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TECHNICAL NOTE - FUNCTIONAL NEUROSURGERY - OTHER

Wedge-technique for transposition of the vertebral artery in microvascular decompression for hemifacial spasm: technical nuances and surgical outcomes

Yoichi Nonaka[1] · Naokazu Hayashi[1] · Mitsunori Matsumae[1] · Takanori Fukushima[2,3]

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Abstract

Background Transposition of the vertebral artery (VA) for microvascular decompression for hemifacial spasm (HFS) is often challenging. Various procedures have been proposed to transpose the immobile tortuous VA that cannot be decompressed satisfactorily in the usual manner.

Methods A Teflon piece that is cut into a wedge shape was used for transposition of the VA as an offending artery in HFS. One or more wedge-shaped Teflon pieces were simply inserted into a small space between the VA and the brainstem or cerebellar hemisphere without any contact with the entry into the root exit zone (REZ) of the facial nerve. A minimal space can be created by slight mobilization of the VA through rostral or caudal, or in between to the lower cranial nerves (LCNs). In cases of a hypertrophic VA that is hard to mobilize, two or more rigid wedge-shaped Teflon pieces that are coated by fibrin glue can be applied to obtain adequate mobilization of the VA. Moreover, a much harder Teflon bar, which is bent into a V shape, can be used in cases of an immobile VA. Once the VA is transposed to an appropriate position, the Teflon, VA, and contacted surface of the brainstem are fixed together by drops of fibrin glue.

Results The offending arteries were VA-posterior inferior cerebellar artery (PICA) in eight cases, VA in four cases, PICA in four cases, VA-anterior inferior cerebellar artery (AICA) in one case, and AICA in one case. Eighteen cases of HFS were successfully treated using the “Wedge technique.” Symptoms disappeared within 2 weeks in all patients. Transient facial nerve palsy developed in one case, and transient hoarseness developed in one case.

Conclusions The wedge technique is a simple straight-line maneuver that facilitates sufficient transposition of the VA without any related complications. This technique is also useful for other large offending vessels, such as the anterior or posterior inferior cerebellar arteries, which are hard to mobilize due to the torque of the vessels.

Keywords Hemifacial spasm · Indirect interposition technique · Microvascular decompression · Vertebral artery

This article is part of the Topical Collection on *Functional Neurosurgery - Other*

✉ Yoichi Nonaka
ynonaka1971@yahoo.co.jp

1 Department of Neurosurgery, Tokai University School of Medicine, 143 Shimokasuya, Isehara, Kanagawa 259-1193, Japan

2 Division of Neurosurgery, Duke University Medical Center, Durham, NC, USA

3 Carolina Neuroscience Institute, Raleigh, NC, USA

Abbreviations

ABR	Auditory brainstem response
AICA	Anterior inferior cerebellar artery
CPA	Cerebellopontine angle
CSF	Cerebrospinal fluid
HFS	Hemifacial spasm
LCNs	Lower cranial nerves
MVD	Microvascular decompression
PICA	Posterior inferior cerebellar artery
PTFE	Polytetrafluoroethylene
REZ	Root exit zone
TN	Trigeminal neuralgia
VA	Vertebral artery
VBA	Vertebrobasilar artery
VBD	Vertebrobasilar dolichoectasia

Introduction

Microvascular decompression (MVD) is an ultimate surgical procedure that has been widely used for the treatment of hemifacial spasm (HFS), trigeminal neuralgia, and glossopharyngeal neuralgia [1–11]. Several kinds of vessels of the posterior circulation are responsible for these diseases. Transposition of the vertebral artery (VA) in MVD for HFS is often challenging. Various procedures have been proposed to transpose the immobile tortuous or dolichoectatic VA that cannot be decompressed satisfactorily in the usual manner [1–3, 5, 6, 8–17]. Furthermore, various materials including muscle pieces, dura mater, Teflon®, Ivalon® sponges, Gore-Tex®, polytetrafluoroethylene (PTFE), Prolene® sutures, silicon tubes, and aneurysm clip have been used for transposition of the offending arteries in MVD for HFS or trigeminal neuralgia (TN). These techniques are basically divided into two types: interposition technique and transposition technique. In the interposition technique, direct contact of the implant material and the root exit zone (REZ) of the facial nerve should be avoided because the pulsatile pressure will again be transmitted to the facial nerve when the texture of the material changes to be firm by adhesion or granulomatous change [7].

