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Vestibular schwannoma and hearing preservation: Usefulness of level specific CE-Chirp ABR monitoring. A retrospective study on 25 cases with preoperative socially useful hearing

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ABSTRACT

Background and objectives: Decision-making regarding the therapy of vestibular schwannoma (VS) changed over the last decades, during which curative microsurgery has been promoted. Goals of VS microsurgery are: extensive resection, facial nerve (FN) preservation and, in selected cases, hearing preservation (HP). The aim of this study is to evaluate postoperative HP with reference to tumor size in patients operated on with Level Specific (LS)-CE-Chirp® ABR monitoring.

Patients and methods: Twentyfive consecutive patients with socially useful hearing (SUH) underwent VS microneurosurgery by retrosigmoid (RS) approach. Selection criteria were: pure tone audiogram <50dB loss and speech discrimination score >50% (50/50 criterion; AAO-HNS class A-B). In relation to maximum diameter, we identified 2 size-groups: A) ≤2cm (13 cases); B) >2cm (12 cases). HP attempt was assisted by intraoperative ABR evoked by LS CE-Chirp® acoustic stimuli.

Results: Mean age was 44,3 years (20–64); average maximum diameter 2,04cm (8 40mm). Total and nearly-total (>95%) resection was possible in all. Mortality and major morbidity were zero. In all, FN was anatomically and functionally preserved; in 10 an incomplete FN deficit (House-Brackmann II and III) was followed by complete recovery (House-Brackmann I). SUH preservation rate was 52%, with significant differences in relation to size: 61,5% group A and 41,7% group B (p = 0,014). Postoperative AAO-HNS C (serviceable) hearing was observed in 36%, deafness in 12%.

Conclusion: Microsurgery represents a valid therapeutic option for small growing VS with SUH. Our data confirm that RS removal of VS with intraoperative ABR monitoring allows good rate of SUH preservation, especially if maximum diameter does not exceed 2cm. LS-CE-Chirp ABR represent a safe and effective method for monitoring cochlear nerve, with fast and clear intraoperative neurophysiological feedback.

1. Introduction

Decision making of VS treatment changed over the years [1]. Introduction of MRI into routine diagnostics of hearing disturbances led to an increasing number of small VS diagnosed in early stage [2,3]. It remains an open question if small VS need treatment or not [1]: MRI monitors their size and volume and offers safe and feasible observation management [2,3], even if irreversible hearing loss affects about 50% of patients during observation time [4–9].

The alternative strategies to serial MRI observation are microneurosurgery and stereotactic radiosurgery (SRS) [1,10–14]. SRS is considered less invasive and allows tumor control with good functional results: facial nerve (FN) function can be preserved in >95% of patients and socially useful hearing (SUH) in 61%–78% [12,13,15–19], but it does not ensure its cure [15–19].

In accordance with experienced neurosurgeons, on the basis of microsurgical results [20–24], SRS seems to be recommended only in growing recurrent tumors, if second operation is not suitable. In patients with VS <2 cm of maximum diameter and complete hearing loss

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wait and control with serial MRI appears as the best choice, especially in older patients [25]. In cases with large VS or with small tumors with SUH microsurgical removal by retrosigmoid (RS) approach is widely indicated in the literature [3,20,21,23,24,27].

Many Authors promote to treat small VS with curative microsurgery [21,23,24,26,27]. To achieve better outcome, surgical technique has been supported by ultrasonic aspirators, hand-held lasers, dedicated micro-instruments, continuous FN-EMG-monitoring and stimulation, and intraoperative ABR [20,28] for safe and maximal removal.

The purpose of this manuscript is to report the hearing functional outcome after removal of VS by RS approach [23] in 25 patients with AAO-HNS class A-B preoperative hearing function [29]. In the present series, HP was attempted by using intraoperative ABR, evoked with LS-CE-Chirp stimuli [28], allowing frequent, fast, and reliable cochlear nerve evaluation.

2. Materials and methods

2.1. Study design and setting

Between March 2015-December 2016, we enrolled 25 patients: 15 men, 10 women, age 20–64 (mean 44,3 ± 8,3 years), affected by VS with SUH (40,9% of 61 VS operated on in the same period). All patients underwent microsurgical removal by RS approach [20,23], attempting FN and hearing preservation.

LS-CE-Chirp stimuli (Eclipse-EP15, Interacoustics, Middelfart, Denmark) ABR are currently used by Pediatrics and Neuro-Otological Units and approved from Ethics Committee of our Hospital; for this reason we did not to request approval by internal Ethics Committee [28].

LS-CE Chirp® ABR wave-V is 2-times larger than the corresponding Click ABR wave-V, reducing the averaging sweeps from 1024 to 256. LS-CE Chirp® evoke two-time larger waves in 1/4 of the evaluation time requested by Click stimulus-evoked ABR [4,28].

Informed consent was obtained from any patient for possible scientific issues.

