Hearing recovery after surgical resection of non-vestibular schwannoma cerebellopontine angle tumors

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Abstract

Purpose: Post-operative outcomes for hearing after resection surgery to remove cerebellopontine angle (CPA) tumors other than vestibular schwannomas (VS) are not well understood. This study presents a series of patients with significant post-operative hearing recovery, trying to define the incidence among all patients operated on for removal of non-VS CPA tumors.

Methods: This is a retrospective observational case series of 8 patients among 69 operated on for removal of non-VS CPA tumors between 2012 and 2020. All patients had pre- and post-operative hearing measurement with pure-tone average (PTA) and speech discrimination score (SDS), according to the American Academy of Otolaryngology-Head and Neck Surgery recommendations, auditory brainstem response (ABR) measurements and imaging.

Results: Six meningiomas and two lower cranial nerve schwannomas operated on with a retrosigmoid approach were included for analysis. The mean pre-operative PTA and SDS were 58±20.7 dB and 13±17.5%, respectively. All patients had pre-operative class D hearing and asynchronous ABRs. They all showed significant hearing recovery, with an improvement of 36±22.2 dB (p=0.0025) and 85±16.9% (p=0.0001) in PTA and SDS, respectively, with mean follow-up of 21±23.5 months. Seven patients recovered to a class A hearing level and one patient to class B. The ABRs became synchronous for three patients. The incidence of auditory recovery was 13% for patients operated on with a conservative approach (n=60).

Conclusion: A significant post-operative improvement in hearing could be a reasonable expectation in non-VS tumors extending into the CPA and a retrosigmoid approach should always be considered regardless of pre-operative hearing status.

Introduction

The most common cerebellopontine angle (CPA) tumor is vestibular schwannoma (VS) which represents approximately 6% of all intracranial [1] and 91% of CPA tumors [2]. Meningiomas are the second most common tumors of the CPA affecting 6% to 15% of patients [2]. Lower cranial nerve and trigeminal schwannomas are rare lesions and represent 0.7% and 1% of CPA tumors, respectively [3].

Regardless of the tumor histology, hearing loss is one of the most common symptoms of CPA tumors [4–7]. To date, when there is an indication for surgical treatment of these tumors, the choice of surgical approach is guided by the tumor size, growth, location and hearing level [7, 8]. Although preservation of facial nerve function is still the main goal of surgery, hearing preservation should be considered whenever possible [5, 6, 8, 9].

Apart from VS, where hearing preservation was obtained in 43% of patients in a large series [10] and significant hearing recovery is not an expectable result, hearing recovery could be a reasonable expectation in non-VS CPA tumors since the they arise outside the acoustic-facial bundle. Up to now, only a few case reports have been published on hearing recovery after surgical resection of non-VS CPA tumors [4, 7, 11–15].

In this study, we evaluated the hearing results in non-VS CPA tumors with particular regard to those patients who had significant hearing recovery, trying to analyze the incidence of such events and the possible surgical implications.

Materials and methods

This article follows the STROBE (STrengthening the Reporting of OBservational studies in Epidemiology) [16] guidelines for the reporting of observational studies.

Study population

This monocentric retrospective study, conducted in a tertiary referral center, included patients who experienced significant hearing recovery after non-VS CPA tumor removal through a retrosigmoid approach between 2012 and 2020. All patients gave their informed consent for the use of their clinical data. The study complied with Public Health code (CNIL #2211758).

The inclusion criterion was a post-operative hearing improvement of more than 30 dB in pure-tone audiometry (PTA) and/or a 50% gain in the speech discrimination score (SDS).

Exclusion criteria were neurofibromatosis type II (NF2) related tumors, meningiomatosis, pseudotumors of the CPA (arachnoid and epidermoid cysts), tumors of the central nervous system extending to the CPA (pilocytic astrocytoma, choroid plexus papilloma, ependymoma, ganglioglioma) and revision surgical procedures.