The HFS can be classified into VA-associated HFS and non-VA-associated HFS according to the offending vessel. In the case of non-VA-associated HFS, the anterior inferior cerebellar artery (AICA) or posterior inferior cerebellar artery (PICA) or both are identified as the offending arteries. Basically, the transposition of the vessel is thought to be much easier in such cases than in the case of VA-associated HFS. The technical difference originates from the ability to mobilize. It makes no difference if the VA compresses the REZ directly or indirectly. Even in the case of indirect VA compression, transposition of the VA is required in most cases to move the offending vessel (mainly the PICA) away from the REZ of the facial nerve. A unique interposition technique for HFS caused by the VA, which results in no contact against the REZ of the facial nerve, is described.

Methods and materials

Patient characteristics

Eighteen patients with HFS, whose ages ranged from 33 to 67 years (mean 50.7 years) and who had undergone MVD by using the “Wedge technique,” were retrospectively reviewed.

Surgical procedure

A conventional retrosigmoid approach is used in MVD for HFS with the patient in the lateral decubitus position under the monitoring of auditory brainstem response (ABR) [3, 18]. A 2-in.-long, linear scalp incision and a 1-in. craniotomy are made in the retroauricular area. The dura mater is incised in a curvilinear shape parallel to the border of the sigmoid sinus. The inferior basal aspect of the cerebellum is retracted from caudal to rostral to avoid mechanical pressure to the cochlear nerve. Care must be taken not to retract the cerebellum and arachnoid membrane too much, since some leptomeningeal vessels and vagal bridging veins are easily damaged. The arachnoid membrane over the spinal accessory nerve is cut to remove the CSF, which facilitates relaxation of the cerebellum. Sharp dissection of the arachnoid membrane and trabeculae by microscissors is advanced toward the ninth and tenth cranial nerves to expose the choroid plexus of the lateral recess of the fourth ventricle. After careful dissection, to retract the choroid plexus by a brain spatula from the flocculus to the rostral area is essential for safe exposure of the REZ of the facial nerve at the pons. This allows the safest exposure of the REZ without applying any retraction force to the eighth cranial

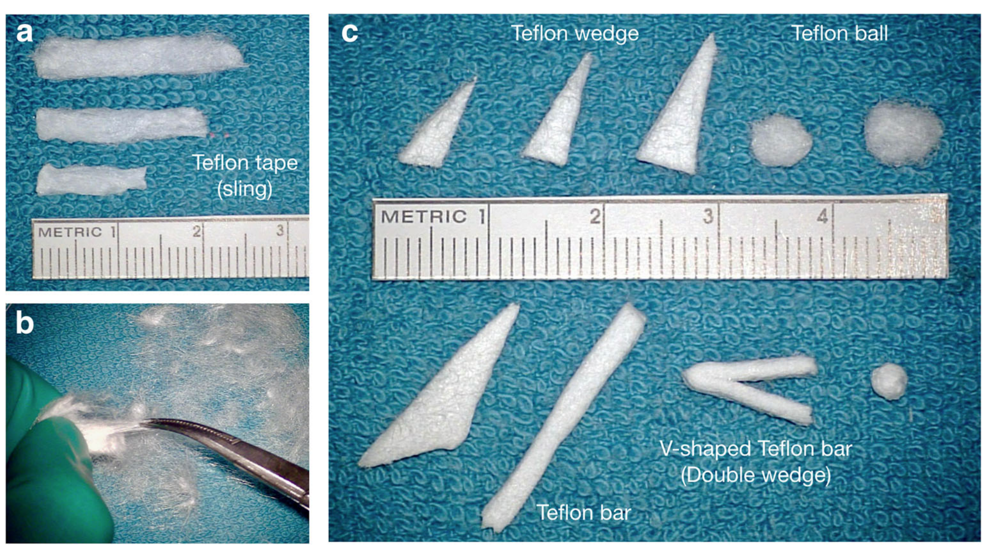

Fig. 1 Teflon prosthesis. **a** Teflon tapes (slings) used for regular transposition. **b** A Teflon sheet is teased into thin strips to form Teflon tapes or balls. **c** Thick Teflon pieces are prepared for VA transposition. Wedge shapes, ball shapes, and bar shapes are used alone or in combination. Pieces in the lower part are coated by fibrin glue and show their smooth surface compared to those of the upper part

