Fully Endoscopic Microvascular Decompression for Trigeminal Neuralgia: Technical Note Describing a Single-Center Experience

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BACKGROUND: Microscopic microvascular decompression (MVD) of the trigeminal nerve is the gold standard surgical treatment for medically refractory classical trigeminal neuralgia. Endoscopy has significantly advanced surgery and provides enhanced visualization of the cerebellopontine angle and its critical neurovascular structures. We present our initial experience of fully endoscopic microvascular decompression (e-MVD).

METHODS: This retrospective case series investigated e-MVD performed from September 2016 to February 2020 at a single institution. Clinical data including presenting symptoms, medications, operative findings, postoperative complications, and outcomes were recorded. The 5-point Barrow Neurological Institute (BNI) pain intensity score was used to quantify patients' pain relief.

RESULTS: During the study period, 25 patients with trigeminal neuralgia (10 males, 15 females; mean [SD] age = 63 [10.4] years) underwent e-MVD. All patients had a preoperative BNI score of V. The left side was affected in 15 patients. Complications occurred in 2 patients: both experienced hearing loss, and one experienced transient facial weakness 7 days after surgery. The facial weakness had resolved by the last follow-up. All patients were completely pain-free (BNI score I) immediately postoperatively. On latest follow-up, 22 patients have remained pain-free, and 3 patients have recurrent pain that is being controlled with medication (BNI score III).

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CONCLUSIONS: Our study demonstrated that e-MVD is a safe, possibly effective method of performing MVD with the added benefit of improved visualization of the operative field for the operating surgeon and the surgical team. Larger prospective studies are required to evaluate whether performing e-MVD confers any additional benefits in long-term clinical outcome of patients with trigeminal neuralgia.

INTRODUCTION

Trigeminal neuralgia (TN) is a chronic neuropathic pain condition that is characterized by recurrent unilateral, short-lasting, very severe episodes of stabbing, electric shock–type pain in the distribution of the trigeminal nerve. Attacks are typically triggered by non-noxious cutaneous or intraoral stimulation; a refractory period after an attack is often reported by patients.[1] Drugs, such as sodium channel blockers (e.g., carbamazepine) are the mainstay of treatment.[2] Up to 50% of patients may eventually become refractory to medical treatment and require a surgical assessment.[3] Trigeminal microvascular decompression (MVD) remains the treatment of choice where indicated, and current data indicate that 62%–89% of patients remain pain-free 3–10 years after surgical treatment.[2] The best treatment outcomes are obtained in patients with purely paroxysmal classical TN.[4]

Most clinicians consider offering MVD to patients with refractory TN if the magnetic resonance imaging (MRI) scan demonstrates trigeminal neurovascular conflict causing morphological changes (distortion, indentation, nerve atrophy) to the nerve.[5] Nevertheless, trigeminal MVD is a major procedure, with reported morbidity and mortality rates of 0.1%–4.5% and 0.1%–0.7%, respectively.[6] Thus, developing new techniques

Key words
- Endoscopic skull base surgery
- Microvascular decompression
- Trigeminal nerve
- Trigeminal neuralgia

Abbreviations and Acronyms
BNI: Barrow Neurological Institute
CN: Cranial nerve
e-MVD: Endoscopic microvascular decompression
MVD: Microvascular decompression
MRI: Magnetic resonance imaging
TN: Trigeminal neuralgia

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Figure 1. Patient in park bench position after application of Mayfield clamp.

to improve intraoperative visualization and safety should always be investigated. The introduction of the endoscope has led to a paradigm shift in the way anterior skull base surgery is performed owing to better illumination and the ability to provide a panoramic view.[7-9] More recently, studies have proposed using the endoscope during trigeminal MVD to improve intraoperative visualization of the nerve and target vessel.[9] Other studies have described performing the whole operation using the endoscope.[7,8,10-17] Initial reports using a fully endoscopic microvascular decompression (e-MVD) approach have highlighted the potential advantages of this technique craniotomy compared with microscopic MVD, including reduced invasiveness, smaller incision, and smaller craniotomy,[10,18,19] which ultimately may result in lower complication rates than microscopic MVD,[9,20,21]

