Appendicular Osteomyelitis in Horses: Etiology, Pathogenesis, and Diagnosis

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ABSTRACT: Osteomyelitis can be caused by trauma in horses of any age or may have a hematogenous origin in foals. Diagnosis of this disease is based on clinical signs, radiographic changes, and laboratory values of protein and inflammatory cells, especially neutrophils. Clinical signs of inflammation may include edema, joint effusion, fever, and pain. Lameness is a variable clinical sign depending on the structures involved in the infection. Radiographic changes are usually diagnostic, but the use of advanced imaging modalities, if available, may also be of significant value.

Osteomyelitis is a bone infection involving the cortical bone and the marrow cavity, whereas osteitis involves only the cortical bone. Osteomyelitis can affect membranous or long bones.\(^1,2\) It typically involves only one bone; however, multiple bones can be simultaneously affected, especially in foals.\(^1,2\) Osteomyelitis of the appendicular skeleton is relatively common in horses of all ages but occurs more frequently in foals.

Hematogenous osteomyelitis occurs as a result of bacteremia with spread to bones and joints and is most common in foals. The infection may be predisposed by trauma, neonatal infections (e.g., omphalophlebitis), or other infections that result in bacteremia. Osteomyelitis after trauma occurs when the infection reaches the bone by direct contamination of open fractures or penetrating wounds or by indirect insult to structures (e.g., tendon sheath, joint, bursae). This type of osteomyelitis may have draining tracts and occurs more...
commonly in adult horses. Iatrogenic infection can occur at any age and may result from a break in aseptic technique during surgical repair of a fracture.\textsuperscript{3–5} Clinical signs of osteomyelitis may include edema, joint effusion, fever, and pain. Lameness is a variable clinical sign depending on the structures involved in the infection. Radiographic changes are usually diagnostic, but positive cultures are needed for an etiologic diagnosis.

The most common sites of osteomyelitis in foals are the medial and lateral femoral condyles, the tibial tarsal condyles, the lateral styloid process of the radius, the distal tibia, the patella, and the metacarpal and metatarsal bones.\textsuperscript{6} The most common sites of osteomyelitis in adult horses are the metacarpal and metatarsal bones and the phalanges.\textsuperscript{3,6}

**Etiology**

Hematogenous osteomyelitis usually results in isolation of a single organism, which is identified as the cause of infection; in posttraumatic osteomyelitis, multiple organisms are usually identified.\textsuperscript{7,8} Omphalophlebitis, gastroenteritis, and pneumonia are the common sources of bacteria for hematogenous osteomyelitis in foals.\textsuperscript{3,6,8,9} Despite this, bacteremia and secondary abscesses may be present without a primary pulmonary or digestive disease.\textsuperscript{10} It is not surprising that enteric gram-negative bacteria are the most frequent isolates from foals with osteomyelitis,\textsuperscript{3,6,9} but *Rhodococcus equi*, a gram-positive respiratory and intestinal bacterium, has also been reported.\textsuperscript{10–12}

In a retrospective study of 235 adult horses with septic arthritis/tenosynovitis ($n = 192$) and osteomyelitis after fracture repair ($n = 41$), a total of 424 bacteria were isolated.\textsuperscript{13} Most of the isolates were aerobic and included Enterobacteriaceae, streptococci, staphylococci, other gram-negative and gram-positive bacteria, and miscellaneous isolates.\textsuperscript{13} In adult horses, *Staphylococcus aureus* was less frequently (11%) isolated than Enterobacteriaceae (23%) or *Streptococcus* species (18%). *Salmonella* species, *Corynebacterium* species, *Pseudomonas* species (7%), and anaerobic bacteria (5%) were reported to be the least frequently isolated.\textsuperscript{14}

Coccidiodomycosis, a fungal disease caused by *Coccidioides immitis* that occurs in the arid and semiarid (lower Sonoran zone) climates of North and South America, has been reported to cause osteomyelitis in horses.\textsuperscript{15} This disease is thought to occur as a result of lymphatic and hematogenous dissemination secondary to inhalation of the organism.\textsuperscript{16} *Halicephalobus deletrix* (formerly *Micronema deletrix*) has been diagnosed by histopathology of tissue obtained at necropsy, but the route of infection was not determined.\textsuperscript{17,18}
PATHOGENESIS

