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HOW I DO IT

Surgical technique for trigeminal microvascular decompression

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Abstract
Background Microvascular decompression (MVD) is a non-ablative technique designed to resolve the neurovascular conflict responsible for typical idiopathic trigeminal neuralgia (TN).
Method With the patient in a supine position, a small elliptical retrosigmoid craniectomy is used to approach the cerebellopontine angle and the trigeminal nerve. After careful exploration of the trigeminal root entry zone, the offending vessel is identified and moved away. Oxidized regenerated cellulose is used to keep the vessel in its new position far from the nerve.
Conclusion MVD represents the gold standard first line treatment for TN; its aim is to free the nerve from any contact.

Keywords Microvascular decompression · Trigeminal neuralgia · Surgical technique · Retrosigmoid approach

Abbreviations

MVD	Microvascular decompression
TN	Typical idiopathic trigeminal neuralgia
CSF	Cerebrospinal fluid
TREZ	Trigeminal root entry zone
GA	General anesthesia
OA	Occipital artery
MEV	Mastoid emissary vein
TS	Transverse sinus
SS	Sigmoid sinus
CN	Cranial nerve
CPA	Cerebellopontine angle
SPV	Superior petrosal vein
MR	Magnetic resonance

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Introduction

The clinical features of so-called "typical-idiopathic trigeminal neuralgia" (TN) have been widely described. It is a chronic pain syndrome characterized by episodes of spontaneous or evoked unilateral facial pain experienced in one or more divisions of the trigeminal nerve. The neurological examination is almost always normal, and diagnosis should primarily be based on the patient's clinical history [3]. The pathophysiology of TN is thought to be related to a compression of the nerve root, usually by a blood vessel, at or near the trigeminal root entry zone (TREZ) [6]. Jannetta was the first to propose a microsurgical decompressive procedure to resolve this neurovascular conflict, with good results in terms of pain relief; this technique is known worldwide as microvascular decompression (MVD) [7, 8]. MVD is a non-ablative treatment designed to resolve the compressive conflict between the trigeminal nerve and a blood vessel. Today, MVD is widely recognized as the primary therapeutic option in the treatment of TN [2, 5, 8, 9]. This article presents the microsurgical anatomy and surgical details of MVD, focusing particularly on minimally invasive access to the cerebellopontine angle (CPA) and on the authors' technique for decompressing the trigeminal nerve.

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Indications and limitations

Even though it has general indications and limitations, these are not standardized and may vary considerably between institutions and surgeons. As shown in Table 1, the authors believe that MVD is indicated for all patients suffering from drug-resistant TN due to a neurovascular conflict if general conditions do not contraindicate general anesthesia (GA). In this report, both the microsurgical anatomy and the operating details of MVD are presented.

Relevant surgical anatomy

The relevant surgical anatomy includes: muscular layers of the neck; petrous and occipital bones; occipital artery (OA), extradural vertebral artery and mastoid emissary vein (MEV); transverse and sigmoid sinuses (TS and SS); IVth, Vth, VIth, VIIth-VIIIth and IXth-Xth-XIth cranial nerves (CN); cerebellar hemisphere and brainstem; arteries and veins of the CPA and others. Most of these structures will be in the surgical field at some stage during the procedure, and they must be known and recognized. All surgical anatomical details of the retrosigmoid approach along with advice about avoiding complications are presented in the following paragraphs.

Description of the technique

Patient positioning

Step 1: Following the induction of GA and intubation, with the patient supine, the head is supported by a Mayfield three-point fixation device. Care is taken to position the frontal pin behind the hair line. The head is then elevated above the level of the heart with the intention of facilitating cranial venous drainage. *Step 2:* The head is gently and carefully rotated toward the contralateral side, and a sandbag is then placed under the ipsilateral shoulder in order to support it. *Step 3:* The neck is flexed 10–15° anteriorly with the chin positioned approximately two-finger breadth from the shoulder while keeping the vertex almost parallel to the floor. These steps aim to create a working corridor for the surgeon with minimal disturbance from the ipsilateral shoulder. *Step 4:* The vertex is then gently depressed 10° inferiorly to allow optimal visualization under the surface of the tentorium and the upper neurovascular structures of the CPA. Finally, with the head fixed on the Mayfield support, the patient is taped securely onto the table to allow for further rotation during the procedure when necessary (Fig. 1). This position provides an optimal trajectory straight to the nerve. Special attention must be paid to the ipsilateral shoulder, which in some cases (especially in overweight or obese patients) should be taped and gently pulled caudally so that it does not decrease the view or the working corridor.

