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Determining prognostic factors in the treatment of primary hemifacial spasm: Clinical outcomes and complications. A literature review

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ABSTRACT

Objective: Primary Hemifacial Spasm (PHFS) significantly impacts quality of life, necessitating effective treatment like microvascular decompression of the facial nerve. This study aims to identify prognostic factors related to surgical treatment to enhance outcomes and minimize complications. A systematic review of literature from the past five years was conducted.

Methods: Following PRISMA guidelines, we systematically searched databases like PubMed, Embase, Scopus, Ovid, EBSCO, and Cochrane using keywords such as 'Hemifacial spasm,' 'Microvascular decompression,' 'Neurovascular conflict,' and 'Surgical techniques.' The search spanned January 2018 to November 2023. The 'Rayyan' program facilitated data compilation. Each author reviewed abstracts, applying inclusion criteria like systematic reviews, clinical trials, observational studies, and case series, while excluding theoretical or non-English articles.

Results: Of 26 selected articles, those solely addressing PHFS treatment with botulinum toxin and lacking surgical procedure data were excluded. Thus, our analysis focused on 16 articles, including meta-analyses, systematic reviews, clinical trials, and observational studies.

Discussion: Microvascular decompression at the cerebellar pontine angle is the mainstay treatment for hemifacial spasm. Despite limited statistically significant prognostic factors in the literature, overarching recommendations aim to improve outcomes, minimize complications, and prevent recurrences. Key considerations include surgeon expertise, precise techniques, thorough nerve exploration, identifying the conflict's cause, and intraoperative monitoring.

Conclusions: PHFS significantly impacts patients' lives, necessitating timely surgical intervention if initial treatments fail. While statistically significant prognostic factors may be lacking, this study highlights crucial considerations for successful treatment.

1. Introduction

Since 1875, when Schultze provided the initial description of Primary Hemifacial Spasm (PHFS), the clinical, pathophysiological, and therapeutic concepts have undergone continuous evolution. He defined PHFS as the "involuntary contraction of the musculature of half of the face," and although the first documented case was attributed to an aneurysm of the vertebral artery in contact with the facial nerve, it laid the foundation for understanding the pathophysiology.[1–5] The modern concept of PHFS emerged in 1888 (W R Gowers) and was termed "Clonic spasm," distinguishing it from other forms of abnormal facial movements. It wasn't until 1947 that Campbell and Keedy associated facial symptoms with arterial compression of the nerve.[1,6–9]

With an estimated incidence of 0.74 per 100,000 inhabitants and a prevalence of 7.4 per 100,000 for men and 14.5 for women, PHFS is considered a rare condition.[1,10,11] The most widely accepted definition is that of a chronic benign involuntary movement on one side of the face, characterized by spasmodic contractions, tonic activity, and synkinesis

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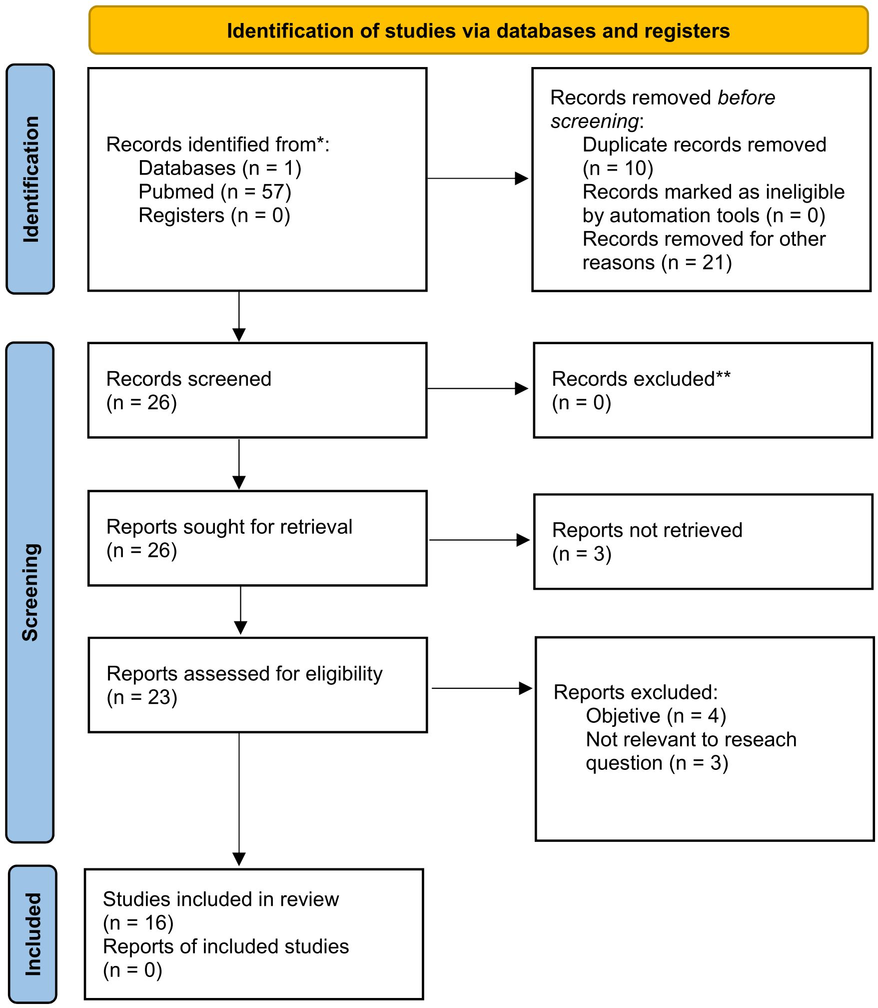
Table 1
PRISMA flow diagram.



*Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers).

**If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools.

of the musculature innervated by the affected facial nerve. In most cases, it originates from an abnormal and pathological contact between an artery in the pontocerebellar angle (most frequently the anteroinferior cerebellar artery) and the Root Exit Zone (REZ - Obersteiner Redlich) of the facial nerve (95 % of cases) and/or in the distal, cisternal, or intrameatal portion of the nerve (5 %).[1,9–11] This zone (REZ), described by Emil Redlich and Heinrich Obersteiner in 1897, represents a transitional segment between the peripheral portion (Schwann cells) and the central portion (oligodendrocytes more sensitive to mechanical compression) of the nerve (cranial and spinal). It is considered the structural and functional boundary between the peripheral and central nervous systems. The pathological contact between the artery and nerve gives rise to a dual mechanism (peripheral and central) of demyelination and hyperactivity that triggers the symptoms.

While initial treatment may involve pharmacological or percutaneous approaches such as botulinum toxin application, the definitive and curative intervention is microvascular decompression of the facial nerve. Walter Dandy was the first to draw attention to the abnormal contact between the artery and nerve, although he did not identify it as the underlying cause of the symptoms. In 1962, James Gardner and GA Sava published the first series of 19 patients treated with decompression, presenting the initial article establishing this pathological contact between artery and nerve as the pathophysiology of PHFS with the potential for definitive treatment. It was Gardner in 1962 who described the decompression procedure (J Neurosurg 1962, 19:947–957), later popularized by P.J. Jannetta (Pittsburgh), who performed the first microvascular decompression surgery through a retromastoid approach in 1966. This procedure was further popularized by Jules Hardy in Montreal.[1,6–9]

In 2018, a systematic review and meta-analysis on the surgical treatment of PHFS and its prognostic factors were published in the journal Neurochirurgie. In this study, we conduct a systematic review of the literature from the past 5 years and propose an innovative analysis of the elements and factors influencing the prognosis of surgical treatment

Table 2
Summary of the articles selected in the systematic review.

