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Permalink
https://escholarship.org/uc/item/1c16p96m

Journal
REGIONAL ANESTHESIA AND PAIN MEDICINE, 41(6)

ISSN
1098-7339

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Publication Date
2016

DOI
10.1097/AAP.0000000000000481

Peer reviewed
Ultrasound-Guided Percutaneous Peripheral Nerve Stimulation for Postoperative Analgesia

Could Neurostimulation Replace Continuous Peripheral Nerve Blocks?

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(Reg Anesth Pain Med 2016;41: 720–722)

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 pain states has been limited by the invasive nature of the available techniques that are frequently complicated due to fibrous capsule formation adherent to the target nerve. 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 analogic “ceiling.”22

To enable application of neurostimulation for the treatment of postoperative pain, optimally an analogic 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 Huntoon and Burgher28 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,23,33 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%
DISCUSSION

In the setting of the population health risks related to prescription opioids and the logistical limitations of continuous local anesthetic infusions, novel and effective techniques to improve the acute pain experience would be both timely and important. The confluence of 4 relatively recent developments may now permit the wide application of pPNS to treat postoperative pain: (1) the proliferation of accessible ultrasound machines, (2) the high prevalence of anesthesiologists with skills in ultrasound-guided regional anesthesia, (3) the development of a stimulator small enough to be adhered to the skin, and (4) the development of an insulated electrical lead specifically designed for percutaneous, extended use (up to 60 days) in the periphery.

With the limited available data and no direct comparisons, we can only speculate on the pain reduction provided by pPNS versus continuous peripheral nerve blocks. Unlike continuous peripheral nerve blocks, pPNS theoretically induces no proprioception, motion, or sensory deficits, permitting unconstrained participation in physical therapy and decreasing the possibility of an increased risk of falling. Helically coiled leads theoretically minimize the risks of fracture, migration, dislodgement, and infection, permitting a dramatically long duration of lead retention—in some cases, well over a year. The footprint of new electrical generators are so small they may be adhered directly to the patient, thus avoiding the challenges of heavy local anesthetic reservoirs and portable infusion pumps. Combined, these characteristics permit a far longer duration of use for pPNS compared with continuous peripheral nerve blocks, possibly providing both preoperative and subsequently postoperative analgesia that outlasts the pain resulting from nearly all surgical procedures. In addition, there are no risks of local anesthetic leakage or toxicity, the latter allowing the concurrent use of multiple leads. Also notable is that leads may be inserted with minimal concern of fascial planes between the uninsulated tip and target nerve because fascia impedes electrical current far less than local anesthetic. Because the theoretical optimal lead location is relatively remote from target nerves—between 0.5 and 3.0 cm—there is the possibility of an easier/faster insertion, lower incidence of failure, and perhaps even a decreased risk of nerve injury.

There are noteworthy limitations of ultrasound-guided pPNS, the first of which is that there are currently no commercially-available temporary and reversible leads purposely designed for extended percutaneous use cleared or approved by the US Food and Drug Administration specifically for acute pain within the peripheral nervous system (although one system recently received Food and Drug Administration 510(k) clearance for use up to 30 days in the back and/or extremities for the symptomatic relief of chronic, intractable pain and acute pain, including postsurgical and posttraumatic pain, but is not yet commercially available). A second concern is that the specific lead used for the described cases has a 7.5% fracture rate of the terminal anchor during removal when used for the treatment of pain (Joseph Boggs, PhD, personal communication, October 6, 2015). Lastly, although neurostimulation has previously been described involving nearly every major peripheral nerve, it remains undetermined how effective pPNS will be for the treatment of acute pain in anatomic locations other than the femoral and sciatic areas.

Robust clinical trials examining important outcome metrics such as pain experience, functionality, health care expenditure, hospital length of stay, and incidence of adverse events will be needed to assess whether this technology can provide value in the management of acute postoperative pain. We believe that pPNS has the potential to completely revolutionize postoperative analgesia—and, specifically, regional anesthesia/analgesia—as it has been practiced using local anesthetics and medication adjuvants for the past century.

REFERENCES


