Original Article

Clinical Outcome of Partial Sensory Rhizotomy in Negative-Exploration Trigeminal Neuralgia and Technical Nuances

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Background: Microvascular decompression is considered to be a potential treatment for most trigeminal neuralgia cases with obvious neurovascular conflict. Partial sensory rhizotomy (PSR) is an alternate option in cases of negative investigation for neurovascular conflict, although its effectiveness and technical complexity are still being debated.

Objective: To evaluate the therapeutic efficacy of PSR following negative-exploration trigeminal neuralgia (NETN) in terms of pain control, adverse effects from sensory fiber destruction, and patient satisfaction in the short-term or after 1 month, and in the long-term or after 12 months. In addition, technical nuances were highlighted to mitigate the negative effects of PSR.

Materials and Methods: The present study enrolled 27 NETN patients, and all were operated by the same neurosurgeon. The patients underwent surgery via a keyhole retromastoid technique, with extensive exploration for any possible intraoperative neurovascular conflict. A modified PSR approach was used to operate on these negative exploration cases, and this entailed cutting fewer than 1/5 of the trigeminal sensory fibers. The short-term or within one month, and long-term or after one-year intervals were used to track all instances. The therapeutic efficacy of employing pain score and subjective sensation in terms of pain control, adverse consequences from sensory fiber destruction, and patient satisfaction were investigated.

Results: Eighty-five point two percent of patients reported excellent pain control following PSR, in terms of both pain score and total pain alleviation. Despite having their trigeminal nerve fibers severed, not all of the patients experienced numbness, and 45% of patients recovered to some extent on their own within a year. Only 13% of patients had Anesthesia Dolorosa in the present trial, which could be attributable because only 1/5 of the trigeminal nerve fibers were severed. There was no relationship between pain distribution and pain alleviation efficacy before and after PSR. When PSR was effective, most patients should notice an improvement within a month of the surgery.

Conclusion: For patients with negative exploration following keyhole suboccipital craniectomy, PSR proved to be therapeutic and effective in alleviating trigeminal neuralgic pain. The majority of the patients can tolerate the minor side effects from minute nerve destruction well, particularly numbness, which partially resolves on its own with time.

Keywords: Negative exploration; Trigeminal neuralgia; Microvascular decompression; Partial sensory rhizotomy; Efficacy

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Trigeminal neuralgia (TN) is one of the most debilitating forms of hemifacial pain. Most patients describe sharp, paroxysmal, and excruciating pain along the trigeminal distribution. Although the pain is most commonly unilateral, it can also be bilateral, but not usually in the same episode. Simple, tactile, or non-painful stimuli, such as gentle contact across the facial or intraoral region, frequently elicit discomfort. Even a light touch in trigger zones, particularly on the lateral surface of the nose and the angle of the mouth, can worsen a severe paroxysm of pain in most individuals. Even though trigger zones are pathognomonic for TN, not all cases have these areas. Usually, combined medications are the first line of treatment, but some individuals either do not respond to any medications or have intolerable side effects. For these patients, surgical treatment by microvascular decompression (MVD), involving decompression between the conflicted vessels and the trigeminal nerve, could be an alternative. Furthermore, it is one

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of the most reliable procedures for immediate pain relief. Although the majority of trigeminal neuralgic cases present with neurovascular conflict (NVC) intraoperatively, substantial numbers do not show any obvious signs at this stage. In cases with negative explorations, partial sensory rhizotomy (PSR) is considered as a surgical alternative. The goal of the present study was to assess the therapeutic efficacy of PSR following TN in terms of pain control, adverse effects from sensory fiber loss, and patient satisfaction in both the short-term, or one month, and the long-term, or one year. Meanwhile, technical nuances were noted in an attempt to counteract detrimental consequences of the procedure.

Materials and Methods

The Rajavithi Hospital Ethics Committee approved the present retrospective study. The data were collected from patients that underwent surgery between January 2010 and October 2020 (EC no. 19/2565). Diagnostic criteria for TN were based on the guideline of the International Headache Society (IHS) as follows[1]:

A. Paroxysmal attacks of pain lasting from a fraction of a second to two minutes, affecting one or more divisions of the trigeminal nerve, and fulfilling criteria B and C

B. Pain has at least one of the following characteristics:

- is intense, sharp, superficial, or stabbing
- is precipitated from trigger zones or by trigger factors

C. Attacks are stereotyped in the individual patient

D. There is no clinically evident neurologic deficit

E. It is not attributed to another disorder

Imaging

Prior to surgery, all of the patients received a 1.5-Telsa magnetic resonance imaging (MRI) to rule out the possibility of NVC or concurrent brain tumor.