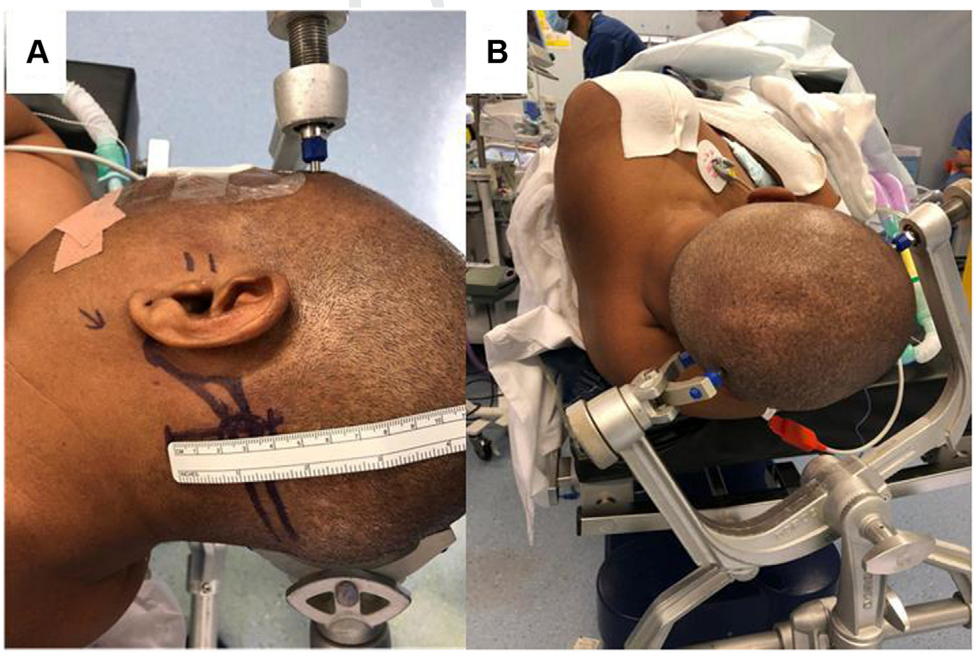

Figure 2. (**A**) Marking of the 40-mm vertical retromastoid incision. (**B**) Positioning, Mayfield placement, and neuromonitoring of the patient.

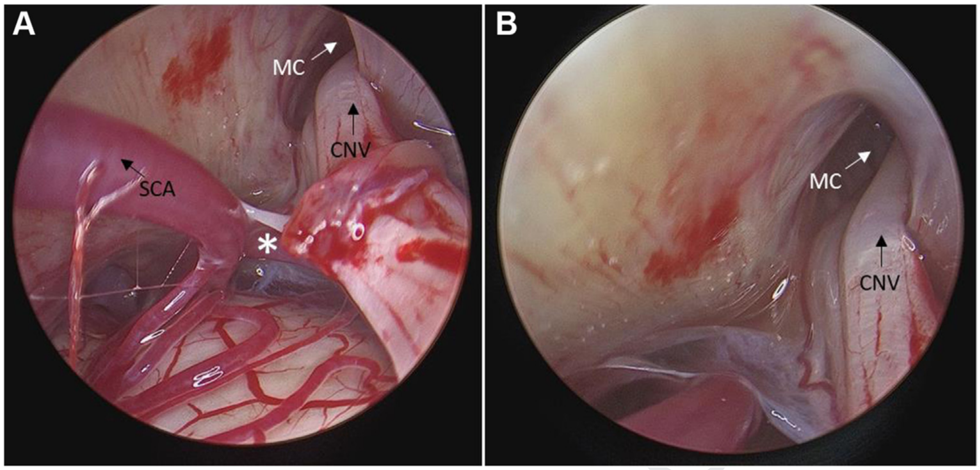

Figure 3. (**A**) Endoscopic view demonstrating the offending vessel (branch of superior cerebellar artery) (*asterisk*) superomedial to the right trigeminal nerve with a view of the nerve entering Meckel's cave and the superior cerebellar artery. (**B**) Closer endoscopic view of right trigeminal nerve and Meckel's cave. SCA, superior cerebellar artery; CNV, cranial nerve V (right trigeminal nerve); MC, Meckel's cave.

