but individually do not have adequate sensitivity or specificity to rule in or to rule out the diagnosis; a synovial fluid analysis should also be done if there is any suspicion for septic arthritis.

Gonococcal Septic Arthritis

In the United States, N. gonorrhoeae is the most common cause of septic arthritis in sexually active patients. A person with gonorrhea...
of the urethra, cervix, rectum, or pharynx has a 1 to 3% chance for development of disseminated gonococcal infection (DGI). More than 75% of the cases of DGI occur in women, possibly because of the increased risk of asymptomatic infection in women. DGI is common during pregnancy or after menstruation when the alkaline vaginal environment makes the organisms more resistant to host defenses in the bloodstream and therefore more likely to disseminate.

The classic triad of gonococcal bacteremia is migratory polyarthritides, tenosynovitis, and dermatitis. Asymmetrical polyarthralgia, which may be migratory, is the most common presenting complaint, occurring in two thirds of cases; 25% of patients have monarthralgia. The arthralgia is usually asymmetrical and most frequently involves the knee, although the elbow, wrist, metacarpophalangeal, and ankle joints are also affected. The sacroiliac and sternoclavicular joints may be involved, although these sites are far less common. Tenosynovitis occurs in about 20% of patients with bacteremia, usually in the hands and fingers, and hemorrhagic pustules on the skin are seen 41% of the time. These are scattered, painless, nonpruritic, small (0.5- to 0.75-cm) papules distributed below the neck that can involve the palms and the soles. These papules can turn into pustules on a broad erythematous base with either a necrotic or hemorrhagic center. There are usually fewer than 50 lesions, distinguishing DGI from the rash of meningococcus.

Septic arthritis develops in approximately 40% of patients with DGI. This is usually a monarticular process, although polyarticular arthritis has been reported. The patient will present with classic signs of a septic joint, including a joint effusion, warmth, tenderness, decreased range of motion, and marked erythema. There is usually no clear progression of DGI and polyarthralgias to purulent monarticular arthritis, and many patients are afflicted with dermatitis and tenosynovitis without the development of true arthritis. Some of the strains of N. gonorrhoeae that produce DGI favor the development of tenosynovitis and dermatitis, whereas others favor the development of purulent arthritis.

The diagnosis of gonococcal arthritis is made by synovial fluid culture results; however, gonococci are recovered from synovial fluid in less than 50% of cases. The common finding of sterile joint fluid in DGI, even when mucosal cultures are positive, suggests that the host immune response plays a significant role in the development of purulent arthritis. Joint fluid analysis in gonococcal arthritis reveals some differences in comparison with other types of bacterial arthritis. The synovial fluid WBC count in gonococcal arthritis is often less than 50,000 cells/mm³. Gram’s stains of aspirated joint fluid are positive for bacteria only 25% of the time in gonococcal arthritis, and cultures of the joint fluid are negative in approximately 50% of cases. This may be due to poor culture techniques or because a suppurative reactive process can occur in the joint in DGI even when bacteria are no longer present. When gonococcal arthritis is suspected, cultures of the synovial fluid are plated on prewarmed chocolate agar for the highest yield. To increase the chance of making a firm diagnosis, specimens of the mucosal surfaces for culture of N. gonorrhoeae are obtained as these may be the only places where bacteria are readily recovered. Cultures of the genital tract, pharynx, or rectum will be positive in 80% of cases of gonococcal arthritis.

Gonococcal septic arthritis responds rapidly to antibiotic treatment and unlike other types of bacterial arthritis rarely causes permanent damage to the joint. Patients with gonococcal septic arthritis require hospital admission with antibiotic coverage against the likely pathogens until laboratory results are available. With the rise in fluoroquinolone-resistant gonorrhea, the recommended treatment of gonococcal arthritis is a third-generation cephalosporin, such as ceftriaxone, cefixime, or cefotaxime. Patients are given the first dose intravenously or intramuscularly in the ED and admitted until culture results are available. If the diagnosis of gonococcal arthritis can be definitely established in the ED, patients with reliable follow-up can be treated with an intravenous or intramuscular dose of antibiotics and then sent home with an oral regimen that should be continued for 1 week.

