Comparative Evaluation of Surgical Procedures for Trigeminal Neuralgia

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Abstract Trigeminal neuralgia (TN) is a debilitating ailment. Pharmacotherapy still remains the first line therapy for the management of TN. However, often the patients become refractory to the pharmacotherapy and need surgical interventions. There is a wide array of surgical treatment modalities available for TN and it is important to select the most appropriate surgery for a patient. This review evaluates the various surgical modalities by employing a comparative analysis with respect to patient selection, success rate, complications and cost effectiveness. For the evaluation, a critical review of literature was done with predefined search terms to obtain the details of individual procedures, which were then compared, under similar parameters. The results suggested that microvascular decompression seem to be the most effective treatment in terms of patient satisfaction and long term cost effectiveness. However, if patient factors do not permit, then the peripheral procedures may be employed as a substitute, though they have higher recurrence rate and complications and have relatively lower long term cost effectiveness. The newer modalities like stereotactic radiosurgery and botulinum injections have promising results

and further refinement in these procedures will provide additional options for the patients suffering from TN.

Keywords Trigeminal neuralgia · Surgical modalities · Comparative evaluation

Introduction

While trigeminal neuralgia (TN) continues to perturb the patients, its treatment too has beleaguered the doctors since ages. John Fothergill, in the latter half of the 18th century used hemlock for its treatment. Since then, treatment for TN has evolved from the use of simple herbal remedies to new age medicines and microsurgery. Microvascular decompression (MVD) and percutaneous ablative techniques have revolutionized the treatment of TN [1]. Although various surgical techniques are used in the treatment of TN, yet there is no consensus on an ideal algorithm [2]. Further, the published literature suggests varying and often conflicting results [3]. Hence, in this article, an attempt is made to evaluate various surgical modalities for TN.

History of Trigeminal Neuralgia Surgeries

The history of TN surgery can be traced back to 1856 when Carnochan described a trans-antral approach to the gasserian ganglion. Later during 1891 and 1892, Hartley and Krause described extradural sub-temporal approach for gasserian ganglionectomy which was later modified by Frazier and Spiller. Harvey Cushing, in early 1990's, played a crucial role in developing surgical modalities for TN. He modified Hartley–Krause technique which resulted in a significant reduction in mortality. Later, Walter Dandy proposed a

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Fig. 1 Surgical modalities for trigeminal neuralgia

“cerebellar route” for section of trigeminal nerve at brainstem. This approach led to the discovery that compression of the sensory root is often present in the patients with TN. This hypothesis was a milestone in the surgical management of TN and formed the basis for MVD [1].

Surgical Modalities for Trigeminal Neuralgia

The available surgeries for TN are either destructive (trigeminal nerve sensory function intentionally destroyed), or non-destructive (trigeminal nerve decompressed, with sensory function usually preserved) [4].

The surgical modalities for TN (Fig. 1) include: (1) Peripheral procedures (targeting portions of trigeminal nerve distal to gasserian ganglion), (2) Percutaneous procedures (targeting gasserian ganglion), (3) Open procedures (posterior fossa exploration) and (4) Stereotactic radiosurgery (targeting trigeminal root) [5].

Comparative Evaluation of Surgical Procedures

Whilst pharmacotherapy remains the first line of treatment for TN, about half the patients do not achieve optimal results and may require surgical interventions [6].

An ideal TN surgery should be minimally invasive, acceptable to the patient, provide consistent and immediate pain relief, safe, without pain recurrence, eliminate medication need and, improve the quality of life. However, the literature review suggests that no surgical modality fulfils

all of the aforementioned criteria. A growing body of literature supports the use of a systematic and ‘evidence based’ approach for making informed decisions. However, the evidence for selection of an ideal method is at present lacking. This may be because of [7]:

- Lack of Level I evidence (randomized controlled studies)
- Lack of clear diagnostic criteria and baseline assessments
- Poor methodology (low numbers, shorter follow-up, higher cost to follow-up)
- Mixture of cases (e.g., previous surgery, including repeated treatments)
- Lack of Kaplan-Meier assessment of pain relief
- Poorly defined outcome measures
- Incomplete reporting of all complications
- No quality-of-life evaluations
- Lack of independent evaluation

Because of the aforesaid lacunae, an individualized benefit-risk analysis of a procedure needs to be assessed. In this article, we have tried to overcome some of these lacunae by performing a comparative evaluation, under similar assessment parameters.

