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Original research article

Surgery for sporadic vestibular schwannoma. Part II. Complications (not related to facial and auditory nerves)

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ARTICLE INFO

Article history:
Received 12 June 2015
Accepted 6 January 2016
Available online 15 January 2016

Keywords:
Vestibular schwannoma
Neurosurgery
Retrosigmoid approach
Postoperative complications
Cerebrospinal fluid leakage

ABSTRACT

Introduction: The aim of this study was to analyze the frequency and consequences of postoperative complications (PC) after surgery for sporadic vestibular schwannoma and to find factors that increase the risk of PC occurrence.

Materials and methods: The study included 220 consecutive patients (134 women, 86 men; age ranged from 18 to 74) operated on with the retrosigmoid (217) or translabyrinthine (3) approach. Complicated postoperative period was defined as an occurrence of at least one of: cerebrospinal fluid (CSF) leakage, hematoma in the tumor bed, intracerebellar hematoma, cerebellar swelling, brainstem stroke, hydrocephalus (HCP), healing problems, meningitis and cranial nerves (excluding VII–VIII) palsies or cerebellar symptoms. Correlation studies and multivariate regression analysis were performed.

Results: PC occurred in 55 patients (25%). PC included lower cranial nerve (LCN) palsy (8.2%), cerebellar symptoms (7.3%), CSF leakage (5.9%), HCP (5%), CNVI palsy (3.1%), meningitis (1.8%), cerebellar swelling (1.4%), CNV dysfunction (0.9%), intracerebellar hematoma (0.5%) and lethal brainstem stroke (0.5%). In long term follow-up, LCN deficit was present in 2 patients (0.9%), cerebellar syndrome in 4(1.8%) and facial hypoesthesia in 2(0.9%). One patient (0.5%) developed bilateral blindness, secondary to preoperative optic nerve atrophy. As a result of PC, 10 patients (4.5%) required 11 additional surgical procedures. In statistical analysis, PC were independently related to preoperative cerebellar syndrome ($p = 0.002$) and tumor size (>30 mm vs.<30 mm, $p < 0.05$). The risk of PC diminished significantly with the increased number of performed procedures from 40% at the beginning to 16.4% in the last 55 cases.

Conclusions: Tumor size, cerebellar syndrome at presentation and experience of the team were the three most important risk factors for PC occurrence. Permanent deficit secondary to PC remained in only 4% of the patients.

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http://dx.doi.org/10.1016/j.pjnns.2016.01.002
0028-3843/

1. Introduction

Patients with small vestibular schwannoma (VS) are less and less frequently operated on by neurosurgeons now. Increasingly often, they are treated by otolaryngology teams or with radiosurgery, or are observed and followed with serial MRI. Despite the improvement in the availability of diagnostic methods, neurosurgeons continue to operate large tumors. Probably in the future, this most challenging subgroup will continue to be referred for neurosurgical treatment. It can be assumed that if the global number of VS operated by neurosurgeons decreases then it will be harder to go further up the learning curve to a level that guarantees a further decrease in the risk of postoperative complications. In this context, a thorough analysis of postoperative complications takes on a new meaning. Currently, the literature rarely focuses on these issues and the main topic of interest is the preservation of auditory and facial nerves. Other neurological deficits, or life-threatening complications (frequent in the past but now extremely rare), indicate the level of difficulty of VS treating. Currently, it is not only a theoretical threat, because surgery for large and giant VS is always risky and gaining the experience in complex cranial base surgery becomes more difficult. In the United States, in recent years, the number of VS surgery has gradually decreased, while hospital stay and the rate of postoperative complications has increased [1]. The aim of this study is to analyze the frequency and consequences of various types of postoperative complications, as well as attempt to find factors that increase the risk of their occurrence.

