Eur Arch Otorhinolaryngol (2013) 270:1277–1284
DOI 10.1007/s00405-012-2112-6

OTOLOGY

Impact of video-endoscopy on the results of retrosigmoid-transmeatal microsurgery of vestibular schwannoma: prospective study

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Received: 4 March 2012 / Accepted: 5 July 2012 / Published online: 4 August 2012

Abstract Endoscopy-assisted microsurgery represents modern trend of treatment of the cerebellopontine angle (CPA) pathologies including vestibular schwannoma (VS). Endoscopes are used in adjunct to microscope to achieve better functional results with less morbidity. Angled optics, magnification and illumination enable superior view in the operative field. Consecutive 89 patients with untreated unilateral sporadic vestibular schwannoma undergoing tumor resection via a retrosigmoid approach during 2008–2010 were prospectively analysed. Endoscopy-assisted microsurgical (EA-MS) removal was performed in 39 cases (Grade 1: 2, Grade 2: 5, Grade 3: 9, Grade 4: 22, Grade 5: 1) and microsurgical (MS) removal was performed in 50 cases (Grade 1: 1, Grade 2: 3, Grade 3: 9, Grade 4: 34, Grade 5: 3). Minimally invasive approach with craniotomy $\leq$2.5 cm was employed for small tumors (Grade 1 and 2) in the EA-MS group. Endoscopic technique was used for monitoring of neuro-vascular anatomy in CPA, during dissection of the meatal portion of tumors, assessment of radicality and for identification of potential pathways for CSF leak formation. All cases in MS group were deemed as radically removed. In the EA-MS group, residual tumor tissue in the fundus of internal auditory canal not observable with microscope was identified with endoscope in four cases. Such cases were radicalized. Tumor recurrence was not observed during the follow-up in EA-MS group. There is a suspicious intrameatal tumor recurrence on the repeated MRI scan in one patient in the MS group. Neither mortality nor infection was observed. The most common complication was pseudomeningocele (EA-MS 20 cases; MS 23). It was managed with aspiration with or without tissue-gluing in all cases without the need for any surgical revision. Adjunctive use of endoscope in the EA-MS group identified potential

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pathways for CSF leak formation, which was not observable with the microscope in five patients. Improved cochlear nerve (EA-MS: 22, MS: 14; $p = 0.012$), brainstem auditory evoked potentials (EA-MS: 3 of 8, MS: 0 of 4) and hearing (EA-MS: 14 of 36, MS: 4 of 45; $p = 0.001$) preservation were observed in EA-MS group. Despite the trend for better useful hearing (Gardner–Robertson class 1 and 2) preservation (EA-MS: 8 of 26, MS: 1 of 16) there were no significant differences in the postoperative hearing handicap inventory in both groups. There were no differences in the postoperative tinnitus in both groups. Better facial nerve preservation (EA-MS: 39, MS: 44; $p = 0.027$) and excellent–very good (House-Brackmann 1 or 2) facial nerve function (EA-MS: 31, MS: 29; $p = 0.035$) were observed in EA-MS group. Postoperative compensation of vestibular lesion, symptoms typical for VS, patients assessed by dizziness handicap inventory, facial disability index were comparable in both studied groups. Adjunctive use of endoscope during the VS surgery due to its magnification and illumination enable superior view in the operative field. It is valuable for assessment of radicality of resection in the region of internal auditory meatus. Improved information about critical structures and tumor itself helps the surgeon to preserve facial nerve and in selected cases also hearing. These techniques can help to decrease incidence of postoperative complications.

Keywords Vestibular schwannoma · Acoustic neuroma · Endoscopy-assisted microsurgery · Retrosigmoid approach · Hearing preservation · Facial nerve

Introduction

Similar to other specialities, endoscopes represent established components of the contemporary neurotologic-neurosurgical armamentarium. Employment of endoscope either as a sole visualizing tool or as an adjunct to the microscope, is constantly expanding in the field of skull base surgery [1, 2]. Development of endoscopic surgery of vestibular schwannoma (VS) parallels application of endoscopes for other procedures in the cerebello-pontine angle (e.g. diagnostic cisternoscopy, vestibular neurectomy, microvascular decompression) [3–5]. Although fully endoscopic procedures have been reported, probably the most widespread technique is the endoscope assisted microsurgery (EA-MS) that combines the advantages of both operating microscope and endoscopy [1]. Vast majority of the published works represent case series proving the applicability and benefits of the endoscopic technique with potential for improvement of surgical results. Studies comparing results of microsurgery (MS) and endoscope assisted microsurgery are rare [6].

