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Trigeminal branch stimulation for the treatment of intractable craniofacial pain

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OBJECT Trigeminal branch stimulation has been used in the treatment of craniofacial pain syndromes. The risks and benefits of such an approach have not been clearly delineated in large studies, however. The authors report their experience in treating craniofacial pain with trigeminal branch stimulation and share the lessons they have learned after 93 consecutive electrode placements.

METHODS A retrospective review of all patients who underwent trigeminal branch electrode placement by the senior author (C.J.W.) for the treatment of craniofacial pain was performed.

RESULTS Thirty-five patients underwent implantation of a total of 93 trial and permanent electrodes between 2006 and 2013. Fifteen patients who experienced improved pain control after trial stimulation underwent implantation of permanent stimulators and were followed for an average of 15 months. At last follow-up 73% of patients had improvement in pain control, whereas only 27% of patients had no pain improvement. No serious complications were seen during the course of this study.

CONCLUSIONS Trigeminal branch stimulation is a safe and effective treatment for a subset of patients with intractable craniofacial pain.

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KEY WORDS headache; neuromodulation; neuropathic pain; peripheral nerve stimulation; trigeminal nerve

The use of peripheral nerve electrical stimulation in the treatment of facial pain was first described in the 1960s. Using the intellectual framework provided by the gate control theory of pain described in 1965,[8] clinicians initiated experiments showing that electrical stimulation of peripheral nerves is capable of reducing pain. As described by Young in a later work, Shelden was probably the first to use electrical stimulation, to treat 3 patients with trigeminal neuralgia.[14] Subsequently, in 1967, Wall and Sweet reported reduced facial pain perception in themselves as well as in 1 patient with trigeminal neuralgia after infraorbital nerve electrical stimulation.[13] Over the next half century the use of peripheral nerve stimulation in the treatment of intractable facial pain has become increasingly reported.[1,6,7,9–12] Significant advances in electrode construction, generator manufacturing, and surgical technique now allow for the permanent implantation of trigeminal branch electrodes by using minimally invasive methods. However, because very few practitioners routinely perform this procedure, the literature consists mainly of case reports and small case series. Thus the risks and benefits of trigeminal branch stimulation remain unclear. We report, to our knowledge, the largest consecutive series of trigeminal branch electrode placements in patients with craniofacial pain in an effort to shed further light on this promising treatment modality.

Methods

Data Collection and Analysis

A retrospective chart review of all patients who underwent trigeminal branch electrode placement by the senior author (C.J.W.) between 2006 and 2013 was performed. Hospital records, office charts, and radiographic studies were reviewed in accordance with the Columbia University Institutional Review Board requirements. Demographic data, craniofacial pain diagnosis, pain description, and prior therapeutic interventions were recorded. Surgical details including location and number of electrodes placed, need for repeat operations, and all complications attributable to electrode or generator placement were also recorded. Subjective patient-reported response to stimulation graded as pain improved, unchanged, or worse was noted.

Statistical analyses were performed using GraphPad Prism 4. Pain improvement duration analysis was performed using the method of Kaplan and Meier. Fisher's test was used to compare categorical data and the unpaired t-test was used for continuous variables. A p value of less than 0.05 was considered significant.

Surgical Procedure

The patient is placed supine on the operating table with

ABBREVIATION TMJ = temporomandibular joint.

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the head turned opposite the affected side on a cerebellar headrest. Conscious sedation with monitored anesthesia care is administered for trial electrode placement, whereas general anesthesia is used for permanent electrode and pulse generator implantation. The starting points for electrode placement are marked behind the hairline above or below the zygoma, allowing for medial tunneling toward the painful region. The affected side is prepared and draped, and local anesthesia is given.

Perioperative antibiotics are given prior to making a small stab incision with a No. 11 blade at the tunneling starting point. A contoured large-gauge Tuohy needle is passed subcutaneously under fluoroscopic guidance to the supraorbital, infraorbital, or temporal regions. The needle is passed 1 cm above or below the orbital rim until the tip reaches the medial border of the orbit, for V1 or V2 distribution pain, respectively. The V3 electrodes are infrequently placed because the mobility of the mandible promotes electrode migration. After needle passage to the painful region, the stylet is removed and a 4- or 8-contact electrode (St. Jude Medical-ANS, Medtronic, or Boston Scientific) is passed to the region of interest through the needle. The needle is then withdrawn, leaving the electrode in a subcutaneous position.