Table 1 Summary of characteristics of 18 patients with hemifacial spasm treated by the "wedge technique"

Case no.	Age/sex	Side	Offending artery	Types of Teflon used	Surgical difficulties	Complications	Fu (mo.)
1	42/M	L	VA-PICA	Single wedge ×1 + ball ×1	–	–	72
2	33/F	L	VA	single wedge ×1 + sling ×2	Deep posterior fossa	Transient FN palsy	62
3	45/M	L	VA-PICA	Single wedge ×2 + double wedge ×1 + ball ×2	ABR decrease	–	60
4	52/M	L	VA-PICA	Single wedge ×2	–	Transient hoarseness	58
5	67/F	R	PICA	Single wedge ×1 + ball ×2 + sling ×1	–	–	43
6	57/F	L	VA-PICA	Single wedge ×1	–	–	40
7	51/F	R	VA	Single wedge ×1 + ball ×2 + sling ×2	Tortuous VA	–	39
8	38/M	L	VA	Single wedge ×3 + double wedge ×1 + ball ×4	Tortuous VA, ABR decrease	–	37
9	44/M	L	VA-PICA	Single wedge ×1 + ball ×1 + sling ×1	Tortuous VA, ABR decrease	–	34
10	46/F	L	PICA	Single wedge ×1 + ball ×1 + sling ×1	–	–	33
11	58/F	L	VA	Single wedge ×1 + ball ×2	Tortuous VA	Recurrence	29
12	43/M	L	VA-PICA	Single wedge ×1 + ball ×2	Short perforators	–	27
13	58/F	R	PICA	Single wedge ×1 + ball ×1	Short perforators	–	27
14	62/F	L	PICA	Single wedge ×1	–	–	26
15	61/F	R	VA-PICA	Single wedge ×1 + ball ×2	Short perforators	–	24
16	46/F	L	VA-PICA	Single wedge ×1 + ball ×1+ sling ×1	–	–	14
17	57/M	L	VA-PICA	Double wedge ×1	–	–	4
18	53/F	R	AICA	Single wedge ×1	Short perforators	–	2

ABR auditory brainstem response, *AICA* anterior inferior cerebellar artery, *ball* Teflon ball, *double wedge* double wedge type (V-shaped) Teflon bar, *FN* facial nerve, *fu* follow-up period (month), *PICA* posterior inferior cerebellar artery, *single wedge* Teflon wedge or Teflon bar, *sling* Teflon sling, *VA* vertebral artery

nerve. The offending arteries can be clearly observed through this angle without exposing the seventh and eighth cranial nerves. The offending artery is dissected by cutting the arachnoid trabeculae and gently elevating it with a microprobe and transposing it to the appropriate position toward the petrous surface over the jugular foramen. Extreme care must be taken not to stretch the perforating branches originating from the vessel. If the offending artery is easy to mobilize and transpose, it can be wrapped with Teflon (Bard PTFE Felt, Bard Peripheral Vascular, Tempe, AZ, USA) tape or a sling (Fig. 1a) that is teased from a Teflon sheet (Fig. 1b) and fixed over the petrous dura by spreading out the fine Teflon fibers of both ends [3, 18, 19]. Pieces of Surgicel® (Ethicon US, LLC, Cincinnati, OH, USA) are used to fill in the space between the nerve and the artery-Teflon complex. These complexes are then fixed by drops of fibrin glue (Bolheal®) (Teijin, Tokyo, Japan). Threaded Teflon can also be used as a sling or as a cover fence over the artery.