in addition to reducing postoperative pain and duration of inpatient hospital stay. Here, we report our initial experience on the use of e-MVD in patients with TN with a view of assessing complications and the initial efficacy outcome.

MATERIALS AND METHODS

Data Collection

This retrospective case series investigated all e-MVD procedures performed for TN from September 2016 to February 2020 in a single institution in the United Kingdom. Information was collected from the patients' electronic records, and follow-up of patients was conducted by consultation or telephone interview. The following details were obtained: demographic data, affected side and dermatomal distribution,

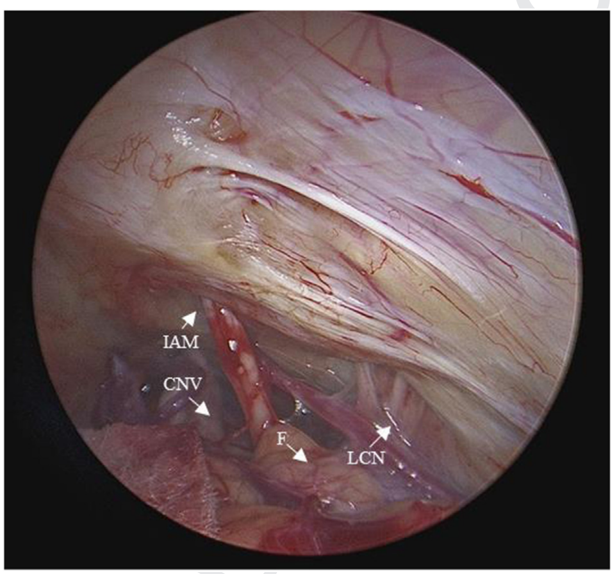

Figure 4. Panoramic view with the endoscope of the cerebellopontine angle where the trigeminal nerve, lower cranial nerves, and internal auditory meatus with vestibulocochlear/facial complex and flocculus can be seen. CNV, cranial nerve V (right trigeminal nerve); LCN, lower cranial nerves; IAM, internal auditory meatus; F, flocculus.

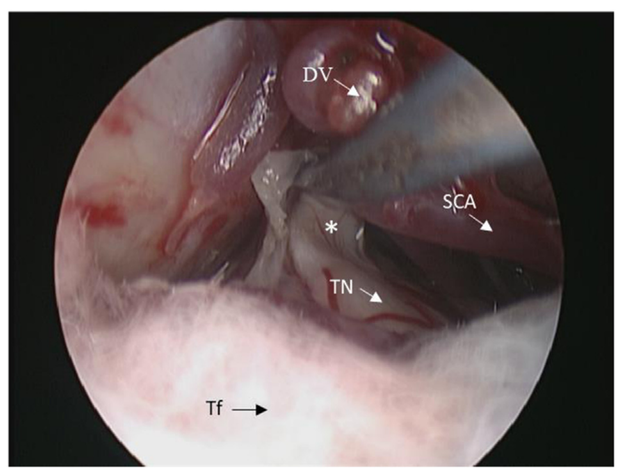

Figure 5. View of cauterized superior petrosal vein (also known as Dandy's vein) and groove (*asterisk*) in right trigeminal nerve, caused by loop of the superior cerebellar artery before interposition of Teflon. DV, Dandy's vein; TN, trigeminal nerve; SCA, superior cerebellar artery; Tf, Teflon.

