

Wireless Neuromodulation By A Minimally Invasive Technique For Chronic Refractory Pain. Report Of Preliminary Observations.

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Abstract

Objective: Evaluation of the safety and efficacy of a minimally invasive neuromodulation device to treat intractable chronic trunk and limb pain.

To report preliminary results using the wireless design and percutaneous implant system in two diverse conditions.

Methods: Two patients with intractable pain, one following a back surgery and the second one with post herpetic neuralgic pain received treatment. For both subjects, pain was refractory to pain medication, interventional pain procedures and physiotherapy. This modality delivered neuromodulation via a percutaneously implanted electrode remotely controlled by a wireless device. The back pain surgery patient received high frequency dorsal root ganglion (DRG) stimulation to cover the areas that were deemed unsuitable for conventional spinal cord stimulation methods. The second patient had our novel technology for peripheral nerve stimulation (PNS) along the affected intercostal nerve. A Visual Analog Scale (VAS), Oswestry Disability Index (ODI), EQ-5D-5L Quality of Life Questionnaire and Global Impression scale (PGIC) were administered at 3, 5, 8, 12 weeks and 6 months post-implantation.

Results: In both patients there was significant relief of symptoms and reduction in pain medication during the short term follow-up. Pain levels, as reported by both patients at three months post-implantation, decreased by up to 60% with continuously applied stimulation. Stimulation remained paresthesia-free for both subjects while the disability improved by 50%. The procedure as well as the wireless system was tolerated very well and was devoid of any side effects or adverse events.

Conclusion: We have developed a novel, neuromodulation system with a minimally invasive percutaneous implantation suitable for both PNS and DRG stimulation. These preliminary results are very encouraging for the minimally invasive wireless approach for treatment of chronic, intractable back and leg pain. This was safe and also effective.

1. Introduction

Chronic pain is one of the most common complaints that take the general population for a medical visit and remains a prevalent public concern.^{1,2} Spinal cord stimulation (SCS) is a time tested and widely accepted technology in terms of safety and efficacy.³⁻⁵ Studies established its cost effectiveness in Failed Back Surgery Syndrome (FBSS) as well as complex regional pain syndromes.^{6,7} Yet, SCS has limitations and about 20% of patients do not proceed beyond the trial and only 50% cases with successful trial continue with long-term therapy.^{6,8,9} Some of the reasons of failed SCS include device misalignment, stimulation parameters and implant related complications like dislocation, migration, or fracture. Body movement related changes in the device position and vice versa can also produce alterations in the paresthesia distributions. Due to the bulk of the battery and the extensive wiring involved in the SCS operating system the relative distance between the electrodes and spinal cord tracts can change with positions of the patients.^{10,11}

Thus, alternative techniques of stimulation and their targets are recommended to provide better relief to the intractable pain syndromes.

Dorsal root ganglion (DRG), a cluster of primary sensory neuron somata enclosed in the dural sheath, transmit sensory information, including nociceptive signals, from distal locations in the body to the dorsal columns of the spinal cord.¹² Previous reports have implicated DRG in the development and maintenance of chronic pain.^{12,13}

The relative immobility of the bony vertebral structures surrounding the DRG may also provide some defense against device migration. The cerebrospinal fluid

(CSF) layer interposing the DRG and the electrodes is thinner than that in dorsal column stimulation suggesting that the energy requirements of a DRG stimulator will be lower compared to traditional SCS.¹⁴

In some instances where SCS fails to reach target locations, PNS becomes a valuable alternative. However, at present both PNS and DRG stimulation still utilize the conventional SCS equipment, carrying the burden of their complications.^{11,15}

We have developed a minimally invasive percutaneous neuromodulation system suitable for DRG stimulation and PNS without the complications of the conventional SCS components.

2. Methods

Two patients received our minimally invasive neuromodulation for chronic intractable pain: one following failed back surgery and the other after herpes zoster infection.

