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Influence of clinical and neurophysiological parameters on the function outcome of the facial nerve after vestibular schwannoma surgery

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ABSTRACT

Introduction: Vestibular schwannomas are benign neoplasms of the nerve seath, and they represent the third most common endocranial tumour, following the meningioma and the pituitary adenomas. The primary symptoms of vestibular schwannomas are hearing loss, tinnitus as well as a balance disorder. The therapy of vestibular schwannoma consists of observation, surgery and radiosurgery. The majority of patients who are good candidates for surgery are already affected by significant hearing impairment, thus one of the primary goals of the surgery is the preservation of facial nerve function.

Aim: To analyze the outcome of facial nerve function one-year post-surgery using clinical and neuropsychological parameters.

Material and methods: This study analyzed the patient's clinical status on admission along with the neuroradiological characteristics of tumours and the neurophysiological intraoperative parameters and their effect on the facial nerve function in the early postoperative period as well as one year after the surgery using the House–Brackmann scale.

Results: A total of 30 patients who underwent surgery from January 1st 2015 to December 31st 2018 at the Clinical Centre of Serbia, Neurosurgery Clinic for vestibular schwannomas were examined. The median age of the patients was 51 years. Hearing loss was present in all patients. Sensitivity drop in the innervation region of n. trigeminus was present in 7 (23.3%) patients, as was tinnitus. Cerebellar symptomatology (76%) was present in the highest percentage of patients.

Conclusion: We can conclude that the most important aspects of the facial nerve function are the preoperative state of the facial nerve and the electrophysiological parameters. Although the radical procedure of surgery led to an immediate postoperative outcome, it was not significant for the ultimate outcome of treatment. Thus, radical surgery may be considered to carry the same risk of definitive impairment of the facial nerve function, just like a combination treatment with subtotal resection and stereotaxic radiosurgery.

Keywords
facial nerve,
nerve palsy,
paralysis,
vestibular schwannoma

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Introduction

Vestibular schwannomas, also called acoustic neuromas, are benign intracranial tumors arising from Schwann cells of the vestibular portion of the eight cranial nerve. The cause of vestibular schwannomas is usually unknown; however there are evidences that sporadic defects in tumor suppressor genes, including familial and sporadic vestibular schwannomas, have been linked to a mutation in a single gene, the neurofibromin 2 (NF2). The gene is located on the long arm of chromosome 22, band q11-13.1 [1].

Vestibular schwannomas represent 85% of intracranial growths arising at the cerebellopontine angle [2]. The size of the tumor is commonly classified via the Koos grading scale with respect to extrameatal extension and brainstem compression (Table 1) [3].

Table 1. Koos grading system for vestibular schwannoma

Koos grade	Description
I	Intracanalicular
II	Extension into cerebellopontine angle, <2cm
III	Occupies cerebellopontine angle, no brainstem displacement, < 3cm
IV	Brainstem displacement, > 3cm

Vestibular schwannomas represent a risk to varius intracranial structures due to mass effect. Symptoms include progressive hearing loss and tinnitus which are reported in over 60% of patients. Larger tumor manifestations can cause hydrocephalus and brainstem compression which are followed with symptoms such as facial paraesthesia, vertigo, and headache [4].

Approximately around 8% of all intracranial tumors are vestibular schwannomas with an incidence of 10.4 per million per year [5]. In the population at a median age of 50 years, vestibular schwannomas are presented. They are predominantly unilateral in >90% of patients, with an equal incidence on the left and right. Patients are more often presented with chronic asymmetric sensorineural hearing loss than tinnitus or unsteadiness. Via audiometry and brain stem-evoked response audiometry, sensorineural hearing loss can be confirmed in >90%-95% of patients with vestibular schwannomas [6]. From the pathological aspect of the tumor behavior, more than half of all vestibular schwannomas grow at an average of 2-4mm/year, whereas <10% regress [7].

One study has revealed that extrameatal tumors (28.9%) show a tendency to grow progressively compared with intrameatal tumors (17%), and a larger percentage of tumors grew early on after detection [8]. Some studies have also revealed that vestibular schwannomas of >2cm are more likely to grow compared with a smaller size [9], [10]. Decreased rates of hearing preservation have been associated with growth rates of>2mm/year, compared with slower growth rates [11].

