Symptom-Based Opioid-Free Treatment for Persistent Postoperative Headache After Vestibular Schwannoma Resection via the Retrosigmoid Approach

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(Citation)
World Neurosurgery,162:e347-e357

(Issue Date)
2022-06-01

(Resource Type)
journal article

(Version)
Accepted Manuscript

(URL)
https://hdl.handle.net/20.500.14094/0100477293

Symptom-based opioid-free treatment for persistent postoperative headache after vestibular schwannoma resection via the retrosigmoid approach

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Keywords: headache; postoperative headache; retrosigmoid approach; vestibular schwannoma

Short title: Treatment for postoperative headache

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Abstract

Objective: Postoperative headache (POH) is a disturbing complaint following vestibular schwannoma (VS) resection. However, there are currently no treatment guidelines. The aim of this study was to evaluate the usefulness of symptom-based opioid-free treatments for persistent POH following VS resection.

Methods: Of 137 patients whose sporadic VS was resected via the retrosigmoid approach, 74 had persistent POH beyond 3 postoperative months. Their symptoms were classified as tension-type headache (TTH), migraine, neuralgia, or other and were treated. We retrospectively analyzed the treatment outcomes during 2 postoperative years.

Results: Patients with persistent POH were significantly younger ($P = 0.003$) and had significantly smaller tumors ($P = 0.001$) and a greater extent of resection ($P = 0.04$) than those without POH. The most common simple symptom was TTH in 56 patients, followed by migraine in 6 and neuralgia in 5. All 7 patients with complex symptoms had a mixture of TTH and migraine. The complete disappearance of POH was achieved in 40 patients (54%) and a medication-free condition in 51 (69%). No patients had residual severe POH that could not be controlled with medication. Achievement of a medication-free outcome that included complete disappearance of the persistent POH was significantly more common in patients with preserved facial nerve function ($P = 0.008$) and those with simple symptoms ($P < 0.001$).

Conclusion: The symptom-based approach is appropriate for understanding and managing persistent POH after VS resection with excellent pain control. Preserved facial nerve function

and simple symptoms are significant prognostic factors for a medication-free outcome.

INTRODUCTION

Vestibular schwannoma (VS) is a representative benign skull-base tumor in the cerebellopontine angle. Postoperative headache (POH) is one of a number of complaints following VS resection[1] that can decrease quality of life (QOL).[2–8] Some patients chronically experience intractable POH beyond 3 postoperative months and are diagnosed with "persistent POH" according to the diagnostic criteria of the International Classification of Headache Disorders 3rd edition (ICHD-3).[9] The incidence of POH is affected by numerous surgical procedural factors.[1,5–7,10–22] The retrosigmoid approach is a workhorse for neurosurgeons resecting the VS,[23–25] and an overview of the literature suggests an average POH incidence of 44% (1–93%) after VS resection via this approach.[1,7]

Management of POH generally involves simple analgesia with, for example, acetaminophen and nonsteroidal anti-inflammatory drugs (NSAIDs).[6,8,12,18,26,27] Opioids are prescribed in some cases depending on pain intensity, but their casual use can lead to addiction.[6] Many studies have focused on preventing POH as part of the surgical technique, but few have focused on treating POH.[5,7] Therefore, no guidelines are currently available for POH treatment.

Patients report various symptoms connected to POH.[8,13,27] As the POH persists, each patient's symptoms, such as primary headache-like symptoms, become apparent. In our clinical practice, we preferentially treat persistent POH using a symptom-based approach that focuses on both the intensity and nature of the pain, hypothesizing that this approach would maintain excellent pain control and effectively screen for POH and clarify treatment options for it. This study aimed to clarify the symptom-based opioid-free treatment outcome for persistent POH after VS resection via the retrosigmoid approach and to identify the prognostic factors contributing to this outcome.

METHODS

Study design

The institutional review board approved this study, waiving the need for informed consent due to its retrospective nature (protocol number B210110). The study was conducted according to institutional and national ethical guidelines and in accordance with the Helsinki Declaration.

Between January 2011 and December 2019, 172 consecutive patients with VS were surgically treated via the retrosigmoid approach at our institution by a senior skull-base neurosurgeon (EK). Of these patients, 137 were selected using the following criteria: newly diagnosed sporadic VS without neoadjuvant stereotactic radiosurgery (SRS), postoperative follow-up period ≥ 2 years in which the patients received our treatment protocol for POH, and age ≥ 20 years. The remaining 35 patients (11, neurofibromatosis type 2; 7, recurrence; 5, SRS before surgery; 9, deviation from treatment protocol within 2 postoperative years; and 3, age < 20 years).

Of the 137 patients, 74 were diagnosed with persistent POH at 3 postoperative months, and we retrospectively analyzed the symptom-based opioid-free treatment outcome over 2 years for these patients (Figure 1).

