Facial Nerve Outcome after Vestibular Schwannoma Surgery: Our Experience*

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Abstract

In this study we evaluate the postoperative facial nerve function after vestibular schwannoma (VS) surgery and analyze the factors that cause it. We included 97 consecutive patients undergoing surgical excision of sporadic unilateral VS. Patient and tumor characteristics, surgical approaches, facial nerve function, extent of tumor removal, perioperative complications are all analyzed through standardized systems. Four different surgical approaches are used: translabyrinthine, retrolabyrinthine, retrosigmoid, and middle cranial fossa. Anatomic preservation of the facial nerve is achieved in 97% of patients. The incidence of postoperative facial palsy is found to be statistically correlated to tumor size, but not to the surgical approach used and to extent of tumor penetration in the internal auditory canal. A significant improvement of the short-term facial nerve outcome is detected in patients undergone simultaneous intraoperative electromyography (EMG) and pneumatic facial nerve monitoring. Complete tumor excision is achieved in 94% of cases. Complication rates are excellent and no deaths are reported. Short- and long-term facial nerve outcome is good and comparable with those of other series reported in literature. In VS surgery both EMG and pneumatic facial nerve monitors should be simultaneously used. Further investigations are desirable to improve the facial outcome respecting the oncological radicality.

Keywords

- vestibular schwannoma surgery
- acoustic neuroma surgery
- facial nerve monitoring
- facial nerve palsy

Vestibular schwannomas (VS) account for ~8 to 9% of intracranial tumors and 80% of tumors found within the cerebellopontine angle (CPA). Bilateral VS are uncommon and typically associated to neurofibromatosis type II (NF2). Unilateral progressive hearing loss, tinnitus, vertigo, and disequilibrium represent the most common symptoms at the time of diagnosis.^{1–3} The VS surgery has evolved drastically since the first case was described by Ballance in 1895 and the operative

mortality rate has considerably dropped from 70% at the beginning of the century to less than 1% in the last decade.^{4,5}

Although death has become a very rare complication thanks to the improved imaging techniques permitting early diagnosis, the use of the microscope and cranial nerves intraoperative monitoring, the postoperative course can be marked by some severe complications such as facial palsy, cerebrospinal fluid leak, meningitis, and other cranial nerve deficit.^{5,6} Anatomical preservation of the facial nerve is now standard, but functional outcomes vary among authors.⁵

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The aim of the study is to evaluate the postoperative facial nerve function and to analyze the factors that cause it, analyzing 10 years of our experience in the surgical treatment of VS and comparing our results with data reported in recent literature.

Materials and Methods

We consecutively enrolled 97 patients who underwent surgical approaches for excision of VS at the Area of Otolaryngology University Campus Bio-Medico and the Rome American Hospital in Rome between January 1998 and July 2008. Exclusion criteria were the incomplete and/or <12 months follow-up, the presence of NF2 or bilateral VS, previous surgical, or radiosurgical treatment (gamma knife).

According to the exclusion criteria, 66 patients (33 females and 33 males; mean age, 49.6 years) were included in the study. Patients were evaluated through the use of a VS evaluation chart, a database created by the authors and filled prospectively as standard of care by all the SV patients in our department. The mean follow-up period was 19 months (range, 96 to 12 months).

By VS size calculated on preoperative magnetic resonance imaging of the brain with gadolinium contrast, 66 VS have been categorized according to the Zini-Magnan classification⁷ in 5 stages and 3 substages. Zini stage I corresponds to tumors confined to the internal auditory canal (IAC); stage II to small tumors (up to 10 mm) confined to prepontine cistern without contact with the brainstem; stage III to middle-size tumors (11 to 20 mm) in contact with the brainstem without displacement of the fourth ventricle; stage IV to large tumors (21 to 40 mm) distorting brainstem and displacing the IV ventricle; stage V to very large tumors (greater than 40 mm) reaching or exceeding the median line. The three substages evaluate the extent of tumor penetration into the IAC: substage A—when IAC is free from disease; substage B—when the tumor penetrates into the IAC, but does not reach the fundus; substage C—when the IAC is totally filled by the tumor.

Surgical procedures were all performed by the same neurotologist team (C.Z. and F.S.) in collaboration with the neurosurgeon (A.G.). Four different surgical approaches were used: translabyrinthine approach (TLA), retrolabyrinthine approach (RLA), retrosigmoid approach (RSA), and middle cranial fossa (MCF) approach.

Intraoperative facial nerve monitoring was systematically used in all the procedures, with our pneumatic system

(Neuromuscular Helper, patent pending number: PCT/IT03/00412) in 51 procedures and with both pneumatic and electromyography (EMG) (Neurosign 800, Magstim, Wales, UK) systems in the remaining 15 procedures.

