Prospective Study

Endoscopic Versus Microscopic Microvascular Decompression for Trigeminal Neuralgia: A Prospective Controlled Study

Wei Shu, MD, Dou Yang, MM, Kai Ma, MD, Xiaohua Zhang, MD, Tao Yu, MD, Tao Du, MD, Junchi Li, MM, and Hongwei Zhu, MD, PhD

From: Department of Functional Neurosurgery, Xuanwu Hospital, Capital Medical University, Beijing, People's Republic of China

Address Correspondence: Hongwei Zhu, MD, PhD Department of Functional Neurosurgery, Xuanwu Hospital, Capital Medical University No. 45 Changchun St, Beijing, People's Republic of China. E-mail: zhuhongwei@xwh.ccmu.edu.cn

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Background: Several studies have suggested favorable results with endoscope-assisted microvascular decompression (EA-MVD) for treating patients with trigeminal neuralgia (TN); however, supporting evidence is limited.

Objectives: This study aimed to compare the efficacy and safety of EA-MVD with microscopic microvascular decompression (M-MVD).

Study Design: Prospective controlled study.

Setting: We performed a prospective controlled clinical study that included 52 patients with TN (36, [69.2%] women; 16, [30.8%] men), from June 2021 through January 2022.

Methods: Patients were assigned to receive either EA-MVD (n = 23) or M-MVD (n = 29). The primary outcome was pain intensity relief, measured using the Visual Analog Scale (VAS) and the Barrow Neurological Institute grading scale. The secondary outcomes were the detection of multiple offending vessels, endoscopic use, operation time, hospital stay length, and complications. All patients were followed-up for ≥ 12 months.

Results: At 12 months, both treatment groups showed similar improvements in pain intensity (P = 0.099). The mean VAS score was 3.5 ± 1.6 and 2.9 ± 1.7 in the EA-MVD and M-MVD groups, respectively. Overall, most patients in both groups reached a pain-free status or had nearly pain-free relief (EA-MVD: 21/23, 91.3%; M-MVD: 27/29, 93.1%). The incidence of multiple offending vessels was higher in the EA-MVD group than in the M-MVD group (52.2% vs 17.2%, P = 0.038). The mean operating time in the EA-MVD group (158 ± 27 minutes) was longer and the hospital stay (6 ± 1 days) was shorter than those of the M-MVD group (144 ± 25 minutes and 8 ± 4 days). No mortality or endoscope-related serious adverse events were noted, with the exception of an intracranial infection case in the M-MVD group.

Limitations: The mean follow-up time was relatively short and a single-center study and a small patient population, which might bring some clinical bias.

Conclusions: M-MVD and EA-MVD achieved similar analgesic effects for TN; however, EA-MVD allowed observation of more probable offending vessels with good flexible operative visualization.

Key words: Trigeminal neuralgia, microvascular decompression, endoscope-assisted microvascular decompression, endoscopic surgery, suprameatal tubercle, visual analog scale, minimally invasive surgery, neuropathic pain

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Trigeminal neuralgia (TN) presents as sudden, severe, brief, stabbing, and recurrent pain within one or more branches of the trigeminal nerve (1-3). The annual incidence of TN is approximately 4.3 – 27.0 per 100,000 persons worldwide (4-6) . British National Formulary Guidelines on TN suggest that treatment should begin with carbamazepine (7); if pain cannot be managed with medication, patients can be referred for surgery (8). Microscopic microvascular decompression (M-MVD) is the only nonneurodestructive procedure that provides long-term pain relief without causing facial numbness or masticatory muscle weakness (3,9). The approach is preferred by most neurosurgeons and is performed worldwide (10), but its application is insufficient. After M-MVD, up to 26.6% of patients are reported to have residual pain, and 0.4 – 13.9% experience complications, including cerebral hemorrhage, facial paralysis, and hearing loss (11-17).

Endoscopes have become increasingly popular as useful tools in minimally invasive neurosurgery and have been widely used for intraventricular, skull base tumors, and neurospinal surgery. Endoscopes have also been introduced in microvascular decompression (MVD). Endoscopes provide better visualization compared with classic microscopes, which could help improve clinical outcomes and safety (18-23). However, the applicability of endoscopes in MVD remains controversial, namely due to prolonged operating times, elevated infection rates, thermal injuries, and unnecessary neural tissue damage (24). Additionally, the current evidence on endoscopic techniques applied to MVD is limited. Therefore, this study aimed to compare the effectiveness and safety of endoscope-assisted microvascular decompression (EA-MVD) vs M-MVD.