2.2. Participants

Eligibility criteria: pure tone audiogram (PTA) loss ≤50 dB and speech discrimination score ≥ 50% (50/50 criterion; AAO-HNS class A-B) [29].

In relation to maximum diameter, we identified 2 size-groups: A: < 2 cm; B: ≥ 2 cm. In all cases, HP was attempted with intraoperative ABR, evoked by LS-CE-Chirp® acoustic stimuli [28].

Each patient received contrast enhanced (c.e.) MRI. Tumor was measured in 3-spatial dimensions and size estimated considering maximum diameter, including intracanalicular portion. All patients underwent RS microneurosurgery [20,23], attempting total or nearly-total (95%–99%) removal, FN preservation and HP. FN function was assessed pre-operatively, 1 week and 4 months postoperatively using House-Brackmann (HB) scale [30].

2.3. Hearing evaluation

Audiological exams were performed the day before surgery, 1 week and 6 months after by PTA, ABR, and monosyllabic speech audiograms.

2.4. Follow-up

Patients were examined every 3–6 months, with minimum follow-up of 4 months and maximum of 25 (median 13). To confirm extent of removal, postoperative Gd-enhanced MRI 24–48 h after surgery and every year were obtained.

3. Intra-operative procedures

3.1. FN intraoperative neuro-monitoring (IONM)

During surgery, FN EMG (Nimbus i-Care-100, Hemodia, Labege, France) was used, with electrodes in orbicularis-oris and orbicularis-oculi muscles. Stimulation: monopolar, 50 ms, on tumor capsule from 2 m Amp ("detector" of nerve course) and 0.3–0.01 m Amp, 50 ms, directly on FN, for confirmation of its function [21,23,25,28].

3.2. Cochlear nerve IONM

Each patient received ABR audiometry (Nicolet Viking III, Viasys HealthCare, Madison, USA) immediately before surgery. ABR were evoked with LS-CE-Chirp® stimuli (Eclipse-EP15, Interacoustics, Middelfart, Denmark) [28], by means subdermal nedlees or surface electrodes placed at vertex (Cz) and on each earlobe (A1 and A2). Filters bandwidth was 150–1500 Hz. Two channels were recorded:1: A1–Cz;A2–Cz [28]. LS-CE-Chirp® ABR were performed by 3M-E-A-RTone Gold-3A insert-earphones.

Stimuli were presented with alternate polarity (41,1 Hz). Sound pressure range was 60-100dBHL, evoking clear monitorable waves; 50dBHL white noise masked contralateral ear.Time analysis was 10–15 s per-sweep. On surgeon's demand, one or more series of 400–1200 acoustic stimuli of LS-CE-Chirp® ABR were registered [8].

3.3. RS approach

RS approach was performed in lateral position (LP) [20,23].

Lateral occipital bone was exposed between superior and inferior nuchal lines [20,23], with 3 × 3 cm craniotomy and sigmoid-transverse sinuses exposure. Dura opening was followed by cutting of lateral-medullary cystern arachnoid, CSF aspiration, and cerebellar relaxation.

For internal auditory canal (IAC) unroofing, dura of meatus was removed with laser [31]; the canal was opened with drill or Sonopet-Ultrasonic-Aspirator (Stryker, Kalamazoo, MI) [20,23].

Cerebellar gentle retraction [22] allowed tumor surface exposure, followed by FN position detection. "V-cut" [20,23] on dorsal surface of tumor was done, followed by debulking with microscissors, microcurettes, bipolar forceps, Sonopet, and laser (vaporizing, cutting) [31]. Tumor dissection from brainstem and cranial nerves and piecemeal capsule removal were done under continuous facial-cochlear IONM. Excision near the fundus was performed under direct visualization [20,23]. In cases with strong adhesion of capsule to brainstem and/or FN a millimetric fragment of capsule was left.

Bone wall of IAC was covered with wax and canal plugged with small pieces of muscle. Tight dura closure was obtained with pericranial graft [32] and bone flap placed back with miniplates.

4. Statistical analysis

Data were expressed by means and standard deviations and percentage of frequency. Chi-square test was used to calculate differences in frequencies of FN preservation and HP rates in size-group-A versus size-group-B patients. Statistical significance was considered p ≤ 0.05).

5. Results

Mean maximum diameter of the entire series was 2,04 cm ± 0,9ncm (0,8–4 cm). Thirteen patients belonged to size-group A and 12 to size-group B. In particular: intracanalicular-VS (Samii group-I) [22]: 4

patients; cerebello-pontine angle extension 10; contact to surface of brainstem 10; 1 VS was cystic.

Mean length of surgery was 237 min (175–380). No deaths nor severe postoperative complications occurred.

Total removal was achieved in 18 patients (Fig. 1a, b), nearly total in 7 (Fig. 2a, 2b), as confirmed by postoperative MRI. Nearly-total resection was preferred in cases with tight adhesion of tumor capsule to FN. Three out of 7 patients with nearly-total resection remained in AAO-HNS Class-B after surgery and 4 worsened to Class-C.