Article	Author, year	Design	Population	Procedure	Outcome
Spasm Freedom Following Microvascular Decompression for Hemifacial Spasm: Systematic Review and Meta-Analysis	Holste K, 2020	Systematic review and meta analysis	6249 patients from 39 studies	Microvascular decompression	Spasm freedom rate 90.5 % 1.25 ± 0.04 years
Usefulness of intraoperative monitoring in microvascular decompression for hemifacial spasm: a systematic review and meta-analysis	Sprenghers L, 2022	Systematic review and meta analysis	42 studies included in quantitative synthesis and 64 studies included in qualitative synthesis	Lateral Spread Response (LSR) and Brainstem Auditory Evoked Potentials (BAEP)	postoperative sensorineural hearing loss 3.4 %.Alarm criteria by the American Clinical Neurophysiology Society are a sensible predictor for postoperative hearing loss. LSR monitoring has high diagnostic accuracy at short-term follow-up.
Microscopic versus endoscopic microvascular decompression for the treatment of hemifacial spasm in China: A meta-analysis and systematic review	Zhao Z, 2021	Meta analysis and a systematic review	1122 patients form 12 studies	Microscopic versus endoscopic microvascular decompression	E-MVD can provide superior treatment effects than MI-MVD for HFS.
The outcome of microvascular decompression for hemifacial spasm: a systematic review and meta-analysis	Li J, 2022	Systematic review and meta analysis	6 articles	Microvascular decompression for vertebral associated HFS and for non associated	VA-associated HFS are predominantly left-sided with older patient age, while women are more prevalent in non-VA-associated HFS patients. MVD for VA-associated HFS may pose a higher surgical risk for post-operative complications.
Predictors of Multi-Vessel Identification, Outcome, and Optimal Surgical Timing for Microvascular Decompression in Hemifacial Spasm	Ghaffari-Rafi A, 2023	Systematic review and meta analysis	21,795 patients from 86 manuscripts	Microvascular decompression	Use of endoscope improves visualization and aids in identifying multiple offending vessels, but doesnt seem to improve overall outcomes. Earlier surgery associated with improved clinical outcomes.
The Utility of Intraoperative Lateral Spread Recording in Microvascular Decompression for Hemifacial Spasm: A Systematic Review and Meta-Analysis	Thirumala PD, 2020	Systematic review and meta analysis	7479 patients from 26 studies	LSR monitoring	Intraoperative LSR monitoring provides high especificity but low sensitivity for predicting postoperative HFS-free
Prognostic Value of Abnormal Muscle Response During Microvascular Decompression for Hemifacial Spasm: A Meta-Analysis	Zhang J, 2020	Meta analysis	14 meta-analysis	Abnormal muscle response (AMR) monitoring	AMR during MVD demonstrate limited prognostic value fora a favorable short-term outcome, and does not appear effective in predicting the long-term outcome.
Influence of Minimum Alveolar Concentration and Inhalation Duration of Sevoflurane on Facial Nerve Electromyography in Hemifacial Spasm: A Randomized Controlled Trial	Yang LN, 2023	Randomized controlled trial.	80 patients	propofol-remifentanil total intravenous anesthesia alone or in combination with sevoflurane at 0.5, 0.75, or 1 MAC.	Sevofluorane reduced de LSR amplitude in a dose dependent and duration dependent manner. The combination of intravenous propofol-remifentanil anesthesia with 0.5 MAC sevoflurane allows reliable intraoperative LSR monitoring in hemifacial spasm patients.
Different MRI-based methods for the diagnosis of neurovascular compression in trigeminal neuralgia or hemifacial spasm: A network meta-analysis	Liang C, 2023	A network meta-analysis.	2085 patients from 26 studies	Performance of different diagnostic imaging methods	3D MIF based on 3D TOF MRA combined with HR T2WI had better diagnostic performance for detecting NVC in patients with TN or HSF than other MRI-based imaging methods.
Comparison of Serum Concentration of Ca, P, Mg, and Fe between Hemifacial Spasm Patients and Healthy Controls; Prospective Randomized Controlled Study	Ulusoy EK, 2018	prospective randomized controlled study	86 patients	Measurement of concentration of serum Ca, P, Mg and Fe	Concentration of serum Ca, P, and Mg in the HFS patients was found to be lower in the control group which was statistically significant ($p < 0.05$). No statistically difference in concentration of Fe.
Efficacy of microvascular decompression on the vascular compression type of neurogenic hypertension: A meta-analysis	Song HD, 2020	Meta analysis	162 patients from 6 studies	Microvascular decompression	MVD of RVLM could be an effective treatment option of this type of hypertension, and the effective rate was 70.1 %. MVD as the treatment of this type of hypertension is both effective and safe.
Risk factors for postoperative delirium in patients undergoing microvascular decompression	He Z, 2019	Retrospective study	912 patients	Identify risk factors for posoperative delirium in patients undergoing MVD	Old age, male sex, a history of hyrtension, preoperative CBZ therapy (especially long-term high-dose therapy), postoperative sleep disturbance, and the Mount Fuji sign on postoperative brain CT scans were associated with developing PODE after MVD procedures

(*continued on next page*)

Table 2 (*continued*)

Article	Author, year	Design	Population	Procedure	Outcome
The Epidemiology, Cause, and Prognosis of Painful Tic Convulsif Syndrome: An Individual Patient Data Analysis of 192 Cases	Yin Z, 2021	IPD meta analysis	57 reports including 192 cases with PTC	Patients with painful tic convulsif (PTC) were analyzed	PTC is more likely to initiate as HFS and afflict middle-aged women between 40 and 60 years old, with left-side symptoms more commonly seen than the right side. MVD could effectively treat PTC,with a cure rate >80 % after surgery. AICA/PICA involvement is predictive of a successful surgery, whereas older age is associated with a higher risk of recurrence.
A segmentation-independent volume rendering visualisation method might reduce redundant explorations and post-surgical complications of microvascular decompression	Wang B, 2020	Prospective study	220 patients	SI-VR and 3D fast spin echo T2WI	SI-VR had a better interobserver agreement (0.82 vs 0.68) and diagnostic accuracy (95.5 % vs 83.6 %, $p = 0.004$) than that of 3D fast spin echo T2WI. The SI-VR method is feasible for the precise demonstration of the anatomy structure along the REZ, with high reliability and reproducibility
A Meta-Analysis of Endoscopic Microvascular Decompression versus Microscopic Microvascular Decompression for the Treatment for Cranial Nerve Syndrome Caused by Vascular Compression	Li Y, 2019	Meta analysis	1093 patients from 9 studies	Endoscopy microvacular decompression and microscopic microvascular decompression	E-MVD is more safe and has better postoperative efficacy in comparison with M-MVD, and hence E-MVD should be considered as the preferred method for the management of trigeminal or glossopharyngeal neuralgia and facial spasm.
Haemodynamic changes and incisional bleeding after scalp infiltration of dexmedetomidine with lidocaine in neurosurgical patients	Kim H, 2019	Randomised controlled study	52 patients	Use od dexmedetomidine or epinephrine to reduce scalp bleeding	Epinephrine-lidocaine mixture may be substituted by dexmedetomidine-lidocaine for scalp infiltration in neurosurgical patients, especially hemodynamically compromised patients or especially in patients with a low blood pressure.

for PHFS.[12–14]

2. Materials and methods

A systematic search of medical literature from the past 5 years (January 2018 to October 2023) was conducted, following the principles recommended by PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis). The search terms employed in the databases included Hemifacial spasm, microvascular decompression, neurovascular conflict, posterior fossa malformations, and vessels. The databases utilized comprised Pubmed, Embase, Cochrane Library, Clinical Trials, Scopus, Ovid, EBSCO Host, and Google Scholar. The "Rayyan" program facilitated the compilation and analysis of information, serving as a platform for data manipulation. Independently, each author reviewed the abstract of every located article, applying the following inclusion and exclusion criteria. Inclusion criteria encompassed systematic literature reviews, clinical trials, observational studies, and case series, while exclusion criteria included theoretical articles, narrative reviews, and articles in languages other than English.