Each patient was categorized on the basis of surgical approach, surgical and anesthesiological events, the extent of tumor removal, and anatomical preservation of the facial nerve.

Facial nerve function was assessed by office examination, according to the House-Brackmann (HB) facial grading system⁸ before surgery, in the immediate postoperative course and 1 year after surgery. The main postoperative complications and the mortality rates were also analyzed.

All data were entered into a computer database. Statistical analysis was performed using the Statistical Package for Social Sciences Software (SPSS 10.0 for Windows, SPSS Inc., Chicago, IL). Data are shown as mean and standard deviation. Statistical analysis was performed with the χ^2 test and Fisher test. Our criterion for statistical significance was set at *p* values of less than 0.05 (two-tailed).

Results

Of 66 patients, 6 (9.0%) presented a stage I tumor (IB = 4.5%, IC = 4.5%), 18 (27.3%) had a stage II tumor (IIA = 3.0%, IIB = 10.6%, IIC = 13.6%), 20 (30.3%) had a stage III tumor (IIIA = 6.1%, IIIB = 19.7%, IIIC = 4.5%), and 22 (33.3%) had a stage IV tumor (IVA = 7.6%, IVB = 12.1%, IVC = 13.6%). There was no predominance regarding the side of the lesion.

The TLA approach was performed in 36 patients (54.5%), RLA approach in 17 patients (25.7%), RSA approach in 12 patients (18.2%), and MCF approach in 1 patient (1.5%). ►Table 1 shows the distribution of surgical approaches according to tumor size.

Alteration of preoperative facial nerve function was present in four patients (6.1%), two of whom had HB grade II and two had HB grade III.

The anatomic preservation of the facial nerve integrity was possible in 64 patients (97%) and in two cases nerve disruption occurred and simultaneously facio-facial anastomosis was performed, after nerve rerouting.

A difficult surgical dissection of the facial nerve was noted in 34.8% of patients (*n* = 23) and it was significantly (*p* = 0.001) correlated to tumor size, being reported in 8.3% (*n* = 2) of stage I and II tumors and in 50.0% (*n* = 21) of stage III and IV tumors.

Table 1 Distribution of Surgical Approaches according to Tumor Size (Zini-Magnan Classification)⁷

Approach	Stage I (<i>n</i> = 6)	Stage II (<i>n</i> = 18)	Stage III (<i>n</i> = 20)	Stage IV (<i>n</i> = 22)
TLA (<i>n</i> = 36)	2 (3.0%)	5 (7.6%)	9 (13.6%)	20 (30.3%)
RLA (<i>n</i> = 17)	1 (1.5%)	8 (12.1%)	7 (10.6%)	1 (1.5%)
RSA (<i>n</i> = 12)	2 (3.0%)	5 (7.6%)	4 (6.0%)	1 (1.5%)
MCF (<i>n</i> = 1)	1 (1.5%)	0 (0%)	0 (0%)	0 (0%)

MCF, middle cranial fossa approach; RLA, retrolabyrinthine approach; RSA, retrosigmoid approach; TLA, translabyrinthine approach.

Table 2 Tumor Size and Facial Function in the Immediate Postoperative Course

Tumor Size	Facial Function (HB Grade)					
	I	II	III	IV	V	VI
Stage I (n = 6)	3 (50%)	1 (16.7%)	1 (16.7%)	0 (0%)	0 (0%)	1 (16.7%)
Stage II (n = 18)	14 (77.8%)	1 (5.5%)	1 (5.5%)	0 (0%)	1 (5.5%)	1 (5.5%)
Stage III (n = 20)	13 (65.0%)	2 (10%)	3 (15%)	2 (10%)	0 (0%)	0 (0%)
Stage IV (n = 22)	8 (36.4%)	3 (13.6%)	4 (18.2%)	0 (0%)	2 (9.1%)	5 (22.7%)

HB, House-Brackmann.

Of 62 patients with preoperative normal facial nerve function (HB grade I), 24 (38.7%) reported immediate postoperative facial nerve deficit ($n = 6$ with HB grade II, $n = 7$ with HB grade III, $n = 1$ with HB grade IV, $n = 3$ with HB grade V, and $n = 7$ with HB grade VI) and subsequently underwent intravenous corticosteroid treatment (► **Table 2**).

No cases of postoperative delayed facial paralysis were reported (onset usually at 8 days after surgery).

