AANHS Journal
Journal homepage: http://aanhsj.usu.ac.id

Predictor of Percutaneous Radio-Frequency Rhizotomy Outcomes for Trigeminal Neuralgia: A Single Center Prospective Cohort Study

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ARTICLE INFO

Article history:
Received : Apr, 27th 2026
Revised : Apr, 29th 2026
Accepted : Apr, 30th 2026
Available : May, 7th 2026

E-ISSN: 2686-0848

How to cite:
Prasetya M, Wardhana AW, Adidharma P, Yefri RF, Sulistyanto A, Fadhil, Oswari S, Keswani RR, Kusdiansah M, Aji YK, Arham A. Predictor of percutaneous radio-frequency rhizotomy outcomes for trigeminal neuralgia: a single center prospective cohort study. Asian Australasian Neuro and Health Science Journal. 2026 Apr 08(01):36-46

 DOI: 10.32734/aanhs-j.v8i01.25357

ABSTRACT

Introduction: Percutaneous radiofrequency rhizotomy (PRFR) offers a minimally invasive alternative for trigeminal neuralgia (TN) patients who are ineligible for microvascular decompression (MVD) or who suffer from refractory TN following MVD. However, clinical outcome predictors for PRFR, particularly in low-to-middle-income countries, remain insufficiently documented.

Methods: This prospective cohort study included 37 surgery-naïve and post-MVD recurrent TN patients who underwent PRFR between 2014 and 2020. Patient characteristics and offending pathologies were documented. Postoperative outcomes were assessed using the Barrow Neurological Institute (BNI) scales and the Numerical Rating Scale (NRS). Univariate and bivariate analyses were utilized to construct prediction models.

Results: The cohort had a mean age of 59 ± 15 years. Among the patients, 51.4% were surgery-naïve, while 48.6% had a history of previous MVD. The PRFR procedure yielded significant NRS improvements in both the surgery-naïve ($p < 0.001$) and post-MVD ($p = 0.001$) groups, with no statistically significant difference in pain reduction between the two ($p = 0.151$). Preoperative identification of the offending pathology was a significant predictor of surgical success ($p = 0.019$), with small artery compression showing the highest rate of satisfactory outcomes.

Conclusion: PRFR provides profound and immediate pain relief for both surgery-naïve patients and those with post-MVD recurrences. The nature of the offending pathology serves as a crucial clinical predictor for achieving optimal outcomes, making PRFR a highly reliable and cost-effective therapeutic pillar in the management of refractory TN.

Keywords: Trigeminal neuralgia, percutaneous radiofrequency rhizotomy, microvascular decompression, prospective cohort, pain management.

1. Introduction

Trigeminal neuralgia (TN) is recognized as one of the most debilitating facial pain syndromes, characterized by sudden, unilateral, and paroxysmal electric shock-like sensations restricted to the distribution of one or more branches of the trigeminal nerve [1]. The condition predominantly affects the elderly population and shows a higher prevalence in females, with annual incidence rates ranging from 4.3 to 27 per 100,000 individuals [2,3]. Morphologically, TN is often associated with neurovascular compression at the root entry zone (REZ) of the trigeminal nerve, leading to focal demyelination and subsequent ephaptic transmission of impulses.[4] Patients typically experience these excruciating attacks triggered by innocuous stimuli, such as light touch or breeze, which profoundly impairs their quality of life and frequently leads to severe psychological distress, including anxiety and depression [1,5].

Pharmacotherapy remains the primary line of management, with sodium channel blockers specifically carbamazepine and oxcarbazepine serving as the first-line agents [1,2]. However, many patients eventually develop resistance to medical therapy or experience intolerable systemic side effects, such as cognitive impairment, ataxia, and hepatotoxicity, necessitating surgical intervention [3,4]. Microvascular decompression (MVD) is widely regarded as the gold standard surgical procedure due to its high long-term success rate and its ability to address the underlying vascular conflict [2,6]. Nevertheless, MVD requires a highly invasive craniotomy and carries risks of major complications, making it less suitable for elderly patients, those with significant medical comorbidities, or those who prefer a less invasive approach [7,8].