Inclusion and exclusion criteria

A summary of the inclusion and exclusion criteria is shown in Table 1. Individuals who received both MVD and PSR in the same setting were omitted from the study to avoid any misinterpretation regarding the effectiveness of PSR alone. Various events, such as NVC by extremely small veins or vessels near the trigeminal nerve without obvious evidence of NVC, were common reasons for these cases.

Table 1. Inclusion and exclusion criteria for the study

Inclusion criteria	Exclusion criteria
Cases of classical TN according to IHS guideline	Cases in which preoperative MRI revealed intracranial tumors or space-occupying lesions
Cases in which intraoperative findings revealed no obvious neurovascular conflict whether or not preoperative MRI revealed it	TN cases with the previous history of any destructive/ablative procedure to the trigeminal nerve
Cases which had failed MVD from previous surgery	Cases which had received both MVD+PSR in the same setting

TN=trigeminal neuralgia; IHS=International Headache Society; MRI=magnetic resonance imaging; MVD=microvascular decompression; PSR=partial sensory rhizotomy

Table 2. The criteria for overall pain relief efficacy 12 months after PSR

Description	Rating
Pain relief more than 90%, without need for medication	Excellent
Pain relief more than 50% with the need for concomitant medications	Good
Pain relief less than 25%; full medication is essential	Poor

Individual patients' subjective feelings were used to rate overall pain relief efficacy, regardless of whether they had a postoperative complication. The criteria for overall pain relief efficacy are outlined in Table 2.

Surgical technique

The same surgeon performed all operations, and because PSR causes irreversible damage to the trigeminal nerve, all patients were educated about the potential risks and expected outcomes before undergoing surgery. All the patients were operated in the supine position using a keyhole retromastoid technique. For better cosmetic outcome, a longitudinal incision along the post-auricular hairline was performed, and the skull was opened to a diameter of about 2 cm (Figure 1a). The skull was fully exposed to the posterior margin of the mastoid bone to avoid the negative effects of over-retraction of the cerebellum. Figure 1b shows how the dura was normally opened in a T-shape. Sigmoid and transverse sinus were located at the operative field's top and lateral aspects, respectively. The cerebrospinal fluid was initially drained to make enough room for an approach between the cerebellar hemisphere and the inner side of the dura. To avoid iatrogenic harm, the arachnoid membrane covering the VIII-VII nerve complex was preserved as much as possible. Before proceeding to PSR, a thorough examination was conducted of the entire trigeminal nerve from the pontine surface

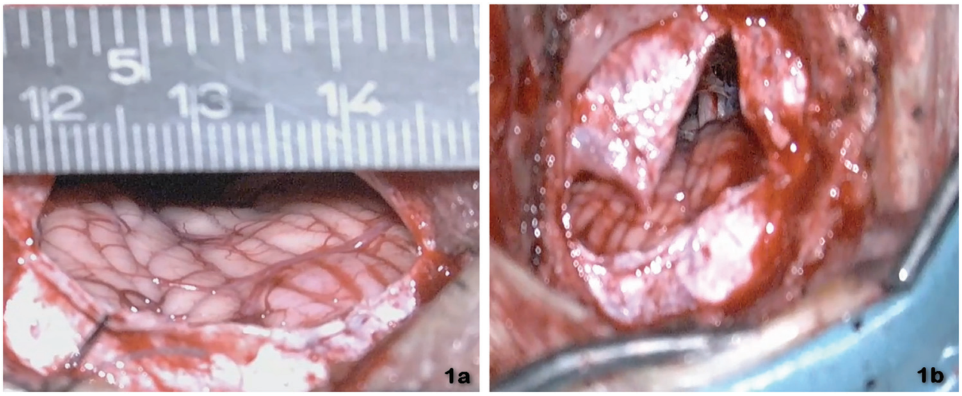

Figure 1. (a) The skull was opened about 2 cm in diameter and (b) Dura was opened in T-shaped.

