Posterior Petrous Meningiomas: Surgical Classification and Postoperative Outcomes in a Case Series of 130 Patients Operated via the Retrosigmoid Approach

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■ OBJECTIVE: **A standardized definition and classification of primary posterior petrous meningiomas (PPMs) is lacking, with consequent challenges in comparing different case series. This study aimed to provide an anatomical description and classification of PPMs analyzing a homogeneous series of patients operated via the retrosigmoid approach.**

■ METHODS: **PPMs originate laterally to the petro-occipital fissure within the venous ring composed of the superior petrosal, sigmoid, inferior petrosal, and cavernous sinuses. We proposed a classification based on tumor site of origin, direction of growth relative to the internal acoustic meatus, and cranial nerves' displacement. Four types of PPMs were defined: retromeatal (type A), meatal (type B), premeatal (type C), and broad-based (type D). We performed a retrospective analysis of 130 consecutive patients with PPMs who underwent surgery as first-line treatment.**

■ RESULTS: **The PPM classification predicted clinical presentation, postoperative morbidity, and resection rates. Headache, hydrocephalus, and cerebellar deficits were more common in type A (59.0%, 37.7%, 49.2%) and type D (66.7%, 66.7%, 33.3%). Hypoacusia/anacusia was more common in type B (87.5%), while trigeminal hypoesthesia/anesthesia was more common in type C (85.0%). After surgery, patients with type A and D PPMs were at higher risk to develop cerebellar deficits (11.5%—22.2%), whereas patients with type B and C PPMs presented with hypoacusia/anacusia (12.5%) and trigeminal deficits (10.0%), respectively. The near-total resection rate was higher in type A (91.8%), followed by types B (82.5%), C (80.0%), and D (77.8%) PPMs.**

■ CONCLUSIONS: **The PPM surgical classification has an operative and prognostic relevance. In expert hands, the retrosigmoid approach represents a safe and effective approach to remove PPMs.**

INTRODUCTION

Primary posterior petrous meningiomas (PPMs) arise from the dura of the posterior surface of the temporal bone.[1-8] Overall, PPMs represent 5%—10% of all intracranial meningiomas and comprise 6%—15% of cerebellopontine angle (CPA) tumors.[9-12] Their clinical presentation varies according to tumor volume, site of origin, and relationships with neurovascular

Key words
- Case series
- Cerebellopontine angle meningioma
- Classification
- Outcomes
- Posterior petrous meningioma
- Retrosigmoid approach
- Surgical technique

Abbreviations and Acronyms
ATPA: Anterior transpetrosal approach
CN: Cranial nerve
CPA: Cerebellopontine angle
CSF: Cerebrospinal fluid
IAC: Internal acoustic canal
IAM: Internal acoustic meatus
NTR: Near-total resection
PPM: Posterior petrous meningioma
RSA: Retrosigmoid approach

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structures. PPMs may be diagnosed incidentally or manifest with headache, hydrocephalus, cranial nerves (CNs), cerebellar, or rarely brainstem deficits.[2,3,5,8,10,12,13] Therapeutic options for PPMs include surgery, radiotherapy, and conservative management. Surgery has been widely recognized as the first-line treatment, especially for symptomatic patients presenting with large-sized tumors. Different surgical approaches have been suggested to achieve maximal safe resection.[1-3,5,6,8,10-25] Alternatively, fractionated radiotherapy and stereotactic radiosurgery have been proposed to treat patients who are not candidates for surgery and patients with recurrent tumor or growing remnants. Patients with incidental PPMs can be conservatively managed and referred to surgery or radiotherapy in case of documented tumor growth.[8,26,27]

The literature on PPMs is limited and conditioned by the lack of a standardized definition and classification of PPMs. Most surgical series are small and heterogeneous, reporting conflicting results that are hard to compare because of varying lengths of follow-up, different surgical approaches, and various inclusion criteria.[1-3,5,6,8,10-25] We aimed to provide an anatomical definition and surgical classification of PPMs, highlighting their operative and prognostic relevance, and report the results of a homogeneous large series of patients operated via the retrosigmoid approach (RSA).

MATERIALS AND METHODS

Patient Population

We retrospectively analyzed 130 consecutive patients presenting with PPMs who underwent microsurgical resection at Bellaria Hospital and ASST Cremona between January 2005 and December 2020. All surgical procedures were performed by 2 dedicated skull base neurosurgeons (F.C. and A.F.). The inclusion criteria were age >18 years; no history of neurofibromatosis; no previous surgery, radiotherapy, or radiosurgery; availability of preoperative and postoperative radiological imaging (magnetic resonance imaging or computed tomography scan); and pathological report consistent with meningioma. Age at surgery, sex, clinical presentation, neurological examination findings, neuroradiological features, histological grading, and postoperative outcomes were prospectively collected. Facial nerve function was scored according to the House-Brackmann grading system,[28] hearing function was assessed through pure-tone and speech audiometry, and swallowing function was assessed by fiberoptic laryngoscopy.

Standard written informed consent was obtained from all patients. Management of patients' data was conducted in accordance with the ethical standards of the institutional and national research committee and with the 1964 Declaration of Helsinki and its later amendments. The case series has been reported following the PROCESS Guidelines (Appendix 1).[29]

Primary Posterior Petrous Meningioma Definition and Classification

PPMs arise from the dura of the posterior surface of the petrous bone laterally to the petro-occipital fissure within the venous ring composed of the superior petrosal, sigmoid, inferior petrosal, and cavernous sinuses (Figure 1A).[1-8] Tentorial, clival, petroclival, jugular foramen/tubercle, foramen magnum meningiomas, and PPMs extending to Meckel cave, cavernous sinus, and middle cranial fossa were excluded from our analysis.