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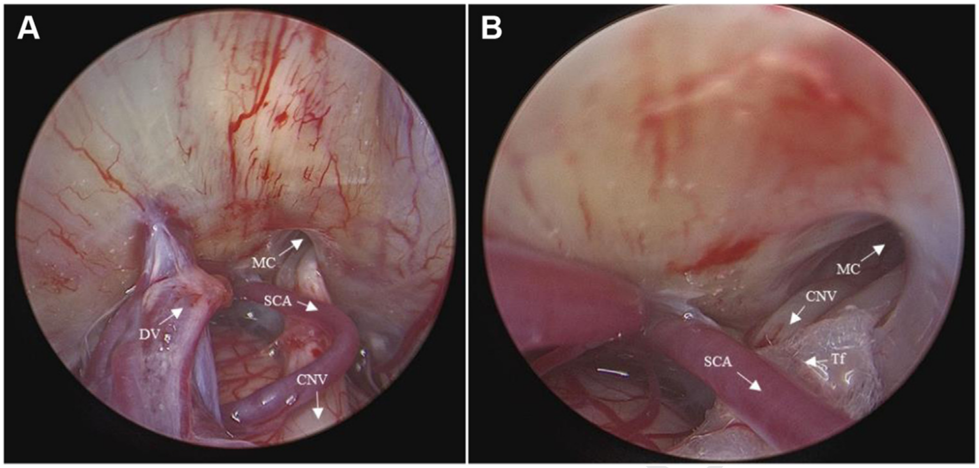

Figure 6. (**A**) Endoscopic view after the vascular loop was mobilized from a medial to lateral position relative to the trigeminal nerve (cranial nerve V), and a Teflon graft was inserted to separate them. Meckel's cave, superior cerebellar artery, and superior petrosal vein (also known as Dandy's vein) are also shown. (**B**) A closer endoscopic view after Teflon was placed between the superior cerebellar artery and trigeminal nerve. CNV, cranial nerve V (right trigeminal nerve); MC, Meckel's cave; SCA, superior cerebellar artery; DV, Dandy's vein; Tf, Teflon.

time between surgery and discharge, surgical complications, and clinical outcome (including change in medication requirement). The 5-point Barrow Neurological Institute (BNI) pain intensity score was used to quantify pain relief in patients, as follows: I = no pain, no medication; II = occasional pain, not requiring medication; III = some pain, adequately controlled with medication; IV = some pain, not adequately controlled with medication; V = severe pain/no pain relief.[22,23]

Patient Selection

All patients were diagnosed and treated by the multidisciplinary facial pain team at Kings' Health Partners, which is a unique clinical and academic entity that comprises the Orofacial Pain and Skull Base Neurosurgery services at King's College Hospital and the Headache and Pain services at Guy's and St Thomas' Hospital. Patients analyzed here underwent surgery at King's College Hospital. The inclusion criteria were 1) medically refractory TN with ≥2 medication failures (BNI score of V) and 2) presence of neurovascular conflict on MRI and intraoperatively.

Surgical Procedure

Patients are prepared in the usual manner for a retrosigmoid approach. The patient is positioned in the park bench position with a 3-pin Mayfield head clamp (Figures 1 and 2). The incision is approximately 40–50 mm, straight and vertical, approximately 2 fingerbreadths behind the external auditory meatus. Image guidance was not deemed necessary: the position of the transverse sinus is approximated using anatomical landmarks, drawing a line between the root of the zygoma and the inion, and the sigmoid sinus is approximated as running at the posterior border of the mastoid process. The head is in the neutral position (or minimal lateral head flexion if the patient has a short, thick neck) to ensure an optimal corridor to the trigeminal nerve. Lateral flexion is avoided to prevent the trigeminal nerve from being concealed behind the facial/vestibulocochlear nerve complex, which can potentially result in a narrow access corridor to the trigeminal nerve. We started to use intraoperative monitoring of trigeminal, facial, and vestibulocochlear nerves as well as motor-evoked potentials in 2018.