Skin incision and soft tissue dissection

A restricted (5×5-cm) area behind the ear is shaved. Identification of anatomical surface landmarks is mandatory before the skin incision. The course of the TS is identified and marked along a line connecting the inion with the zygomatic arch at the level of the supramastoid crest passing through the asterion. A second line showing the tip and body of the mastoid is then drawn. The junction between the TS and the SS is identified and marked at the level of the asterion (Fig. 2a). These important initial landmarks are used to guide the surgeon so as to minimize the length of the incision and the appropriate exposure for the placement of the retrosgmoid craniectomy, which is drawn on the skin, too (Fig. 2b). Neuronavigation can be used to confirm correct landmarks identification and proper craniectomy planning, even though its use is not mandatory. Following the usual sterile draping preparation, a vertical skin incision approximately 4 to 6 cm in length is made about 3 to 5 cm

Table 1 Indications, limitations and relative contraindications of MVD

Indications	Limitations and contraindications
	Relative
Typical idiopathic drug-resistant TN	Atypical or secondary TN (e.g., SM)
Typical idiopathic drug-respondant TN when drug-related side effects are consistent	Typical idiopathic drug-respondant TN without drug-related side effects
MR imaging evidence of neurovascular conflict	No MR imaging evidence of neurovascular conflict
Age<75	Age>75
Good general condition (e.g., suitable to undergo GA)	
	Absolute
	Bad general condition (e.g., not suitable to undergo GA)

TN Trigeminal neuralgia; *MS* multiple sclerosis; *MR* magnetic resonance; *GA* general anesthesia

