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FACIAL NERVE REHABILITATION FOLLOWING VESTIBULAR SCHWANNOMA REMOVAL: A COMPARISON BETWEEN THE TRANSLABYRINTHINE AND THE RETROSIGMOID APPROACH

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Alla mia famiglia.

A te, che mi guardi da lontano.

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ABBREVIATIONS

3D FLAIR	Three-Dimensional Fluid-Attenuated Inversion Recovery
AICA	anterior inferior cerebellar artery
CI	cochlear implant
CN	cranial nerve
CPA	cerebellopontine angle
CSF	cerebrospinal fluid
CT	computed tomography
D	dizziness
DPN	deep petrosal nerve
DWI	Diffusion-Weighted Imaging
EAC	external auditory canal
EMG	electromyography
ENG	electroneurography
FaCE	Facial Clinimetric Evaluation
FDI	Facial Disability Index
FN	facial nerve
FNOC	Facial Nerve Outpatient Clinic
FNP	facial nerve paralysis
GG	geniculate ganglion
GSPN	greater superficial petrosal nerve
GTR	gross total resection
HB	House-Brackmann
HL	hearing loss
IAC	internal auditory canal
ICU	intensive care unit
MCF	Middle Cranial Fossa
MRI	Magnetic Resonance Imaging
NA	not available
NIM	neurophysiological intraoperative monitoring
NMR	neuromuscular retraining
NTR	near total resection

PICA	posterior inferior cerebellar artery
QoL	quality of life
RGS	Rough Grading System
RS	retrosigmoid
SB	Sunnybrook
SCA	superior cerebellar artery
SD	standard deviation
STR	subtotal resection
T0	Time zero post-surgery
TL	translabyrinthine
TT	transcanal transpromontorial
T	tinnitus
VS	vestibular schwannoma

1 INTRODUCTION

1.1 Vestibular Schwannoma

Vestibular schwannoma (VS), also known as *acoustic neuroma*, is a rare benign tumor arising from the Schwann cells of the vestibulocochlear nerve, the 8th cranial nerve (CN VIII). In particular, its origin is in those cells which form the myelin sheath around the vestibular part of this nerve. [1–8] According to some authors, the origin of the VS – superior or inferior – is a parameter to determinate the preoperative management and to predict the outcome, in particular about hearing loss.[9]

VSs are commonly located in the internal auditory canal (IAC) and/or in the cerebellopontine angle (CPA). It is important to focus on the anatomy of these structures, in order to better understand the clinical features of this tumor, the preoperative management and the consequent treatment decisions.[2,8]

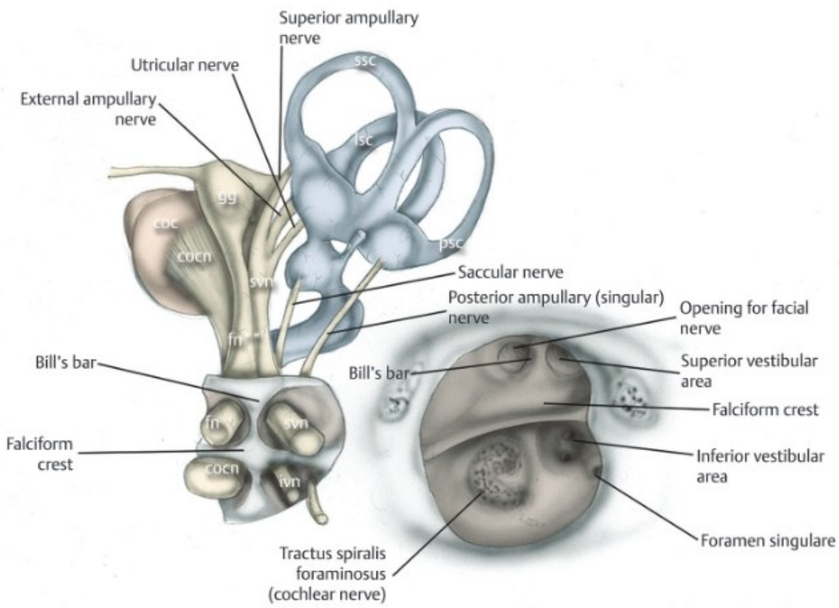

Figure 1. Anatomy of the fundus of the IAC. coc: cochlea; cocn: cochlear nerve; fn**: labyrinthine segment of facial nerve; gg: geniculate ganglion; ivn: inferior vestibular nerve; lsc: lateral semicircular canal; psc: posterior semicircular canal; ssc: superior semicircular canal; svn: superior vestibular nerve. *Marchioni, D. & Presutti, L. Endoscopic Lateral Skull Base Surgery. (Thieme, Stuttgart, Germany, 2022)*

The IAC (illustrated in *Figure 1, 2, 3*) is a bony neurovascular channel, 8 to 10 mm long. It runs from the posterior cranial fossa to the petrous temporal bone. Rather, we can assess that this canal extends from its medial end named "porus", located on the posterior surface of the petrous bone, to the lateral end named "fundus" that separates itself from the cochlea and the vestibule. The IAC contains the facial and the cochlear-vestibular nerves occupying specific positions inside this channel. The fundus (*Figure 1*) is segmented by a transverse crest, the falciform one, and a vertical crest, known as Bill's bar, into four regions housing the facial nerve (FN) in the anterosuperior section, the superior vestibular nerve posterosuperiorly, the cochlear nerve in the anteroinferior section, the inferior vestibular nerve and the singular nerve posteroinferiorly.[2]

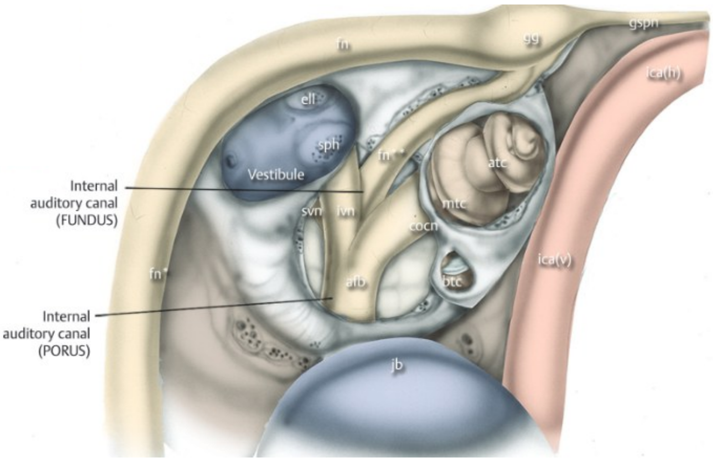

Figure 2. Anatomy of the IAC, medial wall of tympanic cavity. afb: acoustic-facial bundle; atc: apical turn of cochlea; btc: basal turn of cochlea; cocn: cochlear nerve; ell: elliptical recess; fn: facial nerve; fn*: mastoid segment of facial nerve; fn**: facial nerve into the IAC; gg: geniculate ganglion; gspn: greater superficial petrosal nerve; ica(h): horizontal portion of internal carotid artery; ica(v): vertical portion of internal carotid artery; ivn: inferior vestibular nerve; jb: jugular bulb; mtc: middle turn of cochlea; sph: spherical recess; svn: superior vestibular nerve.
Marchioni, D. & Presutti, L. Endoscopic Lateral Skull Base Surgery. (Thieme, Stuttgart, Germany, 2022)

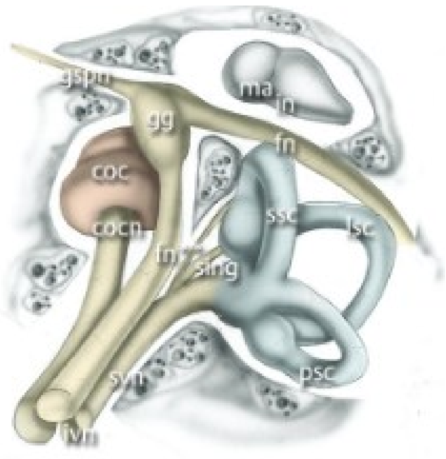

Figure 3. Illustration of the acoustic-facial bundle within the IAC. coc: cochlea; cocn: cochlear nerve; fn: tympanic segment of facial nerve; gg: geniculate ganglion; gspn: greater superficial petrosal nerve; in: incus; ivn: inferior vestibular nerve; lsc: lateral semicircular canal; ma: malleus; psc: posterior semicircular canal; sing: singular nerve; ssc: superior semicircular canal; svn: superior vestibular nerve.
Marchioni, D. & Presutti, L. Endoscopic Lateral Skull Base Surgery. (Thieme, Stuttgart, Germany, 2022)

The CPA (*Figure 4, 5*) is the anatomic space in the posterior cranial fossa, localized between the petrous bone and the petrosal cerebellar surface, folding around the pons and the middle cerebellar peduncle. It is an anatomical region rich in neurovascular elements, listed afterwards, which explains the clinical manifestation of different pathologies involving the CPA: the trigeminal and abducent nerves, the "acoustic-facial nerve bundle" as detailed below, the lower cranial nerves (the glossopharyngeal, vagus and hypoglossal nerves); the cerebellar peduncles, the pons and the medulla; the superior cerebellar artery (SCA), the anterior inferior cerebellar artery (AICA) and the posterior inferior cerebellar artery (PICA).[2,10]

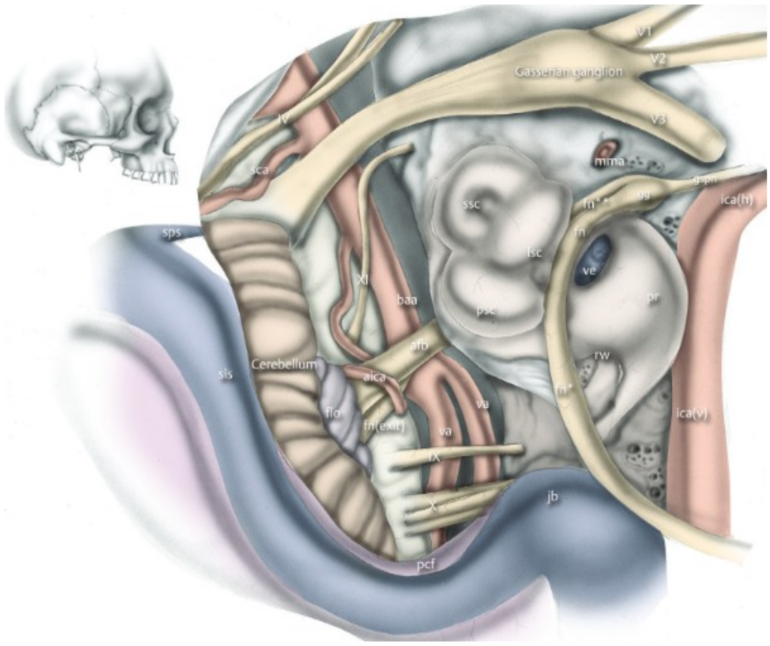

Figure 4. Lateral view of the CPA. afb: acoustic-facial bundle; aica: anterior inferior cerebellar artery; baa: basilar artery; flo: floccules; fn (exit): facial nerve at the exit zone; fn: tympanic segment of facial nerve; fn*: mastoid segment of facial nerve; gg: geniculate ganglion; gspn: greater superficial petrosal nerve; iac: internal auditory canal; ica(h): horizontal segment of internal carotid artery; ica(v): vertical segment of internal carotid artery; jb: jugular bulb; lsc: lateral semicircular canal; mma: middle meningeal artery; pcf: posterior cranial fossa (dura layer); pr: promontory; psc: posterior semicircular canal; rw: round window; sca: superior cerebellar artery; sis: sigmoid sinus; sps: superior petrosal sinus; ssc: superior semicircular canal; va: vertebral artery; ve: vestibule.

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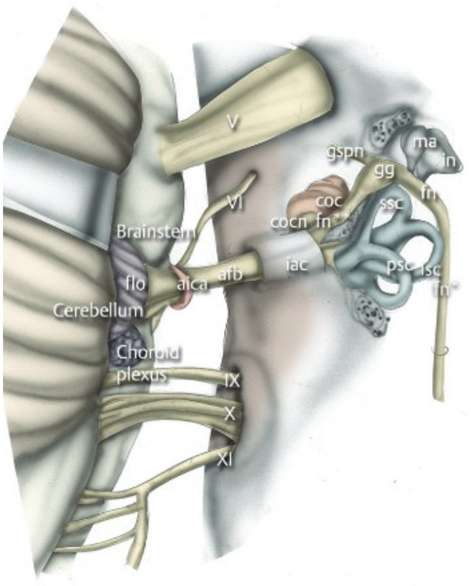


Figure 5. Anatomy of the frontal surface of brainstem and the CPA. aica: anterior inferior cerebellar artery; coc: cochlea; cocn: cochlear nerve; flo: floccules; fn: tympanic segment of facial nerve; fn*: mastoid segment of facial nerve; fn**: intrameatal facial nerve; gg: geniculate ganglion; gspn: greater superficial petrosal nerve; iac: internal auditory canal; in: incus; lsc: lateral semicircular canal; ma: malleus; psc: posterior semicircular canal;ssc: superior semicircular canal.

Marchioni, D. & Presutti, L. Endoscopic Lateral Skull Base Surgery. (Thieme, Stuttgart, Germany, 2022)

The closer relationship observed between the VII and the VIII cranial nerves is known as acoustic-facial bundle (see *Figure 2, 3, 5*). As a matter of fact, these nerves arise very close to each other (about 1-2 mm) from the pontomedullary junction; after this point, as the FN continues his course, it immediately gets closer to the vestibulocochlear nerve and they get into to IAC. As it traverses the CPA, the FN is positioned anteriorly and medially relative to the other nerves until reaching the IAC. In this phase, the vestibular nerve is situated superiorly, while the cochlear nerve lies inferiorly. Upon entering the porus of the IAC, the arrangement shifts: the FN assumes an anterosuperior position alongside the vestibular nerve and the cochlear nerve remains inferior, as previously mentioned.[2]

Considering the anatomical site and the relationship with the nearby structures, it is easy to understand that, as the tumor expands, it projects from the IAC into the CPA, compressing the VII and the VIII cranial nerves. As the tumor continues to enlarge, the cerebellum and/or the brainstem and/or nearby cranial nerves (V, IX, X, XI) can also become compressed. Therefore, although the tumor is considered histologically benign, its growth is associated with several neurovascular dysfunctions, resulting in clinical variability among the patients who receive the diagnosis of VS.