The e-MVD procedure follows largely the same sequence of steps as one would perform during standard MVD albeit with a smaller incision and bony craniectomy. An approximately

Figure 7. Aesculap tubular instruments are used.

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Table 1. Characteristics of Patients with Trigeminal Neuralgia

Characteristic	Value
Number of patients	25
Age, years, mean (SD)	63 (10.4)
Sex	
Female	15
Male	10
Side affected	
Left	15
Right	10
Dermatomes affected	
V_1	0
V_2	6
V_3	9
$V_1 + V_2$	2
$V_2 + V_3$	5
$V_1 + V_2 + V_3$	3
Prior drug treatments	
Carbamazepine	15
Oxcarbazepine	4
Gabapentin	4
Pregabalin	9
Lamotrigine	7
Lacosamide	2
Duloxetine	1
Phenytoin	1
Lidocaine	1
Co-codamol	1
None	1
Medically fit for discharge, days, median (IQR)	3 (2, 4)

V_1, ophthalmic trigeminal nerve; V_2, maxillary trigeminal nerve; V_3, mandibular trigeminal nerve; IQR, interquartile range.

40-mm (depending on the size of the patient's neck) vertical retromastoid incision is made extending down to bone. Using the asterion as the superior landmark, an approximately 20 mm in diameter craniectomy is performed to expose the inferior and medial aspects of the transverse and sigmoid sinuses, respectively. We have observed that our incision and craniectomy sizes are becoming smaller with increased experience. After sealing any exposed mastoid air cells with bone wax, a cruciate durotomy is performed based on the transverse and sigmoid sinuses. A 0° endoscope is introduced, and cerebrospinal fluid is slowly drained from cisterna magna, resulting in relaxation of the cerebellum, obviating the requirement for fixed brain retraction. The cerebellopontine angle is then visualized around the lateral aspect of the cerebellum where the facial and vestibulocochlear nerves are identified first, followed by the glossopharyngeal, vagus, and accessory nerves. To avoid traction injury to the facial and vestibulocochlear nerves, the arachnoid overlying these structures is opened before approaching the trigeminal nerve. The whole length of the trigeminal nerve is visualized, from root entry zone to Meckel's cave (**Figures 3–5**). We try to avoid sacrificing the superior petrosal vein (also known as Dandy's vein) if possible, but we have not encountered any complications when we have had to do so. After the area of neurovascular conflict is identified, polytetrafluoroethylene pieces are placed in between the trigeminal nerve and all offending vessels until adequate decompression is achieved (**Figure 6**); tubular instruments (Aesculap; B. Braun Melsungen AG, Melsungen, Germany) are used for this procedure (**Figure 7**). The cavity is then irrigated with saline, and hemostasis is achieved under normotension. Dura foam and DuraSeal (Integra LifeSciences, Princeton, New Jersey, USA) are used to reinforce the dural closure, and a titanium mesh covers the bony defect.

RESULTS

The study included 25 patients with TN (10 males, 15 females; mean [SD] age = 63 [10.5] years) who underwent e-MVD. Of these patients, 20 presented with either maxillary trigeminal nerve or mandibular trigeminal nerve or both dermatomal distribution of pain, 2 presented with ophthalmic trigeminal nerve and maxillary trigeminal nerve dermatomal pain, and all 3 dermatomes were affected in 3 patients. TN was on the left side in 15 of 25 patients. The median time until patients were medically fit for discharge was 3 days (interquartile range: 2, 4). Characteristics of all patients are summarized in **Table 1**.