A total of 26 articles were obtained and independently reviewed by each author. Among these, those presenting a population analysis were selected. Thirty-three articles were identified as duplicates, and 203 were initially excluded based on title, subsequently by abstract. The reviewed articles encompassed 16 articles, comprising 5 meta-analyses, 6 systematic reviews with meta-analyses, 3 randomized clinical trials, 1 retrospective study, and 1 prospective study (Table 1, Table 2).

3. Results

Out of the 26 selected articles, those solely focused on the treatment of PHFS with botulinum toxin application and lacking data related to surgical procedures were excluded. Consequently, our analysis is centered on 16 articles, which comprise: 5 meta-analyses (Li Y – 2019, Yin – 2021, Song-2020, Liang-2023 and Zhang-2020), 6 systematic reviews with meta-analyses (Holste-2020, Sprenghers-2022, Zhao-2021, Li-2022, Ghaffouri-2023 and Thirumala-2020), 3 randomized clinical studies (Yang-2023, Ulosoy-2018 and Kim-2019), 1 retrospective study (He-2019) and a prospective study (Wang-2020).[15–33] (Table 2)

The 5 meta-analyses span from 2019 to 2023. Notably, Zhang (2020) synthesizes 14 meta-analyses, emphasizing the value of modifying abnormal muscle response during monitoring as a predictor of immediate outcomes. Liang (2023) analyzes 2085 patients across 26 studies, highlighting the diagnostic relevance of resonance and recommending the use of 3D TOF MRA combined with HR T2W1. Song (2020) reviews 162 patients in 6 clinical studies, discussing technical aspects related to essential hypertension treatment. Yin (2021) evaluates 57 studies on trigeminal neuralgia and hemifacial spasm, describing patient characteristics. Lastly, Li (2019) compares clinical studies (9 studies/1093 patients) related to endoscopic vs open MVD techniques, noting similar clinical outcomes with lower complication rates in the endoscopic group.

The 6 systematic reviews with meta-analyses span from 2020 to 2023. For instance, Holste (2020) analyzes 39 clinical studies and 6249 patients, confirming the effectiveness of open surgical treatment MVD in improving patient outcomes. Sprengher (2022) assesses auditory outcomes post-surgery, emphasizing the importance of monitoring LSR and BAEp. Zhao (2021) compares E-MVD vs MVD, highlighting differences in complication rates and outcomes. Li (2022) discusses PHFS secondary to vertebral artery involvement, noting associations with older age and male gender. Ghaffouri (2023) evaluates MVD surgery outcomes in patients with multiple etiologies, noting geographical variations in E-MVD practice. Thirumala (2020) underscores the utility of LSR monitoring in predicting clinical outcomes during MVD.

The 3 randomized clinical studies provide additional insights. Yang (2023) compares the effect of sevoflurane vs Propofol + remifentanil on LSR monitoring. Ulosoy (2018) investigates blood ion concentrations in

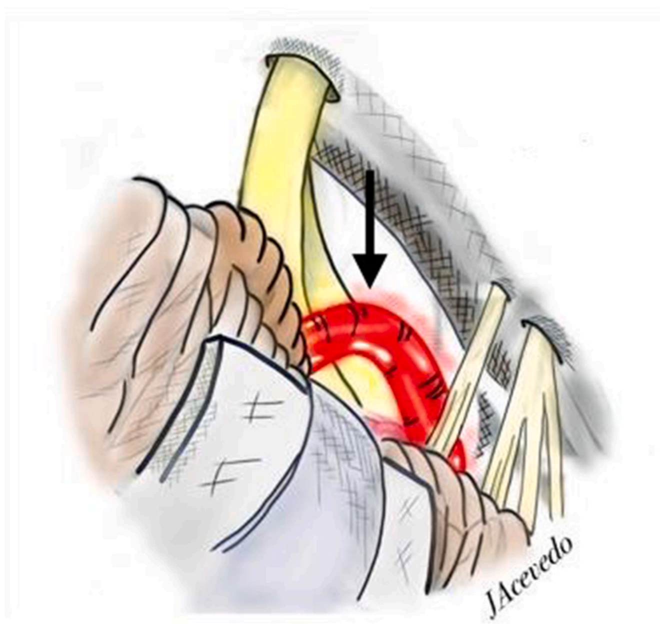


Fig. 1. Surgeon's expertise in managing Hemifacial Spasm (HFS). NERVE/ARTERY CONFLICT: Right cerebellopontine angle illustrating the acoustic facial package (yellow), the lower cranial nerves at the bottom, and the AICA in contact with the facial nerve (black arrow) producing Primary Hemifacial Spasm.

PHFS patients, hypothesizing their role in demyelination. Kim (2019) evaluates hemodynamic effects on skin and soft tissues post-dexmedetomidine infiltration.

These articles collectively contribute to a comprehensive understanding of surgical treatment outcomes for PHFS.

4. Discusion

While clinical evidence may not yield statistically significant data, it is apparent that several pivotal elements influence the successful development of the surgical procedure for PHFS treatment. Establishing a standard set of requirements for microvascular decompression in these patients renders prospective randomized analysis exceedingly challenging. Currently, both retrospective studies and analyses comparing traditional surgery with endoscopy are available. In this context, we identify the following determinant elements.

4.1. Prognostic factors

4.1.1. Demographic factors

- PHFS is more prevalent in women (Jannetta 66.4 %, Ehni 60.4 %, Wilkins 77 %, Sindou-Acevedo 66.6 %), with an incidence of 0.81 for females and 0.74/100,000 population for males. It typically manifests between the fifth and sixth decades of life, with an average age of 52 years (Jannetta – 51 years, Auger-57 years, Nielsen – 54 years, Loeser – 52 years, Sindou – Acevedo - 52 years). Some clinical outcomes have demonstrated poorer results in extreme age groups, particularly in patients under 30 and over 70 years, indicating that the atypical clinical presentation of PHFS is more common in young individuals with a dorso-caudal artery/nerve conflict rather than a ventro-caudal one (more frequent).[1,34–39] There is a higher incidence in the Asian population, possibly associated with the infratentorial space's morphology favoring the displacement of the vertebrobasilar trunk (VBT).[40–47] (Fig. 1).

4.1.2. Clinical aspects

- The "typical" PHFS is more common (Ehni and Waltman 90.9 %, Auger 95 %, 86.7 % Esteban-Molina, 93.3 % Sindou-Acevedo) and characterized by intermittent, irregular, and benign spasmodic contraction of the orbicularis oculi muscle, progressively moving in the rostro-caudal direction. It involves other muscles on the same side of the face but rarely affects the frontalis muscle and often the platysma muscle of the neck, especially in chronic forms. It is exacerbated by voluntary facial movements, emotional tension, fatigue, and even changes in head position. An audible "click" sensation may occur when the face contracts due to the involuntary spasm of the stapedius muscle or stapes muscle, which is innervated by the facial nerve (VII). In chronic conditions, there is a forced and sustained tonic contraction of half the face, often progressing to facial paresis. Typical EHP may be accompanied by "tearing" of the eyes due to the alteration of parasympathetic control exerted by the facial nerve through the greater petrosal nerve, disrupting the gustato-lacrimal reflex. In the "atypical" form, PHFS begins in the orbicularis oris muscle and progresses caudo-rostrally, affecting the frontalis muscle. Although less frequent (6 %), this "atypical" form may be associated with poorer outcomes. The presence of preoperative facial paresis, specifically associated with prolonged treatments with botulinum toxin, was observed in 30.4 % of patients treated by Auger, 44.4 % by Jedynak, and 10 % by Huang, and it was linked to a slower recovery (or lack of recovery) of PHFS symptoms.[1,40–42,45–51]
- While botulinum toxin therapy boasts a notably high response rate of approximately 97 %, necessitating repeated administrations at three to six-month intervals, it is accompanied by adverse effects, including mild facial paresis (23 %), diplopia (17 %), and ptosis (15 %).[51] The utilization of botulinum toxin is restricted to a maximum of three annual administrations, constituting a palliative rather than curative strategy, as the therapeutic effect typically wanes after the fourth month post-procedure.[52]
- The PHFS is more prevalent on the left side of the face in a ratio of 2:1,[1] though not associated with a modification in prognosis. However, this left-sided predominance has been elucidated based on embryological dominance related to the size and location of the REZ in the facial nerve. The left side is more susceptible to pathological contact with arteries in the pontocerebellar angle.[1,52–58] Similarly, the "normal" deviation of the VBT to the left is more common in the general population, especially when accompanied by a posterior cranial fossa "crowded" with prepontine cisterns and a small angle pontocerebellar, and even verticalization of the tentorium and Chiari type I.[56–58] The duration of PHFS can vary, with a tendency to become chronic. Worse outcomes have been identified in more aggressive and rapidly progressive forms compared to slowly progressive forms with a chronic course. However, it is crucial to note that in patients with chronic PHFS, immediate improvement may be less apparent, and one must await intermediate or late follow-ups to reveal the outcome. It is worth recalling that 33 % +- 8 % of operated patients show delayed improvement, which may take up to a year in 12 % of cases (Delayed improvement: Miller/Miller 11.2 %). In 0.5–3% of patients in Jannetta's series, PHFS was accompanied by ipsilateral trigeminal neuralgia. This combination, termed "tic convulsif" was described by Cushing in 1920. Its frequency varies in other series: 15 % Ehni, 6.5 % Huang, and may be explained by an ectatic VBT.[1,10,13,34,52]