1.1.1 Epidemiology

The VS is considered a rare tumor. However, it represents about 8% of all intracranial tumors and 80-90% of all tumors arising in the posterior cranial fossa.[6,8,11–13]

The incidence is estimated at 2-5 case per 100,000 individuals per year.[1,6]

In literature it is widely assessed that the VS is a benign slow-growing tumor.[3] The malignant form is extremely rare and it may represent an evolution of the benign one in patients who underwent a radiation therapy. The 90% of this tumor is sporadic with unilateral presentation. Bilateral manifestation occurs in syndromic conditions such as in Neurofibromatosis type 2, whose genetic etiology is suspected in patients with multiple meningiomas, ependymomas and bilateral vestibular schwannomas presenting a more aggressive biological profile.[6,14]

1.1.2 Symptoms and Signs

The clinical presentation of VS depends on his growth, causing symptoms ranging from mild to moderate and life-threatening. Generally, they present a slow growth, estimated as 2-3 mm per year, leading to a gradual and progressive symptomatic evolution. However, in some patients the tumor seems to grow more rapidly, presenting from the onset with moderate symptoms. Neverthless, this correlation between size and symptoms is not always evident.[6,9,15]

The most commonly observed pattern consists of a progressive unilateral sensorineural hearing loss, initially affecting high frequencies, often accompanied by tinnitus and vestibular symptoms such as imbalance or dizziness.[6,14,16]

Larger tumors may compress the FN (CN VII), causing weakness of muscles it innervates, or the trigeminal nerve (CN V), leading to a less common facial paraesthesia. The reason of these symptoms is in the anatomy of the cranial nerves from their origin and their course. It is well known that the superior part of the pons represents the origin of the trigeminal nerve, whose sensory fibers have their somas in the ganglion sited in the Meckel's cave, that is the dural recess in the apex of the petrous temporal bone.[2]

Furthermore, in advanced cases, compression of the brainstem and cerebellum may lead to ataxia and dysarthria, due to cerebellum dysfunction, showing also signs of increased intracranial pressure such as headache, nausea and papilledema.[8,16]

1.1.3 Diagnosis

The anamnesis and the physical examination allow to collect sign and symptoms. As most of patients report include hearing disorders such as progressive hearing loss, tinnitus and/or ear fullness, the audiometric test is indispensable to confirm and valuate the symptom. The tonal audiometric test typically reveals asymmetric sensorineural hearing loss (*Figure 6*), predominantly affecting high frequencies.[8,16,17]

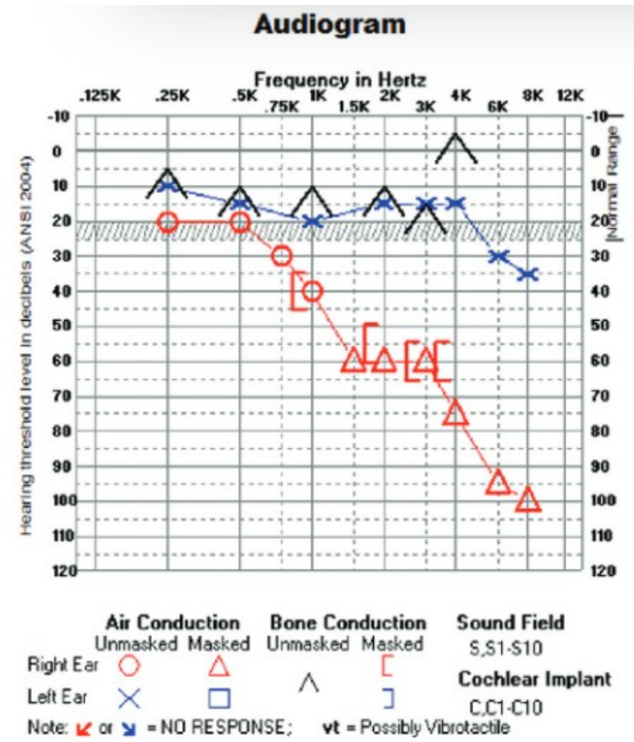


Figure 6. In the diagnostic pathway for VS, the pre-operative tonal audiogram typically reveals a sensorineural unilateral high-frequency hearing loss.
Carlson, M. L., Morreale, R. & F. Comprehensive Management of Vestibular Schwannoma. (Thieme Medical Publishers, New York, 2019)

In association with this previously mentioned finding, the vocal audiometric test, as illustrated in *Figure 7*, often shows a decrease in the word recognition score percentage with increasing presentation levels, a phenomenon referred to as Roll-over. Despite the limited sensitivity of the Roll-over test, it can serve as an additional tool to aid in discriminating the presence of retrocochlear disorders, such as VS, commonly associated with sensorineural hearing loss and a consequent reduction in speech intelligibility.[8,18,19]

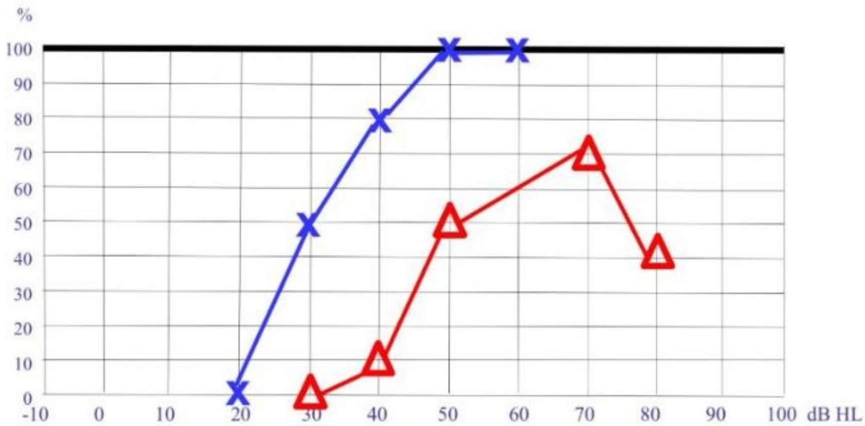


Figure 7. A vocal audiometric test demonstrating a loss of speech intelligibility in the right ear, consistent with the Roll-over phenomenon and indicative of a retrocochlear disorder.

However, the gold standard for diagnosing VS is the contrast-enhanced magnetic resonance imaging (MRI), that is the imaging showing the content of the CPA and the IAC. The tumor is depicted in *Figure 8 and Figure 9* as: a hypointense lesion on T1 sequences, with homogeneous or inhomogeneous pattern of contrast enhancement depending on the presence of solid, cystic (*Figure 10*), necrotic or hemorragic components; a heterogeneous signal on T2 sequences, resulting hyperintense or hypointense in soft and firm schwannomas respectively.[6,20]

A differential diagnosis through morphological and functional imaging can help to distinguish the different lesions of this anatomical region. Diffusion-weighted imaging (DWI) is used to differentiate schwannomas, which do not restrict diffusion, from other CPA lesions such as epidermoid cysts or meningiomas. Moreover, the various inner ear disorders can be better studied through the emergence of 3 Tesla MRI with late Three-Dimensional Fluid-Attenuated Inversion Recovery (3D FLAIR).[8,12]

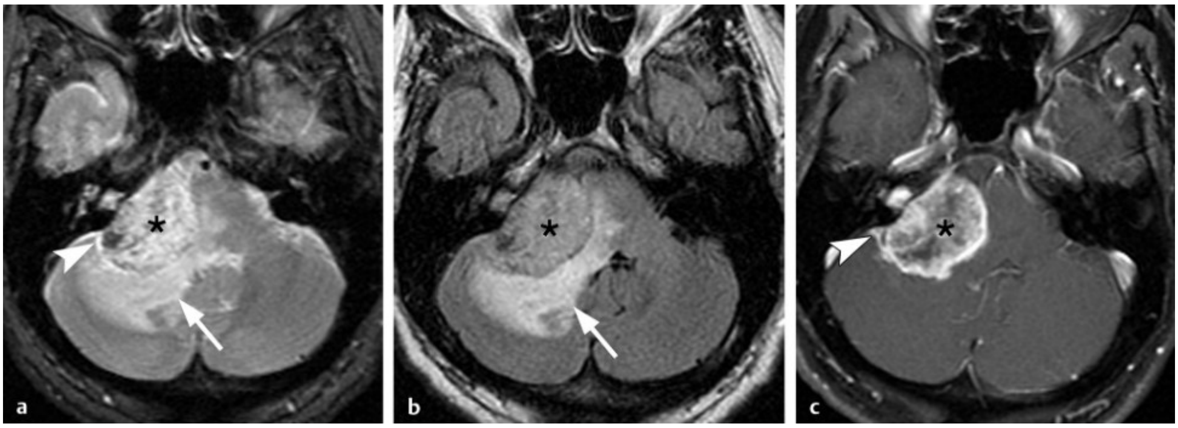


Figure 8. (a-c) Axial T2, FLAIR, T1 sequences respectively, revealing a large right VS (asterisk). *Carlson, M. L., Morreale, R. & F. Comprehensive Management of Vestibular Schwannoma. (Thieme Medical Publishers, New York, 2019).*

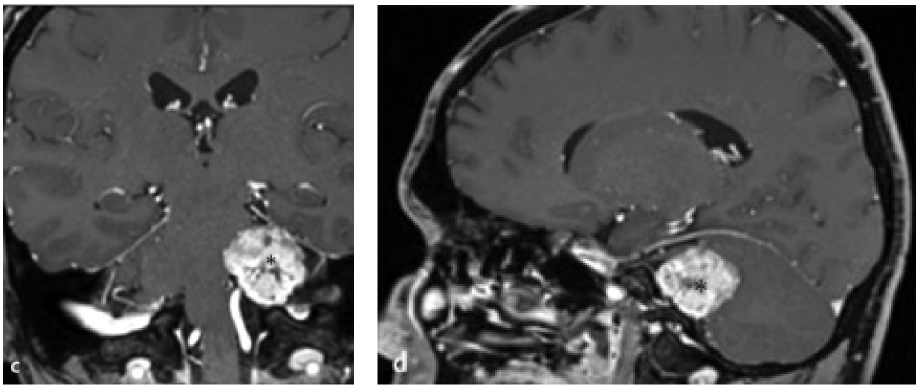


Figure 9. (c-d) Contrast-enhanced MRI scans: coronal T1 and sagittal T1 imaging showing a left VS. *Marchioni, D. & Presutti, L. Endoscopic Lateral Skull Base Surgery. (Thieme, Stuttgart, Germany, 2022).*

Figure 10. Contrast-enhanced MRI with gadolinium scan: axial T1-weighted imaging showing a left cystic VS. *Carlson, M. L., Morreale, R. & F. Comprehensive Management of Vestibular Schwannoma. (Thieme Medical Publishers, New York, 2019).*

1.1.4 KOOS Classification

The Koos classification is used to distinguish 4 Grades of VS (see *Figure 11*), based on their localization and size[16]:

- Koos I:
  the tumor size is < 1cm, exclusively confined in the IAC, generally associated with unilateral hearing loss and tinnitus, rarely dizziness may also appear.[16]
- Koos II:
  the tumor extends from the IAC to the CPA without touching the encephalic trunk. The clinical presentation can be very similar to the VS at the 1st stage.[6,8]
- Koos III:
  the increasing volume of the VS in the CPA is causing brainstem compression, without producing a significant displacement. Additional symptoms can be shown by the patient, such as trigeminal hypoesthesia or a mild ataxia.[16]
- Koos IV:
  it represents a large neuroma whose significant brainstem compression and consequent displacement determine the phenomenon of hydrocephalus. The clinical condition can be characterized by headache and visual impairment, the risk of cerebral edema, hemiparesis, ataxia, up to cardiorespiratory dysfunction. However, some KOOS VI neuromas can be diagnosed in the absence of the significant clinical pattern which has been previously described; infact, the symptoms can sometimes be very nuanced: there are patients who have only auditory asymmetry while the MRI imaging detects the tumor at Stage IV. In contrast, small-medium VS can be related to significant symptoms and signs.[15,16,21]

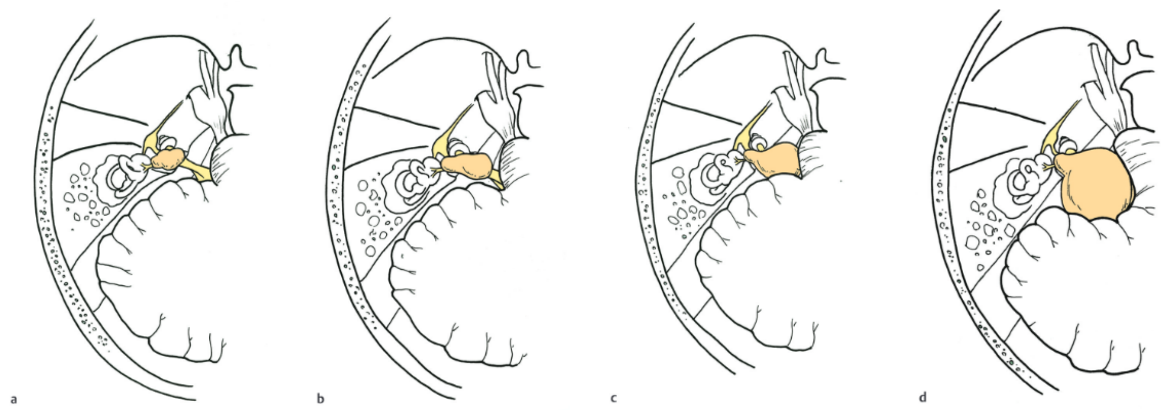


Figure 11. Illustration of the Koos classification for VS. (a-d) Koos I-IV respectively.
Marchioni, D. & Presutti, L. Endoscopic Lateral Skull Base Surgery. (Thieme, Stuttgart, Germany, 2022)

1.1.5 Treatment

Treatment decision making depend on the following factors: age, Koos classification, hearing function, comorbidities and performance status.[17,22]

As with any clinical and surgical therapeutic decision, the patient empowerment should always be respected and applied. It is very important to focus on an adequate counselling with the patient, in order to inform him about all the risks and potential complications of the operation, to allow him to choose the most appropriate treatment that would reflects his own preferences.[8]

The main options include[8,17]:

1. Observation - *"Wait and Scan" or "Wait and See"*

This strategy is indicated for small tumors (KOOS I), asymptomatic or with stable symptoms, with no FN dysfunction detected.[2,6] It is also the option recommended to elderly patients, unable to undergo a surgery treatment due to their health conditions or when they refuse the operation. This approach consists in a follow-up through regular MRI scan every 6 months to monitor tumor growth. If during the *Wait and Scan* it will be detected a fast growing lesion (at least >2 mm/year), another therapeutic approach will be considered.[12]

Only in cases where the small neuroma is accompanied by symptoms affecting the quality of life and/or refractory to pharmacological treatment, the intervention is strictly recommended.[2,6,12,22]

2. Gamma-Knife Radiosurgery

This type of stereotactic radiosurgery is generally used for the treatment of deep intracranial tumors. The goal is to prevent further growth (not blocking tumor evolution completely), controlling it through gamma rays concentrated in that specific target. In this way, the radiation-induced damage should be reduced to the minimum. As regards the VS, it represents a good option for small to medium-sized tumors (<3 cm) in patients with preserved hearing. The Wait and Scan is necessary to verify the stable state of tumoral cells growth or it may suggest the need of another session of radiosurgery.[11,12,23]

However, Gamma-Knife Surgery is not free of complications: a radiation-induced necrosis can be detected as well as secondary malignancies due to gamma rays damage. Also a FN dysfunction with iatrogenic palsy may represent a consequent of this treatment. Other side effects are included, such as hearing impairment, trigeminal neuropathy, hyporesorptive hydrocephalus and increasing of tumor size, the latter being a clear indication of non-responsiveness to therapy. In addition, the tissue treated with radiation therapy is much more difficult to remove surgically, due to the inflammatory and adhesion areas resulting from Gamma-knife. In order to avoid this complication, this type of radiosurgery can be suggested as a solution for the elderly and patients who refuse surgery but not recommended in very young patients who have a longer life expectancy.[11,24]

3. Microsurgery

The surgical approach is decided based on the tumor size and the patient's hearing. Generally, the aim of surgery is the complete VS removal, considering the gross total resection (GTR) as the first choice while the near total resection (NTR) and the subtotal resection (STR) are the other possible options.