One year after surgery, 23 (37.1%) of 62 patients reported a long-term facial nerve deficit ($n = 9$ with HB grade II, $n = 9$ with HB grade III, $n = 2$ with HB grade IV, $n = 1$ with HB grade V, and $n = 2$ with HB grade VI [► **Table 3**]).

One year after surgery, four patients with preoperative facial nerve impairment showed no modifications of facial function.

The incidence of postoperative facial palsy was statistically correlated to tumor size: an increased incidence of facial deficit (HB grade II to VI) was found in patients with stage IV tumor compared with those with stage I, II, and III tumors, either in the immediate postoperative period ($p = 0.014$) or 1 year after surgery ($p = 0.034$).

No statistical correlations were found between the extent of tumor penetration in the IAC (substages A, B, and C) and the facial nerve outcome, either in the immediate postoperative course or 1 year after surgery ($p > 0.05$).

The prevalence of facial nerve deficit was not found to be significantly impacted by the surgical approach used (► **Tables 4** and **5**). An initial analysis showed that facial nerve outcome was better following RLA than after TLA either in the immediate postoperative course ($p = 0.005$) or 1 year after surgery ($p = 0.013$); no significant difference was found while comparing RSA with TLA ($p = 0.233$ and $p = 0.157$) and RSA with RLA ($p = 0.141$ and $p = 0.348$). However, we noticed that tumors treated with RLA were actually smaller than those treated with TLA (► **Table 1**) so we divided the total population ($n = 66$) in two groups: group A ($n = 44$) with stage I, II, and III tumors and group B ($n = 22$) with stage IV tumors: no significant differences in the prevalence of postoperative facial nerve deficit were noted, both in group A and group B, either in the immediate postoperative course or 1 year after surgery, comparing TLA, RLA, and RSA ($p > 0.05$). The MCF approach was not taken

Table 3 Tumor Size and Facial Function 1 Year after Surgery

Tumor Size	Facial Function (HB Grade)					
	I	II	III	IV	V	VI
Stage I (n = 6)	3 (50%)	1 (16.7%)	1 (16.7%)	1 (16.7%)	0 (0%)	0 (0%)
Stage II (n = 18)	14 (77.8%)	1 (5.5%)	2 (11.1%)	0 (0%)	0 (0%)	1 (5.5%)
Stage III (n = 20)	13 (65%)	4 (20%)	3 (15%)	0 (0%)	0 (0%)	0 (0%)
Stage IV (n = 22)	9 (40.9%)	3 (13.6%)	6 (27.3%)	2 (9.1%)	1 (4.5%)	1 (4.5%)

HB, House-Brackmann.

Table 4 Facial Nerve Outcome According to Surgical Approach in the Immediate Postoperative Course

Facial Function (HB Grade)	Surgical Approach			
	TLA (n = 36)	RLA (n = 17)	MCF (n = 1)	RSA (n = 12)
I-II	20 (55.5%)	16 (94.1%)	0 (0%)	9 (75%)
III-IV	7 (19.4%)	0 (0%)	0 (0%)	3 (25%)
V-VI	9 (25.0%)	1 (5.9%)	1 (100%)	0 (0%)

HB, House-Brackmann; MCF, middle cranial fossa approach; RLA, retrolabyrinthine approach; RSA, retrosigmoid approach; TLA, translabyrinthine approach.

Table 5 Facial Nerve Outcome According to Surgical Approach 1 Year after Surgery

Facial Function (HB Grade)	Surgical Approach			
	TLA (n = 36)	RLA (n = 17)	MCF (n = 1)	RSA (n = 12)
I-II	22 (61.1%)	16 (94.1%)	0 (0%)	10 (83.3%)
III-IV	11 (30.5%)	1 (5.9%)	1 (100%)	2 (16.7%)
V-VI	3 (8.3%)	0 (0%)	0 (0%)	0 (0%)

HB, House-Brackmann; MCF, middle cranial fossa approach; RLA, retrolabyrinthine approach; RSA, retro-sigmoid approach; TLA, translabyrinthine approach.

into consideration because of the restriction of the sample (one case).

A significant improvement ($p = 0.01$) of the facial nerve outcome in the immediate postoperative course was detected in patients undergone simultaneous intraoperative EMG and pneumatic facial nerve monitoring ($n = 15$) in comparison with those patients undergone pneumatic monitoring only ($n = 51$).

Extent of Tumor Removal

The excision of the tumor was considered complete in 66 cases (94%), while in the remaining 6% of the cases (four patients), to guarantee the preservation the facial nerve, we preferred to perform a near-total excision, leaving a scrap of tumor adherent to the nerve.

