Clinical Techniques in Equine Practice

Management of Wounds Involving Synovial Structures in Horses

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Wounds involving synovial structures (joints, tendon sheaths or bursae) are very common injuries in horses. Synovial structures of the distal limb (distal to and including the carpus and tarsus) are most commonly involved, although any synovial space can be affected. Acute injuries (<6-8 hours) will usually have synovial contamination of bacteria without a true synovial infection, and if treated promptly will have a very good outcome. More chronic injuries (>6-8 hours) will often have an established synovial infection, and should be treated aggressively to minimize the complications of the secondary infection. The prognosis for horses with more chronic wounds will usually depend on the duration of the infection, the specific synovial structure involved, whether a concurrent osseous or tendon injury is present, and the intended use of the horse. The causative bacteria in synovial wounds can be variable but environmental gram negatives are highly probable, and should be considered when selecting the most appropriate antimicrobial(s) to either prevent or treat these infections. This article discusses the clinical findings, diagnosis, treatment, and prognosis of acute and chronic traumatic wounds that involve synovial structures in horses.

KEYWORDS synovial structures, joints, tendon sheaths, bursae

Synovial infections associated with a laceration or puncture wound can involve any joint, tendon sheath or, bursa in the horse. However, those structures of the distal limb (distal to and including the carpus and tarsus) are most commonly involved. Synovial structures that are often associated with wounds include the navicular bursa, distal and proximal interphalangeal joints, digital tendon sheath, metacarpal/metatarsal phalangeal joint, tarsocrural joint, calcaneal bursa, tarsal sheath, and the carpal joints. These traumatic injuries usually involve only a single synovial structure, but large wounds particularly of the foot region may contaminate multiple synovial structures. If treated appropriately, acute synovial wounds (<6-8 hours) only contaminate the synovial structure without developing a true infection.[1] However, a synovial infection can develop quickly without treatment and any wound affecting a synovial structure greater than 6 to 8 hours old should be considered to have an established synovial infection (chronic injuries). These chronic injuries should be viewed as potentially career limiting as abnormalities secondary to the synovial infection can lead to permanent disabilities in performance horses. In many cases, the severity of these wounds is magnified because of the delay in proper diagnosis and treatment of the infection.

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Synovial infections due to wounds may be monomicrobial or polymicrobial depending on the type of wound, what caused the injury, and the duration of the injury. Most are polymicrobial with environmental bacteria such as Gram-negative enterics, streptococci, and staphylococci commonly associated with these types of infections.[2,3] Although anaerobes and resistant strains of *Staphylococcus aureus* may be identified they are far less common than that seen with bone infections or synovial infections secondary to intraarticular treatment in horses.[4] Culture and sensitivity of the involved synovial cavity is highly recommended because of the variable bacteria that may be contributing to the infection.

Acute Synovial Wounds

Lacerations or puncture wounds into synovial structures often directly introduce bacteria into the synovial space. Initially the synovial structure may only be contaminated with bacteria and provided appropriate treatment is performed at this point, infectious arthritis/tenosynovitis/bursitis may be avoided with minimal to no secondary damage. For this reason, early diagnosis and treatment of open joint, tendon sheath, and bursal injuries is important to successful therapy and returning horses to preinjury athletic performance. In one *clinical* study of open joint injuries, horses treated within 24 hours had a significantly lower chance of developing infectious arthritis and increased chance of survival compared with horses treated after 24 hours.[5] However, of the horses treated within 24 hours, 53% developed

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Figure 1 This young horse had an acute synovial wound in the pastern region that communicated with the digital tendon sheath. The tendon sheath was lavaged and the wound was closed primarily with the horse under general anesthesia. Intrasynovial amikacin and broad spectrum systemic antimicrobials were used to prevent a synovial infection.

infection and only 65% survived suggesting that even earlier intervention of open synovial injuries is needed to increase our success of treatment. An improved prognosis with earlier treatment of synovial wounds was also found in a similar study,[6] but not in a recent study which evaluated horses with septic calcaneal bursitis.[7] In the author's opinion, wounds involving synovial structures that are appropriately treated within 6 to 8 hours of injury rarely develop an established synovial infection (Fig. 1). Two caveats of treating these injuries within this time frame are: (1) early recognition that a synovial structure is involved with the wound, and (2) having horse owners/trainers seek veterinary assistance within this short time frame. Although equine veterinarians have minimal control over the latter we should strive for the earliest possible recognition of synovial involvement.

Clinical Findings and Diagnosis

Horses presented with acute synovial injuries may or may not be lame at the walk depending on the severity of the injury. Clinical signs consistent with synovial infection are uncommon within 6 to 8 hours, but there may be soft tissue swelling, heat and pain associated with the injury itself.[8] Following routine wound exploration and debridement, most wounds in close proximity to joints can be assessed for communication with the joint by injecting sterile fluid into the joint at a site remote from the wound, and observing for fluid exiting the wound.[8,9] If joint effusion is present, arthrocentesis for cytologic examination can be performed at the same time. However, a low white blood cell count and total protein concentration inconsistent with infection at this time does not indicate lack of joint involvement. Injection of fluid into tendon sheaths and bursae is usually more difficult than into joints but still possible, and involvement of these structures can often be determined using contrast radiography or fistulography. Additionally, routine radiographs or ultrasound of the injured site may reveal evidence of gas within the synovial space confirming that the wound entered the synovial space, and will be useful to document if concurrent osteochondral fractures are present.