Five cases with anterior FN was identified, 11 anterior-superior, and 9 anterior-inferior [33].

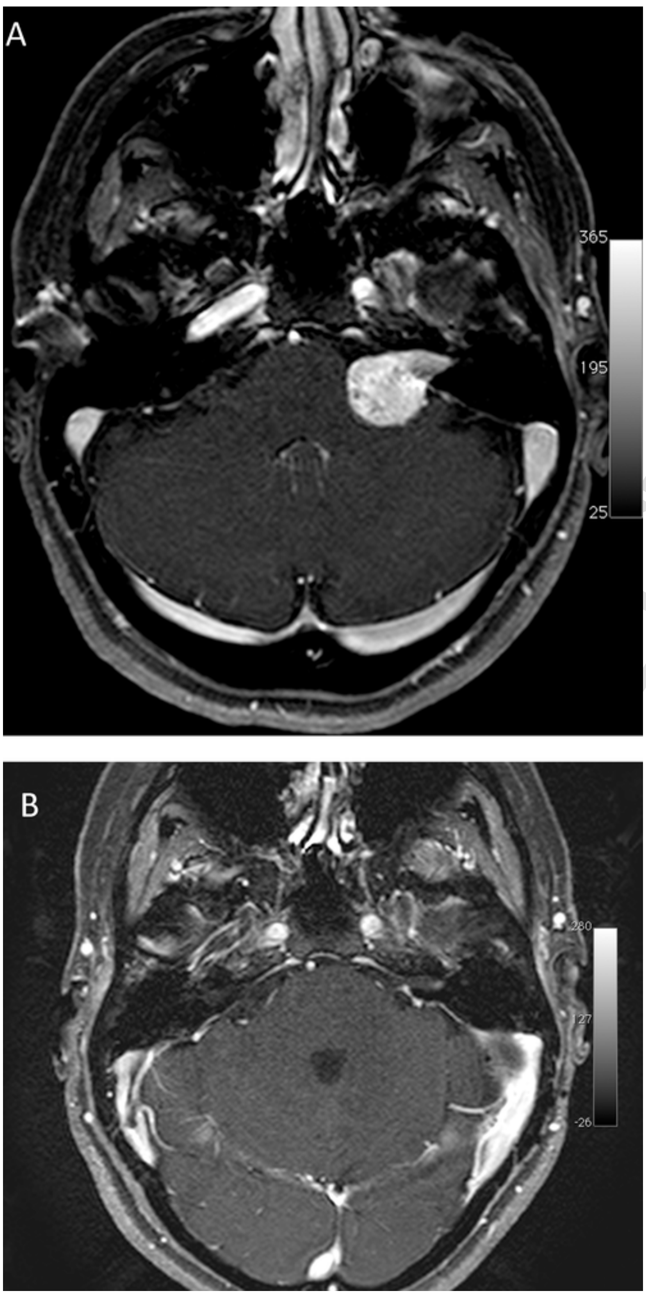

Fig. 1. (a)T1-weighted axial MRI with contrast medium: hyperintense VS arising from IAC; maximum diameter 2,5cm. (b) 6-month postoperative axial MRI on T1 after contrast medium injection: complete removal of tumor. Postoperative hearing: Class B (unchanged).