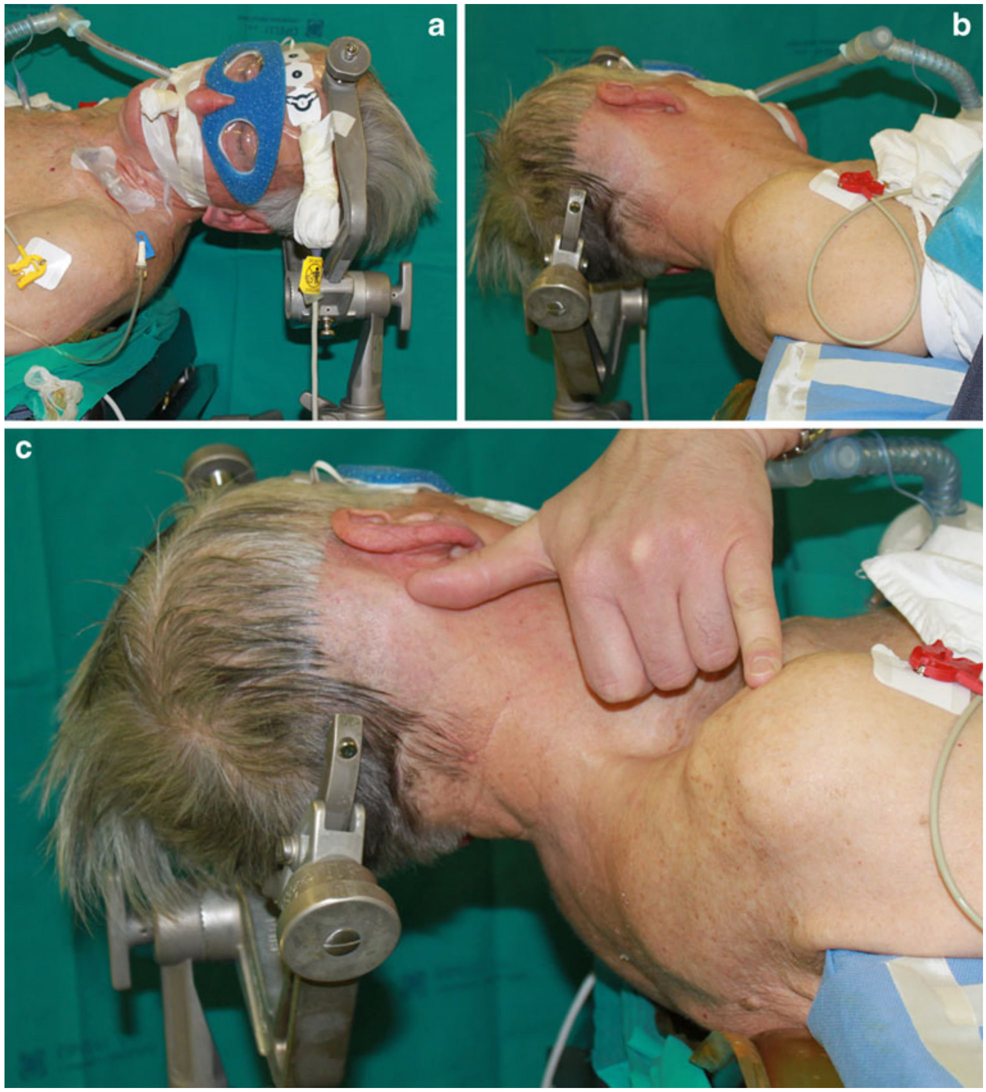

Fig. 1 Patient positioning. **a** Anterior view; note that the vertex is almost parallel to the floor. **b** Posterolateral view; a sandbag is placed under the ipsilateral shoulder in order to minimize the neck rotation. **c** The position should create the necessary working corridor for the surgeon without disturbance from the ipsilateral shoulder

posteriorly from the internal acoustic meatus centered over the pre-planned craniectomy.

The soft tissues are dissected with the aid of a periosteal elevator. The insertion of the splenius muscle is dissected for a brief tract with electrocautery and then retracted to expose the retrosigmoid suboccipital bone area. An orthostatic retractor is positioned to maintain adequate exposure of the occipital bone. The OA is usually encountered as it runs over the deepest muscular layer in the retromastoid area. Once the OA is identified, it is then coagulated and cut. This is generally necessary in order to achieve adequate bone exposure. The MEV connects the suboccipital venous plexus to the SS; this landmark is helpful for localizing the SS. Once the MEV has been identified, its bone orifice(s)

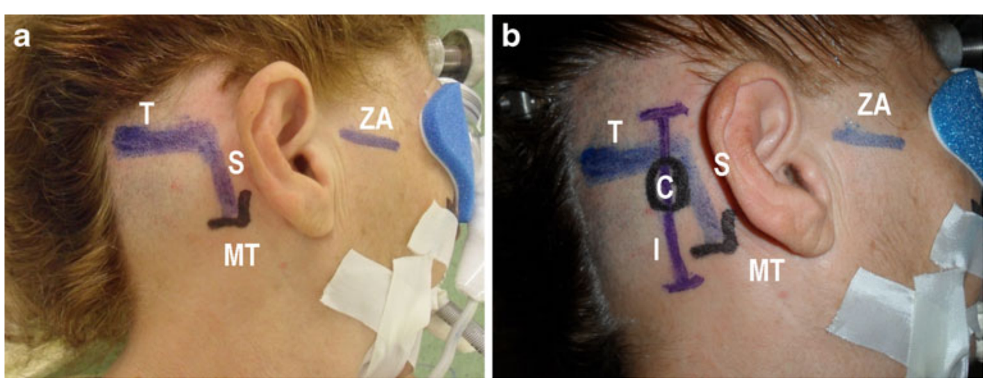

Fig. 2 Identification of the key landmarks. **a** The main anatomical landmarks are drawn on the skin. **b**. The small retrosigmoid craniectomy and the skin incision are marked. T: Transverse sinus. S: Sigmoid sinus. MT: Mastoid tip. ZA: Zygomatic arch. I: Incision. C: Craniectomy

are sealed with bone wax. The size and position of both the OA and the MEV, however, are known to show a considerable variation [1, 10], and knowledge of their anatomy is therefore recommended.