Treatment

Once synovial involvement is documented, recommended treatment should include parenteral broad spectrum antimicrobials, some form of synovial lavage *or endoscopic exploration*, intrasynovial antimicrobials, wound debridement +/− closure and regional IV perfusion of antimicrobials if possible. The primary goal of these treatments is to prevent the development of a synovial infection, which in the end will usually decrease the overall cost of treatment and greatly improve the outcome. Broad spectrum antimicrobials are recommended for all acute synovial injuries until results of culture and sensitivity are known.[1,8,10] The combination of penicillin and gentamicin is used most commonly but the combinations of penicillin and amikacin, penicillin and ceftiofur and penicillin and enrofloxacin may also be employed. Ampicillin and cephazolin may be substituted for penicillin. With acute synovial injuries, the type of synovial lavage (through-and-through with needles or cannulas or rigid endoscopy) is probably less crucial than with chronic injuries with established synovial infections. However, many wounds with synovial involvement will have foreign material within the synovial cavity that can be visualized and removed best with endoscopy[11] (Fig. 2). Intrasynovial antimicrobials (250-500 mg of amikacin) should be placed into the synovial structure following lavage.[8,10] Regional IV perfusion of antimicrobials is advocated by the author as another effective method to prevent the establishment of a synovial infection (see local antimicrobial therapy below for more details). Regional IV perfusion is recommended over intraosseous delivery because it is less invasive, easier to perform, and achieves comparable synovial fluid and soft tissue concentrations of antimicrobials.[12,13]

Probably the most difficult decision to make in horses with acute synovial injuries is whether to perform primary closure of the wound and synovial structure. Trapping bacteria within the synovial space without appropriate synovial drainage would most likely cause a synovial infection, defeating the primary goal of early treatment of these injuries. However, primary closure of the wound will often greatly decrease the healing time and cost of treatment, and may decrease the likelihood of iatrogenic synovial infections. In many cases the decision to close the wound is a mute point due to the surrounding soft tissue damage, size of the wound or loss of skin. If primary wound closure is possible, it is the author's opinion that it can be performed safely without risking subsequent synovial infection provided that all of the above

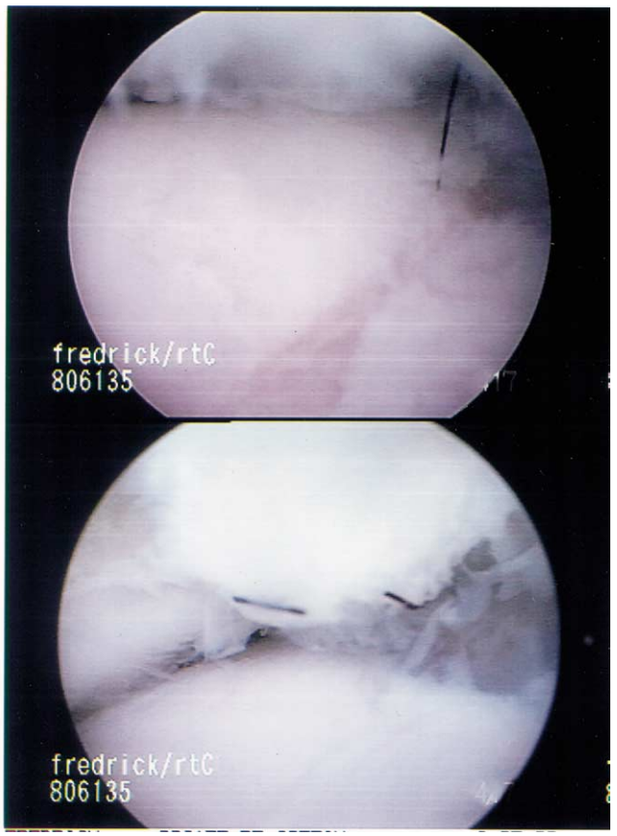

Figure 2 An arthroscopic view of a coffin joint that had sustained a penetrating wound 24 hours earlier. Note the pieces of hair and debris in the joint.

treatment procedures are performed concurrently (parenteral broad spectrum antimicrobials, thorough synovial lavage, intrasynovial antimicrobials, and regional IV perfusion of antimicrobials).[1,11] If in doubt, it is probably best to either use delayed closure or leave the wound to heal by second intention. Delayed primary or secondary closure of the wound may be performed in 2 to 4 days[1] (Fig. 3). This will permit a greater time to reduce/eliminate bacteria from the synovial structure with repeated lavage and the administration of appropriate antimicrobials (intravenously, intrasynovially and with intravascular distal limb perfusion) before wound closure. Although delaying wound repair for a few days will most likely make it more difficult to close due to the formation of granulation tissue and skin retraction, wound closure can usually be accomplished by removing (debulking) the granulation tissue, limited undermining of the skin edges and employment of skin tension suturing techniques.

Chronic Synovial Wounds

Unfortunately, many horses with synovial wounds do not develop signs of infection for several days after injury, delaying veterinary care, referral and appropriate treatment. This time frame often coincides with the wound closing and/or discontinuing antimicrobial therapy. The synovial fluid can no longer drain through the wound resulting in distention of the synovial structure, pain, swelling and lameness. Additionally, the infection becomes trapped within the synovial structure without the benefit of antimicrobial therapy leading to acute signs of synovial infection and prompting further treatment. In general, synovial wounds greater than 6 to 8 hours old (chronic injuries) should be considered to have an established synovial infection and treated accordingly.

Pathogenesis of Infection

The size of the bacterial inoculum required to produce a synovial infection is variable depending on the type and virulence of the bacteria, the specific joint, tendon sheath or bursa involved, the severity of the concurrent soft tissue trauma, and the immune response of the animal.[14] Experimentally, 1.5×10^5 and 1.6×10^6 colony-forming units of *Staphylococcus aureus* were used to cause infection in the tarsocrural joints of normal horses.[15] In a separate study, as few as 33 colony forming units (CFU) of *Staphylococcus aureus* were determined to be a subinfective dose in the middle carpal joint of horses.[16] The results of these studies indicated that a very small bacterial inoculum is capable of causing synovial infections under the right conditions.