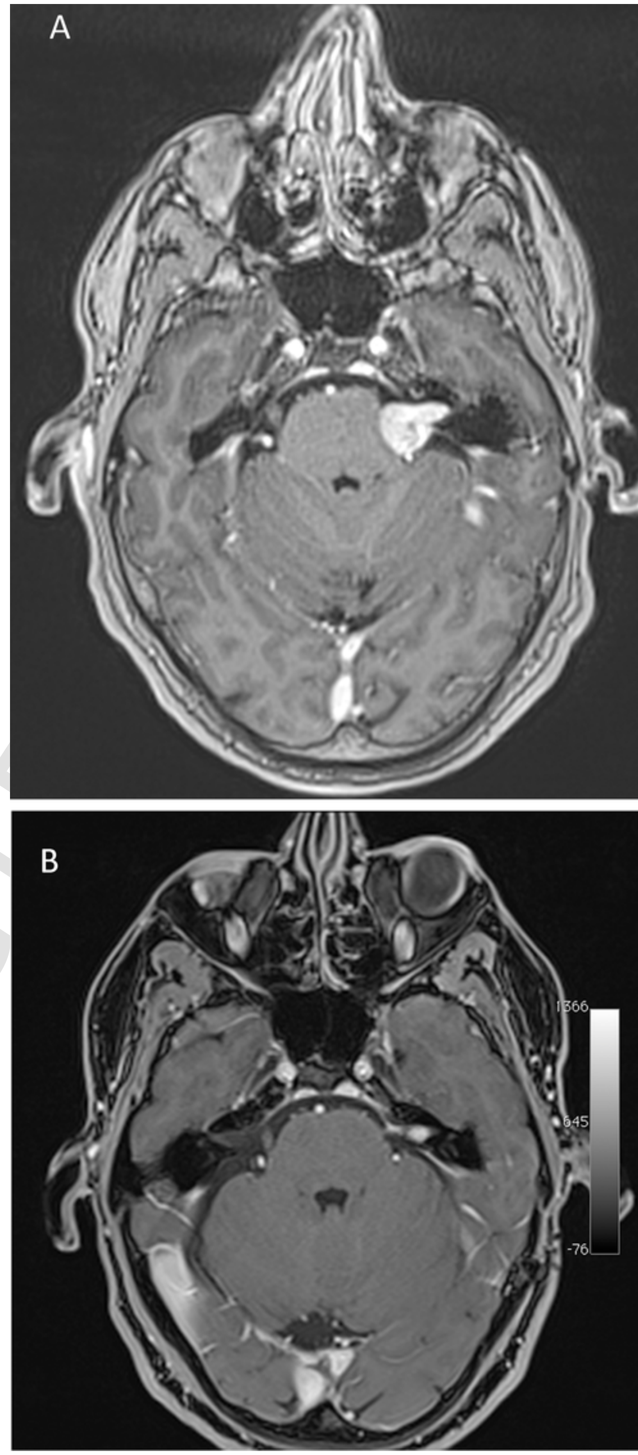

Fig. 2. (a) T1-weighted axial MRI with contrast medium: hyperintense VS arising from IAC; maximum diameter 2,2cm. (b) 6-month postoperative axial MRI on T1 after contrast medium injection; near total removal of tumor (small residual of capsule in the IAC). Postoperative hearing: Class B (unchanged).

Permanent FN deficit was never observed; transient palsy (House-Brackmann Grade-II or III) occurred in 10 cases (40%) followed by normal facial function (HB Grade-I) within 6 months after surgery.

5.1. Hearing results

Table 1 summarizes the hearing results.

Table 1
Hearing results (PTA and speech discrimination) according to AAO-HNS (A, B, C, D) classes.

	Class A	Class B	SUH	Class C	Class D
Preoperatively	3	22	25	–	–
Postoperatively (24 h after surgery)	1	14	15	8	2
Postoperatively (follow-up[a])	1	12	13	9	3

[a] minimum 4 month after surgery SUH: socially useful hearing.

According to the AAO-HNS classification [29], preoperatively 3 patients were Class-A and 22 Class-B, with reproducible preoperative ABR waves. Preoperative tinnitus was present in 10 (40%): 4 (30,8%) size-group A versus 6 (50%) size-group B (p = 0,02).

During surgery, cochlear nerve anatomical preservation was possible in 22 cases (88%).

Immediately after surgery, SUH (Class- A-B) was preserved in 15 cases, whereas 2 were deaf at once (Class-D). In 8 (32%) patients preoperative hearing worsened from Class-B to Class-C; another patient worsened 3-months later and in another one hearing disappeared 3 weeks later. At minimum PTA and speech discrimination follow-up of 4 months, hearing levels were: Class-A 1 patient, Class-B 12 patients (versus 22 in the preoperative period), Class-C 9 and D 3.

Therefore, postoperative SUH was present in 13 cases (52%): 8 (61,5%) size-group-A-patients and 5 (41,7%) size-group B (p = 0,014). Serviceable hearing (Class A-B-C) was present in 22 cases (88%): 12 (92,3%) size-group-A and 10 (83,3%) size-group-B (p = NS) (Table 2).

LS-CE-Chirp® ABR

Sound pressure 90–100 dBHL and series of about 400–800 LS-CE-Chirp® stimuli evoked clear ABR-V waves; more stimuli did not modify significatively their morphology. It was possible to have good LS-CE-Chirp® ABR in 10–15 s and to monitor cochlear nerve 3-6 times every minute.

When ABR changed during resection, we temporarily stopped dissection, irrigated with steroids (dexamethasone 4mg diluted in 20cc of saline), asked to anesthesiologist to infuse I.V. 1000mg of methylprednisolone, and moderately raising the blood pressure by infusion of fluids.

At the end of surgery, in 7 cases waves did not change during procedures (Fig. 3), in 10 showed variable morphological alteration (Fig. 4), and in 5 had latencies longer than preoperative ones (Fig. 5); in 3 ABR-waves were absent.

Among 13 cases with long-term preserved SUH, at the end of surgery 6 had stable waves, 5 elongated latencies, and 2 morphological alteration of waves (both changing from preoperative hearing-Class-A to Class-B).

Table 2
Hearing results (PTA and speech discrimination) according to AAO-HNS (A, B, C, D) classes in relation to size-groups.

	Post op Classes A + B (SUH)	Post op Classes A + B + C (serviceable)
Size-Group A (≤2 cm)	8	10
Size-Group B (> 2 cm)	5	12
Total	13[a]	22[b]

SUH: socially useful hearing.
[a] p = 0014.
[b] p = NS.

