Microvascular decompression surgery: surgical principles and technical nuances based on 4000 cases

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Background: As an etiological treatment of trigeminal neuralgia (TN) and hemifacial spasm (HFS), microvascular decompression (MVD) has been popularized around the world. However, as a functional operation in the cerebellopontine angle (CPA), this process can be risky and the postoperative outcomes might not be good enough sometimes.

Objective: In order to obtain a better result with less complication, this surgery should be further addressed.

Methods: With experience of more than 4000 MVDs, we have gained knowledge about the operative technique. Through abundant intraoperative photos, each step of the procedure was demonstrated in detail and the surgical strategy was focused.

Results: The principle of MVD is to separate the nerve-vessel confliction rather than isolate it with prostheses. A prompt identification of the conflict site is important, which hinges on a good exposure. A satisfactory working space can be established by an appropriate positioning of the patient’s head and a proper craniectomy as well as a rational approach. A sharp dissection of arachnoids leads to a maximal visualization of the entire intracranial course of the nerve root. All the vessels contacting the trigeminal or facial nerve should be treated. Intraoperative electrophysiological mentoring is helpful to distinguish the offending artery for hemifacial cases.

Conclusion: MVD is an effective treatment for the patient with TN or HFS. Immediate relief can be achieved by an experienced neurosurgeon with good knowledge of regional anatomy. A safe surgery is the tenet of MVD, and accordingly, no single step of the procedure should be ignored.

Keywords: Microvascular decompression, Surgical technique, Hemifacial spasm, Trigeminal neuralgia

Introduction

Trigeminal neuralgia (TN) and hemifacial spasm (HFS) account for the majority of cranial nerve diseases. The compression of the V or VII cranial nerve root by vessel(s) has been believed to be the etiology. It was hypothesized that an ephaptic transmission occurred between those individual nerve fibers or the excitability threshold of the neuron dropped following the vascular compression of the nerve root. Our preliminary study implied that the autonomic nervous system in the adventitia of the offending vessel may contribute to the disorder. Carbamazepine may relieve the symptoms for the patients with TN or HFS in the early stage of the disease. When patients are weaned off medications, they may try balloon techniques, glycerol injections, stereotactic radiosurgery with Gamma Knife, or Botox injections. Nevertheless, in spite of being less invasive, all these above modalities are destructive at the cost of partial nerve function loss and may leave facial numbness or palsy. However, as a non-destructive surgery, microvascular decompression (MVD), has nowadays become the most effective remedy for TN or HFS since it was first introduced by Dandy in 1934 and then popularized by Janetta. Although the efficacy of MVD has been reported to be more than 90%, not all institutes reported perfect and consistent results. To date, we have performed 4000 MVDs in China. Most of the surgeries were performed in recent years, and the relief rate is increasing continuously while the complication is decreasing. Therefore, we believe that, theoretically, as soon as the offending vessel(s) is (are) removed away from the nerve, the symptoms of
the patient should be gone immediately. The improvement mainly depends on the surgeons’ understanding, experience, and technical nuances. An unsuccessful MVD may be largely attributable to misidentification of the culprit vessel. Although it was claimed that endoscopy offers enhanced visualization to identify offending vessels,\textsuperscript{28} it remains to be a sort of assistance to MVDs. However, a good working space may finally be obtained anyway with a fine dissection. Apart from a meticulous manipulation under microscope, a successful MVD depends on many other factors, including approach, cranectomy, positioning, and so on. Therefore, every single step of the process needs to be emphasized in order to achieve an excellent postoperative outcome. In this paper, we would like to present our experience with emphasis on surgical principles and technical nuances rather than postoperative outcomes, which have been mentioned much in our previous papers.\textsuperscript{27}

\textbf{Imaging}

Preoperative imaging study is used for exclusion of mass lesions rather than identification of the offending vessel

