# Operative Strategies for Minimizing Hearing Loss and Other Major Complications Associated with Microvascular Decompression for Trigeminal Neuralgia

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**Key words**
- Brainstem auditory evoked potentials
- Hearing
- Intraoperative monitoring
- Operative procedures
- Tic douloureux
- Trigeminal neuralgia

**Abbreviations and Acronyms**
**BAEP**: Brainstem auditory evoked potential
**BNI**: Barrow Neurological Institute
**CN**: Cranial nerve
**CSF**: Cerebral spinal fluid
**EMG**: Electromyography
**MVD**: Microvascular decompression
**TGN**: Trigeminal neuralgia

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■ OBJECTIVE: **To retrospectively assess the surgical outcomes and complication rates following microvascular decompression (MVD) for trigeminal neuralgia, using a targeted, restricted retrosigmoid approach.**

■ METHODS: **During the period 1994-2009, a total of 119 patients underwent MVD for trigeminal neuralgia. A retrospective review was conducted in order to assess pain outcomes following surgery and at most recent follow-up. The intraoperative findings, Barrow Neurologic Institute (BNI) pain scores, medication usage, brainstem auditory evoked potential records, and complication rates (including postoperative hearing status) were reviewed and subsequently analyzed.**

■ RESULTS: **Of the 119 patients who underwent MVD, 61 (51%) were male and 58 (49%) were female. The mean age was 60 years (range 22-86 years). Operative findings included 94 patients (79%) with arterial compression, 16 patients (13%) with isolated venous compression, 1 patient (1%) with a small arteriovenous malformation, and 8 patients (7%) with no obvious source of compression. No perioperative deaths or major complications, including hearing loss, occurred in any patients. Minor complications occurred in 9 patients (8%), including a transient trochlear nerve palsy in 1 patient, transient nystagmus in 1 patient, cerebrospinal fluid leak requiring revision in 1 patient, wound infections requiring revision in 3 patients, and wound infections requiring antibiotics alone in 3 patients. Follow-up data were available for 109 patients, of whom 88 (81%) had excellent outcomes (BNI Score I–II). Ninety-eight patients (90%) had good outcomes (BNI scores I–IIIb), 7 patients (6%) had persistent pain that was not controlled with medications (BNI Score IV), and 4 patients (4%) experienced no relief following surgery (BNI Score V).**

■ CONCLUSION: **The use of a small craniectomy (<20 mm) in conjunction with a restricted retrosigmoid approach, inferolateral cerebellar retraction, and maintenance of the vestibular nerve arachnoid may minimize complications and optimize surgical outcomes associated with microvascular decompression for trigeminal neuralgia.**

## INTRODUCTION

Vascular compression of the trigeminal nerve causing trigeminal neuralgia (TGN, tic douloureux) was first reported by Dandy in 1932 (12). Since the initial description, several modalities for the treatment of TGN have evolved, including medical therapy, stereotactic radiosurgery, glycerol rhizotomy, radiofrequency thermal rhizotomy, balloon microcompression, and surgical microvascular decompression (3). Microvascular decompression (MVD) is commonly relied upon as the definitive nonablative treatment of refractory TGN, with a reported success rate of 63%–94% (1, 2, 5-8, 11, 17-19, 21, 24, 25, 27, 29, 30, 32, 35) and a reported major complication rate of 1.2%–5.2% (2-4, 6, 7).

A relatively infrequent yet significant risk of the MVD procedure is permanent hearing impairment associated with damage to the vestibulocochlear nerve (CN VIII), which typically occurs as a result of excessive retraction of the cerebellum performed in order to expose the trigeminal cistern. Less frequently, hearing loss occurs as a result of direct trauma to the cranial nerve complex or its vascular supply. Earlier MVD procedures that did not utilize more modern operative techniques or brain stem auditory evoked potential monitoring (BAEP) resulted in relatively higher rates of hearing loss ranging from 2% to 19% (5, 8, 9, 18, 19, 23, 26, 31, 34). With the introduction of BAEP and refined exposure techniques, however, more emphasis has been placed on minimizing traction on cranial nerve (CN) VIII, and rates of postoperative hearing loss have been reduced to less than 2% in modern series (2, 5, 8, 17, 20, 27, 28). In the current report, the records of 119 patients undergoing MVD for TGN by the se-

