Ultrasound-Guided Percutaneous Peripheral Nerve Stimulation for Postoperative Analgesia

Could Neurostimulation Replace Continuous Peripheral Nerve Blocks?

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The moderate-to-severe pain many patients experience after orthopedic surgery is often treated with opioids, which are associated with undesirable adverse effects such as nausea, vomiting, sedation, and respiratory depression. Potent site-specific analgesia with far fewer adverse effects may be provided with a continuous peripheral nerve block.1,2 Unfortunately, perineural infusion has its own set of limitations such as inducing motor, sensory, and proprioception deficits that possibly increase the risk of falling; limited duration due to the risk of infection; and, for ambulatory patients, the burden of carrying an infusion pump and local anesthetic reservoir. These, among other limitations, have led some leaders in regional anesthesia to conclude that this technique is often “effective, but unrealistic”; and, calls within the surgical literature to abandon continuous peripheral nerve blocks.6,7 There is new evidence that suggests an analgesic alternative—ultrasound-guided percutaneous peripheral nerve stimulation (pPNS)—holds promise to provide postoperative analgesia free of many of the major limitations of both opioid analgesics and continuous peripheral nerve blocks.

The concept of using electrical stimulation to induce analgesia is hardly new: the ancient Romans prescribed contact with a living torpedo fish—able to deliver up to 220 V of current—as an analgesic; and this technique continued to be recommended through the Middle Ages up until at least the 16th century for a wide variety of pain-inducing ailments.3 Electroanalgesia continued to evolve through the 18th century with the discovery of artificial means to produce electrical current,4 with the first device specifically designed for this purpose—the “Electreat”—produced in the early 1900s.5 Subsequently, the first implantable spinal cord stimulator was described in 1967, with the first implantable peripheral nerve stimulator following a year later.6

MECHANISM OF ACTION

Although multiple theories exist for the mechanism of action of peripheral nerve stimulation for the treatment of pain,11 it is most commonly explained using the “gate control theory” of Melzack and Wall.12 The theory elucidates how electrical current-induced activation of large-diameter myelinated afferent peripheral nerve fibers inhibits transmission of pain signals (the “gate”) from small-diameter pain fibers to the central nervous system at the level of the spinal cord.12,13 Wall and Sweet14 proposed inducing analgesia by stimulating primary afferent neurons, and, soon after, commercially available stimulation systems were used (frequently off-label) to deliver peripheral nerve stimulation.15 In the following decades, the efficacy of neurostimulation was demonstrated in the management of chronic pain states with the use of surgically implanted spinal cord and peripheral nerve stimulators.16,17

However, the application of neurostimulation to postoperative pain states has been limited by the invasive nature of the available electrical leads: conventional units typically require multiple electrodes in close proximity to the peripheral nerve that require invasive and time-consuming surgery to place.18 In addition, these procedures require surgical reversal with removal of the leads, frequently complicated due to fibrous capsule formation adherent to the target nerve.19 Stimulation with electrodes placed on the skin (transcutaneous electrical nerve stimulation) has been investigated previously to determine if it has the potential to avoid these limitations.20,21 However, activation of pain fibers in the skin can greatly limit the degree of tolerated current that can be delivered by transcutaneous electrical nerve stimulation and often creates an undesirable analgesic “ceiling.”22

To enable application of neurostimulation for the treatment of postoperative pain, optimally an analgesic modality should be administered without requiring an open surgical incision. Extremely small, insulated electrical leads have been developed that permit relatively rapid percutaneous insertion through a needle.23,24 When combined with ultrasound guidance, a lead may be reliably inserted approximately 0.5 to 3.0 cm remote from a peripheral nerve using similar landmarks and general approach as for perineural catheter placement.25–27 Ultrasound-guided pPNS was first reported in situ by Huntton and Burgess28 in 2009 using an epidural neurostimulation electrode for the treatment of chronic neuropathic pain. Although similar techniques were subsequently reported for additional chronic pain conditions,29–31 it had yet to be applied to a postoperative pain state.

APPLICATION TO POSTOPERATIVE PAIN

Recently, preliminary data described the use of pPNS to treat pain after total (tricompartment) knee arthroplasty in 11 subjects.32–34 In 2 of these abstracts,32,33 a total of 10 individuals were included who experienced postoperative knee pain difficult to control with oral analgesics between 6 and 97 days after surgery. Using ultrasound guidance, a femoral and/or sciatic nerve electrical lead was inserted, depending on where most of the pain originated (anterior vs posterior). Of these 10 subjects, 5 had complete resolution of their pain at rest, 4 experienced a 57% to 67%
... and, specifically, regional anesthesia/analgia—as it has been practiced using local anesthetics and medication adjuvants for the past century.  

REFERENCES


35. Ilfeld BM. Single-injection and continuous femoral nerve blocks are used for percutaneous neuromuscular stimulation of the peripheral nervous system. *Pain Practice*. In Press.