Pre-operative assessment

Before surgery, all patients underwent a clinical examination (facial nerve function was evaluated according to the House-Brackmann (HB) grading system [17]), hearing assessment and neuroradiological examinations (high-resolution computed tomography and magnetic resonance imaging [MRI]).

Audiometric tests

All patients were evaluated before surgery and post-operatively (at 1 month and at the last visit) by the same audiologist using similar testing equipment and procedures (pure-tone and monosyllabic speech audiometry). Audiometric data included PTA, calculated as the mean of the thresholds at frequencies of 0.5, 1, 2 and 3 kHz and SDS, calculated using a standardized presentation up to 40 dB sensation level or maximum comfortable loudness (whichever was lower). The differences between pre- and post-operative PTA and SDS were calculated (respectively ΔPTA and ΔSDS). Hearing function was graded according to the American Academy of Otolaryngology – Head and Neck Surgery (AAO-HNS) guidelines: **Class A**: PTA≤30 dB and SDS≥70%; **Class B**: PTA>30 dB and ≤50 dB and SDS≥50%; **Class C**: PTA>50 dB and SDS≥50%; **Class D**: PTA any level and SDS<50%) [18]. Hearing recovery was defined as described above corresponding to a change in the AAO-HNS hearing class from non-useful (Class D) to useful or normal hearing (Class A and B).

Pre-operative and post-operative auditory brainstem responses (ABR) using click were collected. Five waves (I-V) were recorded in the first 10 ms after broad-band and high-intensity stimuli. Three 90 dB acquisitions were made, followed by a decrease by 10 dB ranging up to the hearing threshold. ABR were classified as: Synchronous: reproducible ABR waves in three 90 dB stimulations and good visualization of wave V which decreased in intensity and increased in latency with decreasing stimulus intensity; Augmented inter-peak latency: good visualization of the ABR waves, but with a I-V inter-peak interval in the homolateral ear increasing by more than 0.5 ms compared to the contralateral ear; or Asynchronous: no visualization of a reproducible wave V, even at high-intensity stimulation. A detailed analysis of ABR curves has been carried out.

Tumor imaging

Pre-operative MRI allowed morphological characterization of the tumors for diagnostic orientation, measurement of their sizes and analysis of the acoustic-facial bundle position. The MRI protocol included at least a high-resolution 3D T2-weighted image (wi) to analyze the position of the acoustic-facial bundle and a 3D T1-wi after gadolinium chelate injection, allowing tumor characterization and measurements of tumor size in three axial directions (anterior-posterior, medio-lateral and superior-inferior). Brainstem displacement with or without mass effect in the fourth ventricle was collected. Meningiomas were classified according to the modified Desgeorges and Sterkers classification: Posterior petrous (P); Meatus and auditory canal invasion (M); Anterior petrous (A); Anterior petrous and meatus (AM); Posterior petrous and meatus (MP), and anterior and posterior petrous but also meatus (AMP) [19].

Surgery

We used two classifications usually used for VS. The quality of resection was classified following the Monfared classification as gross-total resection (no tumor remnant was visible at the end of surgery), near-total resection (the tumor remnant measured less than 5x5x2 mm over the brainstem and the facial nerve) or sub-total resection (the tumor was resected 80% to 90% by volume and 60% to 70% by surface area) [20]. The Jackler classification was used to describe the acoustic-facial bundle position with regard to the tumor: **Facial nerve course pattern I**: anterior-inferior shift of the VII-VIII bundle; **Facial nerve course pattern II**: anterior shift of the VII-VIII bundle; **Facial nerve course pattern III**: superior shift of the VII-VIII bundle; **Facial nerve course pattern IV:** posterior shift of the VII-VIII bundle [21, 22].

The anatomopathological results were listed, and the meningiomas were graded from I to III according to the World Health Organization (WHO) classification (2007 or 2016).

Post-operative assessment

Complications of surgery were assessed. Post-operative facial (HB) and lower cranial nerve functions were evaluated at the last follow-up. Audiometric tests and ABRs were performed at the last visit.