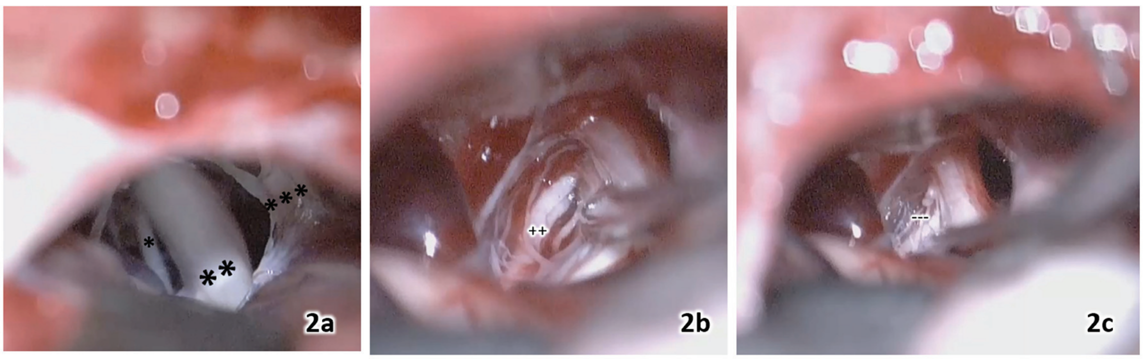

Figure 2. (a) Portio major (**) and portio minor (*) of trigeminal nerve, CN VIII-VII complex (covered by arachnoid membrane) (***), (b) Portio major after interfascicular dissection (++), (c) After partial sensory rhizotomy (---).

(root entry zone) to the porus trigeminus to rule out any problematic arteries or NVC; this was a critical step in the process. As lack of sufficient visualization and inspection of the entire trigeminal nerve may lead to the false conclusion that there was no NVC, both the portio major (large sensory root) and the portio minor (little motor root) were thoroughly explored. In some cases, the relationship between the trigeminal nerve and the offending vessels may change after the patient's positioning, and these relationships may be further altered by intraoperative CSF drainage. As a result, it was important to bear in mind that the offending vessel was frequently found 1 to 2 mm distant from the true location of the NVC. Mobilization and circumferential examination of the trigeminal nerve was also performed, particularly in its medial and anterior sections, as a hidden conflict could be revealed in some cases. When a thorough circumferential examination of the trigeminal nerve failed to reveal a problematic vessel, PSR was performed by interfascicular dissection and then followed by cutting less than 1/5 of the sensory root on the postero-lateral surface of the portio major and no more than 1 cm from the root entry zone (Figure 2), mindful of the fact that it is critical not to cauterize the portio major to avoid posttraumatic trigeminal neuropathic pain. A watertight dural closure was made prior to skin closure to prevent postoperative meningitis caused by cerebrospinal fluid leakage.

Statistical analysis

Statistical analysis was carried out using IBM SPSS Statistics, version 19.0 (IBM Corp., Armonk, NY, USA). To analyze the postoperative pain relief outcome, the non-parametric test was performed using Friedman and Wilcoxon signed rank test, and the differences were considered significant at p-value less than 0.05. In the present study, gender and age were analyzed using categorical data, ages were analyzed using continuous data, and pain score (PS) was analyzed using a non-parametric test.

Results

From the retrospective data, 27 cases TN that

Table 3. Comparison of mean age, affected side, and pain distribution in female and male participants

	Female	Male
Sex; n (%)	15 (55.5)	12 (44.5)
Age (years); mean±SD	58.33±10.37	62.83±13.53
Affected side (%)	Left (67)	Left (50)
Pain distribution; n (%)		
(a) V1	0 (0.0)	2 (7.4)
(b) V2	5 (18.5)	0 (0.0)
(c) V3	4 (14.8)	5 (18.5)
(d) V1+V2	0 (0.0)	0 (0.0)
(e) V2+V3	5 (18.5)	4 (14.8)
(f) V1+V3	0 (0.0)	0 (0.0)
(g) V1+V2+V3	1 (3.7)	1 (3.7)
Duration before operation; n (%)		
<12 months	0 (0.0)	3 (11.1)
12 to 24 months	5 (18.5)	2 (7.4)
24 to 36 months	6 (22.2)	3 (11.1)
36 to 48 months	2 (7.4)	2 (7.4)
>48 months	2 (7.4)	2 (7.4)

SD=standard deviation

underwent PSR during the inclusion period by the same neurosurgeon with more than 20 years' experience of MVD surgery were recruited for the present study. The female group's mean age was slightly lower than the male group, and pain in the female group was slightly more prevalent on the left side than in their male counterparts, in which it was evenly distributed on each side. Table 3 indicates the clinical characteristics and postoperative adverse effects linked with PSR.

