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Percutaneous Trigeminal Neuromodulation for Refractory Facial Pain: A Single-Institution Case Series with Long-Term Follow-up

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Background: Trigeminal neuralgia (TN) and persistent idiopathic facial pain (PIFP) are chronic facial pain syndromes that can be resistant to conventional medical and surgical treatments. Percutaneous trigeminal nerve and ganglion stimulation has emerged as a promising neuromodulation technique, though long-term safety and durability remain concerns.

Case Report: We conducted a retrospective review of patients with refractory TN or PIFP who underwent trial or permanent implantation of a trigeminal nerve stimulator between 2018 and 2024 at our institution. Ten of 11 patients underwent trial stimulation, with 9 proceeding to permanent implantation. At the most recent follow up, all but one patient reported significant pain relief. Device- or procedure-related complications occurred in 3 patients: one developed lead prominence with subsequent threatened anchor erosion requiring revision, one developed a postoperative methicillin-resistant staphylococcus aureus wound infection following device removal for urgent magnetic resonance imaging, and one experienced loss of V2 lead efficacy requiring lead explantation. An additional patient underwent elective device removal after long-term complete pain resolution.

Conclusions: Percutaneous stimulation of the trigeminal nerve and ganglion appears to be a safe and effective treatment option for patients with refractory facial pain. The low complication rate and consistent pain relief support its use as a long-term management strategy. Prospective studies are needed to further validate these findings and guide patient selection.

Key words: Case series, trigeminal neuralgia, trigeminal nerve stimulation, trigeminal stimulation, pain relief

BACKGROUND

Trigeminal neuralgia (TN) and related facial pain syndromes are among the most disabling chronic pain conditions encountered in clinical practice (1). Although classical TN is typically characterized by paroxysmal, electric shock–like pain triggered by innocuous stimuli, many patients present with more complex pain phenotypes that include constant, neuropathic, or poorly localized components. These nonclassical presentations are often more difficult to treat and are associated with lower response rates to conventional therapies (1).

Facial pain disorders involving the trigeminal system encompass a broad and heterogeneous group of conditions, including classical TN, persistent idiopathic facial pain (PIFP), trigeminal neuropathic pain following injury, and deafferentation pain after prior surgical intervention (2). While surgical treatments such as microvascular decompression, percutaneous ablative procedures, and stereotactic radiosurgery are effective

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for selected patients—particularly those with classical TN—their benefit is often limited in patients with constant or multifocal pain. Moreover, these interventions are irreversible and carry risks of sensory deficits, which may limit future treatment options (3,4).

In this context, neuromodulation has gained increasing attention as a nonablative and adjustable treatment strategy for refractory facial pain. Percutaneous trigeminal nerve stimulation allows modulation of pain pathways without intentional nerve injury and can be tailored to individual pain distributions (5-7). Stimulation may be directed toward peripheral trigeminal branches or more proximally at the level of the trigeminal ganglion via the foramen ovale (6). Peripheral nerve stimulation is commonly used for focal pain patterns, whereas trigeminal ganglion stimulation offers a potential advantage in patients with involvement of multiple trigeminal divisions (6). However, comparative data regarding the relative effectiveness, durability, and complication profiles of these approaches remain limited.

Prior reports have demonstrated that trigeminal neuromodulation can provide meaningful pain relief in patients with refractory facial pain, particularly those with PIFP or posttraumatic etiologies (8,9). Nevertheless, much of the existing literature consists of small case series with heterogeneous patient populations, variable stimulation targets, and relatively short follow-up. As a result, questions remain regarding long-term outcomes, device-related complications, and optimal patient selection.

In this study, we present a single-institution retrospective series of patients with treatment-refractory facial pain who underwent percutaneous trigeminal neuromodulation between 2018 and 2024. We describe clinical outcomes, complications, and durability of pain relief, with attention to clinical outcomes across different stimulation approaches. Our aim is to contribute additional long-term data on the safety and effectiveness of percutaneous trigeminal neuromodulation and to better define its role in the management of complex facial pain syndromes.