2. Materials and methods

This retrospective analysis included 220 consecutive patients operated on for sporadic VS between 1990 and 2011. This group included 7 patients previously treated ineffectively, surgically or radiosurgically, in other centers. The group of patients is analyzed in detail in the paper: "*Surgery for sporadic vestibular schwannoma. Part I: General outcome and risk of tumor recurrence*". Complicated postoperative period was defined as an occurrence of at least one of the following events: cerebrospinal fluid (CSF) leakage, hematoma in the tumor bed, intracerebellar hematoma, cerebellar swelling, brainstem stroke, hydrocephalus (HCP), healing problems, meningitis, deep trigeminal nerve (CNV) injury, abducens nerve (CNVI) palsy, cerebellar syndrome or lower cranial nerve (LCN) palsy, lasting more than 7 days. Imbalance, swallowing problems and CNV paresthesia which disappeared within a few days after surgery were not considered as complications. Postoperative facial and auditory nerve function was analyzed in a separate study. Correlation studies and multivariate regression analysis were performed on factors that might influence the risk of postoperative complications. Factors taken into consideration included the age, gender, surgical sequence, preoperative symptoms (cerebellar syndrome, trigeminal symptoms, headache and hydrocephalus), preoperative hearing according to the AAO-HNS grading scale, symptom duration prior to VS treatment, tumor size (maximum extrameatal size, volume, tumor stage according to the Samii grading scale), side of the tumor (left/right), tumor structure (solid/cystic) and histological type (Antoni A, B and A + B), internal auditory canal (IAC) widening (+/−), patient position during the procedure (lateral "park-bench"/supine), approach (retrosigmoid approach (RSA)/translabyrinthine approach (TLA)), and technique of bony closure (craniectomy/craniotomy). To compare the results distributions, the chi-square test or Fisher's exact test was employed. The stepwise Wald logistic regression analysis was applied to evaluate the predictors of dependent variables. The lowest level of significance was set at $p < 0.05$.

3. Results

Postoperative complications occurred in 55 patients (25%). The most common types of postoperative complications included LCN palsy – 18 (8.2%), cerebellar symptoms – 16 (7.3%), CSF leakage – 13 (5.9%) and hydrocephalus – 11 (5%) (Table 1). Different types of complications often occurred in the same patients. For example, hematoma in the tumor bed was the cause of hydrocephalus and cerebellar syndrome in 6 patients.

3.1. *Treatment and follow-up of postoperative complications*

As a result of postoperative complications, 10 patients (4.5%) required 11 additional surgical procedures, including the removal of tumor bed hematoma with external ventricular drainage – 2 (0.9%), only external ventricular drainage – 2 (0.9%), surgery for CSF leakage – 6 (2.7%), ventriculoperitoneal shunt placement – 1 (0.5%).

3.2. *Lower cranial nerve weakness*

Eighteen patients (8.2%) were discharged home with LCN paralysis but they were able to swallow and nourish

Table 1 – Types and rates of postoperative complications.

Type of complication	Number	%
Lower cranial nerves palsy (>7 days)	18	8.2
Cerebellar syndrome (>7 days)	16	7.3
CSF leakage	13	5.9
Hydrocephalus	11	5
- Normal pressure	1	
- Acute	10	
Secondary to:		
- Hematoma in the tumor bed	6	
- Brain stem stroke	1	
- Cerebellar swelling	2	
- Air in the tumor bed	1	
CNVI palsy	7	3.2
Hematoma in the tumor bed	6	2.7
Meningitis	4	1.8
- Meningitis secondary to CSF leakage	3	
Cerebellar swelling	3	1.4
Deep CNV injury	2	0.9
Intracerebellar hematoma	1	0.5
Brain stem stroke (lethal)	1	0.5
Supratentorial subdural hygroma	1	0.5
Blindness (secondary to preoperative optic nerve atrophy)	1	0.5
Wound suppuration	0	0

themselves. These patients were referred to ambulatory phoniatric rehabilitation. Lower cranial nerve paralysis remained only in 2 patients (0.9%) in long-term follow-up. These patients had stage T3 and T4 tumors and no LCN weakness before surgery.

3.3. *Cerebellar syndrome*

Sixteen patients (7.3%) were discharged home with cerebellar syndrome and with a recommendation for further rehabilitation. Ataxia persisted in 4 patients (1.8%) in long-term follow-up. Two of them had already less severe cerebellar symptoms prior to surgery. All 4 patients had stage T4 tumors.

3.4. *CSF leak*

Rhinorrhea was observed in 13 patients (5.9%). It disappeared after acetazolamide administration in one patient. Twelve patients needed external lumbar drainage (ELD) placement. Routinely, it was maintained for 5 days. CSF drainage alone was effective in 7 patients (58%) and the remaining 5 patients required surgical repair. In 2 of these 5 patients, CSF leak was a distant complication. It occurred 4 and 9 months after tumor removal. One patient required revision surgery for recurrent leakage. CSF leak was complicated by meningitis in 3 patients.