5.2. Preoperative tinnitus and HP

At last follow-up, in 6 of 10 patients with preoperative tinnitus hearing worsened from Class-B to Class-C, in 3 remained in Class-B, and in one changed to Class-D (in this case the tinnitus disappeared after surgery).

As regards SUH preservation, 3 of 10 patients with preoperative tinnitus and 10 of 15 without it remained in Class- A-B (p = 0,006).

6. Discussion

Best treatment of VS is still debated. Several Authors consider SRS less invasive than surgery, allowing control over small VS [11,14]. In 123 patients, Elliott et al [34] compared HP between SRS and conservative treatment of unilateral VS, reporting 51% overall serviceable hearing, without significant difference between treatments. SRS offers good tumor control rates and functional results: FN preservation 95%–100%; useful hearing 61%–78% [12,13,15–19,35,36]. According to Akpinar et al [37], SRS performed < 2 years after diagnosis resulted in statistically confirmed long-term better hearing function compared with later treatment. Golfinos et al [38] compared outcomes of microsurgery versus SRS in 399 small-medium-size VS (≤2.8 cm of maximum diameter): SRS was associated with better HP and reduced morbidity, whereas facial function was good in both. In conclusion, SRS ensures good tumor control rates, functional hearing, and facial results, especially in small VS, but not its cure [12,13,15–19,34,38].

In 2006, Samii et al [39] reported total removal in 98% of 200 cases, good-to-excellent long-term FN function in 81%, and HP in 51%. They concluded that total microsurgical removal of small VS (< 20 mm) by RS approach is feasible and curative in one stage, with good preservation of neurological functions, including hearing in patients with preoperative SUH [39]. In 592 patients, Wanibuchi et al [23] reported HP in 53.7% of large VS (diameter > 20) and 74.1% of all sizes. Scheller et al [40] studied long-term stability of HP and regeneration capacity of cochlear nerve in 112 VS operated on by RS approach; in particular, they investigated efficacy of prophylactic parenteral nimodipine, without clinically relevant effects on preservation of cochlear function. They did not find any significant change in HP between early and 1-year control, concluding that result of early postoperative hearing performance is a reliable prognostic factor for future hearing ability [40].

Peng et al [41] maintained that in patients younger than 65 with small VS, microsurgery by middle fossa (MF) approach ensures long-term HP. Satar et al [42] reviewed 11 studies reporting effects of tumor size on hearing (1073 cases) and facial function (797 cases) after MF approach. Their meta-analysis showed that tumor size (including intracanalicular portion) is the main predictor of hearing and FN outcome. On 78 VS with maximum diameter ≤ 2cm, operated on by RS, translabyrinthine, or MF approaches, Anaizi et al [43] reported 95% HBI or HBII FN function at a mean follow-up of about 3 years and 36% serviceable hearing. Sameshima et al [44] compared RS and MF approaches for HP in 504 VS < 1.5cm: SUH preservation was 76.7% in MF-approach-patients and 73.2% in RS (p = NS). Temporary FN deficit was observed more frequently after MF-approach (p < 0.03), with good recovery in both subgroups. In their series, about 14% of MF cases had transient symptoms of temporal lobe edema; no cerebellar side-effects were reported in RS cases [44]. They concluded that although 1-year hearing and FN functions were similar, RS approach had advantages over MF [44]. Therefore, although wait-and-scan and SRS have an established role, microsurgery by RS approach is a safe option