On bacterial colonization of the synovial membrane, an inflammatory response ensues to attempt re-sterilization of the synovial structure.[14] The inflammatory cascades promote the release of a multitude of cytokines, proteolytic enzymes,

Figure 3 This chronic synovial wound involved the rear metatarsophalangeal joint. Because of the external appearance of the wound and the joint with arthroscopy, the wound was not closed at the initial surgery. However, because of its location in a high motion area, the wound was closed at a later time to minimize the complications of second intention healing in this location.

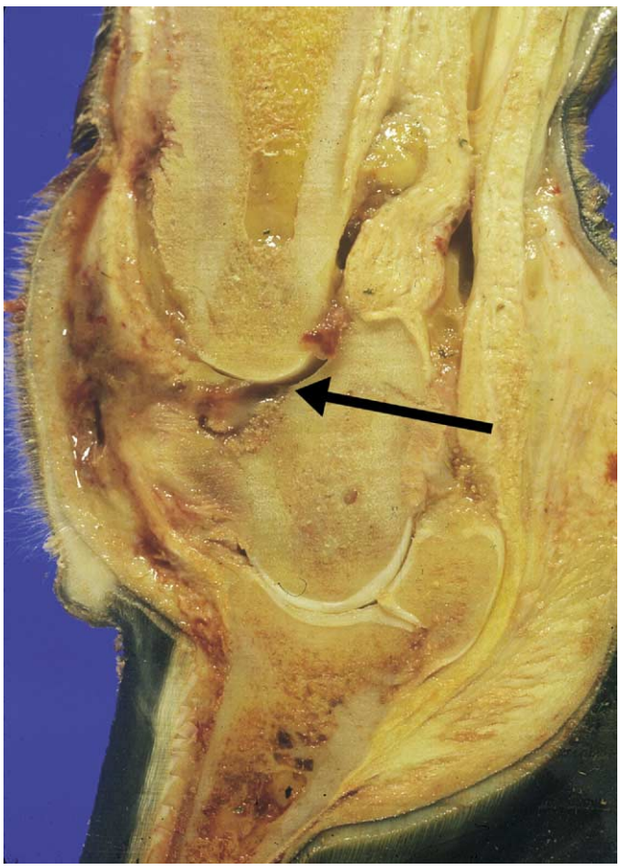

Figure 4 This post mortem sagittal section of the phalanges demonstrates the damage that can occur with chronic infection of the proximal interphalangeal joint secondary to a wound. There was complete loss of the articular cartilage from all joint surfaces and bone lysis was present within the middle phalanx (arrow).

and other inflammatory mediators from a variety of cell types within the joint. These inflammatory mediators serve to increase vascular permeability within the synovium, attract neutrophils and monocytes to the synovial space, degrade hyaluronan within the synovial fluid, and promote the formation of fibrin. Reactive oxygen metabolites and proteolytic enzymes derived from infiltrating neutrophils, chondrocytes, synoviocytes, monocytes, macrophages, and the bacteria themselves may all contribute to the degradation of hyaluronan and depletion of protoeglycans within the articular cartilage observed in infectious arthritis.[17,18] Significant amounts of collagenase and caseinase activity, that were thought to originate from both articular cells and neutrophils, were found in synovial fluid of horses with infectious arthritis.[18]

The longer the duration of the infection, the more likely that permanent damage to the synovial structure will occur. Alterations in synovial fluid usually occur early in the infection, often before clinical signs are present, and can impede synovial membrane function and interfere with chondrocyte nutrition.[14,19] The prolonged inflammatory response in chronic infections can contribute to synovial hyperplasia and hypertrophy, vascular proliferation, thrombosis of synovial vessels, pannus formation, and fibrosis of the joint capsule.[14] Additionally, prolonged infection may contribute to abnormalities in the articular cartilage resulting in the loss of proteoglycans, and exposure of the cartilage to mechanical damage and enzymatic breakdown.[14,17] Irreversible cartilage damage is the end stage of infectious arthritis and contributes to impaired joint function, permanent lameness, and a poor outcome (Fig. 4).

Clinical Findings and Diagnosis

Adult horses with infected synovial structures usually present because of severe (4 - 5/5) lameness. Joint, tendon sheath, or bursal effusion is usually present together with concurrent soft tissue edema, swelling, and heat with severe infections.[8] Most horses usually exhibit severe signs of pain with manipulation and flexion of the affected synovial structure. Those with concurrent open wounds will often have a yellowish to clear, sticky fluid consistent with synovial fluid exiting the wound (Fig. 5). The majority of these wounds are small puncture type wounds located in close proximity to the involved synovial structure.[8,11] Heat and pain with direct pressure are palpable over the involved synovial structure, and synovial fluid can sometimes be expressed through the wound by applying pressure to the opposite side of the joint or tendon sheath. Fever is usually not a consistent clinical finding in adult horses with synovial infections secondary to lacerations, and cannot be used to "rule-out" a possible infection. In one study, approximately 50% of adult horses and foals with synovial infections were febrile at initial examination.[20] However, this study included foals with hematoge-

Figure 5 This small puncture wound on the medial aspect of the calcaneus was draining an abundant quantity of yellowish, sticky fluid, consistent with infection within the calcaneal bursa.

