Evaluation of a balloon constant rate infusion system for treatment of septic arthritis, septic tenosynovitis, and contaminated synovial wounds: 23 cases (2002–2005)

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**Objective**—To determine clinical findings and outcome in horses treated by means of a balloon constant rate infusion system.

**Design**—Retrospective case series.

**Animals**—23 horses.

**Procedures**—Medical records of horses examined at The Ohio State University veterinary teaching hospital from 2002 to 2005 that had septic arthritis, septic tenosynovitis, or penetration of a synovial structure and in which treatment involved a balloon constant rate infusion system were searched. Information pertaining to signalment, history, physical examination findings, clinicopathologic data, treatment, and duration of hospitalization was recorded.

**Results**—Mean ± SD duration of hospitalization was 11.5 ± 5.26 days. No correlation between duration of clinical signs and duration of hospitalization or duration of infusion pump use was detected, but correlations between WBC count and duration of hospitalization and WBC and duration of infusion-pump use were observed. All horses survived to discharge. Follow-up information was obtained on 17 horses, 16 of which were alive at the time of follow-up. Twelve of 13 horses for which follow-up information was available for at least 5 months were alive 5 months or longer after discharge. Thirteen of the 16 horses alive at follow-up were reported by owners as not lame, whereas the remaining 3 were mildly lame or intermittently moderately lame or had developed angular limb deformity in the contralateral limb.

**Conclusions and Clinical Relevance**—Balloon constant rate infusion systems may be used effectively in treatment of septic arthritis, septic tenosynovitis, and contaminated synovial wounds. Clinical response and long-term outcome appeared to be comparable to results obtained with other techniques. (J Am Vet Med Assoc 2006;228:1930–1934)

**Abbreviations**

NSAID Nonsteroidal antiinflammatory drug

**Infective synovitis and arthritis are common and serious medical problems affecting horses.**1–7 Damage to cartilage and synovium may lead to development of osteoarthritis, adhesions between the synovium and tendons, or fibrosis of the joint capsule or tendon sheath.1–7 Chronic lameness or debilitation, sometimes necessitating euthanasia, are potential sequelae if synovial infections are not prevented or appropriately treated.

Treatments for septic arthritis and tenosynovitis include administration of systemically active antimicrobials, locally administered antimicrobials, and lavage with large volumes of isotonic fluids of neutral pH.2–5,28 Lavage may be accomplished through percutaneously placed large-bore needles, through an arthroscopy or tenoscopy procedure.2,7,9,13,17–21 Administration of systemically active antimicrobials alone is rarely effective in eliminating synovial infections.11 Methods of improving delivery of antimicrobials to synovial structures have been described9–12,14,24,25–28 and include intermittent intrasynovial injections, indwelling balloon constant rate delivery systems, placement of antimicrobial-impregnated beads, and regional IV or intraosseous perfusion.

Use of balloon constant rate infusion systems has been described in humans for delivery of analgesics after vertebral column surgery, sternotomy, breast augmentation, thoracotomy, gastric bypass, and cesarean deliveries.19,21 Constant rate delivery of low doses of narcotics and nonnarcotic analgesics to an affected area substantially decreases the level of pain reported by patients and decreases the overall dose of narcotics required.29,30 Clinical use of balloon constant rate infusion systems has only infrequently been reported11 in the veterinary literature, although constant delivery of gentamicin to the tarsocural joint and effects on the synovium in horses have been described.20,21 To the authors’ knowledge, no clinical reports have been published describing the use of a constant rate infusion system for treatment of infected or contaminated synovial structures in a large group of horses. The purpose of the present study was to determine clinical details and long-term outcome of horses with septic arthritis, tenosynovitis, or contaminated synovial wounds in which a balloon constant rate infusion system was used for delivery of antimicrobials.