In cases where MVD is contraindicated or declined, percutaneous procedures at the Gasserian ganglion offer an effective, minimally invasive alternative [7,9]. Among these, Percutaneous Radiofrequency Rhizotomy (PRFR) also known as radiofrequency thermal coagulation (RFTC) is highly preferred for its precision in inducing selective thermal injury to the pain-conducting A-delta and C fibers [8,9]. PRFR provides an immediate pain-free state in over 90% of patients and is particularly advantageous for its durability and repeatability in recurrent cases [7,9]. While complications such as facial hypoesthesia or masseter weakness may occur, the overall safety profile and the ability to perform the procedure under sedation make it a crucial component of the neurosurgical armamentarium [8].

Despite its widespread use globally, the clinical landscape and outcome predictors for PRFR in Indonesia remain insufficiently documented. Establishing a high-volume neurosurgical service for MVD in low-to-middle-income countries (LMICs) presents significant economic and logistical challenges [10]. Consequently, PRFR serves as a vital, cost-effective intervention in our setting. This study aims to bridge the current literature gap by: (1) presenting the clinical characteristics of patients undergoing PRFR at a national tertiary brain center; and (2) identifying specific clinical variables that can predict optimal long-term outcomes following the procedure.

2. Methods

This prospective cohort study includes all surgery-naïve and post-MVD recurrent TN patients who underwent Percutaneous Radiofrequency Rhizotomy (PRFR) between 2014 and 2020 at our center. The patients clinical characteristics, previous history of MVD, and offending pathology were documented. Outcomes were assessed using validated instruments, including the Barrow Neurological Institute (BNI) pain and numbness scales, as well as the Numeric Rating Scale (NRS). Univariate and bivariate analyses were employed to construct prediction models.

2.1 Study Settings and Population

Starting from April 2014 to November 2020, we conducted an observational prospective cohort study, enrolling all consenting adult patients (≥ 18 years old at the time of first contact) who were diagnosed with trigeminal neuralgia (based on the International Classification of Headache Disorders-3rd Edition, ICHD-3 criteria), were refractory to medication, had a positive MRI finding, and underwent PRFR at the NBC. Patients with trigeminal neuropathic pain, trigeminal deafferentation pain, symptomatic TN from space-occupying lesions, postherpetic neuralgia, atypical facial pain, and secondary TN were excluded. Records of previous neurosurgical procedures (including prior MVD) were obtained retrospectively from the electronic medical records system for baseline comparison.

2.2 Data Collection

Pre-operative data collection was conducted by independent physicians at the first contact in our neurosurgery clinic. This consisted of the patient's gender, age, side of pain, duration from onset of symptoms, pre-operative pain severity, previous history of invasive procedures for pain control, and TN clinical classifications. Pre-operative pain severity was assessed using the Numeric Rating Scale (NRS). Clinical symptoms of the included patients were classified based on the classification by Burchiel (type 1 or type 2 TN) [11]. The duration between the first contact at the outpatient clinic and surgery was also documented.

2.3 Surgery Technique and Intraoperative Findings

Three-dimensional pre-operative reconstruction was conducted on all patients to visualize neurovascular compression and the surrounding anatomical relationship using T2-sampling perfection with application-optimized contrasts using different flip angle evolution (T2-SPACE) and modified time-of-flight magnetic resonance angiography (TOF-MRA) fusion.

The PRFR procedure was performed using the classic anterior percutaneous approach described by Hartel. Patients were placed in a supine position under conscious sedation using intravenous agents. Local anesthesia was infiltrated at the puncture site on the face. Under continuous C-arm fluoroscopic guidance (submental-vertex and lateral views), a radiofrequency cannula was advanced through the foramen ovale into Meckel's cave. Upon confirming the correct trajectory, patients were briefly awakened for sensory (50 Hz) and motor (2 Hz) physiological testing to reproduce paresthesia in the affected trigeminal division and ensure the avoidance of the motor root. Following target confirmation, the patient was re-sedated, and radiofrequency thermocoagulation was delivered. The lesioning temperature and duration (typically 70–75°C for 60–90 seconds) were titrated according to the targeted division and the patient's intraoperative response to achieve dense hypoesthesia in the painful dermatome while preserving the corneal reflex.

2.4 Evaluation of Surgical Outcomes

Post-operative data collection was performed by independent physicians. Pain control was assessed using the validated BNI pain intensity scale. Facial numbness was classified according to the BNI numbness scale. Other complications (e.g., masseter weakness, dysesthesia) were described independently. The outcome of the surgery was classified into four categories: excellent, good, fair, and poor, based on the summation score of the BNI pain and numbness scales (Table 1). A lower score indicates better outcomes. Follow-up procedure(s) for uncontrolled pain or recurrence were documented.