4.1.3. Electrophysiological aspects (hearing evaluation)

- The close anatomical, functional, and vascular relationship between the auditory/vestibular nerve and the facial nerve necessitates constant consideration of hearing-related factors in the preoperative, intraoperative, and postoperative therapeutic analysis. It is crucial to note that the AICA is one of the arteries that most frequently causes

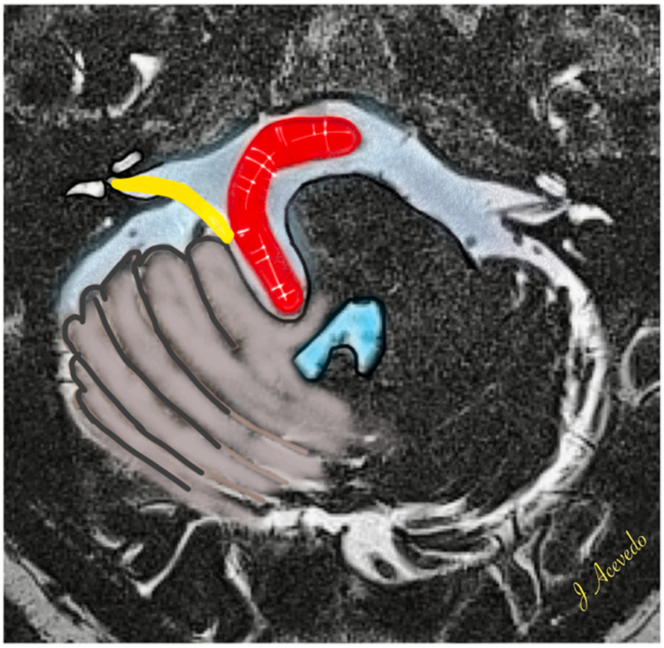


Fig. 2. MRI in axial section in the posterior fossa illustrating the ARTERY/NERVE conflict in the right cerebellopontine angle.

Fig. 3. Surgical positioning to properly expose the facial nerve. COMPLEX NERVE/ARTERY CONFLICT: Right cerebellopontine angle illustrating the acoustic facial package (yellow), and the AICA + labyrinthine artery in contact with the facial nerve (black arrow) producing Primary Hemifacial Spasm.

conflict (with the facial nerve), accounting for approximately 45.9 %. Mobilizing it to perform the treatment properly involves displacing the labyrinthine artery and exerting traction on perforating arteries that may directly impact hearing. Distal compressions to the nerve may be encountered in a low percentage, but they pose greater difficulty as they involve the labyrinthine artery and compress the interior of the auditory meatus. Patients with preoperative perceptual hearing loss and delayed auditory latency in evoked potentials, especially at peak V, are at a higher risk of experiencing auditory complications postoperatively or even deafness. Similarly, exercising utmost care during dissection and treatment processes to avoid disrupting Auditory Evoked Potentials (AEPs) indirectly enables the vigilant handling and treatment of the facial nerve. Auditory symptoms post-surgery was observed in 15 % of Ehmi's series, 6.5 % in Huang's, and 5.5 % in Jedynak's.[1,59–69]

4.1.4. *Radiological aspects*

- Radiological studies serve to rule out specific structural lesions such as tumors, aneurysms, malformations, and cysts, and above all, confirm the conflict between the artery and the nerve by characterizing it. Magnetic resonance imaging should include high-resolution T2-weighted anatomical sequences and magnetic resonance angiography using 1.5 or even 3 T magnets. By confirming and characterizing the conflict between the artery and the nerve, one not only identifies the primary culprit (AICA, PICA, VBT, Vein) but also determines favoring anatomical factors such as the presence of arterial dolichoectasia, asymmetry in the VBT, vertebral artery hypoplasia, the posterior cranial fossa with a small volume and reduced cisterns, Chiari malformation, and/or bone malformations. These imaging findings allow the characterization of vascular conflict and the formulation of an appropriate surgical plan.[69–76] (Fig. 2).

4.1.5. *Previous treatments*

- There are no prognostic elements associated with the type of anti-neuropathic medications used prior to surgical treatment, but it is essential to remember that allowing PHFS to become chronic can lead to less favorable surgical outcomes. Generally, medical treatment only provides a transient resolution of spasms in around 20 % of cases and a lasting improvement in approximately 30 %. The use of Botulinum Toxin (BT) in some mild and initial forms of PHFS may be beneficial, controlling symptoms for variable periods. However, its chronic use in severe cases can result in facial paresis, which is specifically associated with worse clinical outcomes after microvascular decompression surgery. Increased toxin use and injection frequency can elevate complication rates, including ptosis (7–20 %), facial paresis (1–20 %), burning sensation on the face (24 %), and tearing (20 %). Therefore, BT is recommended for debutant PHFS, patients who cannot undergo surgery, or those with residual or recurrent symptoms.[48–51]

4.1.6. *Surgical technique*

- Positioning: Optimal exposure facilitates reduced retraction and mitigates the risks of complications, a principle directly applicable to the PHFS. Prudent consideration of the patient's positioning entails consistently favoring cerebral venous drainage through the neck veins. Excessive rotation of the head can impede the jugular system, leading to cerebral venous dilation, which, in the case of the PHFS, manifests as treatment challenges and an increased incidence of hematomas.

The selection among semi-seated, supine with forced head rotation, or park bench positions is pivotal for PHFS treatment, acknowledging the potential repercussions of each. Even strict lateral positioning, with the contralateral arm placed on an additional support rather than beneath the trunk, serves to minimize complications related to peripheral nerve compression (brachial plexus, median, ulnar, or radial nerves), which may give rise to postoperative dysesthesias or painful neuropraxia.

