How to Use Indwelling Intravenous Regional Limb Perfusion for Managing Horses With Persistent Distal Limb Infections

Gal Kelmer, DVM, MS

1. Introduction
Synovial infection is one of the most common causes of morbidity and mortality in the horse. Regional limb perfusion (RLP) is an established, effective method of treating horses with synovial infection that significantly decreased mortality and loss of use in these cases. RLP is performed by injecting diluted antimicrobials into the limb either through the medullary cavity or intravenously while isolating the affected region in the limb by the use of a tourniquet. In this manner, one can achieve high and effective local concentrations of antimicrobials that are practically impossible to reach with systemic administration alone. Additional indications for RLP include orthopedic surgical site infections, open fractures, septic physitis, and osteomyelitis. Recently, the technique was also advocated as a prophylactic measure in lengthy orthopedic surgeries such as arthrodesis and fracture repair. In cases when the injury is recent, 1–3 perfusions are typically sufficient for resolution of infection. Often, however, multiple daily RLPs are needed to resolve an established synovial infection, and frequently, RLP administered intravenously (IV-RLP) becomes more difficult to perform with each treatment. Repeated daily puncture of the veins of the distal aspect of the limb leads to inability to perform of RLP because of the loss of venous access. Many injuries of the distal aspect of the limb, such as lacerations of a collateral ligament or a flexor tendon, result both in infection of one or more synovial structures and in loss of axial stability. After initially treating the horse by debriding the wound, lavaging the contaminated synovial structure, and administering RLP, the clinician must choose to either provide limb stability with a cast or continue unrestricted access of the limb for treating the existing synovial infection. Applying a half-limb cast might be an ideal method of providing stability, but the cast may hamper or prevent daily, local therapy of the wound, such as joint lavage or administration of RLP. An indwelling catheter maintained in the cephalic or saphenous vein allows daily administration of RLP to horses to eliminate or prevent synovial infection when the distal limb is maintained in a cast.

2. Materials and Methods
To perform RLP in the most effective manner and to minimize associated complications, all the necessary materials should be obtained and organized before
the procedure is performed: a sedative, a local anesthetic agent, appropriate syringes and needles, a 20- or 22-g IV catheter, an extension set, glue, suture material (2–0 polypropylene/nylon), a pneumatic tourniquet, clippers, antiseptic soap and alcohol, sterile gloves, the appropriately diluted antimicrobial drug to be perfused, and bandage material.

An indwelling, IV catheter can be placed in the palmar or plantar digital vein, the cephalic vein, or the saphenous vein. When using the cephalic vein, the catheter should be placed slightly distal to the level of the chestnut (Fig. 1), and when using the saphenous vein, the catheter should be placed ~10 cm proximal to the medial malleolus of the tibia. When using the palmar or plantar digital vein (Fig. 2), the catheter should be placed slightly proximal to the proximal sesamoid bones. These locations are general guidelines, and the exact placement site may vary according to local swelling, width of the tourniquet’s cuff, and ease of insertion. In all locations, a 20-g, 4- or 5-cm, over-the-needle catheter is used. For neonates, a smaller gauge catheter, such as a 22-g catheter, can be used.

The horse is sedated with detomidine HCl (0.006–0.01 mg/kg, IV) and butorphanol (0.01–0.02 mg/kg, IV). Additional sedation is added, if necessary, to minimize the horse’s movement. Desensitizing the limb proximal to the site of venipuncture, using regional, perineural anesthesia, minimizes discomfort to the horse associated with the use of a tourniquet, venipuncture, and securing of the catheter. Before inserting a catheter into the cephalic or palmar digital vein, the forelimb can be desensitized by anesthetizing the median, ulnar, and musculocutaneous nerves with 10 ml of mepivacaine HCl deposited adjacent to each nerve. Before inserting a catheter into the saphenous or plantar digital vein, the hindlimb can be desensitized by anesthetizing the common peroneal and tibial nerves with 10 ml of mepivacaine deposited adjacent to each nerve.