Table 1. BNI pain scale, BNI numbness scale, and summation score for result conclusion

Domain	Score*	Definition
Pain Control (P)	1 (I)	No trigeminal pain, no medication required
	2 (II)	Occasional pain not requiring medication
	3 (III)	Some pain adequately controlled with medication
	4 (IV)	Some pain not adequately controlled with medication
	5 (V)	Severe pain, no pain relief
Numbness (N)	1 (I)	No facial numbness
	2 (II)	Mild facial numbness that is not bothersome
	3 (III)	Somewhat bothersome facial numbness
	4 (IV)	Very bothersome facial numbness
Result Conclusion (P+N)	2	Excellent
	3	Good
	4	Fair
	≥5	Poor

Follow-up timings were one week, one month, and one year after the PRFR procedure. Based on previous studies on pain resolution and the onset of complication symptoms, two follow-up periods (one week and one month after the surgery) and one follow-up period (one year after the surgery) were chosen for short-term and long-term outcome analyses, respectively.

2.5 Statistical Analysis

Statistical analyses were conducted within the IBM SPSS Statistics environment (version 30.0) by an independent physician. Patients' characteristics were descriptively presented, where mean and median values were reported with ± standard deviation (SD). Only patients with at least a one-year follow-up were included for the final outcome analysis. Bivariate analyses were conducted to explore the relationship between each demographic characteristic and postoperative outcomes one year after surgery, with the aim of identifying prognostic factors that distinguish between the "Satisfactory" and "Unsatisfactory" groups. Bivariate analyses, including Chi-square, Fisher's exact, Wilcoxon signed-rank test, and Mann-Whitney U test, were used to evaluate these relationships. A p-value of less than 0.05 was considered statistically significant.

3. Results

3.1 Patient Characteristics and Baseline Demographics

A total of 37 patients who underwent percutaneous radiofrequency rhizotomy (PRFR) for the treatment of trigeminal neuralgia (TN) were included in this study. The patient cohort had a mean age of 59 ± 15 years, with a higher prevalence in females (62.2%, n = 23) compared to males (37.8%, n = 14). The laterality of the facial pain was distributed as 48.6% (n = 18) on the left side, 43.2% (n = 16) on the right side, and 8.1% (n = 3) presenting with bilateral pain. The mean duration of symptoms from onset to the time of intervention was 4.5 ± 4.2 years.

Table 2. Baseline Patient Characteristics

Variables	Values
Age – year*	59 ± 15
Sex – n (%)	
Male	14 (37.8)
Female	23 (62.2)
Side affected – n (%)	
Right	16 (43.2)
Left	18 (48.6)
Bilateral	3 (8.1)
Duration from onset – year*	4.5 ± 4.2
Offending pathology – n (%)	
Small artery†	16 (43.2)
Large artery	4 (10.8)
Vein‡	8 (21.6)
Artery and vein	1 (2.7)
Mass	6 (16.2)
None	2 (5.5)
Burchiel et al. TN classification – n (%)	
Type 1	25 (67.6)
Type 2	12 (32.4)
Previous intervention – n (%)	
MVD	18 (48.6)
None	19 (51.4)

*mean ± standar deviation

† Superior cerebellar artery; anterior inferior cerebellar artery

Based on their clinical presentation, the majority of the cohort (67.6%, n = 25) was diagnosed with typical paroxysmal pain, classified as Burchiel Type 1 TN, while 32.4% (n = 12) presented with Burchiel Type 2 TN. Regarding previous surgical interventions, 51.4% (n = 19) of the patients were surgical-naïve, whereas 48.6% (n = 18) had a prior history of microvascular decompression (MVD) surgery but experienced refractory or recurrent pain. Preoperative neuroimaging revealed various offending pathologies contributing to the neurovascular conflict: a small artery was the most frequently identified offender (43.2%, n = 16), followed by a vein (21.6%, n = 8), a mass lesion (16.2%, n = 6), a large artery (10.8%, n = 4), and mixed artery-vein compression (2.7%, n = 1). No obvious offending pathology was identified in 5.5% (n = 2) of the cases.