Surgical Approaches

Surgical techniques which are used to approach the tumor are the translabyrinthine approach (TL), retrosigmoid approach (RS), or middle fossa (MF) craniotomy. At the Clinical Centre of Serbia, Neurosurgery Clinic, the prefered surgical approach is the retrosigmoid approach (RS).

The retrosigmoid approach is a posterior approach that which allows the neurosurgeon a panoramic view of the cerebellopontine angle (CPA). This approach also allows the neurosurgeon to have a better view on the facial and vestibulocochlear nerve; hence the facial nerve and hearing preservation has a higher rate. Following a suboccipital craniotomy posterior to the sigmoid sinus, the cerebellum is then retracted medially, that allows the exposure of the cerebellopontine angle (CPA) mass and neurovascular structures. The facial nerve can be identified, and the cerebellopontine angle (CPA) component is dissected. With the use of the neurosurgical drill on the posterior meatal lip, the intrameatal component can then be accessed and removed. Vestibular schwannoma infiltration of the cochlear nerve, poor preoperative hearing, and larger tumor size, decrease the likelihood of hearing preservation [12].

With the retrosigmoid approach (RS) the neurosurgeon can resect large extrameatal and small medial intrameatal tumors while allowing hearing preservation [13], [14], [15].

The retrosigmoid approach to intrameatal vestibular schwannomas can be limited by a high-riding jugular bulb or obstructed by the labyrinth [15]. When the cerebellum is retracted the consequence can be a parenchymal injury. Also included are early postoperative headaches which are more often in the retrosigmoid approach (RS) than in the translabyrinthine approach (TL) [16].

Electrophysiological monitoring

Electrophysiological monitoring is a standard procedure in modern neurosurgery of the vestibular schwannoma. The main goal of the intraoperative monitoring process is the preservation of the facial nerve. In cases with large tumors it is necessary to monitor the brain stem function that includes monitoring the long motor nerve pathways and other cranial nerves. Beside the neuromonitoring, the electrophysiological methods can give us also the location of the cranial nerves, which by the presence of the vestibular schwannoma can be dislocated and deformed [17].

Materials and Methods

A retrospective analysis of 30 patients with histologically confirmed vestibular schwannoma was performed. The cohort consisted of adult patinets operated on between January 2015. and December 2018. by a surgical team of neurosurgeons at the Department of Neuro-oncology of the Clinical Senter of Serbia. This study analyzed the patients clinical status on admission along with the neuroradiological characteristics of tumors and the neurophysiological intraoperative parameters and their effect on the facial nerve function in the early postoperative period as well as one year after the surgery using the House–Brackmann scale. This study also analyzed the intraoperative neurophysiological parameters and their influence on the facial nerve function in the early postoperative period, likewise one year after the surgery using the House-Brackmann scale (HB scale) (Table 2). Patient demographics, clinical preoperative features, extent of resection, postoperative treatment modalities, date of progression, or reoperation, salvage chemotherapy, and date of latest follow-up or death were retrieved from an electronic database.

Table 2. House-Brackmann scale

Grade	Description	Measurement	Function %	Estimated function%
I	Normal	8/8	100	100
II	Slight	7/8	76-99	80
III	Moderate	5/8 – 6/8	51-75	60
IV	Moderately severe	3/8 – 4/8	26-50	40
V	Severe	1/8 – 2/8	1-25	20
VI	Total	0/8	0	0

Statistical analysis

From statistical methods, frequency estimation and relative numbers were used as methods of descriptive statistics. In the analysis of the results, depending on the nature of the variables themselves, the Pearson-ov x2 was used in the form of stacking tests and contigency tables to compare the frequency difference in nonparametric features respectively. Fisher0s exact probability test was applied twice to the numerical constraints of the table. In the statistical analysis, the p-value <0,005 was taken as a statistically significant. The data are presented in tables and graphs. Data were prcoessed using the easy-R system (EZR, version 1.41. 64-bit).

Results

Our study consisted of 30 patients with histologically confirmed vestibular schwannoma from the period 01.01.2015. till 31.12.2018 at the Department of Neuro-oncology of the Clinical Senter of Serbia, where 18 patients were female (60%), and 12 patients were male (40%) (Figure 1). Mean age was 51 years, the youngest patient was 30 years of age, and the oldest was 76 years old (Figure 2).

