SURGICAL TECHNIQUE MANAGEMENT OF MICROVASCULAR DECOMPRESSION FOR TRIGEMINAL NEURALGIA

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Trigeminal neuralgia is a severe neuropathic disorder, affecting the distribution area of the trigeminal nerve and often impairs the quality of life of patients. More and more scholars agree that one of the pathogenesis of trigeminal neuralgia is due to the demyelinating lesion caused by vascular compression or arachnoid bundle wrapping on the root exit zone of trigeminal nerve. In this regard, the most effective method is microvascular decompression, which can relieve the compression of the offending vessels and the thickened arachnoid on the trigeminal nerve. However, it still has some disadvantages, such as the possibility of fatal complications. In recent years, with the advancement of neurosurgical treatment technology, new progress has been made in microvascular decompression. This article mainly introduces the surgical techniques and new methods of the microvascular decompression.

Keywords: *trigeminal neuralgia, microvascular decompression, surgical techniques, complication, superior petrosal vein*

SEBÉSZI TECHNIKÁK A TRIGEMINUSNEURALGIA MICROVASCULARIS DEKOMPRESSZIÓVAL TÖRTÉNŐ KEZELÉSÉHEZ

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A trigeminusneuralgia a trigeminusideg eloszlási területét érintő, súlyos neuropathiás rendellenesség, ami gyakran a betegek életminőségének romlásával jár együtt. Egyre több idegtudós egyetért abban, hogy a trigeminusneuralgia hátterében álló egyik ok a trigeminus ideggyök kilépési zónájának demielinizáló laesiója, amit vascularis kompresszió vagy az arachnoidalis köteg szorítása okoz. Ebből következően a leghatékonyabb kezelési mód a microvascularis dekompresszió, ami feloldja az erek és a megvastagodott arachnoidalis köteg szorítását a trigeminusidegről. Mindazonáltal, a microvascularis dekompressziónak számos hátránya is van, így például fatális komplikációkkal járhat. Az elmúlt években azonban az idegsebészeti technológia sokat fejlődött, így előrehaladás történt a microvascularis dekompresszió módszereiben is. Tanulmányunk bemutatja az új sebészi technikákat és a microvascularis dekompresszió új módszereit.

Kulcsszavak: *trigeminusneuralgia, microvascularis dekompresszió, sebészi technikák, komplikáció, vena petrosus superior*

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Primary trigeminal neuralgia (TN) is an uncommon unilateral paroxysmal pain with a rapid, severe, and electric shock-like pain due to trigeminal nerve damage mainly triggered by innocuous stimuli. According to statistics, in most cases, the age of the first onset of TN is between 50 and 60 years old age, and it is more common in women than men. Moreover, more than the average patient begins to have initial symptoms after 40 years old age[1].

The incidence of primary TN is about 5 for100,000 people per year, and a large number of studies have agreed that the nerve root exiting from the pons is chronically compressed by surrounding blood vessels, which causes the demyelination of the compressed parts, which in turn makes the pain and touch abnormal. Among these culprit's vessels, the superior cerebellar artery (SCA) accounts for 75%, the anterior inferior cerebellar artery (AICA) accounts for 10%, and the veins account for 7%[2]. At present, there are many treatment methods for TN. Medication interventions are the first-line therapy, and less invasive treatment methods such as percutaneous balloon compression, stereotactic radiosurgery, trigeminal rhizotomy, and microvascular decompression (MVD) proved to be effective treatment methods by a large number of studies.

Gardner was the first to perform MVD, which could separate the offending vessel from the trigeminal nerve root exit zone (TREZ) and was popularized by *Jannetta* in 1967[3]. However, this technique is not perfect, some patients can not completely relieve symptoms after MVD, and many works of literature report that it has a recurrence rate of 3~30%, which brings much pain to patients. Many scholars have recently proposed some techniques and procedures to refine the MVD surgical technique for this reason[4].