To clarify the prognostic factors contributing to treatment outcome, we analyzed not only the nature of the headache, but also the following demographic and tumor characteristics: age, sex, history of preoperative headache, tumor laterality, preoperative tumor size (max CPA[28] and Koos grading[29]), preoperative magnetic resonance imaging (MRI) findings, extent of resection (EOR), surgical time, nerve origin of tumor, postoperative hearing status and facial nerve function (House-Brackmann [H-B] grading[30]), postoperative hydrocephalus requiring ventriculoperitoneal shunt (VPS), and postoperative SRS.

Treatment and evaluation of persistent POH

As the first step in treatment, we classified the persistent POH symptoms into four categories that mimic the ICHD-3 diagnostic criteria of primary headache: tension-type headache (TTH), migraine, neuralgia, and other.[9] We then provided tailor-made opioid-free treatment for each symptom. We also treated patients with complex symptoms with a combined therapy for each of their symptoms. For TTH, one or more antispasmodic drugs (afloqualone [60 mg/day], tizanidine [3–9 mg/day], eperisone [150 mg/day], shakuyakukanzoto [7.5 g/day]) were orally administered as first-line drugs. If these were inadequate, etizolam (1–3 mg/day) and/or amitriptyline (10–60 mg/day) were added. Anti-inflammatory analgesic plaster and exercise therapy (yoga) were used in combination with the above oral medications for muscle relaxation. For migraine, triptans were administered as first-line drugs to relieve the attack. Lomerizine hydrochloride (5–20 mg/day) was added for poorly controlled migraine. Sodium valproate was used for migraine with aura such as scintillating scotoma. For neuralgia, local anesthetic blocks were given at the trigger points. Furthermore, vitamin B12 was administered by intravenous drip infusion (500 μg/day) and/or oral administration (1500 μg/day) was continued. If these were inadequate, amitriptyline (10–60 mg/day) was added. For all categories, acetaminophen (300–1000 mg) and/or NSAIDs (loxoprofen sodium hydrate [60 mg], diclofenac sodium [25–50 mg], ibuprofen [200 mg]) were used as a rescue drug when needed. No patients used opioids. Table 1 briefly summarizes the symptom categories and treatments.

Persistent POH intensity was evaluated using four levels and five scores (Table 2): none (score I: no pain, no medication); mild (score II: occasional pain, not requiring medication); moderate (score IIIa: occasional pain adequately controlled with medication; score IIIb: daily pain adequately controlled with regular medication); and severe (score IV: intolerable pain reducing

QOL, not adequately controlled even with medication). As outcome measures, persistent POH intensity was evaluated at diagnosis (at 3 postoperative months) and at 1 and 2 postoperative years by a headache specialist (YY) and neurosurgeons (EK, YU, and YF) based on patient-oriented reports. A favorable outcome was defined as score I or II, indicating a medication-free condition that included POH disappearance.

Surgical technique: retrosigmoid approach for VS resection

(1) Craniectomy (Fig. 2A–C): The patient was placed in the park bench position. A linear-shaped postauricular incision was made to adequately expose the suboccipital region (total length, 10 cm). Craniectomy was performed with several burr holes, exposing the edge of the sigmoid and transverse sinuses. The foramen magnum was not decompressed. Craniectomy size (4 × 4 cm) was always the same, regardless of tumor size.

(2) Tumor resection: The tumor was microsurgically removed via the retrosigmoid approach, using facial nerve monitoring with or without auditory brainstem responses. Drilling of the internal auditory canal was done whenever necessary based on the surgical goals, followed by careful aspiration of intradural bone dust and irrigation of the cistern.

(3) Cranioplasty (Fig. 2D–F): Primary water-tight closure of the dura was performed. Cranioplasty was cosmetically performed with bone dust collected at the time of the craniectomy and fibrin glue. Muscles and skin were finally sutured layer by layer. No drainage tube was placed.

Statistical analysis

The Mann–Whitney U test and Fisher's exact test were used to compare patient characteristics

based on the presence of persistent POH and the prognostic factors by treatment outcome. Patient characteristics based on persistent POH symptoms were compared using the Kruskal-Wallis test with the Steel-Dwass post hoc test and the Fisher's exact test with the Bonferroni post hoc test. All statistical analyses were performed with EZR (Saitama Medical Center, Jichi Medical University, Saitama, Japan), which is a graphical user interface for R software (http://www.r-project.org/).[31] A two-sided P-value < 0.05 was considered statistically significant.

