Feasibility of Ultrasound-Guided Percutaneous Placement of Peripheral Nerve Stimulation Electrodes in a Cadaver Model: Part One, Lower Extremity

Marc A. Huntoon, M.D., Elizabeth A. Huntoon, M.S., M.D., Jon B. Obray, M.D., and Timothy J. Lamer, M.D.

Background and Objectives: Peripheral nerve stimulation (PNS) is analgesic for some lower extremity neuropathic pain syndromes. PNS currently involves open surgical placement of electrode(s). Increasingly, ultrasound guidance is used for perioperative neural block. Minimally invasive placement of PNS electrodes for lower extremity targets using ultrasound guidance has not been reported. We hypothesized that ultrasound-guided placement of PNS electrodes was feasible.

Methods: Four cadaver mid-thigh transected fresh frozen specimens were studied. Specimens were scanned utilizing a 14 to 7 MHz linear probe and electrodes were placed proximal to the tibial, peroneal, and sciatic nerves at various locations. Anatomical dissection was performed to check placement accuracy and evaluate for grossly visible neural injuries.

Results: Acceptable locations for ultrasound-guided electrode placement were: (1) tibial nerve, approximately 8 to 14 cm superior to the medial malleolus above the tarsal tunnel, or at the upper popliteal fossa; (2) peroneal nerve, approximately 2 to 4 cm inferior to the lateral fibular head or at the upper popliteal fossa; (3) sciatic nerve immediately superior to the bifurcation (high popliteal area); and (4) lateral sural nerve at the lower popliteal fossa. No grossly visible neural injuries were seen. Electrode placements appeared to be in satisfactory locations for stimulation.

Conclusions: Ultrasound imaging to facilitate peripheral nerve electrode placement is feasible. This new minimally invasive approach to lead placement requires further study to determine trial implantation criteria, optimal locations, anchoring techniques, and best clinical practice. *Reg Anesth Pain Med 2008;33:551-557.*

Key Words: Peripheral nerve, Peripheral neuropathy, Neuropathic pain, Electrical stimulation therapy, Peripheral nerve stimulation.

Peripheral nerve stimulation (PNS) electrodes have been implanted to treat intractable painful conditions affecting peripheral nerves since the late 1960's. Shortly after the publication of the gate control theory by Melzack and Wall, wherein stimulation of large afferent neural fibers would decrease painful sensation in smaller pain fibers,[1] the concept of peripheral stimulation as a treatment for nerve pain was tested by Wall and Sweet. Peripheral nerve stimulation produced a temporary reduction in pain, seemingly corroborating the gate control hypothesis.[2] Percutaneous techniques for the treatment of peripheral nerve pain date back to 1978 and the introduction of percutaneous trigeminal nerve stimulation via a needle advanced through the foramen ovale.[3] Recently there has been a resurgence of interest in peripheral nerve stimulation techniques using percutaneous placement near target nerves, such as the supraorbital nerves.[4] Occipital nerve stimulation has also been performed extensively using percutaneous electrodes.[5]

Generally, placement of flat "plate" electrodes or circumferential cuff electrodes for PNS requires surgical dissection to place the electrode near the target

From the Department of Anesthesiology, Mayo Clinic, Rochester, MN.

Accepted for publication April 22, 2008.

Supported by a $4,800 grant from the Department of Anesthesiology, Small Grants Program, Mayo Clinic, Rochester MN. The data in this study were presented in part at the American Society of Regional Anesthesia and Pain Medicine Annual Fall Meeting, November 15, 2007, Boca Raton, FL.

Reprint requests: Marc A. Huntoon, M.D., Department of Anesthesiology, Mayo Clinic, 200 1st St. SW, Rochester, MN 55905. E-mail: huntoon.marc@mayo.edu

1098-7339/08/3306-0001$34.00/0
doi:10.1016/j.rapm.2008.04.007

nerve under direct vision.[6-12] Surgical placements have been hampered by the necessity for revisions, and the lack of minimally invasive trial techniques. Thus, patients considered for PNS must undergo a surgical dissection/stimulator placement and potentially the surgical removal of same for failed initial trials.