Methods

Patients Characteristics

This single-center, prospective controlled trial enrolled adults from July 1, 2021, through January 31, 2022. The inclusion criteria were as follows: patients with classic TN according to the 3rd edition of the International Classification of Headache Disorders (ICHD-3 Beta) (1); aged between 18 – 80 years with a single affected side; and patients who underwent MVD without other invasive treatments. Patients with secondary TN caused by tumors, multiple sclerosis, or any infectious disease in the occipital area were excluded.

Based on the operative technique, the patients were divided into 2 groups: EA-MVD (n = 23) and M-MVD (n = 29). The study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the local ethics committee. All patients, or their legal representatives, provided written informed consent.

Preoperative Magnetic Resonance Imaging Evaluation

All patients with classic TN and unilateral symptoms underwent preoperative T1- and T2-weighted magnetic resonance imaging and 3-dimensional time-of-flight magnetic resonance angiography (GE Healthcare) in order to evaluate the anatomical structure of the posterior cranial fossa, especially the cerebellopontine angle (CPA), which may help surgeons in intraoperative decision-making in identifying the offending vessels.

Operative Process

All operations were performed under general anesthesia, with the patients were placed in the lateral park bench position (also known as the lateral decubitus position). In the lower retrosigmoid approach, after making a linear skin incision of approximately 4 cm behind the ear, a craniectomy, with a diameter of 1.5 – 2.5 cm, was performed at the junction of the transverse and sigmoid sinuses. The dura mater was then opened using an X-shaped incision. Using a microscope, the membrane of the subarachnoid cisterns was incised sharply to release cerebrospinal fluid and create a sufficient workspace.

In the EA-MVD group, rigid rod lens endoscopes (4.0 mm diameter optical cables with 0° or 30° angulations; XION GmbH) were introduced to the CPA to observe the trigeminal nerve from the root to Meckel's cave and to identify the neurovascular relationship. Usually, a 0° endoscope is positioned to provide an overview of the operative field. If the anatomical structure obstructed the visual line, a 30° endoscope was used to inspect the offending vessel on the trigeminal nerve, especially the root entry zone (REZ). During exploration, the lens could zoom in and out to observe the location of neurovascular contact. Subsequently, the offending vessels were dislocated from the trigeminal nerve, Teflon pledgets (Chest) were interposed using a microscope, and the dura was sutured in a waterproof-tight pattern. The bone flap was replaced with a titanium plate. Details of the surgical technique used in the M-MVD

group have been reported previously (25). All surgeries were performed by one of 4 senior neurosurgeons who are proficient with the endoscopic system.

Follow-up

The primary efficacy endpoint was pain intensity at 12 months postprocedure, which was measured using the Visual Analog Scale (VAS; 0 to 10) and the Barrow Neurological Institute (BNI) pain intensity score (I to V; Table 1).

Secondary efficacy endpoints were compared at 12 months postprocedure and included the detection rate of multiple offending vessels, endoscopic use, operation time, hospital stay length, and complications. Information was collected from electronic records and follow-ups with patients were conducted through consultation or telephone interviews.

Statistical Analysis

Data are presented as mean ± standard deviation or median (quartile). Data analyses were performed using IBM SPSS Statistics 26.0 (IBM Corporation). Student's t tests were performed for quantitative data, and χ^2 tests were used for qualitative data. Comparisons between the 2 groups were considered statistically significant at $P < 0.05$. GraphPad Prism 9 (GraphPad Software) was used to plot the graphs.

Results

Patients' Characteristics

From June 1, 2021, through January 31, 2022, 52 patients were assigned to one of 2 MVD treatment groups: the EA-MVD (n = 23) or the M-MVD (n = 29) groups (Fig. 1).

In the EA-MVD group, 18 (78.3%) patients had right-sided symptoms. The median patient age was 61.4 ± 10.0 years (range: 39 – 80 years) with a median disease process of 128.6 ± 66.0 months (range: 3–240 months). The most affected division (30.4%) was a combination of the maxillary (V2) and mandibular nerves (V3).

In the M-MVD group, 20 (69%) patients had right-sided symptoms. The median patient age in the M-MVD group was 58.8 ± 9.8 years (range: 35 – 73 years) with a median disease process of 145.4 ± 103.4 months (range: 5 – 360 months). The most affected division was also a combination of V2 and V3 (37.9%). The patients' baseline characteristics were similar between the 2 groups (Table 2).

Table 1. *BNI scale for assessing pain intensity.*

BNI Pain Intensity Score	
I	No trigeminal pain, no medication
II	Occasional pain, no medication
III	Some pain but adequately controlled with medication
IV	Some pain, not adequately controlled with medication
V	Severe pain or no pain relief

BNI: Barrow Neurological Institute.