**Criteria for Selection of Cases**

Medical records from The Ohio State University College of Veterinary Medicine teaching hospital were searched from January 1, 2002, to February 1, 2005, for records of horses with a diagnosis of septic arthritis, septic tenosynovitis, or wounds with synovial involvement and for which a balloon constant rate infusion system was used.
Procedures—Data collected included age, sex, breed, duration of injury, severity of lameness, affected structure, results of analyses of synovial fluid (eg, WBC count and protein concentration), results of bacterial culture, systemically acting antimicrobials and analgesics used, duration of hospitalization, number of general anesthetic episodes, duration of use of the balloon constant rate infusion system, antimicrobials used in the infusion system, and number of times the affected joint or tendon sheath was lavaged. Follow-up information was collected from owners, trainers, or referring veterinarians and was obtained during telephone interviews. Follow-up information collected included long-term survival (eg, survival for longer than 5 months after discharge); cause of death or euthanasia; degree of residual lameness (if any); present use; and level of activity, compared with the pre-injury level of activity.

Balloon constant rate infusion systems are composed of a reservoir, flow restrictor, and fenestrated catheter (Figure 1). Commercially available systems have various reservoir volumes and flow rates. The system used in the horses reported here had a 100-mL reservoir and a flow rate of 2 mL/h. In each horse, the infusion system was inserted via 1 of 2 techniques. In the first technique, the 20-gauge catheter provided with the system was inserted into the affected joint or tendon sheath. The catheter’s placement in situ was viewed arthroscopically in horses in which arthroscopy was performed. The catheter stylet was removed, and fenestrated tubing was inserted into the synovial structure, with care taken to ensure that all fenestrations were situated in the synovial structure. The sheath of the catheter was separated and removed, leaving only the fenestrated tubing remaining in the joint space or tendon sheath. The tubing was secured to the skin with a finger-trap suture pattern and placement of additional tape proximal to the suture. In the second technique, a fenestrated Jackson-Pratt drain was placed in the synovial structure through arthrotomy incisions and the infusion system was attached directly to the fenestrated drain. The infusion systems were filled with either 2 g of a third-generation cephalosporin (ceftazidime or ceftriaxone) or 2 to 3 g of an aminoglycoside (amikacin), thereby delivering approximately 100 mg of antimicrobial/h. Thirty milliliters of 2% mepivacaine solution (when used) and additional sterile saline (0.9% NaCl) solution were added to the reservoir to achieve a total fluid volume of 48 mL. The pump was filled to a volume of only 48 mL to necessitate daily replenishment of the system, ensure that patency of the system would be monitored on a daily basis, and reduce adverse effects of prolonged exposure of antimicrobial solutions to ambient temperature. The infusion system was incorporated into and protected by a heavy bandage. Bandages were changed every 24 hours, and the system was checked and determined to be patent if the pump reservoir was empty at the time of bandage changes. Addition of locally acting anesthetics to the infusion solution was limited to horses with severe lameness that did not initially improve in response to lavage and administration of NSAIDs and opioids.

Statistical analysis—Spearman rank correlations were used to determine whether WBC count or duration of injury was correlated to duration of balloon constant rate infusion pump use or hospitalization. Nonparametric analysis by use of the Wilcoxon rank sum test was used to evaluate relationships between use of fenestrated drains and number of synovial lavage and anesthetic episodes, respectively. Analyses were performed by use of statistical software, with values of \( P < 0.05 \) considered significant.

Results

Twenty-three horses met the inclusion criteria. Breeds represented included the Thoroughbred (n = 6 horses), American Quarter Horse (5), Standardbred (4), Tennessee Walking Horse (2), American Saddlebred (2), American Paint Horse (1), Rocky Mountain Horse (1), American Sufolk Horse (1), and pony (1). Thirteen of the horses were female, 7 were geldings, and 3 were sexually intact males. Median age at initial evaluation was 26 months, with a range of 8 days to 12 years. Sixteen (70%) horses were mature (> 18 months of age) at initial evaluation.
age), 3 (13%) were young (6 to 18 months of age), and
4 (17%) were foals (< 6 months of age).