Statistical analysis

Results are presented as mean ± SD for continuous variables and as numbers and percentages for categorical variables. Statistical analysis was performed using Prism (GraphPad Software, San Diego, CA, USA). The pre-operative and post-operative audiological results were compared using two-way ANOVA and Mann–Whitney tests. Differences between groups were considered to be significant for $p \leq 0.05$.

Results

Patients

Among 99 patients operated on between December 2012 and January 2020 for non-VS CPA tumors, 69 were eligible for this study, from whom 60 were operated on with a retrosigmoid approach (**Fig. 1**). A significant post-operative hearing recovery was found in eight patients who were included in this study, representing 13.3% (8/60) of all non-VS CPA tumors operated on with a conservative approach. Patient characteristics for inclusion are detailed in the flow chart (**Fig. 1**).

Baseline characteristics

Baseline characteristics of the 8 patients with hearing recovery are described in Table 1. Their mean age was 58±9.9 years [40–72 years]. The right side was involved in half of the cases. One patient had pre-operative grade II HB facial nerve function. All patients had a significant degree of pre-operative hearing loss. For all patients but one, who had a sudden hearing loss which was unresolved after 5 days of corticosteroid therapy, the hearing loss was progressive, with an average evolution of 1 year. Patients were not premedicated with steroids or other drugs in the pre-operative period.

Tinnitus and balance disorder were present in one and four cases, respectively. Two patients were experiencing hemifacial hypoesthesia. Regarding lower cranial nerve function, one patient, affected by a lower cranial nerve schwannoma, had a X and XI palsy. One of the patients had morning headaches suggesting early intracranial hypertension.

Pre-operative assessment

Hearing

Complete audiological data were available for all eight patients (Table 1). The mean pre-operative PTA was 58±20.7 dB and SDS was 13±17.5%. All patients presented with class D hearing. ABR were asynchronous for all patients, but in 3 patients, we identified the isolated presence of wave I at 90 dB stimulation.

Imaging

In all cases, the pre-operative MRI allowed a correct diagnosis of tumor histology. The mean tumoral measurements in the three axial directions were 32±5.8 mm, 28±6.9 mm, and 31±5.0 mm for anterior-posterior, medio-lateral and superior-inferior diameters, respectively.

Six patients had a significant brainstem compression (**Fig. 2**), four with and two without fourth ventricle displacement/compression. No hydrocephalus was observed pre-operatively. Four patients showed internal auditory canal invasion.

Regarding the displacement of the acoustic-facial bundle, in two cases, an anterior course was observed, while it was anterior-superior in two cases, superior in two others and no nerve deviation and posterior-inferior switch in the two remaining patients.

Surgery

All patients were operated on with a retrosigmoid approach using a continuous facial nerve monitoring system (NIM3®, Medtronic, Minneapolis, MN, USA).

Intraoperative displacement of the acoustic-facial bundle by the tumor was as follows: two patients had facial nerve course pattern I, one had pattern II, and five had pattern III. Gross total resection was achieved in four cases, and sub-total resection in four (Table 1). MRI analysis of the VII-VIII bundle displacement matched the intraoperative observed displacement in five cases.

Regarding the histological analysis, the most common lesion was CPA meningioma (n=6), followed by lower cranial nerve schwannoma (n=2) (Table 1). Four of the six meningiomas were classified as grade I in the WHO classification, and the other two as grade II. The proportion of grade I and grade II in our series was comparable to the proportion in the entire cohort (52 grade I WHO and 8 grade II WHO).

Post-operative assessment

Hearing

The mean follow-up was 21±23.5 months [1–54 months]. At the last visit, ΔPTA was 36±22.2 dB, with a significant improvement at all frequencies ($p<0.0001$, two-way ANOVA, n=8, **Fig. 3A**), and ΔSDS was 85±16.9% ($p=0.0002$, Mann–Whitney test, n=8, **Fig. 3B**). There was no significant difference between the hearing results at 1 month and at the last visit, or the mean PTA (20±9.7 dB vs 18±10.6 dB, p=0.25, Mann–Whitney test), or the mean SDS (95±8.8% vs 92±18.9%, $p>0.999$, Mann–Whitney test). Table 1 shows the results for all patients at the last visit.