Intraoperative Findings

Offending Vessel

During MVD, we explored the CPA area to identify TN's causative factors. In the EA-MVD group, 12 patients (12/23, 52.2%) had a single-vessel contact. Specifically, the most common offending vessel (8/23, 34.8%) was the superior cerebellar artery (SCA; Fig. 2). Ten patients (10/23, 43.5%) had multiple vessel contacts (Fig. 2). In one case (1/23, 4.3%), the trigeminal nerve was trapped by thickened arachnoid membranes without any offending vessels (Fig. 3).

In the M-MVD group, 24 patients (24/29, 82.8%) had single-vessel contact; the most common (20/29, 69.0%) vessel was also the SCA. Of the 29 patients, 5 (5/29, 17.2%) had multiple vessel contacts; a significant difference was noted in the multiple offending vessels detection rate ($P = 0.038$).

Application of Endoscopy and Operation Time

According to a survey of endoscopic use (26), endoscopes played a critical role in the exploration of the operative field (Table 3). In 18 operations (78.3%), the endoscope was essential to improve visualization, helping the surgeon to identify the neurovascular relationship. For instance (see supplementary video), when the suprameatal tubercle conceals the trigeminal nerve and offending artery, a 30° endoscope enables the surgeon to explore missing critical information in the surgical blind area (Fig. 4).

The EA-MVD group had a longer operation time than the M-MVD group ($P < 0.001$). The operation times in the EA-MVD and M-MVD groups were 153 ± 28 minutes and 144 ± 25 minutes, respectively.

Clinical Outcomes

The primary outcome was pain intensity (Fig. 5), measured using VAS and BNI scores. Postprocedure, patients experienced pain reductions from 7.9 ± 0.8 to 3.3 ± 0.9 in the EA-MVD group, and from 8.0 ± 0.8

