NEUROMODULATION: TECHNOLOGY AT THE NEURAL INTERFACE

Volume 12 • Number 3 • 2009
http://www.blackwell-synergy.com/loi/ner

TECHNICAL REPORTS

Electromagnetic Navigation Technology for More Precise Electrode Placement in the Foramen Ovale: A Technical Report

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ABSTRACT

Introduction. Interventional pain management techniques require precise positioning of needles or electrodes, therefore fluoroscopic control is mandatory. This imaging technique does however not visualize soft tissues such as blood vessels. Moreover, patient and physician are exposed to a considerable dose of radiation. Computed tomography (CT)-scans give a better view of soft tissues, but there use requires presence of a radiologist and has proven to be laborious and time consuming. **Objectives.** This study is to develop a technique using electromagnetic (EM) navigation as a guidance technique for interventional pain management, using CT and/or magnetic resonance (MRI) images uploaded on the navigation station. **Methods.** One of the best documented interventional procedures for the management of trigeminal neuralgia is percutaneous radiofrequency treatment of the Gasserian ganglion. EM navigation software for intracranial applications already exists. We developed a technique using a stylet with two magnetic coils suitable for EM navigation. The procedure is followed in real time on a computer screen where the patient's multislice CT-scan images and three-dimensional reconstruction of his face are uploaded. Virtual landmarks on the screen are matched with those on the patient's face, calculating the precision of the needle placement. **Discussion.** The experience with EM navigation acquired with the radiofrequency technique can be transferred to other interventional pain management techniques, for instance, for the placement of a neuromodulation electrode close to the Gasserian ganglion. Currently, research is ongoing to extend the software of the navigation station for spinal application, and to adapt neurostimulation hardware to the EM navigation technology. This technology will allow neuromodulation techniques to be performed without x-ray exposure for the patient and the physician, and this with the precision of CT/MR imaging guidance.

KEY WORDS: *Chronic pain, electromagnetic neuronavigation, electrode placement, radiofrequency, trigeminal neuralgia.*

Introduction

Trigeminal neuralgia (TN) also referred to as "tic douloureux" is an extremely painful condition. When pharmacologic treatment fails to provide satisfactory pain relief or causes intolerable side-effects, interventional pain management techniques may be indicated. Several interventional treatment possibilities exist such as glycerol injection into the Gasserian Ganglion, radiofrequency (RF) thermo lesion of the Gasserian Ganglion, balloon compression into the ganglion, and micro vascular decompression surgery

Source of financial support: no financial support was obtained for this paper.
Disclaimer: not applicable.
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(Janetta operation). The selection of the interventional technique is mainly guided by the patient's age and general condition (1–3). Certainly for older patients with frequent co-morbidity, the minimal invasive percutaneous techniques are preferred (1,4). RF treatment of the Gasserian ganglion for the management of TN is probably the oldest documented radiofrequency procedure (5); although no randomized controlled trials are published, the efficacy was documented in large patient series (6). Radiofrequency thermo lesioning of the Gasserian ganglion can induce neurologic complications such dysesthesia, anesthesia dolorosa, and diminished corneal reflex (6). More recently pulsed radiofrequency (PRF) also is used. This is an adapted RF technique whereby the high frequency current is delivered in bursts of 20 msec followed by a silent period of 480 msec allowing the generated heat to be washed out and thereby taking care that the temperature at the electrode tip does not exceed 42°C, thus reducing the risk for neurologic complications (7). Patients suffering TN who can not adequately be controlled by pharmacologic treatment receive extensive explanation on the potential interventional treatment options. Based on the patient's general condition, a microvascular decompression surgery or a radiofrequency treatment is proposed. The patient helps selecting between treatment options after having received information relative to expected duration of action and potential complications of the treatment.

The success rate of these interventions depends largely on the precision with which the Gasserian Ganglion is reached.

We introduced the use of electromagnetic (EM) navigation technology to improve precision of the electrode placement. The use of this navigation technique has been reported in cardiology (8), but to our knowledge its application for the correct electrode insertion in the foramen ovale was not described yet.