Pre-surgical assessment

First of all, accurate clinical diagnosis of TN plays a critical role in achieving a good prognosis after MVD. Before surgery, the neurosurgeon must perform a complete neurological examination of the patient and make the correct diagnosis according to the American Academy of Neurology and the European Federation of Neurological Societies guidelines[5]. Secondly, the preoperative assessment to elaborate the structure of the vascular compression area is an important part. As a routine clinical imaging examination of TN, three-dimensional fast-imaging employing steady-state acquisition (3D FIESTA) or three-dimensional time-of-flight sequence magnetic resonance angiography (3D-TOF MRA) examinations were performed on all patients before surgery to provide the morphology of blood vessels around the trigeminal nerve and the structural information of the posterior cranial fossa. Magnetic resonance examination can detect whether TN secondary to tumors or cysts, and can also identify trigeminal nerve atrophy, deformation, or bending. At the same time, it can help to determine whether this blood vessel is the superior cerebellar artery, anterior inferior cerebellar artery, or vein before surgery, which is very helpful for neurosurgeons in performing surgery.

ABBREVIATIONS

AICA: anterior inferior cerebellar artery
BAEPs: brainstem auditory evoked potentials
CSF: cerebrospinal fluid
3D FIESTA: three-dimensional fast-imaging employing steady-state acquisition
3D-TOF MRA: three-dimensional time-of-flight sequence magnetic resonance angiography
MRI: magnetic resonance imaging
MVD: microvascular decompression
SCA: superior cerebellar artery
SPV: superior petrosal vein
TN: trigeminal neuralgia
TREZ: trigeminal nerve root exit zone
TREZ: trigeminal nerve root exit zone
VBA: vertebrobasilar artery

Interposition techniques

In all cases the conventional lateral suboccipital retrosigmoid approach was used under general anesthesia[6]. After dural opening, the neurosurgeon first identified the trigeminal nerve, then gently dissected the arachnoid around the trigeminal nerve with sharp microscissors, and gradually exposed TREZ through the natural subarachnoid space to find offending vessels. According to statistics, SCA is the most common offending vessel, but other small arteries, pure venous compression, multivessel arteries and veins compression have also been reported. When the culprit's vessel is detected, the prosthesis is placed between the trigeminal nerve and the offending vessel to achieve the purpose of decompression in the traditional MVD. A study reported that various prostheses, such as autologous fascia, fat, muscle, and different kinds of non-absorbable or absorbable foreign materials were used in MVD[7]. Among them, Teflon is the most widely used prosthetic material. It is elastic and soft with good neural tissue compatibility making it a shock absorber for MVD. A neurosurgeon makes shredded Teflon fibers into a cigar shape or shreds Teflon sponge as an inserted material as usual[8]. However, these Teflon fragments sometimes shift or adhere to the trigeminal nerve, which will reduce the decompression effect. When overfilling Teflon, it causes new compression to the trigeminal nerve, even distorts the surrounding vessels, affects the blood supply and causes ischemic stroke[9]. These will lead to the failure and recurrence of MVD.

Recently, *Jiao* and his colleagues[10] have proposed surgical techniques for using Teflon. Teflon fiber was torn into flocculence and gathered into a ball. Then it was placed in the compressed position of the trigeminal nerve. In the second step, it gently spreads out from the center of the spherical Teflon to the periphery to form a nest-shaped prosthesis under the use of microscissors. It improves the decompressive effect by increasing the nest-shape compressible space, also reduces the use of Teflon. Besides, this low-density hollow structure facilitates the flow and circulation of cerebrospinal fluid, flushing away the blood clots left during surgery, and reduces the chance of adhesion between Teflon and trigeminal nerve and the formation of granulomas. As *Vishwaraj Ratha* described[11], the culprit vessel and the trigeminal nerve were first divided by a Teflon pledget, and then a fat globule was placed between the Teflon and the trigeminal nerve. They called this Fat-Teflon sandwich technique and thought it could prevent the occurrence of Teflon granuloma.

However, the technique of implanting materials during MVD is facing increasing challenges, because various implant materials may compress or adhere to the trigeminal nerve, resulting in recurrence of symptoms. Recently, many studies have suggested that we should not just place a prosthesis between the culprit vessel and the trigeminal nerve as much as possible, and the culprit vessel should be removed from the site of vascular compression reliably and thoroughly.