Lyme Arthritis

Lyme disease is the most common tick-borne disease in the United States and is caused by infection with a spirochete, Borrelia burgdorferi. Transmitted by the Ixodes tick, it is an important cause of arthritis in endemic areas and the incidence is on the rise. Lyme disease has been reported in all 50 states, but endemic areas including Maryland, Massachusetts, Minnesota, New Jersey, New York, Pennsylvania, Wisconsin, Connecticut, Delaware, and Rhode Island account for 93% of all cases annually. There is a bimodal distribution, in children aged 5 to 9 years and adults aged 55 to 59 years. Children infected by B. burgdorferi are more likely than adults to have arthritis as the initial manifestation of the disease. Whereas it is important to determine a history of a tick bite, up to 30% of people do not remember being bitten. There are three phases of the infection: early localized, early disseminated, and late.

Arthritis, which is the most distinguishing feature of late-stage Lyme disease, develops in up to 60% of untreated Lyme patients and is manifested months after disease onset. After infection, spirochetes are disseminated and invade synovial joints, resulting in a profound immune response, similar to that seen in bacterial arthritis. Patients with Lyme arthritis present with migratory polyarthralgia involving not only joints but also bursae and tendons. This usually evolves into a monarticular process, although polyarticular processes are reported, and most commonly involves single, large joints. More than 90% of patients report knee inflammation, but other affected joints include the wrist, elbow, ankle, and hip. The Centers for Disease Control and Prevention defines Lyme arthritis as “recurrent, brief attacks (weeks or months) of objective joint swelling in one or a few joints, sometimes followed by chronic arthritis in one or a few joints.”

The rash is often overlooked by patients and is generally not present in patients who have arthritis in the later stage of the disease process. Fever is noted in up to half of all children who have Lyme arthritis. Clinically, the arthritis is similar to other inflammatory processes of the joint and includes warmth, erythema, swelling, and pain on motion of the joints; however, the effusion is usually large and out of proportion to the patient’s complaints. The effusion also generally recurs after aspiration, even when the joint is appropriately treated.
The most widely used test for diagnosis of Lyme disease is the serum antibody titer, including enzyme-linked immunosorbent assay (ELISA) and Western blot testing, but serum testing does not differentiate between acute and past infection. Synovial fluid analysis is also not helpful in distinguishing Lyme arthritis, but it usually reveals an inflammatory process with WBC counts ranging from 500 to 98,000 cells/μL. Arthrocentesis cannot differentiate between bacterial and Lyme arthritis because serologic analysis is similar. Cultures of synovial fluid in Lyme arthritis are usually nondiagnostic. Testing of synovial fluid with ELISA or Western blot methods for Lyme disease is not recommended as no consensus exists on how to interpret these data.

Lyme arthritis can be successfully treated with oral doxycycline, amoxicillin, or cefuroxime for 30 days. If this is unsuccessful, patients can be re-treated with the same oral regimen for another 30 days, or the antibiotic can be changed to intravenous ceftriaxone for 14 to 30 days.

Fortunately, Lyme arthritis has an excellent prognosis. Up to 95% of children remain asymptomatic after a single course of antibiotics; adults may show an increased incidence of persistent joint swelling months to years after initial infection, even after appropriate antibiotics. A small minority of patients have chronic Lyme disease despite appropriate treatment, with symptoms similar to chronic fatigue syndrome.