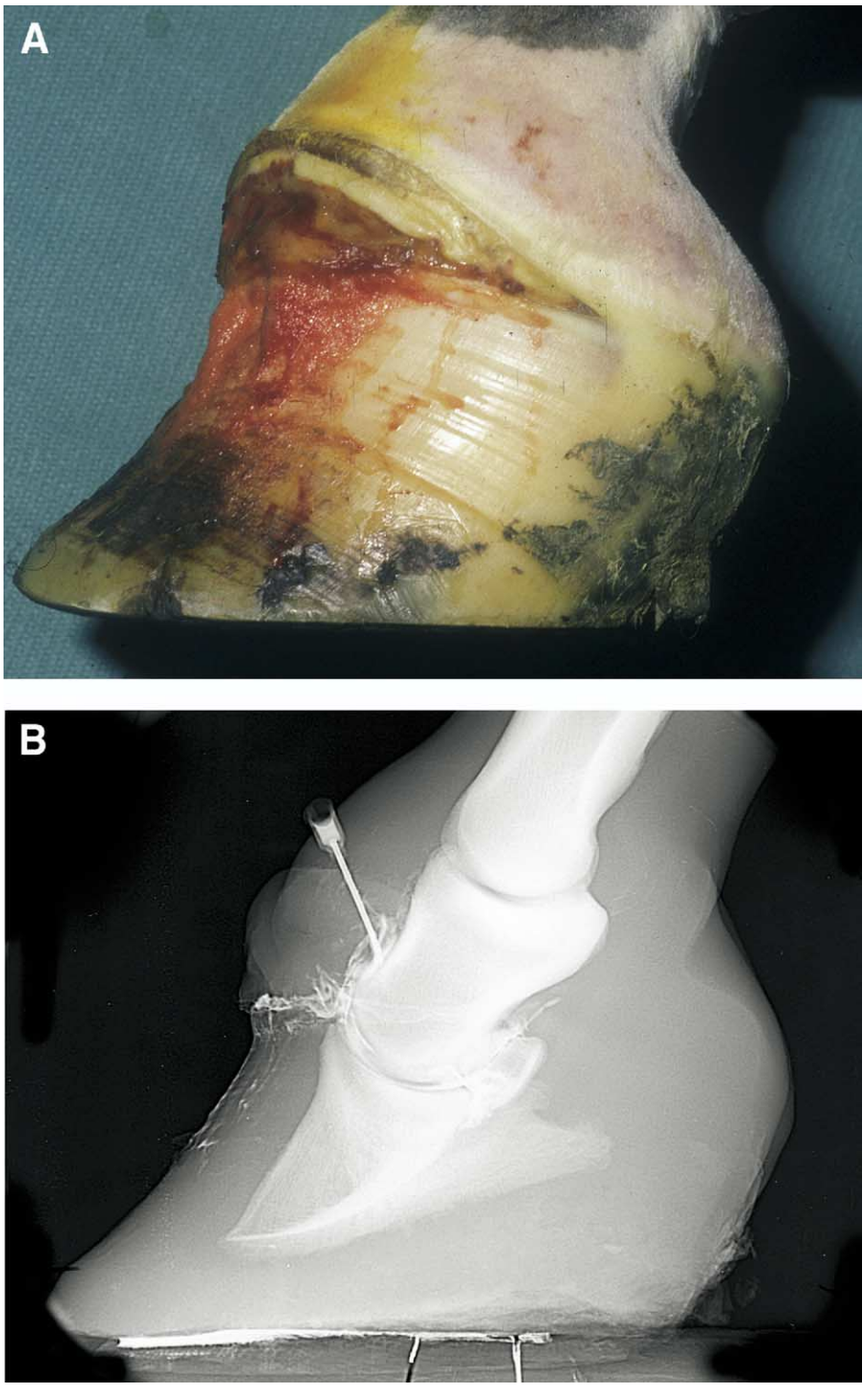

Figure 6 This horse sustained a coronary band injury to the left front hoof (A) that was found to communicate with the distal interphalangeal joint using contrast radiography (B). A sterile cannula was placed into the wound and contrast material was injected while manually closing the external wound opening to keep it from simply exiting the wound.

nous sources of synovial infections which often are febrile, thus overestimating the percentage of horses with synovial wounds that are likely to be febrile.

Methods to document synovial involvement and possible infection in horses with chronic injuries is similar to those with acute wounds. These include injecting sterile fluid into the synovial structure at a site remote from the wound and observing for fluid exiting the wound, arthrocentesis for cytologic examination, total white blood cells and total protein concentration, contrast radiography or fistulography (Fig. 6), or documentation of air within the synovial space using routine radiographs or ultrasound. Radiography is also used in chronic synovial wounds to rule out secondary bone involvement that may be present with chronic infections.[8] Periosteal proliferation, multifocal areas of osteolysis, collapsing joint space with subchondral bone erosion, and periarticular osteophytes may be present depending on the duration of the infection.[21] However, many of these injuries are characterized by soft tissue swelling with the absence of bone abnormalities. Ultrasonography has somewhat limited use in documenting synovial infections, but may be helpful in joints of the upper limb where radiography and palpation have limited diagnostic capabilities.

Cytologic evaluation of synovial fluid is considered to be critical in the diagnosis of synovial infections. Synovial fluid white blood cell counts >30,000 cells/μl and total protein

concentrations >3.5 to 4.0 g/dL are considered to be highly consistent with infection.[8,9] Many synovial infections have white blood cell counts >100,000 cells/μl in synovial fluid, and the severity of the clinical signs often correlates with the white blood cell count. Infections within tendon sheaths and bursae may result in more variable changes in synovial fluid white blood cell and total protein values (generally lower than in joints),[24] but still fall into the previously stated guidelines (average values of 34,750 cells/μl and 5.0 g/dL total protein in one study of infectious tenosynovitis).[20,22] In one study of synovial infections, the average white blood cell count and total protein concentration were 76,500 cells/μl (range 1100-380,000) and 5 g/dL (range 2.5-9.8) respectively.[20] In this study there were no significant differences in these parameters between joint and tendon sheath infections. The majority of the white blood cells were neutrophils (average was 83.7%), and bacteria were observed on direct smears of the fluid in 24% of the samples.[20]