RESULTS

Patient characteristics

Of 137 patients who underwent successful resection of sporadic VS, 74 (54%; 32 men, 42 women; median age, 44 [range, 23–70] years) had persistent POH beyond 3 postoperative months. Two patients (3%) had a history of preoperative headache (both migraine). Median preoperative tumor size (max CPA) was 21.5 (range, 0–48) mm. Sixty-one tumors (82%) were in contact with the brain stem (Koos grade ≥ 3). Cystic changes on preoperative MRI were evident in 16 tumors (22%) and fundal fluid cap was present in 42 (57%). Total resection (EOR, 100%) was achieved in 69 patients (93%), subtotal resection (EOR, 90%–99%) in 4 (5%), and partial resection (EOR, < 90%) in 1 (1%). Nerve origins of the tumors were identified in 65 patients (88%; 27 from a superior vestibular nerve, 38 from an inferior vestibular nerve). Postoperatively, 57 patients (77%) lost their effective hearing. Sixty-four patients (86%) had successfully preserved facial nerve function (H-B grade I–II). Only one patient had severe facial paralysis (H-B grade V); this patient underwent facial nerve reconstruction using the sural nerve 1 year later. No patients needed VPS for hydrocephalus or SRS. Patient characteristics did not differ significantly between those with and without persistent POH, except that patients with

persistent POH were significantly younger (P = 0.003) and had a significantly smaller tumor (P = 0.001) and greater EOR (P = 0.04) (Table 3).

Persistent POH symptoms

Figure 3A shows the distribution of symptoms. Sixty-seven patients (91%) had simple symptoms and 7 (9%) had complex symptoms. None showed progression of simple symptoms to complex symptoms beyond 3 postoperative months. TTH was the most common simple symptom, in 56 patients (76%), followed by migraine in 6 (8%) and neuralgia in 5 (7%), with no cases of switching to other symptoms. All 7 patients with complex symptoms had a mixture of TTH and migraine. There was no significant difference in the baseline characteristics based on symptoms, except that patients with migraine had a significantly higher rate of a history of preoperative headache than those with other symptoms (Table, Supplementary material).

Symptom-based treatment outcomes

Intensity at diagnosis was score II in 26 patients (35%), IIIa in 31 (42%), IIIb in 15 (20%), and IV in 2 (3%). Forty-three patients (58%) showed score improvement in year 1, with persistent POH disappearing in 28 (39%). However, in 4 patients (5%), POH worsened. Six patients (8%) still had severe persistent POH (score IV) at 1 year. Over the next year, 26 patients (35%) showed score improvement, with persistent POH disappearing in another 12 patients (16%). No patients' POH worsened beyond 1 year. Finally, after 2 years, persistent POH had disappeared in 40 of the 74 patients (54%).

A medication-free condition that included POH disappearance (score I or II) was achieved in 51 patients (69%). No patients had severe persistent POH (score IV). Although the remaining 23

patients (31%) still required medication for persistent POH, it was adequately controlled (score IIIa or IIIb). Figure 3B shows the treatment outcomes.

Prognostic factors contributing to treatment outcomes

Achievement of a favorable outcome (score ≤ II) was significantly more frequent in patients with preserved facial nerve function (H-B grade I-II) ($P = 0.008$) and with simple symptoms ($P < 0.001$). No patients with complex symptoms improved to a medication-free condition. There was no significant difference in the other factors by treatment outcome (Table 4).

DISCUSSION

Along with the decades-long evolution of the microsurgical technique and intraoperative nerve monitoring, the surgical treatment outcomes for VS have improved remarkably.[32–35] However, postoperative care of POH after VS resection has been overlooked, with no established treatment guidelines available. In this study, we clarified the clinical usefulness of symptom-based opioid-free treatments for persistent POH after VS resection via the retrosigmoid approach. Our treatments were able to improve persistent POH to, at least, an adequately controlled condition within 2 years of surgery. Furthermore, we identified the complexity of the POH symptoms and preservation of facial nerve function as significant factors contributing to treatment outcome.

Incidence of POH

The reported incidence varies considerably and depends on the definition, evaluation method, and follow-up duration of the POH.[5,7] Not every study identified a similar trend. In general, the retrosigmoid approach, a sigmoid-shape incision, and craniectomy had higher rates of

POH.[5,10,15,16,19,21,22] In our series, we preferentially used the retrosigmoid approach with a linear-shaped incision and craniectomy followed by cosmetic cranioplasty for VS resection (Fig. 2) and had a 54% incidence rate of POH beyond 3 postoperative months. Although this rate is relatively high, this is probably because of our careful interviewing and rigorous diagnostic process using the ICHD-3.[9] Incidence at 3 postoperative months decreased to 35% when limited to POH requiring medication (score ≥ IIIa) and dropped further to just 1% when limited to POH that was uncontrollable even with medication (score IV) and affected QOL. These results indicate that, compared with previous reports, our surgical procedures in the retrosigmoid approach for VS are satisfactory for preventing intractable POH.