The aim of this study was to evaluate the effect of employment of endoscopic technique on the results of surgical treatment of VS via a retrosigmoid-transmeatal approach.

Patients and methods

A prospective study was performed that included all consecutive 89 patients with untreated unilateral sporadic VS indicated for surgical treatment via a retrosigmoid-transmeatal approach in the period from January 2008 to December 2010. All patients were operated at the Department of Otorhinolaryngology, Head and Neck Surgery, 1st Faculty of Medicine, Faculty Hospital Motol, Charles University, Prague, Czech Republic by the same team of two neurotologists (JB, MC) and a neurosurgeon (EZ). Design of the study was approved by the local ethical committee. Patients were given chance to choose between the microsurgical (MS) and endoscopy-assisted microsurgical (EA-MS) tumor removal. Participance in the study was confirmed with the explicit informed consent. EA-MS group consisted of 39 patients and MS group of 50 patients.

Details of the surgical technique were reported elsewhere [7, 8] thus only critical steps are reviewed here. All surgeries were performed in supine position with head fixation in the 3-point Mayfiled clamp. Facial nerve monitoring was used to identify and confirm the function of the facial nerve in all cases and continuous brainstem auditory evoked potentials (BAEP) for hearing; monitoring was employed when applicable (EA-MS: 8 cases, MS: 4: cases) (NeMo NeuroMonitor, Inomed Medizintechnik GmbH). Craniotomy has been performed exposing the edges of the transverse and sigmoid sinuses. Opened mastoid air cells were closed with bone wax. Minimally invasive approach with craniotomy ≤ 2.5 cm was employed for small tumors (≤ 20 mm extrameatal extension) in the EA-MS group. Dural incision has been done along the sinuses and lateral cerebello-medullary cistern was opened to allow egress of CSF. Before durotomy, controlled hypotension and assisted hyperventilation to obtain a $p\mathrm{CO}_2$ of about 25 mmHg and to lower the intracranial pressure to help spontaneous cerebellar retraction have been instituted. Bolus of corticoids at the same moment could be beneficial. Mannitol infusions and lumbar drainage were not needed. Thus, a minimal brain retraction was necessary. The intrameatal tumor portion was approached by removing the posterior wall of the internal auditory canal (IAC). Any dissection of the tumor from cranial nerves and vessels was performed after sufficient tumor debulking. Endoscopic technique (rod-lens Hopkins® II endoscopes 4 mm lens with 0°, 30° and 70° viewing angle and length 18 cm, Clearview, Image 1 HD three-chip camera, KARL STORZ GmbH & Co) with standard neurotological and neurosurgical instruments were used for monitoring neurovascular anatomy in cerebello-pontine angle (CPA), during dissection of the meatal portion of tumors, to assess radicality of resection and for identification of potential pathways for CSF leak formation. Multiple muscle pieces and fibrin glue have been used to plug the drilled IAC after tumor removal. Dura was closed with absorbable stitches. Pieces of muscle, fascia and fibrin glue have been used to augment duraplasty. Previously removed bone and collected bony pate have been used for reconstruction of the skull at the end of the procedure.

The data collected in each patient included the patient's age, sex, size of tumor, pre- and postoperative hearing level, pre- and postoperative facial nerve function, pre- and postoperative vestibular pathology and level of vestibular compensation postoperatively, intraoperative findings (e.g. facial and cochlear nerve structural and functional preservation, radicality of tumor resection, identification of the opened petrous bone air cells) and perioperative complications. Validated questionnaires (Hearing Handicap Inventory for Adults, HHI; Tinnitus Handicap Inventory, THI; Dizziness Handicap Inventory, DHI; Facial Disability Index for a Patient with Facial Neuromuscular Dysfunction, FDI) were employed for assessment pre- and postoperative symptoms.