Transposition techniques

More and more scholars have advocated the "vascular transposition" technique first proposed by Fukushima in recent years[12]. They believe that to solve the problem once and for all requires the trigeminal nerve and the oppressive blood vessels to be permanently separated while nothing coming into contact with the trigeminal nerve. In his article, *Sindou* wrote that patients with TN treated with the "no touching" technique had a better long-term prognosis than those treated with the „touching" technique[13].

But the "transposition technique" is not suitable for all TN. Depending on the situation, different surgical techniques are needed to achieve the purpose of vascular transposition. When the offending vessel was SCA, *Masuoka*[14] first sutured 5-0 thread to the center of the tentorium cerebelli to avoid the sinuses and arteries near the edge of the tentorium cerebelli. Then, he passed the surgical suture around the SCA and tied it into a sling, checking whether the offending vessel twisted. If the compression vessel was AICA, transposed it toward the caudolateral with a surgical suture stitched to the petrous dura. Meybodi used a similar method to treat patients with TN that recurred after previous MVD and achieved good results. Besides, *Gonzalez-Quarante*[15] wrapped around the SCA in the fenestration with a sizable fenestrated clip, and then closed the blades to attach it to the adjacent dural flap.

These methods do a good job of pulling the involved vessels away from the compression point, and there is no implant material in the place where the trigeminal nerve compression generates, which reduces the recurrence rate and the complications rate related to the interposing material to a certain extent. But this technique requires more working space and more time to manipulate the culprit's vessels and to attach them to the dura, which poses a challenge for neurosurgeons, because in the process, it is easy to damage the culprit vessels and their branches, including some veins that have to be sacrificed to create a sufficient working space, which may cause infarction. Besides, it may also cause vascular distortion, vasospasm, or affect the eighth cranial nerve due to excessive retracting of the cerebellum, resulting in deafness.

Recently, someone has come up with a relatively simple technique for transposing and fixing the culprit's vessels. *Otani*[16] utilized an elastic, shapeable TachoSil soaked with fibrin glue to anchor the offending vessels to the adjacent dura mater during MVD. It allows him to quickly and accurately transpose the culprit's vessels and reduce the complications related to intraoperative procedures. However, this technique still has the possibility of kinking of the offending vessels, and some biomedical glue problems are also involved, such as the transmission of prion diseases and whether the adhesion is sufficient to ensure lasting separation.

In the cases of vertebrobasilar artery (VBA) compression, some techniques may not be suitable. According to some literature reports, VBA accounts for 2–7.7% in TN as an offending vessel[17]. In previous MVD, neurosurgeons usually only placed prosthetic material between the compressed trigeminal nerve and the VBA, but the prognosis of patients after MVD was not good. It is related to the characteristics of VBA. First of all, it is difficult to move with its large size, bad elasticity, and relative stiffy. Second, some segments of VBA can be atherosclerotic. Some small plaques may fall off and cause stroke during traction. Third, VBA sends out many important perforating branches to the brainstem, limiting the movement of VBA. These features increase the complexity of the surgery, prolong the surgery time and bring more complications.

In this case, *Raabe*[18] proposed a strip-clip technique that could achieve a lasting decompression effect in which he made a small hole at each end of a strip of equine collagen sheet and then used it to wrap around the VBA into a sling. Then, he used a mini aneurysm clip to pass through these two holes and move to the adjacent dura to determine the best position for the lightest part of the VBA. Then he used microscissors to make a hole in the dura at this position and fix the strip-clip to the petrous dura with a branch of the clip passing through the hole. It was a direct technique of „no touching" without any implanted material placed on the trigeminal nerve. Through retrospective analysis, *Liu*[19] believes that the biomedical glue sling is very efficient and relatively safe for patients with the vertebral artery as an offending vessel.

The above techniques represent different series of transposition techniques. But no one technology is suitable for all situations, and it still needs to be combined with the interposition technique if necessary. Only with adequate preoperative assessment can the most beneficial method be determined for the patient.

Management of veins

Many studies have reported that arteries are the main offending vessels in TN, but more and more reports related veins as well. According to the literature, venous compression alone accounts for 5-18% of the causes of TN[20]. Some people believe that the main reason for the recurrence of TN symptoms or inadequate decompression after MVD may be the venous compression. These veins, such as the transverse pontine and middle cerebellar peduncle, are mainly the trunk or branch of the superior petrosal vein (SPV). They are often encountered during MVD and are an important anatomical landmark for this surgery.