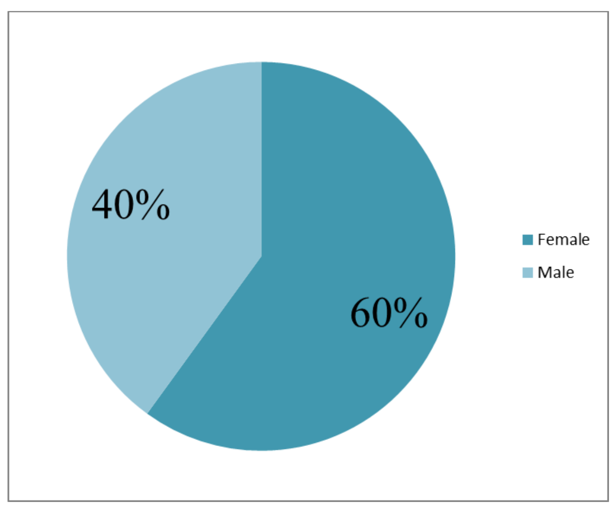

Figure 1. Gender distribution.

The symptoms lasted 3,3±2,1 years at avreage, with maximum od 10 years, and minimum of 2 months. The loss of sensation in the trigeminal nerve region and tinitus was reported in 7 (23,3%) patients. Most of the patients had cerebelar simptomatology (76%). Preoperative facial nerve palsy was reported in 23,3% patients (Figure 3.).

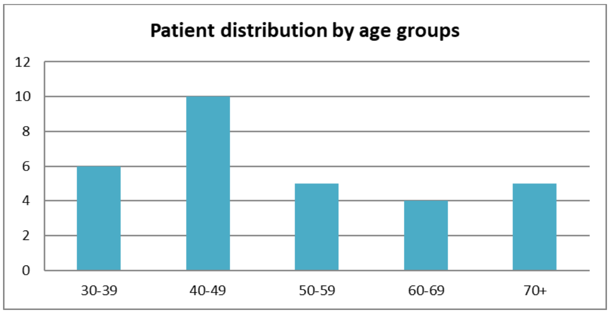

Figure 2. Distribution by age groups.

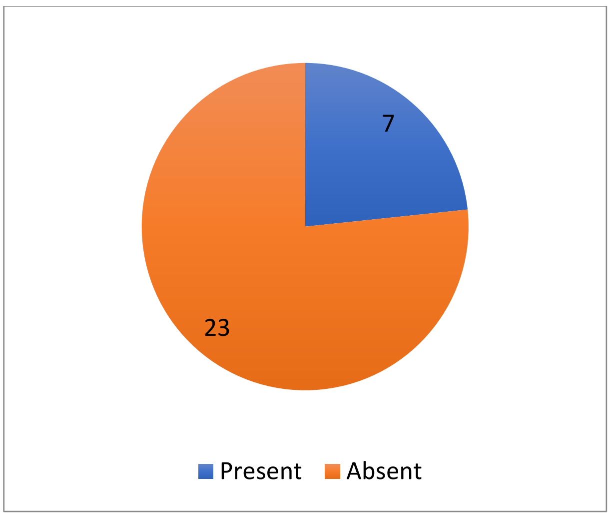

Figure 3. Frequency of the preoperative facial nerve lesion.

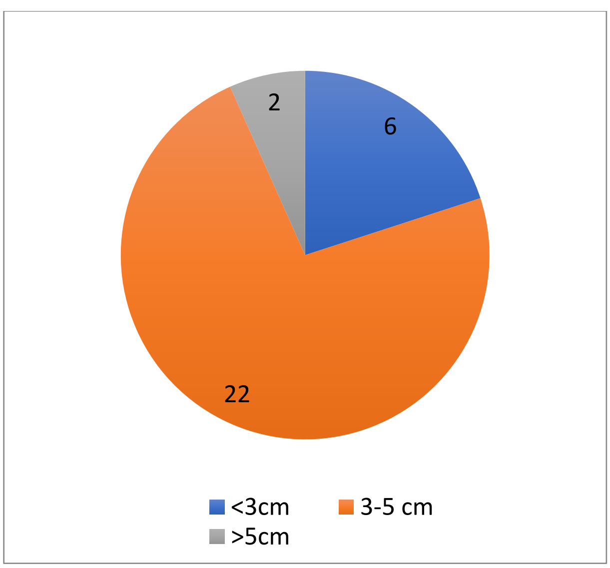

Figure 4. Patient distribution by tumour size.