During trials the temporary electrode is connected to an external pulse generator to confirm adequate coverage of the painful region below the motor stimulation threshold. The electrode may be repositioned if adequate stimulation paresthesias are not produced. Once the electrode is in a good position it is anchored to the skin with silk sutures. After 1 week of trial stimulation during which the generator settings may be adjusted for maximal benefit, the electrode is removed in the office. If trial stimulation is deemed beneficial the patient is electively brought back to the operating room, where a permanent electrode is fluoroscopically guided to the trial location as previously described. A subcutaneous infraclavicular pocket is made for the generator and its wire is tunneled superiorly to the retromastoid region. The distal end of the stimulating electrode is tunneled to the retromastoid region as well, where it is connected to the pulse generator (St. Jude Medical-ANS, Medtronic, or Boston Scientific).

Results

Clinical Presentation

A total of 35 patients underwent stimulator placement during the study period (Table 1). There were 16 men and 19 women in the cohort, with a mean age of 53 years. Patients presented after an average of 5.6 (0.5–27) years of intractable craniofacial pain that was refractory to multimodality therapy, including various medical and surgical interventions. A total of 9 different pain diagnoses are represented in the cohort, with definitions consistent with the Burchiel classification (Fig. 1).[4] Pain was distributed throughout all 3 divisions of the trigeminal nerve, with most patients having isolated ophthalmic (V1) division pain (Fig. 2). Prior to proceeding with trigeminal branch stimulation all patients were referred for psychological evaluation and medical clearance. A brain MRI study with fine cuts through the posterior fossa was also performed in all patients to rule out mass lesion or microvascular nerve compression as the cause for craniofacial pain.

Trigeminal Branch Stimulation

During the course of this study a total of 93 electrodes consisting of 58 trial electrodes and 35 permanent electrodes were placed (Table 2). Electrode locations included 56 supraorbital, 27 infraorbital, 8 temporal, and 2 mandibular. Fifty-one percent of the cohort (18 of 35) had a poor response to trial stimulation and were therefore not considered for permanent stimulator implantation. Of the remaining 17 patients who had subjective benefit from trial stimulation, 15 of them went on to receive permanent electrode and generator implantation. Age, sex, and symptom duration prior to presentation were found to be poor predictors of response to trial stimulation ($p > 0.05$).

Patients in whom permanent hardware was implanted were followed for an average of 15 months. As predicted from trial stimulation, all 15 patients who underwent the procedure reported initial pain improvement after permanent electrode implantation. Patients with all pain diagnoses except temporomandibular joint (TMJ) disorder were found to experience at least temporary benefit from trigeminal branch stimulation. At the time of the last follow-up office visit, 73% of patients (11 of 15) had improvement in pain control over their preoperative baseline, whereas only 27% of patients (4 of 15) had no improvement. None of the 15 patients had worse pain compared with the preoperative baseline. Based on this cohort data, Kaplan-Meier estimates of pain improvement indicate that 90%, 77%, and 51% of patients will retain benefit from trigeminal branch stimulation at 12, 24, and 36 months postoperatively, respectively (Fig. 3). Of note, although not systematically studied, it was observed that the institution of a "stimulator holiday" of several days to weeks allowed for the resumption of stimulator benefit when it appeared to wane in some cases.

Repeat Surgery and Complications

A total of 50 initial surgeries were performed for the placement of trial and permanent stimulators during the study period. Subsequently there were 12 repeat surgeries in 7 patients. This included 7 revisions due to electrode malfunction, 1 revision due to extension wire malfunction, 1 revision for moving the pulse generator due to patient discomfort, and 3 complete hardware removals due to inadequate pain relief. There were no infections or serious complications due to either trial or permanent stimulator placement. One patient developed a superficial temporal artery pseudoaneurysm associated with the distal tip of his temporal electrode. The pseudoaneurysm was resected without electrode removal.[5]

Discussion

Although it has been nearly 50 years since research on trigeminal branch stimulation was first published, there remains much to be learned about this pain-relieving modality. Indeed, the mechanism by which peripheral neurostimulation works is unclear and probably involves a complex interplay between the central and peripheral nervous system.[2,3] Only a few practitioners at specialized centers