Different approaches are used for the excision of the acoustic neuroma, belonging to lateral skull base surgical techniques: the translabyrinthine (TL), retrolabyrinthine, transotic, transcochlear approaches – included in the transpetrous approach – the retrosigmoid (RS), the middle cranial fossa (MCF) and the infratemporal approaches. Moreover, recently also the transcanal transpromontorial approach has emerged. As a matter of fact, the hearing loss is the unavoidable consequence of the otic capsule-crossing techniques – the TL, the transotic, the transcochlear and the transcanal transpromontorial (TT) – while the hearing preservation is possible in the other ones, depending also on the tumor size.[2,25,26]

Among the techniques outlined above, the RS and TL approaches are the most utilized: the first is suggested in case of serviceable hearing function, while the latter is indicated in case of severe hearing loss. In contrast, the MCF and TT approaches are employed in selected cases of small VS (KOOS I/II) located exclusively within the IAC, with potential limited extension into the most lateral portion of the CPA. Specifically, the TT approach is indicated in cases where hearing is already compromised, whereas the MCF technique is the preferred surgical option for patients whose primary objective is hearing preservation.[26]

1.1.6 The Translabyrinthine approach

The TL approach, shown in *Figure 12,* is primarily indicated for tumors located mainly in the IAC with limited involvement of the CPA in patients with ipsilateral hearing dysfunction or totally compromised one. Considering the advantages of this technique, a direct access to both the IAC and CPA is performed, without requiring cerebellar retraction. Furthermore, it allows the early identification of the FN at the fundus of the IAC, while the continuous intraoperative FN monitoring is required.[2,4,25,27]

The surgical steps of TL approach are therefore depicted: 1) incision: a C-shaped skin incision is approximately 4 cm posterior to the retroauricular sulcus; 2) the occipitomastoid bone is exposed elevating a muscle-periosteal flap and identifying the posterior wall of the external auditory canal (EAC); 3) an extended mastoidectomy is performed, removing the mastoid cells between the middle cranial fossa and the sigmoid sinus; this procedure guarantees the exposure of the antrum, the short process of the incus, the labyrinthine block, the mastoid tract of the FN, the endolymphatic sac, the sigmoid sinus until the jugular bulb. 4) The labyrinthectomy is conducted and the semicircular canals – lateral, posterior, anterior – are opened, then also the vestibule is detected and opened, exposing the fundus of the IAC; 5) under continuous neurophysiological intraoperative monitoring (NIM), the IAC is drilled out, respecting its anatomical boundaries: the jugular bulb inferiorly, the posterior fossa medially, and the middle cranial fossa superiorly; once fully exposed, the dura of the IAC and that one of the posterior cranial fossa is cut, entering the CPA. 6) The VS is detected and its removal is started, carefully detaching the tumor from the FN first, then from the vascular structures arising from the AICA; if the VS had more elevated dimension, the need of detachment from CNs IX, X, XI, V would have been necessary. At the end of dissection, the vestibular and the cochlear nerves are cut and the VS is removed from the CPA. 7) The FN anatomical and functional integrity is tested; then, the surgical site is reconstructed using muscle graft, oblitering the antrum, and abdominal fat graft in order to prevent cerebrospinal fluid (CSF) leaks. Bone dust and fibrin glue are applied to seal the middle ear, and the incision is closed with a compressive dressing applied.[2,4]

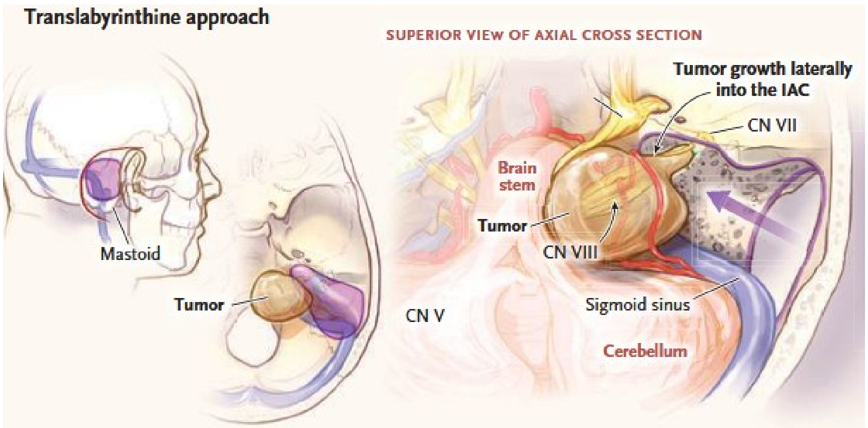


Figure 12. Illustration of the TL approach. *Carlson, M. L. & Link, M. J. Vestibular Schwannomas. N. Engl. J. Med.* ***384****, 1335–1348 (2021).*

Generally considered a safe and effective technique, the potential complications linked to the TL approach are described: CSF leakage, facial or lower cranial nerve deficits, meningitis or other postoperative infections, hemorrhage or hematoma formation within the CPA, ischemic events, including infarction or stroke. Moreover, as mentioned above, hearing loss is intrinsic to the surgical technique.[2,4,25]

1.1.7 The Retrosigmoid approach

The RS approach, displayed in *Figure 13*, is a traditional microscopical technique widely used to access directly the posterior fossa and the CPA, suited for the VS removal of any dimension, usually combined to endoscopic assistance which may improve the limited exposure of lateral IAC.[2,4,25,27]

Different advantages are linked to the combined microscopical-endoscopic procedure: 1) a better surgical precision is guaranteed; 2) the visibility of the IAC is improved, identifying and removing lesions extending into the fundus; 3) an extensive posterior IAC drilling is avoided, reducing operative time and preserving the surrounding neurovascular structures. Furthermore, the VS located in the CPA and extending into the IAC is only one of the possible indications for this type of surgical intervention. Another relevant condition is a neurovascular conflict, typically characterized by compression of the acoustic-facial nerve bundle by the anterior inferior cerebellar artery (AICA), which can lead to significant functional disturbances and often necessitates decompression. [2,27]

The surgical procedure is better described in this paragraph: 1) the facial NIM is applied, then a retroauricular skin incision, 3 cm behind the sulcus, is performed, exposing the occipital bone behind the sigmoid and below the transverse sinus. The temporal muscle is incised and detached until reaching the digastric insertion on the mastoid tip. 2) A 4×4 cm craniotomy is performed, then the dural incision of the posterior fossa allows the cerebellum exposure. 3) The cerebellum is gently elevated, using neurosurgical cottonoids, in order to visualize the cerebellopontine cistern and the CPA. Finally, the tumor is detected in the surgical field. 4) A 0-degree endoscope is introduced to evaluate the relationship between the mass and surrounding neurovascular structures. The VS removal is executed using an ultrasonic aspirator, starting with a central debulking which facilitates mobilization and dissection of the capsule. Then, the tumor is carefully detached from the lower cranial nerves, the trigeminal nerve, the acoustic-facial bundle. The cochlear and facial nerves preservation is attempted. 5) Once the CPA portion is removed, the surgical attention shifts to the residual intrameatal part of the schwannoma localized in the IAC. The dissection is performed in a medial-to-lateral direction, carefully preserving both the FN and the internal auditory artery. Continuous FN monitoring is essential. The porus of the IAC is exposed, drilled to enlarge the opening if necessary – any surrounding bone defect is repaired immediately using bone dust or muscle and fibrin glue – allowing the removal of any residual tumor until the fundus. Considering the dissection of an encapsulated schwannoma, it is clear that it results easier than a not encapsulated neuroma for which angled instruments and more delicate handling should be required. 6) A final check is conducted endoscopically and microscopically to confirm hemostasis. The dura is closed in a watertight fashion, and small defects are repaired with a muscle plug. The preserved bone is repositioned, and the surgical site is closed in muscular, subcutaneous and cutaneous layers.[2,4]

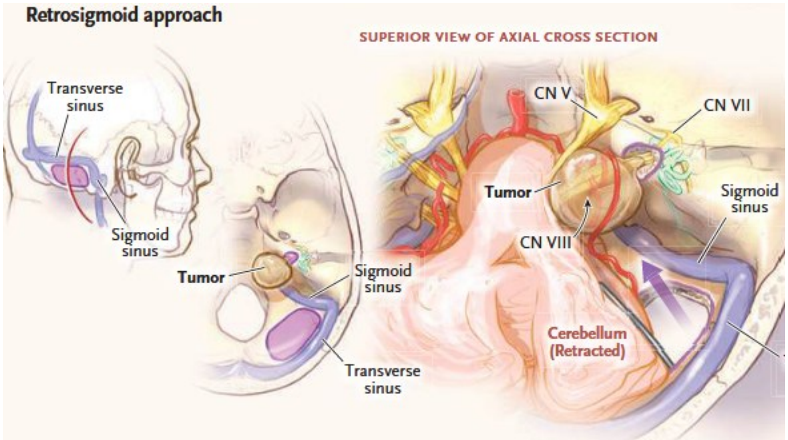


Figure 13. Illustration of the RS approach.
Carlson, M. L. & Link, M. J. Vestibular Schwannomas. N. Engl. J. Med. ***384****, 1335–1348 (2021).*

Postoperatively, the patient may be monitored in the intensive care unit (ICU) for the first 24-36 hours. Regardless of the type of approach employed, a computed tomography (CT) scan is performed 6 hours after surgery, as the immediate postoperative status must be evaluated so as to exclude acute complications, primarily hemorrhages, cerebral edema, and pneumocephalus. A second CT scan is performed between 48 and 72 hours. Around 48 hours postoperatively, a gradual mobilization should be undertaken by patients in order to reduce the risk of deep vein thrombosis and pulmonary embolism. The long-term follow-up includes an MRI scan at one year to evaluate surgical outcomes and detect any signs of tumor recurrence.[2,8]

1.1.8 Post-operative complications

The safety of such surgical operations is very high, thanks to the evolution of microsurgery techniques, according with some authors the associated mortality is low, between 0.3-0.4% and 1.3%.[4,13] Furthermore, the essential instrument of facial NIM is requested in order to ensure the functional integrity and to monitor the responsiveness of the FN during the various stages of surgery and particularly after the tumor removal, considering the difficulty presented in case of tumor adhesion to the FN sheath. The NIM has been widely recognized as the approach that lays the foundation for a successful procedure, maximizing the chances of nerve preservation to the greatest extent possible.[28,29]

Focusing on the TL and RS approaches discussed above, post-surgical complications are examined here. Differently to the previously described TL technique, the RS approach is characterized by different access with better visualization of the CPA but limited IAC exposure, the intradural drilling, the cerebellar retraction – associated to higher risk of cerebellar edema and hematoma, postoperative headache, ataxia - the potential hearing preservation.[4,25]

As regards the TL approach, the hearing should be sacrificed as the surgical technique provides for the otic capsule crossing, with the demolition of the labyrinth. In this context, it is important to highlight the feasibility of performing delayed or simultaneous cochlear implant (CI) placement after VS surgical resection. Critical prerequisites for this approach include the preservation of the cochlear nerve with its vascular supply and the anatomical integrity of the cochlea. During tumor dissection, a meticulous attention must be paid and the cochlear NIM should be employed to protect these structures. Furthermore, the results reported in literature are controversial and, according to some authors, the cochlear ossification during the postoperative time has been associated with a poorer hearing outcome following CI.[2,30]

Common complications among the lateral skull base surgical approaches are as follows, not listed in order of frequency: 1) vascular damages with hemorrhages and hematomas in the CPA; a severe postoperative bleeding is rare, but life-threatening complication, that can be avoided through the wide knowledge of anatomy and an advanced surgical skill; the most frequently involved vessels are: the AICA, the internal auditory artery (branch of the AICA), the PICA, the SCA, the basilar artery.[2] 2) nerve dysfunction, involving especially the FN in a transient or permanent Facial Paralysis; also lower cranial nerves deficits can be detected, especially in elderly patients, therefore dysphagia and swallowing difficulty, dysphonia, trapezius and sternocleidomastoid weakness can be shown. 3) ischemic events including cerebellar infarction, cerebral ischemia or stroke; 4) equilibrium impairment, due to cerebellar damage and vestibular dysfunction; 5) tumor recurrence, primarily related to subtotal or near total resection[21,31]; in comparison with the TL approach, an higher risk is associated to the RS surgery, probably linked to the different surgical field visualization and the tumor dimension; 6) CSF leakage: the pathological condition resulting from a defect in the dura or skull, creating an abnormal connection or fistula that permits the CSF outflow through a breach in the external ear canal (otorrhea) or through the eustachian tube, manifesting as rhinorrhea. The CSF risk seems to be related to the type of the approach, in particular the final dural closure step, resulting in higher risk for RS approach,[25] but according to some authors, the size of the tumor appears to be a contributing factor in the formation of a CSF leak.[25,32] 7) as a consequence of an abnormal communication with the sterile subarachnoid space, a secondary meningitis may result from a postoperative CSF leakage, whether as an aseptic form or bacterial one with *Streptococcus pneumoniae* and *Haemophilus influenzae* being the most common causative agents.[2,4,33]

1.2 Facial nerve paralysis: evaluation and rehabilitation

1.2.1 Facial Nerve Anatomy

The origin of the FN is located in the pons, ventrolateral to the abducens nucleus. The FN course is illustrated in *Figure 14*.

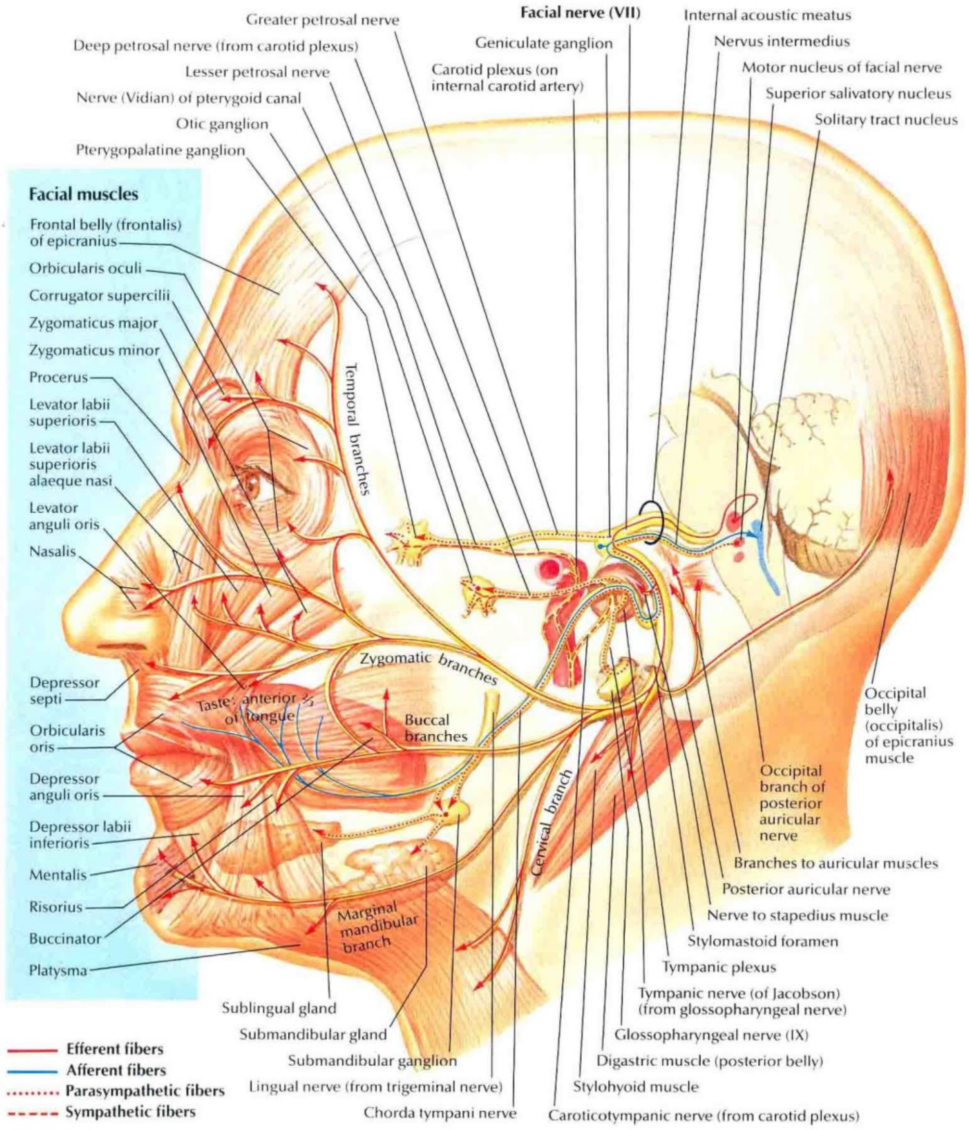


Figure 14. Representation of the course of the FN and its branches. *Weber E, Vilensky et al. (2011) Netter's Concise Radiologic Anatomy.*