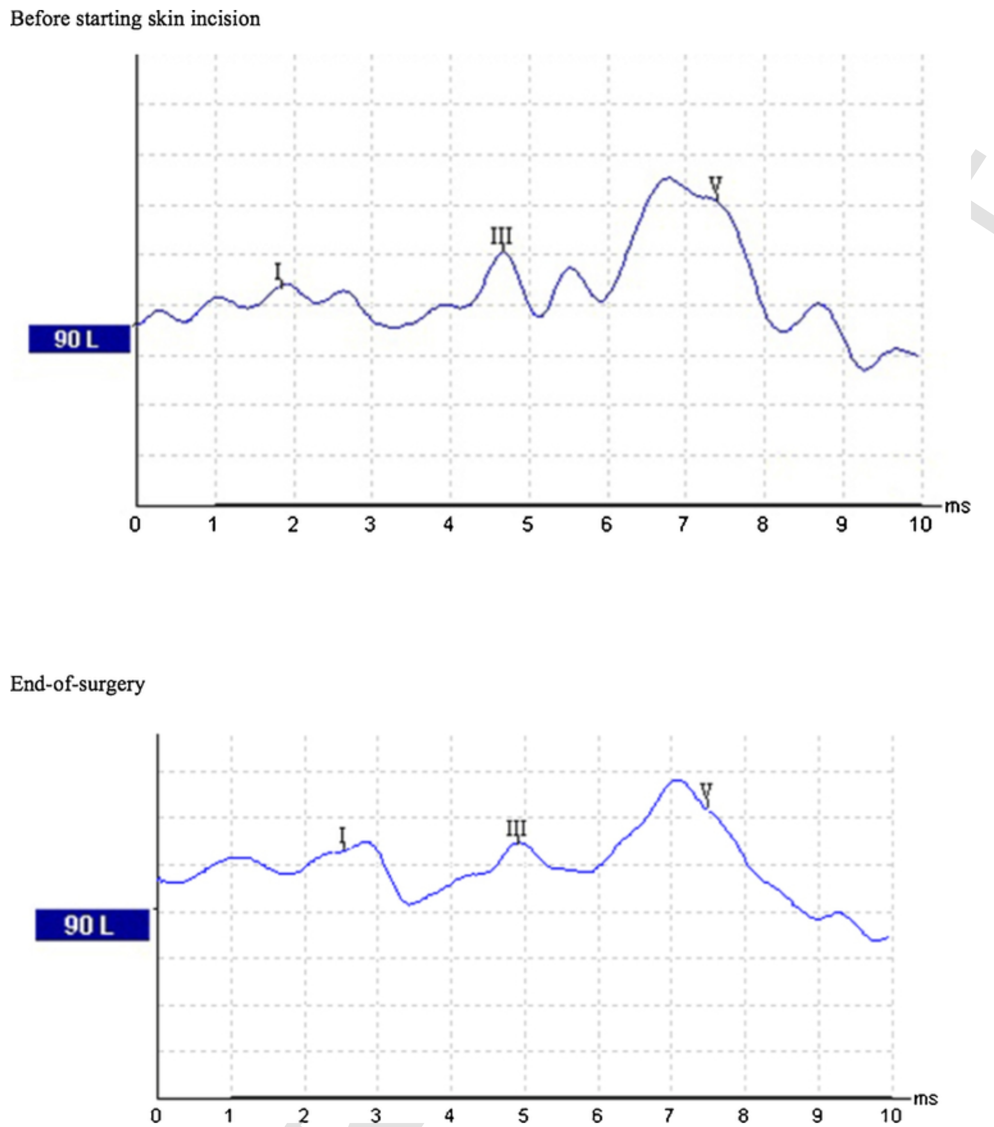

Fig. 3. LS CE-Chirp® ABR: preoperative AAO-HNS Class A hearing, unchanged at last follow-up. End of surgery: waves unchanged in length and amplitude.

for small VS, with low morbidity and good FN and HP results [23,39,44].

As regard surgical position for RS approach, there is not universal accordance. Roessler et al [45] compared 30 patients operated on in semi-sitting position (SSP) with other 30 operated on in LP, obtaining better results with SSP: shorter length of surgery (about 50%), 3-time lower CSF leaks, better 6-month facial function (63% versus 40% HBI) and better HP (44% versus 14%). Notwithstanding the experience of outstanding Authors using SSP [25,39,45], in our daily practice we prefer the LP [20,23].

In 85 patients with VS having maximum diameter >3 cm operated on by RS approach, Mendelsohn et al [46] reported that hypertension, diabetes, and preoperative tinnitus are clinical factors predicting low rate of HP. In our series, preoperative tinnitus was present in 10 patients (40%): 4 of 13 (30,8%) size-group A, versus 6 of 12 (50%) size-group B (p = 0,002). At last follow-up, 6 worsened from Class-B to Class-C, 3 remained in Class-B, and one D; as regard preservation of SUH, 3 of 10 (30%) with preoperative tinnitus versus 10 of 15 (66,7%) without it remained in Class A-B (p = 0,006).

The nerve of origin of VS seems to have predicting role in HP. According to He et al [47], vestibular-evoked myogenic potentials and surgeon verification during operation allow its identification: HP was possible in 61.5% of cases with superior-vestibular nerve tumors versus 16,7% of inferior.

6.1. *Intraoperative neuromonitoring (IONM)*

Improvement of IONM impacted on postoperative HP. Yamakami et al [24,48,49,50] removed small VS with RS approach using newly designed intracranial electrode enabling continuous monitoring of cochlear nerve compound-action-potential (CNAP). In comparison to ABR, CNAP reflects effect of surgical manipulations on hearing and predicts postoperative HP [48]. In 44 VS with maximal diameter ≤1.5 cm, they observed postoperative SUH in 72% and serviceable hearing (A,B,C Classes) in 84% of patients [24], concluding that reliable monitoring was more frequently provided by CNAP than by ABR (66% vs 32%, p < 0.01) and had better rates of HP [24]. Their results [24,48,49,50] were compared to ABR evoked by classical square-wave click stimuli [28,51,52]. Furthermore, the electrode placed on cochlear nerve is an occupying-space element, wire-connected, on the way of surgical instruments, associated with frequent displacements and need to repositioning.