Device description

Subjects were implanted with one or more Freedom stimulators (Stimwave Technologies, Fort Lauderdale, FL, USA) each containing four or eight contacts (3 mm in diameter with 4 mm spacing). The stimulator system utilizes an implantable electrode contact array, microprocessor receiver and antenna embedded within the electrode wire that couples to an external transmitting antenna and pulse generator (Figures 1 and 2). The implanted stimulator is without a power source and thus 100% passive. The external transmitters (Figure 3) are worn by the patient over a single layer of clothing and are wirelessly coupled to the implanted stimulator. The external pulse generator is programmed by the clinician to send desired stimulation parameters through a direct electric coupling RF (Radio

Frequency) transmitting antenna to the electrode receiver, thereby wirelessly transferring stimulation commands and power to the implanted stimulator. The system uses radiofrequency energy in the GHz range to transfer power and selected parameters to the implanted stimulator. The implanted stimulator and power source are coupled at a short distance so that the energy emitted from the antenna is relatively low. Wavelengths and product specifications have been designed to decrease risk related

to the wireless transmission of energy (16) and reliably transfer the clinician's intended stimulation parameters. The stimulation parameter spectrum available for clinical use and evaluation include:

- * Amplitude: 1 – 24 mA
- * Pulse Width: 10 – 1000 microseconds
- * Frequency: 2 – 10,000 Hz

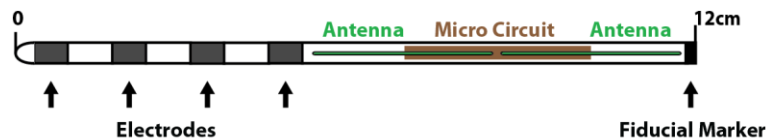


Figure 1: Neuro-stimulator electrode, MRI compatible, for both 1.5 and 3 Tesla

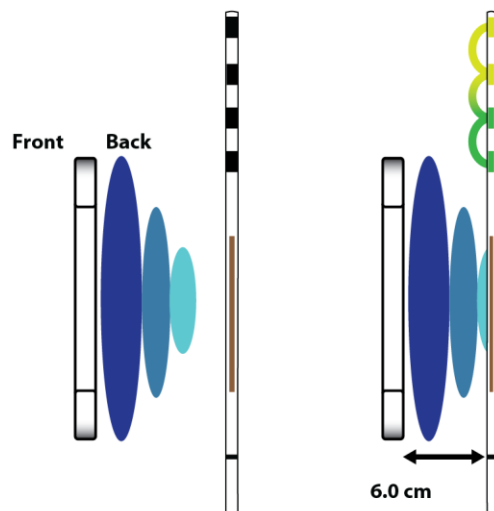


Figure 2: Neurostimulator receiver

Surgical procedure

Under strict aseptic precautions, the skin and subcutaneous tissues were infiltrated with local 1% lidocaine®. A small skin incision was made for a 14-gauge Tuohy needle insertion, which was shaped by hand to match the body contours for an

appropriate device placement under Biplanar fluoroscopic guidance. The stimulator system was subsequently activated wirelessly to confirm electrode positioning with the patient feedback about comfortable paresthesia along the distribution of the targeted field, after retraction of the needle tip exposing electrode contacts. The device

was anchored via a sub-dermal suture located at the skin entry point. Distal tubing cut at the insertion point, was buried subcutaneously and skin incision was closed.

Stimulation protocol

Stimulation parameters were set at pulse widths of 100-200 microseconds

and frequency of 60 Hz. A therapeutic stimulation regimen was applied for up to 30 days followed by removal of the trial devices (under fluoroscopy). During stimulation sessions, when therapy was needed to alleviate pain, patients wore an external transmitter over a single layer of clothing, positioned over the implant location of the electrode array (Figure 3).

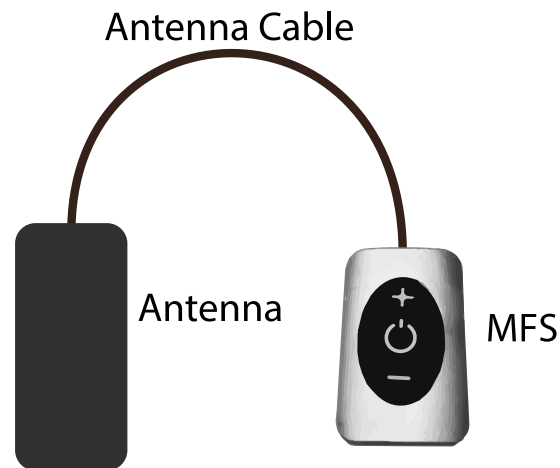


Figure 3: Freedom SCS external device

Case 1

This patient following a disc surgery and an anterior lumbar interbody fusion at L5 and S1 presented with disabling refractory back pain and persisting neuropathic pain along right L5 dermatome. Interventional pain management did not provide relief and bilateral DRG stimulation with implantation of Freedom 4A quadripolar electrode array with adjustable polarity at the L2 dorsal root ganglion under fluoroscopic guidance was performed. The implanted electrode communicated wirelessly from an externally placed transmitter for stimulation of 10 kHz frequency, 30 μ s pulse width, and 2 to 3.5 mA current intensity.