It is anatomically divided into intracranial and extracranial segments. Initially, the intracranial course is described: after emerging from the brainstem within the posterior cranial fossa, it enters the IAC along with the vestibulocochlear nerve occupying the anterosuperior quadrant of the canal (*Figure 1, 5*). This portion is referred to as the "cisternal tract" and it is the segment primarily involved in VS pathology. The IAC segment, or "meatal tract", continues from the porus to the fundus. Subsequently, the nerve traverses the FN canal where it is further divided anatomically into three intratemporal segments: labyrinthine, tympanic, and mastoid. The labyrinthine segment extends to the first genu, the geniculate ganglion (GG), and gives rise to its first branch, the greater superficial petrosal nerve (GSPN); this one travels forward to the foramen lacerum, where it joins the deep petrosal nerve (DPN) to form the Vidian nerve. The tympanic segment passes posteriolaterally to the tympanic cavity, superiorly to the oval window, and continues as the mastoid segment after forming a second genu. The mastoid segment gives off two additional branches: the stapedius nerve and the chorda tympani nerve; this one traverses the tympanic cavity in close proximity to the ossicular chain. The extracranial segment of the FN begins as the nerve exits the stylomastoid foramen. It then enters the parotid gland posteriorly, crossing the external jugular vein and the external carotid artery. Within the parotid gland, collateral branches are given off, including the auricular posterior nerve, the digastric nerve, and the stylohyoid nerve. Within the gland, the FN course separates the superficial and deep lobes through a cleavage plane, dividing into two terminal trunks which give rise to five terminal branches: the temporofacial trunk superiorly ends with the temporal, zygomatic, and buccal branches; the cervicofacial trunk inferiorly end with the mandibular and cervical branches.[2]

The FN is a mixed nerve composed of four types of fibers: motor and sensory, both somatic and visceral. Below, its components are described, along with the structures innervated by the respective nerve branches:

- Motor fibers, originating from the FN motor nucleus located at the pontine level, innervate: 1) the stapedius muscle (via the stapedius nerve of the mastoid segment; its insertion on the stapes is crucial for the stapedius reflex); 2) the posterior belly of the digastric muscle (through the intraparotid collateral branch directed to the digastric); 3) the stylohyoid muscle (the homonymous intraparotid collateral branch); 4) the cutaneous muscles, also known as the mimetic muscles, involved in altering facial expressions (via terminal branches of the facial nerve).
- Visceral parasympathetic motor fibers, attributed to the nervus intermedius, also known as Wrisberg's nerve, originating in the superior salivatory nucleus; these fibers are directed to the lacrimal, nasal and palatine glands (via the GSPN), as well as the submandibular and sublingual salivary glands (via the chorda tympani).
- Somatic sensory fibers: these ones provide sensory innervation to the auricle, the skin of the EAC and the lateral surface of the tympanic membrane.

- Gustatory sensory fibers: these originate from the chorda tympani and provide taste sensation to the anterior two-thirds of the tongue.[2]

1.2.2. Post-Surgery Facial Nerve Paralysis

As mentioned above, one of the most common postoperative complications resulting from the acoustic neuroma surgery is the FN dysfunction. This phenomenon occurs as this nerve is displaced along its course together with the acoustic-facial bundle (*Figure 2, 3, 5*), as discussed in the previous chapter; this can lead to compression phenomena caused by the tumor and affecting the FN (see *Figure 15*). It is well known that the growth of VS does not lead to infiltration of the FN but rather causes its compression and the fanning out of its fibers. Under these conditions, the FN becomes challenging to be dissected from the tumor, with repeated manipulation being required, particularly for the segment located within IAC.[8]

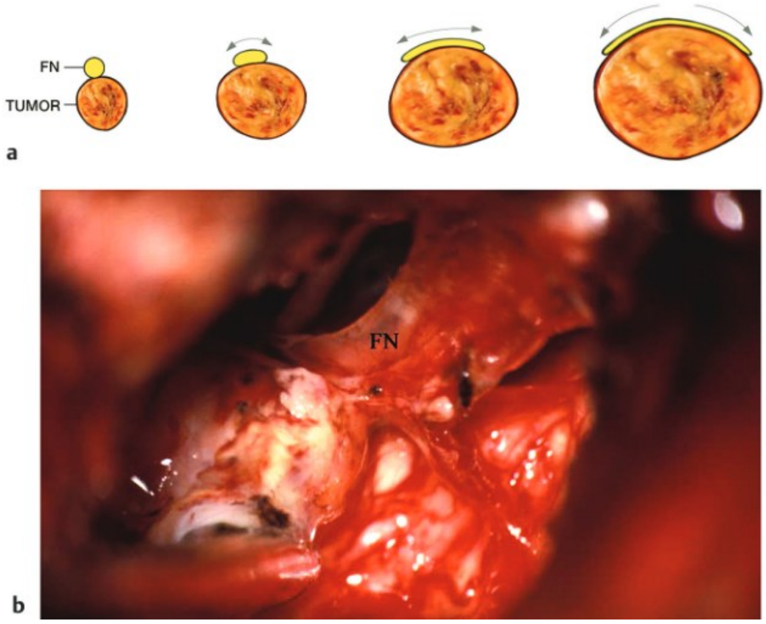
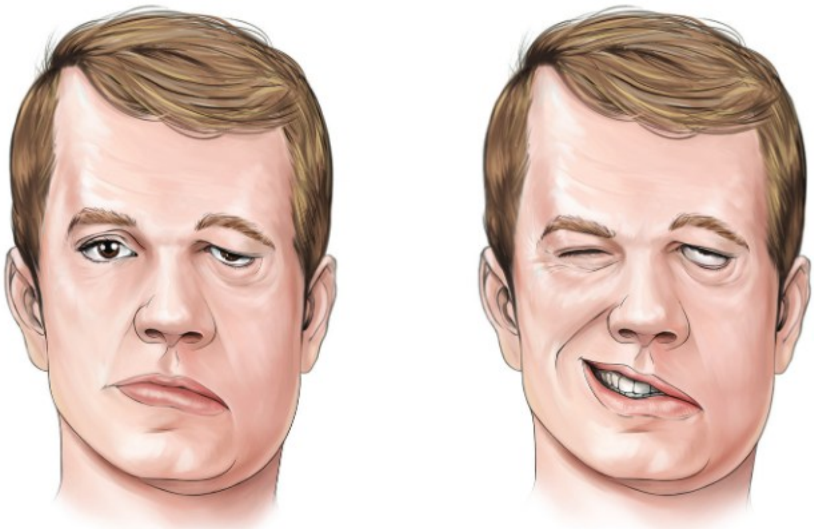


Figure 15. The FN fibers are "stretched and splayed over the tumor capsule"[8].
Carlson, M. L., Morreale, R. & F. Comprehensive Management of Vestibular Schwannoma. (Thieme Medical Publishers, New York, 2019).

The facial nerve paralysis (FNP) refers to the complete or partial functional deficit of the nerve VII, resulting primarily in facial muscle weakness or absence of movement – being this alteration of movement particularly significant in terms of quality of life.

The FNP observed after VS surgery, based on clinical and speech therapy evaluations, is typically peripheral and unilateral. The distinction between *peripheral* and *central* FNP is aided by the observation of frontal muscle contraction: in cases of central FNP, the upper facial muscles are preserved due to bilateral cortical innervation, while only the contralateral lower half of the face is affected; conversely, all the muscles of one side of the face are involved in the peripheral FNP, with severity according to the nerve dysfunction grade.

Regarding the latter, the FNP is characterized by the loss of tone in facial muscles of the affected hemifacial region, observing static and dynamic signs (*Figure 16*): the depression of the lateral canthus, the ectropion (outward turning of the lower eyelid margin, leading to increased corneal and conjunctival exposure), the lagophthalmos (the inability to fully close the eye), the Bell's phenomenon (the oculomotor reflex during eyelid closure, characterized by the conjugate upward and outward rotation of the eyeball), the lowering of the oral commissure, and the flattening of the forehead wrinkles and nasolabial fold.



a. **b.**

Figure 16. (a) Static and (b) dynamic signs of peripheral FNP.
Carlson, M. L., Morreale, R. & F. Comprehensive Management of Vestibular Schwannoma. (Thieme Medical Publishers, New York, 2019).

During the clinical FN evaluation, the strength of facial muscles is assessed through a sequence of movements, therefore the patient is instructed to gently close their eyes, then squeeze them tightly; raise their eyebrows and wrinkle their forehead; inflate their cheeks; protrude their lips as if to kiss; smile while showing their teeth; clench their teeth.

The House-Brackmann (HB) Facial Grading System (*Table 1*)[34] is the widely used tool to evaluate the FN functional recovery, classifying it into six grades based on the quality of movement and the degree of symmetry, ranging from HB Grade I, representing normal facial function, to HB Grade VI, indicating complete paralysis.[2,8,34,35]

Grade	Description	Characteristics
I	Normal	Normal facial function in all areas
II	Mild dysfunction	Gross: slight weakness noticeable on close inspection; may have very slight synkinesis At rest: normal symmetry and tone Motion Forehead: moderate to good function Eye: complete closure with minimum effort Mouth: slight asymmetry
III	Moderate dysfunction	Gross: obvious but not disfiguring difference between two sides; noticeable but not severe synkinesis, contracture, and/or hemifacial spasm At rest: normal symmetry and tone Motion Forehead: slight to moderate movement Eye: complete closure with effort Mouth: slightly weak with maximum effort
IV	Moderately severe dysfunction	Gross: obvious weakness and/or disfiguring asymmetry At rest: normal symmetry and tone Motion Forehead: none Eye: incomplete closure Mouth: asymmetric with maximal effort
V	Severe dysfunction	Gross: only barely perceptible motion At rest: asymmetry Motion Forehead: none Eye: incomplete closure Mouth: slight movement
VI	Total paralysis	No movement

Table 1 [34]. The House-Brackmann Facial Grading System.
Carlson, M. L., Morreale, R. & F. Comprehensive Management of Vestibular Schwannoma. (Thieme Medical Publishers, New York, 2019).

However, a more objectively detailed analysis is provided by the Sunnybrook (SB) Facial Grading System (*Table 2*) which assigns three separate scores—one for the degree of symmetry at rest, one for the quality of voluntary movements and the last one for the extent of synkinesis (referring to involuntary movements associated with the voluntary activation of different muscles) — the sum of which determines the final score (from 0 to 100).[8,36,37] The superior level of detail in assessment, alongside the enhanced sensitivity conferred by a more comprehensive and investigatory scoring methodology, could suggest that the SB scale is preferable to the HB one. Moreover, the SB system allows a more refined qualitative and quantitative evaluation of voluntary movement excursion as well as a more thorough assessment of synkinesis.

A recent contribution by Alicandri-Ciufelli et al.[38] introduced the Rough Grading System (RGS), an innovative scale designed to validate a more objective method for achieving more precise evaluations in this field. However, despite its validated reliability, the RGS has yet to see widespread adoption in clinical practice.

Sunnybrook Facial Grading System

Resting Symmetry

Compared to normal side

Eye (Choose one only)		
	normal	0
	narrow	1
	wide	1
	eyelid surgery	1
Cheek (naso-labial fold)		
	normal	0
	absent	2
	less pronounced	1
	more pronounced	1
Mouth		
	normal	0
	corner drooped	1
	corner pulled up/out	1
	Total	☐
Resting symmetry score	Total x 5	☐

Patient's name

Dx

Date

Symmetry of Voluntary Movement — Degree of muscle EXCURSION compared to normal side; **Synkinesis** — Rate the degree of INVOLUNTARY MUSCLE CONTRACTION associated with each expression

Standard Expressions	Unable to initiate movement/no movement	Initiates slight movement	Initiates movement with mild excursion	Movement almost complete	Movement complete		NONE: no synkinesis or mass movement	MILD: slight synkinesis	MODERATE: Obvious but not disfiguring synkinesis	SEVERE: Disfiguring synkinesis/Gross mass movement of several muscles	
Forehead Wrinkle (FRO)	1	2	3	4	5	☐	0	1	2	3	☐
Gentle eye closure (OCS)	1	2	3	4	5	☐	0	1	2	3	☐
Open mouth Smile (ZYG/RIS)	1	2	3	4	5	☐	0	1	2	3	☐
Snarl (LLA/LLS)	1	2	3	4	5	☐	0	1	2	3	☐
Lip Pucker (OOS/OOI)	1	2	3	4	5	☐	0	1	2	3	☐
	Gross Asymmetry	Severe Asymmetry	Moderate Asymmetry	Mild Asymmetry	Normal Symmetry	Total ☐					
				Voluntary movement score:	Total X 4	☐	Synkinesis score:			Total	☐

Vol mov't score	☐	-	Resting symmetry score	☐	-	Synk score	☐	= Composite score ☐

Table 2 [36]. The Sunnybrook Facial Grading System.
Carlson, M. L., Morreale, R. & F. Comprehensive Management of Vestibular Schwannoma. (Thieme Medical Publishers, New York, 2019).