As reported previously,[6,7,11,15,18,20] we found that smaller tumor size and younger age were significantly associated with the development of persistent POH. Although the mechanism underlying this result remains unclear, differences in sensitivity to pain in younger patients who underwent resection of smaller VS might play a role. Furthermore, we found that greater EOR was significantly associated with the development of persistent POH. This result would likely be associated with a significantly higher achievement rate of total resection in smaller VS. Nevertheless, our results indicated that POH should be kept in mind after smaller VS resection in younger patients.

POH symptoms, symptom-based treatment outcomes, and prognostic factors

Despite the various symptoms comprising POH, their management nonetheless involved only simple painkillers, depending on symptom intensity.[6,8,12,18,26,27] Schankin et al. reported a tension-type-like POH as the most prevalent symptom.[8] Ducic et al. identified neuralgia caused by occipital nerve injury.[13] Gantenbein et al. reported migraine-like headaches after VS resection.[27]

These are the few similar studies that have attempted to describe and categorize the nature of the POH to improve treatments. To effectively screen the various POH symptoms and simplify the subsequent treatment options, we classified the symptoms into primary headache-like categories (Table 1). We treated each in the same way as in the approach to primary headache. Therefore, our treatment regimen is unremarkable in that sense (Table 1). During the 2-year postoperative course, the complete disappearance of POH was achieved in 54% of patients and a medication-free condition in 69%. Although 31% treated with our regimen had moderate POH that could be adequately controlled with medication, none of our patients had residual severe POH that could not be controlled with medication, indicating excellent pain control. We could relieve even the most severe headaches without opioids.

In our series, complex symptoms comprised a mixture of TTH and migraine in all cases and were a significant contributor to the medication-needed condition at 2 postoperative years. Among the complex symptoms, migraine took longer to be adequately controlled. This indicates that managing migraine symptoms as soon as possible might shorten the duration of intractable POH, improving QOL. A humanized monoclonal antibody targeting calcitonin gene-related peptide might be a suitable option[36] and its effectiveness should be studied.

Deterioration of postoperative facial nerve function (H-B grade ≥ III) was also a significant factor contributing to the medication-needed condition. All 10 patients without preserved facial nerve function had TTH symptoms, 4 of whom did not benefit from our treatments and their intensity scores remained unchanged for 2 years. Asymmetry due to facial paralysis might affect body balance, inducing muscle stiffness and muscle spasm around the head and neck. Furthermore, facial paralysis might be associated with depressive mood disorder,[37] and depression was associated with POH.[18]

The exact mechanisms underpinning each POH symptom remain unclear. Our classification and treatment approach for POH was based on the following speculations: that TTH is derived from muscle injury and/or muscle spasm, that migraine is derived from the trigeminal nerve endings distributed in the dura and intracranial blood vessels, and that neuralgia is derived from occipital nerve injury and/or adhesion. These speculations are very similar to those in previous reports.[1,8,10,12,13,27,38–40] Although we could not elucidate the cause of the POH symptoms, we successfully demonstrated that POH is treatable by classifying and managing it as a primary headache-like condition.

Limitations

Our study has several limitations. First, it was conducted at a single institution with a small sample. However, our series was the largest among reports on POH symptoms to date. Second, the effect of natural healing cannot be excluded. Larger, prospective studies are needed to clarify this effect. To investigate the true prevalence and treatment outcomes of POH, a globally accepted method for assessing POH is desirable. In this regard, our proposed symptom-based approach can help in clinical practice. Third, this study could not qualitatively evaluate patients' mental status and QOL in detail. Lastly, medications selected depended on the clinician's experience and judgment. Strict criteria need to be determined for the use of each medication in consideration of future prospective studies.

CONCLUSIONS

This study provides new evidence indicating that the symptom-based opioid-free treatment of POH classified into primary headache-like categories is appropriate and provides excellent pain

255 control for persistent POH after VS resection via the retrosigmoid approach. POH with simple
256 symptoms and preserved facial nerve function are significant prognostic factors for a medication-
257 free outcome. The symptom-based approach could help quick and easy understanding and
258 effective management of persistent POH after VS resection.
259
260 **Funding:** This work was supported in part by Grants-in-Aid for Scientific Research from the
261 Japanese Ministry of Education, Culture, Sports, Science and Technology (grant numbers
262 19K09507 to Yoichi Uozumi and 20K09369 to Takashi Sasayama). The sponsor had no role in
263 the study design; in the collection, analysis, or interpretation of data; in the writing of the report;
264 or in the decision to submit the article for publication.
265
266 **Declarations of interest:** None.

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386 **Figure legends**

387 **Figure 1.** Flow chart showing the patient selection process.

388

389 **Figure 2.** Intraoperative images showing craniectomy and cranioplasty via the retrosigmoid
390 approach for resection of left vestibular schwannoma. A linear-shaped postauricular incision is
391 made and muscles are retracted bilaterally to expose the suboccipital bone (A). Asterisk shows
392 the asterion. Several burr holes were then made (B), and craniectomy was performed (C). After
393 tumor resection followed by water-tight closure of the dura, cranioplasty was cosmetically
394 performed with bone dust and fibrin glue (D, E). A three-dimensional skull image constructed
395 from postoperative computerized tomography images shows the status of the skin incision
396 (stapler) and cranioplasty (F).