Foals younger than 2 months of age are more susceptible to hematogenous osteomyelitis compared with older horses. The vascular anatomy of the metaphysis may predispose the juvenile bone to this type of infection. Vascular sludging and stasis in the venous sinu-
soids at the chondroosseous epiphyseometaphyseal junction results in low oxygen tension and establishes a suitable environment for osteomyelitis. In cases of septicemia, bacteria travel via the transphyseal vessels to the rest of the bone. Reduced blood perfusion and lowered oxygen tension resulting from soft tissue injury and the presence of bacteria, parasites, or fungi may result in osteomyelitis in foals with compromised passive immunity. In addition, foals have increased blood flow in developing bones and the immature hepatic and renal systems, which slow the elimination of toxic waste products.

The presence of inflammatory mediators, biomaterials, or fracture repair implants may predispose horses to developing osteomyelitis. Injuries disrupt blood supply and lymphatic drainage and impair the local immune response to contaminants. These insults result in thrombosis and accumulation of serum protein and cellular debris within bone, providing an environment conducive to bone necrosis, sequestrum formation, and infection. Bacterial colonization and growth are promoted by formation of an adherent biofilm of fibrous exopolysaccharides (slime) and glycoproteins (glycoca-
lyx) that sequesters bacteria from host defense mechanisms and functions in nutrient trapping. The cell walls of gram-positive bacteria bind to surface fibronectin of the bone. Gram-negative bacteria have less ability to bind with fibronectin; instead, they have pili and fimbriae that enhance the attachment of glycolipids in the bacterial cell membrane to the matrix proteins of the bone. Both gram-positive and gram-negative bacteria have the ability to bind to sialoproteins and hydroxyapatite crystals of damaged bone. Adherent bacteria maintain an environment conducive to their survival through slime production and phenotypic transformation that acts as a barrier against local defenses and prevents antibiotics from diffusing into the infected area.

DIAGNOSIS

Clinical signs, radiographic findings, and bacteriologic cultures are necessary for the diagnosis of hematogenous or posttraumatic bacterial osteomyelitis.

Clinical Signs

In foals, the common clinical signs of osteomyelitis are fever, pain, depression, lethargy, and joint effusion in one or more joints. In a retrospective study of 20 foals with osteomyelitis and septic arthritis of the femoral condyles, lameness was a frequent clinical sign. In adult horses with or without fever and pain, draining tracts were common clinical signs of osteomyelitis. Lameness is a variable finding in adult horses with osteomyelitis. Chronic weight loss, respiratory disease, and musculoskeletal pain were reported in foals and adult horses with a diagnosis of fungal osteomyelitis.

Radiography

Radiography may support the diagnosis of equine osteomyelitis. However, it may be difficult to differentiate between focal osteomyelitis and normal bone remodeling and repair on radiographs. Lysis of bone may not be recognized on radiographs until 30% to 50% of the
mineral from the bone has been removed. Radiographic signs of osteomyelitis may include soft tissue swelling, loss of detail of the cancellous trabeculation, periosteal bone formation, radiolucent areas of bone lysis with sclerotic margins, and the presence of sequestra. In a retrospective study of 18 horses with septic osteitis of the distal phalanx confirmed at surgery, the most common radiographic signs were focal bone lysis, focal and generalized roughening of the bone around the lesion, and widening of the vascular channels. In one report of osteomyelitis and septic arthritis in foals, discrete areas of radiolucency within the subchondral bone without subchondral bone fragmentation were evident on radiographs. Necropsy lesions of the same foals revealed defective subchondral bone, while the articular cartilage remained intact. Excess callus formation may also be recognized in these cases. Primary subacute pyogenic osteomyelitis with well-circumscribed cavity formation (Brodie’s abscess) is more common in humans than in horses. In affected animals with infected implants, radiographic signs may include lysis around the implant and an active periosteal response. Excessive callus formation may also be recognized in these cases. Primary subacute pyogenic osteomyelitis with well-circumscribed cavity formation (Brodie’s abscess) is more common in humans than in horses.