1.2.3 Postoperative rehabilitation and follow-up

After surgery, generally, an initial therapeutic approach is suggested to attempt resolving the FN dysfunction, involving the use of corticosteroids, in order to reduce edema and inflammation, and B-group vitamin supplements to enhance nerve trophism.[4,8] However, the ideal follow-up in the clinical-therapeutic pathway for patients operated for VS removal is defined by a post-surgery integration of the patient into the Facial Nerve Outpatient Clinic (FNOC) at the University Hospital of Modena.[39] The patient is entrusted to the care of a multidisciplinary team, including a surgeon, a speech therapist, and a neurologist, with the shared aim of ensuring guidance and support throughout the therapeutic and rehabilitative process. The follow-up is conducted three-monthly, by appointment. During each outpatient visit, a neurological physical examination is performed to evaluate the degree of FN function (using the HB and SB Facial Grading Systems, previously described); additionally, a neurophysiological assessment with electroneurography (ENG) and electromyography (EMG) is required in order to objectify nerve impairment and the severity of motor deficits.[8]

Within the non-surgical rehabilitative pathway for these patients, neuromuscular retraining (NMR), as proposed by Balliet and colleagues[40], represents a valid and decisive approach for improving outcomes in peripheral FNP following VS surgery. The NMR is a specialized form of physiotherapy aimed at re-educating the affected facial muscles to restore effective communication between the brain and the “effector”, in parallel with the FN regeneration process. In this therapeutic program, lasting for 1 to 3 years, the speech therapist acts as the central professional figure, assisting the patient in re-learning and re-gaining voluntary control of the affected muscles in a coordinated and symmetrical manner. The rehabilitation plan encompasses the instruction of precise and controlled movements targeting individual muscles, symmetrical movement patterns, techniques designed to reduce synkinesis, a program of exercises to be performed regularly at home to consolidate the acquired techniques. Furthermore, NMR employs a dynamic and individualized approach whereby the therapeutic regimen is adapted to the patient on an ongoing basis, according to their progress, movement recovery and nerve regeneration.[8,41] In addition, botulinum toxin injections (Botox) may be indicated for the management of facial muscles paresis if clinical evaluation reveals incomplete nerve recovery, specifically to inhibit muscular hypertonia at rest and synkinesis. [8,42]

In cases where the nerve recovery does not occur, a surgical plan, targeted at improving the outcome of paralysis or addressing its sequelae, will represent the most appropriate course of action. The surgical FN rehabilitation is made possible through various techniques, briefly outlined as follows: 1) Reinnervation techniques, including the end-to-end anastomosis, the cable nerve grafting, the hypoglossal-facial nerve anastomosis and the cross-facial nerve graft.[2] It is important to emphasize that reinnervation, aimed at restoring an electrical impulse along the physiological pathways of the nerve, should be performed within two years of the onset of paralysis. Beyond this timeframe, muscle degeneration or adipose metaplasia may be detected; 2) Static techniques, without achieving dynamic function and without any planned reinnervation. In this context, to manage lagophthalmos caused by facial paralysis and initially treated with eye drops to alleviate dryness, eyelid weights are surgically implanted at the level of the upper eyelid. Additionally, incisions and lateral canthal sutures may be required to further reduce conjunctival exposure. Marked asymmetries of the orbicularis oris muscle are addressed through orbicularis oris suspension, achieved with tendon grafts harvested from the leg and transferred at the zygomatic subperiostal level; 3) Dynamic techniques, which, unlike the static approaches, aim to restore a degree of movement in the facial muscles. For this purpose, the Labbé flap, obtained through fascia Lata autograft and temporal muscle transposition, or free microvascular reinnervated flaps harvested from the gracilis or latissimus dorsi muscles, are utilized.[8]

1.2.4 Quality of Life Evaluation

Following the delineation of the characteristics of FNP, it is reasonable to consider this condition a clinically debilitating one for patients. However, it is equally important to emphasize the associated aesthetic and psychosocial impact. Facial muscles are also responsible for conveying facial expressiveness, which constitutes a fundamental aspect of one's personality. A range of complications stemming from FNP may contribute, to varying degrees, to the patient's quality of life (QoL): 1) ocular complications and visual discomfort - as a result of lagophthalmos and ectropion, patients may experience ocular dryness and irritation due to inadequate lubrication of the ocular surface, an increased risk of corneal abrasions with potential ulceration, a higher susceptibility to conjunctival infections, and visual impairment; 2) difficulties in food and liquid intake, arising from the inability to completely close the mouth and the inadequate retention of food and liquids; 3) speech and communication difficulties with impaired emotional expressiveness - the psychological impact of static and dynamic facial deformities, due to movement abnormalities and asymmetries in facial expression, is particularly significant, especially in younger patients.

Considering QoL as a significant determinant of health, the assessment of peripheral FNP in patients undergoing VS surgery should necessarily include, alongside clinical evaluation, based on HB and SB Facial Grading Systems, the use of questionnaires which take into account both deficits and disabilities associated with the condition. To this purpose, two assessment tools are available: the Facial Disability Index (FDI) and the Facial Clinimetric Evaluation (FaCE) scale.

The validated pioneering instrument in this field is the FDI (*Figure 17* and *Figure 18*), developed by VanSwearingen with Brach.[43] It is a self-administered questionnaire consisting of 10 items divided into two subscales of 5 items each – physical function (difficulty in eating, drinking, speaking, tearing/dryness of the eyes, oral hygiene) and social function (calmness, irritability, social isolation, self-consciousness, general well-being) – with a total score ranging from 0 to 55.[8,44] Similarly, the FaCE Scale, created by Kahn and colleagues, represents a reliable tool for measuring the patient's subjective experience, assessing 15 items with a score ranging from 0 to 100 using appropriate formulas (see *Figure 19* and *Figure 20*). These items include: facial movement, facial and ocular comfort, tear control, oral function, and social function. Compared to the FDI, the FaCE Scale provides a more comprehensive assessment of particular symptoms and quality of life dimensions, facilitating a deeper insight into the patient's condition. [8,45]

However, the FaCE questionnaire has been recently translated and validated into an Italian version (I-FaCE) by Nizzoli et al.[46], with the resulting scores subsequently correlated with the HB, SB, and FDI scales.

FACIAL DISABILITY INDEX (FDI)

Name: ______________________________ Date: ______________

Please choose the most appropriate response to the following questions related to problems associated with the function of your facial muscles.
For each question, consider your function **during the past month**.

Office Use Only
Score / Goal

Physical Function

1. How much difficulty did you have keeping food in your mouth, moving food around your mouth, or getting food stuck in your cheek?
   Usually did with:
   5 = No difficulty — 2 = Much difficulty
   4 = A little difficulty — 1 = Usually did not eat because of health
   3 = Some difficulty — 0 = Usually did not eat because of other reasons

1. ________

2. How much difficulty did you have drinking from a cup?
   Usually did with:
   5 = No difficulty — 2 = Much difficulty
   4 = A little difficulty — 1 = Usually did not eat because of health
   3 = Some difficulty — 0 = Usually did not eat because of other reasons

2. ________

3. How much difficulty did you have saying specific sounds while speaking?
   Usually did with:
   5 = No difficulty — 2 = Much difficulty, slurring most of speech
   4 = A little difficulty — 1 = Usually did not eat because of health
   3 = Some difficulty — 0 = Usually did not eat because of other reasons

3. ________

4. How much difficulty did you have with your eye tearing excessively or becoming dry?
   Usually did with:
   5 = No difficulty — 2 = Much difficulty
   4 = A little difficulty — 1 = Usually did not eat because of health
   3 = Some difficulty — 0 = Usually did not eat because of other reasons

4. ________

5. How much difficulty did you have with brushing your teeth or rinsing your mouth?
   Usually did with:
   5 = No difficulty — 2 = Much difficulty
   4 = A little difficulty — 1 = Usually did not eat because of health
   3 = Some difficulty — 0 = Usually did not eat because of other reasons

5. ________

Total: ________

(____ - 5) / 5 x 25 = ________ Physical Score
(____ - 5) / 5 x 25 = ________ Physical Score Goal
For office use only

Figure 17. The FDI questionnaire. Part 1: physical function. Patients rate their difficulties on a scale, which is used to calculate the total FDI score.
VanSwearingen, J. M. & Brach, J. S. The Facial Disability Index: reliability and validity of a disability assessment instrument for disorders of the facial neuromuscular system. Phys. Ther. ***76****, 1288–1298; discussion 1298-1300 (1996).*

Facial Disability Index – Part 2

Please choose the most appropriate response to the following questions related to problems associated with the function of your facial muscles.
For each question, consider your function **during the past month**.

Office Use Only
Score / Goal

Social / Well-being Function

6. How much time have you felt calm and peaceful?
6 = All of the time   3 = Some of the time
5 = Most of the time   2 = A little bit of the time
4 = A good bit of the time   1 = None of the time

6. ______

7. How much of the time did you isolate yourself from people around you?
1 = All of the time   4 = Some of the time
2 = Most of the time   5 = A little bit of the time
3 = A good bit of the time   6 = None of the time

7. ______

8. How much of the time did you get irritable toward those around you?
1 = All of the time   4 = Some of the time
2 = Most of the time   5 = A little bit of the time
3 = A good bit of the time   6 = None of the time

8. ______

9. How often did you wake up early or wake up several times during your nighttime sleep?
1 = Every night   4 = Some nights
2 = Most nights   5 = A few nights
3 = A good number of nights   6 = No nights

9. ______

10. How often has your facial function kept you from going out to eat, shop, or participate in family or social activities?
1 = All of the time   4 = Some of the time
2 = Most of the time   5 = A little bit of the time
3 = A good bit of the time   6 = None of the time

10. ______

Total:
______

For office use only
(____ - 5) / 5 x 20 = ________ Social/Wellbeing Score
(____ - 5) / 5 x 20 = ________ Social/Wellbeing Score Goal

Physical (_____) + Social (_____) = (________/ 200) total FDI Score

Physical (_____) + Social (_____) = (________/ 200) total FDI Score Goal

Figure 18. The FDI questionnaire. Part 2: social function. Patients rate their difficulties on a scale, which is used to calculate the total FDI score.

VanSwearingen, J. M. & Brach, J. S. The Facial Disability Index: reliability and validity of a disability assessment instrument for disorders of the facial neuromuscular system. Phys. Ther. 76, 1288–1298; discussion 1298-1300 (1996).

You may have answered these or similar questions before. Please answer ALL QUESTIONS as best you can.
The following statements are about how you think your face is moving.

(CIRCLE only ONE number)	One side	Both sides	I have no difficulty
When I try to move my face, I find that I have difficulty on	1	2	0

(If you have problems on BOTH sides, answer the questions in the remainder of the survey with regard to the more affected side, or with regard to both sides if they are equally affected.) **In the PAST WEEK:**

(CIRCLE only ONE number on each line)	Not at all	Only if I concentrate	A little	Almost normally	Normally
1. When I *smile*, the affected side of my mouth goes up	1	2	3	4	5
2. I can raise my eyebrow on the affected side	1	2	3	4	5
3. When I *pucker* my lips, the affected side of my mouth moves	1	2	3	4	5

The following are statements about how you might feel because of your FACE OR FACIAL PROBLEM.
Please rate how often each of the following statements applied to you during the PAST WEEK.

(CIRCLE only ONE number on each line)	All of the time	Most of the time	Some of the time	A little of the time	None of the time
4. Parts of my face feel tight, worn out, or uncomfortable	1	2	3	4	5
5. My affected eye feels dry, irritated, or scratchy	1	2	3	4	5
6. When I try to move my face, I feel tension, pain or spasm	1	2	3	4	5
7. I use eye drops or ointment in my affected eye	1	2	3	4	5
8. My affected eye is wet or has tears in it	1	2	3	4	5
9. I act differently around people because of my face or facial problem	1	2	3	4	5
10. People treat me differently because of my face or facial problem	1	2	3	4	5
11. I have problems moving food around in my mouth	1	2	3	4	5
12. I have problems with drooling or keeping food or drink in my mouth or off my chin and clothes	1	2	3	4	5

The following are statements about how you might have felt *or* been doing in the PAST WEEK because of your FACE OR FACIAL PROBLEM. **Please rate how much you agree with each statement**:

(CIRCLE only ONE number on each line)	Strongly agree	Agree	Don't know	Disagree	Strongly disagree
13. My face feels tired or when I try to move my face, I feel tension, pain, or spasm	1	2	3	4	5
14. My *appearance* has affected my willingness to participate in social activities or to see family or friends	1	2	3	4	5
15. Because of difficulty with the way I *eat*, I have *avoided* eating in restaurants or in other people's homes	1	2	3	4	5

Figure 19. The FaCE Scale Instrument.
*Kahn, J. B. et al. Validation of a Patient-Graded Instrument for Facial Nerve Paralysis: The FaCE Scale. The Laryngoscope **111**, 387–398 (2001).*

Facial Movement Score	=	(((Items 1 + 2 + 3) - # valid) / 4 × (# valid)) × 100
Facial Comfort Score	=	(((Items 4 + 6 + 16) - # valid) / 4 × (# valid)) × 100
Oral Function Score	=	(((Items 11 + 12) - # valid) / 4 × (# valid)) × 100
Eye Comfort Score	=	(((Items 5 + 7) - # valid) / 4 × (# valid)) × 100
Lacrimal Control Score	=	(((Item 8) - # valid) / 4 × (# valid)) × 100
Social Function Score	=	(((Items 9 + 10 + 14 + 15) - # valid) / 4 × (# valid)) × 100
Total Score	=	(((Sum of all 15 items) - # valid) / 4 × (# valid)) × 100

valid = number of items within the domain for which an adequate response was given.

Figure 20. Formulas used for calculating the FaCE Scale domains and total scores, resulting in a scale ranging from 0 to 100.
Kahn, J. B. et al. Validation of a Patient-Graded Instrument for Facial Nerve Paralysis: The FaCE Scale. The Laryngoscope ***111****, 387–398 (2001).*

2 STUDY OBJECTIVES

The aim of this study is to analyse FN outcomes following VS resection. Specifically, by considering the preoperative and intraoperative characteristics of the tumor, we evaluated whether the choice of surgical approach affects the severity of postoperative FN palsy. Furthermore, a secondary objective focuses on patient follow-up and FN rehabilitation, assessing whether the degree and quality of FN recovery may be influenced by the surgical technique performed. To our knowledge, based on the existing literature, this is the first study to analyse using the Sunnybrook grading system.

3 MATERIALS AND METHODS

3.1 Study design

This is a retrospective study performed in a tertiary academic center. The study was conducted in accordance with the Declaration of Helsinki and approved by the Local Ethics Committee (261/2023/OSS/AOUMO, ID 6052).

This investigation included patients with a diagnosis of VS surgically treated with the TL or RS approach between January 2018 and May 2024. Patients with postoperative FN palsy were enrolled in the FNOC at the Department of Otolaryngology-Head and Neck Surgery of the University Hospital of Modena for multidisciplinary follow-up.

The inclusion criteria were as follows:

- Patients diagnosed with VS and with complete documentation related to preoperative clinical evaluation.
- Patients presenting with an anatomically and functionally intact FN prior to surgery.
- Patients who underwent VS surgical resection through the TL and RS approaches.
- Patients who underwent VS removal at the Department of Otolaryngology–Head and Neck Surgery of Modena or another medical centre, provided complete intraoperative data were available.
- Patients followed postoperatively at the FNOC of the University Hospital of Modena, with documented FN outcomes and for a follow-up period of up to 2 years.

The exclusion criteria were as follows:

- Patients treated for FN schwannoma.
- Patients with VS treated with gamma-knife therapy.
- Patients who underwent facial anastomosis or cable nerve grafting.
- Patients who underwent revision surgery for VS.
- Patients presenting with FN dysfunction prior to surgery.
- Patients with pre-surgical complications (e.g., hydrocephalus).
- Patients with incomplete preoperative and intraoperative documentation.
- Patients who required intraoperative facial nerve sacrifice.
- Patients enrolled in follow-up more than 2 months after VS surgery.
- Patients with inadequate follow-up.

3.2 Data collection

The initial phase of data collection for this study involved the review of speech therapy clinical records belonging to patients treated at the FNOC of the University Hospital of Modena for FN rehabilitation following VS resection. Only patients who had undergone surgery using the TL or RS approaches were included. Data related to speech therapy FN evaluation, assessed using the SB scale, were extracted for the follow-up period of up to 24 months (specifically at 3-, 6-, 9-, 12-, 18-, and 24-months post-surgery). SB scores were matched to HB scale scores, based on the conversion method presented in *Table 3*.

SB Grading System	HB Grading System
100	I
80-99	II
60-79	III
40-59	IV
20-39	V
0-19	VI

Table 3. The illustration of correspondence between the two scoring systems: conversion of scores from SB Grading System to HB Scale.