The disease is diagnosed in the light of the characteristic symptom, while iconography is a supplementary entity that is valuable in finding secondary TN or HFS. Magnetic resonance imaging (MRI) with three-dimensional time-of-flight (3D-TOF) sequence is recommended, which may provide accurate information on the relative locations of the nerve and the vessel (Fig. 1A). Our previous study has observed that a tortured vertebrobasilar artery deviated to the symptomatic side in 86.4\% of HFS patients (Fig. 1B).\textsuperscript{29} However, this phenomenon is not so common in TN patients. Actually, the main function of MRI is to exclude the neoplastic pathologies in the cerebellopontine angle (CPA), e.g., meningiomas, acoustic neuromas, cholesteatomas, etc. The occurrence of these neoplasms, which in all intracranial tumors mentioned above, were

![Preoperative imaging study](image)

Figure 1 Preoperative magnetic resonance imagings (MRI). (A) MRI with three-dimensional time-of-flight (3D-TOF) sequence showed an artery contacting the left facial nerve root. (B) A tortured vertebrobasilar artery deviated to the symptomatic side in a hemifacial case. (C) It was a case of secondary hemifacial spasm (HFS). The space of left cerebellopontine angle (CPA) was bigger with different signal intensity compared to the right side, which delineated a cholesteatoma.
about 13–26%\textsuperscript{30} 8–10\textsuperscript{31} and 3–10\textsuperscript{32} respectively, according to the literature. It should be noted that cholesterol is apt to be missed in the imaging before posterior fossa exploratory surgery (Fig. 1C).\textsuperscript{33} Computed tomography (CT) scan is an alternative when MRI is not applicable because of metal implants.

**Indications**

*Microvascular decompression is appropriate for most TN or HFS patients*

Generally, MVD is indicated for all the patients suffering from drug-resistant TN or HFS as long as their general conditions do not contraindicate general anesthesia. Drug-resistant TN or HFS is defined as uncontrolled pains or spasms when more than 1200 mg per day of carbamazepine is needed or unacceptable complications occur. We would like to point out that old age is not a contra-indication for MVD surgery. Instead, it is much easier to operate on old patients because of wide subarachnoid space as a result of brain atrophy; only those with decompensated dysfunction of vital organs (heart, lungs, kidneys, or liver) should be evaluated cautiously. In our cohort, the patient age at the time of surgery ranged from 8 to 93 years without significant difference in gender and side; the length of symptomatic illness ranged from 3 months to 22 years. We suggest performing the surgery in the early stage before the patient’s quality of life is awfully influenced. Especially for those undernourished because of reduced eating to avoid an attack of severe pain induced by oral movement, a prompt surgery is encouraged.

**Position**

*A proper positioning contributes to a satisfactory exposure*

General anesthesia is the best option for MVD patients. We place the patient in a park bench position (3/4 lateral prone decubitus). This position is superior to supine or full prone position because it obviates the need to turn the patient’s head into an uncomfortable position and therefore decreases the risk of postoperative neck pain. This is especially important for obese patients who usually have generous supraclavicular fat pads. It is necessary to point out that the contralateral shoulder should be close to the edge of the bed so that the surgeon can easily reach the surgical site. Meanwhile, the ipsilateral shoulder should be slanted forward and pulled away from the head by a shoulder belt so as to create a satisfactory working space, which facilitates the instruments getting in and out of the surgical field. A fixation frame is used to hold the patient’s head stable and make it possible to apply the retractor system when necessary during the surgery, though we have not used it even in cases of secondary TN or HFS resulting from CPA masses since 2010, when we began to choose an oblique position for the patients’ head (Fig. 2A). This inclined position with the patient’s head turning back 15–20° from the level surface facilitates the cerebellum to fall away under its own gravity from the petrosal bone and obviates the need of retractors (Fig. 2B). Actually, a good exposure is achieved by rational positioning rather than retracting. Brain relaxation methods such as mannitol/hypertonic saline/hyperventilation are unnecessary in MVD surgeries, especially in old patients, since cerebrospinal fluid (CSF) removal from the cisterns works well. For TN cases, if a very steep tentorium was showed after dural opening, the rostral end of the table could be lowered a bit.

As the approach trajectory is somewhat different between TN and HFS, the patient’s position varies accordingly. As the cranial nerve VII is behind the VIII in the surgical field, the axis of the head should be placed 15–20° downward to expose the proximal aspect of the facial nerve in HFS cases (Fig. 2C). In TN cases, the axis is level.