The experience gathered with the RF electrode placement with EM navigation will help to expand its use to other pain management techniques such as neuromodulation procedures.

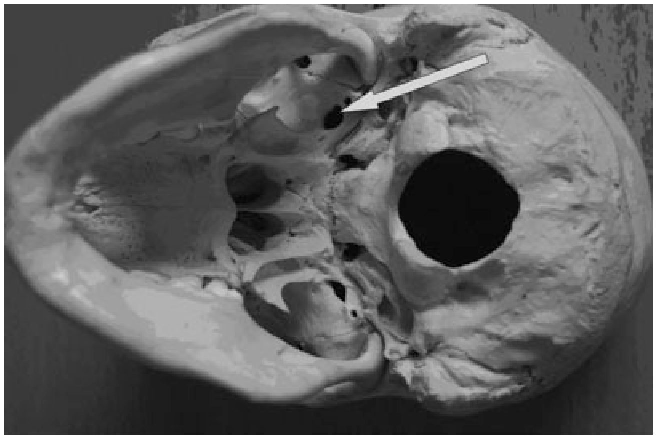

FIGURE 1. The arrow shows the left foramen ovale.

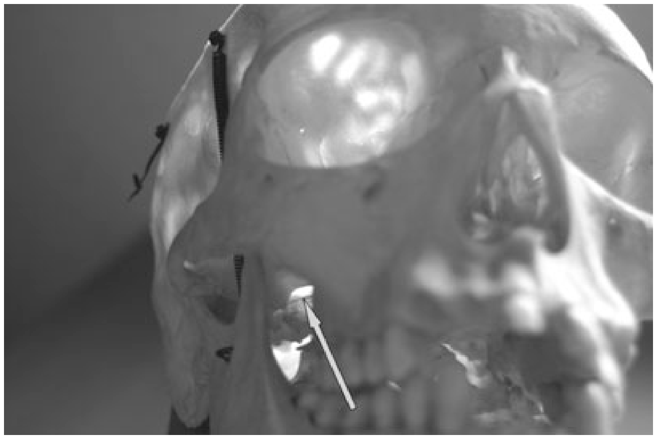

FIGURE 2. The arrow indicates the track of the needle.

Radiofrequency Treatment of the Gasserian Ganglion

The Gasserian ganglion is commonly reached through the foramen ovale. (Fig. 1). The needle trajectory is indicated in Figure 2. Correct identification of the foramen ovale and progressive insertion of the electrode requires different fluoroscopic controls. For patient's comfort the procedure is performed under mild sedation. The patient must be awakened to be able to report sensation upon sensory stimulation at 50 Hz. When electro-stimulation confirms the fluoroscopically observed correct needle placement, the patient is again sedated to perform the thermo lesion or PRF treatment. The use of imaging technique exposes the patient and the physician to high dose radiation. Because of the danger of long-term x-ray exposure, it is impossible to do real time follow-up of the needle trajectory. The fluoroscopy has the disadvantage to give you only a two-dimensional view of the procedure. Moreover, with conventional x-rays it is not always easy to view the foramen ovale and soft tissues such as blood vessels are not visualized. Therefore, occasional puncturing of the facial artery leading to postoperative hematoma occurs.

Alternatively computed tomography (CT)-scan guided techniques have been proposed (9). This imaging technique allows visualization of the soft tissue and is consequently more accurate. This allows you real time follow-up and the trajectory of the needle is followed in three dimensions with a coronal, axial, and sagittal view. An example of a CT-scan with insertion of the needle in the foramen ovale is given in Figure 3. We used this technique for several years but the obligatory presence of a radiologist, and the longer

FIGURE 3. Computed tomography-guided placement of the needle through the foramen ovale.

time needed to perform the procedure both contribute the patient's discomfort and a higher cost for the hospital. In our department more than 90 procedures treating TN have been carried out with the CT-guided technique, yielding good results with great precision and without any technical or medical complication.

