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Оригинальное исследование / Research article

Short and long term follow-up of microvascular decompression for the management of trigeminal neuralgia caused by venous compression

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Abstract

Introduction. Classical trigeminal neuralgia is caused by the compression of the trigeminal nerve root and often requires surgical intervention due to the maladaptive intense pain syndrome. Both arteries and veins are considered compressing vessels, however, the role of venous compression in the development of neuralgia remains undefined. The aim of the study was to investigate the effectiveness of microvascular decompression in the treatment of trigeminal neuralgia caused by venous compression, considering the use of various surgical tactics**. Material and methods.** A retrospective analysis of surgical outcomes in 70 patients who underwent microvascular decompression for trigeminal neuralgia at the Federal Neurosurgical Center (Novosibirsk, Russia) between 2017 and 2021 was conducted. The study included 46 women and 24 men aged 23–82 years with unilateral facial pain. Brain MRI was performed preoperatively to evaluate neuroimaging picture and to clarify the relationships between the trigeminal nerve root and adjacent vessels. The surgical results were assessed during follow-up using the Barrow Neurological Institution (BNI) scale. **Results.** The study showed that venous neurovascular compression is frequently found in trigeminal neuralgia patients undergoing microvascular decompression in 26.9 % of cases. Various operative strategies were used when venous compression was detected, with high short-term success rates and lower recurrence rates. Long-term monitoring indicated pain relief in 71.4 % of cases (BNI I–II) and pain recurrence in 28.6 % of cases (BNI III, IV, V). **Conclusion.** This study highlights the effectiveness of microvascular decompression in treating classical trigeminal nerve neuralgia caused by venous compression and emphasizes the importance of individual surgical tactics based on the characteristics of the adjacent veins to achieve optimal results.

Key words: trigeminal neuralgia, microvascular decompression, venous compression, neurovascular conflict.

Conflict of interest. The authors declare no conflict of interest.
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Ближайшие и отдаленные результаты микроваскулярной декомпрессии у пациентов с тригеминальной невралгией, обусловленной венозной компрессией

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Резюме

Классическая тригеминальная невралгия вызвана компрессией корешка тройничного нерва и часто требует хирургического вмешательства в связи с дизадаптирующим интенсивным болевым синдромом. В качестве компримирующих сосудов рассматриваются как артерии, так и вены, однако роль венозной компрессии в развитии невралгии до сих пор не определена. Цель исследования – изучить эффективность микроваскулярной декомпрессии в лечении тригеминальной невралгии, вызванной венозной компрессией, с учетом применения различной хирургической тактики. **Материал и методы.** Проведен ретроспективный анализ результатов операций у 70 пациентов, перенесших микроваскулярную декомпрессию по поводу тригеминальной невралгии в Федеральном нейрохирургическом центре (Новосибирск, Россия) в период с 2017 по 2021 г. В исследование включены 46 женщин и 24 мужчины в возрасте 23–82 лет с односторонней лицевой болью. МРТ головного мозга применяли до вмешательства для оценки нейровизуализационной картины и уточнения варианта взаимоотношений корешка тройничного нерва и прилежащих сосудов. Результаты операции оценивали в катамнезе по шкале Barrow Neurological Institution (BNI). **Результаты.** Исследование показало, что венозная компрессия довольно часто встречается у пациентов с тригеминальной невралгией – в 26,9 % случаев. При обнаружении венозной компрессии использовались различные оперативные стратегии в зависимости от взаимоотношения вены с корешком нерва. Длительный катамнез показал облегчение боли в 71,4 % случаев (BNI I–II). Рецидивы наблюдались в 28,6 % случаев (BNI III, IV, V). **Заключение.** Данное исследование подчеркивает эффективность микроваскулярной декомпрессии в лечении классической невралгии тройничного нерва, вызванной венозной компрессией, и демонстрирует важность индивидуальной хирургической тактики в зависимости от характеристик прилежащих к корешку вен для достижения оптимального результата.

Ключевые слова: невралгия тройничного нерва, микроваскулярная декомпрессия, венозная компрессия, нейроваскулярный конфликт.