Methodology

A cumulative search for the articles was conducted using publicly accessible literature databases. The search terms used were: “Trigeminal Neuralgia”, “tic douloureux” “facial neuralgia” “AND” “cryotherapy”, “alcohol”, “glycerol”, “botulinum”, “neurectomy”, “gasserian ganglion”,

“radiofrequency thermocoagulation”, “rhizotomy”, “rhizolysis”, “electrocoagulation”, “coagulation”, “retro-gasserian”, “thermal rhizotomy”, “gangliolysis”, “percutaneous glycerol rhizotomy”, “microcompression”, “compression”, “balloon compression”, “MVD”, “posterior fossa surgery”, “partial rhizotomy”, “radiosurgery”, and “stereotactic surgery”. The bibliographies of retrieved articles were also searched. Every study was assessed for relevance. A comparative evaluation of surgical procedures was done using descriptive statistics. The parameters considered for the comparison were as follows:

1. Patient selection
2. Success rate of the procedure
3. Complications
4. Cost effectiveness

Results

Patient Selection

TN usually presents after the third decade of life [8, 9]. Considering the higher occurrence of medical comorbid conditions like hypertension, diabetes in the usual incidence age group for TN, it is important to tailor the intervention protocol as per the patient. In Table 1, we describe the comparative analysis of the patient selection criteria with respect to various surgical procedures.

The choice of the surgical procedure depends upon various patient factors. The patients with bleeding diathesis are not ideal for peripheral neurectomy (PN) and Cryotherapy (CT) as these procedures require a surgical flap to be raised. Elderly or medically compromised patients are not suitable candidates for open procedures. Patients with cardiovascular morbidities are not good candidates for percutaneous balloon decompression (PBC) because of high incidence of intra-operative arrhythmias and hypotension. Further, in such patients, alcohol injections (AI) should also be used with caution as the pain caused by AI may provoke an increase in systolic blood pressure and cardiac rhythm abnormalities [12]. Glycerol rhizotomy (GR), because of its low risk of trigeminal motor dysfunction, is particularly advantageous for patients with trigeminal motor weakness and temporomandibular joint dysfunction [18].

One additional factor that needs to be considered while selecting the most appropriate procedure is the severity/onset of pain. For the patients presenting with acute pain, percutaneous procedures are usually better suited than open procedures or Stereotactic radiosurgery (SRS) as open procedures require significant planning and SRS usually has a latency period before pain relief [19].

Success Rate of the Procedure

The major criterion in selection of any surgery remains the success rate. We reviewed the procedures with respect to the initial pain relief (IPR) and pain free duration (PFD) offered by them. The same was analysed relating to the enrolled population size and the recurrence rates were calculated. The success of various procedures is displayed in Tables 2–5.

Among the peripheral procedures, the maximum IPR and longest PFD have been observed with PN's. Among the peripheral injections, glycerol injections (GI) have shown the most promising results. CT has shown good results in terms of IPR. However, the pain recurrence is relatively earlier with CT.

The available data for the percutaneous procedures suggests that more patients have been managed by RFT than PBC and GR; presumably because of consistently higher IPR. PBC has also shown promising results with respect to IPR and PFD with lower recurrence rates. Among the percutaneous procedures, GR is the least favoured because of lower IPR and higher recurrence rate.

Open procedures provide the highest patient satisfaction rate with respect to IPR and PFD. These procedures are the only ones targeted towards alleviating the underlying cause of TN. Hence, in recent years there is a trend for early use of MVD, if the patient factors permit. The overall IPR for MVD is more than 90 % with PFD of more than 5 years. The success parameters with partial sensory rhizotomy (PSR) are slightly lower than MVD. The probable reason behind this may be that MVD is directed towards the resolution of obvious neurovascular conflict whereas in PSR, the primary cause for TN is usually not recognizable.