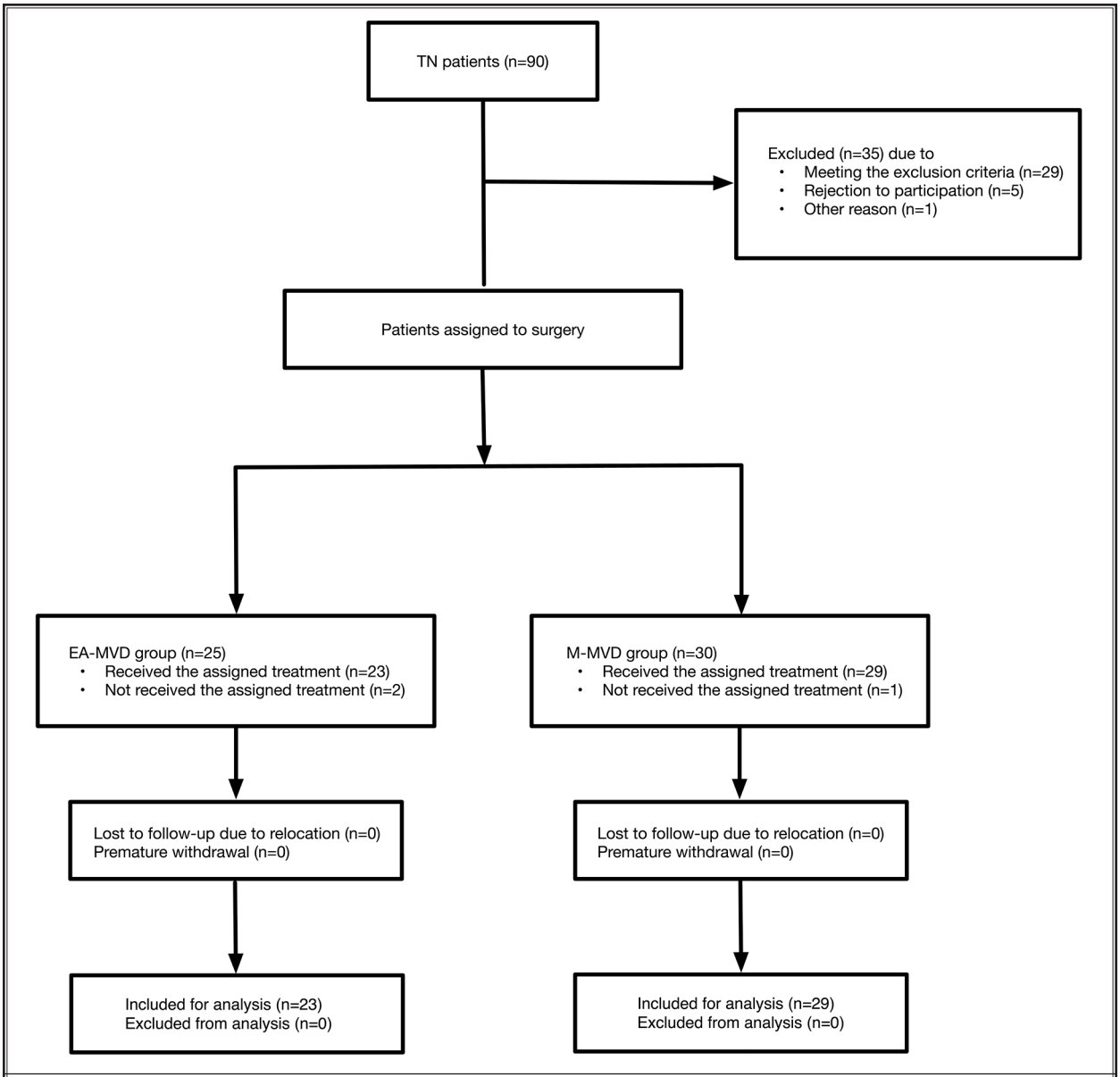

Fig. 1. *Flow chart of the study.*

to 3.1 ± 1.0 in the M-MVD group (Table 4). During the follow-up period, analgesic effects remained relatively stable in both groups. At 12 months postprocedure, all patients reported a substantial reduction in pain intensity, with a mean pain score of 3.5 ± 1.6 in the EA-MVD group, and 2.9 ± 1.7 in the M-MVD group. The two groups were not significantly different in the rate of total pain relief, assessed using the VAS and BNI scores (Table 4). At the last postprocedure follow-up, a total of 21 out of 23 (91.3%) patients in the EA-MVD group and 27 out of 29 patients (93.1%) in the M-MVD group had achieved pain-free relief (BNI grades I-II). Overall, no significant differences were noted in the analgesic effects between the 2 treatments.

Regarding adverse events, no severe complications occurred in either group, namely stroke, cerebrospinal fluid leakage, or facial paralysis. One patient in the M-MVD group developed an intracranial infection; however, after appropriate antibiotic therapy, the patient eventually fully recovered. The postoperative length of stay in

Table 2. *Baseline patient characteristics.*

Characteristic	EA-MVD	M-MVD
Patient Characteristics		
Number, n	23	29
Gender, n		
Women	14 (61)	22 (76)
Men	9 (39)	7 (24)
Age, mean (SD),yrs	61.4 ± 10.0	58.8 ± 9.8
Pain-related characteristics		
Pain duration, months (mean ± SD)	128.6 ± 66.0	145.4 ± 103.4
Affected side, n		
Left	5 (22)	9 (31)
Right	18 (78)	20 (69)
Affected division, n		
V1/V2/V3	0/5/2	0/5/9
V1, 2	5	2
V2, 3	7	11
V1, 2, 3	4	2

EA-MVD: endoscope-assisted microvascular decompression; M-MVD: microscopic microvascular decompression; SD: standard deviation; V1: ophthalmic division of trigeminal nerve; V2: maxillary division of trigeminal nerve; V3: mandibular division of trigeminal nerve.

the EA-MVD and M-MVD groups was 6 ± 1 days and 8 ± 4 days, respectively ($P < 0.001$). Even if we excluded the patient with an intracranial infection patient, the average length of stay in the M-MVD group would be 7 ± 1 days, but the length of stay in the EA-MVD group would still be shorter than that in the M-MVD group ($P < 0.001$).

Discussion

The pathogenesis of TN, supported by established neurophysiological evidence, involves the focal demyelination of primary afferents near the entry zone of the trigeminal root into the pons, where Schwann cells are susceptible to damage caused by vessels or tumors (2,27). Based on this mechanism, MVD can be used to decompress the offending vessels from the trigeminal nerve. This causal cure provides long-term pain relief for patients with TN (21,28-30).