3.5. *Hydrocephalus*

Surgery was complicated by obstructive HCP in 10 cases (5%). This was a direct consequence of a tumor bed hematoma in 6 patients, intracerebellar edema in 2, brainstem stroke in 1, and tumor bed air collection in 1. Six patients have been successfully treated with mannitol alone. Temporary external ventricular drainage (EVD) was needed in 4 patients. In all patients, acute hydrocephalus resolved after a few days, without the need for additional surgical procedures (permanent shunt placement). One patient developed chronic normal-pressure hydrocephalus 1 month after surgery complicated by meningitis (post-inflammatory hydrocephalus). Ventriculoperitoneal shunt implantation brought complete symptoms relief.

3.6. *Abducens nerve palsy*

In all 7 patients (3.2%), the palsy withdrew spontaneously within 6 months after surgery.

3.7. *Hematoma in the tumor bed*

This type of complication occurred in 6 patients (2.7%). In all 6 patients, it was the cause of supratentorial ventricular system enlargement. The tumor bed hematoma manifested with consciousness deterioration during postoperative day 0 in 2 patients, in the first postoperative day in 1 patient, in the second postoperative day in 2 patients, and in the fourth postoperative day in 1 patient. Mannitol administration was sufficient in 4 patients. Urgent hematoma removal and EVD placement was necessary in 2 patients. The level of consciousness normalized in all of the patients. However, the cerebellar symptoms were present until discharge in all patients and disappeared in late follow-up.

3.8. *Cerebellar swelling and intracerebellar hematoma*

Cerebellar edema occurred in 3 patients (1.4%) and intracerebellar hematoma in 1 (0.5%) patient. All 3 patients had stage T4 tumors. Cerebellar swelling induced obstructive HCP in 2 cases. Decreased levels of consciousness appeared in all patients with cerebellar swelling, in postoperative day 0 in 1 patient, in first postoperative day in 1 patient and in the second postoperative day in 1 patient. The patient with intracerebellar hematoma presented with cerebellar symptoms alone, without consciousness deterioration. Mannitol administration was sufficient in 3 cases and EVD placement was necessary in one. None of the patients required revision surgery. Cerebellar syndrome was present at discharge in 3 cases, although subsided in follow-up.

3.9. *Meningitis*

Meningitis was noted in 4 patients (1.8%), however, in 3 patients, it was related to CSF leakage. Two of them had ELD for CSF leak. Meningitis was diagnosed in postoperative day 13, 16, 23 and 25. The infection was successfully treated with antibiotics in all cases.

3.10. *CNV dysfunction*

Ipsilateral face hypoesthesia increased significantly after surgery in 2 patients and persisted in follow-up. These patients had giant tumors (size: 60 mm and 56 mm, stage T4B). The CNV continuity was preserved during surgery in both cases.

3.11. *Brainstem stroke*

Brainstem stroke after large VS removal (grade T4B) was the most severe complication in the analyzed series. The course of the surgery in this patient was uneventful. The tumor created a distinct niche in the brain stem, nevertheless there were no significant adhesions to the arachnoid membrane. A cardiac arrest and respiratory failure suddenly occurred 2 h after the end of the procedure. CT imaging was performed immediately after successful resuscitation and it revealed obstructive HCP without intracranial bleeding. EVD was placed. However, the patient's condition did not improve and she died 3 days after surgery. An autopsy demonstrated an ischemic brainstem stroke with secondary hemorrhage, interpreted as a consequence of urgent decompression effect on the brain stem after the large tumor removal. It was the only lethal complication of 220 patients in the group, creating a mortality rate of 0.5%.

3.12. *Subdural hygroma*

Supratentorial subdural hygroma occurred in 1 patient. It was asymptomatic and did not require any treatment.

3.13. *Vision loss*

One patient developed bilateral blindness a few weeks after surgery. The patient was operated on for huge VS

Table 2 – Pre- and intraoperative risk factors for postoperative complications.