These recommendations for body positioning, particularly regarding the contralateral arm, facilitate improved head mobilization, ensuring an unimpeded neck and direct exposure of the ponto-cerebellar angle and the VII cranial nerve conflict. It is imperative to recognize that the chosen position is not merely for exposing and accessing the ponto-cerebellar angle but specifically for reaching (with minimal retraction)

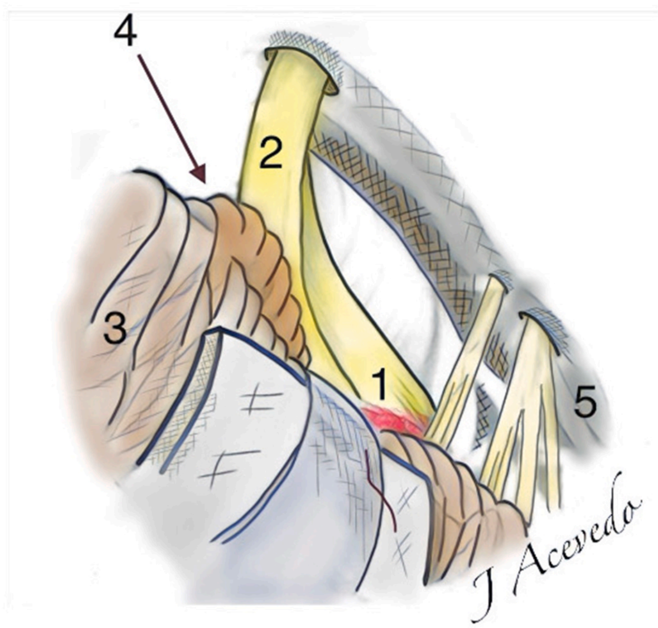


Fig. 4. Exploration of the nerve (VII) from its origin at the Root Entry Zone (REZ). ANATOMY IN THE CEREBELLOPONTINE ANGLE: 1. Facial nerve, 2. Acoustic nerve, 3. Cerebellum, 4. Flocculus, 5. Lower cranial nerves.

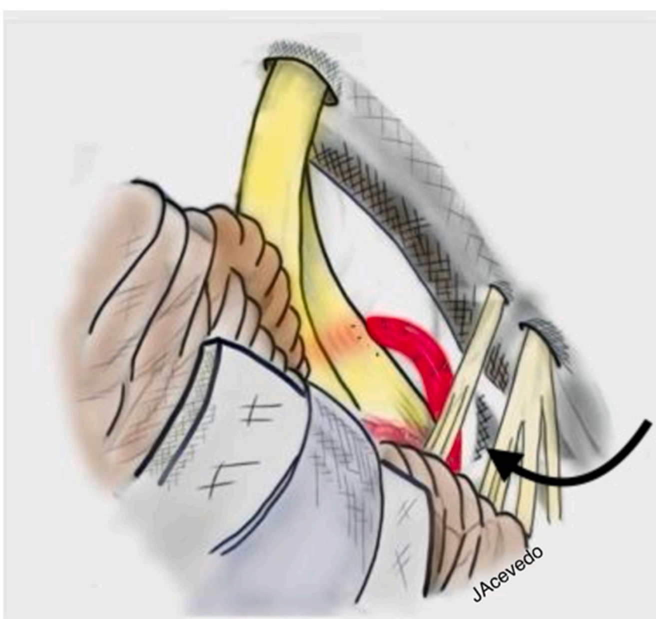


Fig. 5. Bottom-up surgical approach, releasing the arachnoid very well and identifying the flocculus. Identification of the conflict's cause is imperative; localization of the conflict typically occurs ventrocaudally and on the most proximal portion of the nerve (VII).

the seventh cranial nerve, allowing exploration along its entire course from the Root Exit Zone (REZ) to the auditory meatus (Fig. 3).

The lateral decubitus position is preferred due to its lower intraoperative risk of gas embolism (in comparison to the seated position), decreased cerebrospinal fluid loss during surgery, enhanced access to the inferior aspect of the REZ at the bulbopontine sulcus, and the ability to approach the facial nerve acoustic bundle from below rather than laterally, reducing traction on the vestibuloacoustic bundle and lowering the incidence of complications such as vertigo, tinnitus, and hearing loss. Deviations from these recommendations introduce an element of risk, potentially yielding partial results and complications.[1,10,13,34,52,55,60,77–81] (Fig. 4).

- Incision. The incision should be in a slightly medial position to the base of the mastoid and with a discretely oblique direction from superior to inferior and lateral to medial. Always keeping in mind, the position of the transverse sinus and the angle with the sagittal sinus, to properly position the craniotomy. In its realization, the superficial nerves in the retromastoid area and more specifically the greater occipital nerve, a posterior branch of the C2 spinal root that emerges from the trapezius muscle two centimeters below and lateral to the external occipital protuberance, must be considered, which can be avoided with a lateral incision. The posterior branch of the large auricular nerve is usually lateral to the incision and can also be avoided. the position of the greater occipital nerve, which must be preserved because its ablation can cause Arnold's neuralgia and chronic neuropathic pain with painful, even intractable, dysesthesias. A muscle/aponeurotic dissection should be performed and the occipital artery at the bottom of the approach should be ligated.[1,82–85]
- Key-hole technique. The craniotomy performed under the parameters of a "keyhole" (2 cm in diameter) posterior to the tip of the mastoid allows adequate access of the REZ of the facial nerve, which is in a ventrocaudal position on the ventro/lateral aspect of the brainstem, at the cerebellopontine angle. The success of this technique is directly related to the position of the head. A limited bone approach and resection allows for less surgical preparation time, reducing the risk of infection, but also less exposure of the cochlea and inner ear to the noise of the motors used for this surgical moment. Less exposure and small dural opening decreases the risk of postoperative CSF fistulas. The opening of the mastoid cells can happen, and care must be taken not to allow fluid to enter the mastoid cells and the middle ear as it can be the cause of hearing alterations in the postoperative period. If they (the cells) are opened, they should be properly occluded with bone powder or any material that has proven to function properly. (1,13,86–99).
- Dissection: The dissection process has proven to be a decisive factor in achieving proper treatment of PHFS, with a reduced incidence of complications, recurrences, or partial outcomes. Dissecting the pontocerebellar angle from bottom to top, rather than laterally to medially, allows for the preservation of hearing and necessitates less cerebellar retraction (Flocculus) (Fig. 5). Liberating the arachnoid from cranial nerves X and XI, and particularly from the IX, dissecting the flocculus to expose the choroid plexus exiting through the Luschka foramen, recognizing its close adherence to the VII/VIII, and ensuring its release from the arachnoid tethering it to neural structures, are crucial steps (Fig. 6). Placing the separator over the flocculus reveals the bulbo/pontine sulcus, the posterior location of the VIII REZ, and the inferior location of the VII REZ. Excessive traction on the flocculus, without proper arachnoid release, is directly associated with postoperative hearing loss. Throughout the dissection, preserving the inferior petrosal vein and labyrinthine arteries is imperative. The subarachnoid artery can be coagulated before tearing, preventing hemorrhage. Conflict between the artery and the VII nerve is more frequent ventro-caudally (proximal), and the approach should be from bottom to top, consistently preserving perforating arteries (Fig. 7). These recommendations directly mitigate the risks of auditory nerve injury and associated complications, enhance the exposure of conflicts between the artery and the VII nerve, reduce the likelihood of recurrence or partial outcomes, diminish the risk of arterial and venous bleeding (hematomas), and facilitate a prompt and effective treatment approach.[1,13,85,86–88]
- Element Involved in Vascular Conflict: Typically, conflicts over the seventh cranial nerve manifest in various forms, such as single proximal, multiple proximal, multiple proximal and distal, single

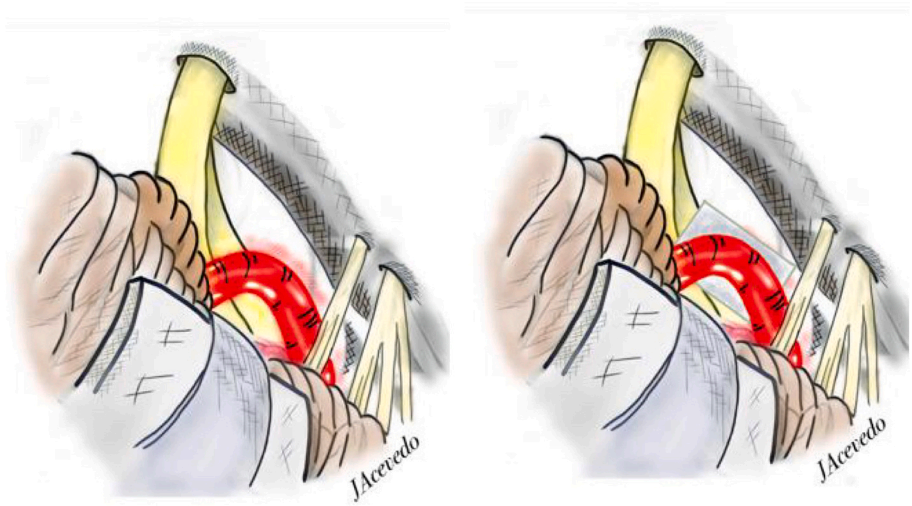


Fig. 6. Illustration of the surgical decompression of the facial nerve. (Left) Nerve/artery conflict. (Right) Treatment of the conflict.