The largest number of patients 22 (73,4%) had tumors in size between 3 to 5cm, in 6 (20%) patients the tumor size was less then 3cm, and in 2 patients (6,6%) a giant tumor, whose dimensions are >5cm in size. The average tumor size was 38±9,4mm. The distribution of patients according to tumor size iz shown in Figure 4.

The tumor was localized with approximately the same frequency in the left and right internal auditory canal (meatus acusticus internus – MAE) (56,7% on the left, and 43,3% on the right).

Hydrocephalus was noted in 16 patients (53,3%) and a VP shunt was placed in all patients before surgery. Optic nerve papillary edema was present in 3 patients (10%).

Half of the patients, 15 (50%), underwent radical surgery when the MAE was opend and part of the tumor was removed, while in the other half of the patients, a smaller part of the tumor was left in the porus of the mantle of the tumor towards the brainstem and the facial nerve. On this occasion, more than 90% of the tumors were removed. Patients who had a residual tumor were treated with stereotactic radiosurgery. None of the patients progressed during the follow-up period.

Postoperative complications occured in 2 patients (6,7%) – hematoma located in the field which required surgical evacuation. Also, in 2 patients (6,7%) there were general complications – pneumonia and systemic infection. No postoperative local infection, and CSF infection, nor infection of the central nervous system was present.

Examination of electrophysiological parameters proved the connection of the baseline function of the facial nerve with a clinical presentation, and in 7 patients (23,3%) in whom preoperative facial nerve paresis was reported, neurophysiological damage to the nerve function was detectetd preoperatively.

Table 3. Postoperative facial nerve function

House Brackman	n (%)
I	5 (16,7)
II	8 (26,7)
III	8 (26,7)
IV	8 (26,7)
V	1 (3,3)

The facial nerve was located in the region of the brainstem, and in the porus region, as well as in relation to the localization of the tumor via the direct nerve stimulation. In 3 patients (10%) there was a decrease in the facial nerve potential reported during tumor removal, but the potentials were not completly extinguished in any patient. Posteperatively, in most patients there was a deterioration in facial nerve function (Table 3.).

Postoperative physical therapy measures were implemented, and the House Brackman scale (HB) was tested at subsequent controls. After a follow-up period of 2 years, the results of the recovery of the facial nerve function were recorded (Table 4.). Satisfactory results were achieved in 17 patients (56%), their facial nerve function can be considered perserved (HB gradus 1 and 2). In 4 (13%) patients the results were unsatisfactory, there still was severe impairment of the facial nerve function present (HB grade 4 and 5).

Table 4. Facial nerve function 2 years after surgery.

House Brackman	(%)
I	12 (40)
II	5 (16)
III	9 (30)
IV	3 (10)
V	1 (4)

In the further course, predictor factors – clinical, and electrophysiological parameters of postoperative facial nerve function were examined, immediately postoperatively, and 2 years after surgery.

In relation to the immediate postoperative function of the facial nerve, (Table 5) were examined, where no statistical sigificance was detected (p> 0,05).

The degree of tumor resection (p=0,025) proved to be a statistically significant parameter, which indicates that in patients who underwent radical surgery, statistically significantly more patients had worse results on the HB scale. The existene of preoperative neurophysiological impairment of the facial nerve function also stood out as a predictor of poor outcome (p=0,015).

In relation to the facial nerve function, 2 years after surgery, the factors (Table 6) were examined, where the existence of statistical significance was not reported (p>0,05).

Preoperative facial nerve function (p=0,012) was singled out as a predictor of the facial nerve function after 2 years of surgery, with a worse outcome in patients who had preoperative loss of facial nerve function. Preoperative neurophysiological impairment of the facial nerve function (p=0,022) as well as a decrease in potentials during surgery (p=0,018) were also singled out as negative predictors.

Table 5. Presentation of predictor factors for immediate postoperative function of the facial nerve in which the existence of statistigal significance was not detected.