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Introduction

Trigeminal neuralgia (TN) is defined as pain in the distribution of at least one of the branch of fifth cranial nerve distributions. The pain is paroxysmal, with sudden onset and termination of pain episodes [1]. The episodes can be brief, lasting only a few seconds, or can last up to 2 minutes and are stabbing, sharp, shooting, and electric shock in quality [2]. The pain episodes can be induced by mechanical stimuli such as a light touch or a breeze or by movements such as smiling or applying makeup [1–3]. The symptoms may be accompanied by weight loss, poor quality of life, or depression [4]. Vascular compression of the trigeminal nerve root by an arterial loop of superior cerebellar and/or anterior-inferior cerebellar arteries at the trigeminal root entry zone (TREZ) is the main cause of classical TN. But a neurovascular conflict (NVC) between the trigeminal nerve and a vein can be an acceptable cause of classical TN too [5, 6]. The routine magnetic resonance imaging (MRI) and its different sequences use to reveal potential vascular compressive lesions by clearly indicating the contact position, degree, and origin of blood vessels (arteries and veins) between the nerve and blood vessel [7–11]. Microvascular decompression (MVD) may have excellent immediate and long-term pain relief outcomes and is, by some, considered the “gold standard” surgery for managing classical TN [1, 12, 13]. MVD has been widely accepted as an effective surgical choice for classical trigeminal neuralgia (CTN) patients who fail to respond or become intolerant to medical treatment. If a vein is discovered during surgery as a factor of nerve compression it is difficult to dissect offending veins from the nerve, and thus, the neurosurgeon faces the difficult choice of sacrificing the veins or decompressing them with preservation. There is no universal consensus on the management of veins. Some authors advocated the preservation of veins because sacrificing the veins may affect the brainstem or cerebellum and cause severe complications [14–16]. Others claimed to cut the veins because saving the veins may result in unsatisfactory decompression or recurrence [17, 18]. This article was devoted to examining the patient’s characteristics, clinical presentation, and surgical management options for CTN caused by neurovascular conflicts, particularly focusing on the challenges and controversies surrounding the management of veins in microvascular decompression procedure.

The aim of the study was to investigate the effectiveness of microvascular decompression in the treatment of TN caused by venous compression, considering the use of various surgical tactics**.**

Material and methods

Patient population

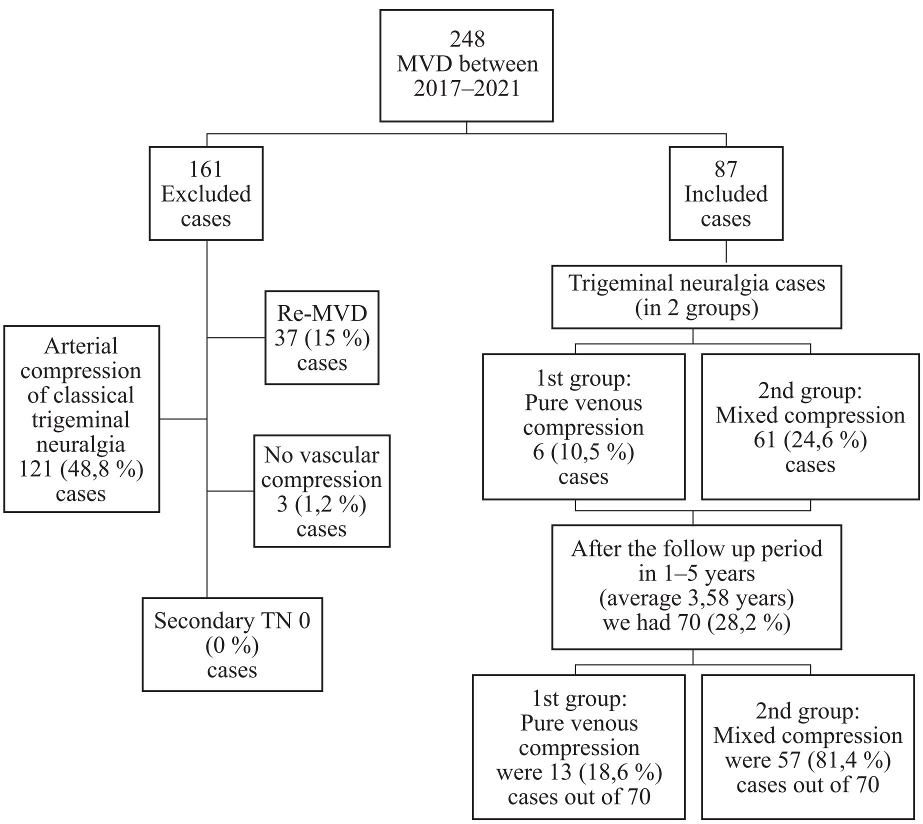
From January 2017 to December 2021, 248 cases underwent MVD for V cranial nerves neuralgias at the federal neurosurgical center, Novosibirsk, in Russia. For this retrospective study we included 70 (28.2 %) cases of CTN. The inclusion criteria were as follows: all ages; both genders; failed medical treatment to control the symptoms of TN; an MRI showed clear neurovascular compression; CTN caused by pure venous and mixed compression; first-time MVD; history of TN, paroxysmal and constant pain. Exclusion criteria: re-MVD; secondary TN, due to tumors, multiple sclerosis, or vascular malformation; CTN caused by pure arterial compression; no vascular compression near V nerve on the pain side