3.2 Postoperative Pain Relief and Clinical Outcomes

The PRFR procedure yielded significant improvements in pain control across the entire cohort. Clinical outcomes were quantitatively evaluated using the Numerical Rating Scale (NRS). In the surgical-naïve group, the mean NRS score decreased significantly from a preoperative baseline of 7.9 ± 1.6 to a postoperative score of 1.6 ± 2.5 ($p < 0.001$). Similarly, patients who underwent PRFR following a failed previous MVD demonstrated a highly significant reduction in their mean NRS score, dropping from 7.2 ± 1.7 to 2.6 ± 3.3 ($p = 0.001$).

Table 3. Clinical Outcomes Based on NRS Score Improvement

Group	Preoperative NRS*	Postoperative NRS*	Bivariate Analysis	NRS Improvement*	Bivariate Analysis
Surgical naive	7.9 ± 1.6	1.6 ± 2.5	<0.001[a]	6.3 ± 2.9	0.151[b]
Post-MVD	7.2 ± 1.7	2.6 ± 3.3	0.001[a]	4.9 ± 3.0	

*Wilcoxon signed-rank test; [b]Mann-Whitney Test

*mean ± standard deviation

The mean absolute NRS score improvement was 6.3 ± 2.9 for the surgical-naïve group and 4.9 ± 3.0 for the post-MVD group. An independent comparative analysis revealed no statistically significant difference in the degree of pain improvement between the surgical-naïve and post-MVD groups ($p = 0.151$). This finding highlights that PRFR provides an equally efficacious degree of pain relief regardless of a patient's prior MVD surgical history.

3.3 Predictors of Satisfactory Surgical Outcomes

To identify independent clinical predictors of surgical success following PRFR, the cohort was stratified into a satisfactory outcome group (n = 21) and an unsatisfactory outcome group (n = 16) based on the BNI scales. Bivariate analyses were performed across multiple preoperative clinical and demographic variables.

Table 4. Bivariate Analysis of Clinical Predictors for Postoperative Outcomes

Variables	Satisfactory Group – n (%)	Unsatisfactory Group–n (%)	Bivariate Analysis
Age - Year	58.5 ± 14.0	59.0 ± 16.7	0.623[a]
Sex			0.733[c]
Male	7 (19%)	7 (19%)	
Female	14 (38%)	9 (24%)	
Side affected			0.639[b]

Right	10 (27%)	6 (16.2%)	
Left	10 (27%)	8 (21.7%)	
Bilateral	1 (2.7%)	2 (5.4%)	
Duration from onset – year*	3.8 ± 3.9	5.4 ± 4.6	0.191[a]
Offending pathology			0.019[b]
Small artery	13 (35.2%)	3 (8.1%)	
Large artery	2 (5.4%)	2 (5.4%)	
Vein	2 (5.4%)	6 (16.2%)	
Artery and vein	1 (2.7%)	0 (0%)	
Mass	1 (2.7%)	5 (13.5%)	
None	2 (5.4%)	0 (0%)	
Burchiel et al. TN classification			0.565[b]
Type 1	15 (40.6%)	10 (27%)	
Type 2	6 (16.2%)	6 (16.2%)	
Previous intervention			0.886[b]
MVD	10 (27%)	8 (21.7%)	
None	11 (29.6%)	8 (21.7%)	

*Mann-Whitney test; [b]Chi-square; [c]Fisher's exact

Age (p = 0.623), sex (p = 0.733), affected side (p = 0.639), duration of symptom onset (p = 0.191), and Burchiel clinical classification (p = 0.565) did not show any statistically significant association with the final postoperative outcome. Furthermore, a prior history of MVD intervention (p = 0.886) did not predispose patients to a worse PRFR outcome, reinforcing its utility as a reliable secondary intervention.

However, the nature of the offending pathology identified on preoperative imaging was found to be a significant predictive factor for PRFR outcomes (p = 0.019). Patients whose preoperative imaging demonstrated compression by a small artery showed a markedly higher rate of satisfactory outcomes (13 out of 16 patients) compared to those with venous or mass-related compressions. This suggests that the underlying anatomical etiology of the trigeminal conflict is an important clinical factor that can aid in outcome prediction and managing patient expectations following PRFR.