Once the patient cohort for our study was identified, data collection focused on reviewing the medical records of these patients, stored in the database of the Department of Otolaryngology at the University Hospital of Modena. These records were accessed using AUSL Policlinico di Modena software systems (e.g., RDS Abete and Auriga). Among the collected data, particular attention was given to the preoperative clinical-anamnestic documentation, which included information regarding the presenting symptomatology at the first visit – hearing loss, tinnitus, dizziness, CN V deficit, headache and intracranial hypertension, considered either individually or in combination – as well as to the tumor characteristics. From the intraoperative reports, information was extracted regarding the type of surgical approach and resection, the anatomical and functional integrity of the FN intraoperatively, any additional postoperative complications and the degree of FNP at discharge assessed within the first 48 hours post-surgery, using the HB scale. The SB(T0) score used in the analysis of the study corresponded to the score recorded during the first speech therapy assessment conducted within the first 2 weeks post-surgery.

Only patients meeting all inclusion criteria and without any exclusion criteria were selected.

3.3 Statistical Analysis

Statistical analysis were performed using the software STATA version 18.

Continuous data were described using means, standard deviations, medians, quartiles and ranges; these data are listed as follows: *SB(T0)* score*, SB(T12)* score*, deltaSB* – defined as the difference between *SB(T12)* and *SB(T0)* – *SB(T12)synkinesis* score. Categorical variables employed were described by frequency counts and percentages, which included: *type of approach* (*0=RS, 1=TL*), *tumor diameter* expressed in millimetres (*<15, ≥15 and ≤30, >30*), *Koos* Grade (*1,2,3,4*), *HB(T0)* ranging from I to VI according to HB scale.

A two-simple t-test was used to compare means of *SB(T0)* between the two groups; a multivariate analysis was performed using linear regression and considering simultaneously multiple predictors (*SB(T0)* and *type of approach*) to explain the variability of the dependent variable (*SB(T12)*). Pearson's correlation coefficient was used to assess potential correlation between *SB(T0)* and *SB(T12)*, as well as between *SB(T0)* and *tumor diameter*.

A univariate analysis was conducted based on Koos stages, dividing the cohorts into subgroups (excluding the single patient with a Koos 1, thus considering only *Koos* stages *2, 3 and 4*) and comparing the mean *SB(T0)* scores within each subgroup, for both the RS and TL groups. A median test was performed, followed by t-tests.

A second univariate analysis required categorizing *tumor diameter* into three levels, as described above, in order to relate them to the mean *SB(T0)* values in t-tests for both approaches.

Functional recovery at 12 months was calculated by dividing the cohorts into two subgroups, resulting in two dichotomic variables as follows: *recovery40* – defined as the functional recovery with a deltaSB of almost 40 points in those patients with total FNP after surgery (HB Grade VI) – and *recovery20* – indicating the functional recovery with a deltaSB of almost 20 points in those patients with partial FNP after surgery (HB Grades II-V). The distribution of patients in the two groups was examined based on value of *recovery40* (0= no; 1= yes) and *recovery20* (0= no; 1= yes) through the Chi-squared test.

Finally, a Student's T-test was conducted to analyse the potential difference in the incidence of synkinesis at 12 months, considering the corresponding *SB(T12)synkinesis* score within the total *SB(T12)* score.

The results were considered statistically significant for p-values < 0.05.

4 RESULTS

4.1 Descriptive results

Based on the inclusion and exclusion criteria, the cohort consisted of 108 patients who underwent VS surgery, of whom 55 (50.9%) were treated using the RS approach and 53 (49.1%) using the TL technique. The mean age at the time of first clinical assessment at the FNOC was 55 years (range 22-81 years).

Starting from the preoperative clinical-diagnostic evaluation of the patients included in the study, data regarding tumor characteristics were collected and summarized in *Table 4*. Among the total 108 patients who underwent surgery, 55 (50.9%) were diagnosed with right VS, while 53 (49.1%) presented with left VS, with the distribution outlined below. Analysing tumor size and localization, it was observed that in the RS group, 7 individuals (12.7%) had a VS with Koos Grade II, 28 (50.9%) with Koos III, 20 (36.4%) with Koos IV, and none presented with Koos I. On the other hand, in the TL group, Koos Grade II was the most represented (n=21; 39.6%), followed by Koos III (n=19; 35.8%), Koos IV (n=12; 22.6%) and only 1 (1.9%) Koos Grade I VS.

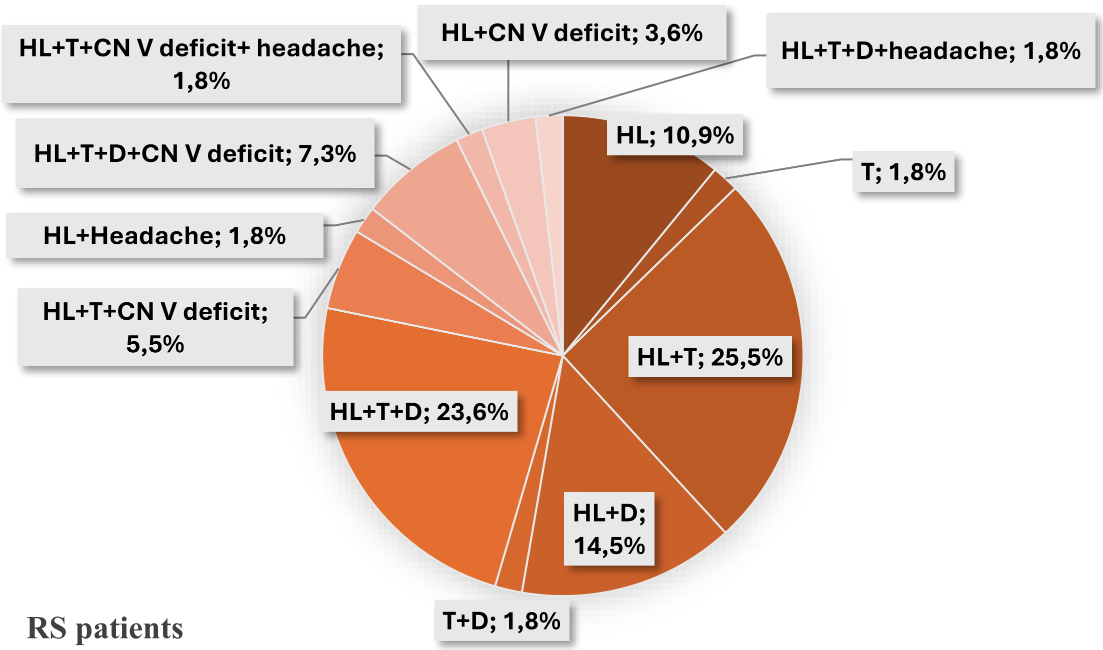
The mean tumor size in the RS group was 24 mm (range 12–43 mm), slightly larger than the mean size for tumors removed using the TL technique, which was 20 mm (range 6–50 mm). Beyond these variables, it was hypothesized that a significant determinant of FN outcomes could be the extent of tumor involvement of IAC structures, fundus, and CPA, as well as brainstem compression. Findings revealed that in the RS group, all patients (n=55; 100%) exhibited a neurinoma localized in the CPA, 52 (94.5%) showed involvement of the IAC, and only 12 (21.8%) showed involvement of the fundus; among these, 20 (36.4%) presented with VS causing brainstem compression. Conversely, in the TL group, all patients included in the study (n=53; 100%) demonstrated VS involving the IAC, nearly all also involving the CPA (n=52; 98.1%), 25 (47.2%) with fundus involvement and 12 (22.6%) causing brainstem compression.

Finally, regarding radiological findings, the dataset recorded 16 (29.1%) cystic neurinomas in the RS group and 8 (15.1%) in the TL group.

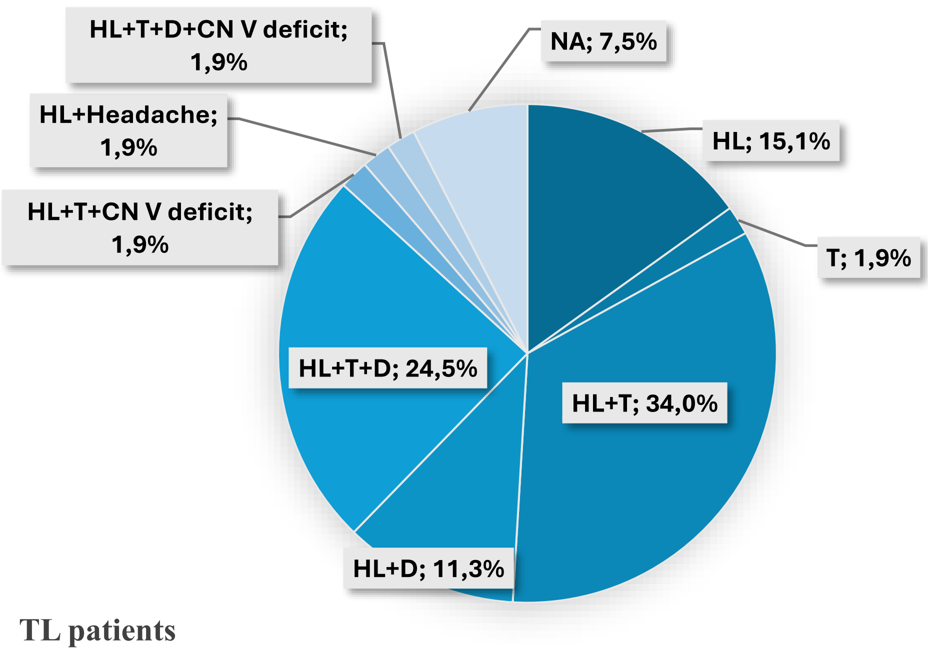
Variables	Overall n=108	RS n=55 (50.9%)	TL n=53 (49.1%)
LATERALITY			
Right	55 (50.9%)	34 (61.8%)	21 (39.6%)
Left	53 (49.1%)	21 (38.2%)	32 (60.4%)
KOOS			
I	1 (0.9%)	0 (0%)	1 (1.9%)
II	28 (25.9%)	7 (12.7%)	21 (39.6%)
III	47 (43.5%)	28 (50.9%)	19 (35.8%)
IV	32 (29.6%)	20 (36.4%)	12 (22.6%)
TUMOR DIAMETER (mm)			
Average (range)	22 (6-50)	24 (12-43)	20 (6-50)
LOCALIZATION			
IAC involvement	105 (97.2%)	52 (94.5%)	53 (100%)
Fundus involvement	37 (34.3%)	12 (21.8%)	25 (47.2%)
CPA involvement	107 (99%)	55 (100%)	52 (98.1%)
Brainstem compression	32 (29.6%)	20 (36.4%)	12 (22.6%)
VS CHARACTERISTICS			
Cystic	24 (24.2%)	16 (29.1%)	8 (15.1%)
Solid	82 (75.9%)	38 (69.1%)	44 (83%)
NA	2 (1.8%)	1 (1.8%)	1 (1.9%)

Table 4. Data collected from the diagnoses and imaging of VS in patients in both groups, presented in absolute values and percentages. NA: not available.

As shown in *Graphic 1* and *Graphic 2*, the most frequent symptoms in the cohort and in both groups were hearing loss (HL) and tinnitus (T) when occurring simultaneously (14 patients undergoing RS and 18 undergoing TL, corresponding to 25.5% and 34%, respectively). However, a modest number of cases, evenly distributed between the two groups, also exhibited dizziness (D) in addition to these symptoms (13 patients in each group, corresponding to 23.6% in the RS group and 24.5% in the TL group). The occurrence of hearing loss alone or associated with dizziness was similar between the two groups, whereas a slight difference was observed in the combined presentation of hearing loss, tinnitus, dizziness and CN V deficit – 4 patients (7.3%) in the RS group versus 1 (1.9%) in the TL group – and in the combination of hearing loss, tinnitus and CN V deficit – 3 patients (5.5%) in the RS group versus 1 (1.9%) in the TL group. Additionally, no patients in either group exhibited dizziness, CN V deficit, or headache as isolated symptoms.



Graphic 1. Symptoms in RS patients, presented in percentages. HL: hearing loss; T: tinnitus; D: dizziness.



Graphic 2. Symptoms in TL patients, presented in percentages. HL: hearing loss; T: tinnitus; D: dizziness; NA: not available.

Upon reviewing tonal audiometry tests available in clinical records, moderate hearing loss was found to be the most represented grade in the RS group (n=27; 49.1%), whereas in the TL group, mild hearing loss (n=19; 35.8%) and moderate hearing loss (n=18; 34%) were predominant. Hearing loss severity data is summarized in *Table 5*.

HEARING LOSS SEVERITY	*Overall* ***n=108***	*RS* ***n=55*** *(50.9%)*	*TL* ***n=53*** *(49.1%)*
Mild (26-40 dB)	34 (31.5%)	15 (27.3%)	19 (35.8%)
Moderate (41-70 dB)	45 (41.7%)	27 (49.1%)	18 (34%)
Severe (71-90 dB)	10 (9.3%)	6 (10.9%)	4 (7.5%)
Profound (>90 dB)	11 (10.2%)	5 (9.1%)	6 (11.3%)
NA	8 (7.4%)	2 (3.6%)	6 (11.3%)

Table 5. Hearing loss severity at diagnosis in both patient groups, presented as absolute values and percentages. The hearing impairment scale is taken from the ASHA classification. NA: not available.
Clark, John. (1981). Uses and abuses of hearing loss classification. ASHA. 23. 493-500.

Moving to the intraoperative data, collected from the respective operative reports and summarized in Table 6, beyond the type of surgical approach utilized and the type of resection – with GTR being widely employed for both groups – the focus was on the intraoperative status of the CN VII. Similar data were recorded across both groups, with the predominant finding for the FN status being *intact and responsive* in 44 RS patients (80%) and 43 TL patients (81.1%).

In the immediate postoperative period, the most recurrent complication was CSF leakage, showing similar incidence in the two groups (10.9% in RS group vs. 11.3% in TL group). However, 78.7% of the total patient cohort did not show complications (specifically, 80% of RS group and 77.4% of TL group).

Focusing on postoperative FNP, the degree of paralysis was assessed at time of discharge (time zero post-surgery, T0) using the HB grading system. It was observed that among RS patients, an HB Grade V predominated (n=18; 32.7%) whereas in the TL group, more cases of Grade II were recorded (n=11; 20.8%) on par with Grade V. Interestingly, 2 patients of TL group (3.8%) had a normal FN function at T0 (HB Grade I) but developed delayed FNP, as noted during the first speech therapy visit after surgery. In terms of SB score, an average of 28 was estimated for the RS group (range 0–88) compared to 36 for the TL group (range 0–92).

