Abstract

Objective. Vestibular schwannoma (VS) is a benign tumor of the lateral skull base. Different microscopic surgical techniques are described in literature: the retrosigmoid and translabyrinthine approaches are used to treat big tumors located in the cerebellopontine angle, and the middle cranial fossa approach is utilized for small tumors with good hearing preservation. The expanded transcanal transpromontorial (ExpTT) approach is a combined microscopic-endoscopic technique previously indicated for Koos stage I and II VS and now proposed for larger VS, up to 3 cm in diameter, with linear progression into the cerebellopontine angle and touching the brainstem.

Study Design. The study was a retrospective case series of patients who underwent ExpTT surgery for VS in our ear, nose, and throat department.

Setting. We reviewed the surgical videos and electrophysiological data recorded during the surgical operations.

Subjects and Methods. From January 2015 to January 2017, 20 patients affected by Koos stage II and III VS underwent surgery in our department with the ExpTT approach. This novel technique is described step by step, with a focus on the surgical procedure and anatomic landmarks; outcomes are detailed in terms of early and late complications. The mean follow-up was 15 months.

Results. The ExpTT approach permitted, in all patients, gross total resection of the tumor without any complication and with preservation of facial nerve function. All patients had a good postoperative recovery.

Conclusion. The ExpTT technique is a new approach that combines the advantages of a microscopic technique with the ones offered by the endoscope in removal of VS.

Keywords
endoscopic ear surgery, vestibular schwannoma, inner ear, skull base
The aim of this study was to describe the technique and to verify the feasibility in terms of results and complications. This is the first case series of patients with Koos stage II and III VS treated with the transcanal approach.

**Material and Methods**

**Subjects**

Table 1 details the clinical data of the patients. The mean age of our cohort was 53.35 years. The male:female ratio was 8:12, and the tumor was on the right:left side in a ratio of 14:6. The mean diameter of the tumor was 16.21 mm (range, 11-30 mm). Koos classification was used to evaluate the growth pattern of the tumor. Magnetic resonance imaging was used to stage the VS: 16 cases were defined as Koos stage II and 4 as Koos stage III (Figure 1). Preoperative computed tomography scan was performed to detect anatomic malformations or variations (ie, very high jugular bulb). Moreover, to be managed with a transcanal approach, the neuroma extension in the CPA should be in the axis of the IAC. The compression of the brainstem (Koos grade IV) was considered an exclusion criterion. Preoperative bone conduction and air conduction thresholds were evaluated, ranging from 5 to 65 dB HL and from 10 to 70 dB HL in 16 patients, respectively; 4 patients were completely deaf. The mean speech reception threshold was 45.9 dB. Five patients had tinnitus; 9 had vertigo and neurovegetative symptoms. Nineteen patients showed grade I (normal) preoperative facial nerve function according to the House-Brackmann grading system, and 1 had grade II. The procedure was explained to all 20 patients, including surgical technique, intra- and postoperative complications, compliance, morbidity, recovery, and discharge.

Written informed consent for the surgery, as provided by the University Hospital of Verona (MU 09301350), was obtained from all patients.

**Instrumentations**

A standard otologic microscope and a 15-cm-length, 4-mm-diameter, 0°-angled endoscope (Karl Storz, Tuttlingen, Germany) were employed. The endoscope and the microscope were connected to a 3-chip high-resolution camera system (Karl Storz). All operations were recorded and stored in a digital archive for documentation and further analyses. Intraoperative facial nerve monitoring (NIM Nerve Monitoring System; Medtronic, Minneapolis, Minnesota) was also used to detect facial nerve function during identification and removal of the neoplasms.

**Surgical Approach**

The patient lies in the supine position, with the head slightly rotated contralaterally. A Shambaugh intercartilaginous incision is performed between the helix and the tragus to enlarge the approach and uncover the bone of the external...
auditory canal. A circular incision of the external auditory canal is performed under endoscopic control, about 1.5 cm from the tympanic anulus, and the distal part of the skin is removed with the tympanic membrane.

Under microscopic view, the bone is drilled to create a wide atticotomy to expose and remove the incus and the malleus (Figure 2A). The tympanic tract of the facial nerve, the geniculate ganglion, and the cochleariform process are exposed. At the end of this step, the following landmarks are clearly detectable: the carotid artery anteriorly below the tympanic tube orifice (in the protympanic space), the jugular bulb inferiorly, and the third tract of the facial nerve posteriorly.