Median duration from the onset of clinical signs to initial evaluation was 4 days, with a range of 12 hours
to 35 days. A lameness grade, determined on the basis of a described scale, was reported for 22 horses.
A lameness score for those 22 horses was 4 on a scale of 1 to 5, with 1 denoting mild lameness and 5 denoting non–weight-bearing lameness. Affected structures among all 23 horses included 8 flexor tendon sheaths (1 in the right forelimb, 2 in the right hind limb, 2 in the left forelimb, and 3 in the left hind limb), 4 tarsocural joints (1 right and 3 left), 3 carpal joints (1 involving the right radiocarpal joint, 1 involving the left middle carpal joint, and 1 involving the right radiocarpal and middle carpal joints), 3 cubital joints (2 right and 1 left), 2 tarsal sheaths (right), 1 proximal interphalangeal joint (left forelimb), 1 distal interphalangeal joint and podotrochlear bursa (left forelimb), and 1 carpal sheath (left). Seven of the 23 (30%) horses had septic arthritis, 5 (22%) had septic tenosynovitis, and 11 (48%) had contaminated joints and tendon sheaths. The cause of the synovial infection or contamination was known in 22 of the 23 horses; in 18 (78%), infection resulted from a laceration or puncture wound; in 3 (13%), the infection was hematogenous in origin; and in 1 (4%), infection developed after arthroscopic surgery. In the horse for which the cause or source of infection was unknown, hematogenous delivery of infection secondary to a chronic skin condition and administration of corticosteroids was suspected. In 6 (26%) horses, synovial infection was accompanied by osteomyelitis; of those horses, the distal portion of the radius was involved in 1 horse, the distal portion of the humerus was involved in 2 horses, the sustentaculum tali was involved in 2 horses, and the lateral proximal sesamoid bone was affected in 1 horse. Three (those with involvement of the distal portions of the radius and humerus) of the 6 horses with osteomyelitis were foals younger than 1 month of age, 1 horse was 7 months old (1 horse with involvement of the sustentaculum tali), and the remaining 2 horses were older than 24 months (1 horse with involvement of a proximal sesamoid bone and the other horse with involvement of the sustentaculum tali).

Arthrocentesis or tenocentesis was performed in 19 of the 23 horses; synovial fluid WBC counts were determined in all 19 of those horses, and total protein concentration was determined in 17 horses. Protein concentration was not recorded in 2 horses because of small sample size. The median synovial fluid WBC count was 48,730 X 10^6 cells/L (range, 113 to 314,000 X 10^6 cells/L). Mean total protein concentration was 5.0 ± 1.4 g/dL (range, 3.0 to 7.5 g/dL).

Synovial fluid was obtained for bacterial culture prior to surgery or intraoperatively in all horses. Bacterial growth was obtained in 11 of 23 (48%) horses. Bacteria recovered included Actinobacillus suis (n = 4 horses), Escherichia coli (2), Proteus spp (1), Salmonella spp (1), Streptococcus zooepidemicus (1), coagulase-negative Staphylococcus spp (1), and Staphylococcus aureus (1).

All horses received broad-spectrum antimicrobials and analgesics immediately prior to or during surgery. Antimicrobial combinations included potassium penicillin G (dosage, 22,000 U/kg [10,000 U/lb], IV, q 6 h) and gentamicin (6.6 mg/kg [3 mg/lb], IV, q 24 h; 11/23 [48%] horses); ampicillin (10 mg/kg [4.5 mg/lb], IV, q 6 h) and gentamicin (6.6 mg/kg, IV, q 24 h; 6/23 [26%] horses); potassium penicillin G (22,000 U/kg, IV, q 6 h) and amikacin (25 mg/kg [11.4 mg/lb], IV, q 24 h; 2/23 [9%] horses); enrofloxacin (5 mg/kg [2.3 mg/lb], IV, q 12 h) and rifampin (5 mg/kg, PO, q 12 h; 2/23 [9%] horses); ampicillin (10 mg/kg, IV, q 6 h) and amikacin (25 mg/kg, IV, q 24 h; 1/23 [4%] horses); and ampicillin (10 mg/kg, IV, q 6 h) and enrofloxacin (5 mg/kg, IV, q 12 h; 1/23 [4%] horses). In addition to antimicrobials, 22 of the 23 (96%) horses received phenylbutazone orally or IV at a dosage of 1.1 to 2.2 mg/kg (0.5 to 1.0 mg/lb) every 12 hours. Twelve (52%) horses were treated with morphine at a dosage of 0.05 to 0.1 mg/kg (0.02 to 0.05 mg/lb), IM, every 6 hours.