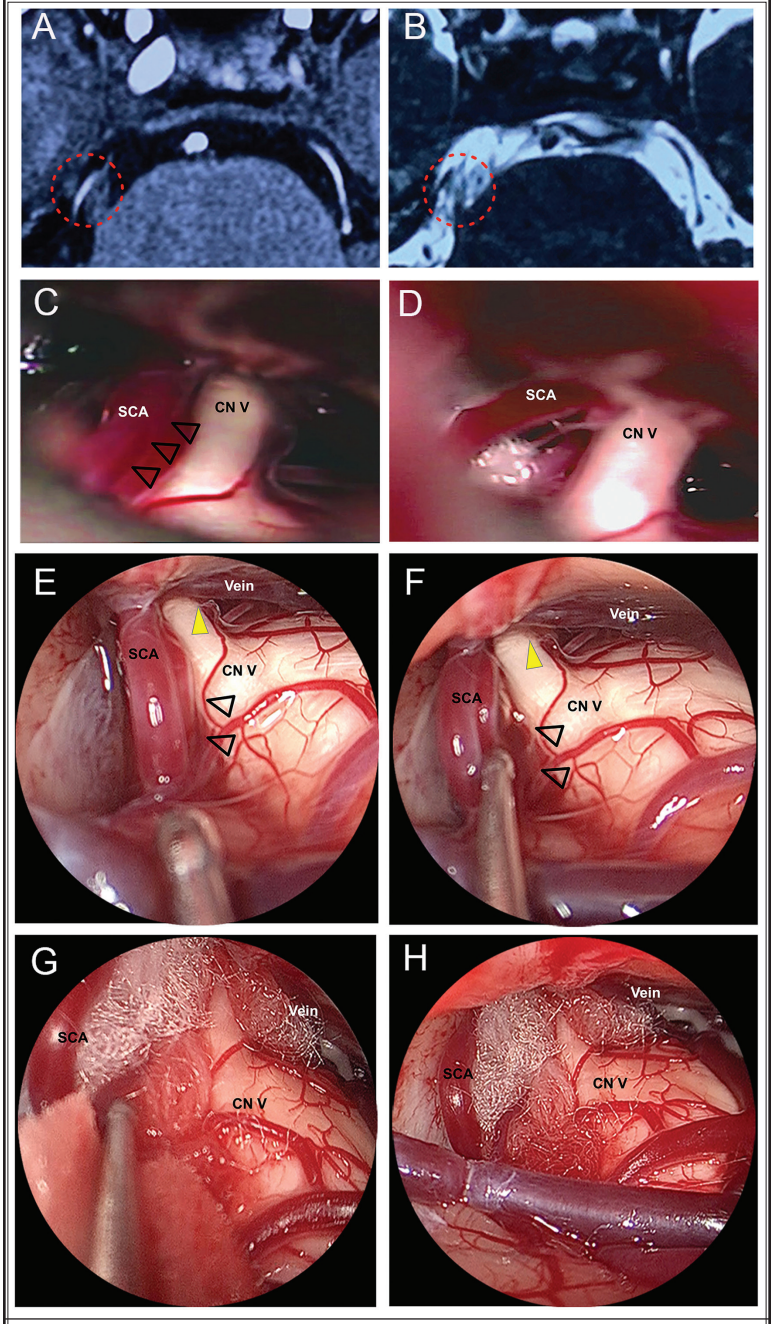

Fig. 2. *Radiographic images and intraoperative photographs of endoscope-assisted microvascular decompression (EA-MVD). (A and B) Magnetic resonance imaging (MRI) with 3-dimensional time-of-flight (A) and T2-weighted (B) sequences shows neurovascular compression by a looped vessel (red circle). (C) Microscopic exploration shows the superior cerebellar artery (SCA) compressing the trigeminal nerve at the entry zone (triangle). (D) The SCA was lifted off the nerve. (E and F) Endoscopic inspection with a 0° endoscope after retraction of the petrosal vein provided a clearer operative field, which identified an additional conflict site (yellow triangle) by the vein. (G and H) Both the SCA and the vein were dissected out and transposed by the Teflon sponges.*