**Incision**

*The incision is not ‘the smaller, the better’, but too large is not actually good for exposure*

Despite transversal, arc, or reverse ‘U’ shape incisions having been reported,\textsuperscript{34} we choose a vertical linear incision. It is laterally parallel to the hairline and crosses the inion-zygomatic line with 1/3 above and 2/3 below for TN cases and a bit lower for HFS cases (Fig. 3). Nowadays, we have adopted a mastoid retractor to hold the incision and no scalp clip is needed. Owing to the limitation of the retractor’s open angle, a longer than 7 cm incision is not really necessary. To save a good blood supply, undue coagulation should be avoided and a quick retraction of the incision is recommended.

**Craniectomy**

*The craniectomy should be as lateral as possible*

A craniectomy of 3 cm in diameter is enough for most cases. The edge of the sigmoidal sinus should be exposed for both the TN and HFS cases to ensure an ideal surgical corridor. Particularly, the craniectomy should be rostral enough to the transverse sinus for TN cases while low enough to expose the caudal nerves for HFS cases. To avoid dural sinus injury, we prefer craniectomy with pneumatic drill and Kerrison rongeur to craniotomy with milling cutters. Bone dust and chips were preserved for the later cranioplasty. The bone over the sigmoid sinus should be removed in small pieces. Bone wax is effective for homeostasis at the edge of dural sinuses. To obtain a good working angle, the mastoid antrum could be opened if necessary, but it should be immediately waxed to prevent infection and CSF leak.
Figure 2  Positioning. (A) The patient is placed in a 3/4 lateral prone decubitus position with the ipsilateral shoulder slanted forward (a) and pulled away from the head. The patient's head is turned back 15–20° from the level surface (b). (B) The sketch exhibits the benefits of an inclined head position. It offers a bigger visualizable area (B) than a flat position (A) does.
Durotomy
The dural opening is tailored to a maximal exposure of the conflict site
The dural opening is tailored to the anatomy of each case to allow a maximal exposure, which differs between TN and HFS cases. We prefer to make a wide ‘Y’ shape cutting with its tip pointing to the junction of the transverse and sigmoid sinus for TN cases, while to the lower outer quadrant in the surgical area for HFS cases. The end of the durotomy should be 1–2 mm away from the bone edge, so that a gutter is built along the edge of craniotomy after the dura flap is reflexed, which maintains the surgical filed clear from potential outside bleeding. After the dural mater is sutured back with double knotting, the suture thread remains in place (without cutting off), which facilitates tightening when necessary during the procedure. This pattern of dural opening leaves the majority of the dura on the cerebellum, which avails the protection of the cerebellar hemisphere during the process. To avoid shrinkage of the dura due to the heat generated by the operating microscope’s lamp aimed at the surgical field during the intradural portion of the operation, pieces of wet gelfloms are placed over the dura.

Exposure
A good exposure is obtained by sharp microdissection as well as proper positioning and craniectomy rather than harsh retraction
With analysis of our data, we found that approximately 4.5% of the patients had no symptomatic relief postoperatively,18 and the main reason of a failed surgery was that the exact offending vessel(s) was(were) not recognized or the neurovascular contact site was inaccessible intraoperatively. So we believe a full exposure of the trigeminal or facial nerve root is the key to obtaining a good result. Usually, an unhurried suction drainage of CSF and an ample adhesiolysis are effective enough to achieve brain relaxation and no mannitol or lumbar puncture is needed for most of the cases. We do not use retracting blades because a narrow suction tube allows more mobility and can actually afford more working space than a wider spatula does during the operation at a moment when a specific area is dissected. As a matter of fact, with a good knowledge of the regional anatomy, one does not have to visualize the whole area of CPA while operating at a particular site (but those surrounding structures should always be in mind). Basically, an alternate use of a pair of the microinstruments, i.e., a Fukushima teardrop suction tube, a microscissors, a microdissector, and a bipolar coagulation forceps, are enough to complete all the intracranial manipulation. Instead of the ordinary gun-shape forceps, a self-irrigating bipolar forceps can keep the cottonoid over the cerebellum moist all the time and avoid cerebellar contusion. The action of clamping an artery should be avoided, which may cause vasospasms. In that way, one can achieve more effective exposure with less manipulation of the cerebellum (Fig. 4).