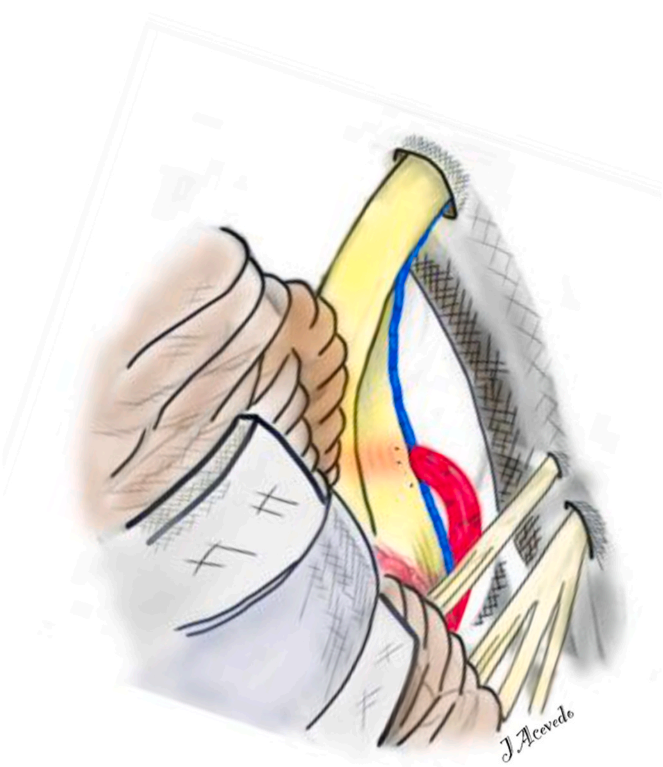


Fig. 7. Pathological complex nerve/artery/vein in hemifacial spasm.

distal, or multiple distal conflicts. This underscores the necessity of not merely exploring the REZ (Root Exit Zone) and the proximal portion of the nerve but obligatorily considering the potential presence of multiple pathological elements throughout the nerve's entire length. In most cases (99 %), a conflict is identified, with a negative exploration encountered in only 1–2%. Multiple conflicts are observed in 20–37 % of cases, with the posterior/inferior cerebellar artery (PICA - 47.2 %), anterior/inferior cerebellar artery (AICA - 45.9 %), vertebrobasilar trunk (VB - 17.5 %), and other arteries (11.7 % - perforating arteries) and veins (0.7–7.9 % with an average of 4.9 % - middle cerebellar peduncle vein, cerebello/medullary fissure vein, pontomedullary groove vein) being frequent contributors (Fig. 6). While the flocculus, choroid plexus, and arachnoid (arachnoiditis) play roles in favoring compression on the facial nerve, it is exceedingly rare for them to be the sole primary cause of conflict. Arachnoiditis around the facial nerve, identified by Illingworth in 1996, has been noted as a recurrent symptom cause (Fig. 7). Isolated venous conflicts are more commonly observed in younger individuals and are associated with symptom recurrence. Isolating the vein from nerve contact is complex, and coagulation and cutting are generally recommended. These data emphasize that for optimal clinical outcomes related to symptom improvement, a meticulous exploration of the nerve from the REZ to the meatus is imperative, considering that not only vascular structures can contribute to the conflict. The presence of megadolicho arteries (3.5–29 %) and arteriosclerosis-hardened VBs may be associated with recurrence or partial treatments. The VB can directly participate in the conflict (causing it) or indirectly by pushing branches (AICA or PICA) into contact with the nerve. This necessitates difficult mobilization of the VB for a satisfactory clinical outcome. Similarly, arteries inserting between the VII and VIII (AICA - 8 %) are linked to more challenging treatments and not always favorable outcomes, as a sandwich decompression is required. It is worth noting that arteries passing between the facial bundles, compressing it not only from the outside in but also from the inside out, can result in a higher percentage of complications and limited results (Fig. 8). When the conflict is distal (5 %) and caused by the AICA, exposing the nerve and arteries is exceedingly challenging, leading to more frequent hearing loss and vestibular symptoms. Zhong compared the clinical outcomes of patients who underwent a comprehensive exploration of the nerve pathway, demonstrating superiority (not statistically significant) over those whose treatment included only the REZ exploration[1,13,89–91] (Fig. 8).

- Degree of Nerve Compression: Chronic contact between the artery and the nerve can impact its morphological structure, reflecting the severity of the pathology. Three compression grades have been described: Grade 1, close contact between the artery and nerve without superficial alterations in the anatomical appearance of the nerve. Grade 2, deformation of the nerve surface without evidence of trophic changes. Grade 3, severe contact between the artery and nerve with changes and deformation in the superficial appearance of the area of the seventh nerve in contact with the artery. The vascular element leaves a mark on the nerve. Grade 3 has been associated with slower or incomplete recovery processes.[1,13,92–95]
- Type of Decompression: A review of the literature reveals a multitude of variations in the type of decompression, as diverse as the expert surgeons specializing in. The utilization of novel materials

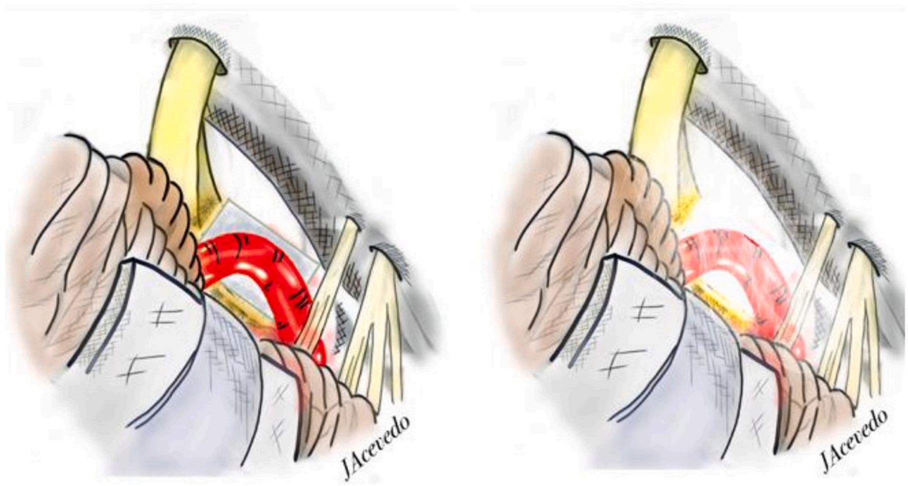


Fig. 8. Recurrence of hemifacial spasm due to fibrosis and arachnoiditis. (Left) MVD. (Right) Arachnoiditis around the Dacron and Teflon fragment used.