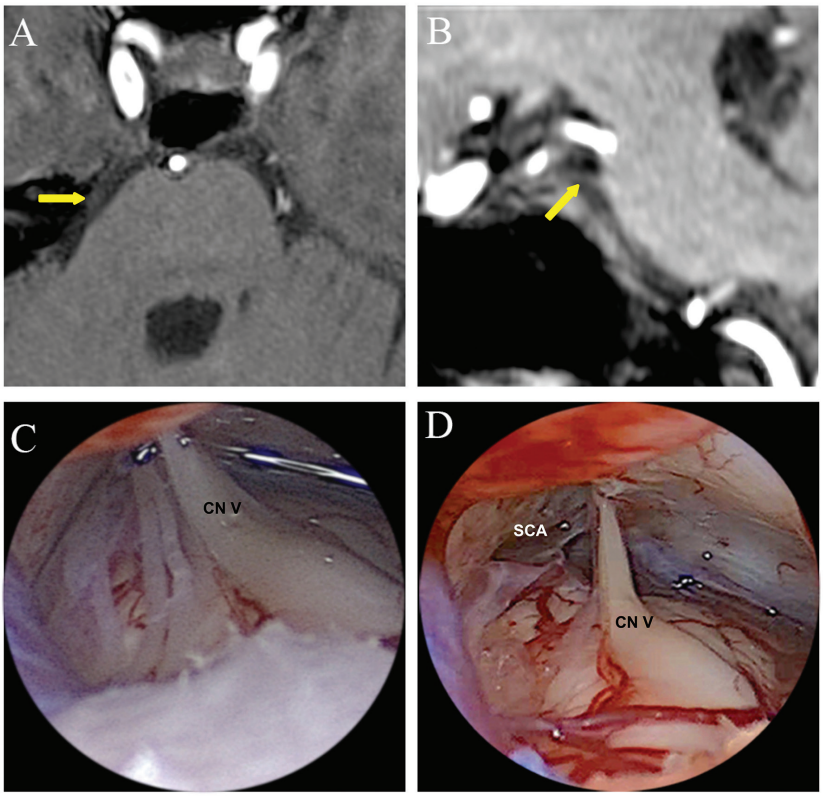

Fig. 3. *Preoperative magnetic resonance image and intraoperative photos of one patient.*
Exploration of the trigeminal nerve under endoscopic view in a patient without a definite offending vessel. (A and B) Preoperative 3-dimensional time-of-flight magnetic resonance angiograph imaging shows a right atrophied trigeminal nerve (yellow arrow) without a significant offending artery. (C and D) Using the megascopic view of the endoscope, the surgeon explored the nerve from the root entry zone to Meckel's cave and identified arachnoid adhesions as the offending factor, since the tiny artery was away from the nerve.

Table 3. *Endoscopic use.*

Endoscopic Use	EA-MVD
Grade I (Used but no role)	4 (17.4)
Grade II (Visualization assist)	18 (78.3)
Grade III (Procedure assist)	1 (4.3)
Grade IV (Used primarily)	0 (0.0)

EA-MVD: endoscope-assisted microvascular decompression.

The key to MVD is complete decompression of the REZ, via identifying offending vessels or other oppressive factors (31). However, the anatomical character of cranial nerve V itself may contribute to inadequate decompression. The histological length of the trigeminal nerve's REZ is longest compared with those of the facial and glossopharyngeal nerves, sometimes extending into Meckel's cave (32). Additionally, the distal segment of the trigeminal nerve close to Meckel's cave is often compressed by the SCA or the trigeminal vein, which is easily ignored in indistinct operative fields. These characteristics may cause the offending factor to persist and result in MVD failure; however, using endoscopes in MVD procedures may help overcome these issues, due to improved panoramic visualization (33) .

The endoscope, in conjunction with a high-definition camera (34,35), provides better visualization than a traditional operating microscope (24,36). Compared with the latter, the endoscope can enter the posterior cranial fossa, which provides closer visualization to explore the oppressive factors on the trigeminal nerve (33,37). Even in deeper locations, the critical neurovascular complex anatomy can be observed with good illumination during decompression procedures (23). Thus, EA-MVD provides a panoramic view to observe the whole nerve, thereby avoiding the omission of offending vessels and checking the correct placement of the Teflon sponge, especially in relation to the vein, arachnoid frenum, and nerve (37).

The interchangeable lens of an endoscope expands surgical visualization in microsurgeries, which enables surgeons to explore the critical information behind prominent tissues or around blind areas. In M-MVD, a classic microscope only provides a straight-line view, which is limited by craniectomy or other anatomical features. If the offending artery is covered by a nerve, bulky vein, or bony protuberance, the anatomical relationship may not be identified, leading to a failed operation. In EA-MVD, the endoscope can be used with lenses with different optic angles to obtain a flexible visual field (Fig. 4). Usually, a 30° endoscope provides an excellent compromise in maneuverability, which enables physicians to identify compressive factors behind the bone or nerve itself (Fig. 4). This flexibility and improved visualization in EA-MVD may contribute to