Study Description

Patient Selection and Data Collection

We conducted a retrospective review of medical records for patients diagnosed with refractory facial pain who underwent trials or permanent implantation of a trigeminal nerve stimulator between 2018 and 2024. Pain diagnoses were assigned using clinical criteria aligned with the Burchiel classification system. Lead selection was based on pain distribution and the number of involved trigeminal divisions, with peripheral branch stimulation chosen for focal pain patterns and combined peripheral and trigeminal ganglion stimulation selected for patients with more diffuse or multidermatomal facial pain. Demographic information, pain characteristics, prior medications and interventions, complications, and outcomes were collected. Satisfactory pain relief after trial stimulation and permanent implantation was defined as at least a 50% subjective reduction in pain. Trial stimulation typically lasted 3-5 days. Different commercially available neuromodulation systems were used off-label for this study. This study was approved by the institutional review board, and because of its retrospective chart-review nature, patient consent was not required.

Surgical Technique

All procedures were performed by fellowship-trained functional neurosurgeons (JR, AB) under general anesthesia. Trigeminal ganglion stimulation was performed using Härtel's approach (10) to the foramen ovale. Preoperative computed tomography was registered for navigational guidance, and intermittent anteroposterior and lateral fluoroscopy was used throughout the procedure. A Tuohy needle was inserted approximately 2 cm lateral and 1 cm superior to the oral commissure and advanced through the cheek toward the posteromedial aspect of the foramen ovale. Intraoral digital palpation was performed during needle advancement to avoid mucosal penetration. Entry into Meckel's cave was confirmed by cerebrospinal fluid egress, after which the stimulating electrode was advanced and the needle withdrawn under fluoroscopic visualization (Fig. 1A).

For peripheral trigeminal branch stimulation, lead placement was guided by surface landmarks and fluoroscopy. For V1 targeting, a curved Tuohy needle was advanced perpendicularly above the orbit toward the supraorbital nerve. For V2 and V3 stimulation, similar trajectories were used to access the infraorbital nerve and mandibular branch, respectively. Fluoroscopy was used to confirm appropriate lead position prior to deployment (Fig. 1B).

Statistical Analysis

Continuous variables are presented as the mean, median, and standard deviation as appropriate. Categorical