Factor		Postoperative complications		Chi-square or Fisher's exact test
		/−/	/+/	
Gender	F	103 (77%)	31 (23%)	p-NS
	M	62 (72%)	24 (28%)	
Age	≤50 y.o.	99 (79%)	26 (21%)	p-NS
	>50 y.o.	66 (69%)	29 (31%)	
Surgery sequence	1–106	75 (68%)	35 (32%)	$p < 0.05$
	107–112	90 (82%)	20 (18%)	
Cerebellar symptoms	/−/	131 (80%)	32 (20%)	$p = 0.01$
	/+/	34 (60%)	23 (40%)	
CNV symptoms	/−/	122 (79%)	33 (21%)	p-NS
	/+/	43 (66%)	22 (34%)	
Headache	/−/	147 (77%)	43 (23%)	$p = 0.04$
	/+/	18 (60%)	12 (40%)	
Hydrocepalus	/−/	160 (76%)	50 (24%)	p-NS
	/+/	5 (50%)	5 (50%)	
Hearing	Class A–C	39 (76%)	12 (24%)	p-NS
AAO-HNS	Class D	126 (75%)	43 (25%)	
Previous VS treatment	/−/	159 (75%)	54 (25%)	p-NS
	/+/	6 (86%)	1 (14%)	
Symptom duration	≤24 months	92 (79%)	24 (21%)	p-NS
	>24 months	73 (60%)	31 (30%)	
Tumor stage acc.	T2–T3	52 (83%)	11 (17%)	p-NS
Samii scale	T4	113 (72%)	44 (28%)	
Maximal diameter	<30 mm	99 (82%)	22 (18%)	$p < 0.05$
	>30 mm	66 (67%)	33 (33%)	
Tumor volume	<10 cm3	93 (82%)	21 (18%)	$p < 0.05$
	>0 cm3	72 (68%)	34 (32%)	
Tumor structure	Solid	138 (75%)	47 (25%)	p-NS
	Cystic	27 (77%)	8 (23%)	
Side of the tumor	Right	80 (74%)	28 (26%)	p-NS
	Left	85 (76%)	27 (24%)	
Widening of IAC	/−/	19 (76%)	6 (24%)	p-NS
	/+/	146 (75%)	49 (25%)	
Histopathology pattern (Antoni)	A	49 (73%)	18 (27%)	p-NS
	B	19 (66%)	10 (34%)	
	A + B	97 (78%)	27 (22%)	
Patient positioning	Lateral park bench	63 (67%)	31 (33%)	$p = 0.03$
	Supine	102 (81%)	24 (19%)	
Bony closure	Craniectomy	17 (57%)	13 (43%)	$p = 0.02$
	Craniotomy	148 (78%)	42 (22%)	

Abbreviations: CNV – trigeminal nerve, AAO-HNS – the American Academy of Otolaryngology-Head and Neck Surgery, IAC – internal auditory canal, T – tumor stage according to Samii grading scale.

(stage T4B, size: 50 mm) with HCP. A year before the operation, the patient complained of blurred vision, and pre-operative ophthalmological examination showed significant peripheral field of view limitation and optic disc edema. In the early postoperative period, the visual acuity and field of vision worsened in both eyes (VOD = 0.8–0.9; VOS = 0.1–0.2) and also the left optic disc became pale. Postoperative CT imaging did not reveal HCP. A few weeks after discharge, binocular blindness occurred and an eye examination showed secondary bilateral optic nerve atrophy. Of the remaining 5 patients presenting with papilledema at admission, none experienced further vision deterioration after surgery, including one patient with postsurgery visual acuity improvement.

In summary, permanent neurological complications were observed in 9 patients (4%), including: death in 1 and persisted neurological deficits in 8.

3.14. *Risk factors for postoperative complications*

A comparative study and multivariate regression analysis of factors that might influence the postoperative complications occurrence are shown in Tables 2–4. There were no significant

Table 3 – Distribution of postoperative complications according to surgery sequence.

Surgery sequence	Postoperative complications		Pearson Chi-square test
	/−/	/+/	
Patients 1–55	33 (60.0%)	22 (40.0%)	$p < 0.05$
Patients 56–110	42 (76.4%)	13 (23.6%)	
Patients 111–166	44 (80.0%)	11 (20.0%	
Patients 167–220	46 (83.6%)	9 (16.4%)	

Table 4 – Multivariate regression analysis for postoperative complications.

Factor	p	Exp (β)	95% confidence interval for Exp (β)
Cerebellar symptoms	0.02	0.448	0.226–0.888
Tumor volume	0.01	1.03	1.007–1.050
Constant	0.01	0.372	

Variables that did not enter the model: headache, CNV symptoms, hydrocephalus, maximal extrameatal tumor size, patient position during surgery, surgery sequence and bony closure pattern. *Abbreviation*: Exp (β) – exponentiated regression coefficient.

differences in complications incidence depending on the age, sex or symptomatic period length. Postoperative complications occurred significantly more frequently in patients presented with headache (40% vs. 23%, $p = 0.04$) and cerebellar symptoms (40% vs. 20%, $p = 0.01$, Table 2). Other preoperative symptoms were not significantly associated with complications rate.