Size of the tumor was based on preoperative magnetic resonance imaging (MRI). The diameter was measured on the axial scans in the plane parallel with the long axis of the IAC including both intra- and extrameatal portion of the tumor. Furthermore, international grading system was used to classify the tumor grade based on measurement of the extrameatal portion of tumors. Grade 1 was for small tumors extending $\leq$10 mm beyond the IAC. Grade 2 was for medium tumors extending 11–20 mm. Grade 3 was for moderately large tumors extending 21–30 mm. Grade 4 was for large tumors extending 31–40 mm. Grade 5 was for giant acoustic tumors extending $\geq$1 mm into the posterior fossa. Postoperative MRI scan to exclude tumor recurrence were undertaken at 3, 12 and 24 months postoperatively.

Facial nerve function was assessed using the House-Brackmann grading system at discharge and on the last follow-up control (12–41 months postoperatively) [9].

Hearing level was assessed according to the pure tone audiogram with measurement of pure tone average (PTA) and speech discrimination score (SDS). It was graded according the Gardner–Robertson's (GR) classification (Class 1 for PTA $\leq$ 30 dB and SDS $\geq$ 70 %; Class 2 for PTA 31–50 dB and SDS 50–69 %; Class 3 for PTA 51–90 dB and SDS 5–49 %; Class 4 for PTA $\geq$ 90 dB and SDS 1–4 %; Class 5 for no hearing) [10]. Classes 1 and 2 were accepted as useful hearing levels.

Vestibular examination consisted of clinical examination, electronystagmography, subjective visual vertical and posturography (Balancemaster, Neurocom Internacional, Inc.) [11]. Absence of spontaneous nystagmus, deviation of subjective visual vertical $\leq\pm2$ and absence of subjective perception of rotational vertigo were assessed as postoperatively compensated vestibular lesion.

The Chi square test, Fisher's exact test and Student's *t* test were used to compare the outcome in both the groups and a difference of $p < 0.05$ was accepted as significant.

Results

The mean age of the patients was 47 years in the EA-MS group and 45 years in the MS group (Table 1). Both groups had similar clinical presentation that included most frequently sensorineural hearing loss (EA-MS: 38, MS: 48), tinnitus (EA-MS: 27, MS: 46), instability (EA-MS: 23, MS: 35), vertigo (EA-MS: 10, MS: 6), facial hypesthesia or dysesthesia (EA-MS: 9, MS: 10), headache (EA-MS: 12, MS: 12), facial nerve palsy (EA-MS: 3, MS: 7), mental changes and visual loss as signs of intracranial hypertension (EA-MS: 1, MS: 2). Distribution and mean values of the preoperative HHI, THI, DHI and FDI were similar in both groups. Concerning the preoperative vestibular pathology distribution of unilateral peripheral vestibular loss (EA-MS: 19, MS: 17), combined vestibular loss (EA-MS: 18, MS: 25) and central vestibular loss (EA-MS: 2, MS: 8) were similar as well.

The mean tumor size was 26 mm in the EA-MS group and 28 mm in the MS group. Data on tumor grading are presented in Table 1. The mean follow up period for EA-MS group was 26 months (range 13–40 months) and for MS group 28 months (range 13–41 months).

The inspection with the endoscope provided clear and detailed view of the anatomical relations within the CPA and in the IAC, up to its fundus. There were no mechanical

Table 1 Patient and tumor characteristics in the group of endoscopy-assisted microsurgery (EA-MS) and microsurgery (MS) group

	EA-MS	MS
Age (years)	47 ± 12 (26–73)	45 ± 14 (20–71)
Male	21	30
Female	18	20
Tumor size (mm)	26 ± 12 (9–56)	28 ± 11 (11–58)
Tumor grade		
Grade 1	2	1
Grade 2	5	3
Grade 3	9	9
Grade 4	22	34
Grade 5	1	3
Total number	39	50

injuries during the introduction of the endoscope, its manipulation close to the neural and vascular structures or its removal.

Extent of tumor resection based on inspection with operating microscope was deemed as radical in all patients from the MS group. Employment of endoscopic technique during dissection of the intrameatal portion of tumors led to identification of tissue not observable with the operating microscope in the fundus of IAC in seven patients. Because such findings were suspicious for residual tumor they were radicalized. In four of these cases tumor tissue was confirmed histopathologically. In the remaining three cases either ganglionar tissue or structures of peripheral nerve were observed. In one patient such suspicious tumor tissue was tightly adherent to the cochlear nerve, and the attempt to dissect the nerve from the tumor capsule led to intense changes of the BAEP. In this case a deliberate near-total removal was performed with an attempt to preserve useful hearing. Repeated postoperative MRI scans in this case show stable linear enhancement in the fundus of IAC. Remaining 38 cases from the EA-MS are nonsuspicious of tumor reccurence on serial MRI studies. In one (2 %) patient from the MS groups nodular enhancement in the fundus of IAC suspicious for residual/recurrent tumor was observed on MRI scan 12 and 24 months postoperatively.