**Periprosthetic Joint Infections**

Infections occurring after joint replacement are a challenging and dangerous complication of arthroplasty, with rates reported to be 1 to 2% at 2 years postoperatively in native joints and up to 7% in the patients undergoing joint revision. The prosthesis and cement are foreign bodies and are ideal sites for bacterial colonization. The most common infectious agents are *S. epidermidis* (40% of cases), *S. aureus* (20%), and streptococcal species (20%). Risk factors for periprosthetic joint infections have been identified to be rheumatologic disease, preoperative anemia, coagulopathy, diabetes, depression, and socioeconomic status. The most commonly identified organisms are *S. aureus* (methicillin sensitive and methicillin resistant) and *S. epidermidis*. The American Academy of Orthopaedic Surgeons clinical practice guideline summary recommends that patients who present to the ED should initially be stratified to high or low probability for a periprosthetic joint infection. Patients who have received antibiotics within 2 weeks will have a very low yield with intra-articular cultures, even if infection is present. Because of the difficulty in isolation of infectious organisms from the prosthesis, even if it is done intraoperatively, orthopedists generally recommended that antibiotics not be started until after culture specimens are obtained.

**Septic Arthritis in Patients with Existing Joint Disease**

Patients with underlying joint disease are more likely to have septic arthritis than are their counterparts with normal joints. This is especially true for patients with rheumatoid arthritis and crystal-line arthritis. If septic arthritis is suspected, laboratory and radiographic evaluation is of lower yield, and antibiotics are started immediately after synovial fluid is sent as these patients have high mortality. In patients with the crystal arthropathies, neutrophil invasion secondary to septic arthritis also leads to increased precipitation and release of crystals. Therefore, the clinician who discovers crystals on joint fluid aspiration should not abandon the search for an infectious agent. The clinical course is variable. With *S. epidermidis* infections, the course is usually indolent. With *S. aureus*, a more aggressive infection occurs, with more pronounced inflammation, effusion, and systemic symptoms.

**Septic Arthritis in Atypical Joints**

Septic arthritis can be particularly difficult to diagnose and to treat if it occurs in fibrocartilaginous joints, such as the sternoclavicular, acromioclavicular, and sacroiliac joints, and the symphysis pubis. Septic arthritis of the axial skeleton, especially of the sternoclavicular joint, is commonly seen in injection drug users, with *Pseudomonas* a common infecting agent. In patients who do not have other predisposing factors, the most common bacterial causes are *S. aureus* and *S. epidermidis*. The presentation is usually pain and point tenderness over the involved joint. Fever and an elevated ESR are commonly reported, although they are not always present because of the suppressed immune status of the patient. CT and MRI are the preferred imaging techniques and are helpful in diagnosis of septic arthritis in the fibrocartilaginous joints.

**Differential Considerations**

Many disease processes can be confused with septic arthritis. Metaphyseal osteomyelitis may mimic septic arthritis because the adjacent joint may develop an effusion and the two infections can be concurrent. Juvenile rheumatoid arthritis is usually more gradual in onset and produces polyarticular arthritis in children younger than 16 years but may be manifested as a monarticular process that mimics septic arthritis. Toxic or transient synovitis is another inflammatory process in children that can be confused with septic arthritis. It occurs in the 3-month to 6-year age range, usually affects the hip, and is a self-limited disease with no long-term morbidity. It may be more common after upper respiratory infections. Children with transient synovitis have less pain with passive joint motion than do patients with septic arthritis; they do not usually have a fever or appear ill but tend to favor the unaffected leg as in septic arthritis. Diagnostic evaluation typically reveals a normal WBC count and ESR and no radiographic abnormalities. If fluid is needed for analysis, this is usually obtained under ultrasound guidance.

Other diseases of the hip in children that are included in the differential are Legg-Calvé-Perthes disease (avascular necrosis of
the femoral head) and slipped capital femoral epiphysis; however, these processes are not as acutely disabling as septic arthritis is. Rheumatic fever commonly presents with a migrating polyarthritis and may mimic gonococcal bacteremia. Patients with Lyme arthritis are not as debilitated as those with septic arthritis, but in endemic areas, serum antibody titers should be obtained.