Figure 3 Incision. A 7-cm vertical linear incision paralleling laterally to the hairline is made. It crosses the inion-zygomatic line with 1/3 above and 2/3 below for trigeminal neuralgia (TN) cases and a bit lower for hemifacial spasm (HFS) cases. This picture exhibited a trigeminal case.

Figure 4 Exposure. With a proper positioning and an appropriate craniectomy, a satisfactory exposure is established using a sharp microdissection of arachnoids. This was a right trigeminal case. The complete intracranial course of the trigeminal nerve root (V) from pons to Meckel’s cave was visualized.
**Approach**

*A caudorostral approach is suggested*

For TN cases, the protection and management of petrosal veins (PV) poses the main challenges and risks during the operation.\(^{35,36}\) In early cases, we approached the trigeminal nerve from the superolateral aspect of the cerebellum, and PV were obstructing the access path. We used to sacrifice the petrosal vein or its branches to prevent unintentionally tearing at its entry to the superior petrosal sinus, which is disastrous and difficult to manage. In that case, compression with gelfoam is the only way for homeostasis, while coagulation only makes things worse. However, when a gelfoam is used to cover the bleeding point, working space becomes narrower and the following process can be very difficult. Our previous study showed that sacrifice of the petrosal vein may lead to a risk of delayed intracerebellar hemorrhage, which was fatal unless timely identified and treated.\(^{37}\) To detour off PV, we suggest a new entry corridor. Recently, we started to select a caudorostral approach (via cerebellar fissures), through which the root entry/exit zone (REZ) of trigeminal nerve could be accessed directly without sacrifice of PV (Fig. 5a).

For HFS cases, the dissection should also start from the lower cranial nerves with sharp opening of the surrounding arachnoid, while the cerebellum is superomedially retracted by a suction tube. The retraction is most effective when it is parallel to the VII/VIII cranial nerves. Arachnoid membrane over the VII/VIII nerve complex is then cut with microscissors, while the cerebellum is further retracted medially until the pontomedullary sulcus is visualized (Fig. 5B). The REZ of nerve VII is anterior and slightly inferior to nerve VIII and may be directly visualized upon gentle elevation of nerve VIII using a fine dissector.

**Identification of the Neurovascular Confliction**

*A full-way inspection of the nerve root increases the chance to find the culprit*

Apart from I and II, the other cranial nerves are composed of a central nervous system segment and a peripheral nervous system segment. The central segment has a structure similar to that of white matter of the brain, consisting of parallel traveling nerve fibers. It lacks funicular structure and is less vascularized. Conversely, the winding density in the peripheral segment is greater than in the central segment, consisting of undulating nerve fibers, which creates a more elastic and firmer structure. As a result, the peripheral segment of the nerve is more resistant to compression. The central segments of the 12 cranial nerves differ in length. Basically, motor nerves have a shorter central segment than sensory nerves.\(^{38}\) As the central segment of the trigeminal nerve is longer than that of the facial nerve, logically, the TN patients have more chances of lateral confliction than HFS patients.\(^{39-42}\) Hence, TN patients have more chances of lateral confliction (Fig. 6A) than HFS patients (Fig. 6B), which is in accordance with our data (Table 1) as well as others.\(^{43}\) The neurovascular confliction of TN patients is relatively complicated, and a superior cerebellar artery (SCA) along the shoulder of the REZ compressing the caudal side of the trigeminal nerve ventromedially is common.\(^{9,19,44}\) The possibility of multiple offending vessels (arterial and/or venous loops) should be excluded with careful inspection (Fig. 6C). In our series, venous compression is not rare in TN patients.\(^{45}\) For HFS cases, the very medial location of the contact site increases the risk/chances of being missed by a poor exposure and may thus lead to unsuccessful decompression and failure of MVD. In accordance with others,\(^{46-50}\) we found that the most frequent offending vessel was the anterior inferior cerebellar artery (AICA) followed by posterior inferior cerebellar artery (PICA) or vertebral artery.\(^{41}\) Sometimes, the culprit could be those...
arterioles (Table 2) (Fig. 6E). Mobilization of the arterial loop often discloses a site of discoloration (or even an indent) along the nerve, which confirms that the intended pathology is found and predicts a good outcome postoperatively (Fig. 6D). Accordingly, for TN patients, we would check the entire root from pons distally, while focusing on the medial portion of the facial nerve for HFS patients. Nevertheless, to achieve