397

398 **Figure 3.** Distribution of persistent POH symptoms and intensity. POH symptoms at diagnosis
399 (A); there were no cases corresponding to the category “Other”. POH intensity at 3 months, 1
400 year, and 2 years after surgery, representing treatment outcomes (B).

Fig.1

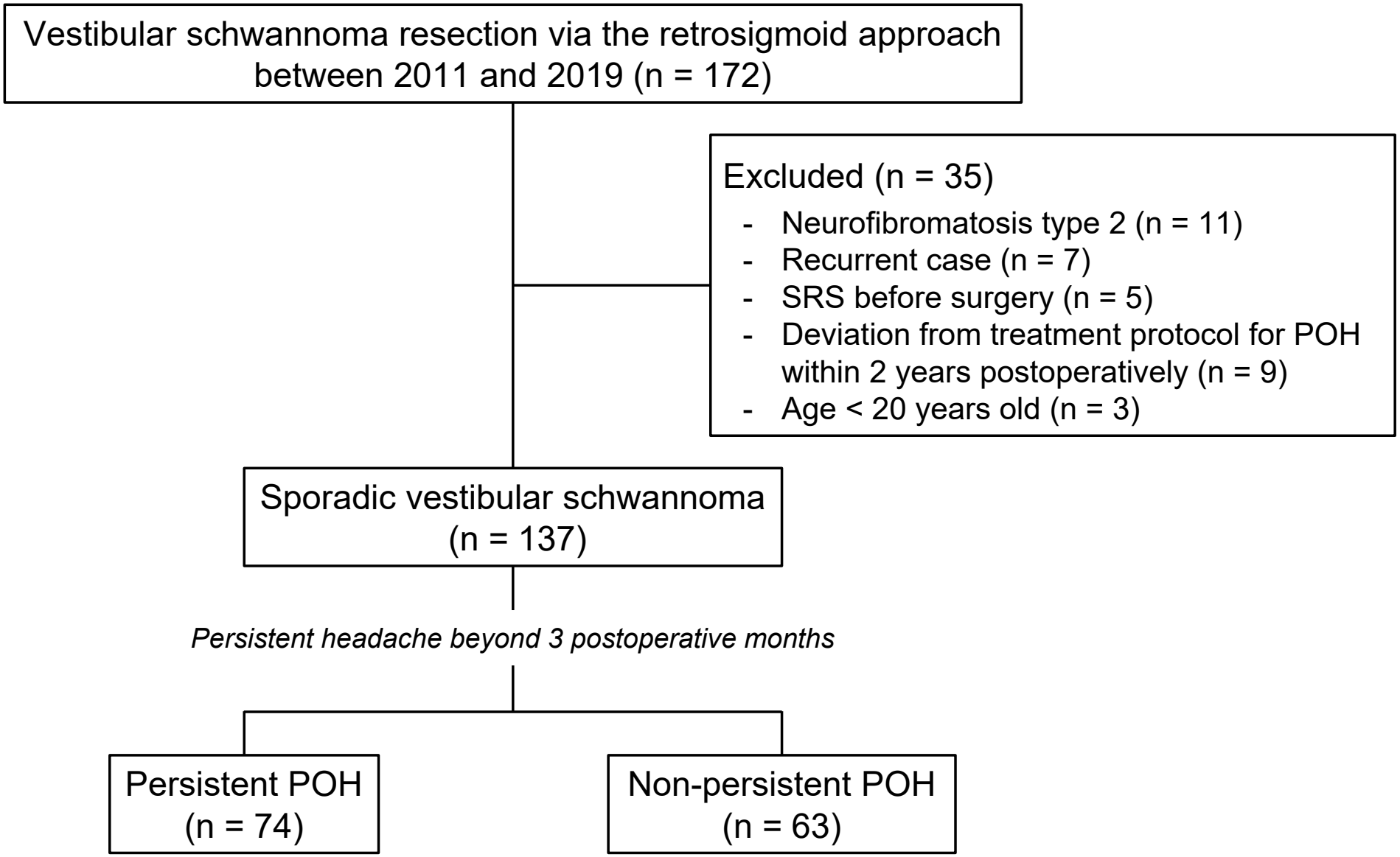
Vestibular schwannoma resection via the retrosigmoid approach between 2011 and 2019 (n = 172)
Excluded (n = 35)
- Neurofibromatosis type 2 (n = 11)
- Recurrent case (n = 7)
- SRS before surgery (n = 5)
- Deviation from treatment protocol for POH within 2 years postoperatively (n = 9)
- Age < 20 years old (n = 3)
Sporadic vestibular schwannoma (n = 137)
Persistent headache beyond 3 postoperative months
Persistent POH (n = 74)
Non-persistent POH (n = 63)