**Table 1.** Patient Characteristics

| Characteristic | n | % |
|---|---|---|
| Number of patients | 119 | 100 |
| Sex | | |
| Female | 58 | 49 |
| Male | 61 | 51 |
| Age (years) | | |
| Mean | 60 | |
| Range | 22-86 | |
| Side | | |
| Right | 79 | 66 |
| Left | 40 | 34 |
| Prior procedures | | |
| Any procedure | 28 | 24 |
| Stereotactic radiosurgery | 15 | 13 |
| Microvascular decompression | 7 | 6 |
| Radiofrequency ablation | 6 | 5 |
| Glycerol rhizotomy | 7 | 6 |

nior author (S.L.G.) were retrospectively reviewed. Particular features of the operative technique used at our institution include a small keyhole craniectomy (less than 20 mm in diameter) positioned adjacent to the asterion, a supracerebellar approach following the petrotentorial junction, minimal inferolateral retraction of the cerebellum, and preservation of the arachnoid sheath covering CN VIII. In this report, we describe the operative technique used at our institution, as well as the clinical outcomes, intraoperative neurophysiologic monitoring results, and complication rates of patients undergoing MVD for TGN.

## CLINICAL MATERIALS AND METHODS

### Patient Population

During the period of June 1994–July 2009, a total of 119 patients underwent MVD for refractory TGN (**Table 1**). There were 61 males (51%) and 58 females (49%). The mean patient age at surgery was 60 years (range 22–86 years). Right-sided TGN was observed in 66% of patients and left-sided TGN in 34% of patients. Nineteen patients (16%) presented with atypical pain, defined as any presentation not conforming to the features described by White and Sweet (33).

In addition to standard medical therapy, 35 prior treatment procedures were attempted in 28 patients (24%). These procedures included prior stereotactic radiosurgery in 15 patients (13%), MVD in 7 patients (6%), radiofrequency ablation in 6 patients (5%), and prior glycerol rhizotomy in 7 patients (6%).

### Operative Technique

The surgical technique for performing a retrosigmoid approach and vessel decompression has been described elsewhere in detail (4, 5, 7, 13, 14). To minimize the risk of hearing impairment, significant emphasis is placed on minimizing traction on CN VIII during exposure of the trigeminal cistern. The optimal operative trajectory is a posterior-lateral supracerebellar approach that is targeted parallel and adjacent to the petrotentorial junction. This corridor minimizes the amount of lateral cerebellar retraction (and subsequent traction on CN VIII) required to expose the trigeminal nerve (5, 8, 10, 14, 17). Furthermore, by following the petrotentorial junction, inadvertent encroachment on the eighth nerve complex is avoided. The use of a small keyhole craniectomy (less than 20 mm in diameter) as opposed to a larger, more traditional craniectomy (35 mm in diameter) is preferred, and has been previously described as a method of reducing postoperative complications and increasing patient satisfaction (14).

All patients are placed under general anesthesia and at-risk neural structures are monitored with BAEPs and selective cranial nerve electromyography (EMG) (see below). The estimated location of the transverse-sigmoid sinus junction is approximated prior to final positioning by defining the line between the inion and root of the zygoma, one fingerbreadth behind the mastoid process (13). Mannitol, lasix, dexamethasone, and antibiotics are administered preoperatively. The patient is typically positioned in the supine position with the head placed in three-point fixation and turned 90°, so that the lateral aspect of the head is parallel to the floor. An ipsilateral shoulder roll is frequently used. In some cases, the lateral or park-bench positioning is preferred to achieve optimal head positioning.