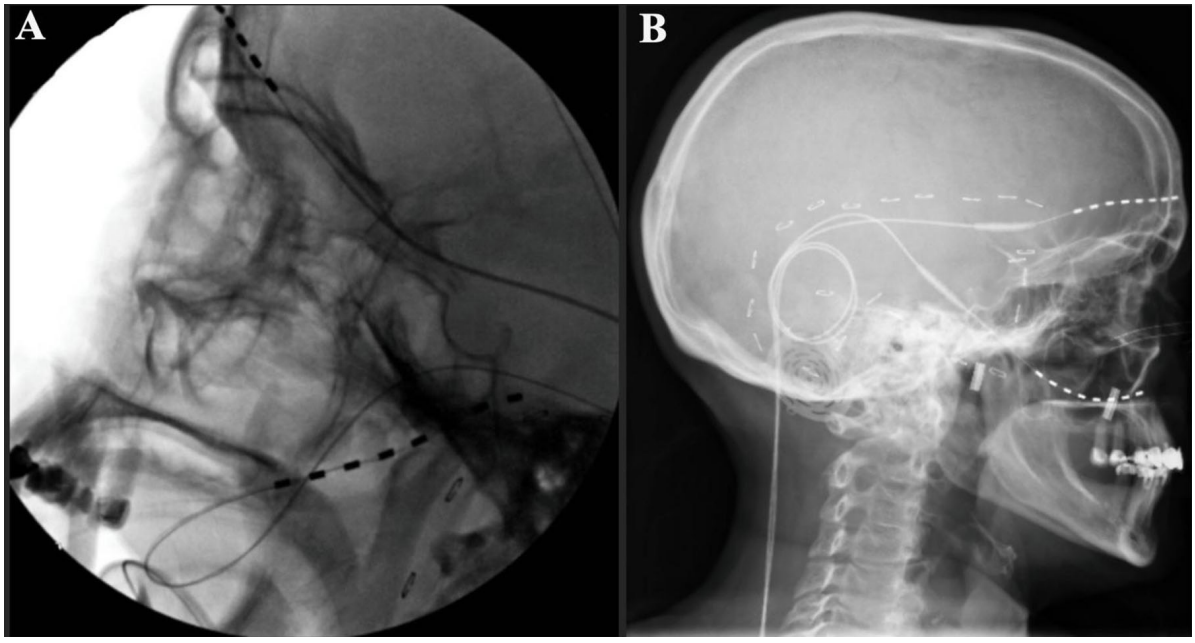

Fig. 1. (A) Intraoperative lateral skull radiographs showing placement of a percutaneous trigeminal ganglion lead through the Foramen Ovale (inferior). (B) Percutaneous lead placement to cover the V1 (superior) and V2 (inferior) segments of the trigeminal nerve.

variables are described with absolute and relative frequencies. All analyses were performed using Microsoft Excel Version 16.91 and XLStat.

RESULTS

Eleven patients underwent percutaneous trigeminal stimulation for treatment-refractory facial pain between 2018 and 2024. Eight patients (73%) received peripheral nerve stimulation (PNS) alone, and 3 patients (27%) underwent combined peripheral nerve stimulation and trigeminal ganglion stimulation (TGS). No patient underwent isolated trigeminal ganglion stimulation without an accompanying peripheral lead. Although Patient 9 had a diagnosis of occipital neuralgia, trigeminal peripheral branch stimulation was selected because of predominant coexisting facial pain symptoms in the distribution of the V1 and V2 nerves. The mean follow-up time for the cohort was 31.2 ± 21.9 months.

Baseline demographic and clinical characteristics are summarized in Table 1. The mean age was 55.4 ± 9 years, and the majority were female (81%). The mean duration of pain before implantation was 47 ± 24 months. Pain distribution most commonly involved V2 (91%), followed by V1 (63%) and V3 (63%).

Prior to stimulation, all patients had been taking multiple medications and undergone multiple procedural interventions (Tables 1, 2). Pain relief outcomes for each

Table 1. Summary of baseline characteristics, medications, and procedures

Baseline Characteristics	
Age (mean ± SD)	55.4 ± 9
Male Gender (%)	2 (18%)
BMI (mean ± SD)	28.8 ± 7.7
Smoking history (%)	3 (27%)
Hypertension (%)	9 (81%)
Duration of pain in mos (mean ± SD)	47 ± 24
CN V branch involvement - V1 (%)	7 (63%)
CN V Branch Involvement - V2 (%)	10 (91%)
CN V Branch Involvement - V3 (%)	7 (63%)
Prior Medications	
Gabapentin (%)	7 (63%)
Oxcarbazepine (%)	4 (36%)
Opioids (%)	2 (18%)
Topiramate (%)	3 (27%)
Tramadol (%)	1 (9%)
Pregabalin (%)	1 (9%)
Prior Procedures	
Microvascular Decompression (%)	7 (63%)
Gamma Knife Radiosurgery (%)	7 (63%)
Balloon Compression Rhizotomy (%)	2 (18%)
Trigeminal Nerve Stimulation (%)	1 (9%)
Glycerol Rhizotomy (%)	1 (9%)

patient are detailed in Table 2. Seven patients (63%) underwent microvascular decompression and gamma knife radiosurgery.

Trial Stimulation and Permanent Implantation

Ten patients (91%) underwent trial stimulation at our institution, with 9 of 10 (90%) achieving ≥50% pain relief during the trial period and proceeding to permanent implantation. One patient (Patient 1) did not undergo a new trial due to prior successful stimulation at an outside facility.

One patient (Patient 6) was nonresponsive during the trial and was not implanted permanently.