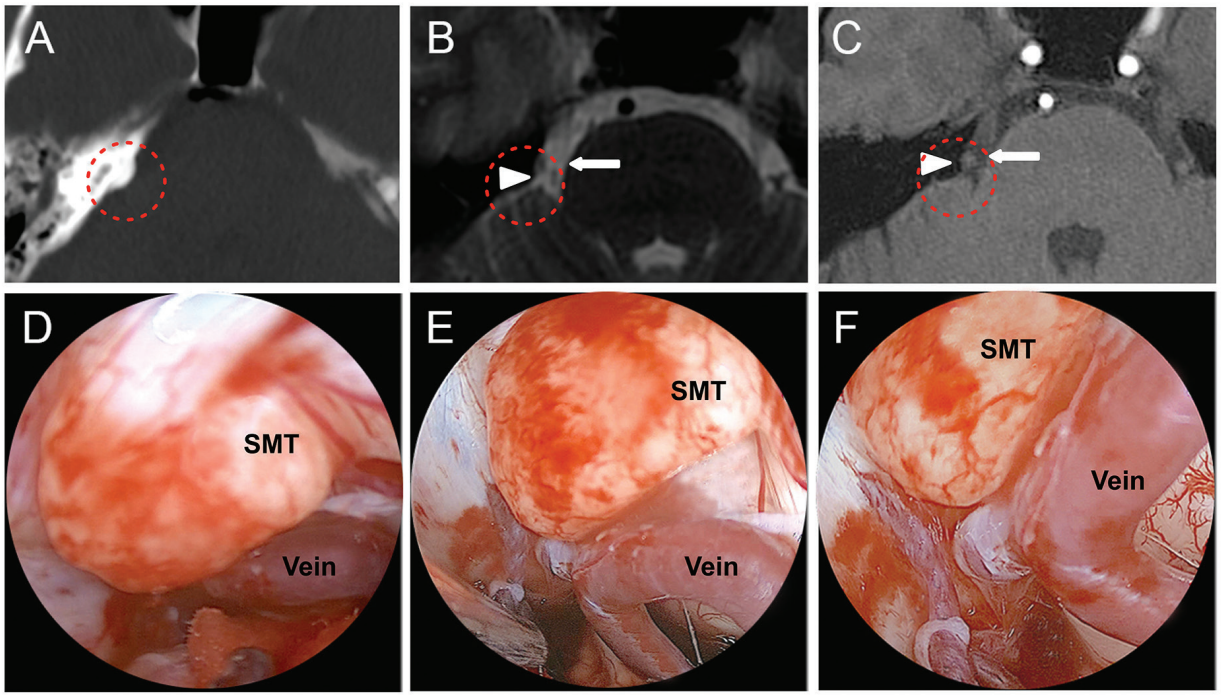

Fig. 4. *The alternative lens of endoscopic views in a case of a prominent suprameatal tubercle (SMT). Cranial computed tomography (A) and brain magnetic resonance imaging (B and C) show the anatomical relationship of the enlarged SMT (red circle), vessel (arrowhead), and trigeminal nerve (arrow). (D) An endoscopic view with a 0° lens on the endoscope of the endoscope-assisted microvascular decompression (EA-MVD) in the right approach could not demonstrate all around the vein and nerve hidden by a prominent SMT. (E and F) After replacing the optic of the endoscope with a 30° lens in the same patient, the lateral area of the trigeminal nerve and the distal part of the vein were visualized clearly.*

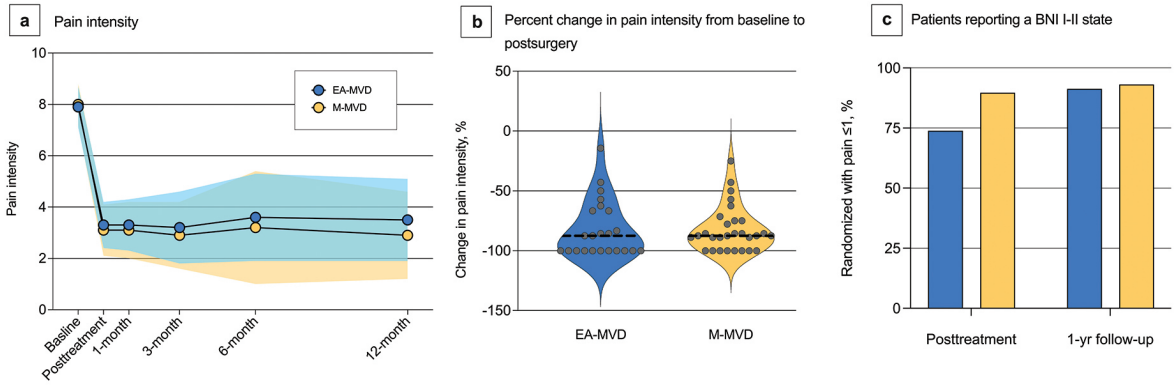

Fig. 5. *Analgesia outcome of endoscope-assisted microvascular decompression (EA-MVD) and microscopic microvascular decompression (M-MVD).*
(A) Shading indicates standard error. (B) Dots represent individual patients; thick lines represent the group mean. (C) Percentage of patients reporting pain scores of Barrow Neurological Institute I-II (pain-free or nearly pain-free) at posttreatment and at one-year follow-up.