Identification of the causative organism(s) is extremely helpful in the management of synovial infections. Positive cultures and sensitivity patterns not only direct antimicrobial therapy but may also help determine the chance for successful therapy. Infections caused by highly resistant and virulent bacteria are usually more difficult to treat than those associated with more commonly isolated bacteria. Direct culturing of synovial fluid has been commonly performed with variable results. Culturing the synovial membrane has been previously advocated to increase the probability of obtaining a positive culture. However, a clinical study in horses and an experimental study in dogs have both found that synovial fluid yielded more positive cultures than did synovial membrane.[23,24] It is considered beneficial to place synovial fluid into blood culture media for 24 hours to increase the probability of bacterial isolation.[24] In a study in dogs, synovial fluid incubated in blood culture media was significantly more reliable in growing bacteria than was direct culturing of synovial fluid and synovial membrane biopsies.[24] In addition, Gram staining can provide early information as to the cause of the infection (especially with anaerobic bacteria),[4] and the results of the Gram stain correlate well with the eventually cultured organism(s).[23,25] Several studies have reported better than a 70% chance of identifying the causative organism in synovial infections.[20,22,23] With wounds that involve synovial structures, the likelihood of having a positive culture may vary widely depending on the duration of the injury. In acute injuries (<6-8 hours), identifying bacteria within synovial fluid would be less likely than in more chronic injuries where a true synovial infection has become established. Isolation of bacteria in synovial infections should be possible in many horses with wounds, but a negative culture does not preclude synovial contamination or infection.

Treatment

Systemic Antimicrobials

Systemic antimicrobials are the cornerstone of therapy for synovial infections in horses. In an experimental infectious arthritis study, increasing the dose of antimicrobials from once daily to twice daily, regardless of the method of joint drainage, significantly decreased the isolation rate of *S. aureus* at the end of the study.[15] Increasing the dose of antimicrobials was the only treatment that significantly decreased the number of positive cultures at the end of the study.[15] However, systemic antimicrobials are rarely used alone to treat horses with severe or chronic synovial infections. Broad spectrum antimicrobials are recommended for all chronic synovial injuries until results of culture and sensitivity are known. The combination of penicillin and gentamicin is used most commonly but the combinations of penicillin and amikacin, penicillin and ceftiofur and penicillin and enrofloxacin may also be employed. First generation cephalosporins may be substituted for penicillin in some cases but the added expense of these antimicrobials limits their use in horses. Despite their low cost and ease of administration, trimethoprim–sulfonamides should not be used routinely to treat horses with chronic synovial injuries until culture and susceptibility results are known because of the high bacterial resistance to this drug.[2] Oral trimethoprim-sulfonamides are often used as follow-up therapy after the infection has been controlled with parenteral antimicrobials.[8,25] Parenteral antimicrobials administered IV, in most cases, are recommended for a minimum of 7 to 10 days before changing to an oral drug. Antimicrobials are usually continued for approximately 2 to 4 weeks depending on the severity of the infection, the response to therapy, and the specific lavage/drainage technique(s) employed.[9,26,27]

Other antimicrobials that are used less frequently to treat horses with synovial wounds include metronidazole, rifampin, enrofloxacin, vancomycin and tobramycin. Metronidazole is indicated for anaerobic infections that are resistant to penicillin.[4] Rifampin may be beneficial in treating staphylococcal infections, but should always be combined with another drug to decrease the development of resistance.[25] Rifampin and erythromycin are recommended for rhodococcus infections.[25] Enrofloxacin is a fluoroquinolone antimicrobial that has a very broad spectrum of activity and is useful in the treatment of aminoglycoside-resistant Gram-negative bacteria.[28] Enrofloxacin may cause articular cartilage damage in young animals and, therefore, should probably not be used in foals.[28] Vancomycin and tobramycin are rarely used parenterally because of the expense but may be beneficial to treat refractory infections through local delivery.[10,29]

Intrasynovial Antimicrobials

In recent years, intrasynovial antimicrobials have become widely used to treat infectious synovitis. Initial studies which evaluated intraarticularly administered gentamicin (150 mg) demonstrated that the synovial fluid concentration of gentamicin remained well above the MIC values for many common equine bacterial pathogens for 24 hours after intraarticular injection, and the use of intraarticular gentamicin significantly reduced the isolation of *E. coli* from known infected joints when compared with intraarticular buffered gentamicin or IV gentamicin.[30,31] These were the first studies to suggest that the use of unbuffered gentamicin may be beneficial in treating horses with synovial infections. Currently, the use of intraarticular antimicrobials is considered a vital adjunctive treatment for synovial infections in horses. However, because of its increased spectrum of activity amikacin (250-500 mg) has replaced gentamicin as the preferred intraarticular antimicrobial.[8,10,20] Other antimicrobials that may be used intraarticularly (depending on the bacteria involved)

include gentamicin (200-500 mg), cefazolin (500 mg), penicillin (2-5 × 10^6 IU), and ceftiofur (500 mg).[8,10,20] Antimicrobials used less frequently intraarticularly include Timentin (ticarcillin–clavulonic acid), methicillin, oxacillin, and imipenem–cilastatin.[10] The dose and frequency of administration of these antimicrobials is empirical but should probably not exceed a single systemic dose of the drug and should not be repeated more than every 24 hours[9,10] If repeated intraarticular antimicrobials are considered necessary the author prefers an every other day treatment regimen.

Synovial Lavage/Drainage

Methods of synovial lavage/drainage include through and through lavage, endoscopy with or without synovectomy, arthrotomy, closed suction drainage, and either passive or active egress drainage. Passive or egress lavage/drainage is used rarely by the author and will not be discussed. The goals of synovial lavage/drainage are to remove potentially damaging inflammatory mediators, foreign material and bacteria from the synovial cavity, to debride osseous lesions if present, and to decrease intrasynovial distention and pain. The method(s) used depend(s) on the characteristics of the infection (location, presence of an open wound, duration, severity, etc.), the value of the horse, and clinician preferences. However, one single method of synovial drainage may not be used universally, and each case should be evaluated individually as to the most appropriate method of synovial lavage/drainage. Regardless of the drainage technique used, it should be combined with appropriate systemic, intrasynovial, and local antimicrobial therapy to achieve the best success.