Group's formation

Between 2017 and 2021, 248 patients of V cranial nerve neuralgia underwent MVD surgery at Federal neurosurgical center. Some cases (121 with arterial compression, 3 without vascular compression, and 37 who underwent repeated MVD) were excluded based on the exclusion criteria. After the follow-up period ranging from 1 to 5 years (with an average of 3.6 years) 87 cases were selected for this study as they were diagnosed with CTN caused by venous and arteriovenous compression. During the follow-up period, 17 out of the 87 cases who diagnosed with venous and mixed compression did not respond to our follow-up attempts and were therefore excluded. These 70 cases were divided into two groups: 13 cases (18.6 %) with pure venous compression and 57 cases (81.4 %) with mixed compression (arteriovenous combination) (refer to figure).

Neuroimaging techniques

In this study, as a clinical routine for TN, pre-operative brain MRI sequences T1, T2 Axial, 3D TOF, FIESTA-C/CISS were done for all cases to identify the relationships between the trigeminal nerve and the offending vessels, utilized both 1.5 Tesla and 3 Tesla MRI machines, to enhance the detection of neurovascular conflicts and trigeminal nerve morphology, crucial for preoperative evaluation in TN treatment.



Group's formation

Формирование группы пациентов

Clinical assessment

The clinical diagnosis of TN was confirmed by a well-collected history of the disease, physical examination, and multiple MRI sequences. A detailed description of the TN was obtained to define its paroxysmal and constant pain history, which corresponds to the International Classification of Headache Disorders [19]. Patients were primarily evaluated at 1 week (short-term outcome) and at the last follow-up (long-term outcome) at least more than 1 year after surgery by using the Barrow Neurological Institute (BNI) pain intensity score [20]. Patients were classified as having a favorable outcome of BNI I and II, which represented successful treatment of TN symptoms following MVD surgery. An unfavorable outcome was represented by BNI III, IV, and V, representing the failure of the surgical treatment.

The surgical procedure involved performing a craniectomy with a burr hole over the asterion area, with a diameter ranging from 1–3 cm between patients. The dura mater was then opened, and cerebrospinal fluid was drained to facilitate cerebellum retraction. The superior petrosal vein (SPV) was visualized and dissected, with the sacrifice of these veins avoided as much as possible. Then the neurovascular conflict was searched for. The next step was to free the trigeminal nerve root from all arachnoid filaments and adhesions, entirely from the TREZ at the brainstem to the porus trigeminus of Meckel's cave. The conflicting arteries in the mixed group were separated from the trigeminal nerve root and maintained apart, using Teflon felt fibers to achieve optimal transposition and keep them away from the root. However, if the artery had an arteriole, if the cerebellopontine cistern was narrow, or if there was no space due to superior petrosal trunks, interposition with Teflon was used instead. In both groups (1st and 2nd), the offending vein(s) were managed by transposition, interposition, sacrifice (coagulation-cut off), or kept without manipulation. The trigeminal nerve root was reviewed in all cases to ensure that there was no more vascular compression. The final steps for the closure of the dura mater were sutures and fat grafting; next to that, cranioplasty was performed using the same drilled fragment of the asterion area.

The neurovascular conflict intraoperatively was classified based on macroscopically alterations over the nerve, with and without macroscopic nerve changes such as excavation, indentation, and nerve atrophy. Intraoperatively the situation of the NVC was classified according to the involved portion of the root, the trigeminal root entry zone (TREZ), the mid-cisternal portion, and the portion at the porus trigeminus of Meckel's cave where the root crosses over the petrous ridge [21].