Wedge technique for VA transposition

One of the most difficult decompression procedures is mobilizing a hypertrophied and tortuous VA. The VA or VA-PICA complex as the offending vessel is usually difficult to mobilize due to its rigidity, large diameter, and hard vascular wall. Teflon slings are sometimes not strong enough to hold and fix such large and rigid vessels. Therefore, a thick Teflon piece, made by cutting a Teflon sheet into various shapes, mainly a bar or wedge shape, is prepared for VA transposition (Fig. 1c). The appropriate shape, size, and length of the Teflon piece are determined by the surgeon according to careful observation of the small space that can be created by mobilization of the VA using a microprobe. A bar- or wedge-shape Teflon piece is then inserted into the space between the vertebral artery and brainstem or cerebellar hemisphere at one or more points. The VA is then shifted to an appropriate position with extreme care not to stretch any of its perforators to the brainstem. While the VA-Teflon complex is kept in place by a microprobe, the fibrin glue is applied onto them. The microprobe should be kept on them until the VA-Teflon complex is fixed firmly. Several pieces of Surgicel are applied over them to secure their adherence to the surface of the brainstem or cerebellar hemisphere. Transposition of the VA often necessitates a ventral shift of the VA along the entire segment that can be accessed through caudal and rostral to the LCNs. This

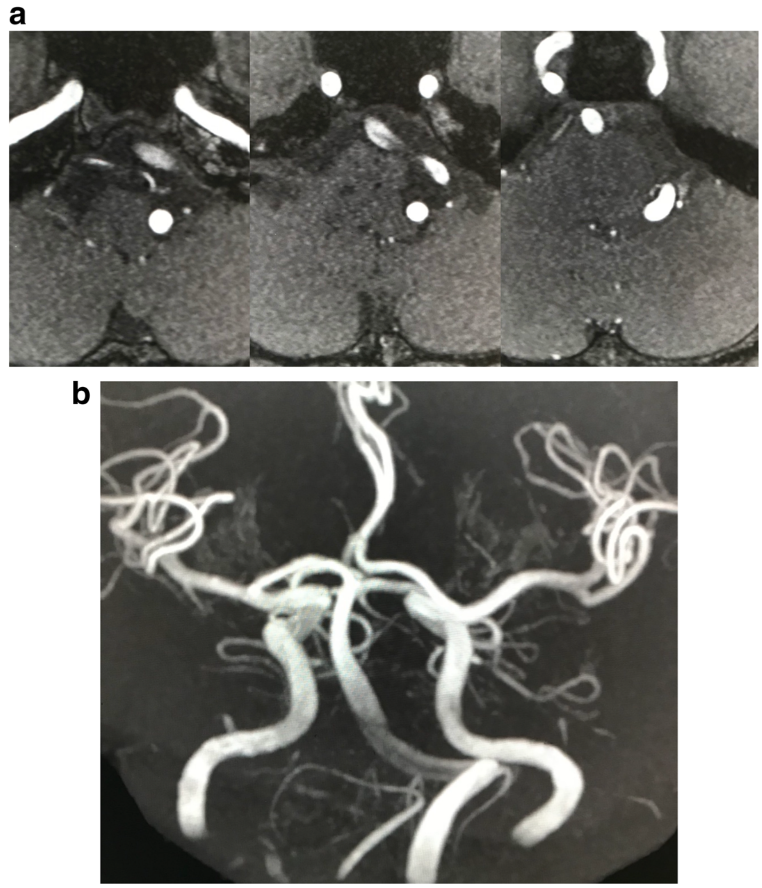

Fig. 2 Preoperative MRI, MRA. **a** Preoperative axial images of time-of-flight MRI demonstrating the compression of the brainstem and REZ of the facial nerve by the left VA. **b** Preoperative MRA demonstrates meander of the left VA

technique is named the "single-wedge" technique. The Teflon piece is cut into a bar, wedge, or triangle shape according to the extent of the space between the VA and the brainstem. A wedge or triangle shape provides much clearer visibility than the bar shape when it is being inserted.