A small S-shaped incision is typically made approximately 2 cm posterior to and just superior to the mastoid process, and centered immediately inferior to the predicted transverse-sigmoid junction. A two-layered scalp opening is performed, by initially opening the skin layers and subsequently performing an L-shaped opening of the occipital fascia that is based and reflected anteriorly toward the mastoid process. A single burr hole is made in the posterior fossa, just inferior and medial to the anticipated transverse-sigmoid junction. The craniectomy is subsequently expanded using a high-speed coarse diamond drill and Kerrison rongeurs. Care is taken to limit the craniectomy to less than 20 mm in diameter to provide as minimally invasive an exposure as is required, yet provides sufficient exposure of the trigeminal cistern. Typically, the transverse sinus is identified and exposed in the superior aspect of the craniectomy as it curves toward the transverse-sigmoid junction. The mastoid air cells may be exposed during the craniectomy and may be occluded with bone wax.

The operating microscope is introduced and the dura is opened in a curvilinear fashion, with a broad base reflected anteriorly toward the sigmoid sinus. The dural leaves are tacked up. Following gentle cerebellar retraction using a 2-mm blade (when necessary), a small arachnoid incision is made and cerebrospinal fluid (CSF) is patiently drained. A lumbar drain is not routinely required. The cerebellum is then progressively retracted in an inferior and posterior direction as it continues to relax (**Figure 1A**), rather than in a strictly lateral direction (**Figure 1B**). Inferior and posterior retraction minimizes traction on CNVIII and is critical in minimizing postoperative hearing loss. Under direct microscopic observation, the petrotentorial junction is identified and followed to the petrosal vein. This reduces the tendency to directly expose the CN VII/VIII complex. Care is taken to maintain the sleeve of arachnoid around the CN VII/VIII complex throughout the entire duration of the procedure. In most cases, maintaining the exposure does not require keeping a retractor blade in place.

The trigeminal cistern is easily viewed at this point in the operation by angling the microscope superiorly toward the cerebellopontine angle. The petrosal vein is commonly identified as it courses over the trigeminal nerve, and its branches may be coagulated and divided if necessary. The trigeminal nerve is explored along its course

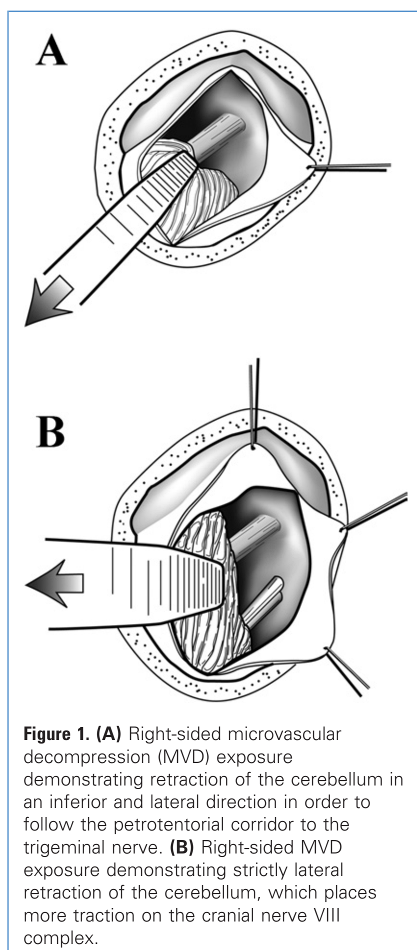


**Figure 1. (A)** Right-sided microvascular decompression (MVD) exposure demonstrating retraction of the cerebellum in an inferior and lateral direction in order to follow the petrotentorial corridor to the trigeminal nerve. **(B)** Right-sided MVD exposure demonstrating strictly lateral retraction of the cerebellum, which places more traction on the cranial nerve VIII complex.

from its dorsal nerve root entry zone to its entry into Meckel's cave. Teflon pledgets are routinely used to bolster any compressing arteries away from the nerve root entry zone and are typically fixed in place using fibrin glue. Care is taken such that neither fibrin glue nor Teflon is in contact with the trigeminal nerve following the decompression. Any veins causing compression of the nerve root entry zone are coagulated and divided. Intraoperative neurophysiologic monitoring is periodically reviewed with the neurophysiology team. Following adequate decompression of the trigeminal nerve, hemostasis is achieved and a watertight dural closure is performed. Suturable dural substitute is required in the majority of cases and is placed deep to the dural leaflets, which are then reapproximated and simultaneously used to tack up the dural graft. This is typically followed by subsequent layers of fibrin glue, collagen sponge, and finally a tailored titanium plate used to cover the craniectomy and serve as a buttress. The wound is irrigated and the fascia and scalp are reapproximated using a multilayered closure.