Even though the trigeminal nerve was partially severed, not all patients experienced numbness, and 6 of 15 (40%) patients improved to some extent within a year. Only 13% of patients suffered the most severe side effect after PAR, Anesthesia Dolorosa (AD). Details are shown in Table 4.

Table 5 summarizes the overall PS before PSR and at one-month and one-year after surgery. It also summarizes the overall pain relief assessment after one year. Using partial sensory as an indicator for success, there was statistically significant PS improvement at both one-month and one-year after PSR (p=0.00), but there was no statistical significance between PS improvement at one-year compared to one-month after PSR (p=0.18).

Overall pain relief was rated as bad in 14.8% of cases, good in 14.8% of cases, and excellent in 70.4% of cases at one-year after PSR. In summary, despite complications linked to trigeminal nerve injury, 85.2% of PSR cases reported pain alleviation (Table 6).

Table 7 summarizes pain area distribution. Using

Table 4. Postoperative dysesthesia associated with PSR

Adverse effects	Cases; n (%)	Recover >80% after 1 year follow up; n (%)
Facial numbness		
V1	0 (0.0)	-
V2	2 (13.0)	0 of 2 (0.0)
V3	2 (13.0)	2 of 2 (100)
V1+V2	0 (0.0)	-
V2+V3	2 (13.0)	1 of 2 (50.0)
V1+V3	0 (0.0)	-
V1+V2+V3	1 (6.6)	0 of 1 (0.0)
Intraoral numbness	6 (40.0)	3 (50.0)
Anesthesia Dolorosa	2 (13.0)	1 of 2 (50.0)

Table 5. Summarizes of pain score before PSR and 1 month and 12 months after surgery together with overall pain relief assessment 1 year after PSR

Pain score (PS)	PS before PSR; n (%)	PS 1 month after PSR; n (%)	PS 12 months after PSR; n (%)
0	0 (0.0)	4 (14.8)	7 (25.9)
1	0 (0.0)	12 (44.4)	5 (18.5)
2	0 (0.0)	3 (11.1)	6 (22.2)
3	0 (0.0)	5 (18.5)	2 (7.4)
4	0 (0.0)	2 (7.4)	1 (3.7)
5	0 (0.0)	1 (3.7)	3 (11.1)
6	1 (3.7)	0 (0.0)	0 (0.0)
7	5 (18.5)	0 (0.0)	1 (3.7)
8	6 (22.2)	0 (0.0)	1 (3.7)
9	10 (37.0)	0 (0.0)	1 (3.7)
10	5 (18.5)	0 (0.0)	0 (0.0)
Total	27 (100)	27 (100)	27 (100)
Min	6	0	0
Max	10	5	9
Median	9	1	2
p-value		<0.01	<0.01

PSR=partial sensory rhizotomy

A p-value less than 0.05 is statistically significant

Table 6. The overall pain relief assessment (12 months after PSR)

Overall pain relief assessment (12 months after PSR)	n (%)
Poor	4 (14.8)
Good	4 (14.8)
Excellent	19 (70.4)

PSR=partial sensory rhizotomy

Table 7. Pain area distribution

Pain area	n	Mean rank
V1	2	10.25
V2	5	13.4
V3	9	14.56
V2+3	9	16.28
V1+2+3	2	6.5

chi-square test, there was no statistically significant relationship between pain relief after PSR and pain distribution (p=0.318).