Fig.2

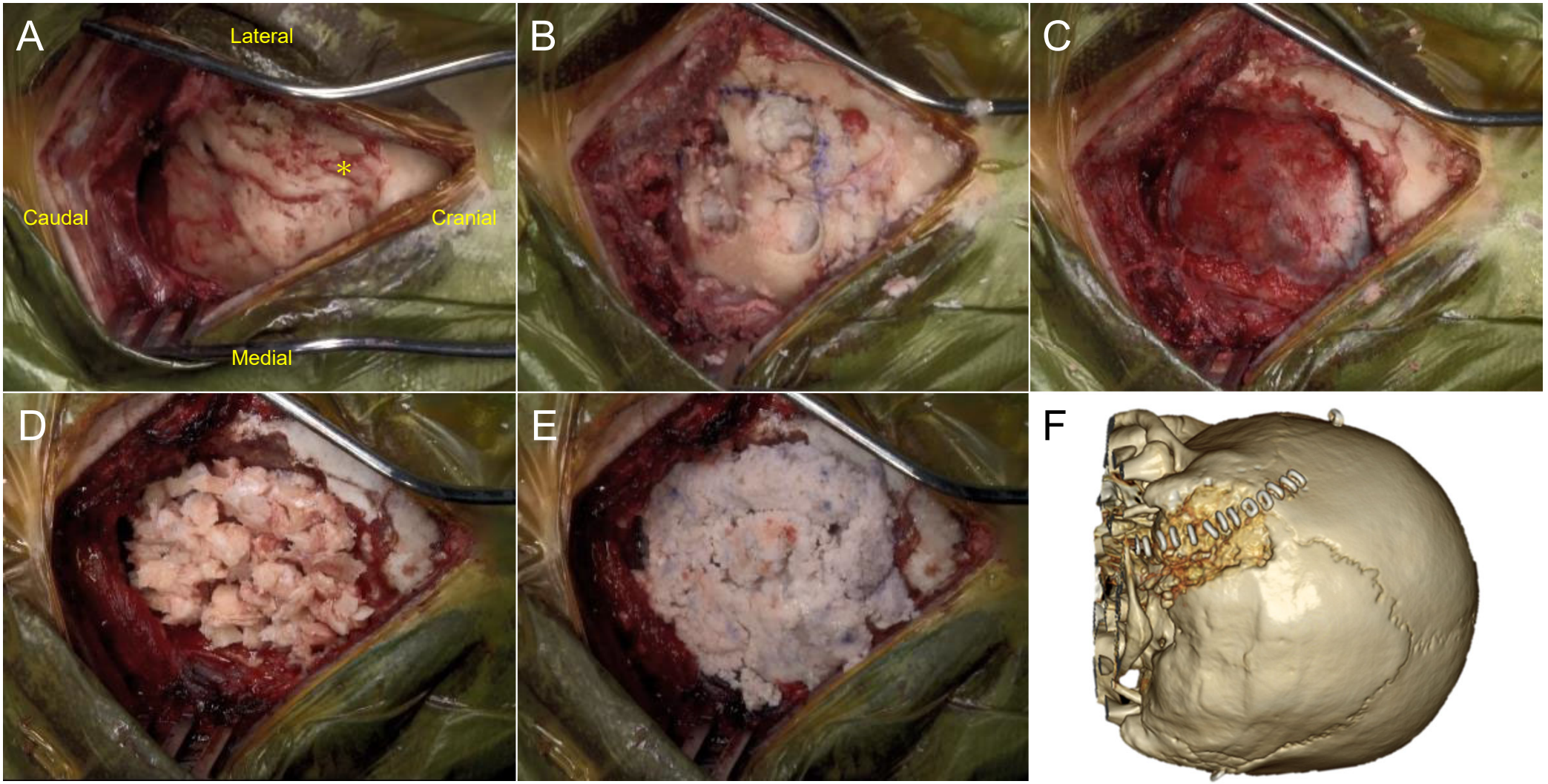

Fig.3

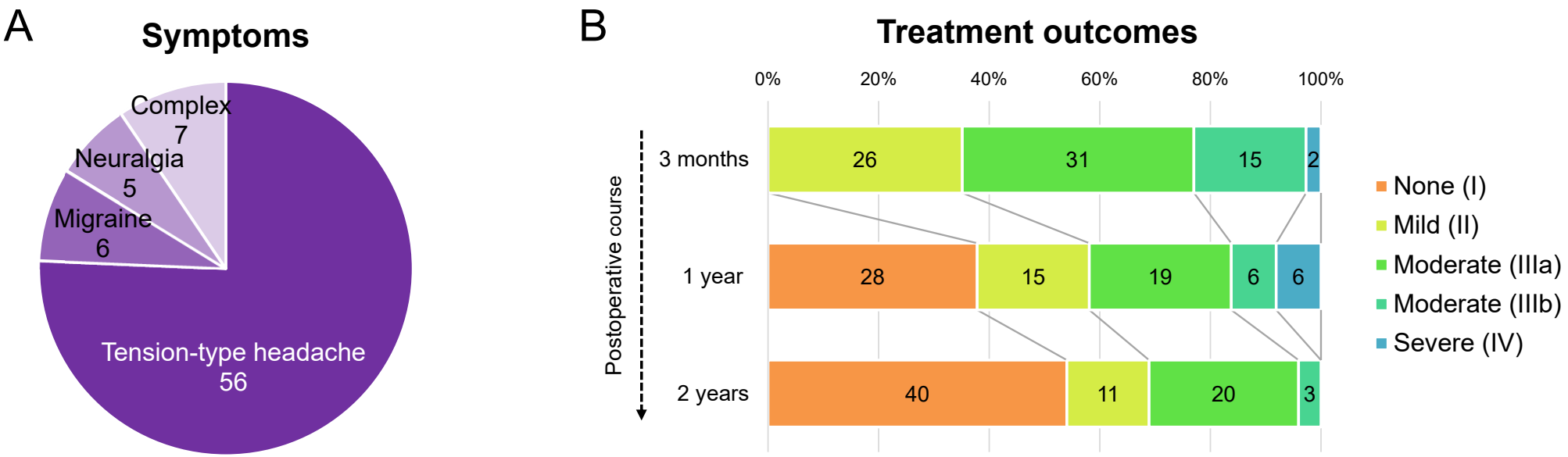
A
Symptoms
Complex
7
Neuralgia
5
Migraine
6
Tension-type headache
56
B
Treatment outcomes
0%
20%
40%
60%
80%
100%
Postoperative course
3 months
1 year
2 years
26
31
15
2
28
15
19
6
6
40
11
20
3
None (I)
Mild (II)
Moderate (IIIa)
Moderate (IIIb)
Severe (IV)

Table 1. Classification of postoperative headache symptoms and treatments for each postoperative headache symptom

Classification	Characteristic	Treatment
Tension-type headache (TTH)	− Bilateral location − Pressing, tightening, or non-pulsating quality around forehead or back of head and neck − No nausea or vomiting − Photophobia or phonophobia	1. One or more antispasmodic drug (afloqualone, tizanidine, eperisone, shakuyakukanzoto) 2. Etizolam and/or amitriptyline 3. Acetaminophen and/or NSAIDs (as a rescue drug when needed) 4. Anti-inflammatory analgesic plaster* 5. Exercise therapy (yoga) for muscle relaxation* * Use in combination with the oral medications (1–3)
Migraine	− Unilateral or bilateral location − Pulsating quality − Nausea and/or vomiting − Photophobia and/or phonophobia − Aura, such as fortification spectrum	1. Triptans 2. Lomerizine hydrochloride (calcium channel blocker) 3. Sodium valproate 4. Acetaminophen and/or NSAIDs (as a rescue drug when needed)