In recent past, SRS has acquired a major role in treatment of TN. Up to 90 % of the patients treated with SRS achieve an IPR, though after a latency of several days to weeks [19]. Early recurrences are common with SRS. However, the procedure may be repeated after the recurrence. The advances in imaging modalities have improved the success rate of the procedure significantly.

Complications

Analysis was performed with respect to the various complications associated with each procedure. However, as reported by previous studies, the review of literature suggested a lack of precision in describing the terms like “analgesia”, “hypoalgesia”, “paraesthesia”, and “dysaesthesia” [73]. Another challenge observed was the non-uniformity in the follow-up duration of various studies. It was observed that a prolonged follow-up was associated with reporting of a higher frequency of certain events. Further, a lack of randomized controlled trials (RCT) with

Table 1 Patient selection criteria

Procedure	Age/physical status	Contraindications	Special considerations
PN [10]	Elderly/debilitated/cognitively impaired patients [11]	LA/GA contraindications, bleeding diathesis [11]	None
CT [11]	Elderly patients with paroxysmal TN	LA/GA contraindications, bleeding diathesis	
GI [11]	Any	LA/GA contraindications	
AI	Elderly/debilitated, patients unwilling for surgeries [11]	Contraindications for LA, cardiovascular disorders [11, 12]	Accurate placement of needle [13]
BI [14]	Any (data currently limited)	Allergic disorders, pregnancy (category C), breastfeeding	NMJ disorders
PBC	Any [15]	Arrhythmias, hypotension [16]	None
GR [11]	Any	Bleeding diathesis	None
RFT [11]	Any	Bleeding diathesis	None
MVD [15]	<65; Medically fit	Contraindications to GA and craniotomy	None
PSR [15]	<65; Medically fit	Contraindications to GA and craniotomy	None
SRS [17]	Any	Allergy to i/v contrast, contraindications for CT/MRI	None

PN peripheral neurectomy, CT cryotherapy, AI alcohol injection, GI glycerol injection, BI botulinum injection, PBC percutaneous balloon compression, GR glycerol rhizotomy, RFT radiofrequency thermocoagulation, MVD microvascular decompression, PSR partial sensory rhizotomy, SRS stereotactic radiosurgery, LA local anaesthesia, GA general anaesthesia, CT computerized axial tomography, MRI magnetic resonance imaging, i/v intravenous, NMJ neuromuscular junction

Table 2 Success rate of peripheral procedures

Procedure	Study	N	FU (months)	IPR (%)	PFD (months)	Recurrence rate (%)
PN	Haliasos et al. [20]	47 (56 PN's)	101	78.7	30.2	14.9
	Shah et al. [21]	50	60	70	24–60	12 (24 months)
	Freemont and Millac [22]	26 (43 PN's)	72	97	26.5	18 (12 months) 52 (24 months)
	Murali and Rovit [23]	40	60	79	Up to 60	12.5 (24 months)
CT	Zakrzewska [24]	29 (83 CT's)	85	72	Up to 12	37 (12 months)
AI	Grant [25]	331	NA	79.7	13.6	NA
	McLeod and Patton [11]	49 (278 inj)	NA	90	11	NA
	Shah et al. [13]	100 (250 inj)	60	86	10–56	14
	Fardy et al. [26]	68	60	NA	13	NA
GI	Erdem and Alkan [27]	157	60	98	48	38
	Wilkinson [28]	18 (60 inj)	NA	87	9	63 (12 months)
BI	Piovesan et al. [29]	13	NA	100	2	NA
	Zúñiga et al. [30]	12	NA	100	2	NA
	Borodic and Acquadro [31]	11	NA	73	2–4	NA

PN peripheral neurectomy, AI alcohol injection, CT cryotherapy, GI glycerol injection, BI botulinum injection, N patient number, inj injections, FU follow up, IPR immediate pain relief, PFD pain free duration, IO infra-orbital, IA inferior-alveolar, LB long-buccal, NA not available

complications considered as endpoints was also noted. As a result a descriptive analysis for the complications could not be performed. Hence, we have tabulated the data with respect to the commonest complications observed with each procedure in a qualitative manner so as to display a consistency in the observations. However, the data where available, is represented as discrete figures (Table 6).