Before the operation, 24 of 25 patients were taking medications for TN. Carbamazepine was the most frequently prescribed treatment ($n = 15$, 60%). Polytherapy with antineuropathic medications was prescribed in 18 (72%) patients. One patient was not taking medication owing to unacceptable side effects and lack of

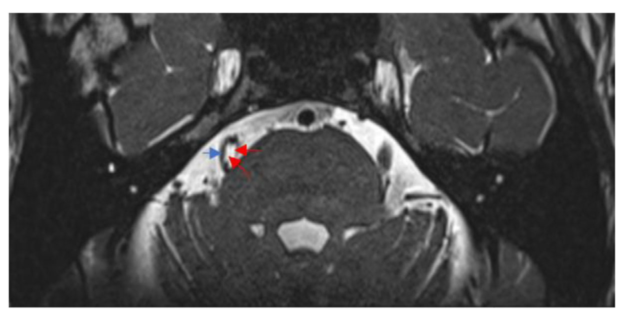

Figure 8. Preoperative magnetic resonance imaging fast imaging employing steady-state acquisition with phase cycling/constructive interference in steady-state sequence demonstrating the vascular loop compressing the right trigeminal nerve. The *red arrows* point to the superior cerebellar artery, while the *blue arrow* shows the trigeminal nerve bowing laterally.

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Table 2. Morphological Findings on Magnetic Resonance Imaging and Intraoperatively

Morphological Findings	Intraoperative	MRI
Degree of compression		
Significant with morphological changes	14	16
Contact (no morphological changes)	11	9
Site of compression		
Root entry zone	16	
Cisternal	8	
Root entry zone and cisternal	1	
Offending vessel		
Artery		
Superior cerebellar artery	16	
Anterior inferior cerebellar artery	3	
Vertebral artery	2	
Vein	4	

MRI, magnetic resonance imaging.

response to previous oral preventive treatments. Vascular compression was confirmed by fine-cut fast imaging employing steady-state acquisition with phase cycling/constructive interference in steady-state sequences on 1.5T MRI before surgery (Figure 8 and Table 2). Intraoperative monitoring was performed in 18 of 25 patients. Intraoperative findings are also noted in Table 2.

The median length of follow-up in this study was 22 months (range, 8–49 months). Preoperatively, all patients reported a BNI score of V (severe pain with no pain relief). All patients were completely pain-free (BNI score I) immediately postoperatively. On latest follow-up, 22 patients (88%) have remained pain-free (BNI score I), and 3 patients (12%) have reported recurrence of pain that was adequately controlled with medications (BNI score III).

Postoperative complications occurred in 2 patients. One patient developed delayed facial paresis (House-Brackmann grade IV), disequilibrium, and ipsilateral hearing loss 7 days after the operation. The facial paresis, but not hearing, had recovered at the patient's latest follow-up. The patient's TN was adequately controlled with medication at the latest follow-up (Table 3). One patient presented with ipsilateral hearing loss, which had recovered to a serviceable level with the use of a hearing aid at the latest follow-up.

DISCUSSION

To the best of our knowledge, this is the first European series describing the outcome of fully e-MVD in TN. Our analysis suggests that fully e-MVD is a safe and effective method of treating TN. Following surgery, 22 patients (88%) were pain-free, which is comparable to previously reported series in which e-MVD was performed with 80%–95% pain control achieved.[7,8,10,11,14,15,17,18,21,24,25] Similar to previous reports, we chose to perform e-MVD with the patient placed in the park bench/lateral position.[10,12,13,16,18,26] We found that this position provided optimal access to the cerebellopontine angle and was the greatest position of comfort for the operating surgeon.[27] In contrast to other authors,[7,8,10-16] we chose not to use an endoscope holder. Similar to Teo et al.,[26] we observed that dynamic positioning of the endoscope performed by the assistant surgeon provided continual optimal visualization during the procedure. Some surgeons prefer to transpose the offending vessel from the nerve using a sling, but we have not found any disadvantage to interposing Teflon (The Chemours Company, Wilmington, Delaware, USA) between the vessel and the nerve.[28]

The superior cerebellar artery was the most common offending vessel (64%) in our study, and the most common site found was the root entry zone (64%) (Table 2), similar to other e-MVD studies.[7,8,14,24,25,29] While the severity of morphological changes varied between MRI scans and intraoperative findings,[30] neurovascular compression was observed intraoperatively in all patients who underwent the procedure. These findings are correlated to a better long-term outcome of the decompression.[31] Of particular note, the 4 patients with venous compression were no longer taking medications and were pain-free at latest follow-up.