### Intraoperative Neurophysiologic Monitoring

Intraoperative BAEP recording was performed using Cadwell Cascade (Cadwell Laboratories, Kennewick, WA, USA). An ipsilateral and contralateral auditory stimulus was delivered using ear-inserts. The stimulation parameters consisted of alternating condensation and rarefaction clicks (100 $\mu$s, 11.1 Hz) with an intensity of 80 dB, and contralateral white nose of 40 dB to avoid contributions from the contralateral ear. Bilateral recording baselines were obtained shortly after induction, but only ipsilateral recordings were continuously performed during the procedure. Recordings were obtained using sterile subdermal needles positioned at A1, A2, and Cz using a standard 10-20 system. Recording parameters consisted of two channels (ipsilateral ear-Cz and contralateral ear-Cz), a time base of 10 ms with filters between 30 and 3000 Hz, and 500-2000 responses averaged per trial. The amplitude and latencies of wave I, III, V, and interpeak latencies were calculated after each trial, and the surgeon was notified if any significant changes were noted.

### Outcome Measures

A modified version of the Barrow Neurological Institute (BNI) pain intensity score was used to assess postoperative outcomes following MVD (25). Patients are assigned a score of I for no pain and off medications, II for occasional pain and off medications, IIIa for no pain and continued use of medications, IIIb when pain persists but is adequately controlled with medications, IV when pain is not adequately controlled with medications, and V for no relief. By definition, all patients undergoing MVD for the treatment of TGN have an initial pain score of V, as refractory pain is not adequately managed by medication use. Barker et al. (5) defined an excellent MVD outcome as one that is completely free from lancinating facial pain, or a reduction in pain of at least 98% off medications. They further defined a good outcome as a 75% reduction in pain with or without intermittent treatment using low doses of medication. According to the BNI pain scale, an excellent outcome is defined as a BNI score of I–II, and a good outcome defined as a BNI score of I–IIIb. Although a postoperative BNI pain score of I (no pain, off medications) is the ideal outcome in patients with debilitating TGN pain, postoperative BNI pain scores of I–IIIb are generally considered good outcomes because patients experience return to normal function.

Outcome assessment in this series was based on qualitative patient self-assessment of pain and reporting of medication use, both immediately following surgery and at most recent follow-up. Audiometry data were not routinely performed for assessing absolute quantitative changes in hearing. Functional hearing assessment, based on patient self-reporting, was considered the primary endpoint of this study and assessed immediately after surgery, at subsequent follow-up visits, and via telephone interviews. The maximum follow-up time was 15.1 years, median was 1.7 years, and mean was 3.3 years. Kaplan–Meier analysis was performed for all patients (16). Patients who were lost to follow-up were censored at postoperative day 1.

**Table 2.** Operative Findings

| Abnormality | n | % |
|---|---|---|
| SCA | 72 | 61 |
| AICA | 9 | 8 |
| SCA + AICA | 10 | 8 |
| SCA + basilar artery | 2 | 2 |
| PICA + vertebral artery | 1 | 1 |
| Arteriovenous malformation | 1 | 1 |
| Vein only | 16 | 13 |
| No finding found | 8 | 7 |
| Arterial + vein (included in above) | 18 | 15 |

SCA, superior cerebellar artery; AICA, anterior inferior cerebellar artery; PICA, posterior inferior cerebellar artery.