The major complication noted with TN surgeries is varying degree of sensory loss. The highest incidence of facial hypoesthesia has been associated with PSR followed by RFT and PBC. The highest incidence of corneal hypoesthesia has been observed with RFT and GR. Among all the peripheral procedures, the incidence of facial sensory loss is similar. However, the same observed with CT is usually reversible [24]. A

Table 3 Success rate of percutaneous procedures

Procedure	Study	N	FU (months)	IPR (%)	PFD (months)	Recurrence rate (%)
PBC	Skirving and Dan [32]	496	5	100	80.8	19.2
	Liu et al. [33]	290	32	91.3	18.7	5.2
	Mullan and Litchor [34]	61	60	97	80	20
	Kouzounias et al. [35]	61	36	85	20	50 (21 months)
	Park et al. [36]	58	42	92	18	16
GR	Xu-hui et al. [37]	3,370	156	73.6	60	35
	Saini [38]	552	12–72	96	24	28 (12 months)
	Steiger [39]	122	5	84	59	41
	Pollock [40]	98	42	73	28.7	16.7
	Pickett et al. [41]	97	81	78	20	59
RFT	Wu et al. [42]	1,860	24	78.8	24	25 (24 months)
	Kanpolat et al. [43]	1,600	5	97.6	57.7	42.3
	Loveren et al. [44]	700	6	81	61	20
	Fouad [45]	312	12	100	12	13.5
	Tronnier et al. [46]	206	14	NA	25	75
	Latchaw et al. [47]	96	5	NA	53	35
	Yoon et al. [48]	81	6	87	26	74

PBC percutaneous balloon compression, *GR* glycerol rhizotomy, *RFT* radiofrequency thermocoagulation, *N* patient number, *FU* follow up, *IPR* immediate pain relief, *PFD* pain free duration, *NA* not available

Table 4 Success rate of open surgical procedures

Procedure	Study	N	FU (months)	IPR (%)	PFD (months)	Recurrence rate (%)
MVD	Tyler-Kabara et al. [49]	1,918	60	98.2	60	25
	Barker et al. [50]	1,155	72	98	70	30
	Sindou et al. [51]	362	84	86	80	15.1
	Kondo [52]	279	120 (mean)	94.8	86.1	8.3
	Bederson and Wilson [53]	246	60 (mean)	NA	83	17
	Tronnier et al. [46]	225	132	76.4	65	NA
	Zakrzewska et al. [54]	245	64	90	60	21 (60 months)
	Olson et al. [55]	156	10	93	74	18
	Lee et al. [56]	146	5.7	96.5	89	8.6
	Zakrzewska and Thomas [57]	65	5	NA	62	38
	Sun et al. [58]	61	6.6	NA	82	18
	Mendoza and Illingworth [59]	60	7.5	NA	71	18
	Walchenbach et al. [60]	58	6.4	80	71	29
PSR	Bederson and Wilson [53]	86	60 (mean)	83	22.8	12
	Zakrzewska et al. [54]	60	64	88	84	28
	Adams et al. [61]	57	60	84.2	54	5.7
	Klun [62]	42	62.4	86	NA	49

MVD microvascular decompression, *PSR* partial sensory rhizotomy, *N* patient number, *FU* follow up, *IPR* immediate pain relief, *PFD* pain free duration, *NA* not available

gradual decline in the sensory loss over the years (*of publication*) was observed with SRS in the literature. This may be due to the advancement of imaging modalities. Trigeminal motor disturbance leading to masseter weakness is the major complication of PBC followed by RFT.