The postoperative complications rate was 33% for tumors >30 mm. For smaller tumors, the PC rate was 18% ($p < 0.05$). The mean tumor size in the PC group was 33 mm, whereas in patients with uneventful postoperative course – 29 mm ($p = 0.01$, independent samples T-test). Similarly, if the tumor volume was greater than 10 cm^3, the risk of complications was 32% and 18% for smaller tumors ($p < 0.05$, Table 2). The average tumor volume was 21 cm^3 in the PC group and 13 cm^3 in the uneventful group ($p = 0.01$, independent samples T-test).

A history of prior treatment such as radiosurgery or non-radical operations in other centers did not significantly affect the PC risk after surgery at our institution. Although it should be noted that this group was limited to 7 patients (Table 2).

Statistically significant differences in complications rates were revealed depending on the operation methods, i.e., patient positioning and bony closure pattern (Table 2). The complications rate was 33% for operations performed in the lateral "park bench" position and 19% for those operated on in the supine position with the head rotated ($p = 0.03$). Comparison between craniectomy and craniotomy showed a higher PC risk in the former one (43% vs. 22%, $p = 0.02$). An analysis of the operation sequence showed that among the first 55 patients the PC rate was 40% and among the last 55 patients – 16% ($p = 0.02$, Table 3).

3.15. *Multivariate regression analysis*

A larger tumor volume ($p = 0.01$) and cerebellar symptoms at presentation ($p = 0.02$) were found to be independent risk factors for postoperative complications (Table 4).

3.16. *Factors that may influence the risk of liquorrhea*

CSF leakage is qualitatively a different kind of complication as compared to neurological deficit and their causes. For this reason, CSF leak underwent additional separate analysis to identify factors that might be associated with its occurrence. Patients with VS removed via the translabyrinthine approach were excluded from this analysis. In this limited subgroup, CSF leakage appeared in one (33%) of three patients. The study group included 216 patients (the patient who died was also excluded), of which 12 had CSF leakage. The analysis showed no statistically significant differences for any of the examined factors (Table 5). However, it is worth mentioning that the highest liquorrhea rate (10%) was noted in the group of the first 30 patients.

Table 5 – CSF leak distribution according to potential risk factors.

Factor		Rate of CSF leakage		Fisher's exact test
		/–/	/+/	
Gender	F	122 (94%)	8 (6%)	p-NS
	M	82 (95%)	4 (5%)	
Age	≤50 y.o.	119 (97%)	4 (3%)	p-NS
	>50 y.o.	85 (91%)	8 (9%)	
Surgery sequence	1–54	49 (91%)	5 (9%)	p-NS
	55–108	53 (98%)	1 (2%)	
	109–162	51 (94%)	3 (6%)	
	163–216	51 (94%)	3 (6%)	
Previous VS treatment	/–/	198 (94%)	12 (6%)	p-NS
	/+/	6 (100%)	0 (0%)	
Widening of IAC	/–/	23 (92%)	2 (8%)	p-NS
	/+/	181 (95%)	10 (5%)	
Tumor grade	T2–T3	57 (92%)	5 (8%)	p-NS
	T4	147 (95%)	7 (5%)	
Tumor size	≤3 cm	110 (93%)	8 (7%)	p-NS
	>3 cm	94 (96%)	4 (4%)	
Bony closure	Craniectomy	27 (90%)	3 (10%)	p-NS
	Craniotomy	177 (95%)	9 (5%)	
Mastoid air cells protection	Wax	40 (91%)	4 (9%)	p-NS
	Wax + bone chips + fibrin glue	164 (95%)	8 (5%)	

Abbreviations: CSF – cerebrospinal fluid, VS – vestibular schwannoma, T – tumor stage according to Samii grading scale, IAC – internal auditory canal.

4. Discussion

Postoperative complications occurred in every fourth patient, but persistent neurological consequences remained in only 4% of them. The most common complications were: LCN palsy, cerebellar ataxia, CSF leakage and HCP. Additional surgical procedures due to complications were required by 4.5% of patients. Postoperative complications occurred significantly more often in patients presented with headache ($p = 0.04$) or cerebellar syndrome ($p = 0.01$). It can be assumed that headache is a collinear factor with tumor volume, which was found to be the strongest risk factor for complications occurrence ($p = 0.01$). However, preoperative cerebellar symptoms showed independent influence on complications risk as well ($p = 0.02$). While the significance of tumor size and volume are evident for the risk of surgery, the interpretation of cerebellar ataxia impact is not simple. Preoperative cerebellar dysfunction might be derived from local edema or microcirculation disturbances in the surrounding structures, which may not be directly related to tumor size. The same mechanism may be responsible for increased vulnerability of these structures to intraoperative manipulation. The cerebellar syndrome was also an important factor for unfavorable postoperative course after large VS removal in the series of Blok et al. [2].