Neuralgia	− Unilateral or bilateral pain in the distribution of the greater, lesser, and/or third occipital nerves	1. Local anesthetic blocks at the trigger points 2. Intravenous drip infusion and/or oral

	− Paroxysmal attacks lasting from a few seconds to minutes − Shooting, stabbing, or sharp in quality − Tenderness over the affected nerve branches − Trigger points at the emergence of the greater occipital nerve or in the distribution of C2	administration of vitamin B12 3. Amitriptyline 4. Acetaminophen and/or NSAIDs (as a rescue drug when needed)
Other	− Not-classifiable headache as described above − Secondary headache with obvious factors such as infection and intracranial hypotension caused by cerebrospinal fluid leakage	1. Treated individually for each cause
Complex symptoms	− Mixture of above types	1. Combined treatment for each type

2 NSAIDs, nonsteroidal anti-inflammatory drugs

Table 2. Evaluation of persistent postoperative headache intensity

Level	Score	Characteristics
None	I	No pain and no medication needed
Mild	II	Occasional pain that does not need medication
Moderate	IIIa	Occasional pain that needs medication and can be adequately controlled
	IIIb	Daily pain that needs regular medication and can be adequately controlled
Severe	IV	Intolerable pain reducing QOL that cannot be adequately controlled even with medication

QOL, quality of life

Table 3. Patients' demographic and tumor characteristics based on the presence of persistent postoperative headache at 3 postoperative months

