Managing pain effectively is one of the most important tasks that veterinarians perform on a daily basis in clinical practice. Successful treatment of pain affecting the forelimbs in horses is complicated, not only because responses to injuries vary among individual animals but also because horses put a high load on their forelimbs for most of the day (30% to 33% of their body weight per forelimb), predisposing them to overloading the contralateral limb after either a severe injury to or major orthopedic surgery in one forelimb.

Alleviation of pain is an important aspect of equine orthopedic treatment because it significantly decreases physiologic stress on the animal and reduces perioperative complications. Systemic administration of opioids and NSAIDs has been widely accepted for short- and long-term analgesia in horses with severe tissue injury but often is not very effective or is associated with multiple adverse events. Only continuous-rate infusion (CRI) of butorphanol, a κ-opioid receptor agonist and μ-receptor antagonist, has been reported recently as lacking major side effects while significantly improving behavior scores during the first 24 hours after exploratory celiotomy; the investigators interpreted these results as being consistent with effective analgesia provided by the prolonged intravenous butorphanol administration. Further studies are needed to characterize the potential advantages of a butorphanol CRI in alleviating orthopedic pain.

The relatively low cost and minimal systemic absorption of local anesthetics (LAs) make them optimal alternatives or adjuncts to opioid- and/or NSAID-based analgesia. In recent years, applications of peripheral nerve blocks in humans have increased considerably and have gained much popularity among clinicians for the treatment of virtually all types of severe surgical and procedural pain. Regional analgesia/anesthesia has been applied in awake and anesthetized patients. Two discoveries fueled the exploration of regional analgesia/anesthesia techniques in pain management, especially lower-extremity nerve blocks:

1. Peripheral and central sensitization play a major role in prolonging postoperative pain and can be effectively inhibited only by peripheral nerve blockade, not by opioid-based analgesia, if they can be inhibited at all.4,5
2. When discontinued or used over longer periods, opioids may even exhibit pronociceptive effects, depending on the doses administered and duration of treatment.5

In veterinary medicine, LAs have been administered by a number of routes, including local/regional nerve blocks, systemic infusion, epidural delivery, intraarticular and intra-
cavitary infusion, and, more recently, single-dose local wound lavage (splash block) and perineural techniques. In horses, a local/regional technique of analgesia, such as epidural analgesia for pain originating in the hindlimb, is currently not available for treating severe pain in the forelimb.

Alternative methods of postoperative analgesia, such as single-dose or continuous peripheral nerve blockade (CPNB), have long been introduced in human medicine with great success and hold considerable promise in small animals, where they have more recently been tested to minimize intra- and postoperative discomfort in surgical patients. In humans, numerous benefits of the CPNB technique have been recognized, including reduced hospital stay and duration of convalescence as well as improved functional rehabilitation and postoperative outcome. These benefits also emphasize the importance of integrating regional analgesia into multimodal pain treatment regimens and more sophisticated rehabilitation programs.

The CPNB method entails continuous or intermittent low-volume infusion of LAs by placing catheters along or close to peripheral nerves. Three techniques have been proposed to place perineural catheters: the nonstimulating needle technique, the stimulating needle technique, and ultrasound-aided needle/catheter placement. A fourth technique, which is no longer used, is the periarterial placement of axillary catheters under direct vision after cut-down during local anesthesia.

With the support of ultrasound imaging, nonstimulating perineural catheters can be placed with great accuracy, allowing imaging and assessment of all anatomic structures and the position of the catheter tip relative to the nerve and the LA spread. In humans, it has been demonstrated that ultrasound guidance, more than any other technique, can significantly improve the quality of nerve blocks in almost all types of regional anesthesia/analgesia procedures. In addition, such complications as intraneuronal and intravascular injection can be avoided.

Continuous perineural block often provides much better pain control with fewer side effects than systemic analgesia and may not impair normal motor function in the affected extremity—a feature of particular importance in the standing horse. The CPNB technique, when used as part of a multimodal anesthetic regimen, also may substantially reduce the amount of general anesthetic needed to maintain a surgical plane of anesthesia, thus helping preserve adequate cardiovascular and respiratory functions in the anesthetized patient undergoing surgery.