Statistical analysis

The statistical analysis for this study was meticulously designed to assess the relationship between various factors and the outcomes of MVD surgery. The primary statistical tools and methods used in this analysis include the following. Continuous variables were examined in detail using the non-parametric test called the Mann – Whitney U Test to evaluate the median values of age, gender, side of the face affected, type of TN, duration of pain, location of the vein, situation of the vein, number of the veins, nerve macroscopic changes, and intraoperative management tactics across two independent groups. The pain relief (BNI I–II) and recurrence pain (BNI III, IV, V) for TN cases following MVD surgery were assessed using chi-square analysis in both pure and mixed compression groups. It was also utilized to investigate the viability of implementing venous compression manipulation techniques, particularly in the pure venous group.

Results

Demographic information

The demographic profile of the 70 patients analyzed in this study (tab. 1) predominantly comprises female subjects (46 cases), representing 65.7 % of the total cases, with an age distribution spanning from 23 to 82 years and an average age of 58.7 years. A significant proportion, 77.1 % (54 cases), reported a history of paroxysmal pain characteristic of TN, and the others, 22.9 % (16 cases), reported a history of continuous pain characteristics. While 67.1 % (47 patients) suffered from right-sided TN and 32.9 % (23 patients) from left-sided TN. The most frequently impacted portions of the trigeminal nerve were the V2-V3 divisions, accounting for 40 % (28 cases) of the cohort. The pain duration ranged from 1 to 44 years (average duration of 9.1 years). In accordance to the Mann-Whitney U test, these clinical characteristics as the age, gender, side of the face affected, affected branch, type of TN, duration of pain, across two independent groups were not significant factors in evaluating the outcomes of the MVD surgery. These elements exhibited $p > 0.05$, indicating their limited predictive value regarding surgical success.

Intra-operative anatomical findings

Anatomical-surgical features: In 70 pts (pure and mixed group), the conflicting veins were either of the superficial superior petrosal vein system in 51 (72.9 %) cases or of the deep superior petrosal vein system in 19 (27.1 %) cases. While the most common arterial conflict in 50 (87.8 %) patients out of 57 in the mixed group was caused by the superior cerebellar

Table 1. *Basic information about the patients*

Таблица 1. *Основная информация о пациентах*

Parameter	Total	1st group: pure venous compression	2nd group: mixed compression
Number of the cases	70 (28.2 %) cases	13 (18.6 %) cases	57 (81.4 %) cases
Age at MVD	23 to 82 years (mean age: 58.66 years)	23 to 82years (mean age: 59.30 years)	33 to 81years (mean age: 58.50 years)
Gender	F:M = 46:24	F:M = 10:3	F:M = 36:21
Affected side	R:L = 47:23	R:L = 11:2	R:L = 36:21
Type of TN	paroxysmal = 54 continuous = 16	paroxysmal = 9 continuous = 4	paroxysmal = 45 continuous = 12
Affected branch	V2 = 16 V3 = 13 V2–V3 = 28 V1–V2 = 8 V1–V3 = 5	V2 = 2 V3 = 2 V2–V3 = 7 V1–V2 = 1 V1–V3 = 1	V2 = 14 V3 = 11 V2–V3 = 21 V1–V2 = 7 V1–V3 = 4
Symptoms duration	1 year to 45 years (mean: 9.05 years)	2 years to 44years (mean:15.46 years)	1 year to 45 years (mean: 7.61 years)

Note. F – Female; M – Male; R – Right; L – Left; V1 – the first division of the trigeminal nerve; V2 – the second division of the trigeminal nerve; V3 – the third division of the trigeminal nerve.

artery. Anatomical features of the venous NVC: Situation of the venous conflict along the trigeminal nerve root: The offending veins were situated in 34 (48.8 %) cases on the TREZ, which is the most common affected portion (tab. 2). In accordance with the Mann – Whitney test, situation of the vein across two independent groups were not significant factor in evaluating the outcomes of the MVD surgery. These elements exhibited $p > 0.05$, indicating its limited predictive value regarding surgical success.

Location of the venous conflict around the trigeminal nerve root

According to the location of the venous NVC on the trigeminal nerve root surfaces, the most common affected location was the superior surface with 32 (33.7 %), followed by the posterior surface with 28 (29.5 %) (tab. 3). The location of the offending vein statistically was not significant factor to evaluate the outcomes of MVD and showed a $p > 0.05$.