EM Navigation Guided Procedure

The introduction of navigation technology in surgery triggered the idea of using this technology for interventional pain management techniques. Classical navigation with infrared camera proved to be time consuming and not very accurate. EM tracking, however, allows navigating with needles under "real time" supervision. Needles suitable for EM navigation, and allowing real time monitoring of the needle placement during percutaneous pain management techniques, have been developed (AZ Nikolaas, Sint-Nikolaas, Belgium in cooperation with the Surgical Navigation Technology, a company based in Denver (Col) USA, presently known as Medtronic-SNT).

The navigation needle is in fact a stylet equipped with two magnetic coils, inserted into the thermo couple needle, normally used for the RF procedure.

First a multislice CT-scan is taken of the area between the puncture (entry point) of the skin and the target (the foramen ovale). The best scans where the target is most visible in coronal, axial and sagittal view are downloaded from the hospital network or from an optical disc to the computer of the navigation system.

During the procedures, the patient's head is positioned upon a magnet and so maintained within a magnetic field.

FIGURE 4. Noninvasive dynamic reference frame.

Certain reference points on the three-dimensional reconstruction of the face are ticked into the computer by simple mouse click. The same reference points are indicated with a coiled stylet applied to the face and sent to the navigation machine by pushing a foot switch. One reference point (antenna) is fixed to the frontal area of the skull. (Fig. 4)

This point also is entered into the computer, thus situating the position of the patient within the magnetic field, and allowing the patient to move without causing any loss of precision of the representation. The track is dotted out virtually on the computer screen. (Fig. 5)

The computer, matching virtual landmarks on the three-dimensional reconstruction of the face with the same landmarks on the patient's face, then calculates the circle with a precision of approximately 1 mm within which we can work. The coiled stylet is introduced into the thermocouple needle and then we can navigate real time following exactly the virtual track toward the foramen ovale (Fig. 6). Once our needle passes the foramen a short control of the position of the needle is made by a one shot fluoroscopic image not lasting longer than 1 sec. By removing the coiled stylet, we lose contact with the magnetic field and the navigation station.

Because of the real time visualization of the needle placement (Fig. 7) the procedure can be performed under local anesthesia or light propofol sedation. Considering that patients treated by RF of the Gasserian ganglion are mainly elderly and frail, sedation increases patient's comfort and safety of the intervention.

Discussion

The percutaneous approach of the foramen ovale is sometimes difficult because of the unclear visualization of the foramen with fluoroscopy and the many anatomic variations of this foramen. This fact leads to long x-ray exposure