TABLE 1. Characteristics of 35 patients with intractable craniofacial pain

Case No.	Age (yrs), Sex	Diagnosis	Pain Distribution	Duration of Sxs (yrs)	Prior Treatment	Good Response to Trial Stimulation
1	38, F	Headache	Bilat V1	12	Botox, nerve block, steroid injection, meds	Yes
2	45, F	Trigeminal neuropathic pain	Rt V1, V2	2	MVD, sinus surgery, meds	Yes
3	73, M	Headache	Bilat V2	3	Botox, acupuncture, meds	Yes
4	87, F	Postherpetic neuralgia	Lt V1	1	Nerve block, meds	Yes
5	49, F	TN Type 2	Lt V1, V2	2	Meds	Yes
6	92, M	Postherpetic neuralgia	Lt V1, V2	1	Meds	Yes
7	25, M	SO neuralgia	Bilat V1	10	Meds	Yes
8	80, M	TN Type 1	Rt V1, V2	4	Radiosurgery, meds	Yes
9	76, M	Postherpetic neuralgia	Rt V1, V2	2	Acupuncture, meds	Yes
10	64, F	Trigeminal deafferentation pain	Rt V2	1	Radiosurgery, radiofrequency ablation, meds	Yes
11	37, F	Headache	Bilat V1	3	Acupuncture, trigger point injection, facet joint injection, meds	Yes
12	48, F	Headache	Rt V1	4.5	Nerve block, meds	Yes
13	66, F	TN Type 2	Rt V1–V3	3.5	Botox, meds	Yes
14	50, M	Trigeminal neuropathic pain	Lt V1	2	SO nerve decompression, nerve block, meds	Yes
15	53, F	TN Type 1	Lt V1–V3	15	Radiosurgery, MVD, balloon compression rhizotomy, meds	Yes
16	19, M	SO neuralgia	Bilat V1	3	Botox, meds	Yes
17	67, F	Symptomatic TN	Rt V2, V3	0.5	Radiosurgery, radiofrequency ablation, meds	Yes
18	48, M	TN Type 2	Lt V1, V2	4	Sinus surgery, meds	No
19	67, M	Postherpetic neuralgia	Rt V2, V3	1	Nerve block, meds	No
20	42, F	TN Type 2	Rt V1	5	Botox, meds	No
21	44, M	Trigeminal neuropathic pain	Bilat V1	2	Botox, meds	No
22	42, F	SO neuralgia	Lt V1	5	Botox, meds	No
23	42, F	Trigeminal neuropathic pain	Lt V2	1	Acupuncture, meds	No
24	51, F	Trigeminal neuropathic pain	Rt V2	4	Nerve block, meds	No
25	29, M	TN Type 2	Lt V2	2.5	Sinus surgery, meds	No
26	45, M	TN Type 2	Lt V1, V2	9	Sinus surgery, meds	No
27	43, M	Headache	Bilat V1, V2	27	Meds	No
28	59, M	SO neuralgia	Bilat V1	20	SO & ST nerve transection, sinus surgery, Botox, nerve block, meds	No
29	26, F	Trigeminal neuropathic pain	Rt V2	5	Root canal, nerve block, meds	No
30	59, F	Headache	Bilat V1	9	Acupuncture, meds	No
31	83, M	TN Type 2	Rt V2, V3	15	Radiosurgery, radiofrequency ablation, meds	No
32	62, M	TN Type 2	Lt V1, V2	5	Acupuncture, meds	No
33	19, F	TMJ disorder	Rt V2, V3	2	TMJ surgery, meds	No
34	61, F	Trigeminal deafferentation pain	Lt V2, V3	9	MVD, radiofrequency ablation, glycerol rhizotomy, meds	No
35	47, F	TN Type 2	Rt V1, V2	1	MVD, tooth extraction, meds	No

Meds = medications; MVD = microvascular decompression; SO = supraorbital; ST = supratrochlear; Sxs = symptoms; TN = trigeminal neuralgia.

routinely implant peripheral neurostimulatory devices, so it comes as no surprise that case studies in its use for craniofacial pain have been limited. Thus, we have shared our extensive experience with the use of trigeminal branch stimulation in the treatment of intractable craniofacial pain.