Structural preservation of the facial nerve was possible in all patients from EA-MS group and in 44 (88 %) of patients from MS group ($p = 0.027$). In all six cases with anatomically discontinuous facial nerve both proximal and distal stump of facial nerve were preserved and direct end-to-end anastomosis in the CPA/IAC with or without graft from the greater auricular nerve was performed (in five cases simultaneously with resection, in one case 12 days later) with successful reinervation and good function. Excellent–very good (House-Brackmann 1 or 2) postoperative facial nerve function was observed in 23 (59 %) in the EA-MS group and in 25 (50 %) in the MS group postoperatively. Such results were observed in 31 (80 %) in the EA-MS group and in 29 (58 %) in the MS group at last follow-up ($p = 0.035$) (Table 2). Better results of structural and functional facial nerve preservation in the EA-MS group were not correlated with better scores in the FDI. Significant differences in the distribution and mean values of postoperative FDI across both studied groups ($\text{mean}_{\text{postop physical}}\text{FDI}^{\text{EA-MS}} = 22.76$, $\text{mean}_{\text{postop social functioning and well being}}\text{FDI}^{\text{EA-MS}} = 19.87$; $\text{mean}_{\text{postop physical}}\text{FDI}^{\text{MS}} = 22.32$, $\text{mean}_{\text{postop social functioning and well being}}\text{FDI}^{\text{MS}} = 20.7$) were not observed.

We observed improved identification and preservation of the cochlear nerve in the EA-MS group (Table 3). At the end of tumor resection cochlear nerve was anatomically intact in 22 (56 %) patients from the EA-MS group and in the MS group in 14 (28 %) patients only ($p = 0.007$). Success rate of preservation of intraoperative BAEP was 38 % (3 out of 8 cases) in the EA-MS group. In the MS group none of the case had BAEP preserved. Any electrophysiological changes directly related to the application of the endoscope during the EA-MS procedures were not observed. Hearing preservation (Gardner–Robertson class 1–4) was achieved in 14 of 36 (39 %) hearing ears in the EA-MS group and in only 4 of 45 (9 %) hearing ears in the MS group ($p = 0.001$). Useful hearing preservation (Gardner–Robertson class 1 and 2) was observed in 8 of 26 (31 %) cases in the EA-MS group and in 1 of 16 (6 %) cases in the MS group. Inspection of the drilled IAC with angled endoscope identified inadvertent opening of the posterior semicircular canal in three and of vestibule in two cases not directly visible with the microscope when cochlear nerve integrity was preserved, but hearing deteriorated. Such openings were plugged but hearing preservation was achieved in only one of these patients. Data presenting rates of cochlear nerve, BAEP, hearing and useful hearing preservation rates as a function of tumor grades in both groups are presented in Table 4. Despite all the trends in favor of EA-MS group, there were no significant differences in the distribution and mean values of pre- and postoperative HHI across both groups

Table 2 Facial nerve outcome in the endoscopy-assisted microsurgery (EA-MS) and microsurgery (MS) group of patients

Anatomical preservation of facial nerve	EA-MS			MS		
	39 (100 %)			44 (88 %)		
	Preoperative	Postoperative	Last follow-up	Preoperative	Postoperative	Last follow-up
House-Brackmann classification						
HB I	36 (92 %)	18 (46 %)	27 (70 %)	43 (86 %)	20 (40 %)	28 (56 %)
HB II	3 (8 %)	5 (13 %)	4 (10 %)	6 (12 %)	5 (10 %)	1 (2 %)
HB III	0 (0 %)	8 (21 %)	8 (20 %)	1 (2 %)	3 (6 %)	20 (40 %)
HB IV	0 (0 %)	5 (13 %)	0 (0 %)	0 (0 %)	7 (14 %)	0 (0 %)
HB V	0 (0 %)	2 (5 %)	0 (0 %)	0 (0 %)	9 (18 %)	1 (2 %)
HB VI	0 (0 %)	1 (2 %)	0 (0 %)	0 (0 %)	6 (12 %)	0 (0 %)

