Ultrasound imaging and occipital nerve stimulation

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Objectives: Occipital nerve stimulation (ONS) is a peripheral nerve stimulation (PNS) technique that has been used with success in the management of intractable chronic daily headaches (CDHs) and occipital neuralgia (ON). The technique involves the placement of a stimulating surgical or percutaneous electrode over the occipital nerves within the subcutaneous tissues at the skull base. Until recently, procedures involving the occipital nerves were based on identifying bony or arterial landmarks with direct palpation or fluoroscopy. Although universally accepted as an imaging technique, fluoroscopy does not provide real-time imaging of the occipital nerves or vessels. Furthermore, therapeutic efficacy of ONS is directly related to the ability of the stimulating electrode to produce peripheral nerve dermatomal paresthesia, emphasizing the need for precision placement.

Materials and Methods: A total of six patients, diagnosed with refractory CDH and ON, after failing extensive medical management, were diagnosed as potential candidates for ONS. Subsequently, all underwent successful percutaneous trials of bilateral octopolar (Advanced Neuromodulation Systems, Plano, TX, USA) ONS under ultrasound guidance, followed by permanent surgical implantation.

Results: In this case series, ultrasound provided accurate, real-time placement of introducer needles and stimulating electrodes by allowing visualization of tissue planes (epidermis, dermis, subcutaneous fat, and trapezious muscle), as well as vessels and nervous structures.

Conclusions: Ultrasound imaging has been used increasingly for peripheral nerve blockade in surgical anesthesia and in chronic pain management as it allows real-time localization of both nervous and vascular structures (color flow Doppler) and, thus, a method for increasing blockade precision and safety. As an adjunct to ONS, the position of the introducer needles and electrodes can be visualized in relation to the occipital nerves and vasculature. This reproducible positioning allows accurate depth of placement (assuring production of the prerequisite PNS dermatomal paresthesia required for ONS efficacy) and limits the risk of injury to the occipital artery or nerve(s). In this case series, ultrasonography provided real-time, safe, and reliable placement of ONS electrodes. It also allowed identification of nervous and vascular structures unable to be seen with fluoroscopy. The portable nature of modern ultrasound machines, together with an ever improving pixelation of the Doppler color flow images/real-time measurements, and a lack of radiation exposure make this technology an attractive emerging modality in the field of Neuromodulation.

Keywords: Electrode placement, headache, occipital nerve stimulation, occipital neuralgia, peripheral nerve stimulation, PNS, technical report

Conflict of Interest: The authors reported no conflicts of interest.

INTRODUCTION

Chronic daily headache (CDH) syndromes represent a major health issue worldwide in terms of lost workdays and revenue (1–3). Diagnoses include migraine, atypical migraine, cluster, transformed migraine, and cervicogenic headaches, as well as occipital and facial hemicranias, or any combination of the above. Many of these patients are totally disabled, having failed conservative and pharmacologic treatments (4,5).

Occipital neuralgia (ON), however, is described by the National Institute of Neurological Diseases and Stroke as a “distinct type of headache characterized by piercing, throbbing, or electric-shock-like chronic pain in the upper neck, back of the head, and behind the ears, usually on one side” (6). Typically, the pain of ON begins in the base of the head and spreads upward within the distribution of the greater and the lesser occipital nerves and is of neuropathic character with paroxysmal episodes of shooting electric type symptoms. Although the symptom etiology includes trauma, infection, and surgery, the vast majority of these patients have idiopathic etiologies (7).

Initial treatment for both CDH and ON is symptomatic and pharmacologic (8). Nonresponders have been treated with occipital nerve blockade (9), radiofrequency ablation (10), botulinum toxin A injections (11,12), surgical decompression (13), and occipital nerve stimulation (ONS) (7,14–18).
ONS involves placement of trial peripheral nerve stimulation (PNS) stimulating electrode(s) over the occipital nerves. If the trial is successful in achieving prerequisite dermatomal paresthesia, then pain relief from permanent implantation has been reported as high as 80% (7,14–16,18). The anatomic location of the occipital nerves in individual patients, however, may be quite variable (19,20). Cadaver studies assume that we have tools to approximate the location of these nerves in our everyday clinical practice (19). To the contrary, anatomic palpation has been the mainstay for clinical localization (one thumb breath lateral and inferior to the occipital protuberance at the skull base) (19).