Indications for Trigeminal Branch Stimulation

Trigeminal branch stimulation is indicated for neuropathic facial pain in a distribution amenable to peripheral nerve stimulation. Trigeminal neuropathic pain, trigeminal deafferentation pain, postherpetic neuralgia, headache, and trigeminal neuralgia were common indications in this series. Regarding trigeminal neuralgia Type 1, trigeminal branch stimulation should typically not be the primary surgical treatment attempted. It is our opinion that the lancinating pain of trigeminal neuralgia Type 1 responds poorly

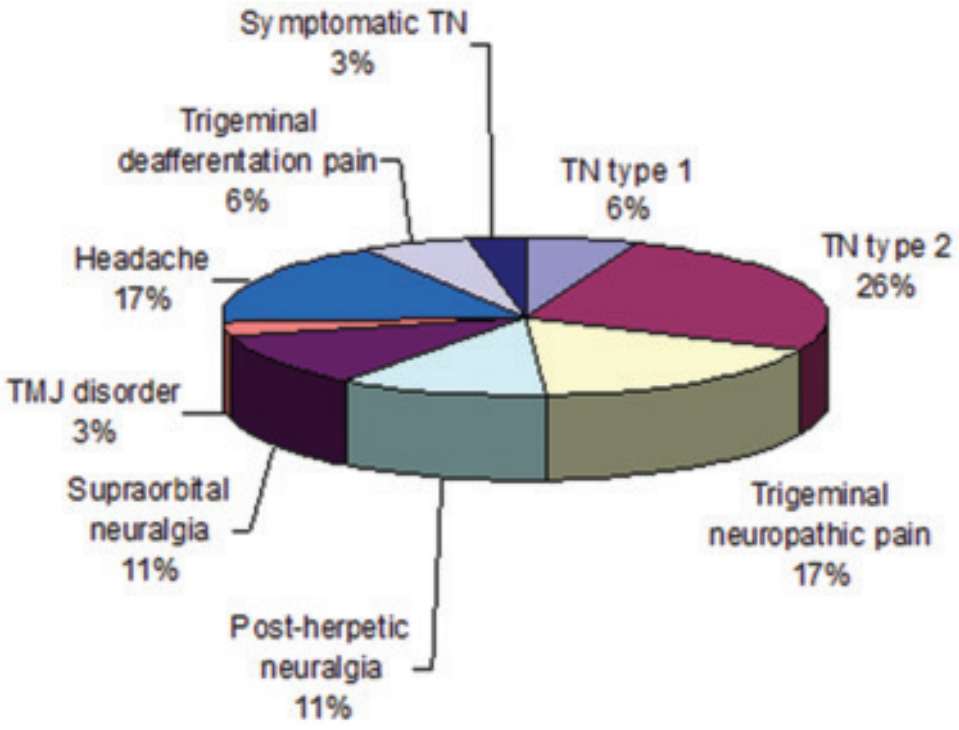

FIG. 1. Chart showing pain diagnoses within the patient cohort. Figure is available in color online only.

to neurostimulation and is generally best treated with microvascular decompression, radiosurgery, or an ablative technique, as appropriate. If these techniques repeatedly fail or if deafferentation pain develops, then stimulation becomes a more attractive option.

Anesthetic Considerations

The choice of anesthesia is dictated most significantly by patient safety considerations, but surgeon preference may also play a role. When possible, we prefer to use light sedation for the trial electrode placement, and general anesthesia (without paralysis) with a laryngeal mask airway for the permanent electrode placement. Obviously, maintaining the ability to test the electrode placement intraoperatively is ideal, allowing confirmation that there is a sufficient range of paresthesia amplitudes prior to motor stimulation (therapeutic window). This advantage, however, must be balanced against the inability of some patients to tolerate electrode tunneling and generator pocket creation with only light sedation and local anesthesia. On the other hand, narrower than expected therapeutic windows have been seen postoperatively after using general anesthesia without intraoperative testing. Thus, there is no perfect anesthesia regimen for these procedures. The surgeon must assess the needs of each patient and the capabilities of the health care team while carefully considering the limitations of each anesthetic option.

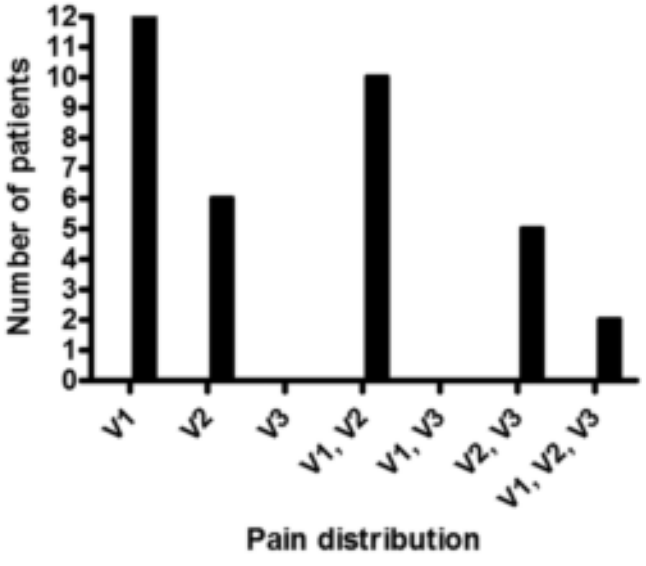

FIG. 2. Bar graph showing distribution of trigeminal pain.