Table 3 Results of cochlear nerve, brainstem auditory evoked potentials (BAEP) and hearing preservation (Gardner–Robertson's classification) in the endoscopy-assisted microsurgery (EA-MS) and microsurgery (MS) group of patients

	EA-MS		MS	
Anatomical preservation of cochlear nerve	22 (56 %)		14 (28 %)	
Reproducible BAEP	Preoperative 8	Postoperative 3	Preoperative 4	Postoperative 0
Gardner–Robertson's classification	Preoperative	Postoperative	Preoperative	Postoperative
Class 1	13 (33 %)	2 (5 %)	5 (10 %)	1 (2 %)
Class 2	13 (33 %)	6 (16 %)	11 (22 %)	0 (0 %)
Class 3	6 (16 %)	1 (3 %)	16 (32 %)	2 (4 %)
Class 4	4 (10 %)	5 (12 %)	13 (26 %)	1 (2 %)
Class 5	3 (8 %)	25 (64 %)	5 (10 %)	46 (92 %)

Table 4 Results of cochlear nerve, brainstem auditory evoked potentials (BAEP) and hearing preservation (Gardner–Robertson's classification) represented as a function of grading of vestibular schwannoma in the endoscopy-assisted microsurgery (EA-MS) and microsurgery (MS) group of patients

	EA-MS				MS			
	Cochlear nerve	BAEP	GR 1–4	GR 1–2	Cochlear nerve	BAEP	GR 1–4	GR 1–2
Tumor grade								
Grade 1	2 (100 %)	0 (0 %)	1 (50 %)	1 (100 %)	1 (100 %)	0 (0 %)	1 (100 %)	0 (0 %)
Grade 2	5 (100 %)	1 (100 %)	3 (60 %)	2 (40 %)	3 (100 %)	0 (0 %)	1 (50 %)	0 (0 %)
Grade 3	5 (56 %)	2 (40 %)	5 (56 %)	4 (80 %)	4 (44 %)	0 (0 %)	3 (33 %)	1 (33 %)
Grade 4	9 (41 %)	0 (0 %)	5 (26 %)	1 (7 %)	6 (18 %)	0 (0 %)	0 (0 %)	0 (0 %)
Grade 5	0 (0 %)	0 (0 %)	0 (0 %)	0 (0 %)	0 (0 %)	0 (0 %)	0 (0 %)	0 (0 %)

($\text{mean}_{\text{preop}}\text{HHI}^{\text{EA-MS}} = 18.15, \text{mean}_{\text{postop}}\text{HHI}^{\text{EA-MS}} = 30.10$; $\text{mean}_{\text{preop}}\text{HHI}^{\text{MS}} = 20.04$, $\text{mean}_{\text{postop}}\text{HHI}^{\text{MS}} = 31.76$).

There were no significant differences in the postoperative tinnitus in both groups. Tinnitus disappeared in 11 patients, occurred as a new symptom in two patients and stood unchanged in 13 patients in the EA-MS group. Patients from the MS group reported disappearance of tinnitus in 26 cases, new tinnitus in two cases and stable tinnitus in 22 cases. Reported distribution and mean values of postoperative THI across both groups were comparable ($\text{mean}_{\text{preop}}\text{THI}^{\text{EA-MS}} = 12.56, \text{mean}_{\text{postop}}\text{THI}^{\text{EA-MS}} = 12.61$; $\text{mean}_{\text{preop}}\text{THI}^{\text{MS}} = 17.24, \text{mean}_{\text{postop}}\text{THI}^{\text{MS}} = 12.96$).

Neither mortality nor infection occurred in both the groups. The most common complication was pseudomeningocele (lateral variant of CSF leak following VS surgery) (Table 5). It was observed in 20 of the cases in the EA-MS group and 23 in the MS group. Pseudomeningocele was accompanied by nasal liquorhea in three patients in the EA-MS group and ten patients in the MS group. These complications were managed with needle puncture, aspiration with or without injection of fibrin glue only without the need for any surgical revision or lumbar drainage. Opened air cells in the IAC, not directly visible with the microscope, have been found in five (13 %) patients. In all of these cases, opened air cells were meticulously plugged with pieces of muscle and fibrin glue. Medial variant of CSF leak was not observed in both the groups during the postoperative period.