## RESULTS

### Operative Findings

The intraoperative findings from the current series of 119 MVD procedures are summarized in **Table 2**. In 94 patients (79%), arterial compression of the trigemi-

**Table 3.** Ipsilateral Wave V BAEP Changes

| Parameter | Value (ms) |
|---|---|
| Mean | 0.26 |
| SD | 0.30 |
| Max | 1.24 |
| Min | −0.42 |

BAEP, brainstem auditory evoked potential; SD, standard deviation; Max, maximum; Min, minimum.

nal nerve was identified. Sources of arterial compression were as follows: Superior cerebellar artery in 72 patients (61%), anterior inferior cerebellar artery in 9 patients (8%), superior cerebellar artery and anterior inferior cerebellar artery in 10 patients (8%), superior cerebellar artery and basilar artery in 2 patients (2%), and posterior inferior cerebellar artery and vertebral artery in 1 patient (1%). Eighteen patients (15%) with arterial compression had concurrent compression from a vein, whereas compression from a vein only was noted in 16 patients (13%). One patient (1%) had a small arteriovenous malformation noted within the trigeminal nerve. In 8 patients (7%), there was no obvious intraoperative source of compression identified.

## Intraoperative Neurophysiologic Monitoring Results

Of the 119 patients undergoing MVD procedures, complete BAEP records were available for 71, in which an assessment of permanent changes in wave V latency could be performed. Intraoperative BAEP waves I, III, and V were monitored for changes in amplitude, latency, and interpeak latency. Transient changes of absolute or interpeak latency in excess of 10% of baseline value, which returned to a normal range prior to the completion of surgery, were noted in 9 patients (7.6%). The surgeon was notified in each of these instances. Modifications made by the surgeon and anesthesia team included reduction of cerebellar retraction, reduction of anesthesia, warm irrigation, and elevation of blood pressure.

The distribution of BAEP wave V changes during MVD in the current series is summarized in **Table 3**. A mean latency of 0.26 ms with a standard deviation of 0.30 ms was observed. Two patients had wave V latency changes in excess of 1 ms. One of these patients had a wave V latency increase of 1.04 ms that was felt to be caused by an increase in intraoperative anesthesia administration. The second patient exhibited a wave V latency increase of 1.24 ms with no extraneous reason for the change, and experienced no adverse postoperative complications. The 9 patients with transient changes noted intraoperatively had a mean wave V latency shift of 0.40 ms and a maximum change of 0.8 ms.

**Table 4.** Pain Score for Patients Undergoing MVD for TGN

| | Postoperative | | Last Follow-Up | |
|---|---|---|---|---|
| | n | % | n | % |
| Total patients | 119 | | 109 | |
| Pain score I | 103 | 87 | 82 | 75 |
| Pain score II | 5 | 4 | 6 | 6 |
| Pain score IIIa | 0 | 0 | 1 | 1 |
| Pain score IIIb | 6 | 5 | 9 | 8 |
| Pain score IV | 1 | 1 | 7 | 6 |
| Pain score V | 4 | 3 | 4 | 4 |
| Pain score I–IIIb | 114 | 96 | 98 | 90 |

MVD, microvascular decompression; TGN, trigeminal nerve.

## Pain Control Outcomes

In this series, 114 patients (96%) reported marked postoperative improvement in pain scores (BNI outcome scores of I–IIIb) (**Table 4**). Of these patients, 108 (91%) had excellent postoperative outcomes (BNI score I–II), whereas 6 patients (5%) reported some postoperative pain that was adequately controlled with medications (BNI score IIIb). One patient (1%) reported persistent pain not controllable with medications (BNI score IV), and 4 patients (3%) experienced no postoperative pain relief (BNI score V).

Delayed follow-up outcomes were available in 109 patients (92%). The remaining 10 patients (8%) were lost to follow-up. At most recent follow-up, 98 patients (90%) had good outcomes (BNI scores I–IIIb). Of these patients, 88 (81%) had excellent outcomes (BNI score I–II), 1 (1%) had no pain but continued use of medications (BNI score IIIa), and 9 patients (8%) had pain that was adequately controlled with medications (BNI score IIIb). Seven patients (6%) had persistent pain that was not adequately controlled with medications, and 4 (4%) experienced no pain relief (BNI score V). All the 10 patients lost to follow-up were pain free and off medications (BNI score I) immediately following surgery.