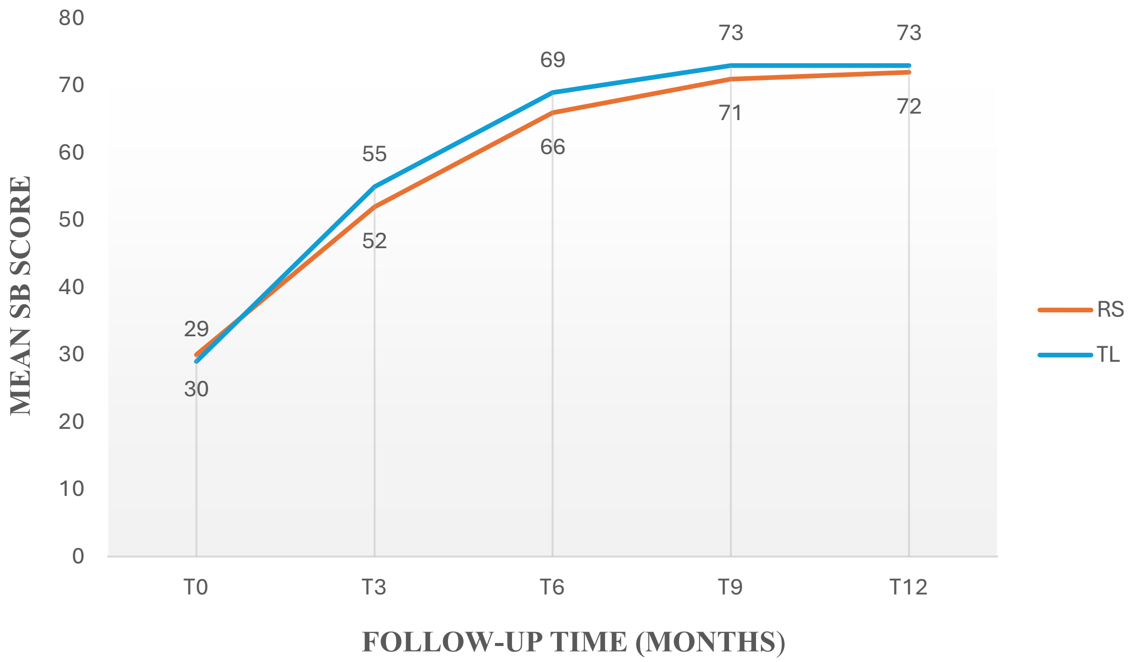
Surgical data	**Overall** n=108	**RS** **n=55** (50.9%)	**TL** **n=53** (49.1%)
TYPE OF RESECTION			
GTR	102	53 (96.4%)	49 (92.5%)
NTR	6 (5.6%)	2 (3.6%)	4 (7.5%)
STR	0 (0%)	0 (0%)	0 (0%)
INTRAOPERATIVE ASSESSMENT OF CN VII			
Intact and responsive	87 (80.5%)	44 (80%)	43 (81.1%)
Damaged but responsive	8 (7.4%)	4 (7.3%)	4 (7.5%)
Intact but unresponsive	5 (4.7%)	2 (3.6%)	3 (5.7%)
Damaged and unresponsive	1 (0.9%)	1 (1.8%)	0 (0%)
Intact but with reduce response	7 (6.5%)	4 (7.3%)	3 (5.7%)
POSTOPERATIVE COMPLICATIONS			
None	85 (78.7%)	44 (80%)	41 (77.4%)
CSF leakage	12 (11.2%)	6 (10.9%)	6 (11.3%)
CSF otorrhea	6 (5.6%)	2 (3.6%)	4 (7.5%)
Subarachnoid hemorrhage	1 (0.9%)	1 (1.8%)	0 (0%)
Meningitis	1 (0.9%)	0 (0%)	1 (1.9%)
Surgical wound infection	1 (0.9%)	1 (1.8%)	0 (0%)
Wound hematoma	2 (1.8%)	1 (1.8%)	1 (1.9%)
TYPE OF FNP			
Unilateral right	55 (50.9%)	34 (61.8%)	21 (39.6%)
Unilateral left	52 (48.1%)	21 (38.2%)	31 (58.5%)
Bilateral	1 (0.9%)	0 (0%)	1 (1.9%)
HB GRADE AT T0			
I	2 (1.9%)	0 (0%)	2 (3.8%)
II	19 (17.6%)	8 (14.5%)	11 (20.8%)
III	14 (13%)	7 (12.7%)	7 (13.2%)
IV	27 (25%)	14 (25.5%)	13 (24.5%)
V	29 (26.9%)	18 (32.7%)	11 (20.8%)
VI	17 (15.7%)	8 (14.5%)	9 (17%)
SB SCORE AT T0			
Average score (range)	31 (0-92)	28 (0-88)	36 (0-92)

Table 6. Intraoperative e postoperative data of patients comparing the two groups. Absolute values and percentages are reported.

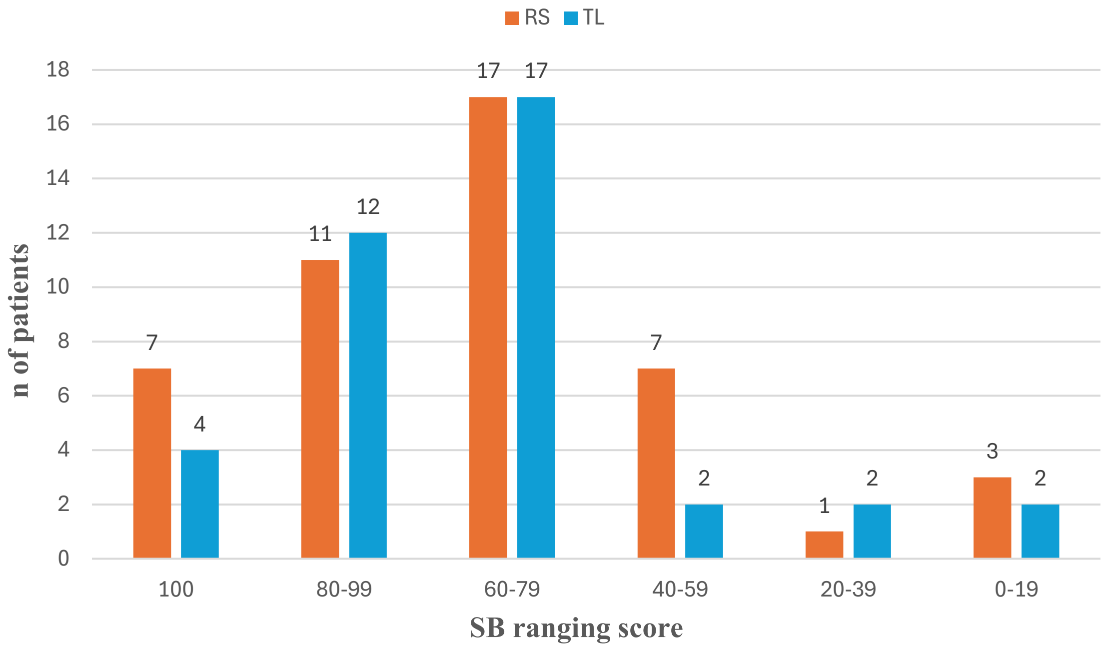
Regarding the second endpoint of the study, only follow-up data at 12-months were considered to avoid heterogeneity between patients followed up to 24-months and those 23 patients (21.3%) who discontinued the therapeutic-rehabilitative program before 12 months. Consequently, the cohort was reduced to 85 patients (78.7% of the initial cohort), retaining 46 patients from the RS group and 39 from the TL group, which represent 54.1% and 45.9% of the new total, respectively.

Although the SB score was calculated at each follow-up visit at 3, 6, 9, and 12 months at the FNOC, as shown in *Graphic 3*, the statistical analysis focused on the 12-month follow-up values to accurately assess the course of FN recovery. The mean SB score at 12 months was nearly overlapping between the two groups: 72 in the RS group (range 12–100) and 73 in the TL group (range 13–100). Similarly, the trend of the two groups over the follow-up period up to 12 months was quite comparable: 30 vs. 29 at the first FNOC visit, 52 vs. 55 at 3 months post-surgery, 66 vs. 69 at 6 months, 71 vs. 73 at 9 months.

As depicted in *Graphic 4,* an equal number of patients in each group achieved an SB score within the range of 60–79 (corresponding to HB Grade III, as detailed in *Table 3*), with 17 patients in each group, corresponding to 34.7% in RS group and 43.6% in TL group. Comparing RS to TL patients, higher numbers were observed in the RS group for SB score of 100 (n=7; 14.3% vs. n=4; 10.3%), the 40-59 range (n=7; 14.3% vs. n=2; 5.1%) and the 0-19 range (n=3; 6.1% vs. n=2; 5.1%). Conversely, the TL group had slightly more patients in the 80-99 range (n=12; 30.8% vs. n=11; 22.4% in the RS group) and in the 20-39 range (n=2; 5.1% vs. n=1; 2% in the RS group).



Graphic 3. Trend of average SB scores during follow-up.



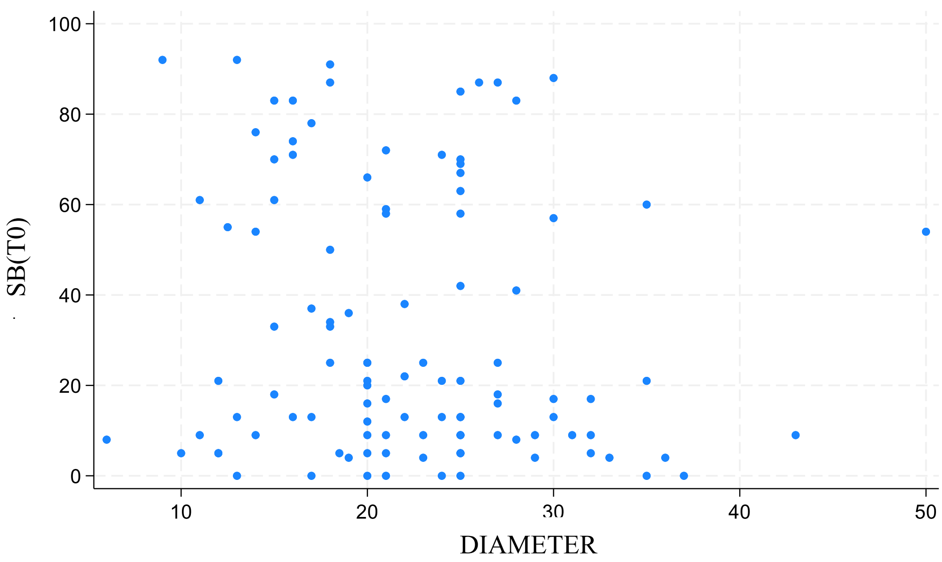
Graphic 4. FNP evaluation at 12 months: comparison of scores between RS and TL groups, using SB score ranges. Data presented in absolute values.

Botulinum toxin injections (Botox) were administered to 3 patients during the rehabilitation pathway at FNOC, including 2 (4.1%) after the RS approach and 1 (2.6%) after the TL approach. Furthermore, it was observed that among these 85 patients, 10 showed unchanged scores compared to the previous 9-month follow-up visit, indicating a stabilization in FN regeneration and rehabilitation. These included 4 patients (8.2%) who had previously undergone an RS approach and 6 patients (15.4%) with a TL approach. Additionally, among these 10 patients, 4 – 2 from the RS group (4.1%) and 2 from the TL group (5.1%) – required a hypoglossal-facial nerve anastomosis at 12 months post-surgery, given their stabilized, non-improving condition.

4.2 Univariate and multivariate analysis

Analysis of *SB(T0)* means allowed for a comparison of baseline clinical conditions of patients across the two groups. As summarized in *Table 7*, the mean scores were 28.09 in the RS group and 36.04 in the TL group (SD ±27.40 and ±30.77, respectively). The two-sample t-test showed no statistically significant difference between the means (p= 0.1589), indicating that the two groups had comparable baseline conditions.

As depicted in *Graphic 5*, Pearson's correlation coefficient between *SB(T0)* and *tumor diameter* showed a weak correlation between the two variables, with no statistical significance (r= -0.1438, p= 0.1413).

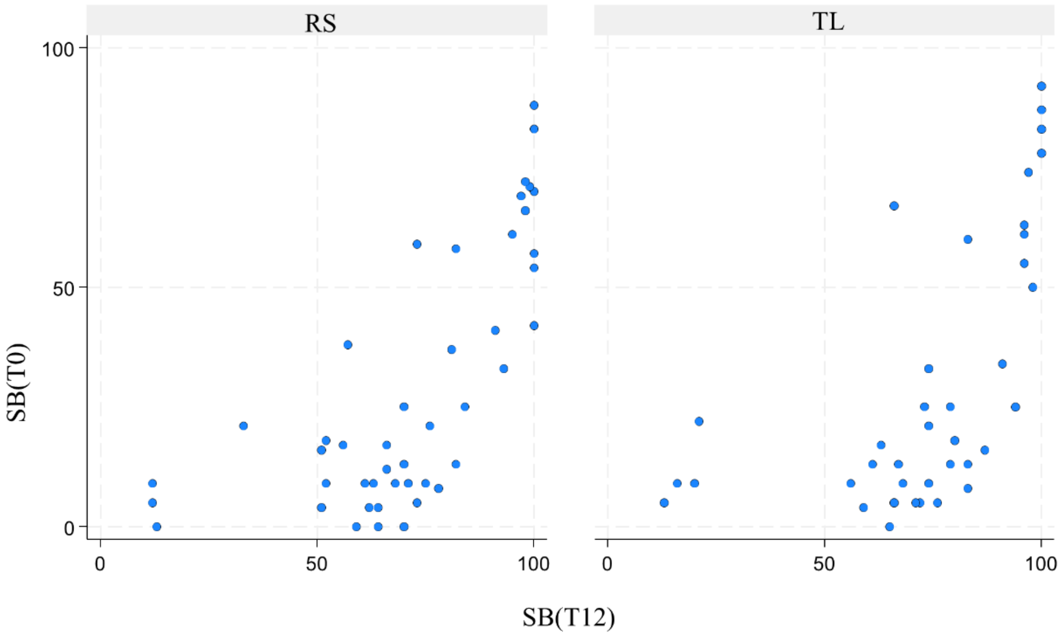


Graphic 5. Relationship between *SB(T0)* and *tumor diameter*: a weak and not statistically significant correlation (r= -0.1438, p= 0.1413).

The mean *SB(T0)* scores for *Koos levels 2, 3 and 4* appear to vary significantly, as shown in the *Table 8,* but the median test yielded a chi^2 = 3.4267 with p= 0.180, far from statistical significance. T-tests were conducted to compare the mean *SB(T0)* values across the Koos subgroups (*Table 7*) between the two approaches separately, without revealing any statistically significant differences (p= 0.2269 for *Koos 2*, p= 0.8098 for *Koos 3*, p= 0.0600 for *Koos 4*).

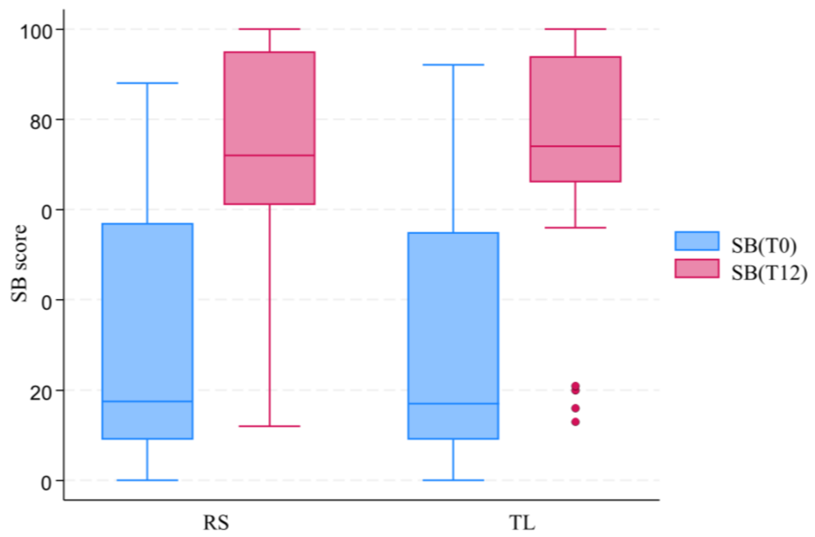
The t-tests conducted to compare the mean *SB(T0)* values between the two groups based on *tumor diameter* showed no significant differences (see *Table 7*).