Characteristic	Persistent POH (n = 74)	Non-persistent POH (n = 63)	P-value
Age, years			
Median (range)	44 (23–70)	53 (21–86)	0.003
Sex, n (%)			
Male	32 (43)	23 (37)	0.49
Female	42 (57)	40 (63)	
History of preoperative headache, n (%)	2 (3)	0 (0)	0.50
Tumor laterality, n (%)			
Right	28 (38)	30 (48)	0.30
Left	46 (62)	33 (52)	
Preoperative tumor size			
Max CPA, mm			
Median (range)	21.5 (0–48)	31.0 (0–70)	0.001
Koos classification, n (%)			
Grade 1	1 (1)	1 (2)	0.03
Grade 2	12 (16)	8 (13)	
Grade 3	21 (28)	7 (11)	
Grade 4	40 (54)	47 (75)	
Preoperative MRI finding, n (%)			
Cystic change	16 (22)	16 (25)	0.69
Fundal CSF cap	42 (57)	42 (67)	0.29
Extent of resection, n (%)			
Total	69 (93)	50 (79)	0.04
Subtotal	4 (5)	10 (16)	
Partial	1 (1)	3 (5)	
Surgical time, h			

Median (range)	4.7 (2.7–9.0)	5.3 (3.3–10.9)	0.09
Nerve origin of vestibular schwannoma, n (%)			
Superior vestibular nerve	27 (36)	26 (41)	0.61
Inferior vestibular nerve	38 (51)	27 (43)	
Unidentified	9 (12)	10 (16)	
Postoperative hearing loss, n (%)	57 (77)	48 (76)	> 0.999
Postoperative facial nerve function, n (%)			
H-B grade I-II	64 (86)	54 (86)	0.89
H-B grade III-IV	9 (12)	7 (11)	
H-B grade V-VI	1 (1)	2 (3)	
Hydrocephalus requiring VPS after surgery, n (%)	0 (0)	0 (0)	> 0.999
SRS after surgery, n (%)	0 (0)	2 (3)	0.21

CSF, cerebrospinal fluid; CPA, cerebellopontine angle; H-B, House-Brackmann; MRI, magnetic resonance imaging; POH, postoperative headache; SRS, stereotactic radiosurgery; VPS, ventriculoperitoneal shunt surgery

Table 4. Comparison of baseline factors by symptom-based treatment outcome at 2 postoperative years

Factors	Medication-free	Medication-needed	P-value
	Score ≤ II (n = 51)	Score ≥ IIIa (n = 23)	
Age, years			
Median (range)	44 (23–70)	44 (25–68)	0.51
Sex, n (%)			
Male	24 (47)	8 (35)	0.69
Female	27 (53)	15 (65)	
History of preoperative headache, n (%)	2 (4)	0 (0)	>.999
Tumor laterality, n (%)			
Right	20 (39)	8 (35)	0.80
Left	31 (61)	15 (65)	
Preoperative tumor size			
Max CPA, mm			
Median (range)	22.0 (0–38)	21.0 (3–34)	0.80
Koos classification, n (%)			
Grade 1	1 (2)	0 (0)	0.82
Grade 2	7 (14)	5 (22)	
Grade 3	15 (29)	6 (26)	
Grade 4	28 (55)	12 (52)	
Preoperative MRI finding, n (%)			
Cystic change	12 (24)	4 (17)	0.80
Fundal CSF cap	30 (59)	12 (52)	0.62
Extent of resection, n (%)			
Total	48 (94)	21 (91)	0.72
Subtotal	2 (4)	2 (9)	
Partial	1 (2)	0 (0)	
Surgical time, h			
Median (range)	4.6 (2.7–9.0)	4.9 (3.0–8.5)	0.33

Nerve origin of vestibular schwannoma, n (%)			
Superior vestibular nerve	19 (37)	8 (35)	>.999
Inferior vestibular nerve	26 (51)	12 (52)	
Unidentified	6 (12)	3 (13)	
Postoperative hearing loss, n (%)	41 (80)	16 (70)	0.37
Postoperative facial nerve function, n (%)			
H-B grade I-II	48 (94)	16 (70)	0.008
H-B grade III-IV	3 (6)	6 (26)	
H-B grade V-VI	0 (0)	1 (4)	
Hydrocephalus requiring VPS after surgery, n (%)	0 (0)	0 (0)	>.999
SRS after surgery, n (%)	0 (0)	0 (0)	>.999
Symptom type of persistent POH, n (%)			
Tension-type headache (TTH)	42 (82)	14 (61)	0.0002
Migraine	4 (8)	2 (8)	
Neuralgia	5 (10)	0 (0)	
TTH and migraine	0 (0)	7 (30)	
Symptom complexity, n (%)			
Simple symptom	51 (100)	16 (70)	0.0001
Complex symptom	0 (0)	7 (30)	

CSF, cerebrospinal fluid; CPA, cerebellopontine angle; H-B, House-Brackmann; MRI, magnetic resonance imaging; POH, postoperative headache; SRS, stereotactic radiosurgery; TTH, tension-type headache; VPS, ventriculoperitoneal shunt surgery