**Figure 2** shows the results of the Kaplan–Meier analysis for both excellent (BNI score

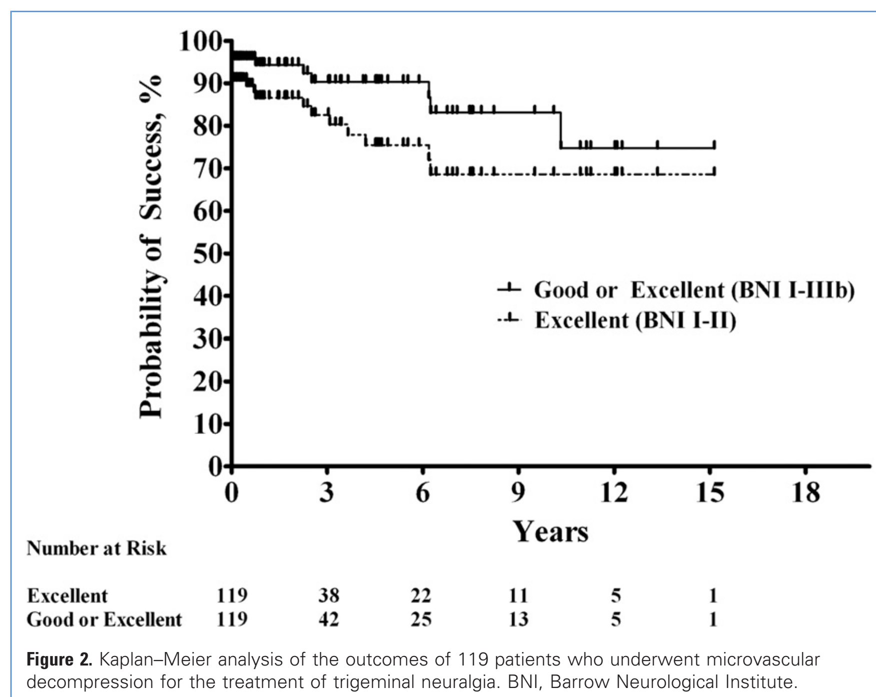


**Figure 2.** Kaplan–Meier analysis of the outcomes of 119 patients who underwent microvascular decompression for the treatment of trigeminal neuralgia. BNI, Barrow Neurological Institute.

**Table 5.** Complications in 119 Patients Undergoing MVD for TGN

| Complication | n | % |
|---|---|---|
| Transient CN IV palsy | 1 | 0.8 |
| Transient nystagmus | 1 | 0.8 |
| CSF leak | 1 | 0.8 |
| Wound infection | | |
| Requiring surgical debridement | 3 | 2.5 |
| Requiring antibiotics alone | 3 | 2.5 |

MVD, microvascular decompression; TGN, trigeminal neuralgia; CN, cranial nerve; CSF, cerebrospinal fluid.

I–II) and good (BNI score I–IIIb) outcomes. At 10 years following surgery, 83% of patients maintained good outcomes, and 69% of patients maintained excellent outcomes.

### Operative Complications

Postoperative complications are listed in **Table 5**. In the current series, no major complications were observed. No patients reported functional hearing loss following the operation. Minor complications were observed in 9 patients (7.6%). All resolved completely with appropriate management. One patient (0.8%) experienced a transient trochlear nerve palsy, and 1 patient (0.8%) experienced transient postoperative nystagmus, both of which were self-limited. Additional complications included a postoperative CSF leak requiring surgical revision in 1 patient (0.8%), wound infections requiring surgical debridement in 3 patients (2.5%), and wound infections requiring antibiotics alone in 3 patients (2.5%). All wound infections were isolated to the skin layers and no involvement of the CSF or dural closure was found.