Figure 6 Identification of the offending vessel. (A) For trigeminal cases, the neurovascular conflict could be anyway along the nerve root. In this case, the trigeminal nerve (V) was compressed rostrally by superior cerebellar artery (SCA) in cisternal portion, which was separated by Teflon (T). (B) For hemifacial cases, the offending artery (*) is often discovered in the axilla (caudal root exit zone) of the hemifacial nerve (VII). (C) Sometimes the nerve is compressed by multiple vessels. In this case, the trigeminal nerve (V) was compressed by the SCA rostrally and by petrosal veins (PV) dorsally. (D) Sometimes an indent or discoloration could be found in the nerve when an arterial loop is removed, which confirms that the intended pathology is found and is predictive of a good outcome postoperatively. (E) Arterioles could also be the culprit. Note that one (a) of the arterioles had been separated by Teflon in this left hemifacial case. These arterioles (a) looked redder in color compared to those veins around under microscope. REZ: the root entry zone of trigeminal nerve; AICA: anterior infracerebellar artery; VIII: the vestibulocochlear nerve; IX-X-XI: caudal cranial nerves.
a high cure rate, it is recommended that the whole intracranial nerve course be a thorough exposed.

**Decompression**

*The principle of MVD is separation of the nerve–vessel confliction rather than isolation with prosthesis between them*

As a matter of fact, a skillful driving of a microdissector in assistance with a fine suction tube by the operator’s two hands are enough to complete the decompression process, including removal of the offending vessel(s) and placement of Teflon felts piece by piece, and no other instruments controlled by a third hand are needed in such a small room. Moving the vessel with forceps is not recommended. The substance of decompression should be separation of the neurovascular confliction rather than isolation with prosthesis between the nerve and the vessel (Fig. 7). Actually, the role of the Teflon is to keep the offending vessel from rebounding, and therefore it is unnecessary to be always put at conflict site.

**Intraoperative Monitoring**

*Electrophysiological monitoring could be used to predict a satisfactory decompression for HFS cases*

Electrophysiological monitoring has been routinely used in our department for years, and it has been proved to be a good way to predict the results for HFS cases. Short acting neuromuscular junction blocking medications were used for intubation. No additional paralytic agent was administered during electromyography (EMG) monitoring. Our published data demonstrated that the abnormal muscle response (AMR) vanished after the decompression in 93.9% of the relieved HFS patients,\(^5\) which was in accordance with others.\(^6\) However, AMR is not always reliable.\(^7,8\) Recently, we also stimulated the offending artery directly during the operation for HFS cases and achieved a wave analogous to the AMR (Fig. 8). We named this new wave as ‘Z-L response’, which could only be recorded at the offending artery and disappeared immediately after the decompression.\(^9\)

To record the Z-L response, the same needle electrodes as used in AMR recording is used. The reference electrodes are inserted into the frontal muscle, and the recording electrodes are inserted into the orbicularis oculi, orbicularis oris, and mentalis muscles. A non-invasive concentric electrode is placed on the offending artery wall near the compression site before it is detached from the facial nerve.

### Table 1 The conflict site in our series

<table>
<thead>
<tr>
<th>Cases</th>
<th>REZ (%)</th>
<th>non-REZ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TN</td>
<td>52</td>
<td>48</td>
</tr>
<tr>
<td>HFS</td>
<td>93</td>
<td>7</td>
</tr>
</tbody>
</table>

REZ: root entry/exit zone; non-REZ: the lateral (cisternal) segment of trigeminal or facial nerve root; TN: trigeminal neuralgia cases; HFS: hemifacial spasm cases.