An analysis on follow-up at 12 months was conducted, using Pearson's correlation coefficient to examine the relationship between *SB(T0)* and *SB(T12)*. As depicted in *Graphic 6*, a positive correlation is evident between the two variables – r=0.7205, p=0.0000 in RS group, closely to r=0.6039, p=0.0000 in TL group – indicating that the two variables were consistently associated in both groups, showing no difference in the surgical treatments but highlighting a similar recovery trajectory. A multivariate analysis using linear regression was performed (see *Table 9*), where *SB(T12)* was the dependent variable and type of approach and *SB(T0)* were the independent variables. The results confirmed *SB(T0)* as a significant predictor with p<0.0001, whereas type of approach did not represent a statistical significative factor for the study (p=0.685). The analysis yielded an R^2=0.4452, indicating that 44.5% of the variability in *SB(T12)* scores could be attributed to the included predictors, significantly to *SB(T0)* but not to the *type of approach*.



Graphic 6. Positive and strong correlation between *SB(T0)* and *SB(T12):* r=0.7205, p=0.0000 in RS group, closely to r=0.6039, p=0.0000 in TL group. A similar trend during follow-up was observed between the two groups.

Regarding the *deltaSB* (see *Graphic 7*), means of 42,28 in the RS group and 44,05 in the TL group were showed with SD ±19,30 and ±23,08, respectively, as presented in *Table 10*. No significant difference was found between the two approaches (p=0.7013), indicating that recovery pattern was similar in both groups.



Graphic 7. Initial conditions after surgery (SB(T0)) and final conditions at 12 months (SB(T12)) summarized as *deltaSB*: a similar recovery pattern was observed in the two groups.

The Chi-squared test was used to assess the distribution of patients with total FNP after surgery in both groups, based on *recovery40.* The analysis (see *Table 10*) showed that in the RS group 75% (18/24) achieved a recovery of almost 40 points in SB score, while in the TL group the percentage was higher (85,71%, corresponding to 18/21). However, the associated p-value of 0.370 confirmed that this difference was not statistically significant.

Similarly, the analysis of *recovery20* (see *Table 10*) demonstrated no significant difference between the two groups (p=0.972), with very similar percentages registered in those patients with partial FNP after surgery: in the RS group, 72,73% (16/22) achieved recovery of almost 20 points in SB score; in the TL group, this type of patients represented the 72,22% (13/18).

The Student's T-test conducted on *SB(T12)synkinesis* did not show any statistically significative difference between the two groups, with a p-value of 0.4895. Means of synkinesis scores at 12 months were similar in patients treated with RS approach (mean= 4,22; SD= ±3,44) and in those treated with TL approach (mean= 4,71; SD= ±2,87). Data were summarized in *Table 10*.

Variables	**n=108** (RS vs. TL)	Mean (RS vs. TL)	SD (RS vs. TL)	p-value
SB(T0)	55 vs. 53	28.09 vs. 36.04	±27.40 vs. ±30.77	p=0.1589
	n=107 (RS vs. TL)	Mean SB(T0) (RS vs. TL)	SD SB(T0) (RS vs. TL)	p-value
Koos 2	7 vs. 21	22 vs. 39.05	±25.14 vs. ±33.24	p=0.2269
Koos 3	28 vs. 19	37.57 vs. 35.37	±29.58 vs. ±32.12	p=0.8098
Koos 4	20 vs. 12	16.95 vs. 33.33	±20.34 vs. ±26.88	p=0.0600
	n=108 (RS vs. TL)	Mean SB(T0) (RS vs. TL)	SD SB(T0) (RS vs. TL)	p-value
Diameter <15 mm	3 vs. 12	19.67 vs. 37.17	±29.84 vs. ±35.37	p=0.4470
Diameter ≥15 and ≤30 mm	45 vs. 34	31.91 vs. 37.91	±27.99 vs. ±30.86	p=0.3695
Diameter >30 mm	7 vs. 7	7.14 vs. 25	±7.54 vs. ±22.58	p=0.0705

Table 7. Statistical data regarding preclinical and morphological characteristics of VS in treated patients, as well as immediate FN outcomes, analysed to assess the potential impact of surgical approach on the severity of postoperative FNP palsy. Data were summarized in mean, standard deviation (SD) and p-value.

KOOS	N	Mean	SD	p50	p25	p75	Min	Max
2	28	34.79	±31.87	23	6.5	66	0	92
3	47	36.68	±30.31	25	9	66	0	91
4	32	23.09	±23.98	13	8.5	31.5	0	87
Total	107	32.12	±29.34	21	9	59	0	92

Table 8. Distribution of *SB(T0)* values for *Koos* levels 2,3 and 4 within the study cohort (excluding the single patient with Koos Grade 1 from the analysis). The values are presented as: mean, standard deviation (SD), median (p50), first quartile (p25), third quartile (p75), range of values (min, max). The median test yielded a chi^2 = 3.4267 with p= 0.180.

Indipendent Variable	*Coefficient*	*Standard error*	*p-value*	*95% Confidence Interval*
SB(T0)	0.57	0.07	<0.0001	0.43-0.71
Type of approach	1.56	3.82	0.685	-6.05-9.16

Table 9. Results of the multivariate analysis using linear regression, with *SB(T12)* as the dependent variable, while *SB(T0)* and the *type of approach* as independent variables. The analysis yielded an R^2=0.4452.

Variables	**n=85** (RS vs. TL)	Mean (RS vs. TL)	SD (RS vs. TL)	Frequence (RS vs. TL)	Percentage (RS vs. TL)	p-value
deltaSB	46 vs. 39	42.28 vs. 44.05	±19.30 vs. ±23.08			p=0.7013
recovery40	24 vs. 21			18/24 vs. 18/21	75% vs. 85.71%	p=0.370
recovey20	22 vs. 18			16/22 vs. 13/18	72.73% vs. 72.22%	p=0.972
	n=83* (RS vs. TL)	Mean (RS vs. TL)	SD (RS vs. TL)			p-value
SB(T12) synkinesis	45 vs. 38	4.22 vs. 4.71	±3.44 vs. ±2.87			p=0.4895

Table 10. Statistical data regarding follow-up and postoperative FN rehabilitation, summarized in mean, standard deviation (SD), frequence, percentage and p-value. *Two patients in the cohort considered for the second analysis of the study were missing the synkinesis SB score.

5 DISCUSSION

5.1 FN outcome: role of tumor size and Koos Grade

Over the past two decades, the relationship between tumor size and FN outcomes has been widely investigated. Killeen et al.[28] identified tumor volume, rather than tumor diameter, as a more reliable predictor of long-term FN outcomes, due to the increased mechanical strain exerted by higher tumor volumes on the nerve during surgical dissection. Their results on tumor volume were confirmed even after adjusting for demographic factors (age, gender) and certain surgical factors (extent of resection, type of approach, anterior and internal auditory canal involvement). Similarly, Kunert et al.[47] underscored the importance of incorporating tumor volume, alongside other parameters like tumor size, when predicting postoperative FN function. Moreover, Moffat et al.[48] and Tawfik et al.[49] both identified tumor size and growth rate as key determinants of FN outcomes, highlighting their exclusive influence when controlling for the surgical approach. Specifically, Moffat et al.[48] confirmed that tumor size remained a statistically significant predictor in both their univariate and multivariate analyses.

The study by Grahnke et al.[50] focused on the "A/P index", defined as the anterior to posterior extension from the IAC, which they found to significantly affect FN outcomes by stretching and distorting the nerve, leading to worse results after surgery. By contrast, Zohdy et al.[51] in developing a predictive FN outcome model using an *Artificial Neural Network* (*ANN),* observed that clinical variables such as tumor size and preoperative FN grade did not enhance model accuracy. Instead, intraoperative nerve monitoring data were validated as the strongest predictive parameters. Some years earlier, Sun et al.[52] used a nomogram-based approach to identify six key variables for predicting FN outcomes, one of which was tumor size. Following this trend, Di Perna et al.[53] proposed the predictive "FNOS" scoring system by integrating tumor characteristics with intraoperative neurophysiological findings. This approach revealed a strong correlation among these combined data and both short- and long-term FN outcomes, reinforcing the necessity of multidimensional evaluation in surgical planning.

In contrast with our results, Landry et al.[54] found that tumors >3 cm and higher Koos Grade (3 and 4) showed a statistically significant association with worse FN outcomes. Similarly, Michelini et al.[55] observed that larger tumors at Koos stages 3-4 were frequently linked to poorer FN recovery. Lucidi et al.[56] further reinforced the importance of tumor size, noting a linear relationship with FN recovery. In our study cohort, consisting of patients treated with RS and TL approaches, no statistically significant correlation was identified between tumor size (with cut-offs of 15 and 30 mm) and FN dysfunction immediately after surgery (*SB(T0)*), nor between Koos Grade (2,3,4) and early FN outcome. This suggests that short-term FN outcomes were not directly influenced by tumor size or localization. Interestingly, MacDonald et al.[57] found in tumor size a contribuiting factor to early FN dysfunction but its statistical significance was lost when additional variables, such as intraoperative monitoring or surgical determinants, were incorporated into a multivariate analysis. These differing conclusions highlight the necessity of integrating multiple variables, including surgical expertise, in FN prognosis evaluation, recognizing the multifactorial aspect of FN morbidity.

5.2 Relationship between surgical approach and FN outcome

In analysing outcomes between RS and TL groups, no statistically significant differences in recovery pattern were identified. Both groups exhibited a similarly strong positive correlation between *SB(T0)* and *SB(T12)* scores, as well as comparable *deltaSB* values. Recovery rates – *recovery40*, *recovery20* – were also not statistically significant between subgroups. Notably, a higher proportion of patients in TL group with complete FNP (HB Grase VI) achieved satisfactory recovery compared to the RS subgroup.

These findings align with those of Gurgel et al.[31] and Tawfik et al.[49] who reported no significant differences in FN outcomes between the RS and TL approaches when accounting for tumor size. Similarly, Jun et al.[58]'s meta-analysis reinforced the notion of comparable postoperative FN dysfunction rates between these surgical techniques. Conversely, Moffat et al.[48] identified a significant association between surgical approach and FN outcomes, though this correlation did not persist in their multivariate analysis.

Interestingly, Rinaldi et al.[13] observed that the TL approach was predominantly used for larger and more advanced tumors (Koos stages 3-4), potentially explaining its association with poorer FN function compared to the RS group. Nevertheless, no surgical technique emerged as superior in FN outcome. Likewise, Ansari et al.[25] reported that the RS approach yielded better FN outcomes in patients with intracanalicular small tumors (15-30 mm). Conversely, larger tumors (>30 mm) were primarily treated using the TL approach, possibly introducing a selection bias into their findings.

Scrivener et al.[59] emphasized that the RS approach provides superior outcomes in FN preservation, particularly for tumors smaller than 25 mm, and a lower mortality rate compared to the TL group recovery. However, RS outcomes were strongly influenced by tumor size, highlighting the need for a multidisciplinary assessment, as morbidity increases with larger tumors. Consistent with their findings, MacDonald et al.[57] also observed that patients undergoing the RS approach exhibited a reduced incidence of early FN dysfunction compared to the TL group.

In contrast to the previously cited studies, Gibbon et al.[60] observed in their study cohort that patients undergoing the TL approach were more likely to achieve lower HB Grades (indicating better FN outcomes) compared to those treated with the RS approach. However, no statistically significant difference between the groups was observed by tumor size, likely due to the small sample size.

Carlstrom et al.[61] identified in the RS approach a significantly higher risk of delayed facial palsy - the latter described as a decline in FN function by at least 2 HB Grades occurring between the 5th and the 30th postoperative days"- compared to TL and MCF approaches.

Lucidi et al.[56] highlighted the advantages of the TL approach, noting superior FN preservation in patients with Koos stages 2 and 3 tumors compared to the RS approach. These findings were attributed to the surgical field exposure and better visualization of FN course associated with the TL technique.

In our study, multivariate analysis confirmed that the type of surgical approach was not a statistically significant predictor of FN outcomes ($p=0.685$). Nevertheless, it is worth highlighting that RS patients generally exhibited worse FN function in the immediate postoperative period, while TL patients showed slightly less severe initial paralysis, especially in Koos 4 and in tumor with diameter > 30 mm (p.0.06 and p0.07 respectively). From our experience, it is not uncommon for TL patients to avoid postoperative FNP entirely, although such cases were excluded from this study according to inclusion and exclusion criteria. This suggests that clinical and surgical factors beyond type of surgical approach itself may play a critical role in FN recovery.

5.3 Postoperative FN function assessment

Tawfik et al.[49] highlighted early postoperative FN function as a strong predictor of recovery pattern, emphasizing that even mild dysfunction immediately after surgery could signal long-term challenges. MacDonald et al.[57] supported these findings, identifying the recorded HB Grades within the first postoperative month, at specific key time points, as reliable indicators of long-term FN outcomes, underlining the importance of careful early monitoring. In line with these observations, Sun et al.[52] reported a significantly decline in recovery FN rate after one year, suggesting this as a potential cut-off for considering reconstructive FN surgery. Conversely, Yawn et al.[62] identified the 3-month and 12-month follow-up visits as critical time points for FN recovery evaluation. Our study employed the SB grading system to achieve a more precise and detailed evaluation of FN recovery. This approach revealed a strong positive correlation between SB(T0) and SB(T12), confirming that better initial postoperative FN function predicts improved long-term outcomes, while poorer FN function is associated with a lower rate of recovery. While similar correlations have been reported in the existing literature using the HB Scale, these results emphasize the clinical utility of SB grading, suggesting that its finer granularity not only enables a more nuanced assessment of early postoperative FN function but also provides predictive power for long-term outcomes, independently of the surgical approach employed.

6 CONCLUSIONS

Despite advancements in surgical field and literature on VS surgery, postoperative FNP remains a controversial research topic among specialists. This study aimed to investigate whether the surgical approach significantly impacts postoperative FN outcomes and recovery. Our findings revealed that both RS and TL approaches resulted in comparable short-term and long-term FN function at 12 months post-surgery, as well as similar recovery trajectories. This was observed despite RS patients experiencing slightly more severe initial paralysis and TL patients demonstrating marginally better early outcomes, according to SB grading system. These results confirm the absence of a definite role of the surgical approach in predicting FN outcomes.

Additionally, the lack of a statistically significant correlation between tumor size or Koos Grade and early postoperative FN outcomes highlights the need to consider these variables as only part of the multiple factors influencing FN prognosis. Nonetheless, the controversial findings in literature suggest the need to deepen our understanding of FN predictors, without overlooking the importance of surgical expertise and detailed anatomical knowledge.

The study's use of the SB grading system proved essential for providing a nuanced assessment of FNP recovery, offering greater precision and granularity compared to the HB Scale alone. The strong positive correlation observed between initial postoperative and long-term recovery underscores the prognostic value of early FNP function, with better initial outcomes predicting more favourable long-term recovery. Our findings confirm the significant advantages of incorporating the SB grading system in clinical practice and we support its routine adoption. Notably, our study highlights a gap in the current clinical evaluation methodologies for postoperative FNP rehabilitation. Combining the underutilized SB grading system with the HB Scale could provide an opportunity for more comprehensive assessments and refined predictions of recovery trajectories.

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