Twenty-five balloon constant rate infusion pumps were used in the 23 horses. Two pumps were used in 2 horses; in 1 horse, the original pump failed after 3 days and was replaced with a new pump, which was maintained for 6 days. In the second horse, the pump was removed from the cubital joint after 3 days because the foal had improved clinically; however, recrudescence of clinical signs prompted placement of a second pump in the joint for an additional 3 days. Mean ± SD duration for which the infusion pump remained in place in the remaining 21 horses was 4.5 ± 1.4 days, with a range of 3 to 8 days. Mean duration of hospitalization for the 23 horses was 11.5 ± 5.26 days. No correlation was observed between duration of clinical signs and duration of hospitalization (P = 0.67) or duration of infusion pump use (P = 0.67). However, correlations were detected between WBC count and duration of hospitalization (P = 0.03) or duration of infusion pump use (P = 0.006).

Fenestrated drains were used in 8 of the 23 (36%) horses. The indwelling drain enabled lavage of the infected structure while the horse was standing. Affected structures were lavaged daily until clinical signs, WBC counts, or both indicated a favorable response, at which time the fenestrated drains and the balloon constant rate infusion pumps were removed. The mean number of lavages in the Jackson-Pratt drain group (5.1 lavages) was significantly (P = 0.005) different than the number of lavages in the no-drain group (1.8 lavages).

All horses were treated by means of lavage with large volumes of isotonic fluids at the time the constant rate infusion pump was placed in the affected synovial structure. Eight of the 23 (35%) horses underwent arthroscopic (n = 4) or tenoscopic (4) surgery at the time of admission, and the incisions were left open after surgery. In another 10 horses, the laceration, penetrating wound, or incision into the joint or tendon sheath was also left open after surgery. In the remaining 5 horses, the affected area was closed surgically; in those horses, there was no appreciable difference in the degree of joint or tendon sheath distension between horses in which the affected structure was closed for primary-intention healing or left open.

In 12 horses, 30 ml of 2% mepivacaine solution was added to the infusion pump reservoir (yielding an

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infusion rate for mepivicaine of 25 mg/h) to induce local synovial analgesia. This was performed in horses in which severe lameness persisted despite oral or parenteral administration of analgesics and resulted in subjective improvement in lameness in all treated horses.

All 23 horses were discharged from the teaching hospital. Follow-up data were obtained for 17 (74%) horses, 16 of which were alive at the time follow-up information was collected. Twelve of 13 horses for which follow-up information was available for at least 3 months after surgery survived to that time point. Mean follow-up time was 459 ± 254 days, with a range of 14 to 988 days. The 1 horse that died was a foal and was found dead in its stall 3 weeks after discharge. The foal had osteomyelitis involving the distal portion of the humerus, and a Salmonella isolate was cultured from elbow joint synovial fluid and humeral physis. Euthanasia had been recommended in that foal at the time of initial examination and prior to discharge because of the severity of the osteomyelitis and progression of clinical signs, but the foal had been released from the hospital at the owner’s request after 21 days of treatment.

Three of the 16 living horses had some degree of residual lameness at the time of writing. In 1 of those 3 horses, lameness developed inconsistently (2 to 3 times/y) in association with stall confinement, but resolved with controlled exercise and administration of NSAIDs. One horse had persistent mild lameness associated with osteoarthritis in the right cubital joint. One horse developed varus deformity of the contralateral limb and was donated to a rescue organization but was reportedly pasture sound. The 13 remaining horses were reported as not lame on follow-up and, at the time of writing, were performing at their previous level of work, in training for their intended use, turned out because of young age, or still convalescing.

Discussion

Short- and long-term outcome in the present study were similar to those in investigations of conventional treatments for septic synovitis in horses.1,4,5,7,10-18 However, use of constant rate infusion pumps for drug delivery has several advantages over conventional treatments in the management of horses with septic arthritis, septic tenosynovitis, or contaminated synovial wounds, including the ability to maintain a constant high concentration of appropriate antimicrobials in the affected synovial cavity and to concurrently administer analgesics. There was no significant difference in the number of anesthetic episodes between horses in which a fenestrated drain was placed and horses in which a drain was not placed. Three of the horses that underwent multiple anesthetic episodes were foals younger than 1 month of age that had osteomyelitis in addition to septic arthritis. Therefore, use of a balloon constant rate infusion system decreased the number of anesthetic episodes required to effectively treat synovial infection or contamination.