### Table 2 The offending vessel(s) in our series

<table>
<thead>
<tr>
<th></th>
<th>SCA (%)</th>
<th>AICA (%)</th>
<th>PICA (%)</th>
<th>VA (%)</th>
<th>Arterioles (%)</th>
<th>Vein(s) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TN</td>
<td>41</td>
<td>33</td>
<td>9</td>
<td>7</td>
<td>8</td>
<td>35</td>
</tr>
<tr>
<td>HFS</td>
<td>0</td>
<td>36</td>
<td>52</td>
<td>9</td>
<td>13</td>
<td>1</td>
</tr>
</tbody>
</table>

TN: trigeminal neuralgia; HFS: hemifacial spasm; SCA: superior cerebellar artery; AICA: anterior inferior cerebellar artery; PICA: posterior inferior cerebellar artery; VA: vertebral artery; REZ: root entry/exit zone. Sometimes, more than a single vessel accounted for the confliction.

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**Figure 7** Decompression. The substance of microvascular decompression (MVD) process should be separation of the neurovascular conflict rather than isolation with prosthesis between them. This was a left trigeminal case. (A) The superior cerebellar artery (SCA) was identified as the culprit, which contacted with trigeminal nerve (V) rostrally. (B) The offending artery (SCA) was separated from the nerve (V). In case of rebound, a Teflon wadding (T) was placed between them. Notice that the Teflon was not placed at the original conflict site (*). It may work anyway as long as it could keep the vessel from rebounding. VIII: the vestibulocochlear nerve; PV: petrosal vein.
nerve, and a square impulse (2 mA × 0.2 ms) is delivered. Z–L response monitoring is useful when an AMR is not recorded before decompression or persists after all vascular compressions are properly treated. It could help neurosurgeons to determine the real culprit when multiple offending vessels exist. Accordingly, we suggest monitoring both AMR and ‘Z–L response’ during the MVD for HFS cases.

Closure

The dura should be closed in a watertight pattern

At the end of the operation, the surgical field should be well irrigated with 37°C normal saline to assure that there is no bleeding as well as to vent air. Meanwhile, attention should be paid to make sure the implanted Teflon is stable under the flow of CSF. Before dural closure, it is suggested to place a whole piece of wet gelfoam over the cerebellum, which prevents epidural hemorrhage from assessing to the subdural space as well as protects accidental injury to the brain tissue while suturing. In order to prevent CSF leakage, the dura should be closed with stitch as tight as possible. The operator should begin the stitch process from the lowest level while the assistant is pulling the suture thread, which will protect blood inflow from outside. Sometimes, it is difficult to complete a watertight closure due to dura defect. Then, the dura is sealed with glue and covered by an artificial dura plus bone chips to reconstruct the normal anatomy. Finally, the muscles, subcutaneous tissues and the scalp are sutured layer by layer. No drainage is required (Fig. 3).

Complications

Generally, those complications caused by serious organic lesions, such as cerebellar hemorrhage, abrupt hydrocephalus, facial palsy and numbness (Table 3) can be avoided by an experienced operator. However, those mild complications, e.g., dizziness, disequilibrium, nausea, and vomit, may still occur in some cases (Table 4).9,16 It might be attributable to cerebellar laceration or pneumocrania. Therefore, a good approach with gentle sharp dissection is very important, which avoids undue retraction of the cerebellum. Meanwhile, a thorough irrigation with warm normal saline before tying the last suture of the dura stitch (which should be in the highest position) should not be ignored. Occasionally, an ipsilateral facial palsy or lip herpes may occur a couple of days postoperatively for HFS or TN cases.