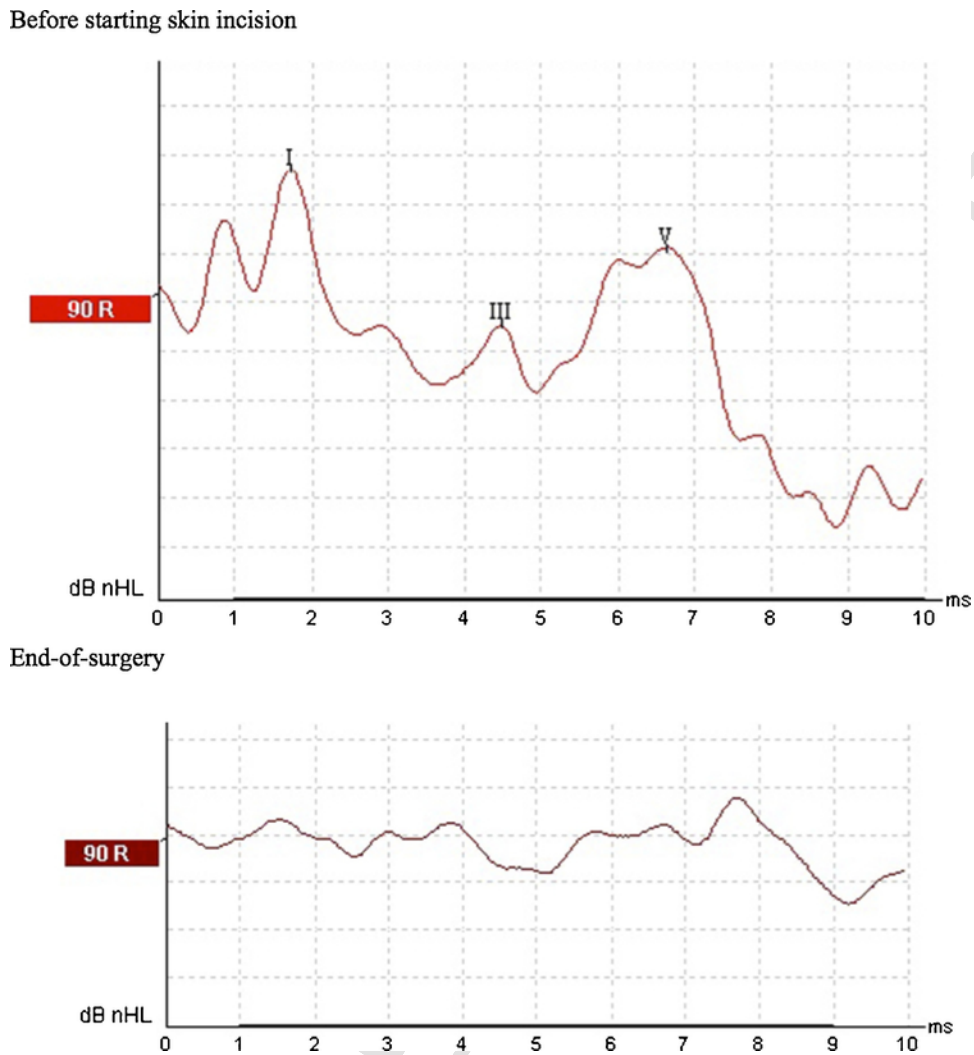

Fig. 4. LS CE-Chirp® ABR: preoperative AAO-HNS Class B hearing, unchanged at last follow-up. End of surgery: morphological alteration of waves.

6.2. Key results, interpretation, and limitations

LS-CE-Chirp® ABR seem to be a fast non-invasive hearing monitoring technique, showing clear morphology and high wave-V amplitude, including doubtful cases [28]. Unlike Click stimulus, using LS-CE-Chirp® ABR, monitoring-team can alert neurosurgeons in 10–15 s about variation of conduction parameters of acoustic pathways. Our HP rates seem not to be very different from the results of Yamakami et al [24]: in size-group A, long-term postoperative SUH was 61,5% and serviceable 93%, versus 72% and 84% with CNAP [24], respectively. Changes in ABR parameters could be due to technical problems, physiologic mechanism, or injury to auditory system [28]. Possible damages to cochlear nerve during VS surgery are related to vascular manipulations, cerebellar retraction [53], and direct approach to tumor. In cases of SUH, continuous and fast monitoring of acoustic pathways during microsurgery provides informations regarding integrity of auditory pathways [24,28,48,49,50,51,52,54]. On considering that LS-CE Chirp® ABR wave-V is 2-times larger than Click ABR wave-V, it is possible to obtain the same Signal-to-Noise Ratio (comparing level of desired signal to level of background noise) reducing averaging sweeps from 1024 to 256. Thus, LS-CE Chirp® evoke 2-times larger waves using ¼-evaluation time necessary with Click stimulus [4].

According to Joo et al [55], reliable waves are obtained with stimulation rate of 43.9 Hz/sec and 400 trials; anyway, LS-CE Chirp® stimulus is more promising than classical Click. At high levels of stimulation, LS-CE Chirp® is as efficient as click in obtaining waves I, III and V for neuroaudiological diagnosis by ABR [56].