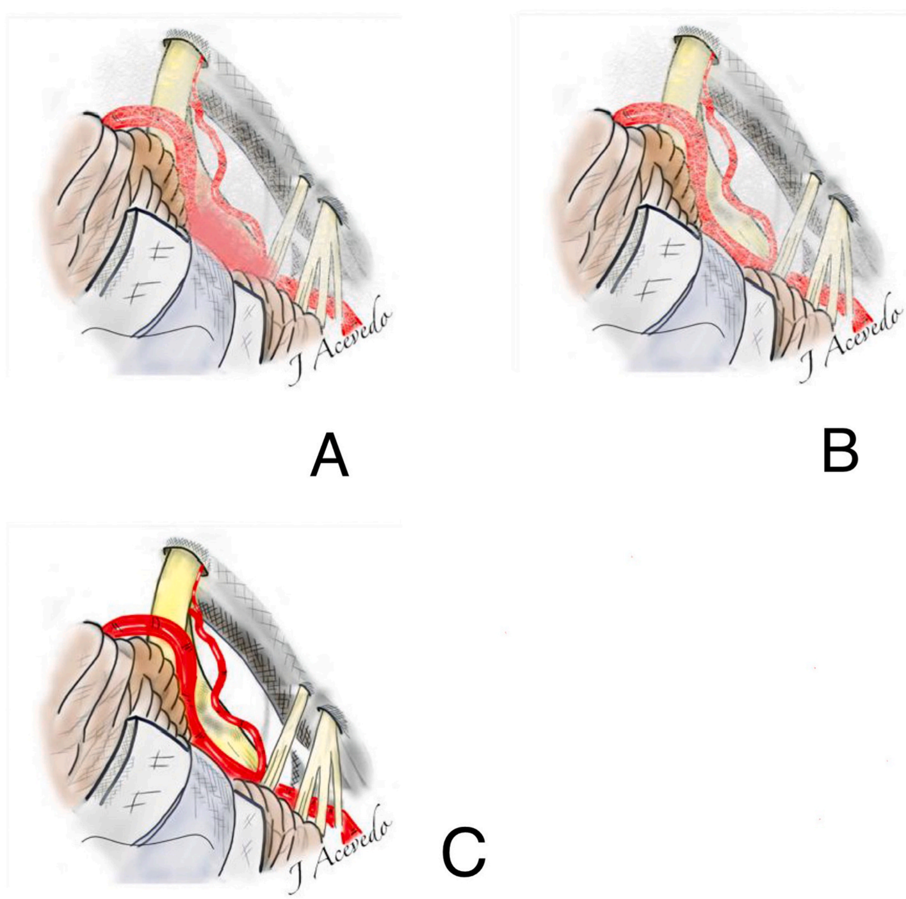


Fig. 9. Dissection of complex artery-nerve conflict. A. Right cerebellopontine angle B. Arachnoid release C. Dissection of conflict.

and the availability of different textures allow for a wide range of combinations. When considering clinical outcomes in terms of clinical improvement and the absence of complications, the paramount consideration in treatment is to avoid inducing new compression on the nerve with the materials employed. This "neo compression" is linked to incomplete results, recurrences due to arachnoiditis, and complications associated with other cranial nerves. An appropriate decompression is always one that facilitates complete nerve release without generating neo compression with the utilized material. Four degrees of decompression have been delineated: Grade 1 (simple) involving only one material (Dacron, Teflon, or another). Grade 2 (intermediate) employing two materials (Dacron, Teflon, or another). Grade 3 (complex) utilizing three materials. Grade 4 involves other materials (muscle, aneurysm clip, etc.). Similarly, there are three methods of conflict treatment: by isolation (inducing adhesions on the nerve), by transposition using a sling (which may be an incomplete treatment, and fixing the sling can be risky), and by interposing Teflon balls between the perforators and the nerve, fixing

Table 3
Positive predictive factors for the surgical treatment of primary hemifacial spasm.

POSITIVE PREDICTIVE FACTORS FOR HEMIFACIAL SPASM	DEFINITIVE FACTORS	1. The surgeon's experience in managing Hemifacial Spasm (HFS). 2. Surgical positioning involves strict lateral decubitus with the contralateral upper limb to the spasm supported and positioned not below the trunk. The neck is freed from venous compression, and the head is appropriately angled for dissection of the conflict along the inferior to superior aspect of the seventh cranial nerve. 3. Thorough exploration of the nerve (VII) from its origin at the Root Entry Zone (REZ), throughout its cisternal course, and up to the meatus is essential. It is crucial to bear in mind that compression (conflict) may be multiple and manifest at various levels along the nerve pathway. 4. Identification of the conflict's cause is imperative. A comprehensive approach must be undertaken, recognizing that the conflict (compression) can be multifaceted, involving veins and implicating the choroid plexus and flocculus, which, while not directly causing compression, may contribute to it. 5. Localization of the conflict typically occurs ventrocaudally and on the most proximal portion of the nerve (VII), understanding that, in less common scenarios, this may vary. 6. Dissection proceeds from bottom to top, ensuring thorough liberation of the flocculus to facilitate optimal exposure and mobilization of the artery and nerve. 7. Treatment involves the use of non-degradable solid materials, primarily avoiding the creation of new compression (neo compression). 8. Intraoperative electrophysiological monitoring includes Early Auditory Evoked Potentials (EAEP) and electromyography of the seventh cranial nerve to ensure ongoing functional integrity.
	RELATIVE FACTORS	1. A more favorable prognosis is anticipated when dealing with a typical case of Hemifacial Spasm (EHP). 2. The typical age range is from the fifth to the sixth decade of life, with a poorer prognosis observed at the extremes of life and in cases of chronic HFS. 3. Adequate prior pharmacological treatment is imperative, including the administration of botulinum toxin. 4. Preventing the chronicity of EHP is crucial, as prognosis worsens in chronic conditions. 5. The absence of prior auditory deficits (tonal and vocal audiometry, Early Auditory Evoked Potentials) is noted. 6. The absence of preceding facial paresis or paralysis, whether associated with the use of botulinum toxin or not, is significant. 7. Intraoperative nerve morphology (VII) is indicative of a better prognosis when there is no atrophy or morphological changes caused by artery or compression.

COMPLICATION	CAUSE	PROGNOSIS FACTOR
Facial Paralysis	- Resulting from direct trauma to the nerve or alterations in microcirculation and vasospasm associated with dissection and manipulation. - Immediate incidence approximately 1–2% (ranging from 0.7 % to 22.5 %) - Definitive incidence ranges from 0.1 % to 8 % - More prevalent in a seated position (17.5 %) compared to lateral decubitus (5 %) - Delayed facial paralysis, even tardy (2.8 %–10.4 %), is observed in association with viral processes	- Surgeon's expertise. - Intraoperative monitoring of Early Auditory Evoked Potentials (EAEP) and Electromyography (EMG) for vigilant and controlled oversight of the dissection process. - Approach and dissection from inferior to superior. - Release of the arachnoid from the flocculus before manipulating the nerve. - Avoidance of generating neo compression of the nerve using solid materials or improperly placed interventions.
Hearing loss	- Ipsilateral and even contralateral deafness, hypoacusis, functional impairment with a decrease in Pure Tone Audiometry (PTA), alterations in Speech Discrimination Test (SDT), middle ear abnormalities, hyperacusis, autophony, and tinnitus. - Overall deficit observed in 1.9 %–20 % of operated patients. - A 2.3 % incidence of significant hearing loss, which rises to 3.9 % in older individuals.	- Occurs in lateral or medial approaches and not infrafloccular in the conflict of the VII. - Excessive retraction of the flocculus. - Injury or tearing of the labyrinthine artery. - Cochlear ischemia due to perforator injury. - Excessive manipulation of the VIII. - Nerve heating due to excessive use of bipolar forceps. - Excessive cold irrigation of the cerebellopontine angle. - Poor closure of mastoid air cells leading to fluid entry into the middle ear. - Excessive manipulation of the AICA. - Traction on the labyrinthine artery altering monitoring with a decrease in Wave I in Early Auditory Evoked Potentials (EAEP). - Neo compression during monitoring leading to an increase in amplitude and latency of EAEP. - The noise produced by high-speed drills can transiently alter nerve functionality, at least temporarily.
Tinnitus	- Prevalence ranging from 1.4 % to 13.3 %. - Incapacitating in 6.3 % of cases.	- Injury to the cochlea and inner ear. - Also associated with the entry of fluid into the middle ear through poorly sealed mastoid air cells.
Autophony	- One perceives the sound of one's own voice	- Influx of fluid into the middle ear.
Pain	- Infrequent occurrence. - Neuropathic pain due to injury to the greater occipital nerve in the incision.	- Occurs due to injury to the greater occipital nerve during surgery. - Can be direct, resulting from cutting in the incision (improperly located) or during dissection. - Can be indirect, involving neuropraxia when placing separators between cutaneous and subcutaneous planes. - The incision should initiate at the base of the mastoid and proceed medially without reaching or crossing the midline. - The greater occipital nerve originates from the C2 root, exits between C1 and C2 vertebrae, traverses the suboccipital triangle and the semispinalis muscle to innervate the skin and the trapezius (TCS). - An incision in a single plane without aponeurotic dissection preserves the nerve branch.