After the removal of the stapes, the vestibule and the spherical recess are visible in the saccular fossa. The oval window is enlarged with a microcurette, a burr, or a piezosurgery instrument. The promontorial bone is removed with a progressive exposure of the basal, medial, and apical turns of the cochlea, preserving the modiolar structure of the cochlea and the cochlear nerve (Figure 2B). The IAC is exposed by drilling the bone between the vestibule and the basal turn of the cochlea while maintaining the integrity of the middle and apical turns. The IAC is skeletonized as far as the porus by removing the bone circumferentially and exposing the dura of the IAC posteriorly and inferiorly. The dura along the IAC is then opened to reach the tumor, which is removed with a piecemeal technique via traditional microscissors (Figure 2C). The endoscope is used during this step as a complementary instrument, for its power of magnification and high definition, to identify landmarks and to safely dissect the facial nerve from the VS. The CPA portion of the tumor is visualized and removed after the approach at the fundus is enlarged with a burr and following the acoustic-facial bundle toward the entry zone (Figure 2D).

The view of the CPA is limited under microscopic view, as shown in Figure 3A. Consequently, complete removal of the tumor is performed and checked with the endoscope (Figure 3B and 3C); facial function is evaluated with the intraoperative monitoring system. Fat harvested from abdomen and covered by fibrin glue is used to close the defect in the inner and middle ear. The eustachian tube is closed with muscle fragments and bone dust. A blind sac closure of the residual skin of the external auditory canal concludes the surgery.

Results

Surgical Procedures

In all patients, the VSs were removed radically, and no intraoperative complications were reported. The mean length of surgery was 205 minutes (range, 145-248 minutes). The final histologic examination confirmed the diagnosis of VS in all the specimens. Two patients were admitted postoperatively in the intensive care unit for 24 hours as a safety measure, due to particular comorbidities and not to the surgical procedure. In 18 cases, the patients were immediately extubated at the end of the surgical procedure and monitored at the inpatient clinic. A postoperative computed tomography scan was performed 6 hours after surgery for all patients and showed no complications. No patient presented postoperative cerebrospinal fluid (CSF) leakage or infections. The mean hospital stay after the ExpTT approach was 5 days (range, 4-8 days). No patient required prolonged treatments or vestibular rehabilitation after the surgical intervention. The mean follow-up was 15 months (range, 3-28 months).

Functional Results

In all cases, ipsilateral deafness was present after surgery, since this procedure is not aimed for hearing preservation or rehabilitation. At discharge, 3 of 20 patients (15%) presented transitory facial palsy, grade II House-Brackmann, with complete recovery during the follow-up period; the remaining 17 (85%) showed normal facial nerve function.
At discharge, no subjects had spontaneous nystagmus or complained about other major vestibular or neurovegetative symptoms; imbalance was present among all subjects, regressing spontaneously after 2 to 3 weeks. Tinnitus was reported by 9 of 20 patients immediately after surgery but was present in only 1 of 20 cases at the last evaluation.

Discussion

The ExpTT approach was positively performed in patients with small VS, Koos stages I and II, with limited extension in the CPA. This study aimed to evaluate the feasibility of the ExpTT approach in removing larger-sized VS, Koos stages II and III, with CPA and brainstem involvement, up to 3 cm in diameter.
The best features of the microscopic and endoscopic techniques are combined to perform a minimally invasive approach with bimanual dissection, easy control of bleedings, as well as direct identification of anatomic landmarks. This combined technique permits direct access to the IAC and CPA without wide external incisions and extended bone removal, as required by the traditional approaches.7,9

For all subjects of this case series, this novel approach permitted a gross total resection of the tumor with no intraoperative complications, as checked and confirmed with postoperative computed tomography scan. These favorable results will further avoid postoperative radiologic examination, unless the patient shows signs or symptoms of complications.