Case 2

This patient on immunosuppressive treatment developed herpes zoster followed by chronic refractory neuralgic pain along intercostal nerve. There was no response to interventional pain management including epidural injections, transcutaneous electrical nerve stimulation and analgesic medication. Percutaneous placement of the Freedom stimulator system electrodes along the intercostal nerve was performed. The procedure was uneventful. Stimulation parameters were set at pulse widths of 100-200 microseconds and frequency of 60 Hz.

3. Results

Both patients tolerated the procedure very well. The pain improvement was more than 60% and the disability decreased by 50% at the end of 3 months. Both of them had reduced pain medication requirement. There were no untoward events or complications reported during the procedure and the follow-up period.

4. Discussion

DRG stimulation is favored over conventional SCS in certain situations, because of its selective stimulation and its ability to cover areas that are typically difficult to reach by SCS. It is also mostly devoid of postural disturbances and has less power consumption.

With this technique the probability of migration is very low (3%) compared to the rates of device migration with percutaneous SCS, 13.2% reported from a review of 51 studies¹¹ and 23% in a prospective study.^{15,17}

With DRG stimulation, 75% of FBSS patients reported relief compared to 50-60% in the PROCESS study.^{6,17} At 1 year follow-up there was robust pain relief and this was attributed to the stability of the stimulation system at the DRG location by Liem et al. Even for lower limb pain the relief was sustainable for a 12-month duration.¹⁸

Post herpetic neuralgia (PHN) itself is a difficult condition to control and only limited experience is available in literature to draw any conclusions regarding efficacy of treatment with PNS. SCS is of limited use because of the location of the pain in the chest and abdominal wall as well as midline. Thus, Subcutaneous PNS may be considered as an indication even prior to SCS.¹⁹ Yakovlev and Peterson and Tamimi et al reported excellent efficacy with subcutaneous electrodes for chronic neuropathic

pain involving intercostal nerve and moderate efficacy for PHN.^{19,20}

However, the present day technology of DRG stimulation and PNS is the same as SCS and carries the burden of all those complications associated with implanted devices. Electrode array and IPG related complications have been significant.

In the nationwide study from Austria, device dislocation occurred in 13% of implantations and device fractures in 5%. Infection was reported in 6% of the cases analyzed.²¹ Hamm-Faber et al reported implanted pulse generator (IPG) problems in 27% cases and repositioning of the IPG due to pain caused by tilting of the battery in 27%. They also had connector problem between lead and the extension cable in 1 patient (9%).²² IPG-related complications were reported in 3 out of every 7 cases (42.8%) in a series reported by Buiten et al where a conventional PNS implant system was utilized for control of refractory angina.²³

The above reported cases illustrate the safety and efficacy of the wireless neuromodulation, emphasizing that this modality is completely devoid of IPG-related complications. The technique requires only a small incision to place the electrode. Percutaneous electrode placement devoid of any implanted pulse generator or the long connective wires can be advantageous to both patient and surgeon. No further incisions or implants are needed during the entire treatment procedure and thus, they not only add to comfort and cosmetics but also reduce costs, operating time, postoperative pain, minimizing adverse events while desired pain control is attained.²⁴

In addition, the technology is beneficial to compromised patients with immune suppression, retroviral infections,

fragile skin conditions that prohibit long tunneling and multiple incisions and also painful conditions associated with limited life expectancy like advanced malignancy.

5. Summary

The minimally invasive wireless neuromodulation yielded encouraging results in both patients with chronic debilitating pain. It required implantation of electrode via percutaneous technique with 14G Tuohy needle. No additional equipment was

required to be inside the patient's body while a wireless externally powered source provided the support. The procedures were uneventful. The implant and the stimulation did not produce any untoward effects or complications. However, larger prospective studies will be required to further our understanding about this method and technology which has shown promising results so far. It is very likely that the spectrum of indications in pain management will become wider.

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