But at the same time, we also know that some of these veins are responsible for draining the deep part of the brainstem, which is very important, and sacrificing these vessels can cause fatal complications, including hemorrhage, brain edema, and even death. Besides, compared to the arteries, some veins adhere to the surface of the brainstem or trigeminal nerve more tightly, and the walls of these veins are so thin and inelastic that it is difficult and dangerous to dissect and separate them. Finally, some anatomical variations in venous drainage paths make it difficult for surgeons to determine whether a vein can be sacrificed during surgery. The above characteristics of these veins make them difficult to handle during MVD.

Feng and his team believe that every effort should be made to preserve drainage veins[21]. They used a suction pipe with a diameter of 2 mm as a reference during surgery to divide the diameter of these veins into three categories: large vein (diameter > 2.0 mm), medium vein (diameter > 1.0 mm but 2.0 mm), and small vein (diameter < 1.0 mm). Then, different strategies are adopted depending on the size of these offending veins. They recommended that the large veins needed to be thoroughly dissected and separated with interposed technique, as these veins can cause severe complications if damaged. As for medium-sized offending veins, especially those draining the brainstem, it will be better to preserve them under the interposed technique. The small offending vein is too delicate to be interposed with a prosthetic material, and its impact on venous drainage is relatively limited, so it is recommended to be sacrificed. But during this procedure, the bipolar coagulation cannot touch the trigeminal nerve, and the current must be low. They think these techniques are very adaptable in reducing the complications caused by venous sacrifice.

Many scholars have also agreed on the principle of preserving the vein as much as possible. Some people have used the biological glue sling technique to adhere some suitable veins to the adjacent petrosal dura[22]. However, others believe that only by sacrificing the offending vein can TN be thoroughly cured. They also suggest including the sacrifice of the SPV in the standard MVD approach. In their opinion, the cause of coma, brain edema, or hemorrhage after MVD is not only the venous sacrifice but also includes sinus thrombosis, excessive traction for preserving the veins or cutting off an unknown artery, etc[23]. The causal relationship between SPV sacrifice and cerebellar or brainstem infarction is overestimated. They also think that there may be some risks in trying to preserve the vein, such as the increased risk of reoperation, a decrease in success rate owing to the vein blocking access to the TN, or secondary hydrocephalus caused by blood accumulated in the cerebral cisterns after unintended vascular rupture. Therefore, venous sacrifice can better ensure that the operation achieves its primary purpose - relieving pain, especially for those patients who suffer from TN for a long time[24].

So far, there is still no universally accepted guideline on venous management during MVD. As a result, surgeons are often confused whether the veins should be sacrificed or preserved. Recently, studies have reported that indocyanine green angiography and venous occlusion test using a mini clip and brainstem auditory evoked potentials (BAEPs) can help surgeons evaluate the drainage of veins and whether they can be sacrificed[25]. However, these techniques still cannot accurately determine the risk of venous sacrifice.

The intraoperative management of veins needs to be further explored, based on full understanding of the anatomical structure of the SPV. With the help of magnetic resonance imaging (MRI) data and more intraoperative monitoring technologies in the future, we can finally determine whether a vein can be sacrificed or preserved.

Awake MVD

According to the literature, the rate of immediate pain relief after MVD is as high as 95 - 97%. However, there are still some patients whose pain has not improved and may have to undergo surgery again, which brings a heavy burden to them. One of the reasons of the failure is the lack of an intraoperative neuroelectro-physiological monitoring indicator that can detect the effect of decompression immediately during surgery. In recent years, awake craniotomy has been widely used in glioma resection, carotid endarterectomy, functional surgery, and even cerebral aneurysm clipping[26]. In 2018, *Abdulrauf* and his colleagues first published an article on the effects of "awake MVD" in the treatment of TN[27]. When the trigeminal nerve is completely exposed, they assess the pain relief gradually before and after decompression under intraoperative electrophysiological monitoring. This technique can help surgeons perform further manipulations that are more beneficial to the patient according to his response during the surgery. For example, it can help determine the necessity and range of internal neurolysis or selective partial rhizotomy, which are effective supplementary means to MVD to achieve complete pain relief. Not only that, but it can also help surgeons find some hidden culprit vessels that are negative in MRI, thereby further improving the success rate of MVD and reducing the chance of insufficient decompression and reinterventions.