The risk of complications in our study does not differ from the results published to date. Recently, Nonaka et al. showed that, in late follow-up, imbalance persists in 6.3%, facial numbness in 2.2%, and paralysis of the lower cranial nerves in 0.5% [3]. In a smaller series (110 patients) presented by Yu et al., hemiparalysis (0.9%) and tetraparesis (3.6%) were also observed [4]. In the Samii series, the risks of tetra-, hemiparesis and LCN paralysis were as follows: 0.1%; 1.0% and 5.5%. The risk factors for complications were tumor size, coexisting significant general and/or neurological co-morbidities and cystic tumor structure. In addition, postoperative LCN paralysis was a risk factor for aspiration and pneumonia [5].

The complications rate in our series was higher in lateral park bench position ($p = 0.03$) and when the bone flap was not restored ($p = 0.02$). Since 1998, the bone flap is routinely restored, and, since 2005, all of the patients were operated on in the supine position. Therefore, it appears that these accidental statistical findings should be interpreted as collinear with the sequence of operation. The incidence of complications was 40% in the first quarter of the analyzed series, and only 16% in the last quarter ($p = 0.02$). In the latter group, permanent neurological deficit occurred in only one patient (2%). This reflects the importance of the growing experience of the team treating vestibular schwannomas, and, most of all, the importance of a neurosurgeon's learning curve. Although the decline in PC incidence with the acquisition of experience was evident in percentage differences, the operation sequence did not show an independent influence in the regression analysis.

In the analyzed series, the average tumor size decreased over 20 years from 32 mm to 28 mm, which makes a difference of only 4 mm. On the other hand, in recent decades, the detectability of small and less symptomatic VS has significantly improved. The combination of these two facts leads to the conclusion that patients with large tumors are still referred for neurosurgical treatment, whereas patients with small tumors are qualified for observation, radiosurgery, or operated on by otolaryngology teams. In a group of 99 tumors with a diameter >30 mm treated at our department, the complications rate was 39% (13/33) among the first 33 patients treated, 45% (15/33) in the second third and only 9% (5/33) in the last third ($p = 0.01$). This indicates a long learning curve in this most challenging subgroup of VS. A possible solution to this problem may be greater treatment centralization of this pathology in specialized centers [6,7].

It should be pointed out that postoperative complications include a non-homogenous group of events. On the one hand, it is difficult to look for universal risk factors for different complications such as cerebellar swelling and CSF leak. On the other hand, the various types of complications occurred so rarely that it is not easy to analyze them separately to find the statistically significant risk factors. However, the common denominator of most complications was cerebellar syndrome or lower cranial nerve palsy due to hematoma, swelling or manipulation. Therefore, it was decided to collect patients with complicated postoperative course into one group, despite an awareness of the limitations of such a study. The result of this analysis is the conclusion that the risk of complications is dependent on the size of the tumor and the presence of cerebellar signs before surgery. An additional important discovery is that the complications rate significantly decreases after about 50 operations performed by one neurosurgeon.

The incidence of post-operative CSF leak after RSA ranges from 6% to 10.6% in meta-analysis [8,9]. In our series, the rate of this complication was 5.7%. We did not find any statistically significant factors for the risk of postoperative liquorrhea. It should be noted, however, that the highest incidence (10%) of leakage was among the first 30 patients treated, while, among the last 30 patients, there was no case of CSF leak. Reducing the risk of liquorrhea can be linked with the evolution of the surgical technique and greater experience of the neurosurgeon. Currently, at the end of the procedure, the IAC is secured with a piece of muscle and tissue glue. Additionally, the opened mastoid air cells are protected first with wax and then with bone chips and tissue glue. Restoring the bone flap may play a role as well, as it supports the stitches on dural incision. On the other hand, the analyzed material indicates that CSF usually leaks through IAC (80%), and only occasionally through mastoid air cells (20%). Therefore, meticulous IAC plasty is crucial in the prevention of CSF leak. Lüdemann et al. indicate that the IAC and mastoid air cells sealing using free fat graft may be more effective than a piece of muscle (CSF leak 2.2% vs. 5.7%) [10]. Surgeons, who use endoscopic control of the IAC bottom, emphasize that it helps to reveal and protect the open air cells which are hidden from the view of a microscope [11].