Bone removal: craniectomy

The recognition of bone landmarks is reconfirmed prior to starting bone drilling. Locating the junction of the TS and SS is critical at this point. The asterion is defined as the junction of the lamdoid, parietomastoid and occipitomastoid sutures. It is usually found in a position over the transverse-sigmoid junction (approximately two thirds of cases), but in approximately one third of cases it is found below the transverse-sigmoid junction [9]. Using a high-speed 5–7-mm cutting drill (X-max/E-max2 plus, Anspach, The Anspach Effort, Palm Beach Gardens, FL, USA), a small vertical elliptical craniectomy (3×2 cm) is performed just caudally to the asterion (Fig. 3). The opening is elliptically shaped with the anterior and superior borders constituted by the posterior margin of the SS and the inferior margin of the TS, respectively, and the upper anterior extremity of the ellipse by the sinuses junction (Fig. 4). The bone is progressively thinned until the internal cortical layer appears transparent and can be removed by means of a periosteal elevator or fine punches. Fine punches can be very useful in increasing the removal of the inner edge of the craniectomy; this "trick" allows an increased angle for visualization by creating a direct corridor of sight along the posterior surface of the petrous bone. In many cases some posterior mastoid air cells must be opened to obtain adequate exposure. These must be sealed with muscle and fibrin glue in order to reduce the risk of infection and rhinoliquorrhea.

Exposure of the CPA and nerve decompression

It is at this stage of the procedure that the microscope is introduced. The dura mater is opened in a curvilinear fashion following the shape of the craniectomy with its base toward the SS. A short cut toward the TS-SS junction allows for retraction of the free dural edge, thus exposing both the tentorium and the posterior surface of the petrous ridge and creating a direct supralateral cerebellar corridor below the superior petrosal sinus. A cottonoid is introduced and advanced over the latero-cerebellar surface until the arachnoid of the CPA cistern is found and opened between the VIIth-VIIIth CN and the superior petrosal vein (SPV) complexes. CSF drainage creates the working corridor for retractorless surgery. The arachnoidal opening proceeds toward the trigeminal nerve, which comes into view deep in the surgical field.

The SPV complex (also called Dandy's veins) is usually located superficially and cranially to the trigeminal nerve without interfering with its exposure. However, in some cases, the SPV complex can be in the way to the nerve. It is typically