Complications

The overall complication rate is shown in ►Table 6. No severe complications such as stroke, intracranial postoperative hematoma, hydrocephalus, and meningitis were reported. In 2 casi (3.0%) è stato riscontrato alla TC con mdc un edema cerebellare, risoltosi rispettivamente in terza e quarta giornata post-operatoria dopo terapia medica. In two cases (3.0%) cerebellar edema was detected on postoperative computed tomography scan and complete recovery was achieved respectively within the fourth postoperative day following medical therapy.

Table 6 Complications

	N	%
CSF leak	3	4.5
Rhinoliquorrhea	2	3
Stroke	0	0
Cerebellar edema	2	3
Intracranial hematoma/hemorrhage	0	0
Meningitis	0	0
Hydrocephalus	0	0
Other cranial nerves deficit	3	4.5
Retroauricular wound infection	0	0
Abdominal wound infection	1	1.5

CSF, cerebrospinal fluid.

In two patients (3.0%) postoperative rhinoliquorrhea was found, both had stage III tumors, and both had been treated with TLA approach; in neither case revision surgery was needed, but only conservative measures, such as pressure dressing, fluid and activity restriction, lumbar drainage, and over-sewing of the incision were needed. Cerebrospinal fluid (CSF) leak was highlighted in three patients (4.5%), all presenting with stage IV tumors: two of these patients presented a subcutaneous retroauricular CSF collection and were successfully managed with conservative measures; in one case CSF leakage from the wound was detected and a subsequent surgical procedure was required.

One patient (1.5%) had a postoperative trigeminal nerve deficit, one patient (1.5%) had abducens nerve paralysis, and one patient (1.5%) had vagus nerve impairment. There were no cases of retroauricular wound infection, while one patient (1.5%) had infection of the abdominal wound. There were no deaths (mortality 0%) reported.

Discussion

In our series of patients the translabyrinthine craniotomy represents the most frequently used approach (54.5%) and this is related to the large presence of stage III and IV tumors (63.6%) where the TLA remains the more safer and effective approach allowing a wide exposure of both IAC and CPA. The RLA, RSA, and MCF aim to preserve the hearing function and, because of the high percentage of severe hearing impairment in our series of patients, they were performed in only 45.4% of the cases.

The preservation of facial function is nowadays, along with the radical removal of the tumor, the main goal of SV surgery. Cystic tumors,^{9,10} previous surgical or radiosurgical treatment,¹¹ and preoperative deficit¹² represent important negative prognostic factors for postoperative facial nerve outcome. In our series of patients, the anatomic preservation of the facial nerve was achieved in 97% of the cases.

When facing giant VS, the facial nerve usually appears very thin, fragile, and it is often hardly dissectable from the tumor. Despite the dissection of the facial nerve proved difficult in 35% of our cases (more frequently stage III and IV tumors), in only two patients facial nerve integrity could not be preserved.

In the immediate postoperative course, a partial-to-total facial nerve deficit (HB grade II to VI) was observed in

Table 7 Facial Nerve Function and Anatomic Preservation Evaluated 1 Year after Surgery as Reported in the Recent Literature

Author	Year	Surgical Approach	No. of Cases	Anatomic Preservation of the Facial Nerve	Postoperative Preservation of Facial Nerve Function (HB Grade I-II)
Hardy et al ¹³	1989	TLA	100	82%	—
Briggs et al ¹⁴	1994	TLA	167	91%	42%
Gormley et al ¹⁵	1997	RSA	179	98%	—
Darrouzet et al ¹⁶	1997	RLA	60	100%	80%
Samii and Matthies ¹⁷	1997	RSA	1000	93%	—
Colletti and Fiorino ¹⁸	1999	RSA - "en bloc" - debulking	40 48	100% 89%	90.3% 68.6%
Lanman et al ¹⁹	1999	TLA	190	93.7%	52.6%
Bruzzo et al ²⁰	2000	RSA	91	100%	96%
Darrouzet ⁴	2002	RSA, RLA, TLA	348	95.7%	52.6%
Brackmann et al ⁵	2007	TLA	512	97.5%	81%
Our series	2010	RSA, RLA, TLA, MCF	62	97%	77.4%

HB, House-Brackmann; MCF, middle cranial fossa approach; RLA, retrolabyrinthine approach; RSA, retrosigmoid approach; TLA, translabyrinthine approach.

24 (38.7%) of 62 patients with preoperative normal facial function (HB grade I); 1 year after surgery, 23 (37.1%) of 62 patients with preoperative HB grade I presented HB grade II to VI.