After surgery, all patients but one recovered from a pre-operative hearing class D to a post-operative class A; the last patient recovered to class B.

Concerning ABRs, three of the five available post-operative ABRs became synchronous, one became synchronous with increased interpeak interval I-V, and only one remained asynchronous.

Complications

Regarding early post-operative complications, one patient experienced a post-operative cerebrospinal fluid leak (7 days after surgery) which required revision surgery.

One patient had a well-tolerated post-operative paralysis of the X and XI nerves (Patient 5) and another had reversible grade II facial paralysis that required no further treatment (Patient 1). The patient presenting pre-operative grade II HB facial nerve function recovered to grade I (Patient 8). Lower cranial nerve functions were improved in Patient 7, with disappearance of the XIth nerve paralysis, improved laryngeal sensitivity, but persistence of ipsilateral vocal cord palsy.

Imaging

Post-operative imaging was available for seven patients. Three had a residual tumor, located in the jugular foramen in two and in the cavernous sinus in one patient (Table 1). All but one residual tumor were stable; the last one showed growth that was treated with Gamma-knife stereotactic radiosurgery.

Discussion

Analyzing our results, among the 69 patients operated on for a non-VS CPA tumor at our institute, we were surprised to note that the incidence of significant hearing recovery was 13.3% after tumor removal with a retrosigmoid approach. These patients experienced a recovery from non-useful hearing (class D) to useful hearing with intelligibility (class A or B), that probably represents a substantial improvement in their everyday quality of life. During the same period, in nine cases, we used a translabyrinthine approach for non-VS CPA tumor removal (**Fig. 1**), because of significant pre-operative hearing loss. It is likely that some of them would have experienced hearing recovery if we had used a retrosigmoid approach in those cases. Therefore, at present, the retrosigmoid approach is the preferred option when dealing with non-VS CPA tumors despite the hearing level and/or the tumor volume, and this has represented an important change in our daily practice.

In the literature, there are a few reports [4, 7, 11–15] on hearing recovery after CPA tumor removal (Table 3), most being case reports generally concerning meningiomas, arachnoid and epidermoid cysts. We decided not to include the cysts in our series because they were not “true” tumors with different biological and histopathological behaviors. Only one study reported a large series of CPA meningiomas [4] and found some degree of hearing improvement in 40 of 421 cases. Unfortunately, they used the Hannover Audiological Classification making comparison with the present study difficult.

Although preservation of hearing in surgical treatment of VS has been emphasized and discussed in the literature [10], little is known about auditory function in non-VS tumors of the CPA. However, extrapolating data on hearing preservation in VS surgery to the post-operative evolution of hearing for non-VS CPA tumors is probably a mistake. First, in VS, pathophysiological evidence indicates that hearing loss is explained by compression of either the cochlear nerve and/or the labyrinthine artery in the internal auditory canal (IAC) with a direct association between VS tumor size and hearing loss [23]. In the case of labyrinthine artery compression, vascular damage to the cochlea with no conceivable recovery could explain the hearing loss. The significant recovery of hearing obtained in this series suggests that the vascular etiology was not involved, similar to a report by Lanzino et al. [7] who described hearing recovery after marsupialization of a CPA arachnoid cyst in a patient who had recordable pre-operative otoacoustic emissions (OAEs) with an asynchronous ABR. The presence of OAEs pre-operatively may predict the integrity of vascular supply to the cochlea and correlation studies would be necessary to define their function in pre-operative care [24]. Similarly, the presence of wave I in the pre-operative ABR, which indicates the cochlear synapse function, could have the same significance and be a good prognostic factor for hearing recovery [25]. Indeed, we found the presence of wave I pre-operatively even in the case of asynchronous ABR, and it could be helpful to use OAEs as an additional tool to select cases with a greater chance of hearing recovery.