The data from various studies suggest that MVD proves to be the safest procedure with respect to complications. On the other hand PSR and RFT have the least favourable outcome followed by PBC. The inconsistency noted in the results for peripheral procedures may be attributed to

Table 5 Success rate of stereotactic radiosurgery

Study	N	FU (months)	IPR (%)	PFD (months)	Recurrence rate (%)
Kondziolka et al. [63]	503	24 (3–156)	89	50	43
Verheul JB et al. [64]	285	28	80	12	40 (60 months)
Maesawa et al. [65]	220	22	85	15.4	16.6
Kano H et al. [66]	193	168	72	49	53
Smith ZA et al. [67]	169	140	71.3	28.8	19.5 (13.5 months)
Pollock et al. [68]	117	26	86	8	20
Young et al. [69]	110	20 (mean)	88	33	34
Urgosik et al. [70]	107	5	80.4	58	25
Rogers et al. [71]	54	12	89	6.7	21
Shen et al. [72]	32	60	84	21	7: (12 months) 15: (36 months) 11: (58 months)

N patient number, *FU* follow up, *IPR* immediate pain relief, *PFD* pain free duration

Table 6 Complications related to surgical treatment of trigeminal neuralgia

Surgery	Mortality	HL	FH	CH	TMW	AD	CNP	Meningitis	Herpes labialis
PN [15, 74–76]	NR	NR	27 %	R	NR	NR	NR	NR	NR
CT [24]	NR	NR	28 %	NR	NR	R	NR	NR	NR
AI [75]	NR	NR	22 %	7 %	NR	11 %	NR	NR	NR
GI [27, 28]	NR	NR	R	R	NR	NR	NR	NR	NR
BI [29–31]	NR	NR	R	NR	NA	R	NR	NR	NR
PBC [77–80]	Y	Y	30 %	1.6 %	66 %	0.6 %	Y	Y	R
GR [38, 80–85]	Y	8.3 %	54 %	R	R	1.6–2.2 %	NR	8.3 %	2–78 %
RFT [44, 57, 75, 86–89]	Y	1.4 %	15–83 %	14.6 %	2.1–24 %	0.6–8 %	Y	Y	NR
MVD [3, 6, 39, 44, 49, 50, 53, 57, 90–93]	0.37	12–31 %	1–2 %	R	NR	2 %	Y	Y	R
PSR [62, 94]	Y	R	65 %	1.50 %	7 %	0.80 %	Y	Y	>90 %
SRS [80]	NR	1.6 %	30 %	1.6 %	NR	NR	R	R	NR

PN peripheral neurectomy, *CT* cryotherapy, *AI* Alcohol injection, *GI* glycerol injection, *BI* botulinum injection, *PBC* percutaneous balloon compression, *GR* glycerol rhizotomy, *RFT* radiofrequency thermocoagulation, *MVD* microvascular decompression, *PSR* partial sensory rhizotomy, *SRS* stereotactic radiosurgery, *HL* hearing loss, *FH* facial hypoesthesia, *CH* corneal hypoesthesia, *TMW* trigeminal motor weakness, *AD* anaesthesia dolorosa, *CNP* cranial nerve palsy, *NR* not reported, *Y* yes, *R* reported in literature

limited data with respect to shorter follow-up and lower sample sizes.

Cost Effectiveness

Very few studies in literature have analysed the cost-effectiveness of TN surgeries in a systematic way. One such prospective study was conducted by Pollock and Ecker [95]. The study analysed MVD, GR and SRS to evaluate the relative cost-effectiveness. The results revealed that the cost per quality adjusted pain-free year in this study was \$6,342 for GR, \$8,174 for MVD, and \$8,269 for SRS. The authors stated

that over short follow-up periods, percutaneous procedures are more cost-effective than SRS or MVD. However, at longer follow-up intervals, MVD was predicted to be the most cost-effective surgery because of lesser requirement of repeated procedures. The results from study conducted by Tarricone et al. [96] suggested that MVD and SRS appeared to be equally effective at 6 month follow-up. However, SRS reduced hospital costs by an average of 34 % per patient. Régis et al. [97], in a prospective study, have suggested lesser time between the date of hospitalization and the date of discharge with the majority of patients (93.7 %, 2 days) undergoing SRS. A subjective overview of cost effectiveness by Perkin [15] suggested that the peripheral procedures are cost effective and

easy to perform. Among the percutaneous procedures, PBC is comparatively less cost effective because of early recurrence. The author stated that in terms of the complications, PSR is less cost effective than MVD [15].