As already reported by several authors,^{5,6} the smaller the tumor size was, the better the facial function that resulted, either in the immediate postoperative course ($p = 0.014$) or 1 year after surgery ($p = 0.034$). Mainly in case of larger tumors, this finding can be also related to a preexisting nerve sufferance (due to the tumoral compression) and to increased number of the harmful surgical maneuvers on the nerve during tumor removal.

No statistic correlation between extent of tumoral involvement of the IAC and facial nerve deficit was detected, in both short- and long-term postoperative course ($p > 0.05$).

Our results concerning the preservation of facial function (HB grade I or II) 1 year after surgery in the present series do not differ significantly ($p = 0.192$) from those of other sizable series reported in literature in the past 21 years (► **Table 7**).

Nowadays facial nerve monitoring is mandatory during VS surgery, because it has been shown to significantly reduce the risk of iatrogenic facial nerve injury.²¹ The main goals of intraoperative facial nerve monitoring are early nerve identification and mapping within soft tissue, tumor, and bone, allowing also to evaluate the neural integrity and prognosis at the end of the surgery.

EMG has long been accepted as the standard facial nerve monitoring in otoneurosurgical procedures, but it has some disadvantageous characteristics such as during surgery facial nerve can be stimulated by electric currents, pressure, traction, and temperature changes.^{22,23} In our series of patients the use of simultaneous intraoperative EMG and pneumatic

facial nerve monitoring was correlated with a significant improvement ($p = 0.01$) of the short-term facial nerve outcome when compared with the use of the pneumatic monitoring only. In particular, the simultaneous intraoperative EMG and pneumatic monitoring was found to be really useful during EMG "dark periods," such as cold irrigation and electrocauterization, when the EMG monitor is not reliable, because of the high production of artifacts.

According to many authors,^{5,24,25} the TLA allows direct access to the tumor, to the lateral aspect of the IAC and CPA and it is associated with excellent postoperative facial function.

As also reported by Darrouzet et al,^{4,6} even in our series of patients the facial nerve outcome was better following RLA than after TLA, both in the immediate postoperative course ($p = 0.005$) and 1 year after surgery ($p = 0.013$). The highlighted differences between RLA and TLA were ascribed to the fact that TLA was most commonly performed for stage IV tumors (55.5% of the cases vs. 5.9% for RLA and 8.3% for RSA), where the facial nerve is exposed to higher risks of injury. As tumors treated with RLA were smaller than those removed with TLA, the population was divided in group A with stage I, II, and III tumors and group B with stage IV tumors; comparing TLA, RLA, and RSA, no significant differences in the facial nerve outcome were found, both in group A and group B, both in the immediate postoperative course ($p > 0.05$) and 1 year after surgery ($p > 0.05$).

The excision of the tumor was complete in 66 cases (94%), while in 4 patients (6%), because of the tumor adherence to the facial nerve, an intraoperative decision was taken by

surgeons to leave a residual fragment of tumor attached to the facial nerve. Brackmann et al⁵ consider these scraps of tumor after near-total resection unlikely to demonstrate growth; long-term radiological follow-up is required in those cases.

In terms of oncological radicality, there were no significant differences among the different surgical approaches (TL, RL, and RS: $p = 0.93$).

In our series of patients complication rates were low. The rates of CSF leak, rhinoliquorrhea, intracranial hematoma/hemorrhage, meningitis, and stroke were comparable with those reported in other large series.⁴ No deaths were reported.

Conclusion

In our series of patients the short- and long-term facial nerve outcome was good and comparable with those of other series reported in literature in the last years. Complication rates were excellent and no deaths were reported. A good facial function was mostly preserved in patients with small and medium size tumors, while lower results were obtained in case of larger tumors. Subtotal resection followed by radiosurgical treatment may play a role in such cases of large VS.⁵

A more safe and effective surgical approach in terms of facial nerve outcome and extent of tumor removal could not be identified.

The surveillance of facial nerve is of extreme importance for the safety and accuracy of VS surgery.

The simultaneous intraoperative EMG and pneumatic facial nerve monitoring allows the surgeon to better evaluate the situation when only one of the two monitors (more frequently the EMG one) is activated, while the other one remains silent, especially during bipolar coagulation.²⁶ However, any facial nerve monitoring system will never be sufficient to guarantee the preservation of the nerve during surgery and there is no substitute for detailed anatomic knowledge, proper training with cadaveric dissection, and meticulous surgical technique.²⁷

The collaboration between neurosurgeon and otolaryngologist, the use of neuronavigation systems, and endoscopy can promote the reduction of the complication rates associated with VS surgery.

Further investigations are desirable to investigate the role of different surgical approaches and radiosurgery, to further improve the facial outcome respecting the oncological radicality.

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