In most studies, the translabyrinthine approach is associated with a higher risk of CSF leak than RSA. A CSF leak occurred in 1 (33%) of 3 patients operated on with TLA in our series. In the meta-analysis by Sughrue et al. this rate was 27% [9].

Other factors mentioned in the literature that increase the risk of liquorrhea are: a second operation via RSA [12] and male gender [10], whereas tumor size seems to have no effect [13,14]. The different methods, from less to more invasive, are applied to stop the CSF leak. When the treatment with acetazolamide is ineffective, temporary lumbar CSF drainage or a series of lumbar puncture with CSF depletion is applied. Eventually surgical repair of the fistula is needed in some patients. Kalamarides et al. found that low CSF pressure in lumbar puncture predicts the ineffectiveness of conservative treatment in patients with CSF leakage [15]. Allen et al. showed that lumbar drainage is effective in 90% of patients after TLA and only in 50% after RSA [16]. In our series, lumbar drainage was effective in 58% after RSA.

CSF leakage is connected with the risk of further complications, i.e., meningitis. In the analyzed series, three (75%) of the four patients with meningitis had CSF leak. From the reverse perspective, meningitis occurred in 3 (23%) of 13 patients with CSF leak, including two (17%) of 12 treated with external lumbar drainage. A literature review by Selesnick et al. showed a strong association between CSF leak after VS surgery and meningitis [13]. Continuous CSF drainage over a period of several days also exposes the patient to infectious complications, despite routine prophylactic antibiotic use. The risk is estimated to be about 4% [17].

The overall risk of meningitis in our study was 1.8%. In other published series, the incidence of this complication is estimated at 1.2–9.9% [3–5,18,19]. Postoperative wound infection did not occur in the presented series, however, the risk may reach 1–4% [3,5,19].

Serious, potentially life-threatening complications such as tumor bed or intracerebellar hematoma, cerebellar swelling and brainstem stroke occurred very rarely in our series. During dissection a lot of attention was paid to protection of emissary veins including the superior petrosal vein. Brainstem stroke was the only lethal complication. In the literature published in the last decade, hemorrhagic complications are reported in 0.6–5.5% of the patients, cerebellar swelling in 0.28% and brainstem stroke in 0.14–0.9% [4,18,20].

One patient developed blindness after surgery, nevertheless significant peripheral field of view limitation and optic disc edema had already been reported before the operation. Investigation of the patient's particular course indicates that this was a consequence of delayed diagnosis and treatment rather than a complication of surgery. On the other hand, the event cannot be ignored in the complications analysis. In the past, papilledema was observed almost in all and blurred vision even in 1/3 of the patients [21]. Currently, the optic nerve atrophy secondary to chronic intracranial hypertension is a casuistic consequence of CPA tumor. This case serves as a reminder of the rationality of ophthalmological examination in patients with large tumors, enlarged ventricular system and with headaches. In case of papilledema, surgery cannot be postponed, and the patient should be warned of the visual sequel risk.

5. Conclusions

The overall risk of postoperative complications was 25%, however the risk declined from 40% to 16% with increasing experience of the neurosurgical team. The most common complication types were lower cranial nerve palsy (8.2%), cerebellar symptoms (7.3%), CSF leak (5.9%) and hydrocephalus (5%). A few patients required additional surgical procedures (4.5%) and experienced permanent neurological sequelae (4%) as their consequence. The most important risk factors for complications occurrence were tumor size and pre-existing cerebellar symptoms.

The removal of a tumor directly adjacent to the brain stem, cerebellum and cranial nerves is and will always be associated with risk. Although currently, the risk of death and severe disability are minimal, the risk of postoperative complications must be presented to the patient before surgery.

Conflict of interest

None declared.

Acknowledgement and financial support

All authors report no any actual or potential conflict of interest including any financial, personal or other relationships with other people or organizations within 3 years of beginning the submitted work that could inappropriately influence, or be perceived to influence, their work.

Ethics

The work described in this article has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans; Uniform Requirements for manuscripts submitted to Biomedical journals.