Increasingly, ultrasound is utilized to visualize peripheral nerves, and both nerve block injections and continuous catheter placements are reported.[13-15] Ultrasound may increase the accuracy and specificity of neural block for perioperative analgesia and anesthesia.[13] We therefore hypothesized that placement of percutaneous electrodes through commercially available epidural (spinal stimulation) needles using ultrasound guidance would be feasible. A study of cadaver lower extremity specimens for ultrasound-guided lead placement was therefore convened to further elaborate potential imaging locations, and potential pitfalls of the technique, compared with open surgical placement.

Methods

The study met guidelines for expedited Institutional Review Board approval. Four fresh frozen cadaver lower extremities were thawed for percutaneous electrical lead placement. Using a Toshiba Nemio XG Model SSA-580A ultrasound machine (Toshiba Medical Systems Corp., 1385 Shimoishagami, Otawara-shi, Tochigi-ken, Japan), each cadaver extremity, previously cut off at the midthigh level, was placed in position, and the region of interest scanned with a 14 to 7 MHz linear array transducer. All needles were advanced a few millimeters beyond the visualized nerve, and the leads were placed through the needle until slight tissue resistance was noted, signifying the lead had emerged from the needle tip. We attempted to place the middle of the visualized electrode array near its intersection with the nerve in a perpendicular orientation. The lead was then held in place, as the needle was extracted over the lead. Nerves were scanned in cross section at locations where visualization was satisfactory, then the transducer was gradually moved more proximally or distally. Comparison was made with gross anatomical cross sectional images to define areas where a good acoustical window might exist. The criteria for acceptable placement locations included: (1) an area that was relatively superficial and where ultrasound guidance and needle placement were possible; (2) the avoidance of vascular structures to the extent possible; (3) minimal traversing of muscular tissue (avoidance of unwanted muscular/motor stimulation effects); (4) the ability to anchor the device in neighboring fascia; and (5) proximal locations for common areas of pathology, such as tarsal tunnel syndrome, common peroneal injury at the fibular head, lateral compartment pain, and distal tibial and peroneal nerve injuries. After several test scans, the following areas were selected: (1) the tibial nerve at a point approximately 8 to 14 cm superior to the medial malleolus, (2) the tibial and peroneal nerves at 2 locations (the popliteal crease, and a point approximately 10 cm superior to the popliteal crease) in the popliteal fossa, and (3) the peroneal nerve at a point 2 to 4 cm inferior to the lateral fibular head. Once a satisfactory image of the nerve was obtained, a percutaneous 14-gauge epidural needle (Advanced Bionics, Boston Scientific, Valencia, CA) was placed under ultrasound guidance, and the 8-contact electrical lead (Advanced Bionics) was advanced through the needle to lie in apposition to the nerve. The needle was directed either immediately superficial to the nerve or deep to the nerve, depending on location, and known anatomical structures. Needles were inserted generally via either an "in plane" technique (needle is placed parallel to the long axis of the transducer) with a short axis/cross sectional view of the nerve, or an "out of plane" technique (needle is placed perpendicular to the long axis of the transducer) in the short axis/cross sectional view. The "in plane" technique allowed direct visualization of the entire shaft of the needle during placement, and was the preferred approach. Electrode visibility during ultrasound scanning was acceptable, often with the ability to identify the individual contacts of the lead. After lead placement, a small incision was made around the electrode and superficial anchoring to nearby fascia was performed. Each lead was dissected to the area of interest to: (1) verify close proximity (within 2 mm) of the lead to the target nerve; and (2) verify no transection or grossly visible injury to the nerve. Two mm was arbitrarily chosen as a reasonable distance based on experience with nonimage-guided percutaneous placement of occipital, supraorbital, and field stimulation trial electrodes. In addition, a Boston Scientific engineer advised that 2 mm was well within the power capacity of the pulse generator, because the intercontact distance on the 8-contact lead was 3 mm (Jay Schiltz, personal communication, March 3, 2008). In all cases, the location of scanning was chosen to be proximal to known sites of nerve entrapment or injury. Femoral nerve placements were not performed for 2 reasons: (1) very few chronic pain syndromes involve the femoral nerve in the upper thigh; and (2) whole leg samples were less readily available for study, and more costly. It was considered likely that conditions acceptable for