In our series, SUH was preserved in 52% of patients: 61% size-group A and 41,7% size-group B ($p = 0{,}014$). Serviceable hearing (Class C) in 88%: 92,3% size-group A, 83,3% size-group B (p = NS). LS-CE-Chirp® ABR allowed to alert neurosurgeon quickly about variation of conduction parameters of acoustic pathways, monitoring cochlear nerve 3–6 times every minute. On considering that >50% of patients of the whole series maintained SUH, according with others [20,21,23,24], microsurgical removal by RS approach could represent the first-line management for VS in patients with SUH. In order to confirm these preliminary observations, use of LS-CE-Chirp® ABR in IONM will be evaluated in large series.

7. Conclusions

Hearing decline during wait-and-scan and after radiosurgery is frequent in small VS. Microneurosurgical technique by RS approach with auditory IONM by LS-CE-Chirp ABR allows total or near-total resection of small VS with good FN outcome and HP. LS-CE-Chirp® stimuli seem

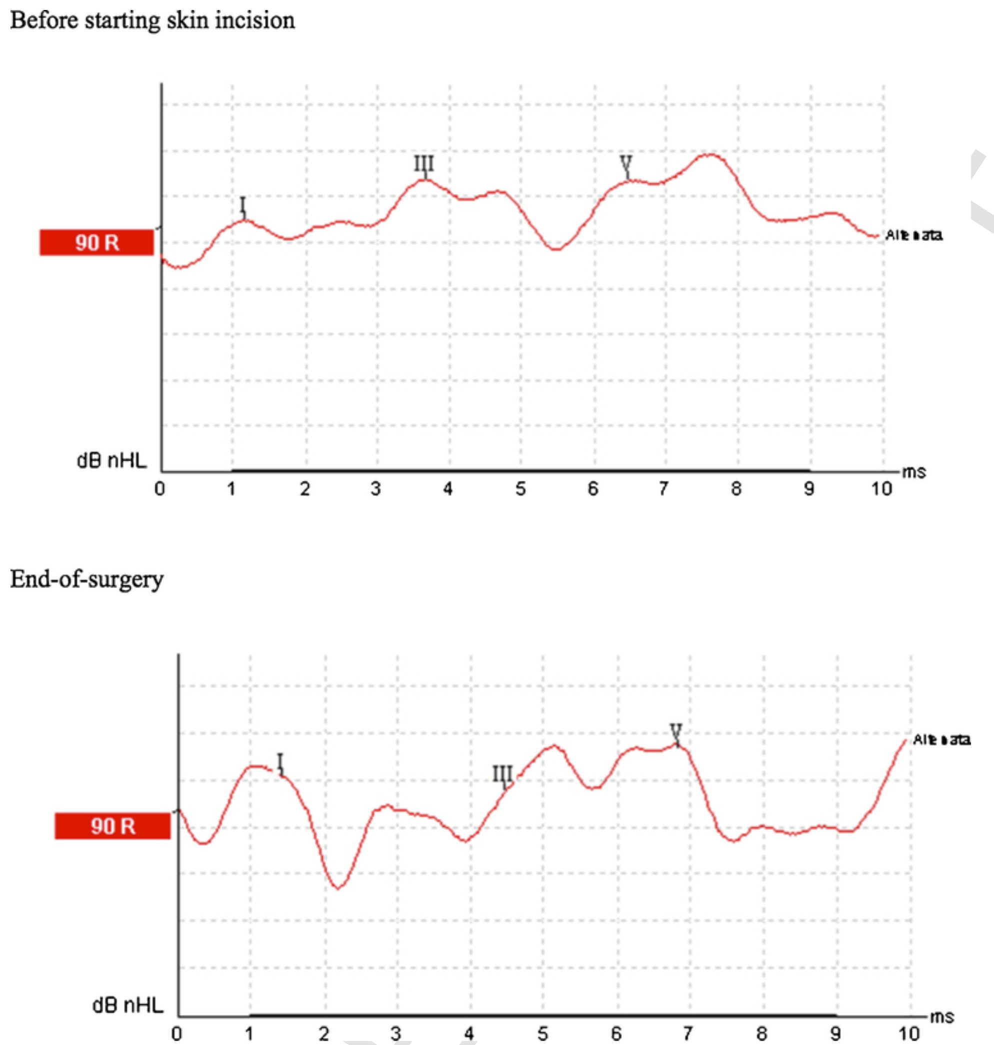

Fig. 5. LS CE-Chirp® ABR: preoperative AAO-HNS Class A hearing, worsened to Class B at last follow-up. End of surgery: longer latencies of evoked waves.

to improve conventional Click ABR. Our results confirm the usefulness of fast IONM of auditory pathways by means LS-CE-Chirp® ABR. Implementation of this technique seems to be necessary for final validation.

8. Disclosures

The Authors did not receive any funding for this study. We do not report any conflict of interest concerning materials or methods used in this study or findings specified in this paper.

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