Feasibility of Ultrasound-Guided Percutaneous Placement of Peripheral Nerve Stimulation Electrodes and Anchoring During Simulated Movement: Part Two, Upper Extremity

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Background and Objectives: Peripheral nerve stimulation (PNS) may provide analgesia for neuropathic pain syndromes in that nerve distribution. PNS electrode placement using ultrasound (US) guidance for upper extremity pain syndromes has not been reported. Existing anchoring technology may allow permanent implantation without significant migration.

Methods: Three cadaver midhumeral fresh frozen upper extremity specimens were studied. US scanning was performed, targeting electrode placement at the radial, ulnar, and median nerves. Leads were anchored in the superficial fascia. The targeted nerves were exposed by careful dissection. Visual inspection for gross nerve damage, and electrode proximity to the nerve was performed. After confirmation of adequate lead placement, 2 extremities were sutured and placed in a continuous passive motion (CPM) machine for 21 hours to simulate activity. Each electrode was assessed for migration.

Results: Acceptable locations for US-guided electrode placement were: radial nerve approximately 10-14 cm superior to the lateral epicondyle; median nerve approximately 6 cm below the antecubital fossa; and ulnar nerve approximately 9 to 13 cm above the medial epicondyle. One electrode was placed at each site without difficulty. After careful exposure, visual inspection showed no gross nerve damage. Each electrode had at least 2 electrical contacts within 2 mm of the nerve sheath. At CPM termination, only the median nerve electrode on 1 cadaver extremity had migrated significantly.

Conclusions: This new minimally invasive approach to lead placement requires further study to determine implantation criteria, optimal locations, anchoring techniques, and electrode design to define best clinical practice. *Reg Anesth Pain Med 2008;33:558-565.*

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

Peripheral nerve stimulation (PNS) electrodes have been implanted to treat painful conditions affecting peripheral nerves since shortly after the description of the gate control theory.[1] Generally, the etiology of nerve pain requiring PNS treatment is surgical iatrogenic injury, trauma, nerve entrapment, or injection injury.[2] Subsequent to the initial description,[3] several small series have described the initial clinical experience of PNS.[4-8] One prospective series[9] examined the outcomes of PNS for complex regional pain syndrome. The existing reports have been remarkably consistent, with a majority of patients receiving long term clinical improvement. Technical issues including movement of electrodes, lost "capture" of stimulation, and need for revision surgery, have plagued early series.[10] As for all invasive neuromodulation treatments, the difficulty in performing randomized blinded trials for electrical therapies[11] has led to a perceived need for expert guidelines. Current guidelines suggest PNS consid-

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eration after noninvasive treatments have failed for pain that exists in the territory of a single traumatized nerve. The guidelines also advocate preprocedural nerve blocks with a high degree of success on 1 or more occasions prior to proceeding with PNS implantation.[12] Electrode designs used for PNS have generally been either circumferential (wrapped around the nerve) or plate electrodes (placed inferior to the nerve), due to the open surgical dissection required.[13] No minimally invasive trial technique using ultrasound (US) guidance has previously been described.

Increasingly, US is used to visualize peripheral nerves, and both nerve block injections, and continuous catheter placements, are reported.[14-16] Ultrasound may increase the accuracy and specificity of neural block for perioperative analgesia and anesthesia.[14] We therefore hypothesized that placement of percutaneous electrodes through commercially available epidural needles (designed for spinal stimulation) using US guidance would be feasible. A study of fresh frozen cadaver extremity specimens was convened, to study the feasibility of this minimally invasive approach to lead placement, and to further elaborate optimal imaging locations, and potential pitfalls of the technique compared with open surgical placement.

Methods

The study met guidelines for expedited Institutional Review Board approval. Three fresh frozen cadaver upper 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 mid- to upper-humeral level, was examined with a 14 to 7 MHz linear array transducer. Sites chosen for study after anatomical study and US scanning were: (1) The radial nerve at a point 10 to 14 cm superior to the lateral epicondyle; (2) The median nerve at a point 6 cm distal to the midantecubital fossa; and (3) The ulnar nerve at a point 9 to 13 cm superior to the medial epicondyle. Each nerve was identified using a short axis, cross sectional US view. Sites were chosen to allow proximal placement of electrodes to treat common clinical syndromes, such as ulnar nerve entrapment syndromes, carpal tunnel syndrome, and distal radial nerve injuries. Also considered were: nerve location superficial enough to be easily scanned; the entry locations with respect to ability to anchor the device, and the potential for traversing vascular structures and muscular tissue that might cause unwanted motor stimulation. In each case, the involved target nerve was initially scanned in the short axis view and the needle was passed in plane longitudinally to the transducer, such that the entire needle shaft could be visualized at all times. More superficial and easily visible locations were chosen, and then scanned more proximally or distally, to find acceptable entry points for needle and electrode. For example, the ulnar nerve was scanned in the ulnar groove, posterior to the medial epicondyle, and then scanning was gradually moved more proximally. The radial nerve was visualized inferior to the spiral groove as it wrapped around the humerus laterally. The median nerve was visualized in the antecubital fossa, and then scanned following the nerve both proximally in the medial arm near the distal humerus, and also more distally in the anterior medial forearm. Anatomical cross sectional images were also viewed to consider areas where minimal muscular and tissue barriers might exist. Once a satisfactory short axis cross section image of the nerve was obtained, a percutaneous 14-gauge epidural needle (Advanced Bionics, Valencia, CA) was placed using US guidance, usually going a few millimeters past the nerve. The 8-contact electrical lead (Advanced Bionics) was advanced through the needle until slight tissue resistance was encountered to lie in apposition to the nerve. This placed the electrode array perpendicular to the crossing nerve, with the electrode contacts within approximately 2 mm of the nerve or less, often directly contacting it. Perpendicular placement is commonly performed for other PNS procedures in this manner.[17] Needles were retracted over the leads once the lead had been placed. The needle was directed either immediate, superficial, or deep to the nerve depending on location and known anatomical structures. Needles were advanced in plane with the long axis of the transducer to allow for continuous visualization. After lead placement and superficial anchoring, each lead was dissected to the area of interest to verify: (1) close proximity (within 2 mm) of the lead to the target nerve; and (2) no transection or grossly visible injury to the nerve.

In order to simulate upper extremity movement, 2 of the cadaver extremities were placed in a continuous passive motion (CPM) machine. The extremities then underwent passive motion to 90 degrees at the elbow.

Results

Radial Nerve

All 3 placements were technically satisfactory within 2 mm from the nerve, and perpendicular

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