Pain Relief Outcomes

At the most recent follow-up (mean 31 ± 15 months), 10 of 11 patients (91%) in the entire cohort reported ≥50% pain reduction from baseline. Table 3 provides a descriptive summary of outcomes across neuromodulation target and pain diagnostic categories.

- Peripheral nerve stimulation group:
  7 of 7 implanted patients (100%) maintained ≥50% pain relief.
- Mixed PNS + TGS group:
  2 of 3 patients (67%) maintained ≥50% pain relief.
- Nonimplanted (nonresponsive trial):
  1 patient (Patient 6) did not proceed to implantation.

Most implanted patients across diagnostic categories achieved ≥50% pain relief at last follow-up, with variable follow-up duration and complication profiles.

Complications, Revisions, and Explants

Across the cohort, 3 of 11 patients (27%) experienced a device- or procedure-related complication: Patient 1 (PNS) had lead prominence along the nasolabial fold requiring early repositioning. Pain relief was maintained after revision. The device for Patient 5 (PNS) was explanted to permit urgent magnetic resonance imaging (MRI) for new visual symptoms (ultimately somatoform and unrelated to stimulation). The patient subsequently developed a postoperative methicillin-resistant Staphylococcus aureus wound infection that was treated successfully with antibiotics. Patient 10 (PNS + TGS) had selective loss of V2 lead efficacy, and the V2 lead was explanted. The V1 and TGS leads remained effective. In addition, one patient underwent elective explantation for long-term complete pain resolution (Patient 9). This was not classified as a complication. No intraoperative complications occurred during trial or permanent implantation procedures.

DISCUSSION

This series provides longer-term follow-up from a single institution describing the use of percutaneous trigeminal stimulation for refractory facial pain. The main observation of this study is that percutaneous stimulation of the trigeminal ganglion and its branches appears to be a safe and effective option for carefully selected patients with treatment-refractory facial pain. In this small cohort, 10 of 11 patients (91%) achieved ≥50% pain reduction at the most recent follow-up, with a mean follow-up duration of approximately 31 months. These findings are noteworthy given that most patients were nonresponsive to multiple pharmacologic agents and at least one surgical intervention, including microvascular decompression and ablative procedures.

Enhanced pain sensitization is a characteristic feature of trigeminal pain, and refractory pain patients suffer from significant reduction in their quality of life (11). Conventional oral medications remain first-line treatment but often fail to provide sufficient relief and may lead to side effects such as tolerance, as seen with carbamazepine in trigeminal neuralgia patients (12). In our cohort, most patients were nonresponsive to multiple treatment modalities before opting for trigeminal nerve stimulation (TNS), highlighting the need for alternative strategies. Recent advances in implantation techniques and neuromodulation devices, including the use of high-frequency stimulation, have facilitated the application of TNS in craniofacial pain syndromes (13,14).

According to a recent meta-analysis, a substantial number of TN patients fail to achieve durable pain relief after initial surgery; namely microvascular decompression, the most effective surgical treatment. Pain freedom is achieved in around 75% at 2 years, dropping to 44%-64% by 10 years (15). Feletti et al (16) emphasized that peripheral trigeminal nerve stimulation shows good outcomes, with overall 80% of cases achieving at least 50% pain reduction, while also highlighting the importance of distinguishing PIFP from classical TN to tailor treatments effectively. Moreover, they noted that complications such as electrode dislocation remain manageable, and technological advances have made facial applications more feasible without esthetic impairments . Similarly, Klein et al (9) reported high success rates in

Table 2. Individual patient characteristics and outcomes across neuromodulation type