In horses that had bone infection for more than 21 days, radiography was 80% to 90% diagnostic. Serial radiographic examination is effective and is recommended in cases of chronic osteomyelitis (Figure 1). Serial radiographs determine the extent and the stage of the lesion and assess the effectiveness of the treatment of osteomyelitis (Figure 2). Despite the value of radiology for clinical diagnosis of osteomyelitis, it does not provide intimate detail of the pathologic process that is appreciated on thin-section radiography (Figure 3).

**Computed Tomography**

Computed tomography (CT) is a recommended modality for early detection and intervention of osteomyelitis in horses but may be limited to select referral institutions. Compared with radiography, CT is more sensitive for detection of bone destruction. Changes identified on CT images of equine osteomyelitis include hypodense focal lesions with hyperdense zones in the deep subchondral areas. CT images of osteomyelitis lesions appeared larger compared with the same lesions on radiographs, and cavitation of bone that could be identified with CT is not visible on radiographs (Figure 4).

**Magnetic Resonance Imaging**

Magnetic resonance imaging (MRI) is a noninvasive and accurate means of imaging soft tissues and the fluid components of bone. Any change in the hydration of bone may be detected as an increase in signal intensity.

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**Figure 4**—(A) Lateral radiographic projection of the fetlock of a foal demonstrating lysis and sclerosis in the distal metaphysis of the third metacarpal. Endosteal cortical margins were irregular and the epiphyseal-metaphyseal junction had irregular width with some sclerosis and lysis. (B) CT of the fetlock and distal metacarpal. More than 20 axial sections were acquired, and six 5-mm sections recorded in a bone window are presented. The areas of lysis and the changes in the endosteal surface (white arrowheads) were documented with better resolution and detail than was possible on the radiographic images.
MRI is considered “the premier noninvasive imaging method” in humans for evaluating the musculoskeletal system.\textsuperscript{30} Among its most widely recognized and accepted applications is the diagnosis of bone trauma.\textsuperscript{31–34} Preliminary use of MRI for imaging the distal limbs of horses presented for necropsy has documented the potential for detecting anatomic, physiologic, and pathologic information.\textsuperscript{35–40} Although MRI of the early stages of osteomyelitis gives superior conspicuity of the tissue change compared with radiography (Figure 5), it has been used in only some areas as a diagnostic modality on a regular clinical basis for equine lameness and skeletal disease.\textsuperscript{41–43}

Scintigraphy and Ultrasonography

Other imaging techniques that have been used to diagnose osteomyelitis include nuclear scintigraphy and ultrasonography. Scintigraphy is a highly sensitive technique for detecting bone turnover but lacks specificity. In the literature reviewed, ultrasonography was used successfully in only one study.\textsuperscript{44} In 32 horses diagnosed with osteomyelitis, ultrasonography was used to correctly diagnose the disease in 30 horses.\textsuperscript{44} The ultrasonographic signs in these horses included accumulation of fluid adjacent to an irregular bony echo.\textsuperscript{44} Ultrasonography is more useful in diagnosing osteomyelitis of bones with minimal muscle coverage.\textsuperscript{14}

Laboratory Tests

- Laboratory tests such as complete blood cell count and plasma fibrinogen concentration are helpful for diagnosing equine osteomyelitis and may show leukocytosis and increased plasma fibrinogen concentration. However, since these changes appear between 10 to 14 days after infection, they may be considered poor indicators of the infection.\textsuperscript{1,2}

  - **Microbiologic culture and sensitivity** are the most important considerations for the diagnosis and treatment of osteomyelitis. Samples from affected regions should be submitted for aerobic and anaerobic bacteriologic and fungal cultures to identify the causative organism(s).
  - Diagnosis of coccidioidomycosis may be made by means of a precipitin test. A complement fixation titer of 1:8 is confirmatory of the disease.\textsuperscript{15} However, a high percentage of animals in the endemic area are seropositive without disease and a negative test may exclude this diagnosis. Definitive diagnosis of coccidioidomycosis may be made by culture or by direct observation of characteristic fungal spherules from the exudate. This agent is a dangerous pathogen that grows well on regular aerobic bacteriologic culture media. If this disease is suspected, laboratory personnel should be warned.
  - **Antimicrobial susceptibility testing** may be necessary to select an appropriate antimicrobial therapeutic agent.\textsuperscript{3}
  - **Blood culture** of samples taken prior to administration of antimicrobial drugs is also useful in the diagnosis of osteomyelitis, particularly in foals.\textsuperscript{3}