Table 4. *Primary and secondary clinical outcomes.*

Outcomes	EA-MVD	M-MVD	*P* value
Primary outcomes			
Pain intensity (0-10)			
Baseline	7.9 ± 0.8	8.0 ± 0.8	0.102
Posttreatment (follow-up)	3.3 ± 0.9	3.1 ± 1.0	0.170
One month	3.3 ± 1.0	3.1 ± 1.1	0.323
3 months	3.2 ± 1.4	2.9 ± 1.3	0.329
6 months	3.6 ± 1.7	3.2 ± 2.2	0.420
12 months	3.5 ± 1.6	2.9 ± 1.7	0.099
BNI Grade (I-II), n			
Posttreatment (follow-up)	17 (73.9%)	25 (86.2%)	0.445
12-month	21 (91.3%)	27 (93.1%)	1.000
Secondary outcomes			
Compressive pattern			
Single vessel	12	24	0.018*
AICA/SCA/V/VA	2/8/2/0	3/20/0/1	
Multiple vessels	10	5	0.038*
Nonvessel (arachnoiditis)	1	0	0.442
Operation time (min)	158 ± 27	144 ± 25	< 0.001*
Length of stay (days)	6 ± 1	8 ± 4	< 0.001*

AICA: anterior inferior cerebellar artery; BNI: Barrow Neurological Institute; EA-MVD: endoscope-assisted microvascular decompression; M-MVD: microscopic microvascular decompression; SCA: superior cerebellar artery; V: vein; VA: vertebral artery.

the high offending vessels detection rate in this surgical technique.

In addition to the endoscope-assisted technique, we initially performed a few surgeries using a fully endoscopic technique, using only the endoscope as a visualization tool. Although this fully endoscopic technique has also been shown to be advantageous for visualization, we preferentially selected the EA-MVD for several reasons. First, in the full endoscopic technique, there is an increased risk of encountering blood vessels and nerves around the surgical pathway, especially in patients with a narrow posterior fossa. This approach only provides images at the lens tip, ignoring the lateral and posterior surgical fields. Second, the endoscope lens is susceptible to blood staining. Once bleeding occurs, hemostasis is difficult to achieve using endoscope instrumentation (38). Third, the learning curve of full endoscope use is steep, particularly for surgeons without MVD experience, causing an unnecessary hemorrhage risk and extended operation time (32). Therefore, we recommend the use of an endoscope for inspection and identification of Teflon positioning, in conjunction with a microscope for dissection and decompression.

In the present study, we found that EA-MVD improved the detection rate of offending vessels. Although the instrument alternation prolonged operation time, the difference between EA-MVD and M-MVD was not statistically significant, which may be due to the time saved from the convenience of endoscopic exploration. In contrast, the hospital stay length was slightly shorter in the EA-MVD group. We speculate that less traction in the exploration of the neurovascular conflict site during endoscopic surgery resulted in a lower incidence of headaches and accelerated recovery (15,36,39).

In terms of postoperative complications, there were no permanent sequelae in either group; only one case of intracranial infection was observed in the M-MVD group. This high level of safety may be explained by the surgeons' experience. In the case of less experienced surgeons, the endoscope itself may be more difficult to operate on a narrow posterior fossa, leading to a higher probability of nerve damage (40). To avoid unnecessary nerve injury, the endoscope should be introduced under a satisfactory workspace after the cerebrospinal fluid has been sufficiently discharged under a microscope. Additionally, some surgeons have argued that thermal injury may be caused by the heat generated at the endoscope tip, leading to delayed facial paresis and hearing loss (39). In our study, applying a medical cold-light source significantly reduced the risk of thermal injury (37).

Limitations

Our study has a few limitations. First, the mean follow-up time was relatively short; a long-term follow-up, such as 5 years or even longer (> 10 years), may provide more longitudinal and detailed outcomes, and a better understanding of postoperative outcomes of pain recurrence in patients with TN. However, several reports suggest that pain relief stabilizes within one year postsurgery. Thus, we believe that the short follow-up period employed in our study did not affect the comparison between EA-MVD- and M-MVD-mediated outcomes (41-44). Second, the study was a single-center study; thus, there was only a small patient population. A larger, multicenter study would potentiate the enrollment of a larger patient population and, therefore, extend our findings on the advantages of EA-MVD. However, differences in methodology, personnel, and management strategies across different centers may

lead to increased variability in final outcomes and treatment-associated complications. Our study involved 4 experienced surgeons who routinely perform MVD operations using standard medical procedures and similar operative techniques. This aspect is helpful in minimalizing clinical bias and variability.

Conclusions

EA-MVD can achieve the equivalent analgesic outcome of M-MVD and slightly reduce hospital stay length. This technique provides magnified high-definition imaging and an adjustable visual angle in order to explore the trigeminal nerve from the REZ to Meckel's cave, which enables the neurosurgeon to visualize the missing critical information around the blind areas, beyond the straight-line view of a classic microscope, thereby elevating the detection rate of multiple offending vessels.

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