Intraoperatively neurovascular conflict in according to the nerve macroscopic changes: The intraoperative management of neurovascular conflict is divided into two groups based on macroscopically nerve change. Firstly, those without macroscopically nerve changes, where the nerve remains intact (in 60 cases), according to the surgical tactics it was divided into 2 groups with and without manipulation of the offending vein. The tactics in the group of with manipulation (51 cases) were the transposition in 3

Table 2. *Situation of the venous NVC along the trigeminal nerve root*

Таблица 2. *Расположение венозных сосудов относительно участков корешка тройничного нерва*

NVC situation	Total number of NVC and cases of venous compression of both groups		1st group: pure venous compression		2nd group: mixed compression	
	Number of the cases	Number of the NVC	Number of the cases	Number of the NVC	Number of the cases	Number of the NVC
TREZ	34	46	10	17	24	29
Cisternal portion	2	3	1	2	1	1
Porus trigeminus portion	2	2	1	1	1	1
TREZ and cisternal	17	24	0	0	17	24
TREZ and porus trigeminus	10	15	1	3	9	12
TREZ and cisternal and porus trigeminus	5	5	0	0	5	5
Total NVC	70	95	13	23	57	72

Table 3. *Location of the NVC*

Таблица 3. *Расположение сосудов относительно корешка тройничного нерва*

Location of the NVC	Total number of venous NVC of both groups	1st group: pure venous compression in 13 cases	2nd group: mixed compression in 57 cases
Superior	32	13	19
Posterior	28	–	28
Anterior	6	1	5
Inferior	12	3	9
Lateral	3	3	–
Not available	14	3	11
Total NVC	95 NVC	23 NVC	72 NVC

cases, interposition – in 20 cases, coagulation-cut off – in 28 cases. The tactics of the group of without manipulation (9 cases) included the vein in 9 cases left without any manipulation due to its tiny small size). Secondly, in group with macroscopically nerve changes, where the nerve undergoes excavation (in 10 cases) according to the surgical tactics it was made only of one group which is with manipulation tactic of the offending vein: the tactics in this group were the transposition in 1 case, interposition – in 5 cases, and the coagulation-cut off in 4 cases (tab. 4, 5). In addition, statistically these nerve macroscopically

Table 4. *Intraoperative management in cases without macroscopically changes over the nerve V root*

Таблица 4. *Интраоперационная тактика при венозной компрессии без макроскопических изменений корешка V нерва*

Cases	Tactics in groups	Tactic types	Vein from the pure	Vein from the mixed	BNI I, II	BNI III, IV, V
60 cases of venous compression Without macro-scopically changes (11 pure group, 49 mixed group)	With manip-ulation (in 51 cases)	Transposition (in 3 cases)	0	3	3 (mixed)	0
		Interposition (in 20 cases)	2	18	12 (1 pure, 11 mixed)	8 (1 pure, 7 mixed)
		Coagulation-cut off (in 28 cases)	9	19	21 (7 pure, 14 mixed)	7 (2 pure, 5 mixed)
	Without any manipulation (in 9 cases)	No manipulation (in 9 cases)	0	9	8 (mixed)	1 (mixed)
		in 60 pts			44 (8 pure, 36 mixed)	16 (3 pure, 13 mixed)

Table 5. *Intraoperative management in cases with macroscopically changes over the nerve V root*

Таблица 5. *Интраоперационная тактика при венозной компрессии с макроскопическими изменениями корешка V нерва*

Cases	Tactics in groups	Tactic types	Vein from the pure	Vein from the mixed	BNI I, II	BNI III,IV,V
10 cases of venous compression	With manipulation	Coagulation-cut off (in 4 cases)	1	3	3 (1 pure, 2 mixed)	1 (mixed)
With macroscopi-cally changes (2 pure group, 8 mixed group)		Interposition (in 5 cases)	1	4	3 (1 pure, 2 mixed)	2 (mixed)
		Transposition (in 1 case)	0	1	0	1 (mixed)
		in 10 pts			6 (2 in pure, 4 in mixed)	4 (in mixed)

changes didn't show its significance as a factor to evaluate the outcomes of the MVD ($p > 0.05$).