## DISCUSSION

We report a series of 119 cases of MVD performed for TGN, in which 91% had excellent outcomes (BNI Grade I–II) following surgery, and 81% retained excellent outcomes at most recent follow-up. In addition, good postoperative and follow-up outcomes (BNI score of I–IIIb) were achieved in 96% and 90% of patients, respectively. These results compare well with results of previous reports, in which initial success rates following MVD for TGN have ranged from 63% to 94% (1, 2, 5-8, 11, 17-19, 21, 25, 27, 29, 30, 32, 35). According to previous series with long-term follow-up, recurrence rates for TGN following MVD in recent studies have been reported as 6% to 27% (2, 8, 19, 28). Independent risk factors for recurrence include female sex, symptoms lasting more than 8 years, venous compression, and lack of immediate postoperative pain relief (5, 28).

In the current series, the rate of postoperative hearing deficits and other major complications was 0%. The incidence of minor complications was 7.6%. As discussed previously, one of the most frequently occurring major complications following MVD is ipsilateral hearing loss from damage to CN VIII incurred during cerebellar retraction or direct injury to the nerve complex. According to previous series, the introduction of BAEP monitoring has helped reduce the incidence of hearing loss from nearly 20% in some earlier reports to less than 2% in more recent surgical series (2, 4, 5, 7, 8, 15, 19). A large series from the Pittsburgh group of more than 4400 MVD procedures performed for numerous indications reported a substantial decline in the incidence of hearing loss reported before and after 1990, from 1.98% to 0.8% (20). A few recent series have also reported a 0% incidence of postoperative hearing loss following MVD for refractory TGN (2, 21, 22, 27).

We attribute the relatively low hearing loss and major morbidity rate in the current series to several key operative techniques. Although some of these operative strategies have been reported elsewhere (4, 5, 7, 8, 10, 13, 14, 17), we believe that the disciplined implementation of the following techniques collectively contribute to lower observed rates of major complications. An optimized petrotentorial corridor is critical in order to minimize the amount of cerebellar retraction required to expose the trigeminal nerve. The ideal placement of the burr hole and subsequent craniectomy are of utmost importance in order to achieve a supracerebellar approach rather than achieving exposure at the expense of lateral retraction of the cerebellum. Furthermore, retraction of the cerebellum in a direction that is inferolateral (tangential to the course of CN VIII) rather than directly lateral (parallel to CN VIII) is a key maneuver that has been described before, and it is emphasized in our approach in order to avoid significant lateral traction of the CN VIII complex (8, 19, 20). Gradual retraction of the cerebellum as CSF is allowed to drain is always performed, obviating the need for a lumbar drain. Finally, the arachnoid sheath over the CN VIII and CN VII complex is preserved throughout the duration of the procedure in order to further protect the nerve from excessive retraction or direct trauma.

Our experience in this series, along with others, suggests that nuanced modifications in surgical technique may aid in minimizing major neurologic complications associated with MVD procedures. Although BAEP monitoring was routinely used in these patients, if the incidence of cranial nerve injury could be reliably minimized, this may leave the surgeon free to eliminate the use of electrophysiologic monitoring in selected cases. Our series demonstrated two patients with BAEP wave V latency changes exceeding 1.0 ms without reported evidence of functional postoperative hearing loss, indicating that more studies may be required to delineate the optimal guidelines for monitoring using BAEP latency changes. Very few will dispute the value that BAEP monitoring played in the evolution and development of the MVD surgical technique. As an individual surgeon ascends the learning curve and gains significant experience with procedures such as MVD, the feedback obtained from monitoring BAEPs and facial nerve EMG is invaluable in honing one's skills. In the future, shifts in the cost–benefit ratio driven by limited sophisticated operating room resources may instead favor evidence-based selected deployment of such techniques rather than rigidly designating them as a surgical "standard of care." Case controlled studies would be valuable to establish evidence about whether monitoring is useful in particular surgical procedures.

## CONCLUSIONS

Microvascular decompression remains the criterion standard intervention for refractory TGN. The success rate in this series of 109 patients with available follow-up, as defined by the BNI pain score, was greater than 90%, with 81% of patients remaining completely off medications. Furthermore, we report no

cases of postoperative hearing deficits or other major morbidity associated with surgery. Several key operative features may contribute to minimizing morbidity associated with MVD procedures for TGN, including a small targeted craniectomy, inferolateral cerebellar retraction, and preservation of the CN VIII arachnoid.

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