We observed several advantages of performing e-MVD over conventional open microscopic surgery. e-MVD provides a panoramic view of the cerebellopontine angle, better illumination, and increased ability to maneuver within the operating field.[7-9] It allows closer inspection of the nerve and its immediately surrounding structures at difficult angles, with excellent visualization of the entire length of the nerve from the pons to the porus trigeminus. We do not use fixed retraction for microscopic MVD or for e-MVD. Fully e-MVD is also better at facilitating teaching and ensures improved surgeon ergonomics and comfort.

The size of the endoscope, however, means that if the tip of the scope is held very close to the nerve, the movement of instruments around this area may be challenging, and the scope would then need to be slightly withdrawn to provide the required space. Care must be taken to avoid instruments "skipping" around the tip of the scope causing potential damage to neurovascular structures. The learning curve associated with using the

Table 3. Barrow Neurological Institute Pain Score in 25 Patients with Trigeminal Neuralgia After Surgery

Pain Score	Number of Patients (%)
I = no trigeminal pain, no medication	22 (88)
II = occasional pain, no medication	0
III = some pain but adequately controlled with medication	3 (12)
IV = some pain, not adequately controlled with medication	0
V = severe pain or no pain relief	0

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endoscope can also be steeper,[9,10,25] particularly when the assistant is required to optimize the endoscope position during different stages of the procedure. While the increasing prevalence of the endoscope in other neurosurgical procedures should help to improve the surgeon's familiarity with it and shorten the learning period,[32,33] it remains a disadvantage.

Two patients experienced complications in our series. Similar complication rates were encountered in other studies, including permanent hearing loss (0.43%–2.1%)[7,10,24,25,29] and transient facial paresis (2.0%–3.9%).[7,8,25] Nevertheless, our results confirm the presence of a surgical learning curve associated with mastering e-MVD.[7,10,11,25] One patient experienced transient facial weakness (House-Brackmann IV) and reduced hearing, which manifested 7 days following surgery. Intraoperatively we encountered hemorrhage from several small arterials over the internal auditory meatus, which was controlled with SURGIFLO (Ethicon Inc., Somerville, New Jersey, USA) and Cottonoids (American Surgical Company, Salem, Massachusetts, USA) rather than cautery owing to the risk posed by the latter to the facial nerve (cranial nerve [CN] VII) and the vestibulocochlear nerve (CN VIII). The patient's facial paresis recovered fully, but her hearing is still slightly impaired 3 years later.

The second case in which our patient experienced hearing loss was due to stretching of the vestibulocochlear nerve when introducing the polytetrafluoroethylene felt pieces into the field of view. The vestibulocochlear nerve was only just visible at the margins of the field of view, as the endoscope was close to the trigeminal nerve. On analysis of the video postoperatively, the stretching of the vestibulocochlear nerve by the rongeur holding the polytetrafluoroethylene felt was evident. For this reason, we advocate the safe introduction of surgical tools under direct vision. The patient's hearing today has recovered to a serviceable level with the use of a hearing aid.

Three patients had a BNI score of 3 on latest follow-up. On revisiting the history of the first patient, it was identified that the onset of pain occurred immediately after a wisdom tooth extraction. This patient was then carefully evaluated by an experienced facial pain neurologist who diagnosed them with concomitant TN. The second patient remained pain-free for 2 years with postoperative MRI showing adequate positioning of the Teflon felt; this patient will undergo repeat phenotyping in our complex facial pain clinic. The third patient, who developed facial weakness and hearing impairment 7 days postoperatively, developed contralateral facial pain inconsistent with TN and will undergo repeat phenotyping in our complex facial pain clinic.