(*continued on next page*)

Table 3 (*continued*)

	Dizziness	- Injury to the vestibular nerve can induce transient dizziness in 5.4 % of treated patients and persistent dizziness in 1.4 %. - May be accompanied by hyperacusis (1.2 %). - Geniculate neuralgia	- Appropriate surgical technique
	Disruption of lower cranial nerves	- Incidence of 0.5 %–1 %. – 1.5 %–4 % prevalence of dysphagia. - Transient vocal cord paralysis observed in 9.7 %, with 2.4 % being definitive. - Caused by vascular traction and arterial manipulation."	- Appropriate surgical technique. - The surgery necessitates a bottom-to-top approach, without the need for dissecting the lower pairs, only the liberation of the arachnoid.
	Ischemic Events and Hematomas	- Incidence of 0.1 %–2.1 %. - Excessive traction on the Posterior Inferior Cerebellar Artery (PICA)/Anterior Inferior Cerebellar Artery (AICA) leading to the rupture of perforating vessels. - Excessive transposition of arteries involved in the conflict, reducing flow, and causing ischemic infarction with hemorrhagic transformation. - Vasospasm and vasoconstriction. - Venous sacrifice resulting in venous infarction. - Injury to the sigmoid sinus or petrosal veins in a superior sagittal sinus with asymmetric drainage.	- Appropriate surgical technique. - Surgeon's experience. - Avoidance of venous sacrifice. - Prior verification of the vertebrobasilar trunk morphology and venous drainage (sigmoid sinus, transverse sinus, and superior sagittal sinus) through magnetic resonance angiography. - Caution against excessive arterial manipulation and avoidance of angulations that may reduce flow and lead to ischemia. - Verification that the material used does not compress the artery or cause angulation.
	CSF leak	- Incidence ranging from 2.5 % to 10 %, with an average of 4.7 %. - May lead to meningitis.	- The implementation of Keyhole-type approaches can reduce the risk of fistula. - Avoid opening mastoid air cells, and if necessary, securely seal them. - Ensure a tight closure of the dura mater
	Mortality	- Incidence of 0.1 %, associated with catastrophic vascular injuries and edema of the cerebral posterior fossa.	- Surgeon's expertise - Appropriate surgical technique

them to the dura mater, by displacement, and adhering them with biological adhesive. Considering these factors enables the selection of a durable and persistent decompression without transforming into new compression by material (Dacron/nerve, Teflon/nerve, etc.) associated with partial or incomplete outcomes (Fig. 9).

- Intraoperative Electrophysiological Monitoring: Early Auditory Evoked Potentials (EAEPs): The use of intraoperative monitoring of early auditory evoked potentials is currently indispensable for the proper execution of this procedure. It is directly associated with better outcomes, resulting in a lower frequency of transient or definitive auditory complications. EAEP monitoring immediately detects distress in the auditory pathway. Before the use of monitoring, the frequency of hearing loss in operated patients was 15–16 %, with 7 % experiencing deafness. With monitoring, this percentage decreased to 1.4 % for hearing loss and exceptionally rare cases of deafness. Wave I represents the cochlea's function, while waves III and V, along with their III-V interval, originate in the brainstem at the superior olivary nucleus and the inferior colliculus. Alteration of wave I suggests cochlear ischemia. A 50 % decrease in wave V or an increase in its latency exceeding 1 ms indicates imminent risk to hearing due to stretching or damage to the cochlear nerve. Intraoperative moments associated with variations in EAEP recordings include:
  - o Anesthetic Induction: Medications used, hypothermia, and assisted ventilation alone can cause modifications in recordings, such as delayed wave V latency. It is recommended to record a baseline after the anesthetic induction and before the start of surgery.
  - o Craniotomy and Mastoid Cell Opening: High-speed motor noise and the entry of fluid into opened mastoid cells can produce subtle waveform changes.
  - o Dissection and Retraction of the Flocculus to Expose the VII Pair REZ: Alters the recording due to distress in the auditory nerve and/or cochlea.
  - o Treatment of Conflict: Excessive traction on the facial acoustic bundle. Moller proposed a vascular theory after studies on primates, suggesting that when treating the conflict and manipulating the facial acoustic bundle, there are hemorrhages in the inner auditory canal's fundus, where branches of the internal auditory artery penetrate. Other associated mechanisms include spasm of the internal auditory artery due to manipulation and the direct traction effect on the cochlear nerve.
  - o Hearing damage: generally, occurs due to stretching of the VIII nerve by excessive flocculus retraction, excessive manipulation of the labyrinthine artery or AICA, direct trauma from an instrument, or bipolar heating and neo compression.
  - o Intraoperative Electromyography of the VII Pair: It should be performed with anesthesiologists avoiding the use of muscle relaxants. Spontaneous muscle activity in major facial muscles is recorded. It is particularly useful to monitor the lateral spread response (LSR) phenomenon, where stimulation of a specific facial nerve branch not only elicits a response in muscles innervated by that branch but also in muscles of other branches in EHP patients. This phenomenon is associated with ephaptic transmission at the lesion site and hyperactivity (hyperexcitability) in the motor nucleus. The use of these monitoring techniques allows real-time surveillance of the dissection and treatment process, confirming the conflict resolution.[1,13,59–66,96,97]

4.1.7. *Risk of recurrence according to compromised vessel*

- In a case series published in 2023 by Alkhayri,[97] it was revealed that recurrence rates following microvascular decompression varied significantly based on the number of conflicts present. Patients with multiple conflicts experienced a notably higher recurrence rate (28.4 %) compared to those with a single conflict, where the risk of an unfavorable outcome was significantly lower (0.8 %) with statistical significance ($p < 0.001$). Surprisingly, conflicts involving the posterior inferior cerebellar artery (PICA), or vertebral artery (VA) did not show a significant association with higher or lower recurrence risk post-operatively.
- Conversely, cases where the AICA caused the neurovascular conflict resulted in less favorable outcomes, with a recurrence rate of 19.9 % compared to 5.3 % in the reverse scenario ($p = 0.02$). The occurrence of venous neurovascular conflicts was notably rare, detected in only one case out of 200 patients. However, this single instance of venous conflict correlated with a recurrence after the initial microvascular decompression, highlighting venous conflict as a significant risk factor for unfavorable outcomes.[97,98] It is important to note that

caution should be exercised in interpreting this statistical analysis due to the rarity of this anatomical and clinical presentation.

Table 3 presents a compilation of positive predictive factors for achieving effective treatment of Primary Hemifacial Spasm with a low percentage of complications (Table 3)

CRediT authorship contribution statement

Juan Carlos Acevedo-González: Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Alex Taub-Krivoy:** Writing – original draft, Methodology, Investigation. **Julian Alfonso Sierra-Peña:** Investigation, Conceptualization. **Julian Geronimo Lizarazo:** Methodology, Investigation, Formal analysis.

Declaration of competing interest

I certified that for the performance of the following work don't have conflicts of interest or any business relationship.

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