The "double-wedge technique" uses a V-shaped Teflon bar that is made by folding a straight Teflon bar in two. The V-shaped bar is much more rigid and resistant to the restoring force of the VA than the single straight bar. There are two ways to insert the V-shaped bar into the space between the VA and brainstem. If there is only a limited narrow space, a V-shaped bar can be inserted into the appropriate position by folding it into two by microforceps. When a V-shaped Teflon bar is left, it will naturally return to the V shape after it is released. Even though it has no space to return to the V shape or the restoring force of the VA is much stronger than that of the Teflon, the space of the double bar, which is enough to shift the VA, is already occupied. When there is enough space vertically, along with the axis of the VA, a V-shaped Teflon piece can be inserted with 90° rotation. This will provide more steadiness and durability than the use of two single bars. Although the "double-wedge technique" requires more space between the VA and brainstem, it is much more effective than the single-wedge technique. In both of the single- or double-wedge technique, the Teflon bar should be placed in like a bridge, between the surface of the brainstem and cerebellar hemisphere.

Results

Surgical results

In the past 6 years, the wedge technique was used alone or in combination with other techniques to achieve MVD in 18 patients with HFS (Table 1). Thirteen cases out of 18 (72.2%) were VA-associated HFS. The most common offending artery was the VA-PICA (eight cases) followed by the VA (four cases) and PICA (four cases). There were no major complications or mortality related to this procedure. There were some surgical difficulties. A decrease of the ABR during the surgical maneuver restricted the exposure of the compression site. The tortuous VA with arteriosclerotic wall and the short length of the perforators originating from the offending vessels resulted in incomplete transposition of the offending vessels. The symptoms resolved immediately after the surgery in 17 patients. The facial spasm disappeared in 2 weeks after surgery in one patient. Only one patient (case no. 11) had a recurrence of spasm during a mean follow-up period of 35.1 months.

Illustrative case

This 38-year-old man presented with a 4-year history of worsening left-side HFS (case no. 8). The spasms originated around the left eye and then extended to involve the entire left side of the face. Preoperative magnetic resonance imaging (MRI) and magnetic resonance angiography (MRA) showed an aberrant VA of the left side compressing the brainstem near the REZ of the facial nerve (Fig. 2a, b). The patient underwent surgery with neurophysiological monitoring of the cochlear nerve (auditory brainstem response: ABR). The lower cerebellopontine cistern was explored via a left retrosigmoid craniotomy and partial transcondylar drilling. The left VA was seen behind the LCNs, coursing toward the REZ of the facial nerve (Fig. 3a). Since slight retraction of the lower cerebellum decreased the amplitude of the ABR, the compression site