Neurovascular manipulations

Intraoperative treatment was performed for 70 patients with venous compression, who were divided into two groups (pure venous and mixed compression groups) along the trigeminal nerve, from the TREZ at the brainstem to the Meckel's cave. The offending vessel(s) were detected, and they were managed by different tactics such as the transposition, interposition, coagulation-cut off tactic, and some had no manipulation of the offending vein, within the first group, the coagulation-cut off tactic was the most commonly used, appearing in 77 % of cases (10 out of 13). In contrast, in the second group, two tactics were equally common in between 57 cases: the interposition was performed in 22 cases (38.6 %) and the coagulation-cut off – in 22 cases (38.6 %) as detailed in (tab. 6).

Outcome

As a result of short-term outcome evaluation (at 1-week post-operative), 68 (97.2 %) cases were classified into the success group (BNI score = I and II), and 2 (2.8 %) cases were evaluated as failure cases (BNI score ≥ III). Within 3 months after the operation, the one of 2 these patients had achieved delayed pain relief (BNI I, II: 69 (98.5 %) cases). As a result of the follow-up of the 70 cases within a period ranging from 1 to 5 years (average: 3.6 years), 50 (71.4 %) cases had achieved control of their pain (BNI I, II); the outcome was not satisfactory (pain recurrences – BNI III–V) in the 20 (28.6 %) other cases (tab. 7).

Early postoperative complications were presented in 13 (18.5 %) cases out of 70, with 2 cases within the first group and the other 11 cases within the second group. In the first group, there was one case of right-side facial palsy and one case complicated by a right subacute subdural fronto-tempo-parietal hematoma. In the second group, there were 6 cases of hemi-facial hypoesthesia, 4 cases of meningitis and wound liquorrhea, and 1 case of acute sensorineural hearing loss. Statically, these complications in two groups exhibited $p > 0.05$. The most common complication observed in both groups during the follow-up period was facial numbness, which occurred in 6 cases (46.2 %), of the 13 cases.

According to the χ^2 test, in the group with purely venous compression, who have undergone MVD with different manipulation tactics (3 cases of interposition, 10 cases of coagulation-cut off) whatever the presence or not of the macroscopic changes by the vein over the nerve, the frequency of favorable outcomes (BNI I-II in 10 cases) following MVD surgery is statistically significantly greater than the frequency of negative results (BNI > II in 3 cases), ($\chi^2 = 3.77$; df = 1, $p = 0.052$). It demonstrates the potential for manipulating the offending vein in order to achieve the positive results of the MVD surgery, while in mixed compression group whatever the used tactic (with manipulation and without manipulation) and the presence or not of the macroscopic changes over the nerve didn't show any significant differences between the negative and positive outcomes.

For the 49 cases in the mixed compression group who were without macroscopic changes by the vein over the nerve, a deeper examination of the manipulation on the offending veins was performed. In which we had 40 cases with manipulations such as the transposition tactic in 3 cases, interposition in 18 cases, and coagulation-cut off in 19 cases, and 9 cases without manipulation of the vein. They did not exhibit any significant differences between the positive and negative outcomes ($\chi^2 = 0.88$, df = 1, $p = 0.35$). These tactics with and without macroscopically changes are detailed in tabl. 4, 5.

***Table** 6. Neurovascular manipulations*

***Таблица 6.** Характеристика хирургических манипуляций, выполненных во время микроваскулярной декомпрессии*

Intraoperative tactics in 70 cases	Total venous cases and NVC in both groups		1st group: pure venous compression in 13 cases		2nd group: mixed compression in 57 cases	
	Number of cases	Number of the NVC	Number of cases	Number of the NVC	Number of cases	Number of the NVC
Transposition	4	6	–	–	4	6
Interposition	25	27	3	5	22	22
Coagulation-cut off	32	50	10	18	22	32
No manipulation	9	12	–	–	9	12
Total	70 cases	95 NVC	13	23	57	72

NVC: Neurovascular conflict.

Note. The Number of NVC refers to the count of veins that exhibited a particular tactic in a given number of patients.