REFERENCES

[1] Patel S, Nuño M, Mukherjee D, Nosova K, Lad SP, Boakye M, et al. Trends in surgical use and associated patient outcomes in the treatment of acoustic neuroma. World Neurosurg 2013;80:142–7.
[2] Blok T, Nowak S, Smól S. Czynniki ryzyka leczenia operacyjnego dużych guzów okolicy kąta mostowo-móżdżkowego. Neuroskop 2005;7:129–34.
[3] Nonaka Y, Fukushima T, Watanabe K, Friedman AH, Sampson JH, Mcelveen Jr JT, et al. Contemporary surgical management of vestibular schwannomas: analysis of complications and lessons learned over the past decade. Neurosurgery 2013;72(2 Suppl. operative):103–15.
[4] Yu LM, Yang SM, Han DY, Huang DL, Yang WY. Management of operative complications in acoustic neuroma surgery. Zhonghua Er Bi Yan Hou Tou Jing Wai Ke Za Zhi 2006;41:26–30.
[5] Samii M, Matthies C. Management of 1000 vestibular schwannomas (acoustic neuromas): surgical management and results with an emphasis on complications and how to avoid them. Neurosurgery 1997;40:11–23.
[6] Ward BK, Gourin CG. Francis HW vestibular schwannoma surgical volume and short-term outcomes in Maryland. Arch Otolaryngol Head Neck Surg 2012;138:577–83.
[7] Hastan D, Vandenbroucke JP, van der Mey AG. A meta-analysis of surgical treatment for vestibular schwannoma:

is hospital volume related to preservation of facial function. Otol Neurotol 2009;30:975–80.
[8] Thakur JD, Banerjee AD, Khan IS, Sonig A, Shorter CD, Gardner GL, et al. An update on unilateral sporadic small vestibular schwannoma. Neurosurg Focus 2012;33:E1.
[9] Sughrue ME, Yang I, Aranda D, Rutkowski MJ, Fang S, Cheung SW, et al. Beyond audiofacial morbidity after vestibular schwannoma surgery. J Neurosurg 2011;114:367–74.
[10] Lüdemann WO, Stieglitz LH, Gerganov V, Samii A, Samii M. Fat implant is superior to muscle implant in vestibular schwannoma surgery for the prevention of cerebrospinal fluid fistulae. Neurosurgery 2008;63:38–42.
[11] Wackym PA, King WA, Poe DS, Meyer GA, Ojemann RG, Barker FG, et al. Adjunctive use of endoscopy during acoustic neuroma surgery. Laryngoscope 1999;109:1193–201.
[12] Stieglitz LH, Wrede KH, Gharabaghi A, Gerganov VM, Samii A, Samii M, et al. Factors affecting postoperative cerebrospinal fluid leaks after retrosigmoidal craniotomy for vestibular schwannomas. J Neurosurg 2009;111:874–83.
[13] Selesnick SH, Liu JC, Jen A, Newman J. The incidence of cerebrospinal fluid leak after vestibular schwannoma surgery. Otol Neurotol 2004;25:387–93.
[14] Bani A, Gilsbach JM. Incidence of cerebrospinal fluid leak after microsurgical removal of vestibular schwannomas. Acta Neurochir (Wien) 2002;144:979–82.
[15] Kalamarides M, Grayeli AB, Bouccara D, Redondo A, Rey A, Sterkers O. Opening cerebrospinal fluid pressure guides the management of cerebrospinal fluid leakage after acoustic neuroma surgery. Otol Neurotol 2004;25:769–72.
[16] Allen KP, Isaacson B, Purcell P, Kutz Jr JW, Roland PS. Lumbar subarachnoid drainage in cerebrospinal fluid leaks after lateral skull base surgery. Otol Neurotol 2011;32:1522–4.
[17] Coplin WM, Avellino AM, Kim DK, Winn HR, Grady MS. Bacterial meningitis associated with lumbar drains: a retrospective cohort study. J Neurol Neurosurg Psychiatry 1999;67:468–73.
[18] Enée V, Guérin J, Bébéar JP, Darrouzet V. Acoustic neuroma surgery. Results and complications in 348 cases. Rev Laryngol Otol Rhinol (Bord) 2003;124:45–52.
[19] Lee SH, Willcox TO, Buchheit WA. Current results of the surgical management of acoustic neuroma. Skull Base 2002;12:189–95.
[20] Sanna M, Taibah A, Russo A, Falcioni M, Agarwal M. Perioperative complications in acoustic neuroma (vestibular schwannoma) surgery. Otol Neurotol 2004;25:379–86.
[21] Mazurowski W, Kuś J, Wisławski J. Clinical symptoms of tumors of cerebellopontine angle. Neurol Neurochir Pol 1969;3:619–25.