Table 5 Complication rate following vestibular schwannoma resection in the endoscopy-assisted microsurgery (EA-MS) and microsurgery (MS) group of patients

Complication	EA-MS	MS
Pseudomeningocele	20 (51 %)	23 (46 %)
Nasal liqourhea	3 (8 %)	10 (20 %)
Headache	9 (23 %)	7 (14 %)
Uncompensated vestibular pathology	6 (15 %)	6 (12 %)
Transient lower cranial nerve dysfunction	1 (3 %)	5 (10 %)
Transient trigeminal dysfunction (dysesthesia)	0 (0 %)	2 (4 %)
Transient abducens nerve palsy	0 (0 %)	1 (2 %)
Wound haematoma	1 (3 %)	0 (0 %)
Pulmonary embolism	0 (0 %)	1 (2 %)

Uncompensated vestibular pathology was demonstrated in six patients from both the groups (Table 5). Significant differences in the distribution and mean values of pre- and postoperative DHI across both groups ($\text{mean}_{\text{preop}}\text{DHI}^{\text{EA-MS}} = 14.36$, $\text{mean}_{\text{postop}}\text{DHI}^{\text{EA-MS}} = 17.85$; $\text{mean}_{\text{preop}}\text{DHI}^{\text{MS}} = 13.64$, $\text{mean}_{\text{postop}}\text{DHI}^{\text{MS}} = 14.56$) were not observed.

Nine patients from the EA-MS and seven patients from the MS group complained about a persisting headache postoperatively. In all such cases, headache represent tension-type-like headaches. Two patients from the MS group presented with transient dysesthesia in the distribution of CN V/2 postoperatively that resolved completely in the early postoperative period. Transient dysfunction of lower cranial nerves occurred in one patient from the EA-MS group and five patients from the MS group. All but one case occurred in tumors of grade 4 and 5 and were related to the dissection of the nerves from tumor. Both symptoms and signs of the lower cranial nerve palsy resolved during the first postoperative year. Transient postoperative abducens nerve palsy occurred in one patient from the MS group. There was one case of wound haematoma in the EA-MS group managed by aspiration and compression. One patient from the MS group suffered from delayed pulmonary embolism, 3 weeks postoperatively. It was successfully managed with thrombolytic therapy (Table 5).

Discussion

Endoscopic techniques have revolutionized the practice of surgery in a number of specialities. Endoscopes have the ability to provide high magnification and illumination of the operative field, as well as the possibility to look around the corner past obstructing tissues and structures, thus allowing for more radical and safer surgeries. Several clinical applications, smaller incisions and surgical approaches are now possible, resulting in decreased postoperative pain, faster rehabilitation, better cosmetic results, and shorter hospitalization.

In the 1990s few teams supported the use of endoscopy during the microsurgery of VS [12–14]. Growing experience with endoscopic control and assistance for microsurgical management of other CPA pathologies led to a broader application of these techniques for tumor treatment in the last two decades [1, 3–5].

Endoscopes increase the light intensity while approaching an object, as such permit clear depiction of details in close-up positions and due to the angled optics extend the viewing angle without the need for retraction. Endoscopes thus represent an ideal adjunct to microsurgery of vestibular schwannomas via a retrosigmoid-transmeatal approach. CPA endoscopes are used to identify critical anatomical structures and their relations to the tumor. The early identification of the brainstem and neuro-vascular structures in case of large tumors may be important in order to plan the subsequent surgical steps. In case of small VS, the relationship between the tumor and facial and cochlear nerves within the IAC can be assessed. Results of this prospective study comparing results of MS and EA-MS of VS show significantly better results of structural and functional preservation of both facial nerve and cochlear nerve with employment of endoscopic technique. Although the results are not as optimistic as some of the previously published works [1, 3, 5] the results of this study must be understood in context of the size of treated tumors (e.g. 82 % of tumors in the EA-MS group were large tumors with extrameatal portion ≥ 21 mm). Success rates of preservation of excellent to very good facial nerve function in vast majority of treated patients, and even the chance for preservation of cochlear nerve and hearing under such conditions were still realistic in the EA-MS group.