**EXPERIMENTAL TECHNIQUES**

To provide alternative methods of pain management in the distal equine forelimb and digit, our research group at the University of Pennsylvania investigated the feasibility of instrumenting the palmar, median, and ulnar nerves with perineural catheters in standing sedated horses. Continuous perineural palmar blocks (proximal or distal to the communicating branch) are recommended primarily in patients in which severe pain is anticipated to occur as a result of palmar fetlock, pastern, or foot surgery and in which early functional rehabilitation can be facilitated. Major surgery, such as phalangeal arthrodesis, or severely painful conditions that put the contralateral digit/foot at risk for developing laminitis (e.g., sesamoid/phalangeal osteomyelitis, severe degloving injuries/truma, septic interphalangeal joints, puncture wound with sepsis of navicular bone, bursa, joint, or deep digital flexor tendon) are examples of possible indications for CPNB of the palmar nerves. In addition, horses undergoing total or partial hoof wall resection may benefit from CPNB.
We first developed a simple and reproducible technique for placing catheters along the palmar nerves. In preparation for the first in vivo instrumentation of horses and to avoid inaccurate catheter placement and/or catheter dislodgment, a number of different studies aimed at identifying anatomic landmarks, potential risk for damage to surrounding tissues during catheter placement, satisfactoriness of the catheter–skin fixation, and incidence of complications (e.g., dislocation/kinking, infection) were conducted. Forty-two forelimb specimens were dissected to locate the anatomic landmarks for safe percutaneous CPNB catheter insertions along the medial and lateral palmar nerves, and the potential for catheter dislodgment was investigated in vitro using fluoroscopy during passive carpal flexion and dye injection following...
Landmarks for palmar CPNB catheter placement were identified and are shown in Figure 1. The studies followed an initial in vivo feasibility study testing the efficacy of CPNB for long-term regional analgesia in the distal equine forelimb. The catheter placement along the palmar nerves in the standing horse as we recommend it has been described in detail elsewhere. Ultrasound imaging before and at the end of the instrumentation procedure helps the operator to become familiar with the local anatomy and confirm correct placement after catheter insertion.

The feasibility of CPNB catheter instrumentation was tested in five standing, sedated pilot horses using ultrasound control. A Perifix epidural catheter set (B. Braun) was used. The set contained a 20-gauge, 8.9-cm Tuohy-Schliff–style tip needle that served as an introducer for the enclosed closed-tip, radiopaque polyamide catheter (20 gauge, 0.80-mm internal diameter, 104 cm), which was flushed with heparin solution before insertion. After subcutaneous tunneling over 2.0 to 2.5 cm, the Tuohy needle was cautiously pushed through the palmar fascia and advanced over its entire length along the nerve.

Subsequently, medial and lateral CPNB catheters were inserted through the needle and advanced for approximately 7 and 10 cm, respectively, to place their tips just proximal to the communicating branch of the palmar nerves. The free endings of the CPNB catheters were later connected to reusable, lightweight, battery-driven ambulatory infusion pumps (Figure 2; Ace Medical Automed 3400, Curlin Medical) by means of proprietary tubing (AM-360/370, Curlin Medical). Pump sets and extension tubing were primed with LA solution before attachment to the CPNB catheters, and the legs were bandaged at the insertion site of the catheters (Figure 2). Subsequent CRI of LAs (lidocaine 2%, mepivacaine 1%, bupivacaine 0.5%) through the CPNB catheters significantly increased pain thresholds and hoof withdrawal response latencies to electrical and mechanical noxious stimulation, while saline infusion did not.

This initial study and a subsequent study showed that the in vitro-developed technique of placing and securing palmar CPNB catheters in the equine forelimb can be successfully applied under ambulatory conditions in the standing horse. Catheters were well tolerated for up to 10 days in saline-infused limbs. However, in the initial experimental series, LA infusion caused limb swelling, thus calling for further exploration of drug and infusion regimens lacking this side effect, although this effect was not observed in a clinical patient in which the technique was applied over 3 weeks. Therefore, additional in vivo studies are under way to refine drug concentrations, infusion regimens,
and the instrumentation technique itself (i.e., catheter advancement beyond the communicating branch of the palmar nerve).

Because the treatment of severe pain in other areas of the forelimb, including the carpus, as well as painful surgical procedures performed in the digit remain a therapeutic challenge in equine patients, we currently are also evaluating a technique for placing peripheral catheters in the antebrachium along the ulnar and median nerves.

**FUTURE WORK AND APPLICATIONS**

Many horses could profit from CPNB techniques. Only clinical studies will eventually reveal more about the usefulness of CPNB techniques for specific clinical conditions in horses. However, not all questions can be readily answered by studies alone, and only long-term experience with CPNB techniques in clinical practice will prove the efficacy of these techniques. The frequency of complications that occur with the multiple regional anesthetic techniques in use today is largely unknown. Thus, large studies are necessary to prove the superiority of CPNB techniques over other methods of pain management in horses.

Future studies should address drug and infusion protocols, possible improvements to the instrumentation technique, and the critical timing of treatments to maximize pain relief in the affected limb while preventing overloading of the contralateral limb. Ultimately, the goal is to minimize adverse events associated with the administered drugs while maintaining an optimal level of analgesia. CPNB techniques in the equine forelimb offer the advantage of more safely carrying out sophisticated surgical procedures with less risk for complications during convalescence and better managing pathologic conditions with recurrent intractable pain.

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**Reviewer Comment**

This article represents the best in equine research. It is focused on the day-to-day management, wellness, and care of horses. The technique is described in clear detail and can be adapted quickly to clinical cases. I applaud the authors and will be happy to share this article with my students.
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