Pt	Age	Gender	Diagnosis	Pain Distribution	Duration (mo)	Prior treatments (meds / procedures)	Target (PNS vs TGS)	Branches Stimulated	Side	≥50% Relief at Trial	Follow-up (mo)	≥50% Relief at most recent FU	Complications / Revisions / Explants
1	50	F	TN1	V2–V3	48	OXC, TPM / MVD, GKR, prior PNS	PNS	V2, V3	L	Prior success (no trial)	24	Yes	Lead prominence → repositioning; later anchor erosion → revision
2	44	F	TN1	V1–V3	24	GBP, oxycodone, tramadol / MVD	Mixed (PNS + TGS)	V1, TG	R	Yes	14	Yes	None
3	55	F	TN2/PIFP	V1–V2	36	GBP, TPM / GKR	PNS	V1, V2	R	Yes	78	Yes	None
4	68	M	TN (stroke)	V1–V3	4	GBP, OXC / –	Mixed (PNS + TGS)	V2, TG	R	Yes	33	No	None
5	50	F	TN1	Occipital, V1–V2	18	Pregabalin / MVD	PNS	V1, Occipital, Temporal	R	Yes	4	Yes	Explant for MRI, postoperative MRSA wound infection
6	66	F	Symptomatic TN (MS)	V2–V3	120	Meloxicam, GBP, OXC / GR, GKR	PNS	V2, V3	R	No trial response	–	–	No implantation
7	68	F	TN1	Occipital, V1–V2	120	GBP / MVD, GKR	PNS	V1–V3	L	Yes	36	Yes	None
8	60	M	TN2/PIFP	V1	–	Botox, SO nerve RF ablation	PNS	V1, Occipital	B/L	Yes	12	Yes	None
9	65	F	Occipital neuralgia with coexisting facial pain	V2–V3	24	– / MVD, GKR, BCR	PNS	Temporal, Occipital	L	Yes	48	Yes	Elective explant after pain resolution
10	47	F	TN1	V1–V3	60	GBP / MVD, GKR, BCR	Mixed (PNS + TGS)	V1, V2, TG	L	Yes	18	Yes	V2 lead loss of efficacy → V2 lead explanted
11	37	F	TN1	V2–V3	14	GBP, OXC, TPM, oxycodone / MVD, GKR	PNS	V2, V3	R	Yes	45	Yes	None

Note: TN; Trigeminal neuralgia, PIFP; Persistent idiopathic facial pain, MS; Multiple sclerosis, OXC; Oxcarbazepine, TPM; Topiramate, MVD; Microvascular decompression, GBP; Gabapentin, GKR; Gamma knife radiosurgery, GR; Glycerol rhizotomy, SO; Supraorbital nerve, RF; Radiofrequency ablation, BCR; Balloon compression rhizotomy, MRI; Magnetic resonance imaging, MRSA; Methicillin-resistant Staphylococcus aureus, FU; Follow-up.

Table 3. Descriptive summary of outcomes across neuromodulation targets and pain diagnosis

Outcome	Neuromodulation Target		Pain Diagnosis			
	Peripheral Stimulation Only	Mixed (Peripheral + TGS)	TN 1	TN 2/PIFP	ON with facial pain	TN due to other causes (stroke, MS)
Patients achieving ≥50% pain relief	7/7 (100%)	2/3 (67%)	6/6 (100%)	2/2 (100%)	1/1 (100%)	1/2 (50%)
Mean follow-up (months ± SD)	34 ± 17	22 ± 10	23 ± 15	45 ± 47	48	33
Trial success rate	6/6 (100%)	2/3 (67%)	6/6 (100%)	2/2 (100%)	1/1 (100%)	1/2 (50%)
Complications	2 (lead prominence/ erosion, infection)	1 (loss of lead efficacy)	2 (lead prominence/ erosion, infection)	None	None	None
Explants (non-complication reasons)	1 (pain resolution)	None	1 (for MRI)	None	1 (pain resolution)	None

Note: TGS, trigeminal ganglion stimulation; TN, trigeminal neuralgia; PIFP, persistent idiopathic facial pain; ON, occipital neuralgia; MRI, magnetic resonance imaging.

their elderly cohort, with significant reductions in pain scores and minimal rates of complications, further supporting the safety and efficacy of TNS for intractable facial pain . Notably, TNS has been shown to achieve higher response rates in cases of traumatic trigeminal injury compared to postherpetic neuralgia, with studies demonstrating success rates of up to 100% in the former cohort (13). In our cohort, 10 patients (91%) reported sustained pain relief at the most recent follow-up period, with an average duration of 31 ± 15 months. This outcome highlights the durability of TNS, although the variability in the follow-up duration suggests that longer-term studies are necessary to fully evaluate the sustained efficacy of this procedure.