Discussion

MVD is considered a first-line surgical treatment for severe pain caused by TN when a preoperative MRI demonstrates vascular compression of the trigeminal nerve. It has been proven to be an effective and reliable method of pain relief after TN[2]; however, in the present research, despite significant TN pain, preoperative MRIs revealed no apparent evidence of NVC in a number of instances. Studies have demonstrated that the absence of NVC following a preoperative MRI is not an indication to abandon surgery[3], and in such circumstances, careful intraoperative observations frequently reveal the troublesome vessels that need to be decompressed. Both groups in the present study had favorable outcomes after MVD, and despite extensive intraoperative exploration, a number of patients with severe trigeminal neuralgic pain showed no evidence of NVC. The theory that TN is caused by NVC has been called into question in certain situations, and because these patients' trigeminal neuralgic pain is often extreme, the surgeon must decide whether to act intraoperatively. Even though postoperative facial or intraoral numbness and dysesthesia are common, one of the recommended intraoperative procedures is ablative surgery on the trigeminal nerve. According to the literature review, intraoperative ablative procedures have been employed to treat these painful sensations, including internal neurolysis (IN), intraoperative glycerin rhizotomy, and PSR of the trigeminal nerve[4]. However, according to Baechli and Gratzl, patients with undiagnosed vascular compression can nevertheless benefit from MVD and even be cured. They argued that the therapeutic effect of MVD was related to little nerve stress and that it should be used first before any ablative techniques[5]. In the event of an undiscovered NVC during an operation, the surgeon usually has three options, MVD, PSR, or both. Before surgery, these potential consequences of each choice must be explained to the patient, especially the irreversible effects that could ensue after PSR. Numbness of the face, intraoral paresthesia, and the highly troublesome AD are the most typical adverse effects after PSR, and they can be either temporary or permanent.

Once PSR is chosen, the surgeon has to decide which part, where, and how much of the trigeminal nerve should be destroyed. Before jumping to any conclusion, the surgeon must look back on the basic principle of MVD for TN. According to studies, the most probable origin of TN is segmental demyelination of the primary sensory root as a result of the persistent vascular conflict. The most commonly held belief is that the root entry zone is the most vulnerable part of the trigeminal nerve[6,7]. Investigations have underlined the importance of vascular conflict with the root entry zone, which is the part of the trigeminal nerve enriched by central myelin, as the precise place of pathogenic localization[8-10]. As a result, PSR should be done at this myelin-enriched area in cases of negative-exploration trigeminal neuralgia (NETN).

Another point of contention is how much, and which part of the trigeminal nerve's myelin-rich region should be damaged to get adequate pain relief with minimal side effects. There have been studies on the association between the location of vascular compression and pain distribution in the trigeminal system. Sindou and Brinzeu had found that more than 90% of cases had the compression coming from above, with 60% of compression from a superomedial direction and 30% from a superolateral direction, whereas inferior compression was present in only10%. The distribution of the pain was significantly different according to the location of the vascular conflict. Patients with superomedial compression usually manifested V1 pain, whereas cases of inferior compression were more likely to present with V3 pain, which was less likely to occur with supero-median compression[11]. Another study from Sindou et al[12] appeared to be the most comprehensive in attempting to explain the relationships between the topography of pain and the location of the NVC. In 52.3% of patients, the NVC was found in the trigeminal root entry zone, 54.3% in the mid-third of the nerve, and 9.8% at the nerve exit from the Meckel cave. In 53.9% of cases, the major conflict with the nerve surface was superomedial, 31.6% was superolateral, and 14.5% was inferior. The major conflict was classified as a simple contact with the nerve in 17.6% of cases, a distortion of the nerve in 49.2% of cases, and a substantial indentation in 33.2% of cases[12]. Based on the findings of the aforementioned studies, the surgeon can conclude that the most appropriate location of PSR should be at the superolateral part and within 1 cm of the point of brainstem exit, especially in the majority of patients who presented after V2+V3 TN.