Through and through lavage/drainage. Through and through lavage is the most commonly used, easiest, and least expensive method to drain synovial structures.[8] It is most appropriate for acute and less severe infections where abundant fibrin deposition is not present. Most synovial structures can be lavaged adequately using large needles (14-gauge),[27] but a more thorough lavage can be accomplished using ingress and egress arthroscopic cannulas (without attaching the camera).[1,8] The disadvantages of through and through lavage are the inability to assess articular cartilage damage, debride osseous lesions if present, remove fibrin and or foreign material, and thoroughly lavage the entire synovial structure. Needle lavage is usually not appropriate or successful in chronic or severe synovial infections where fibrin and foreign material are likely to be present within the synovial space.

Closed suction lavage/drainage. Closed suction drainage for the treatment of infectious arthritis of the tarsocrural joint has been reported in the horse.[26] Fenestrated, latex drains (Jackson-Pratt Hubless, American Hospital Supply Co., Chicago, IL) were placed through the dorsal aspect of the joint and tunneled subcutaneously proximal to the joint following arthroscopic exploration and partial synovectomy. The drains were attached to 60-mL syringes that maintained constant negative pressure within the joint, serving to keep the joint decompressed. Closed suction drainage can also be used in the stifle, carpus and fetlock joints, and in the digital flexor tendon sheath, but drains function poorly in smaller joint cavities.[27] Concurrent use of ingress drains to lavage fluid into a synovial structure is not recommended because of the potential to develop superinfection of the synovial cavity.[26] However, the author has used a single ingress–egress drain (single drain to lavage through the synovial space) to successfully treat synovial infections of tendon sheaths and bursae secondary to wounds in several horses without the development of superinfection. The advantages of closed suction drainage include: the removal of damaging enzymes and bacteria from the synovial space, maintenance of synovial decompression, and the ability to close synovial lacerations at the initial surgery. The disadvantages include the technical difficulties of managing the drains, the risk of secondary infections, and the relatively short duration of synovial drainage. This technique is currently used rarely by the author.

Endoscopic lavage/drainage. Endoscopic lavage of infected synovial cavities has essentially replaced through and through needle lavage in severe and chronic synovial infections.[8,11] However, endoscopy may not be possible in all open joint/tendon sheath/bursae injuries because the size of the wound may preclude adequate synovial distention. Endoscopy permits more thorough lavage, identification and removal of foreign material and fibrin, debridement of osseous or tendinous lesions if present, assessment of cartilage and osseous damage, and performance of a synovectomy if needed.[8,11] Endoscopy also aids the clinician in determining the severity of the infection and thus the prognosis based on abnormalities within the synovial structure. Endoscopic exploration of all aspects of the synovial space (dorsal and palmar/plantar/caudal synovial pouches) should be performed to maximize the benefit of the procedure. Partial synovectomy does not need to be performed in all cases, and its benefit may be overrated.[27] The decision to perform a synovectomy should be based on the duration of the infection and the appearance of the synovium at the time of endoscopy. In general, a synovectomy may be warranted with synovial infections of >7-day duration combined with hyperemic and proliferative synovium visible endoscopically. Endoscopic lavage and debridement is the preferred approach in all horses with wounds with synovial involvement but especially in wounds greater than 24 hours old.[1,11] In addition, endoscopy of the navicular bursa is recommended by the author over the more invasive "street nail" procedure to manage wounds involving the navicular bursa.[32]

Arthrotomy/ventral drainage. Following synovial lavage, continued synovial drainage after surgery may be beneficial in some horses with chronic synovial wounds. However, in a recent study of horses with contaminated or infected synovial cavities, the majority of the wounds were closed at the time of endoscopy with very good results. Postoperative synovial drainage can usually be accomplished by leaving the wound to heal by second intention, partial closure of the wound, or enlarging the wound if it is very small. However, if the wound is located in a region that would not provide drainage, a separate incision in the most dependent aspect of the synovial structure may be necessary. Alternatively, endoscopic portals may be enlarged to provide continued drainage. In one experimental study, the use of a tarsocrural joint arthrotomy was more effective in eliminating joint infection than arthroscopy and partial synovectomy, but was associated with a higher risk of ascending contamination of the joint and

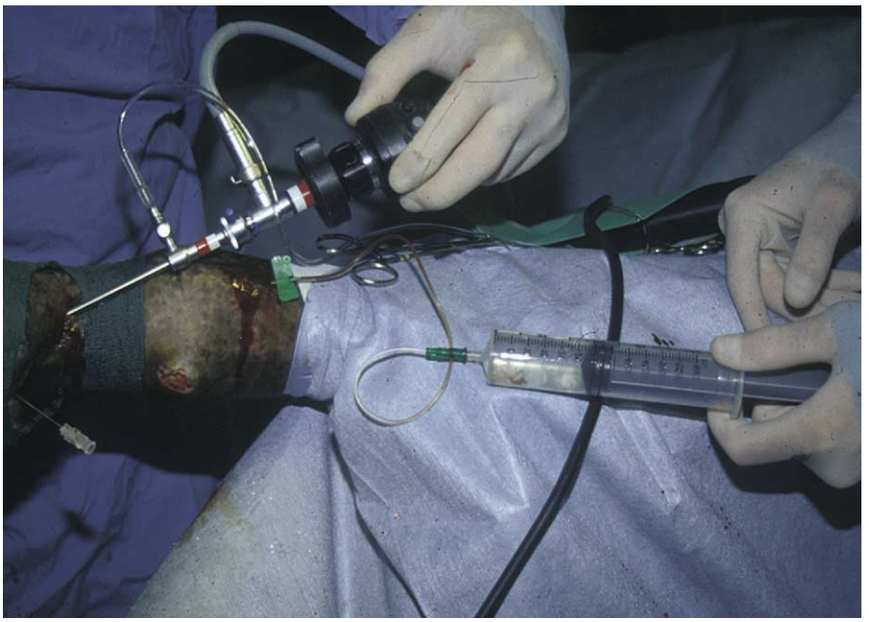

Figure 7 This intraoperative photograph demonstrates IV regional limb perfusion using a butterfly catheter and 60 mL syringe. The lateral palmar vein in the abaxial sesamoid region is the preferred site by the author to perform distal limb perfusion. Endoscopy of the navicular bursa was also performed in this horse.