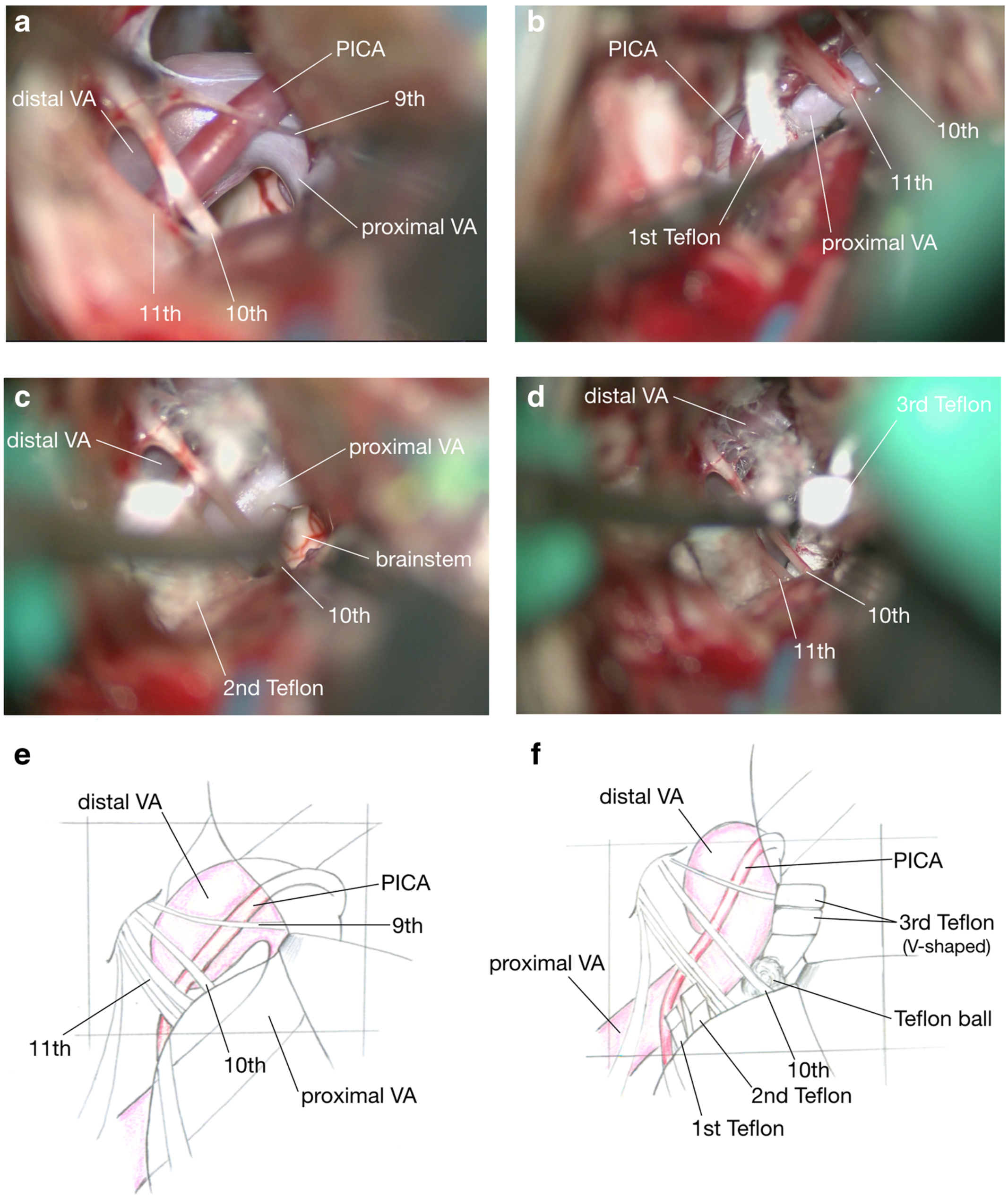

Fig. 3 Intraoperative photos and illustrations. **a** Left-side lower cerebellum is retracted by a brain spatula. A tortuous left VA and PICA are exposed through the LCNs. The proximal portion of the VA and the origin of the PICA are invisible due to limited cerebellar retraction. **b** The first Teflon bar is already inserted into the space between the proximal VA and brainstem through the caudal side of the 11th nerve. It helps to make a small area at the medial aspect of the VA. **c** After insertion of the second Teflon bar, the surface of the brainstem, caudal to the REZ of the facial nerve, is finally exposed. **d** A V-shaped Teflon bar is inserted to transpose the VA firmly just rostral to the ninth nerve. **e** Schematic illustration (of **a**) demonstrating the course of the left VA and PICA before transposition. **f** Schematic illustration (of **d**) demonstrating complete transposition of the left VA with the “wedge technique”

could not be fully exposed. The medial aspect of the tortuous VA was invisible as it coursed toward the REZ. The VA then changed its course sharply distal to the compression site. Due to this exposure limitation and the rigidness of the VA itself, it was clear that the usual method was not strong enough to transpose and keep the VA in the appropriate place. Therefore, thick and long Teflon bars were specially prepared for this case. An initial attempt was made to mobilize the proximal side of the VA by placing a thick Teflon bar between the VA and the cerebellum through the space caudal to the eleventh cranial nerve (Fig. 3b). Another Teflon bar was inserted next to the initial bar rostral to the eleventh nerve. Due to these two Teflon bars, the surface of the brainstem, which was in the vicinity of the REZ of the facial nerve, was finally exposed with minimal shift of the proximal VA (Fig. 3c). Additionally, a V-shaped bar was also inserted next to the second bar for segmental transposition of the VA to the ventral side through the space between the ninth and tenth cranial nerves. Although the REZ and compression site were not visualized, this tortuous VA was successfully transposed as it was gradually shifted from proximal to distal. A thick Teflon sling was also applied to reinforce the transposition of the distal VA and PICA together (Fig. 3d). Care was taken to ensure that there was no kinking or stretching of perforators. The facial spasm disappeared completely after the surgery without any hearing loss. Postoperative MRI showed successful transposition of the left VA by the signal of the Teflon bars (Fig. 4a, b).