In our previous experience, transitory facial nerve palsy, grade II House-Brackmann, was observed immediately after surgery in 3 of 10 patients (30%), with complete recovery during the follow-up period in all cases. The remaining 7 (70%) patients had normal facial nerve function immediately after surgery. These positive results were related to the early stage of VS, with a low involvement of surrounding neurovascular structures, which makes easier surgical dissection.2

For the present cohort of patients, we had promising outcomes regarding facial nerve function: 3 of 20 patients presented transitory facial nerve palsy, grade II House-Brackmann, with complete recovery during the follow-up period, while the remaining 17 patients had normal facial nerve function since discharge. In our opinion, this is one of the main advantages offered by the present technique, which allows direct control over the anatomic structures as well as precision in surgical excision—even in cases of large VS, up to 3 cm in diameter, with CPA extension and brainstem involvement.

Cochlear preservation is not feasible with this approach; therefore, concomitant ipsilateral cochlear implantation is not indicated.10 For this reason, the criterion to be eligible for a transtympanic expanded approach was preoperative poor hearing or intense dizziness.

In our series, patients complained about minor vestibular symptoms after surgery. None of the patients had spontaneous nystagmus at discharge; imbalance regressed spontaneously within 2 to 3 weeks after surgery and did not cause long-term disability. These results, in terms of vestibular symptoms, are in line with data reported in the literature. Saman et al11 stated that only a small number of patients suffered from disability or handicap after VS surgery. The slow growth of VS most likely allows central vestibular compensation; therefore, most patients do not complain about severe vestibular symptoms.11

In our previous article, 1 patient had temporary CSF leakage with otorhinoliquorrhea owing to abdominal fat graft resorption that required revision surgery.2 In this experience, no patient presented CSF leakage. In the literature, the mean percentages reported with the traditional approaches are as follows: 10.3% for the retrosigmoid approach, 5.3% for the middle cranial fossa approach, and 7.1% for the translabyrinthine approach.7,12 Other groups reported a CSF leakage rate <1% after translabyrinthine excision of VS.13

According to our preliminary results, after the exclusive endoscopic transtympanic transpromontorial technique and after the ExpTT approach, the rates of postoperative CSF leakage, even in larger VS, Koos stages II and III, are in line with the data reported in literature, given the small series of patients. In our opinion, the approach is associated with a lower risk of CSF leakage because the technique is minimally invasive, with limited bone removal and minimal extension into the CPA. The possibility to avoid postoperative intensive care unit recovery is an important advantage in terms of not only a reduction of complications but also economic saving. Only 2 patients required this measure as a precautionary approach; 18 of 20 patients after extubation were immediately transferred to the inpatient clinic. Mean recovery was 5 days after surgery, with a 30% reduction of time in comparison with the previous experience, despite the increased size of the tumors. The surgical duration of time was also reduced, moving from 250 to 205 minutes, on average.2 This positive trend suggests, in our opinion, a possible further reduction in term of surgical time and hospital stay.

The ExpTT approach, initially developed to remove small-sized VS, now seems useful to treat larger-sized tumors. Of course, further clinical experience is necessary to confirm the benefits of this expanded approach. The main risk is represented by uncontrollable bleeding—for example, from branches of the anteroinferior cerebellar artery; this complication is more frequent with larger and medial neoplasms. A shift to a retrosigmoid approach in such a situation is facilitated by the low intracranial pressure, because the CSF has already been drained by the translacral transpromontorial approach.

Excellent knowledge of endoscopic landmarks is necessary to recognize and dissect neurovascular structures in the safest manner; these skills can be acquired after a long training period of endoscopic surgical practice, first in middle ear surgery, to obtain adequate manual ability.14,16

Conclusion

The main advantage of this combined microscopic-endoscopic approach is represented by the bimanual dissection of the tumor during the microscopic steps with good control over the neurovascular structures, with the precise identification, direct visualization, and high magnification offered by the endoscope.

The described technique appears to be a safe and minimally invasive approach in removal of large VS (Koos stage II or III) extended in the IAC and CPA and touching the brainstem.

Author Contributions

Daniele Marchioni, surgeon, main intellectual content; Marco Carner, audiological evaluation and patient selection, manuscript writing; Davide Soloperto, audiological evaluation, patient selection, manuscript writing; Luca Bianconi, literature review and manuscript writing; Andrea Sacchetto, literature review and manuscript writing; Luca Sacchetto, surgeon, patient selection,
manuscript revision; **Barbara Masotto**, surgeon, patient selection, manuscript revision; **Livio Presutti**, surgeon, main intellectual content.

**Disclosures**

**Competing interests:** None.

**Sponsorships:** None.

**Funding source:** None.

**References**