Management of Failed MVDs

We have analyzed failed MVDs and found the main reason for the failure was misidentification of the offending vessel followed by insufficient decompression (Table 5).35,41 It was generally caused because a

![Figure 8 Electrophysiological monitoring. For an abnormal muscle response (AMR) wave to be monitored exclusively in patients with hemifacial spasm (HFS), electrophysiology has been widely employed to predict a satisfactory decompression. Recently, we also stimulated the offending artery during the operation for HFS cases and achieved a wave analogous to the AMR. It could only be recorded at the offending artery and disappeared immediately after the decompression. In this case, the offending artery and the conflict site was finally proved to be the anterior infracerebellar artery (AICA) in the cisternal segment of the facial nerve. Notice that the facial nerve was not visualized in this picture due to the positional block of the acoustic nerve (VIII).](image)

Table 3 Postoperative malaises

<table>
<thead>
<tr>
<th>Items</th>
<th>Literatures (%)</th>
<th>Our data (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Face paresthesia</td>
<td>1–35,16,18,63</td>
<td>6.7</td>
</tr>
<tr>
<td>Nausea/vomit</td>
<td>1–29,29,16</td>
<td>15.2</td>
</tr>
<tr>
<td>Hearing change</td>
<td>0.87–16,16,56</td>
<td>2</td>
</tr>
<tr>
<td>Headache</td>
<td>28,29</td>
<td>22.3</td>
</tr>
<tr>
<td>Dizziness/vertigo</td>
<td>0.89–28,16,17</td>
<td>18.2</td>
</tr>
<tr>
<td>Herpes labialis (TN)</td>
<td>1.9</td>
<td>2.1</td>
</tr>
<tr>
<td>Balance disorder</td>
<td>1.6</td>
<td>1</td>
</tr>
</tbody>
</table>

TN: trigeminal neuralgia.

Table 4 Complications of microvascular decompressions (MVDs)

<table>
<thead>
<tr>
<th>Items</th>
<th>Literatures (%)</th>
<th>Our data (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cerebrospinal fluid (CSF) leak</td>
<td>0.89–13,16,63</td>
<td>1.3</td>
</tr>
<tr>
<td>Incisional infection</td>
<td>3–7,16,17,55</td>
<td>0.4</td>
</tr>
<tr>
<td>Meningitis</td>
<td>0.6–9,29,16,17,55</td>
<td>0</td>
</tr>
<tr>
<td>Brain infarctions</td>
<td>0.6</td>
<td>0.2</td>
</tr>
<tr>
<td>Pulmonary embolism</td>
<td>0.6</td>
<td>0</td>
</tr>
<tr>
<td>Facial palsy</td>
<td>0.6–8,17–22,57,58,66</td>
<td>0.7</td>
</tr>
<tr>
<td>Deafness</td>
<td>0.89–8,16,17</td>
<td>0.9</td>
</tr>
<tr>
<td>Cerebellar edema</td>
<td>5.5</td>
<td>3.2</td>
</tr>
<tr>
<td>Hydrocephalus</td>
<td>4.6,16,18,19</td>
<td>2.1</td>
</tr>
<tr>
<td>Cerebellar mutism</td>
<td>1.2,5.5</td>
<td>0.1</td>
</tr>
<tr>
<td>Mortality</td>
<td>0–2.6,16,18,19</td>
<td>0.13</td>
</tr>
</tbody>
</table>
good anatomical angle had not been obtained during the operation. It may happen when PV blocked the surgical way or even when arteries were attached the petrosal bone and made it very difficult to remove the cerebellum (Fig. 9). As TN or HFS is a functional rather than life-threatening disorder, we regard ‘safety’ as the priority of MVD. In case of difficult exposure, we would end the operation if an apparent offending vessel has been identified at the most haunted site, especially when a dent has been observed at the contact point (Fig. 7D). For those patients who do not improve at all after the surgery, we would review the operative video records carefully. As long as we find that not all the entire intracranial root of the nerve has been exposed, we would communicate with the relatives as well as the patient. If the patient is ready to take the risk that arises from additional exposure, we would redo MVD. We are not against the possibility of ‘delayed relief’ mentioned by many authors, especially in HFS cases. However, we do not think it may happen in patients whose symptom were completely unimproved or even deteriorated. It might happen when multiple vessels are involved. Once the larger involved artery is isolated, the symptoms may marginally improve as the main problem has been solved. For the smaller vessel, a little movement may allow the lesions at the interfaces to repair over time. With the restoring of both the epineurium and adventitia, the nerve may finally be isolated from the vessel. Therefore, if the patient hopes for an immediate cure and there is a chance for it, why do we still ask him or her to suffer while anxiously expecting a possible relief? Our philosophy looks like a sort of Eastern view—‘Middle Way’, but it does give the patient more choice. With this surgical strategy, we have achieved a good postoperative outcome with very low incidence of complications.