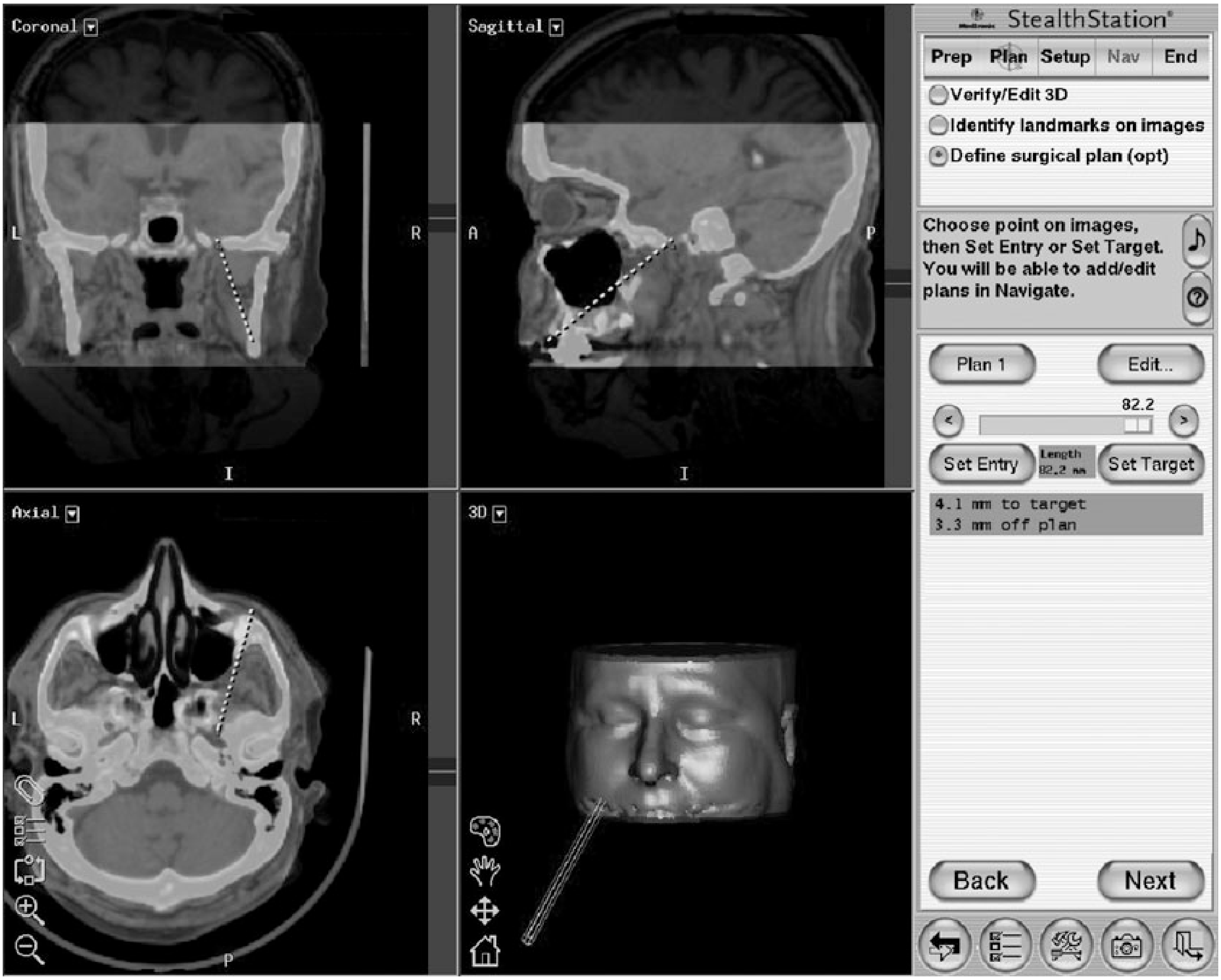

FIGURE 5. Virtual track in coronal, axial, sagittal, and three-dimensional reconstruction of the face, showing entry and target point.

FIGURE 6. Placement of the needle with electromagnetic navigation guidance.

of medical staff and patients and jeopardizes the success of an otherwise very successful procedure. EM navigation makes this procedure simpler, safer, more accurate, faster, and less invasive.

Our pain center works closely together with the department of neurosurgery to perform these procedures. Since the first introduction several procedures have been carried out. After a short learning period we are now able to do three procedures within one hour because most of the programming work can be performed outside the operating room. EM navigation use in interventional pain therapy was, to our knowledge, not reported earlier. In the near future this technology will be used for other applications within interventional pain management and neurosurgery. CT images are by far more precise than the classical fluoroscopy images. The exposure to x-rays of the physician is