In addition to palpation, the pain interventionalist also uses fluoroscopic guidance to try to localize the occipital nerves. The C1–C2 interspace commonly serves as the radiologic landmark for identifying the insertion site of percutaneously or surgically placed electrodes. (17) The assumption is that, by inserting transverse electrodes at this level, they will consistently cross the occipital nerve trunks and/or the greater and lesser divisions within the appropriate connective tissue level necessary to produce useful dermatomal paresthesia. Fluoroscopy, however, cannot image the tissue planes nor the nervous or vascular structures. Thus, a precise relationship between the ONS electrode and these structures is in need of better clinical confirmation.

Ultrasound imaging has been used increasingly for peripheral nerve blockade in surgical anesthesia (21,22) and chronic pain management, as it allows real-time localization of both nervous and vascular structures (color flow Doppler), thus, a method for increasing blockade precision and safety (23–25). As an adjunct to ONS, the position of the introducer needles and electrodes can be visualized in relation to the occipital nerves and vasculature. This reproducible positioning allows accurate depth of placement (assuring production of the prerequisite PNS dermatomal paresthesia required for ONS efficacy) and limits the risk of injury to the occipital artery or nerve(s).

METHODS

A total of six patients, diagnosed with refractory CDH and ON, were referred from the neurology service. After failing extensive medical management (biofeedback, physical therapy, massage, acupuncture, narcotics, NSAID’s, tricyclic antidepressants, anticonvulsants, tryptans, beta blockers), they were diagnosed as potential candidates for ONS after positive anesthetic phase response to occipital nerve blockade. Subsequently, all underwent successful percutaneous trials of bilateral octopolar (Saint Jude Medical, Plano, TX, USA) ONS under ultrasound guidance, followed by permanent surgical implantation. All gave informed consent after evaluation with a clinical psychologist.

All patients were instructed to shampoo with Hibiclens (chlorhexidine) the night prior to and the morning of the procedure. On the day of the procedure, an intravenous was started, and a slow infusion of 2 g of cefazolin (or 1 g vancomycin if Methicillin-resistant Staphylococcus aureus positive) was started before the patients were taken to the operating room. The patients were placed prone with pillows under the chest to augment neck flexion. Monitored anesthesia care was administered with an interactive patient at all times. All hair was shaved below a line connecting the external occipital protuberance to the mastoid processes and prepped with chlorhexidine (Fig. 1). A sterile C-arm was then introduced to obtain a true anterior–posterior image of the cervical spine at the C1–C2 interspace, and the overlying skin was marked with a sterile marker (Fig. 2). Thereafter, a portable ultrasound with a sterile linear array transducer of 5–13 MHz frequency was introduced to obtain images of the bilateral occipital fossae and bilateral greater occipital nerves and arteries (Fig. 3). The ultrasound probe was first placed at the midline just below the external occipital protuberance, and images were obtained (Figs. 4 and 5). It was slowly advanced laterally at the same level until images of the greater occipital artery and nerve were obtained as two distinct structures, the artery as a hypoechogenic oval structure located medially and the nerve as a hyperechogenic structure located laterally (Fig. 6). The nerve could be traced from its exiting trunk into two distinct divisions within the substance of the trapezious muscle. The artery was identified with Doppler ultrasound (Figs. 7 and 8). The locations of the nerve and the artery were marked at the skin with a sterile marker bilaterally. The depth of both artery and nerve identification was consistently noted at 1–1.5 cm from the skin. A skin infiltration of 2–3 cc of 1% lidocaine at the skin needle entry zone was then performed. The stimulating electrodes were introduced through a 14-gauge introducer needle (0.5–0.7 cm below the skin surface) in a medial to lateral position,
guided by the skin markings. Needle entry was consistently higher than the entry point that is traditionally used at the radiologic C1–C2 level (Fig. 9). Needle positioning was verified with fluoroscopy for comparison. The needle advancement was then performed with both fluoroscopic and ultrasonic imaging (Fig. 10). After electrodes were positioned bilaterally, intraoperative testing was performed, confirming adequate dermatomal paresthesia within the occipital nerve distribution. The needles were then withdrawn, the electrodes were sutured with 2.0 silk to the skin, and a sterile dressing was applied (26). Patients were trialed for five to seven days, with an average pain reduction of greater than 70% reported. Permanent systems were implanted with the same approach and technique, with an additional “strain relief loop” added in a midline subcutaneous pocket followed by pocketing to an internal pulse generator over the hip (26).