Examined predictive factor	p-value
Years of age	0,072
Gender	0,631
Lesion of the trigeminal nerve	0,176
Tinitus	0,173
Cerebellar symptomatology	0,839
Comorbidities	0,092
Facial nerve function preoperative	0,247
Tumor size	0,336
The side on which the tumor is located	0,855
Hydrocephalus	0,360
Intraoperative drop of nerve potential of the facial nerve	0,055

Table 6. Predictive factors for the facial nerve function 2 years after surgery in which the existence of statistical significance was not detected.

Examined predictive factor	p-value
Years of age	0,620
Gender	0,586
Lesion of the trigeminal nerve	0,497

Tinitus	0,497
Cerebellar symptomatology	0,942
Comorbidities	0,333
Tumor size	0,736
The side on which the tumor is located	0,847
Hydrocephalus	0,333
Degree of tumor resection	0,547

Discussion

Vestibular schwannomas, although they make up a third of all endocranial tumors, still represent an insufficiently researched topic. In most patients who are candidates for surgical treatment, there is already significant hearing impairment, so one of the main goals of surgery is to perserve the facial nerve function.

The average age of patients with vestibular schwannoma is 50 years of age and it is unilateral in more than 90% of patients, with equal incidence of left and right side.

In the cohort stury of I.Taha et al., in 2020. [18], the function of the facial nerve and the function of the sense of hearing after microsurgical removal of sporadic vestibular schwannoma were analyzed. The average age of the patients was 54 years of age. The study consisted of 95 subjects, 37 males, 58 females, compared to our study which contains 30 subjects, 12 males, 18 females.

After 1 year of surgery in a study by I. Taha et al., 67% of patients had a good outcome (HB 1-2), no intraoperative facial nerve damage, no hydrocephalus, and a 30mm tumor. 16% of patients had a moderate outcome (HB 3-4), while 17% of patients had a poor outcome (HB 5-6). Tumor size varied within groups (p<0,05). Patients were divided into 3 groups based on the House-Brackmann scale, where the third group had the largest tumor diameter 32±15mm, the second group 33±10mm, and the first group 24±12mm.

Based on the HB scale, the symptomatology was also divided into thre groups, where the most pronounced hydrocephalus (33,3%) was in the third group, as well as facial nerve paresis (20%) and headache (15,3%) in the first group together with dizziness (59,3%), impaired hearing (86,4%), tinnitus (32,2%), loss of trigeminal sensigility (25,4%), and cerebellar symptomatology (8,5%). [18]

In the study Lawani et al. [19] the data has shown that HB grade 1 or 2 facial nerve function was 100% for tumors ≤30mm but 79% for tumors larger than 30mm in 1 or more years after surgery. The predictive function was further studied by Fenton et al. [20], and demonstrated that the long-term facial nerve function was strongly correlated with tumor size by a correlation factor of 0.47. In another study by Samii M. et al. [21], a comparsion was made of facial nerve function between tumors larger than 4cm (giant) and tumors smaller than 3.9cm (2.6cm in average). The result indicated that patients with giant tumors were less likely to achieve facial nerve function of HB grade 1. No significant difference was found between two groups with grade 2 to 6.

For large vestibular schwannoma resection, one of the primary goals is to maintain facial neve integrity, which is thought to be the key aspect of good facial nerve function [20]. In this study, the facial nerve functions of 98,1% patients were intact after tumor removal. Acceptable facial nerve function was achieved in 37,8% of total cases 3–7 days after surgery and 78% remained good facial nerve function after 2 years. The adventage of intraoperative neruomonitoring (INOM) is to lessen intraopeative facial nerve damage and to get a higher total resection rate.

One INOM parameter as prognostic factor for postoperative facial nerve function is A-train activity, which is a distinct EMG waveform classified as a sinusoidal symmetric sequence of high-freqzency and low-amplitude signal during intraoperative EMG monitoring [22]. The overall appearance of its pattern might vary in different cases. In a study Prell et al [23], the time exceeding 10s was correlated with deterioration of post-surfical facial nerve function by two or more grades immediately after surgery. In this study, long train time predicted poor facial function.

Another key factor for the prediction of the facial nerve function is the facial motor evoked potential (FMEP), which was documented to be correlated with postoperative facial nerve function [24, 25]. Because of its adventage of less invasivity, FMEP monitoring can be performed before and after operation do tedect nerve integrity without direct visualization and its thought to be a useful supplement for facial nerve monitoring [24]. In a study by Fakuda et al. [20, 26] and Acioly et al. [24], it has been found that a startto-final baseline FMEP amplitude ratio of 50% was a predictive threshold for a poor facial nerve outcome (HB grade 3–6) both in short and long-term follow-up.