A pneumatic tourniquet cuff (10–15 cm wide) is applied ~10 cm proximal to the site of venipuncture. The site at which the catheter is to be placed is clipped and aseptically prepared, desensitized with a local anesthetic agent (0.5 ml 2% mepivacaine HCl) injected subcutaneously, and rescrubbed. The tourniquet is inflated to 300 mm/Hg (Fig. 3). A 20-g, 4-cm, over-the-needle catheter is placed in the vein and directed distally. A 70-cm long-extension set, filled with local anesthetic agent (mepivacaine/bupivacaine), is connected to the catheter and flushed with 5 ml of the same solution through an injection port. After blood is observed flowing into the extension set, the hub of the catheter is secured to the adjacent skin with cyanoacrylate, and the extension set is sutured to the desensitized skin with several simple interrupted sutures of 2–0 polypropylene. After the catheter has been placed
in the cephalic or saphenous vein, 1 g (4 ml) of amikacin® in 56 ml of physiological saline solution or 500 mg of imipenem® reconstituted to 100 mg/ml in 55 ml of physiological saline solution is injected into the catheter over 2–4 min. When performing regional perfusion through the palmar digital vein, the total volume perfused is reduced to 30–40 ml. Antimicrobial choice should be guided by culture and sensitivity when available. The catheter is flushed with 5 ml of heparinized physiological saline solution. The tourniquet is maintained inflated at 300 mm/Hg for 30 min after the end of the antimicrobial drug has been injected; it is then deflated over the course of 1 min. The limb is bandaged routinely with the extension set protruding through the bandage so that it can be flushed with heparinized saline without removing the bandage. The catheter is flushed with 5 ml of heparinized physiological saline solution to examine its patency after the bandage has been applied, and the injection port is covered with an adhesive, elastic bandage. Catheters are flushed with 3–5 ml of heparinized, physiological saline solution every 6 h. Perfusion is performed every 24 h, and complementary therapies, such as joint lavage, are also performed. A new injection port is applied to the catheter before each daily perfusion. Catheters can be maintained for >1 wk. After the catheter is removed, an anti-septic ointment is applied to the venipuncture site, and the limb is left bandaged for an additional 24 h.

3. Results

We have used indwelling catheters for IV-RLP (ID-IV-RLP) in nine horses with good results. Pastern lacerations and penetrating wounds to the feet (Fig. 4) were the most common injuries we treated with this technique thus far. Complications were minimal and decreased as we became more familiar with the technique. The catheters of two horses, an adult with a catheter in the saphenous vein and a foal with a catheter in the palmar digital vein, were dislodged, which necessitated the insertion of a new catheter for subsequent RLPs. For both horses, we were able to continue with daily perfusion, but for the foal, the new catheter had to be placed 10 cm proximal to the proximal sesamoid bone because of swelling around the previous site of catheterization. The vein of one of these horses remained catheterized for 10 days, and the vein of the other remained catheterized for 8 days; overall, the two horses combined received four venipunctures, whereas they would have received 18 if indwelling catheters had not been used. One horse had to receive RLPs through a catheter in the cephalic vein because multiple, open, infected synovial structures of the distal portion of a forelimb resulted in diffuse edema that prohibited further use of the vein and in premature termination of RLP. In this horse, the synovial infection persisted despite systemic antimicrobial therapy. Installing an indwelling catheter into a vein provided venous access for RLP for five horses with feet or distal portions of limbs covered with casts. In a horse with a foot cast or a short limb cast, the technique was used effectively with catheters either in the cephalic or the saphenous vein.

The antimicrobial drug used for RLP of two horses was changed because the horses failed to show clin-
ical improvement after three RLPs; results of culture and sensitivity tests indicated that the cultured bacteria was not sensitive to the chosen antimicrobial agent. In one horse with an infected tarsal sheath and osteomyelitis of the sustentaculum tali of the fibular tarsal bone, a resistant strain of *Staphylococcus intermedius* was cultured, and three RLPs with vancomycin were performed. Although infection resolved, this horse remained too lame for strenuous athletic use, likely because of damage to the sustentaculum tali that resulted in tendonitis of the deep digital flexor tendon. A filly with pneumonia and infection of the proximal physis of the middle phalanx and the proximal interphalangeal joint caused by *Rhodococcus equi* received RLP daily for 10 days through an indwelling catheter in the palmar vein. In this foal, lavage of the proximal interphalangeal joint using amikacin and imipenem was also performed. When this treatment failed to resolve the infection, the filly was treated by opening the infected joint for drainage and performing RLP with erythromycin for 3 additional days. Four months after treatment, the filly was completely sound and did not have a cosmetic blemish on the affected limb.

One horse received perioperative RLP administered through an indwelling catheter when a large fragment of the extensor process of the third phalanx was removed through a trephine hole in the hoof wall.