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**Figure 5**—(A) An unusual oblique projection (Pr80-Di,D75L-PIMO) gave the best radiographic visualization of an area of bone lysis (black arrowheads) and sclerosis (black arrow) in the distal metaphysis of the tibia of a foal. Mild soft tissue swelling or joint distention was present. (B) Three T2-weighted MRIs of the tarsus are presented. There was diffuse increased signal intensity in the distal metaphysis and a focal volume of hyperintense signal at the dorsal distal metaphysis that encroached on the physis. This was a focal bone abscess (white arrowheads) with some diffuse inflammation of surrounding bone.
Many foals with hematogenous osteomyelitis have concurrent joint sepsis. **Synovial fluid analysis** of the affected joints in these foals typically reveals an increased protein concentration (~4.5 g/dl) and leukocyte count (~30,000 cells/µl). Bacteria may be seen microscopically, confirming sepsis. Whenever the differential cell count of the synovial fluid is greater than 90% neutrophils, sepsis should be suspected. This is true regardless of the degree of the leukocyte count in the fluid and serves to differentiate the inflammatory response due to infection from that caused by trauma.45,46

**CONCLUSION**

Osteomyelitis, a common disease in horses of all ages, may be treated successfully if detected in an early stage. Criteria for diagnosing equine osteomyelitis include clinical signs, radiographic changes, and positive microbial cultures. Clinical pathology other than cytology is not always useful for diagnosing equine osteomyelitis. MRI and CT may be used in difficult cases and when available in private equine practices and academic institutions. These imaging modalities may detect the early stages of disease and contribute to successful surgical intervention and medical management.

**REFERENCES**


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1. Equine osteomyelitis most commonly involves the
   a. metacarpus and metatarsus.  
   c. carpal bones.  
   b. skull.  
   d. vertebral column.

2. Mechanisms for developing osteomyelitis include
   a. hyperthermia.  
   b. delayed ossification.  
   c. airborne infection.  
   d. hematogenous, traumatic, and iatrogenic origins.

3. The primary cause of osteomyelitis during surgery is
   a. endotracheal tubes.

b. poor hemostasis.

c. a break in aseptic surgical technique.

d. arterial catheterization for direct blood-pressure measurement.

4. The bacterium/bacteria that most frequently cause(s) osteomyelitis in foals is/are
   a. *S. aureus.*  
   b. *Escherichia coli.*  
   c. *Staphylococcus intermedius.*  
   d. *Corynebacterium* species.

5. The major predisposing factor regarding location of hematogenous osteomyelitis in foals is
   a. physeal vascular architecture that favors vascular sludging and bacterial localization.
   b. a high heart rate, which facilitates bacterial disposal.
   c. greater osseous blood flow near articular areas.
   d. lower immunity compared with that of adults.

6. Bone is most susceptible to infection when
   a. orthopedic implants are used and bone necrosis occurs.
   b. drilled.
   c. cancellous bone grafts are used.
   d. polymethyl methacrylate is used to flatten bone plates.

7. Radiographic signs of osteomyelitis include
   a. sequestrum formation, soft tissue swelling, periosteal bone formation, and loss of detail of the cancellous trabeculae.
   b. uniform cortical thickening.
   c. radiolucency with irregular bone lysis.
   d. a and c

8. Most osteomyelitis cases can be diagnosed via
   a. complete blood cell count and chemistry panel.
   b. signalment, clinical signs, and radiographic findings.
   c. body temperature.
   d. ultrasound.

9. Clinical signs of osteomyelitis in adult horses include
   a. lameness.
   b. joint effusion.
   c. lethargy and depression.
   d. draining tracts with or without fever and pain.

10. MRI may be a premier diagnostic tool for equine osteomyelitis because it
    a. is easy to use, which makes it useful for the general practitioner under field conditions.
    b. is more affordable than other diagnostic techniques.
    c. provides early information on the anatomy, physiology, and pathology of the lesion.
    d. none of the above