Discussion

Decompression of the facial nerve by insertion of some material between the REZ of the facial nerve and an offending artery (direct interposition, cushioning) may be effective only in the short term, because the soft texture of the material will gradually change to become harder due to adhesion or granulation, and then it will lose its shock absorbency. These changes will then allow the pulsation of the offending artery to be transmitted to the REZ again. Therefore, the principle of MVD is to achieve transposition of an offending artery without any material contact with the REZ of the nerve. The senior author first described the importance of no contact of the inserted material with the REZ with the introduction of the unique idea of transposition of the offending vessel using Teflon tape [18]. The Teflon fibers can be used in any shape that depends on the surgeon's preference or the anatomical relationship between the offending arteries and surrounding structures. We routinely prepare various sizes of Teflon slings, tapes, balls, bars, and wedges. These inserts are used alone or in combination with others according to the rigidness of the offending artery, the extent of mobilization, and the anatomical relationships around the lesion. The width and length of these Teflon inserts can be customized taking into account the required space for adequate transposition of the vessel. The Teflon ball is used to make space in preparation for the Teflon insert or for reinforcement after insertion of the main Teflon bar. It is easily inserted into a small space between the vessel and brainstem. However, the Teflon ball shrinks easily and is unsteady; therefore, it is only used as a supplement to a Teflon sling or tape. The fluffy edge of the Teflon piece, which disturbs the surgeon's view and smooth insertion, can be trimmed by scissors and flattened by pinching with fibrin glue-dipped fingers. A clear view of the perforators during Teflon insertion is imperative to avoid pushing them aside. Therefore, this preparation enables visualization of deep small perforators, which should be definitely preserved. Moreover, the smooth surface of the Teflon piece avoids injury to the LCNs and the surface of the cerebellum when it is being inserted.

Several unique techniques and various materials have been reported to achieve successful transposition of the tortuous or dolichoectatic VA and VBA in MVD for HFS or TN [1–3, 5,

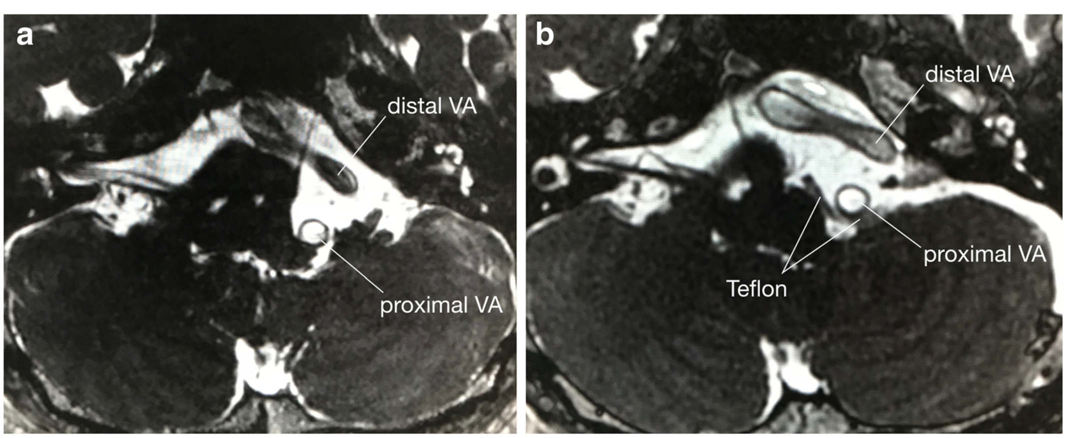

Fig. 4 Pre- and postoperative MRI. **a** Preoperative axial T2-weighted MRI demonstrating the compression of the brainstem and REZ of the facial nerve by the left VA. **b** Postoperative axial T2-weighted MRI demonstrating the successful decompression of the facial nerve with ventral transposition of the left VA. Teflon bars are seen between the left VA and brainstem (*white arrowheads*)