Recent innovations in neuromodulation techniques have contributed to safer and more effective applications of PNS. For instance, targeting the maxillary nerve through the foramen rotundum, as described by Xu et al (17), provides a minimally invasive approach with reduced complication risks. Their findings highlighted the benefits of precise electrode placement to optimize pain relief, particularly when electrodes are positioned away from areas of allodynia and closer to hyperalgesic regions . Trigeminal ganglion stimulation is a unique neuromodulation therapy in that it involves placement of a stimulating electrode, typically a spinal cord stimulation electrode used off-label for this purpose, into the foramen ovale, providing direct stimulation of the trigeminal ganglion and nerve. This approach is potentially attractive for patients who suffer from pain in multiple dermatomes, as stimulation of the trigeminal ganglion targets multiple branches with a single electrode and thus reduces hardware burden (18). A recent large series described 59 patients treated with ganglion stimulation; 71% of them had a successful trial (defined as >50% pain reduction) and permanent implantation was associated with a Visual Analog Scale (VAS) improvement of 2.9 points. However, following permanent trigeminal ganglion stimulator implantation, complications such as erosion (30%), infection (21%-37%), and migration rates (11%) were observed, which were similar to trigeminal branch stimulation complications observed previously (19,20).

A single case of lead migration was observed in our cohort (Patient 1). The patient noted an impression over the left nasolabial fold caused by the V2 lead, indenting the skin surface. Under live fluoroscopic guidance, the lead was retracted by 2-3 mm, and the patient continued to experience significant pain relief following the adjustment. Seven months postoperatively, concern for potential lead erosion arose when the left posterior auricular anchor boot became superficial and visibly indented the skin. The patient subsequently underwent revision surgery to create a deeper subcutaneous pocket, successfully preventing further erosion. Overall, device- or procedure related complications occurred in 3 of 11 patients (27%): lead prominence with anchor erosion requiring revision (Patient 1), post-explantation wound infection (Patient 5), and loss of V2 lead efficacy requiring explantation (Patient 10). Two explantations were performed for reasons unrelated to device failure or procedural complications: urgent MRI (Patient 5) and long-term pain resolution (Patient 9).

Limitations

This study has several limitations inherent to its retrospective design. Enrichment bias is present due to the trial-based neuromodulation paradigm, as only patients who demonstrated meaningful pain relief during trial stimulation proceeded to permanent implantation, likely inflating observed long-term response rates. Diagnostic heterogeneity, small sample size, and variability in follow-up duration further limit generalizability and preclude diagnosis-specific or comparative efficacy conclusions. In addition, pain relief was assessed using patient-reported clinical improvement rather than validated outcome instruments. Future prospective studies incorporating standardized pain scales, such as the VAS, Brief Pain Inventory–Facial Pain, or Penn Facial Pain Scale, are needed to better define long-term outcomes and optimize patient selection. Changes in medication use were not systematically assessed due to the retrospective design of the study, variability in documentation, and concurrent management by multiple providers. Future prospective studies should incorporate standardized assessment of medication burden and dose reduction as secondary outcome measures.

CONCLUSION

Percutaneous trigeminal neuromodulation, using either peripheral trigeminal branch stimulation or combined peripheral and trigeminal ganglion approaches, appears to be a safe, feasible, and durable treatment option for carefully selected patients with refractory facial pain. In this single-institution retrospective series, sustained pain relief was observed across different stimulation approaches with a low complication rate over long-term follow-up.

Author Contributions

GD: manuscript writing, literature review, data collection
CF: data collection, manuscript editing
NJ: data collection, manuscript editing
JR: manuscript editing, patient care, clinical oversight
AB: data collection, manuscript editing, senior supervision, patient care

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