Incomplete tumor resection, especially within the IAC, does occur after retrosigmoid-transmeatal approach [15]. The primary limitation in gaining exposure of lateral extent of the canal is the restriction imposed by the need to maintain integrity of the posterior semicircular canal. In such cases the endoscopic control allows for assessment of the completeness of tumor resection. Although in our study with employment of endoscope we found additional tissue suspicious of residual tumor in seven patients, tumor remnant was histopathologically confirmed in four (57 %) of such cases. Despite the results of endoscopic confirmation of radicality of VS resection are promising technique itself is not able to distinguish tumor from structures of vestibular ganglion or distal stump of vestibular nerves. Furthermore, attempts for radicalization in the fundus can lead to potential sequellae of hearing loss or even facial nerve injury. The only MRI documented tumor recurrence (the only VS recurrence per 305 treated patients over 15 year period with long term follow-up-unpublished data) in our study was in the patient from the MS group when all resections were deemed as radical. However follow-up is short in both studied groups to make clear conclusion.

Furthermore endoscopes have been found useful during opening of the IAC. Close up view of the drilled wall enables improved identification of the structures of the posterior semicircular canal and as such can help to maintain its integrity in the hearing preserving procedures. The endoscopic inspection after tumor removal allows for identification of the opened petrous bone air cells that have to be occluded in order to prevent CSF leaks. We did not encounter any case of medial CSF leakage in our study. On the other hand the most common complication in our series was the pseudomeningocele whose incidence is not dependent on the endoscopic technique. The high prevalence of this complication in our study is influenced by avoidance of lumbar drainage perioperatively. Our technique for its management is sole puncture, aspiration with eventual injection of fibrin glue. Such technique was effective in all of our cases.

Endoscopic approach for VS surgery has some potential disadvantages as well. The two-dimensional view obtained by the endoscope instead of the three-dimensional view of the microscope represents often cited disadvantage. Compared to the static imaging obtained by surgical microscope, endoscopes of varying diameter, length and angulation allow the surgeon to dynamically rotate and alter their perspective of the surgical field to compensate the two-dimensional view. This amounts to a greater appreciation of the three-dimensional relationships between the tumor and the surrounding structures [5].

Because angled endoscopes have a sharp front edge compared with a 0° endoscope, the surgeon cannot see the insertion trajectory directly. It is necessary to keep in mind that there could be a risk of damaging the neuro-vascular structures [16]. Cerebellum can be protected during the procedure by covering it with a blade of retractor, neurosurgical cotton, piece of Penrose drain or artificial dura. However, working with 30° endoscopes has been repeatedly shown safe [1, 3]. Risk of injury with insertion of 45° and 70° endoscopes is probably higher but this can best alleviated by microscopic control.

Another drawback is the risk of injury of critical structures as the endoscope does not see the instrument used before it passes in front of the lens. It is mandatory to achieve synchronized, in-and-out movements of the endoscope together with the instruments. The advantage of the EA-MS technique is that handling of instruments is controlled by the microscope before coming in front of the lens of the endoscope. Complications due to inadvertent injury have not been observed in our study. Potential heat injury from prolonged use of the endoscope close to the cranial nerves and other structures can be alleviated by irrigation of the operating field with the help of irrigation sheath attached to the endoscope. In agreement with others, negative effect on the intraoperative neuromonitoring has not been documented in our study [6]. Such technique was also crucial for clearing the blood and debris from the lens, eliminating the time consuming and unsafe practice of removing and reinserting the endoscope.

Conclusion

Based on the results of our prospective study, we prove that employment of endoscopic technique during retrosigmoid-transmeatal microsurgery of VS represents a safe technique. Endoscopes as an adjunct to the operative microscope improve visualization of neuro-vascular and bony structures and their relationship to the tumor. Improved information and better visual control are related to improvements in both structural and functional preservation of facial and cochlear nerve even in large tumors. Endoscopic exploration of the IAC and endoscopically controlled dissection of the intrameatal portion of VS is helpful to achieve radical tumor removal, preserve neurovascular structures and structures of the labyrinth while minimizing cerebellar retraction. Improved identification of the opened air cells potentially decreases the incidence of CSF leaks.

Acknowledgments This study was supported by the research project of Internal Grant Agency of the Ministry of Health of Czech Republic no. NS/9909-4. The authors are grateful to Ilja Merunka Bc. and Barbora Hajná Bc. for the help in preparation of the manuscript.

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