Fully e-MVD is a relatively new procedure and has potential for having good long-term prognosis for patients. However, this study was limited by the retrospective nature of data collection, small sample size, and limited and variable follow-up times. The BNI pain intensity score was used because there was insufficient information in the patient records to using alternative scoring systems.[34]

Our Experience of MVD from Microscope to Endoscope

From our experience, we have found numerous benefits since we have replaced the microscope with the endoscope. After draining cerebrospinal fluid, we have observed that approaching the cerebellopontine angle under the microscope can sometimes be difficult and may require a degree of dynamic brain retraction when advancing around the lateral aspect of the cerebellum. With the narrow endoscope and the superior visualization that it provides, the corridor to the CPA appears wide, and no retraction has been necessary. Similarly, the approach to the foramen magnum is easier to visualize when using the endoscope, without the need for cerebellar retraction.

When performing a microscopic MVD, the corridor of access to the trigeminal nerve must be such that there is no obstruction to its view by the CN VII/CN VIII complex. To facilitate this, the patient's neck must not be laterally flexed, or this may result in visualization of the trigeminal nerve being at least partially obstructed by the CN VII/CN VIII complex. When operating on patients with short, thick necks, some lateral flexion is sometimes required to allow comfort and space for the surgeon's hands in the angle between the patient's shoulder and side of the head. We have observed that the use of the endoscope allows more forgiving positioning of the head and neck with a degree of lateral flexion still allowing very good access to the trigeminal nerve without obstruction by the CN VII/CN VIII complex, by virtue of the small space required to advance the scope and the use of tubular instruments. This advantage is much more apparent when operating on patients with short, thick necks.

While some studies reported the use of 30° scopes,[7,8,25] we did not find that this offered any significant advantage. We used endoscopic tubular instruments, which was essential owing to the small craniotomy not allowing satisfactory insertion of microscopic instruments.

We did note that there were disadvantages of the endoscope compared with the microscope, as follows: 1) When significant bleeding is encountered, such as, from a superior cerebellar draining vein, hemostasis can be challenging to achieve and has required conversion to the microscope, albeit only for hemostasis. 2) The heat from the tip of the endoscope can theoretically damage adjacent neurovascular structures (e.g., CN VII/CN VIII complex)[35]; to mitigate this, the illumination intensity is kept at about 50%. We have found that increasing the illumination >50% does not provide improved visualization; we have also observed this when performing transnasal endoscopic procedures. 3) When introducing instruments, this should be done under direct vision (i.e., the scope follows the instrument). This will avoid injuring structures outside the field of vision (described in one of our complications).

Unique to our experience, we have found that after further investigations, patients who have recurrence of pain require repeat phenotyping. With our evolving understanding of facial pain syndromes, some patients with TN may indeed have been misdiagnosed, resulting in e-MVD providing suboptimal management for their pain. This highlights the need for better appreciation of the different types of facial pain and for the organization of complex facial pain multidisciplinary teams that include neurosurgeons, neurologists, dentists, maxillofacial surgeons, and pain management specialists to better diagnose, differentiate, and manage patients presenting with TN-like symptoms.

CONCLUSIONS

Fully e-MVD for TN improves intraoperative visualization of the neurovascular structures, and therefore we suggest that it

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improves the chance of adequate decompression. It can be a minimally invasive alternative to standard microsurgical MVD, sometimes, but not always, permitting smaller incisions and craniectomies. We have observed similar surgical risks and short-term clinical outcomes as microscopic MVD. Going forward, a larger study with longer follow-up is required to investigate if endoscopic surgery reduces postoperative wound pain and confers any additional lasting benefit compared with performing MVD using a standard microscopic approach.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

Ho Lim Pak: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization. **Giorgio Lambru:** Resources, Writing – review & editing. **Mohamed Okasha:** Resources, Writing – review & editing, Visualization. **Eleni Maratos:** Resources, Writing – review & editing. **Nick Thomas:** Resources, Writing – review & editing. **Jonathan Shapey:** Resources, Writing – review & editing. **Sinan Barazi:** Conceptualization, Resources, Writing – review & editing, Supervision.

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