Tringali et al. observed a good correlation between caloric weakness and tumour size when they tested the preoperative response of 629 tumour patients. In the group of patients with UW > 70%, who had a larger tumour size, postoperative facial palsy was more frequent. Postoperative hearing preservation was more frequently observed in the "normal group" with a UW < 20%. They concluded that a normal caloric response can be a good predictive factor for hearing preservation and normal postoperative facial function [27].

In our study the tumor size were between 3 and 5cm in 22 patients (73,4%), <3cm in 6 patients (20%), and >5cm in 2 patients (6,6%). Based on th HB slace, preoperative facial nerve lesion was reported in 7 patients (23,3%), hearing loss was present in all patients. Sensitivity drop in the innervation region of n. trigeminus was present in 7 (23,3%) patients, as was tinnitus. Cerebellar symptomatology (76%) was present in the highest percentage of patients.

Conclusion

In the examined series of 30 patients who underwent surgery in the Clinic for Neurosurgery, the function of the facial nerve after vestibular schwannoma surgery was monitored. The degree of tumor resection as well as the existence of preoperative neurophysiological impairment of the facial nerve function stood out as significant predictors of function immediately after surgery. The preoperative neurophysiological impairment of the facial nerve function as well as nerve potential decrease during surgery were singled out as negative predictors.

Based on the results we can conclude that for the final outcome of the facial nerve function and the most important aspects for the facial nerve function are the preoperative state of the facial nerve and the electrophysiological parameters. Although the radical procedure of surgery led to immediate postoperative outcome, it was not significant for the ultimate outcome of treatment. Thus, radical surgery may be considered to carry the same risk of definitive impairment of the facial nerve function, just like a combination treatment with subtotal resection and stereotaxic radiosurgery.

In interpreting these results, it should be borne in mind that this is a relatively small series of patients, and the study should be expanded to include a larger number of subjects. It is also clear that for the successful treatment of these patients it is necessary to diagnose the tumor early as possible, so there would be a significant improvement in outcomes. These outcomes are also in correlation with education of the physicians in primary care, as well as education of the general population, so that hearing loss can be understood as a significant symptom of the vestibular schwannoma. With a better education the diagnostic procedures could be carried out early on, and the result would be a more successful treatment.

References

1. Sughrue ME, Yeung AH, Rutkowski MJ, et al. Molecular biology of familial and sporadic vestibular schwannomas: implications for novel therapeutics. J Neurosurg 2011;114:359–66.
2. Singh K, Singh MP, Thukral C, Rao K, Singh K, Singh A. Role of magnetic resonance imaging in evaluation of cerebellopontine angle schwannomas. Indian J Otolaryngol Head Neck Surg. 2015;67(1):21–7.
3. Koos WT, Day JD, Matula C, Levy DI. Neurotopographic considerations in the microsurgical treatment of small acoustic neurinomas. J Neurosurg. 1998;88(3):506–12
4. Matthies C, Samii M. Management of 1000 vestibular schwannomas (acoustic neuromas): clinical presentation. Neurosurgery. 1997;40(1):1–9.
5. Evans DG, Moran A, King A, Saeed S, Gurusinghe N, Ramsden R. Incidence of vestibular schwannoma and neurofibromatosis 2 in the North West of England over a 10-year period: higher incidence than previously thought. Otol Neurotol. 2005;26(1):93–7.
6. Doyle KJ. Is there still a role for auditory brainstem response audiometry in the diagnosis of acoustic neuroma? Arch Otolaryngol Head Neck Surg 1999;125:232.
7. Smouha EE, Yoo M, Mohr K, et al. Conservative management of acoustic neuroma: a meta–analysis and proposed treatment algorithm. Laryngoscope 2005;115:450–54.
8. StagerupSE, Caye–Thomasen P, Tos M, et al. Natural history of vestibular schwannoma. Otol Neurotol 2006;27:547–52.
9. Nikolopoulos TP, Fortnum H, O'Donoghue G, et al. Acoustic neuroma growth: systematic review of the evidence. Otol Neurotol 2010;31:478–85.
10. Fucci MJ, Buchman CA, Brackmann DE, et al. Acoustic tumor growth: implications for treatment choices. Am J Otol 1999;20:495–99.
11. Sughrue ME, Yang I, Aranda D, et al. The natural history