In the adult, osteoarthritis, gout, and pseudogout may produce findings on joint examination that are similar to the findings of septic arthritis. Other arthropathies that should be considered in the differential diagnosis of septic arthritis are psoriatic arthritis, arthritis associated with inflammatory bowel disease, ankylosing spondylitis, crystal-induced arthritis, and drug-induced arthritis. Collectively, these are known as the seronegative spondyloarthropathies. Trauma to the joint can produce synovitis and hemorrhosis, which may be mistaken for septic arthritis. In a patient with hemophilia, hemorrhosis causes joint inflammation and destruction, and there may be superimposed infection.

Reactive arthritis has been traditionally considered a sterile inflammatory response to a distant infection. However, recent data suggest that antigens from the infectious trigger are often present in the joint. Several viral and bacterial microorganisms can produce reactive arthritis. The most recognized syndrome is postinfectious reactive arthritis. Some other common organisms to produce reactive arthritis. The most recognized syndrome is post-infectious reactive arthritis. Several viral and bacterial microorganisms can produce reactive arthritis. The most recognized syndrome is post-infectious reactive arthritis. Some other common organisms to cause reactive arthritis are Chlamydia, Salmonella, Shigella, B. burgdorferi (Lyme disease), Yersinia, human T-lymphotropic virus type 1 (HTLV-1), rubella virus, hepatitis B virus, adenoviruses, parvovirus, and Epstein-Barr virus. In reactive arthritis, host factors rather than microbial aggression account for most of the inflammatory process. The pathogenesis of reactive arthritis involves deposition of immune complexes in the joint, persistence of organisms in the joint, and stimulation of the immune system. Strong evidence exists to support a link between the susceptibility to reactive arthritis and the HLA-B27 human leukocyte histocompatibility antigen. Reactive arthritis can usually be distinguished from septic arthritis because it tends to involve multiple joints in a migratory pattern. The inflammatory process is more severe with reactive arthritis. There is less effusion and the joint is not as hot or tender as it is with septic arthritis, and joint fluid cell counts are usually below 50,000 cells/mm³.

Management

Septic arthritis is an orthopedic emergency, and once synovial fluid is obtained, empirical antibiotics should be promptly administered on the basis of Gram's stain results, when possible, if the diagnosis is strongly suspected (Table 136-4). Whereas most joint infections require surgical joint decompression, there are a few instances in which medical management will suffice. As reviewed before, antibiotics alone can adequately treat gonococcal septic arthritis as well as Lyme arthritis.

Unlike in most other infectious emergencies encountered in the ED, when time to antibiotic administration decreases morbidity and mortality, definitive management for most cases of septic arthritis requires surgical intervention and a prolonged course of antibiotics. Therefore, it is more important to obtain synovial fluid for Gram's stain and culture than to start antibiotics as this will guide long-term antibiotic treatment.

The selection of antibiotics for the treatment of septic arthritis is outlined in Table 136-2. In most cases the emergency physician does not know the identity of the causative organism, but treatment should be tailored to the most likely causative agents on the basis of the patient's age and immune status. S. aureus accounts for 44% of cases and remains the predominant pathogen for all age groups. Unless gonococcal arthritis is confirmed, antibiotic selection should always include an antibiotic that has excellent bactericidal activity against S. aureus. Empirical antibiotics that are active against MRSA should be considered but based on the prevalence of this pathogen in the community. Risk factors for MRSA include older age, chronic illness, and health care exposure. Group B streptococci have emerged as invasive pathogens in elders, especially those with diabetes mellitus, cirrhosis, and neurologic diseases. Gonococcal septic arthritis is the most common cause of arthritis in young adults. Penicillin- and fluoroquinolone-resistant strains are becoming more prevalent, and a third-generation cephalosporin is the best choice for gonococcal arthritis. Complete recovery without surgical intervention is the rule in gonococcal arthritis. In elders, Gram-negative septic arthritis is more common, and agents such as the third-generation cephalosporins and aminoglycosides are added to the antistaphylococcal regimen. Establishment of good bactericidal serum levels of antibiotics will ensure that the levels in joint fluid are also bactericidal. In pediatrics, there is some evidence to support the early administration of dexamethasone (0.15 mg/kg every 6 hours for 4 days) to accelerate clinical improvement.