Table 7. *BNI outcomes*

Таблица 7. *Исходы микроваскулярной декомпрессии по шкале BNI в катамнезе*

	Total	1st group: pure venous compression	2nd group: mixed compression
Short term outcome (postoperatively until discharge time)	BNI I–II: 68 cases BNI III–V: 2 cases	BNI I–II: 12 cases BNI III–V: 1 case	BNI I–II: 56 cases BNI III–V: 1 case
Short term outcome (within 3 months) Delayed cure	BNI I–II: 69 cases BNI III–V: 1 cases	BNI I–II: 12 cases BNI III–V: 1 case	BNI I–II: 57 cases BNI III–V: 0 case
Follow up period	1year to 5 years (AV: 3.55 years)	1year to 5 years (AV: 4.077 years)	1year to 5 years (AV: 3.44 years)
Long term outcome	BNI I–I: 50 cases BNI III–V: 20 cases	BNI I–I: 10 cases BNI III–V: 3 cases	BNI I–II: 40 cases BNI III–V: 17cases
Recurrence of pain	BNI III–V: 20 cases	BNI III–V: 3 cases	BNI III–V: 17cases

Note. BNI – Barrow Neurological Institute; AV – Average

Discussion

In this study, an examination of 248 individuals who underwent MVD for the alleviation of TN, related to 5th cranial nerve, revealed a nuanced landscape of NVC. Specifically, 28.2 % of these patients were identified with venous NVC. Within the subset of 70 cases linked to TN, a detailed analysis uncovered that 13 cases (18.6 %) had purely venous compression, whereas a significant observation was made that 57 cases (81.4 %) exhibited mixed compression, characterized by the concurrent presence of both arterial and venous NVC. By comparing our findings of venous compression with the previous studies, they are slight differences. As indicated earlier, our findings show that the percentage of venous compression accounts for (28 %). However, Z.Y. Fayed et al. point out that the percentage of venous compression among patients with TN was 10 % [22]. Additionally, M. Wu et al. indicate that the percentage of venous compression among patients with TN was 20.3 % [23]. In contrast, Y. Zhao et al. reported that the incidence of venous compression in patients with TN was 9.2 % [24]. Similarly, W. Wang et al. stated that the prevalence of venous compression in patients with TN was 12.1 % [25] indicating that venous compression plays a significant role in the etiology of TN.

Intraoperatively, the vein was observed in three portions of the trigeminal nerve root. The venous NVC was notably situated not only in the TREZ but also impacted the mid-cisternal and porus trigeminus portions. Additionally, some cases exhibited venous NVC involving combinations of these areas, including the TREZ with mid-cisternal portions, TREZ with porus trigeminus portions, and even across all portions of the trigeminal nerve root. This venous NVC originated from both the superficial superior petrosal venous system, specifically the pontine tributary of the superior petrosal vein, and the deep superior petrosal venous system. These findings highlight the imperative for a thorough examination of the entire trigeminal nerve pathway, from the TREZ to the distal portions, to fully appreciate the extent and nature of venous compression.

Moreover, intraoperatively, the presence of macroscopic changes such as the excavation, indentation or grooving in relation to the venous conflict over the portions of the nerve root was noted in 10 cases (14.3 %) out of 70 cases, revealing significant alterations to the nerve's appearance. Such macroscopic alterations accentuate the critical influence of venous conflict on the trigeminal nerve structure and function.

In particular, our study pays specific attention to the surgical tactics used in the management of offending veins. These tactics included transposition, where the vein is moved away from the nerve, and interposition, where a barrier is placed between the vein and nerve. If both transposition and interposition do not yield the required result or turned out to be acceptable, we resorted to coagulation-cut techniques, where the vein was coagulated and cut to alleviate compression. These approaches were meticulously applied to address the venous conflict and mitigate its impact on the trigeminal nerve. The studies by, C. Durnot et al. [21], J. Baldauf et al. [6], employed various microsurgical techniques, including transposition, interposition, separation, and coagulation cut, to treat TN, each highlighting their specific applications and outcomes. C. Dumot et al. focused on techniques such as coagulation-division or simple cleavage of the conflicting vein, showcasing notable efficacy, with 75.2 % of patients reporting pain relief outcomes during the follow-up period [21]. In contrast, J. Baldauf et al. centered their study on methods like transposing veins with Teflon, separating the vein, or coagulating/dividing veins based on size and collateral presence. Their approach demonstrated significant effectiveness, with 71.4 % of patients achieving excellent to very good pain relief outcomes during the follow-up period [6]. These comprehensive evaluations across various studies provide valuable insights into the effectiveness of these techniques in managing TN.

In our study, patients were initially categorized based on the type of vascular compression affecting them, identifying those with purely venous compression and those experiencing an arteriovenous combination, termed mixed compression.

Our idea for cases featuring exclusive venous compression, the primary surgical objective was to preserve the integrity of the offending vein. This was achieved through meticulous transposition or interposition tactics aimed at relieving pressure on the trigeminal nerve while maintaining venous circulation to avoid the related complications of the brainstem or cerebellum, when direct vein preservation methods were not feasible, a strategic approach was adopted involving venous coagulation-cutting off the vein.