Patient Positioning

The supine position is perhaps the most straightforward option and allows access to the bilateral face if needed. This position facilitates placing stab incisions along the temple and/or zygoma, electrode anchoring just above and behind the ear, and caudal tunneling toward the implantable pulse generator in the infraclavicular space. Patients who have poor neck range of motion may be kept in the neutral position with the use of a shoulder and hip roll, bumping them up to about 30°–45° as needed. We prefer to use the full lateral position with a cerebellar headrest when patients wish to have their generators placed in a low-back or buttock location. This position provides access to the ipsilateral face and back as needed. The lateral position, however, is impractical when bilateral facial electrodes are required.

TABLE 2. Surgical results in 35 patients with intractable craniofacial pain

Factor	Value
Total electrodes	93
Trial	58 (62%)
Permanent	35 (38%)
Electrode location	
SO	56 (60%)
Infraorbital	27 (29%)
Temporal	8 (9%)
Mandibular	2 (2%)
Response to trial stimulation	
Beneficial	17/35 (49%)
Not beneficial	18/35 (51%)
Mean FU in mos (in the 15 pts w/ permanent hardware implantation)	15 (0.5–55)
Pain at last FU	
Improved	11/15 (73%)
Unchanged	4/15 (27%)
Worse	0 (0%)
Surgeries	
Initial (trial & permanent)	50
Repeat (permanent hardware rep, invasive interrogation, or removal)	12 (in 7 pts)
Complications	
Scalp arterial pseudoaneurysm	1

FU = follow-up; pts = patients; rep = replacement.

It is generally our practice to provide independent left- and right-sided systems to patients who require bilateral electrodes. Using this paradigm, electrodes are anchored and tunneled after consecutively prepping and draping each side. This can be done under the same anesthetic. The advantage of such a strategy is that if a revision or removal is required, a unilateral surgery can be performed without compromising the integrity of the entire system. Nonetheless we acknowledge that the development of implantable pulse generators with the capacity to accept 4 electrodes simultaneously may be a compelling argument for tunneling bilateral electrodes to a single side.

Electrode Location

Generally speaking, the location of electrodes corresponds to the location of the patient's pain. The territories in our series that were most commonly amenable to trigeminal electrode placement were the supraorbital and infraorbital nerve distributions. We have attempted to cover a variety of other pain territories, with less frequency and success. For example, TMJ pain may respond to an electrode placed over the joint, but additional studies will be needed to establish whether this technique represents a valid treatment option. We have had little success in the treatment of V3 distribution pain with peripheral neurostimulation, and it is our preference to use high cervical spinal cord stimulation of the spinal trigeminal nucleus and tract in such cases. Further studies are needed to validate such a strategy.

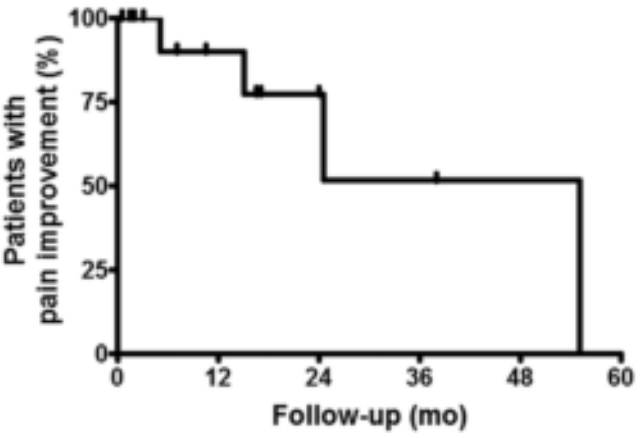

FIG. 3. Kaplan-Meier curve showing pain improvement after trigeminal branch stimulation. A total of 15 patients underwent implantation of permanent stimulators. At 12, 24, and 36 months postoperatively, the survival analysis predicts continued benefit in 90%, 77%, and 51% of patients, respectively.