**DISCUSSION**

Ultrasound guidance in regional anesthesia and pain medicine was first described in 1978 (27). A Doppler ultrasound blood flow detector was used to localize the third division of the subclavian artery, rendering the supraclavicular approach to the brachial plexus safer and highly successful. The ultrasound-guided applications have emerged not only as an alternative to regional anesthesia neurostimulating techniques (21,22) but also as an alternative to radiation emitting fluoroscopic techniques in interventional pain management (23–25,28).

Historically, fluoroscopy has been the primary technique used for placement of ONS electrodes. Fluoroscopic radiation exposure poses significant risk to both patients and pain management intervention lists and should be limited to the lowest possible level (29). With its real-time localization of both nervous and vascular structures, as well as real-time identification and guidance of introducing needles, ultrasound imaging represents an accurate and safe alternative that provides quality imaging without the radiation exposure risks.
In this case series, ultrasound provided accurate, real-time, radiation-free placement of introducer needles and stimulating electrodes by allowing visualization of tissue planes (epidermis, dermis, subcutaneous fat, and trapezious muscle), as well as vessels and nervous structures. The authors did not appreciate any differences in tissue planes when positioning needles and electrodes in different patients. Furthermore, the ability to measure the distance of the needle from skin (depth of electrode position) provided a safe and reliable means for generating the prerequisite dermatomal paresthesia required for ONS efficacy, not as readily achieved historically with fluoroscopy or palpation.

**CONCLUSION**

In this case series, ultrasonography provided real-time, safe, and reliable placement of ONS electrodes. It also allowed identification of nervous and vascular structures unable to be seen with fluoroscopy. The portable nature of modern ultrasound machines, together with an ever-improving pixelation of the Doppler color flow images/real-time measurements, and a lack of radiation exposure make this technology an attractive emerging modality in the field of neurostimulation. Future prospective studies between ultrasonography and traditional methods of occipital nerve identification could provide us with a better understanding of the relation between these techniques.

**REFERENCES**

The difficulties faced in the use of stimulation systems for the treatment of ON include difficulty in capturing paresthesia overlap on pain, migration after final placement, infection, breakage, skin erosion and others. The method discussed in this paper may address the first two of these problems.

It is this reviewer’s opinion that the anatomy of the greater and lesser occipital nerves is relatively predictable and that overlap of these with electrode should be straightforward when implanting with transverse leads of adequate length. In cases where I have noted difficulty in obtaining paresthesia overlap or a “migration”, the difficulty has been leaving the primary lead too caudal, over the C2 segment. Another implant technique that has been used to address this problem is that of leads placed in parallel orientation to the axis of the greater occipital nerve. Unfortunately this leaves the lesser occipital nerve untreated which may leave the patient incompletely treated.

It would appear empirically true that real time ultrasonographic imaging would increase the specificity of these implants, however, a prospective study would have to be completed, by well experienced hands, to further prove this implant methodology and to view it as a potential recommended adjunct for this procedure.

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This manuscript shows another useful application of intra-operative ultrasound imaging. When placement of the lead over the occipital nerve is of paramount importance, direct visualization of the nerve via ultrasound is extremely useful. Even though the course of the nerve is relatively constant, its depth may vary significantly. Ultrasound visualization allows not only to find the course of the nerve, but also to reliably place the lead as close to it as possible. This should maximize the results of the stimulation.

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This paper written by Skaribas and Aló adds valuable information to the literature in a method that may benefit many patients. The use of ultrasound to identify the occipital nerve in a more precise nature also may allow for better comparative studies against other treatment options. This paper should be seen as a possible method to be used in a multi-center analysis of this potentially breakthrough option for implanting the peripheral nerve.

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COMMENTS

Occipital neuralgia (ON) is a common condition that presents after a variety of precipitating conditions. Patients with this condition sometimes present for treatment with neuromodulation devices.