4. Discussion

The results of our prospective cohort study underscore the clinical value of percutaneous radiofrequency rhizotomy (PRFR) in managing trigeminal neuralgia (TN). Whether patients were seeking treatment for the first time or desperate for relief following a failed microvascular decompression (MVD), PRFR consistently provided significant and reliable pain reduction at our center.

TN is widely recognized as a profoundly debilitating condition that disrupts nearly every aspect of a patient's daily life [12]. Beyond the physical toll, the unrelenting nature of this neuropathic pain frequently drives patients toward secondary psychiatric challenges, including severe anxiety and depression, making immediate intervention a matter of clinical urgency [13]. Our data reflect the rapid efficacy of radiofrequency techniques, with mean Numerical Rating Scale (NRS) scores dropping from 7.9 to 1.6 in the surgery-naïve group and from 7.2 to 2.6 in the post-MVD group. These outcomes closely align with previous literature demonstrating the instantaneous pain control achieved by percutaneous approaches [7,9]. Interestingly, we found no statistically significant difference in the degree of pain improvement between those who had prior MVD and those who did not ($p = 0.151$). This strongly positions PRFR as a highly dependable salvage therapy that works independently of a patient's open surgical history.

A particularly compelling finding in our cohort is the predictive value of preoperative magnetic resonance imaging (MRI). The specific nature of the offending pathology significantly dictated clinical outcomes ($p = 0.019$). Patients whose imaging revealed small artery compression experienced substantially higher satisfaction rates than those with venous or mass-related conflicts. This makes sense from a pathophysiological standpoint; classic TN is primarily driven by vascular compression at the root entry zone (REZ), which induces focal demyelination [11]. Even though PRFR is an ablative procedure, identifying the exact type of offending vessel remains crucial for anticipating the patient's long-term response and tailoring their management strategy [6].

The broader institutional context of where these procedures are performed also warrants discussion. A literature demonstrates that surgical volume directly correlates with better clinical outcomes and fewer complications across neurosurgical disciplines [14-18]. Operating near the brainstem for TN presents unique safety challenges, demanding specialized considerations for outcome assurance and procedural safety [19]. Large-scale national data from the United States clearly show that high-volume centers achieve superior results with extremely low mortality rates in TN surgeries [20,21]. Over the years, our institution has successfully established a tertiary-level MVD center within a low-to-middle-income country (LMIC) setting. By strictly adhering to a single-surgeon policy and refining the transposition technique, we have been able to deliver surgical services comparable to those in developed nations [22,23,24,25].

Our current study illustrates why a high-volume MVD center must also possess a correspondingly strong PRFR service. While MVD offers excellent durability, delayed cranial nerve palsies and recurrences remain a clinical reality [26]. By integrating PRFR into our treatment algorithm, we provide a vital safety net for post-MVD recurrences, as well as a minimally invasive option for surgery-naïve patients who are poor candidates for major craniotomies [2,27] To ensure the integrity of these findings, we validated our outcomes using standardized clinical instruments, which is a recognized gold standard for measuring health benefits and ensuring accurate causal inference in surgical research [28,29,30].

Admittedly, our study is limited by its relatively small sample size. Nevertheless, the prospective data emerging from our national brain center offers a critical and foundational look into TN management within Indonesia. Moving forward, larger, multicenter investigations will be necessary to track long-term pain-free survival and fully validate these predictive models across a more diverse patient population.

5. Conclusion

Percutaneous radiofrequency rhizotomy (PRFR) stands as a highly reliable, safe, and cost-effective intervention for severe trigeminal neuralgia, offering profound immediate pain relief for both surgery-naïve patients and those experiencing painful recurrences after microvascular decompression. Crucially, our findings highlight that the specific offending pathology identified through preoperative imaging serves as a vital prognostic tool, with small artery compression being a significant clinical predictor for achieving optimal pain relief. By providing a potent salvage therapy and an accessible primary option for patients whose age or comorbidities carry prohibitive risks for major open cranial surgery, PRFR remains an indispensable pillar in the comprehensive management of TN, particularly within the resource-conscious healthcare frameworks of low-to-middle-income countries.

Acknowledgements

The authors gratefully acknowledge the global community of researchers and clinicians dedicated to improving healthcare access. The insights gathered in this narrative review were made possible by the foundational work of those striving to implement evidence-based medicine in resource-limited settings.

Conflict of Interest

The authors declare that there is no competing interest in this research.

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