Disposition of the Patient with Septic Arthritis

Any patient thought to have septic arthritis requires joint aspiration. In some cases the initial culture results, Gram's stain, and cell counts make the diagnosis of septic arthritis extremely likely. The patient is given an initial parenteral dose of antibiotics in the ED and admitted for continued management. Consultants will then

Table 136-4  Guidelines for Choice of Empirical Antibiotic Based on Gram's Stain

<table>
<thead>
<tr>
<th>GRAM'S STAIN OR CLINICAL CONDITION</th>
<th>PROBABLE ORGANISMS</th>
<th>PREFERRED ANTIBIOTICS</th>
<th>ALTERNATIVE ANTIBIOTICS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gram-positive cocci</td>
<td>Staphylococcus aureus</td>
<td>Nafcillin or cefazolin</td>
<td>Clindamycin</td>
</tr>
<tr>
<td></td>
<td>Streptococci</td>
<td></td>
<td>Trimethoprim-sulfamethoxazole</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Vancomycin</td>
</tr>
<tr>
<td>Gram-negative cocci or negative stain Healthy, sexually active patient</td>
<td>Neisseria gonorrhoeae</td>
<td>Ceftriaxone</td>
<td>Doxycycline</td>
</tr>
<tr>
<td>Gram-negative bacilli</td>
<td>Pseudomonas aeruginosa</td>
<td>Piperacillin ± gentamicin</td>
<td>Third-generation cephalosporin</td>
</tr>
<tr>
<td></td>
<td>Entrobacteriaceae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gram-positive bacilli</td>
<td>Propionibacterium acnes</td>
<td>Penicillin G</td>
<td>Nafcillin</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Vancomycin</td>
</tr>
</tbody>
</table>

determine the need for further procedures. If Gram's stain of the synovial fluid is negative but the clinical appearance strongly suggests septic arthritis, the patient can be treated with appropriate antibiotics and admitted to the hospital while culture results are awaited. If the joint fluid aspirate is negative but the clinical appearance strongly suggests septic arthritis, the patient is treated with appropriate antibiotics and admitted to the hospital while culture results are awaited. If the joint fluid aspirate is not consistent with septic arthritis and clinical findings are equivocal, the patient can be discharged and reevaluated in 24 hours. In immunosuppressed patients, patients with preexisting joint disease, and patients with joint replacements, septic arthritis can be difficult to detect. A conservative approach with in-hospital observation and treatment should be considered if there is any possibility of septic arthritis in these patients.

The prognosis for the patient with septic arthritis is favorable in most cases. From 50 to 75% of afflicted patients can expect to recover completely and to achieve full, painless range of motion of the afflicted joint. In approximately one third of cases there is decreased mobility or ankylosis, pain on joint movement, chronic infection, or overwhelming sepsis and death. Those patients most likely to do poorly include those who have a delay in diagnosis and treatment, patients with underlying joint disease (especially rheumatoid arthritis), those with polyarticular septic arthritis, and those who have positive blood cultures. Despite many advances in diagnosis and treatment, the overall morbidity for patients with septic arthritis has not decreased in the last two decades. A general rule is that if the diagnosis of septic arthritis is made and treatment is initiated within 1 week of the onset of symptoms, the outcome is almost always favorable. Delays to treatment beyond 1 week of symptoms are associated with worse outcomes. Diagnosis and rapid treatment of septic arthritis prove to be most elusive in two groups of patients: infants and people with existing joint disease. In infants and children, early symptoms can be nonspecific and difficult to assess; consequently, children with septic arthritis, especially of the hip, who experience a delay in diagnosis and treatment have a disappointingly high rate of complications. In patients with existing joint disease, septic arthritis may be mistaken for an acute exacerbation of the underlying disease process, so physicians must remain vigilant in their pursuit of the correct diagnosis.

The references for this chapter can be found online by accessing the accompanying Expert Consult website.