In general, awake MVD is an efficient and feasible surgical procedure with a great prospect in the future. However, with few related reports at present, more patients and their long-term follow-up data need to further investigations.

Endoscopic MVD

MVD has been considered an effective and durable treatment for TN since it was proposed for the first time[28]. Traditional MVD uses microscopes, through which the surgeon can achieve good results with skill and carefulness. But there is a nonnegligible limitation: the surgeon can only visualize objects directly ahead, not those structures that are outside the direct field of view. Especially for some patients with abnormal or very complicated anatomic structures of the posterior cranial fossa, sometimes it is difficult to obtain a good visualization for deep structures to identify the offending vessels[29]. Besides, retracting the cerebellum and sacrificing part of the SPV in conventional MVD may be unavoidable to sufficient exposure to the TREZ. These are risk factors that may lead to failure of MVD or serious complications.

In recent years, in addition to the revolution of anterior skull base surgery, endoscopy has been widely used as an imaging tool in neurosurgery. As early as 1917, Doyen applied the endoscopic technique of posterior fossa to trigeminal rhizotomy[30]. Not long before, *O'Donoghue* and his colleagues presented the advantages of endoscopy in the operation of a cerebellopontine angle compared with microscopy. With the development of endoscopic technique, more and more reports about the role of fully endoscopic technique and endoscope-assisted technique in MVD have generated.

Unlike microscopes, endoscopes have better lighting and panoramic view and show the deep structure of CPA more clearly. For the endoscope, it is easy to adjust its angle and depth of the surgical visual field, so to examine the hidden area of TREZ. It is reliable in detecting compressed blood vessels and ensuring adequate decompression. About 8% of the cases in which vascular compression could not found under the microscope could be examined by endoscopy. Moreover, patients no longer need to be repositioned during surgery[31]. Besides, endoscopy is less invasive because it requires only a smaller bone window, less cerebrospinal fluid (CSF) drainage, less damage to the perforating arteries and the SPV, and avoids the traction of the cerebellum and surrounding cranial nerves. Therefore, the endoscopy technique may improve the success rate of MVD and effectively decrease the incidence of complications[29].

However, endoscopy has some limitations of its own. First of all, if the blood vessel ruptures during the surgery, it would obscure the endoscopic display, and even break the surgery, making hemostasis more difficult. Second, the endoscope can only provide vision at the tip, not backward or on both sides. At the same time, the endoscope can continue to produce heat. It is necessary to avoid excessive contact with adjacent tissues during the surgery to prevent damage to surrounding structures. Third, some endoscopes do not have a three-dimensional image and lack a sense of depth. Extensive endoscopic training to apply in delicate microsurgery operations is required for surgeons, which gives the long learning curve of endoscopes. Fourth, endoscopy occupies part of the space in the bone window, and the surgeon needs to hold it with one hand during surgery, which to some extent, limits its dexterity.

At present, there is no accepted selection criterion for using a microscope or endoscope in MVD. Neurosurgeons should be proficient in both techniques, which are complementary rather than competitive. Only in this way can we take full advantage of each method to bring the best outcome to patients with TN.

Conclusions and future perspectives

Nowadays, MVD has been regarded as a safe and effective method to treat TN[32]. However, traditional MVD has some disadvantages that may lead to adverse consequences. With the development of science and technology and the deepening of clinical research, several surgical methods and techniques have been implemented and applied to improve MVD. They can reduce the incidence of complications and improve the life quality of the patients. New techniques, such as „awake MVD" are still in their infancy, and their efficiency is still uncertain. Therefore, more efficient large-scale randomized controlled studies on each new MVD technique are needed in the future to confirm their role and value in clinical treatment. In general, neurosurgeons should fully grasp the anatomy of the posterior cranial fossa, be familiar with the advantages and disadvantages of various MVD technologies, and implement the optimal surgical procedure for the patient in combination with careful preoperative evaluation.

DECLARATION OF COMPETING INTEREST
None.

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