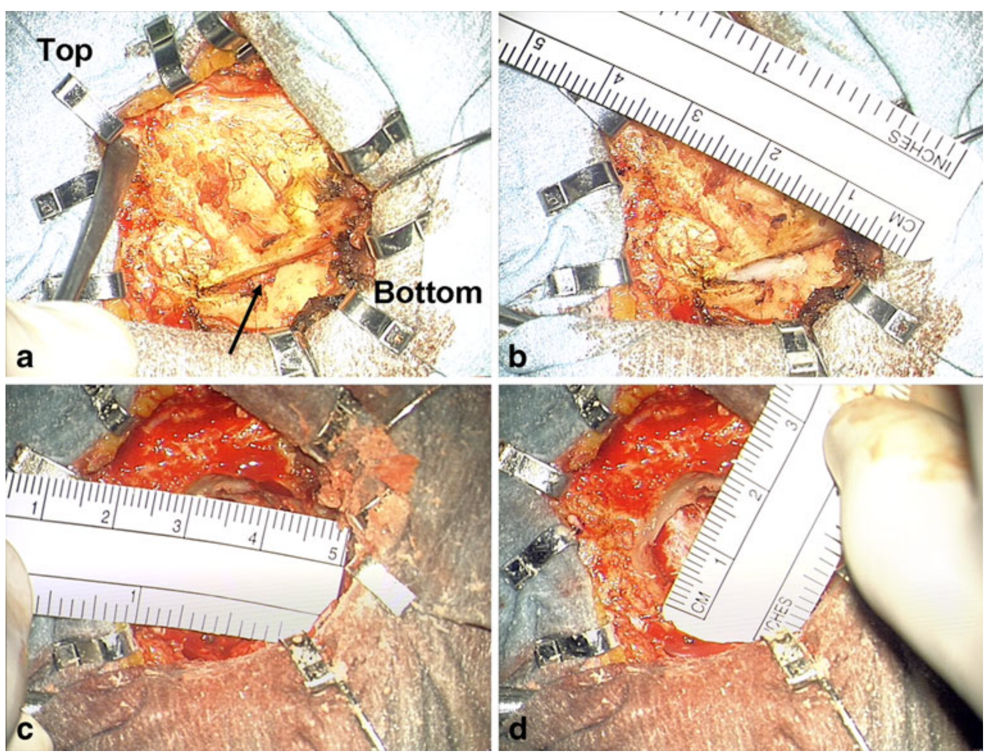

Fig. 3 Right side approach; the top is in the upper left angle, the bottom in the lower right angle. After the incision has been made and the orthostatic retractor positioned, the necessary bone is then exposed. **a** The dissector points to the asterion; the black arrow indicates the digastric groove. **b** Length of the skin incision and bony exposure. **c** Superoinferior measurement of the craniectomy. **d** Anteroposterior measurement of the craniectomy

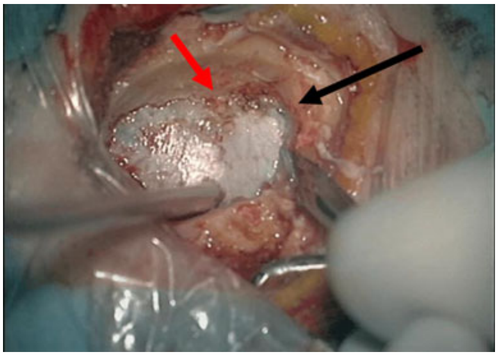

Fig. 4 Left side approach. The craniectomy is completed and the dura mater exposed. The black arrow points to the transverse sinus, and the red arrow points to the sigmoid sinus

formed by three veins converging into a main collector, which can be sacrificed just before entering the superior petrosal sinus without consequences. The indocyanine green temporary clipping test can be used to select patients without an alternative anastomotic drainage pattern [4], in which case venous sacrifice must be avoided.

Once the trigeminal nerve has been identified as running just behind and medially deep to the SPV complex, the nerve is explored along its entire length from its origin at the brainstem to its exit through the porus trigemini.

Cranial nerve electrophysiology, especially the Vth and VIIth-VIIIth nerves, can be monitored during MVD, even though this is not strictly necessary, since the nerves are not manipulated or dislocated (as in cases of CPA tumors, for example). The authors do not perform it on a routine basis.

The neurovascular conflict is often easy to find, although at times it can be hidden by the nerve itself. In these particular cases, the use of an endoscope with an endoscope-assisted technique can be useful. The authors have also performed fully endoscopic MVD, but they believe the microscopic technique is easier, faster and safer.

The TREZ is the most common site of vascular compression. It is the locus of transition from central to peripheral myelin and the most vulnerable part of the nerve. After the neurovascular conflict has been identified (Fig. 5), a sharp dissection of the arachnoidal bands that fix the artery into its position allows for moving away the artery. Great attention must be paid to the small perforating arteries that can, on rare occasions, complicate the artery mobilization. During this stage of the procedure, dedicated micro-instruments are recommended: of these, the Sindou ball-tip 1.2-mm micro-sucker (200005 Sindou Ballpoint suction Kit, Lolbinger LP, Dallas, TX, USA), the Janetta angled-shaft microball-tipped dissector (Stealth Surgical, Gordonsville, VA, USA) and 0.5-mm bipolar forceps are probably the most appropriate for displacing and holding apart the vascular structures and cranial nerves in this region. At this point, pieces of oxidized regenerated cellulose (Tabotamp, Codman Ethicon, Johnson and Johnson, NJ, USA) are strategically placed to keep the artery far from the nerve (Fig. 6). What actually keeps the artery away from the nerve is the wide arachnoidal dissection of all the bands that were holding it close to the nerve. This way the artery finds its new position far from the nerve without the need for any material. Oxidized cellulose is used to reinforce this repositioning far from the nerve. There are cases in which arteries tend immediately to go back on the nerve because of their elastic properties; in these situations the vessels are stuck with fibrin glue as well.

Sometimes the nerve is compressed by one or more veins; these are usually small veins that should be coagulated and sacrificed after the arachnoidal bands that keep them in contact with the trigeminal nerve have been cut. When the conflict is sustained by a large petrosal vein, an indocyanine green temporary clipping test [4] is performed before venous sacrifice. If contrast stagnation is evident (possible lack of collateral drainage pathways), the vein is only displaced. Finally, in cases of conflict due to a vein and an artery, the former is approached as explained above while the latter is delicately mobilized and moved away.