The most challenging task is determining how many trigeminal fibers must be destroyed. It is certain that the more trigeminal fibers are cut, the more likely it is that the patient will experience pain relief. However, because rhizotomy results in permanent injury, the more damage to sensory fibers, the higher the risk of consequences such as facial or intraoral numbness, corneal sensory disturbance, and disabling AD. The latter, also known as deafferentation pain, involve ipsilateral facial numbness and pain along the trigeminal distribution followed by injury to the sensory fiber[13]. Despite the fact that AD following PSR is uncommon, which occurred in 2% to 4%[14], it can produce prolonged and intense pain without any nociceptive stimuli and is challenging to treat with medications. Consequently, every effort must be made to limit the risk of AD following PSR. According to the study by Cohen-Gadol, he did not execute traditional PSR on a regular basis precisely to avoid this severe complication. By delicately pinching the trigeminal nerve with fine forceps, he could accomplish the procedure with the least amount of invasiveness[15]. However, since traditional PSR has been proposed as an alternative way of treating TN, modifications have been applied. According to Liu's findings, if the pain was limited to the V3 division, 1/3 of the sensory root should be cut off, and if the discomfort was limited to the V1 or V2 division, 2/3 of the sensory root should be removed[16]. In contrast, according to a study by Zhao et al, PSR should be conducted on 1/3 to 1/5 of the posterior lateral of the trigeminal nerve root[17]. In the present study, only about a fifth of the sensory root was severed, and cauterization of the trigeminal fiber was forbidden to avoid AD.

As previously mentioned, however, PSR is not a risk-free procedure. Jafree et al stressed that postoperative complications such as pain, numbness, burning sensation, and difficulty in eating were unavoidable in some cases[18]. Young and Wilkins also pointed out that PSR may result in failure of pain control. Despite the high number of excellent results after PSR such as no TN postoperatively and good results after PSR such as pain persisted or recurred but was less severe than preoperatively, there were still some cases with poor outcomes such as persistent or recurrent pain equal or greater than preoperative pain in severity and refractory to medications or severe enough to require additional surgery. Researchers have concluded that poor outcomes could be predicted by prior surgery and lack of preoperative involvement of the third trigeminal division. Xie et al supported the result of the study by Young. They found that results in their rhizotomy and lesioning groups were excellent, but that 50% and 3.6%, respectively had facial numbness[19]. However, they still concluded that PSR was a safe and effective procedure when neurovascular compression was not identified or MVD could not be performed, and this was confirmed by the study of Xie et al that found lesioning to the trigeminal nerves ensured therapeutic efficacy and improved the quality of life in selected trigeminal neuralgic patients[20]. Marco and Luis reported that 88% of patients who suffered from TN experienced complete relief from pain after IN, and there was a mean time recurrence of 27 days in 6%. Although, all patients with IN experienced some degree of numbness, 88% of these cases were resolved within six months[21]. Likewise, Liu et al confirmed that PSR reduced pain with a high effectiveness rate of up to 62.9% and a recurrence rate of 28.6% after an average follow-up of 71.4 months. Even though PSR was associated with an incidence of facial numbness, it did not affect the patients' daily life[16].

The present study proved the efficacy of PSR, with most patients experiencing excellent pain control, both in terms of PS and total pain alleviation. Even though the trigeminal nerve fibers were severed, not all of the patients experienced numbness, and the majority of them recovered to some extent spontaneously within a year. Only 13% of patients had AD, which could be because only 1/5 of the trigeminal nerve fibers were severe in the present study. There was no correlation between pain distribution prior to PSR and pain alleviation efficacy. Moreover, if the treatments resulted in pain relief, most patients would see this benefit within one month of PSR.

Limitation

The limitation of the present study is the small sample size.

Conclusion

Following negative exploration after keyhole suboccipital craniectomy, PSR was therapeutic and beneficial in treating trigeminal neuralgic pain, despite the increased risk of the partial face and intraoral numbness. In the present study, most patients tolerated numbness better than acute pain from TN, and the numbness usually resolved with time. Finally, not more than 1/5 of the trigeminal sensory fibers should be cut, and the cutting spot must be within 1 cm of the brainstem exit point to avoid the disabling AD and the bothersome sensation of numbness.

What is already know on this topic?

For patients with TN who do not have a considerable vascular conflict during posterior fossa exploration, PSR is indicated as an alternative therapy method.

What this study adds?

PSR, when performed correctly and with as little disruption to the trigeminal sensory fibers as feasible with less than 1/5 of the trigeminal sensory fibers should be cut, is the best alternative procedure for relieving the excruciating pain of NETN.

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Conflicts of interest

The author declares no conflicts of interest.