Constant rate infusion pumps are costly, but in most instances, horses were anesthetized only once for initial lavage and placement of the pump, and the savings associated with avoiding repeated episodes of general anesthesia offset the initial cost of the infusion pump. The risk of anesthesia-related injuries is low, but use of the infusion pump minimized that risk by limiting the number of general anesthetic episodes required. Repeated needle penetration into joints and tendon sheaths for lavage traumatizes the synovium and may induce additional inflammation and synovial thickening. Subjectively, horses with infusion pumps had little thickening and swelling of skin or associated soft-tissue structures of the joint. Particularly in foals, the skin frequently becomes inflamed and irritated secondary to repeated application of surgical scrub solution prior to joint lavages. This deleterious effect is also eliminated by use of constant rate infusion systems.

The initial synovial fluid WBC count, duration of hospitalization, and duration of infusion pump use were significantly correlated. Therefore, initial WBC counts may be useful in predicting costs associated with hospitalization and antimicrobial administration.

The mean number of lavages in horses in which a Jackson Pratt drain was used (5.1 lavages) and in horses in which no drain was used (1.8 lavages) was significantly different. That difference may be explained by the daily flushing of affected synovial structures in the drain group for the entire time during which the infusion system was in place. The no-drain group underwent lavage only if clinical signs were deteriorating or WBC counts indicated treatment failure.

The administration rate of 2 mL/h was empirically chosen to provide an adequate flow volume to maintain high antimicrobial concentrations in the synovial cavity for 24 hours. By filling the reservoir to only half its capacity (ie, to only 48 to 50 mL), a fresh solution of antimicrobials was added daily to minimize adverse effects that prolonged exposure to ambient temperature may have had on the reservoir contents and to ensure that a continual full dose (2 to 3 g) of the selected antimicrobial was delivered. Lower flow rates (eg, 0.5 mL/h) may have been just as effective at delivering the same dose of antimicrobials, but the lower daily volume (12 mL) may have adversely altered the effectiveness of the system. Conversely, high flow rates (eg, 5 mL/h) may have caused excessive distension in smaller or closed joints. In addition, 2.5 times the dose of antimicrobials would be required to achieve the same antimicrobial concentration delivered per hour. Further studies are required to determine the pharmacokinetics and pharmodynamics of drugs delivered via this system and whether antimicrobial concentrations at or above the MIC of equine synovial pathogens can be maintained.

To the authors’ knowledge, no reports of the effects of a combination of amikacin, ceftriaxone or cefazidime, and locally acting anesthetics in horses have been published, but those cephalosporin drugs are often combined with locally acting anesthetics for use in humans. When mepivicaine was added to the antimicrobial solution in severely lame horses, a decrease in lameness was observed shortly after addition of the anesthetic. The addition of locally acting anesthetics to antimicrobials in the infusion pump...
reduces the need for high doses of NSAIDs or other analgesics and may decrease the risk of support-limb laminitis or angular limb deformity in young horses.

The catheter supplied by the manufacturer in the balloon constant rate infusion pump worked well in most applications, although problems were encountered when the catheter was placed in the carpus. The catheter migrated between carpal bones and became flattened, reducing patency. Placement of the catheter in the palmar aspect of the carpal joints may eliminate that complication but was not assessed in the present study. Placement of the catheter with arthroscopic guidance helped ensure accurate placement and reduced the risk of postoperative complications associated with catheter patency.

Additional studies are needed to investigate the compatibility of antimicrobials and analogues used in constant rate infusion pumps for treatment of septic arthritis, tenosynovitis, and contaminated synovial wounds. Constant administration of antimicrobials and locally acting analogues (in certain instances) through a constant rate infusion pump reduced morbidity associated with repeated lavage, aided in analgesia in refractory cases, reduced the risk and cost associated with repeat anesthetic episodes, and appeared to be associated with response and survival rates similar to those associated with conventional treatments.

References