In the treatment of conditions involving concurrent arterial and venous compression (mixed compression group), the primary objective is to relocate both offending vessels. Consequently, arterial transposition is adopted as the surgical strategy of choice. This technique is paramount for repositioning arterial structures to relieve the pressure exerted on the trigeminal nerve, directly addressing the root cause of the patient's pain.

While the presence of arterioles from the compressed artery made it difficult to perform the transposition tactic on the artery. Instead of using the transposition tactic here, which would cause bleeding from the rupture of those arterioles, the interposition tactic was used, which places Teflon material between the artery and the nerve. Additionally, the compressed artery interposition tactic was used when transposing the artery was not possible because of the multiple superior petrosal vein trunks, which left no room for the artery to be moved. In addressing venous compression, the strategy also focused on preserving the offending vein circulation and structure by employing transposition or interposition tactics, but when it was not possible to relocate it, the coagulation-cut-off tactic was the best choice to work with. Upon further assessment, it was determined that in certain cases, venous structures, despite their proximity to neural elements, did not warrant manipulation. This decision was grounded in the observation that these veins were of a small size and, critically, didn't cause any macroscopic changes over the nerve. Hence, a 'no manipulation' tactic was adopted for these specific venous instances. This approach underscores a tailored surgical strategy, prioritizing the avoidance of unnecessary interventions that do not contribute to symptom relief or may pose additional risks to nerve fibers integrity. Additionally, in both groups (pure venous and mixed compression), regardless of whether the macroscopic changes over the trigeminal nerve root were presented or not, the tactics used for the offending vein were done as indicated earlier.

In the evaluation of pain outcomes using BNI pain intensity scores, for 70 cases (13 pure and 57 mixed) revealed a significant trend towards achieving BNI pain intensity scores of I and II was demonstrated, indicating successful pain management in the majority of cases (50 cases, 71.4 %). The remaining 20 cases (28.6 %) experienced a recurrence of pain, classified under BNI scores of III, IV, and V, signifying varying degrees of persistent or worsening pain despite initial treatment. In contrast to other outcomes, Y. Wei et al. observed a success rate of 71.2 % and a pain recurrence rate of 28.8 % [26]. J. Herta et al. found a success rate of 59.6 % and a significant pain recurrence rate of 39.4 % [27], while I. Noorani et al. reported a success rate of 75 % and a pain recurrence rate of 25 % for MVD procedures [28]. Our study's outcomes closely resemble those of other studies regarding success rates and the occurrence of pain recurrence.

Our study investigated various factors that could impact the outcomes of MVD in patients with CTN over a 1–5-year follow-up period. These factors included age, gender, affected facial side, type of TN, pain duration, vein situation and location, number of veins, nerve changes, and surgical techniques. Surprisingly, the statistical analysis revealed no significant differences in these factors between patients who experienced favorable outcomes (BNI I–II) and those who faced non-favorable outcomes (BNI III, IV, V).

Detailed analysis using the chi-squared test focused on patients with purely venous compression. These patients underwent MVD with different manipulation tactics: 3 cases of interposition and 10 cases of coagulation-cut off. In this group, the frequency of favorable outcomes (BNI I-II in 10 cases) was significantly higher than the frequency of unfavorable outcomes (BNI >II in 3 cases). This finding highlights the potential for manipulating the offending vein to achieve positive results in MVD surgery.

These findings illuminate the critical role of vein manipulation in the symptomatic presentation of TN and underscore the necessity of adopting specific surgical tactics based on the vein's characteristics and its relationship to the nerve. This nuanced analysis reinforces the importance of precision in surgical technique selection during MVD procedures. By carefully choosing the appropriate intervention or opting for non-intervention in the case of small-sized veins surgeons can achieve better patient outcomes, highlighting the pivotal role of tailored surgical approaches in enhancing the effectiveness of treatment for TN

Conclusions

In conclusion, the study underscores the efficacy of microvascular decompression in addressing TN associated with venous compression. The findings highlight the importance of tailored surgical approaches for optimal outcomes and emphasize the ongoing evolution of treatment strategies in neurovascular conflicts. This research contributes valuable insights to the field, paving the way for enhanced management of TN through refined surgical interventions.

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