References

1. Krafft RM. Trigeminal neuralgia. Am Fam Physician 2008;77:1291-6.
2. Wongsirisuwan M. Short- and Long-term effectiveness of keyhole microvascular decompression for trigeminal neuralgia. J Med Assoc Thai 2018;101:209-16.
3. Lee A, McCartney S, Burbidge C, Raslan AM, Burchiel KJ. Trigeminal neuralgia occurs and recurs in the absence of neurovascular compression. J Neurosurg 2014;120:1048-54.
4. Ishikawa M, Soma N, Kojima A, Naritaka H. Straightening the trigeminal nerve axis by complete dissection of arachnoidal adhesion and its neuroendoscopic confirmation for trigeminal neuralgia without neurovascular compression. Interdiscip Neurosurg 2017;10:126-9.
5. Baechli H, Gratzl O. Microvascular decompression in trigeminal neuralgia with no vascular compression. Eur Surg Res 2007;39:51-7.
6. Love S, Coakham HB. Trigeminal neuralgia: pathology and pathogenesis. Brain 2001;124:2347-60.
7. Bederson JB, Wilson CB. Evaluation of microvascular decompression and partial sensory rhizotomy in 252 cases of trigeminal neuralgia. J Neurosurg 1989;71:359-67.
8. Jannetta PJ. Arterial compression of the trigeminal nerve at the pons in patients with trigeminal neuralgia. J Neurosurg 1967;26(1 Suppl):159-62.
9. Jannetta PJ. Observations on the etiology of trigeminal neuralgia, hemifacial spasm, acoustic nerve dysfunction and glossopharyngeal neuralgia. Definitive microsurgical treatment and results in 117 patients. Neurochirurgia (Stuttg) 1977;20:145-54.
10. Hughes MA, Frederickson AM, Branstetter BF, Zhu X, Sekula RF Jr. MRI of the trigeminal nerve in patients with trigeminal neuralgia secondary to vascular compression. AJR Am J Roentgenol 2016;206:595-600.
11. Sindou M, Brinzeu A. Topography of the pain in classical trigeminal neuralgia: insights into somatotopic organization. Brain 2020;143:531-40.
12. Sindou M, Howeidy T, Acevedo G. Anatomical observations during microvascular decompression for idiopathic trigeminal neuralgia (with correlations between topography of pain and site of the neurovascular conflict). Prospective study in a series of 579 patients. Acta Neurochir (Wien) 2002;144:1-12.
13. Nashold BS Jr, Friedman AH, Sampson JH, Nashold JRB, El-Naggar AO. Dorsal root entry zone lesions for pain. In: Youmans JR, editor. Neurological surgery. Philadelphia: WB Sounders; 1996. p. 3452-62.
14. Nashold BS Jr, El-Naggar AO, Gorecki JP. The microsurgical trigeminal caudalis nucleus DREZ procedure. In: Nashold BS Jr, Pearlstein RD, editors. The DREZ Operation. Park Ridge: AAN; 1996. p. 159-88.
15. Cohen-Gadol AA. Microvascular decompression for the trigeminal neuralgia [Internet]. 2021 [cited 2022 Apr 8]. Available from: https://doi.org/10.18791/nsatlas.v6.ch01.1.
16. Liu Y, Yu Y, Wang Z, Deng Z, Liu R, Luo N, et al. Value of partial sensory rhizotomy in the microsurgical treatment of trigeminal neuralgia through retrosigmoid approach. J Pain Res 2020;13:3207-15.
17. Zhao G, Sun X, Zhang Z, Yang H, Zheng X, Feng B. Clinical efficacy of MVD combined with PSR in the treatment of primary trigeminal neuralgia. Exp Ther Med 2020;20:1582-8.
18. Jafree DJ, Williams AC, Zakrzewska JM. Impact of pain and postoperative complications on patient-reported outcome measures 5 years after microvascular decompression or partial sensory rhizotomy for trigeminal neuralgia. Acta Neurochir (Wien) 2018;160:125-34.
19. Young JN, Wilkins RH. Partial sensory trigeminal rhizotomy at the pons for trigeminal neuralgia. J Neurosurg 1993;79:680-7.
20. Xie ZH, Chen L, Wang Y, Cui ZQ, Wang SJ, Ao Q, et al. Comparison of different microsurgery techniques for trigeminal neuralgia. Transl Neurosci Clin 2016;2:183-7.
21. Gonzales-Portillo M, Huamán L. Internal neurolysis (Nerve combing) for trigeminal neuralgia without neurovascular compression. Arq Bras Neurocir 2021;40:59-70.