Electrode Placement

The placement of trigeminal branch electrodes is generally straightforward. We find that a small stab incision permits easier passage of the large-gauge Tuohy needle. Bending the needle to match the contour of the face facilitates placement within the subcutaneous space throughout the length of the inserted needle. However, aggressively bending the Tuohy needle with a metal stylet in place often causes binding of the stylet, trapping it inside the needle. The use of a plastic or Teflon stylet rather than a metal one prevents this annoying problem. Using a Tuohy needle without a stylet should probably be avoided to prevent the introduction of epidermal tissue into the subcutaneous space.

During correct placement of the needle and electrode the surgeon will notice low resistance to passage through the subcutaneous space in the absence of scarring. High resistance is typically met when the needle is either too deep or too superficial. Superficial electrode placement usually results in the patient experiencing a painful "pinching" sensation along the electrode during testing. Electrode placement that is too deep may result in unacceptable motor stimulation prior to necessary sensory stimulation (small therapeutic window).

Patient Satisfaction

It is noteworthy that the measure of successful pain relief used throughout this study was simply patient satisfaction. Whereas some practitioners seek to achieve a somewhat arbitrarily defined greater than 50% reduction in pain to justify permanent stimulator implantation, we are strongly guided by patient preference. Such an approach seems justified given the low complication rates associated with this intervention as well as the high rate of patient-reported satisfaction with stimulation. Furthermore, we have found that patients easily self-segregate into camps that either like or do not like stimulation-induced paresthesias, thus making a trial stimulation period essential prior to patients undergoing permanent implantation.

Complications

In this study we show that trigeminal branch stimulation is safe and effective in a subset of patients with a variety of craniofacial pain syndromes refractory to conventional treatments. Nevertheless, complications can and do occur. We noted that electrode and extension wire malfunctions (often due to fracture or migrations) can occur but are not common. Early in the series commercially available electrode anchors were used, but were subsequently abandoned in favor of directly suturing electrodes to the fascia at the ear incision. Avoiding anchors lowers the profile of the wires along the scalp and provides security against migration, but may damage the electrode sheath.

Stimulator implantation is minimally invasive, reversible, and is associated with minor morbidity. We encountered the oddity of a superficial temporal artery pseudoaneurysm in this series, which we have described in a separate report.[5] Given the passage of large, sharp devices through the scalp during trigeminal branch stimulation, it is surprising that this does not happen more frequently.

Consistent with prior reports,[6,11] we confirm that more than 70% of patients can expect to experience subjectively worthwhile pain relief with trigeminal stimulation. As with other pain-relieving modalities, loss of benefit over time is observed; however, long-term pain improvement can be seen in a significant subset of patients.

Future Directions

The field of peripheral nerve stimulation in general and trigeminal nerve stimulation specifically is in need of randomized controlled trials to confirm the excellent results we and others have obtained. Unfortunately, randomized clinical trials are prohibitively expensive, thus limiting their initiation and subsequent completion. In contrast, prospective registries are capable of generating high-quality outcomes data and are far less expensive than randomized trials.

Key to the completion of informative clinical studies is the selection of appropriate outcome measures. Moving forward, we are collecting outcome measures on all patients with craniofacial pain, including pain ratings, health care quality of life assessments, depression scores, return to work status, and patient satisfaction to explore more adequately the outcomes of trigeminal branch stimulation.

It is our hope that this and future studies will allow trigeminal branch stimulation to gain wider acceptance in both the medical and regulatory communities at large. As it stands, stimulation systems are often "off label" when used for peripheral nerve stimulation. Larger studies will help to clarify which diagnoses and patient characteristics are predictive of stimulator responsiveness.

Conclusions

Trigeminal branch stimulation is a safe and effective strategy for treating a subset of patients suffering from intractable craniofacial pain. The pain diagnoses for which this modality is effective are variable and will probably expand as peripheral nerve stimulation becomes more accepted. Continued study in the form of randomized trials and/or prospective registry studies will be needed to further clarify the indications and long-term outcomes of this therapy.

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Author Contributions

Conception and design: Ellis, Winfree. Acquisition of data: all authors. Analysis and interpretation of data: all authors. Drafting the article: all authors. Critically revising the article: Ellis, Winfree. Reviewed submitted version of manuscript: Ellis, Winfree. Approved the final version of the manuscript on behalf of all authors: Ellis. Statistical analysis: Ellis. Administrative/technical/material support: Winfree. Study supervision: Winfree.

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