of untreated sporadic vestibular schwannomas: comprehensice review of hearing outcomes. J Neurosurg 2010;112:163–67.
12. Oghali JS, Driscoll CL. Atlas of Neurotologic and Lateral Skull Base Surgery, Berlin: Springer; 2016:19–103.
13. Madjid S, Cordula M. Management of 1000 vestibular schwannomas (acustic neuromas): hearing function in 1000 tumor resections. Neurosurgery 1997;40:248–62.
14. Samii M, Gerganov V, Samil A. Improved perservation of hearing and facial nerve function in vestibular schwannoma surgery via the retrosigmoid approach in a series of 200 patients. J Neurosurg 2006;105:527–35.
15. Blevins NH, Jackler RK. Exposure of the lateral extremity of the internal auditory canal through the retrosigmoid approach: a radioanatomic study. Otolaryngol Head Neck Surg 1994;111:81–90.
16. Ruckenstein MJ, Harris JP, Cueva RA, et al. Pain subsequent to resection of acoustic neuromas via suboccipital and translabyrinthine approaches. Am J Otol 1996;17:620–24.
17. Kircher ML, Kartush JM. Pitfalls in intraoperative nerve monitoring during vestibular schwannoma surgery. Neurosurg Focus 2012; 33-35.
18. Taha I, Hyvärinen A, Ranta A, Kämäräinen OP, Huttunen J, Mervaala E, Löppönen H, Rauramaa T, Ronkainen A, Jääskeläinen JE, Immonen A, Danner N. Facial nerve function and hearing after microsurgical removal of sporadic vestibular schwannomas in a population-based cohort. Acta Neurochir (Wien). 2020 Jan;162(1):43-54. doi: 10.1007/s00701-019-04055-4. Epub 2019 Sep 7. PMID: 31494730; PMCID: PMC6942003.
19. Lalwani AK, Butt FY, Jackler RK, Pitts LH, Yingling CD. Facial nerve outcome after acoustic neuroma surgery: a study from the era of cranial nerve monitoring. Otolaryngol Head Neck Surg 1994;111:561–70.
20. Fenton JE, Chin RY, Shirazi A, Fagan PA. Prediction of postoperative facial nerve function in acoustic neuroma surgery. Clin Otolaryngol Allied Sci 1999;24:483–6.
21. Samii M, Gerganov VM, Samii A. Functional outcome after complete surgical removal of giant vestibular schwannomas. J Neurosurg 2010;112:860–7.
22. Neff BA, Ting J, Dickinson SL, Welling DB. Facial nerve monitoring parameters as a predictor of postoperative facial nerve outcomes after vestibular schwannoma resection. Otol Neurotol 2005;26:728–32.
23. Prell J, Rampp S, Romstock J, Fahlbusch R, Strauss C. Train time as a quantitative electromyographic parameter for facial nerve function in patients undergoing surgery for vestibular schwannoma. J Neurosurg 2007;106:826–32.
24. Acioly MA, Gharabaghi A, Liebsch M, Carvalho CH, Aguiar PH, Tatagiba M. Quantitative parameters of facial motor evoked potential during vestibular schwannoma surgery predict postoperative facial nerve function. Acta Neurochir (Wien) 2011;153:1169–79.
25. Lin VY, Houlden D, Bethune A, Nolan M, Pirouzmand F, Rowed D, et al. A novel method in predicting immediate postoperative facial nerve function post acoustic neuroma excision. Otol Neurotol 2006;27:1017–22.
26. Fukuda M, Oishi M, Takao T, SaitoA, Fujii Y. Facial nerve motor-evoked potential monitoring during skull base surgery predicts facial nerve outcome. J Neurol Neurosurg Psychiatry 2008;79:1066–70.
27. S. Tringali, A. Charpiot, M. Ould, C. Dubreuil, and C. FerberViart, “Characteristics of 629 vestibular schwannomas according to preoperative caloric responses,” Otology and Neurotology, vol. 31, no. 3, pp. 467–472, 2010.