wound healing complications.[15,33] In a clinical study, very good success was reported using open drainage of joint and tendon sheath infections with minimal problems with wound healing or secondary infections.[34] The decision of whether to provide additional drainage in horses with chronic synovial wounds will depend on the location of the original wound, and the duration and severity of the infection. In most cases, additional drainage of the synovial cavity is unnecessary provided that a thorough endoscopic lavage and exploration has been performed, and that systemic, intrasynovial, and local antimicrobial therapies have all been employed.[11]

Local Antimicrobial Therapy

Additional methods to deliver high concentrations of antimicrobials locally to synovial and bone infections in horses include IV and intraosseous regional limb perfusion and antimicrobial impregnated polymethylmethacrylate (PMMA) or biodegradable polymers. Any of these methods may be used to treat synovial infections, but IV regional perfusion of antimicrobials is preferred by the author because it is easier to perform, less invasive and equally effective compared with intraosseous antimicrobial perfusion. Regional IV antimicrobial perfusion is recommended in all horses with wounds that involve a synovial structure either to prevent the development of synovial infection in acute injuries or to treat an established synovial infection in horses with chronic wounds.

Regional limb perfusion. This technique involves infusion of antimicrobials into either a superficial vein or the medullary cavity of bone to obtain high concentrations of the drug within the selected bone, soft tissues, and/or synovial structure.[12,13,35-38] In the initial studies, 1 g of gentamicin was diluted with sterile fluid to approximately a 60 mL volume, and this was infused into the medullary cavity of the metacarpus over a 30-minute period.[35, 36] High concentrations of the drug (100 times that of serum) were found in the synovial fluid and membrane of the antebrachiocarpal joint, and it appeared that intraosseous bone perfusion was more effective at eliminating infection (based on bacterial cultures) from the joint than was gentamicin given IV. Several additional studies have confirmed that regional IV or intraosseous perfusion of gentamicin and amikacin results in high concentrations of drug within the synovial fluid and bone of the perfused site.[12,37,38] One study documented significantly greater synovial fluid concentrations of amikacin within the tarsocrural joint following IV regional perfusion compared with intraosseous perfusion.[12] The dose of antimicrobial used for regional perfusion is empirical but generally up to one systemic dose of the antimicrobial is diluted to a volume of 30 to 60 mL. However, in most cases the total dose of antimicrobial should not exceed 1 g and less than this may be equally effective.[8,10] Amikacin (0.5-1 g) is used most commonly by the author but any concentration-dependent bactericidal antimicrobial may be used (gentamicin, ceftiofur, penicillin, cefazolin, etc.). A bored out 4.5- or 5.5-mm bone screw with a luer-lock head and a small syringe simplify the intraosseous perfusion procedure compared with the more complicated instruments used in the initial studies.[8,37] However, IV perfusion of antimicrobials into a superficial vein has potentially superior efficacy to intraosseous perfusion and can be performed with minimal instrumentation (19-gauge butterfly catheter and 60 mL syringe (Fig. 7).[8] With both procedures, a tourniquet is placed above the site of perfusion in the distal limb, or both above and below the proposed perfusion site if it is located more proximally in the limb such as the carpus or tarsus. The tourniquet is maintained for 20-30 minutes to prevent systemic absorption of the drug, thus maximizing local tissue concentrations. For more information regarding the techniques for limb perfusion the reader is referred to Orsini's article: "Management of severely infected wounds in the equine patient" in this issue.

Antimicrobial impregnated PMMA. The use of antimicrobial impregnated PMMA (Surgical Simplex P, Howmedica, Rutherford, NJ) has been advocated for the prevention and treatment of synovial and bone infections in horses. PMMA is

a high density plastic formed by combining a fluid monomer and powdered polymer; when an antimicrobial is added, it becomes suspended in the cement as it hardens.[29,39] The cement can be placed into the surgical wound while still doughy, such as is done with plate luting or hip arthroplasties, or PMMA can be shaped into beads that are strung on a wire or piece of suture material or shaped into larger cylindrical implants.[10,29] The cement is allowed to harden and the implants are placed into the wound. The antimicrobials are released from the PMMA by diffusion since the tissue fluids surrounding the PMMA implant create a concentration gradient for elution of the antimicrobial from the implant. Elution is bimodal with the greatest quantity released during the first few days, and then gradually decreases.[29] The specific elution rates are dependent on the antimicrobial, the dose used, and the characteristics of the wound.[35]

The primary advantage of antimicrobial impregnated PMMA is the prolonged release of high, local concentrations of antimicrobials (up to 200 times that achieved through systemic administration) at the site of infection.[29] In horses, expensive, highly effective antimicrobials (such as amikacin, tobramycin, and cefazolin) can be used locally without the need for systemic administration. Antimicrobials used with PMMA should be bactericidal, heat stable, and available in powdered form if possible.[29] Gentamicin, tobramycin, amikacin and cefazolin are the most common antimicrobials incorporated into PMMA, but penicillin, metronidazole, and ceftiofur may also be used.[8,10,29,40] Most antimicrobials are mixed in a quantity of 1 to 2 g for every 10 to 20 g of PMMA cement.[10,29]