The aim of MVD, in the authors' opinion, is to free the nerve from any contact. This means that whatever material

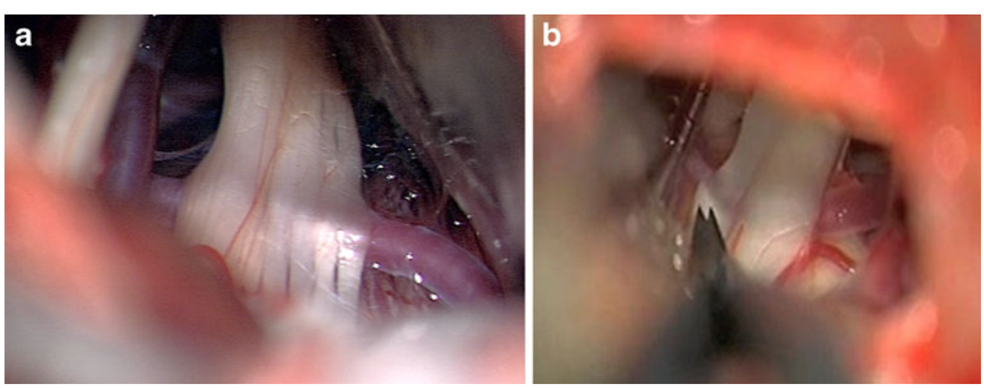

Fig. 5 Examples of neurovascular conflict. **a** Left side. Note to what extent the nerve is split by the artery; the motor fibers are clearly recognizable. **b** Right side. Above the trigeminal nerve elevated by the artery, the petrous vein is visible

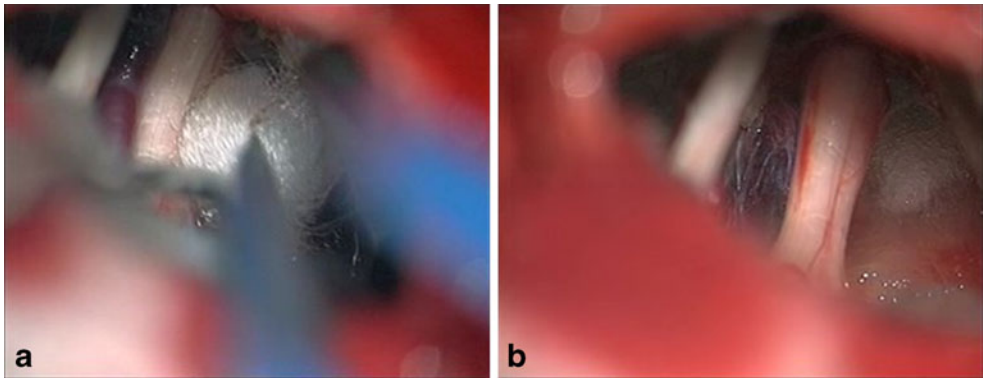

Fig. 6 Same case as Fig. 5a; example of conflict resolution with trigeminal nerve decompression. **a** A tiny ball-shaped piece of oxidized regenerated cellulose (Tabotamp, Codman Ethicon, Johnson and Johnson, NJ, USA) is inserted between the nerve and artery. **b** End of the procedure; the nerve is now free from any contact. The artery is kept away by the Tabotamp. Note that a vein that was also compressing the nerve (superior part) has been coagulated and cut

is used, it should not be applied between the vessel and the nerve, but only on the vessel in order to keep it far from the nerve in its new position. At the end of the procedure neither the material used nor the vessel should be in contact with the nerve.

Surgical closure

Once hemostasis has been assured, the surgical corridor is then irrigated with warm saline. The dura mater is closed by separated 4–0 vicryl stitches. Any residual dural gap is plugged with muscle fragments. Dural closure can be reinforced with sealants (Duraseal, Covidien, Dublin, Ireland; or Tissue-Patch-Dural, TPD, Tissuemd, Ltd., Leeds, UK). The closure is completed by positioning bovine collagen over the craniectomy area (Condress, Abiogen Pharma Spa, Ospedaletto, Pisa, Italy). The operating microscope is moved away, and the craniectomy can by covered with an MR-compatible titanium plate (Bioplate, Bioplate Inc., Los Angeles, CA, USA) to avoid any skin depression. The muscular, subcutaneous and skin layers are closed in the usual manner.