![Figure 9 An unsatisfactory exposure due to individual anatomical difference. This was a left HFS case. The medial portion of the facial nerve could not be exposed because the anterior infracerebellar artery (AICA) was attached to the petrosal bone (*) and made the retraction of cerebellar hemisphere impossible. V: trigeminal nerve; VIII: the vestibulocochlear nerve; IX: glossopharyngeal nerve.](image)

**Table 5** Comparison of surgical findings between primary and reoperative MVDs in HFS patients (adapted from Ref. 41)

<table>
<thead>
<tr>
<th>Patients</th>
<th>Offending artery(ies)</th>
<th>Conflict site (zone)</th>
<th>Severity of compression</th>
<th>Offending artery(ies)</th>
<th>Conflict site (zone)</th>
<th>Severity of compression</th>
<th>The failure reason of the 1st MVD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VA + PICA</td>
<td>2 and 3</td>
<td>Indentation</td>
<td>VA + PICA</td>
<td>2 and 3</td>
<td>Indentation</td>
<td>Teflon was not enough</td>
</tr>
<tr>
<td>2</td>
<td>VA + AICA</td>
<td>3</td>
<td>Indentation</td>
<td>AICA</td>
<td>4</td>
<td>Contact</td>
<td>Zone 4 missed</td>
</tr>
<tr>
<td>3</td>
<td>AICA</td>
<td>3</td>
<td>Indentation</td>
<td>AICA</td>
<td>4</td>
<td>Contact</td>
<td>Zone 4 missed*</td>
</tr>
<tr>
<td>4</td>
<td>AICA</td>
<td>2 and 3</td>
<td>Indentation</td>
<td>AICA</td>
<td>4</td>
<td>Deviation</td>
<td>Zone 4 missed*</td>
</tr>
<tr>
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<td>2 and 3</td>
<td>Indentation</td>
<td>AICA</td>
<td>4</td>
<td>Deviation</td>
<td>Zone 4 missed*</td>
</tr>
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<td>2 and 3</td>
<td>Contact</td>
<td>AICA</td>
<td>4</td>
<td>Contact</td>
<td>Zone 4 missed*</td>
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<td>4</td>
<td>Deviation</td>
<td>Zone 4 missed*</td>
</tr>
<tr>
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<td>2 and 3</td>
<td>Indentation</td>
<td>AICA</td>
<td>2</td>
<td>Indentation</td>
<td>Incomplete decompression\</td>
</tr>
<tr>
<td>9</td>
<td>AICA</td>
<td>2 and 3</td>
<td>Contact</td>
<td>AICA</td>
<td>4</td>
<td>Deviation</td>
<td>Zone 4 missed*</td>
</tr>
</tbody>
</table>

MVD: microvascular decompression; VA: vertebral artery; PICA: posterior inferior cerebellar artery; AICA: anterior inferior cerebellar artery.

*AICA went through between facial and acoustic nerves.

# A vein went through between facial and acoustic nerves.

\(\text{\textbackslash}\) Decompression between AICA and the nerve was not enough.

Zone 1: where the nerve emerges to the brainstem surface from the parenchymal and goes through the pontomesencephalic sulcus; Zone 2: where the root attaches to the surface of the pons; Zone 3: where it is gradually transitioning to be narrower, which corresponds to the Obersteiner–Redlich zone (the traditional REZ); Zone 4: where the nerve fibrils separates from the brainstem and extends to the internal meatus.

**Disclaimer Statements**

**Contributors** Dr Zhong and Dr R Li performed all the MVD surgeries. The others assisted the operations and collected data; Dr Zhong finished the manuscript; and Dr Li supervised all the work.

**Funding** This study was supported by Science & Technology Committee of Shanghai Municipal (124119a0800) and Education Commission of Shanghai Municipal (10YZ42).
Conflicts of interest None.

Ethics approval This study was approved by the Ethics Committee of XinHua Hospital, Shanghai JiaoTong University School of Medicine.

Reference