To achieve the greatest drug concentration and thus the greatest success with antimicrobial impregnated PMMA, wound closure is considered necessary by some human surgeons.[41] Additionally, irrigation–suction drainage should not be employed since the irrigation fluid will wash away the high concentrations of antimicrobials.[41] The PMMA is usually removed in humans, but is not necessary in all cases in horses.[10,29] Biodegradable polymers (polylactic acid, plaster of Paris, collagen sponge) are being investigated for local antimicrobial delivery and their use may avoid some of the potential problems associated with the nonabsorbable PMMA polymer.[3,42,43]

In horses, antimicrobial impregnated PMMA may be most effective at treating soft tissue infections associated with open fractures or as a preventative for osteomyelitis and implant infection in long bone fractures.[10,29] Antimicrobial impregnated PMMA is not used routinely in horses with chronic synovial wounds unless other methods have failed to resolve the infection or if highly resistant bacteria have been isolated from the wound or synovial cavity (Fig. 8). The author has not placed PMMA beads within high motion synovial cavities as has been reported because of the risk of iatrogenic damage to the articular cartilage and synovium that these beads have been reported to cause.[44]

Figure 8 This dorsopalmar radiograph demonstrates the presence of amikacin impregnated PMMA beads within a soft tissue wound that communicated with the palmar aspect of proximal interphalangeal joint. A highly resistant *Enterobacter* species sensitive only to amikacin and enrofloxacin was cultured from the wound and joint in this horse.

Adjunctive Therapy

Nonsteroidal Antiinflammatory Drugs (NSAIDs)

The antiinflammatory and analgesic benefits of NSAID in horses with acute or chronic synovial injuries greatly outweigh the potential risks of these drugs. Phenylbutazone, the most commonly used NSAID, decreases the production of inflammatory mediators, particularly prostaglandin E_2, preventing articular cartilage damage and joint pain.[8,9] The analgesic effects of NSAIDs help improve ambulation and joint motion, thereby improving articular cartilage nutrition and inhibiting periarticular fibrosis. Additionally, maintaining movement within tendon sheaths and bursae is considered beneficial to prevent fibrous adhesion formation between the tendons and the synovium. Phenylbutazone is most commonly used at 4.4 mg/kg orally every 12 hours initially, and then is gradually decreased as the clinical signs improve. In the author's opinion, the risk of phenylbutazone or any other NSAID complicating the clinical assessment of a patient with a diagnosed synovial infection is minimal.

Local and Systemic Synovial Therapy

The use of intrasynovial medications to help treat synovial infections in horses is controversial. However, these drugs are probably of little benefit in the early postoperative period. Corticosteroids and PSGAG have been associated with an increased risk of infection after intrasynovial injection[16] and, therefore, may worsen the infectious process. Although intrasynovial hyaluronan has antiinflammatory effects that may be beneficial during the early treatment of infection, the inflammatory response present within most infected synovial structures may degrade the drug before it can exert its beneficial effects. In horses with persistent synovial inflammation, corticosteroids alone or combined with hyaluronan may be

used as a local antiinflammatory agent with minimal risk after the infection has been resolved.

Intravenous hyaluronan may be the most beneficial adjunctive medication to use with synovial infections. The IV route of administration eliminates the potential complications of intrasynovial use while helping to decrease the inflammation within the synovium early in the course of treatment.[45] Similarly, IM PSGAG has been shown to decrease synovial fluid white blood cell counts and total protein concentrations after arthroscopic surgery,[46] and may also help decrease the inflammatory response in infected synovial structures. However, there is no objective information documenting the benefits of either of these drugs in treating synovial infections in horses.

Rest and Physical Therapy

In most cases, horses with synovial wounds will benefit from stall confinement. Confinement is also necessary to minimize damage to the less resilient articular cartilage in infected joints. External coaptation using bandages, bandages and splints or casts is necessary to decrease soft tissue swelling, edema, and pain, and to immobilize the wound. The duration of the confinement will be variable depending on the location of the wound, the synovial structure that is involved and the severity of the synovial infection if present. In general, it appears that passive motion and other forms of physical therapy are begun earlier postoperatively, and are used more aggressively in people than in horses. Passive manipulation of affected joints has been recommended after surgery in horses to reduce adhesion formation and prevent periarticular fibrosis, and hand walking is thought to reduce the risk of adhesion formation within damaged tendon sheaths and bursae. More aggressive forms of physical therapy may be beneficial in horses with synovial wounds to help improve the success of treatment.

Prognosis

Factors that are likely to affect the prognosis of horses with acute and chronic synovial wounds include the intended use of the horse, the specific synovial structure(s) involved, the duration of the infection before treatment, and whether a concurrent osseous or tendinous lesion was present.[7,8,11,32] In general, the quicker synovial involvement can be identified and treated, the better the prognosis. Additionally, the ab-

prove the prognosis regardless of the location of the injury.[7,8,11] Early studies of horses with synovial wounds and infections reported survival rates ranging from 54 to 85%.[5,20,22,26] The percentage of horses returning to performance following treatment of synovial infections ranged from 33 to 77%.[5,20,22,26] In a recent retrospective case series of 121 horses with contaminated or infected synovial cavities treated with endoscopy, 90% of the horses survived and 81% of the horses returned to performance.[11] A recent study evaluating septic calcaneal bursitis in horses, reported a 67% survival with 81% of those horses returning to full performance.[7] Horses with wounds involving the navicular bursa and distal interphalangeal joint remain a difficult challenge to return to performance.[32,47] However, 10 of 16 horses with septic navicular bursitis returned to performance following endoscopic lavage and debridement. Based on the results of these recent studies and the clinical impression of the author, early endoscopic lavage of synovial wounds combined with systemic, intrasynovial and IV regional perfusion of antimicrobials has increased our ability to successfully treat the majority of these horses.

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