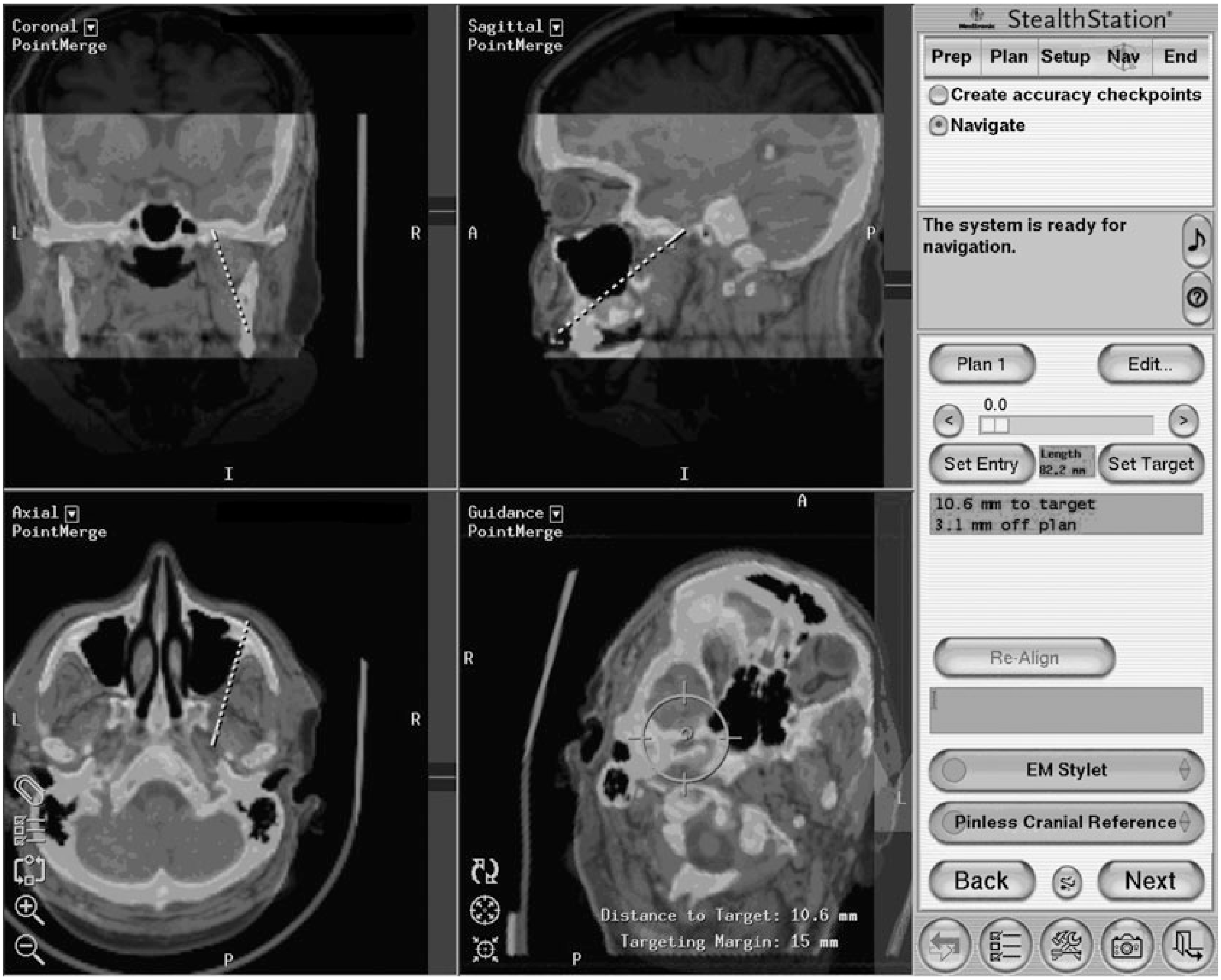

FIGURE 7. Image of the screen of the navigation station during the procedure. Green dot represents the tip of the needle.

much higher using CT guidance as compared with fluoroscopy. The use of EM navigation bypasses this step for the physician and allows working with CT precision and without x-ray exposure. Software for spine surgery is yet available. If the industry can adapt neurostimulation hardware to EM navigation technology by, for example, developing coiled stylets to introduce into the spinal cord stimulation leads, we will be able to do CT-guided, real time imaging for spinal cord stimulation, thus decreasing considerably the exposure time to x-rays, and increasing the comfort of the medical staff by making radioprotection during the procedures useless. Once the technology of following flexible instruments like leads is developed, we are only one step away from using this technology in many other applications where leads and catheters have to be followed or guided.

Conflict of Interest

Dr. J.P. Van Buyten is frequently participating as investigator in clinical trials initiated by Medtronics, the company actively involved in neuromodulation. Dr. J.P. Van Buyten serves on Medtronic's Advisory Committee, and he has subsequently received consulting and speaking fees. The authors declared no other conflicts of interest.

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