Discussion

Despite the availability of newer drugs for TN, many patients still require surgery because of pharmacological refractoriness or intolerance. According to the European Federation of Neurological Societies (EFNS) guidelines on neuropathic pain assessment and the American Academy of Neurology (AAN) guidelines, patients who are not benefited by the effective doses of carbamazepine or oxycarbazepine are the ideal candidates for surgical intervention [98]. Currently, the Level I evidence among the various surgical modalities is lacking in the literature [7]. Further, there are inconsistencies in the literature with respect to the analysis parameters. To the best of our knowledge, the present analysis is the only one describing an amalgamated overview of patient and procedure factors for the various TN surgeries. The following points were noted during the analysis:

- All peripheral procedures are associated with sensory loss and early recurrence [5]. However, these are especially useful for elderly or medically compromised patients. PN's are less in use and their mention in current literature is progressively fading due to higher sensory loss. Further, for PN, it is very important to determine which branch of the trigeminal nerve is involved so as to minimize the risk of complications. CT gives about half the median time to recurrence as compared to AI [26]. However, the sensory loss observed with CT is usually reversible [24]. Glycerol is a difficult drug to administer and also results in marked swelling. However, the procedure is relatively painless when compared with AI [26]. Botulinum injections (BI) being a relatively new modality, have scarcity with respect to efficacy and safety data. However, the available information suggests promising results for this procedure. By far, the major advantage of peripheral procedures is the repeatability. However, the same may not be applicable to BI, where due to development of antibodies to botulinum the patient may become a non-responder to repeated injections [99]. Further, many authors reported that repeated peripheral procedures may result in high incidence of complications [50, 56, 57, 70].
- Among the percutaneous procedures, RFT has the best long-term data [5]. However, it has high rate of long-term failure. PBC can produce significant bradycardia and hypotension during the procedure and has higher

incidence of motor dysfunction [77–80]. GR has both low IPR and shorter PFD's [37–41].

- Despite the inherent risks of craniotomy, MVD remains a popular treatment for TN. PSR is advocated when neurovascular contact at the trigeminal root is absent. The initial results are similar for MVD and PSR. However, the results taper to 50 % in case of PSR at 5 years [100]. Further, highest post-operative anaesthesia and hearing loss has been reported with PSR [62, 94]. In long term analysis, MVD appears to be a cost effective modality [15, 96–98]. Overall, MVD is the only surgical option that allows for long-term pain relief while avoiding much sensory disturbance [3, 6, 39, 44, 49–60, 90–93].
- Several reports have acknowledged that SRS is having a very high rate of pain relief with minimal complications. However, the onset of pain relief is delayed in many patients [19]. Nevertheless, it provides a good option for those unwilling or unable to undergo more invasive surgical approaches.

Overall it may be stated that, although the peripheral procedures provide a greater economical benefit initially, but, in long term follow-up due to the requirement of repeat procedures, the cost-benefit ratio is not favourable. In such cases, the open procedures or SRS provides a better alternative. However, further studies with defined objectives are needed to have more coherent results.

The aforesaid points suggest that each surgery has got its merits and demerits as compared to the other procedures. However, the overall data suggests that MVD has got the most favourable benefit-risk ratio and economic outcome in long term. In our opinion, if patient factors permit, it should be considered as the first line treatment for the patients with drug-resistant TN.

Conclusion

It is evident from the current review that there is a need for quality data so as to have better decision models. There is a need of prospective controlled studies using standardized diagnostic criteria, procedures and endpoints with respect to efficacy and safety so that an accurate assessment of risk-benefit analysis may be made out. Further, patient's physical and mental status, number and type of the previous procedures and socio-economic status may vary significantly among the TN population. Hence, an individualized approach should be undertaken so as to select the most appropriate intervention.

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