4. Discussion

Infection of one or more synovial structures of the distal portion of a limb of a horse is a common cause of persistent lameness or mortality. RLP, performed either intraosseously or intravenously, is a simple, highly effective technique for treating horses with infection of a synovial structure of the distal portion of the limb. Eradicating a synovial infection can be challenging, especially if the infection is well established or involves bone. The major goals of therapy are establishing effective drainage and achieving a high concentration of an appropriate antimicrobial drug in the infected tissue. RLP performed intraosseously or intravenously is an effective means of achieving a high concentration of an

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**Table 1. Summary of Cases Treated With an Indwelling Catheter for Performing Intravenous Regional Antimicrobial Perfusion.** NB = Navicular Bursa, DIPJ = Distal Interphalangeal Joint, PIPJ = Proximal Interphalangeal Joint, DFTS = Digital Flexor Tendon Sheath, PD = Palmar Digital

<table>
<thead>
<tr>
<th>Case Number</th>
<th>Structures involved</th>
<th>Vein used</th>
<th>Number of perfusions</th>
<th>Cast</th>
<th>Complications</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PIPJ &amp; P2 proximal physis</td>
<td>Palmar</td>
<td>10</td>
<td>No</td>
<td>One catheter replacement</td>
<td>Complete recovery</td>
</tr>
<tr>
<td>2</td>
<td>DFTS</td>
<td>Cephalic</td>
<td>8</td>
<td>No</td>
<td>No</td>
<td>Infection resolved</td>
</tr>
<tr>
<td>3</td>
<td>Tarsal sheath</td>
<td>Saphenous</td>
<td>8</td>
<td>No</td>
<td>No</td>
<td>Infection resolved</td>
</tr>
<tr>
<td>4</td>
<td>P3</td>
<td>PD</td>
<td>2</td>
<td>Foot cast</td>
<td>No</td>
<td>Successful prophylaxis</td>
</tr>
<tr>
<td>5</td>
<td>NB &amp; DIPJ</td>
<td>PD</td>
<td>3</td>
<td>Foot cast</td>
<td>No</td>
<td>Good short term</td>
</tr>
<tr>
<td>6</td>
<td>NB</td>
<td>PD</td>
<td>4</td>
<td>Foot cast</td>
<td>No</td>
<td>Infection resolved</td>
</tr>
<tr>
<td>7</td>
<td>Hoof wall avulsion, P3</td>
<td>PDV</td>
<td>3</td>
<td>Foot cast</td>
<td>No</td>
<td>Infection resolved</td>
</tr>
<tr>
<td>8</td>
<td>NB, DIPJ, PIPJ, DFTS</td>
<td>Cephalic</td>
<td>5</td>
<td>Short limb cast</td>
<td>Catheter removed prematurely</td>
<td>Infection persisted</td>
</tr>
<tr>
<td>9</td>
<td>DIPJ</td>
<td>Saphenous</td>
<td>6</td>
<td>No</td>
<td>Catheter replaced twice</td>
<td>Infection persisted</td>
</tr>
</tbody>
</table>

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**Fig. 5.** An indwelling catheter placed in the lateral plantar vein in a horse with a foot cast.
antimicrobial drug in the infected tissue. Intraosseous daily RLP can be performed for prolonged periods using an indwelling cannulated screw, but the technique requires special equipment and may cause discomfort to the horse by increasing intramedullary pressure. The intraosseous route for RLP can serve as an effective, alternative method to IV-RLP when venipuncture is difficult because of cellulitis or phlebitis. Although the indwelling catheter of two horses had to be replaced, catheterization of the vein prevented unnecessary daily venipuncture and associated potential complications. An important advantage of using the cephalic or the saphenous vein for RLP is the ability to use RLP in combination with a foot cast (Fig. 5) or half-limb cast. We have used this technique in cases that required a cast for lesions, including an avulsed hoof wall and a penetrating pastern laceration, with good results.

*R. equi* typically causes pulmonary abscesses, but occasionally, it can infect other body systems, such as the musculoskeletal system. *R. equi* can infect synovial structures and bone, including the physis. One filly did not respond to multiple RLPs using other antimicrobial drugs, including imipenem; however, subsequent RLPs with erythromycin resulted in successful resolution of the infection. Because *R. equi* infection is relatively common, studies to investigate the safety and efficacy of erythromycin administered by RLP are indicated. Although our experience supports the use of indwelling catheters to perform RLP, controlled studies are needed to objectively evaluate the efficacy of their clinical use in horses.

References and Footnotes