Specific information to give to the patient about surgery and potential risks

Patients must be given all necessary information, and consent must be obtained before proceeding with surgery: of all treatments proposed for TN, MVD is the technique that has shown the highest rate of pain relief and the lowest rate of pain recurrence in long-term follow-up; however, even with this treatment modality, both early and late pain recurrence may occur [2, 9]. Of course, when compared with other treatment modalities (percutaneous techniques or radiosurgery), it carries risks of GA and of surgery-related complications. These are rather rare in experienced hands, but include CSF leakage and infections, multiple CN injuries, major stroke and others.

Specific perioperative considerations (pre- and postoperative workup, instructions for postoperative care)

The preoperative workup must include careful evaluation of the patient's pain history, co-morbidities and neurological examination. Preoperative brain MR imaging with ad hoc sequences is strongly recommended to study the trigeminal nerve course and its vascular relationships, and to rule out other causes of TN (tumors, multiple sclerosis, etc.).

When the procedure is completed and the anesthesiologist gives permission, the patient is then sent to the neurosurgical ward. The patient is mobilized the day after the procedure and can generally be discharged on the 2nd or 3rd day postoperatively. Preoperative oral pain medications are progressively reduced.

In case of early pain recurrence, patients are kept on their usual oral pain medications, sometimes at a higher dosage, and followed for at least 6 months. If the patient complains about the same pain as preoperatively at the 6-month follow-up or later (late recurrence), a new MR scan is performed. When this shows a neurovascular conflict, a new MVD procedure is recommended; conversely, if no conflict is proven, either percutaneous procedures or radiosurgery is proposed to the patient.

How to avoid complications

The patient's position is critical in MVD. If the position is incorrect, the surgical corridor may become too narrow, and the procedure may be much more complicated and longer. The aim of positioning is to allow enough space for the surgeon's hands and the surgical instruments without any interference from the ipsilateral shoulder. In the same way, the exact identification of the main anatomical landmarks before starting to drill makes possible to perform a correctly shaped and sized craniectomy during the procedure.

The TS and the SS margins and their junction must be exposed at the end of the craniectomy; by doing this, once the dura is opened and the CSF drained, one will immediately face the angle formed by the tentorioum and the petrous bone. Even though the CSF leakage guarantees the appropriate surgical corridor without any need for cerebellar retraction, the surgeon should always keep in mind that bleeding in this surgical field is difficult to manage and should be strictly avoided; therefore, cautious dissection of the arachnoidal bands, especially nearby vessels, is recommended.

Once the trigeminal nerve is exposed along its entire length and the neurovascular conflict has been found, the vessel should be mobilized very carefully to avoid damage, arterial spasm and ischemia or small perforating arteries rupture.

CSF leakage is the most common and probably the most frightening complication of MVD. If mastoid air cells have been opened during craniectomy, these must be sealed; in the authors' experience, gluing the muscle with fibrin glue is a good option for this purpose. Equally, a watertight dural closure should be assured at the end of the procedure; this is often difficult to obtain and so the use of pieces of muscle, sealants or something similar is suggested.

Conclusion

MVD represents the gold standard first line treatment for TN. The aim of MVD, in our view, is to free the nerve from any contact either with the offending vessel or with the interposed material.

Ten key points

1. Evaluate the neurovascular relationships of the trigeminal nerve on the preoperative MR imaging.
2. Position the patient following the four steps described above.
3. Draw the planned craniectomy and center the skin incision over it.
4. Perform the craniectomy with a high-speed drill.
5. Recognize TS and SS margins.
6. Avoid cerebellar retraction and wait for CSF drainage until adequate gravity-aided cerebellar relaxation has been achieved.
7. Explore the nerve along its entire length.
8. Perform a wide arachnoidal dissection to allow for arterial replacement far from the nerve, avoiding any contact between the nerve and the material used to keep the artery away.
9. Make a watertight dural closure; if necessary add sealants.
10. Stop oral pain medications gradually.

All patients shown in Figs. 1, 2, 3, 4, 5 and 6 gave their permission for use of the photographs at the time of surgical consent.

Conflicts of interest None.

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