Table 2 Reported surgical techniques for transposition of the vertebral artery for hemifacial spasm or trigeminal neuralgia

Authors	Year	No. of cases	Symptom	Offending artery	Surgical materials for transposition of the VA
Fukushima [3]	1985	726	HFS	VA, VA + AICA, VA + PICA	Teflon felt sling, Teflon tape fence + fibrin glue
Takamiya et al.[9]	1985	2	HFS, TN	Tortuous VBA	Fenestrated aneurysm clip
Suzuki et al. [16]	1990	2	HFS	Ectatic BA	Vascular tape + hemostatic clip (WECK Hemoclip®)
Ogawa et al.[5]	1992	1	TN	tortuous VBA	ePTFE tape (6–0 nylon suture)
Stone et al. [8]	1993	1	TN	Ectatic BA	Silicon sling made from 1.7 mm silicone tape
Yoshimoto et al.[10]	1995	1	TN	Dolichoectatic VBA	Ring-shaped piece of silicone rubber
Bejjani and Sekhar [1]	1997	2	HFS	VA	6–0, 7–0 Prolene suture (Teflon padding)
Kyoshima et al.[12]	1999	6	HFS	VA, VA + AICA, PICA	Dural belt (4.5 cm × 4 mm) + Sugita clip (No. 20)
Ferreira et al. [2]	2011	6	HFS	VA	8–0 nylon suture
Masuoka et al. [13]	2011	5	HFS	VA, VA + AICA, VA + PICA	5–0 thread (hemoclip)
Tanaka et al. [17]	2014	3	HFS	Torturous VA	ePTFE belt (1 mm × 2 mm × 40 mm)
Shimano et al.[15]	2015	33	HFS	VA	TachoComb, polyurethane sponge
Zaidi et al. [11]	2015	17	HFS, TN	VBD	Teflon felt pledgets, GoreTex® or Durasis sling
Munich & Morocos [14]	2018	1	HFS	Dolichoectatic VA	GoreTex® sling (nylon suture, hemoclip)
Otani et al.[6]	2018	10	HFS, GPN	VA, VA + AICA, VA + PICA	TachoSil tissue sealing sheet + fibrin glue

BA basilar artery, *ePTFE* expanded polytetrafluoroethylene, *GPN* glossopharyngeal neuralgia, *HFS* hemifacial spasm, *TN* trigeminal neuralgia, *VA* vertebral artery, *VBA* vertebrobasilar artery, *VBD* vertebrobasilar dolichoectasia

6, 8–17] (Table 2). Some of them require complicated manipulations, which necessitate more time and skill within such a small space. Furthermore, not all techniques can always be applied to a particular VA-associated case. Additionally, complicated manipulations or using a needle in such a narrow space lead to more surgery-related complications. Although these reported techniques were effective for transposition of the VA with acceptable postoperative complications, we strongly believe that surgical manipulation in the deep and narrow area must be simple, especially with the difficult situation caused by a tortuous VA. Less complex, less hazardous, easier handling, and possibly quick manipulation are required for HFS surgery [6, 17].

Reduction of the possibility of complications and the recurrence rate is also another indispensable aspect. The volume of the inserts should be minimized to avoid stretching or occluding the small perforators. Furthermore, complete decompression leaving the REZ and nerve isolated from any contact with artificial material is also mandatory to avoid a foreign body reaction that leads to granulomatous change in the long term [7]. Teflon-induced granuloma that rarely occurs can be one of the reasons for recurrence of symptoms. Insertion of too long a Teflon bar may cause compression of the abducens nerve, which results in diplopia. The wedge technique is a simple, safe, and straight-line indirect interposition procedure, which facilitates easy transposition of the VA without any related complications. This technique is also applied to non-VA-associated HFS cases, which are hard to mobilize due to rigidity of the vessels, with or without a combination of other techniques.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Informed consent Informed consent was obtained from all individual participants included in the study.

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