In addition, histological evidence of invasion of the cochlear nerve by VS was reported by Neely et al. [26]. In contrast, in non-VS CPA tumors, although the pathophysiology evidence is poor, hearing loss is probably due to cochlear nerve compression without invasion [14], which would not cause irreversible damage to the nerve and the cochlea, making hearing improvement possible. Indeed, we know that damage to the cochlear nerve cannot be repaired, but compression by a tumor may cause neurapraxia that, once the pressure is alleviated, allows return of axonal transmission and hearing recovery. Thus, the decompression of the cochlear nerve by the tumor removal could allow spectacular recovery of the SDS, as illustrated in our series.

Regarding other post-operative functional outcomes, a good post-operative facial nerve function was obtained in all patients, despite the presence of relatively large lesions, underlining the fact that, when dealing with large CPA lesions, the facial nerve is not at increased risk during a retrosigmoid approach compared to a translabyrinthine approach. Finally, the choice of the extent of resection in our series was mainly decided after considering lower cranial nerve function. In two cases, the lesion arose from these nerves and a gross-total resection might have led to lower cranial nerve injury.

Surgery is not the sole option for treating these lesions. Gamma-knife stereotactic radiosurgery has been employed in the treatment of meningiomas [27] and lower cranial nerve tumors [28]. Results on hearing preservation have been published [27] and a mention of hearing improvement has been reported in that series without any audiological data. Because of the volume of tumors in our cases, radiosurgery was not indicated as first-line treatment. In addition, chemotherapy with bevacizumab could be associated with an improvement in hearing in NF2-related VS, but this treatment is reserved for patients with NF2 and no indications are accepted for other kinds of CPA tumor. The mechanism of hearing recovery is thought to be a decrease in intraneural edema and vascular shrinkage of the tumor which would decrease the compression on the nerve and blood vessels [29].

There are some important limitations that could affect the generalizability of our findings. First, the retrospective nature of this study encompasses biases that are difficult to overcome. Also, we did not use intraoperative auditory monitoring in this study. Looking at our cases, pre-operative ABR were asynchronous in almost all patients making this kind of monitoring impossible. Monitoring with cochlear nerve action potentials (CNAP) would have provided interesting information about the variation of this potential during manipulation of the tumors with the possibility of individualizing some surgical steps/maneuvers important for hearing recovery [30]. Finally, we tried to highlight anatomic, audiological or radiological factors to compare the different groups presented in the flow chart (**Fig. 1**), but the heterogeneity of their presentation and the relatively small number of patients did not allow us to constitute a statistically significant control group.

Conclusion

We would like to alert readers to the potential for significant post-operative hearing recovery in non-VS CPA tumors and stress the importance of considering a conservative surgical approach, even in cases of severely impaired hearing and large tumors. Relying on tumor size and hearing status for choosing the translabyrinthine approach (as classically performed for VS) should not be adopted in non-VS CPA tumors. Larger multi-center studies examining this topic would help corroborate our results.

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Figure legends

Fig. 1 Flow chart of the study population

ΔPTA: difference between pre- and post-operative pure tone average; **ΔSDS:** difference between pre- and post-operative speech discrimination score.

Fig. 2 Axial and coronal views of MRI scans (cerebellopontine angle meningioma) from Patient 1

Pre-operative Fast imaging employing steady-state acquisition in axial **(A, upper left)** and coronal **(B, lower left)** images showing a stage IV tumor with brainstem compression; and post-operative axial **(C, upper right)** and coronal **(D, lower right)** images showing a total tumor resection with acoustic-facial bundle visualization.

Fig. 3 Evolution of hearing between the pre-operative period and the final post-operative visit

A: Pre- and post-operative mean of thresholds of the tonal audiogram at 500, 1000, 2000, and 3000 Hz, showing a significant improvement of thresholds (p=0.0152, p=0.0054, p=0.0002 and p=0.0017, respectively; two-way ANOVA with SIDAK's multiple comparison test).

B: Significant improvement of the pre- and post-operative speech discrimination score (p=0.0002, Mann–Whitney test).