The surgical classification of PPMs was based on tumor site of origin, direction of growth relative to the internal acoustic meatus (IAM), and CNs displacement.[30] Accordingly, we defined 4 types of PPMs (Figure 1B). Retromeatal PPMs (type A) are located posterolaterally to the IAM up to the sigmoid sinus, usually dislocating CNs VII—VIII anteromedially and CNs IX—X—XI inferiorly. Meatal PPMs (type B) originate around the IAM, with possible intrameatal extension, encasement, and inferior or superior displacement of CNs VII—VIII. Premeatal PPMs (type C) are located anteromedially to the IAM up to the petrous apex, laterally to CN V, causing anteromedial or superior CN V displacement and posterolateral dislocation of CNs VII—VIII. Broad-based PPMs

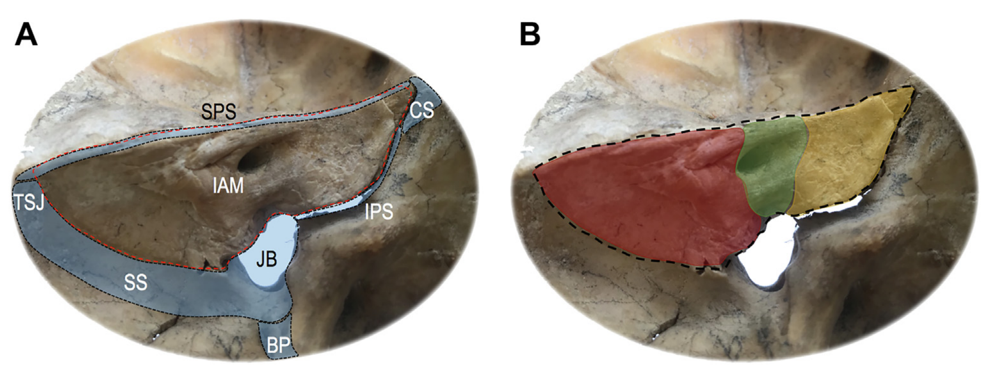

Figure 1. (**A**) The venous ring composed of the superior petrosal, sigmoid, inferior petrosal, and cavernous sinuses delimits the posterior petrous surface of temporal bone (*dotted red line*). (**B**) Primary posterior petrous meningiomas classification: type A (retromeatal) (red area), type B (meatal) (green area), type C (premeatal) (yellow area), and type D (broad-based) (black dotted line). BP, basilar plexus; CS, cavernous sinus; IAM, internal auditory meatus; IPS, inferior petrosal sinus; JB, jugular bulb; SPS, superior petrosal sinus; SS, sigmoid sinus; TSJ, transverse-sigmoid junction.

(type D) mainly arise from the posterior surface of the petrous bone overlapping multiple regions and demonstrating variable relationships with CPA CNs.

Surgical Technique

All patients underwent retrosigmoid craniectomy performed preferably in a semisitting position or in a park-bench position if the former was contraindicated,[31,32] as in cases of patent ventriculoatrial shunt, elevated right-to-left heart pressure gradient, patent foramen ovale, systemic-to-pulmonary shunt, extremes of age, uncontrolled hypertension, or chronic obstructive airway disease. Surgery was performed under continuous intraoperative neurophysiological monitoring by electromyography and evoked potentials and transesophageal echocardiography when a semisitting position was adopted.[18,33-35]

The retrosigmoid craniectomy was tailored in size and location in keeping with tumor features, skeletonizing the transverse and sigmoid sinuses and transverse-sigmoid junction if needed. Cerebellar relaxation was achieved through cerebrospinal fluid (CSF) drainage from the cerebellomedullary and cerebellopontine cisterns. Tumor resection started with PPM devascularization by coagulating the petrous dural attachment. However, intracapsular tumor debulking was first needed to reduce large tumors. The lesion was separated from the surrounding neurovascular structures following the arachnoidal interface. Blunt dissection was achieved through the "2 microforceps technique" by gentle bimanual traction of tumor capsule and arachnoid in opposite directions associated with minimal electrocoagulation of the tumor surface when needed (Video 1).[2,3,18] The internal acoustic canal (IAC), suprameatal tubercle, or inframeatal part of the petrous bone were drilled to complete tumor resection, as needed.[22,33,35-37] The dural attachment was coagulated or excised, and the underlying hyperostotic bone was drilled. When the lesion overran the arachnoidal plane or could not be cleft from neurovascular structures and skull base foramina, a tumor remnant was left and managed in accordance with its progression during the follow-up.[26] A 360° endoscopic inspection was performed to check the extent of tumor resection.[35] The IAC, when opened, was wrapped with muscle and fibrin glue. The dura was closed in a watertight fashion. Mastoid air cells were sealed with muscle flap and fibrin glue. The bone defect was filled with autologous bone dust and covered with a titanium mesh. Muscles were finally sutured in multiple layers. All patients underwent perioperative antibiotic and thrombosis prophylaxis.

Surgical Outcomes

We analyzed surgical outcomes in terms of morbidity, perioperative mortality, and tumor resection rates.[38] Surgical and neurological complications were examined as separate categories. The former included intracranial hemorrhages, hydrocephalus, CSF leakage, wound infections, meningitis, and venous thromboembolism. The latter were defined as new-onset or worsened cerebellar and CNs' deficits. The perioperative mortality was calculated considering deaths occurring within 1 week from surgery or later as a direct consequence of postoperative complications. Tumor resection rates were evaluated according to Simpson grading[39] and extent of resection, defined as near-total resection (NTR) or subtotal resection if tumor removal was >95% or <95% on postoperative imaging, respectively.[40]

Statistical Analysis

Categorical variables were expressed as number (percentage), and quantitative variables were expressed as mean (SD). Normality of distribution was assessed by using histogram visual inspection. Bivariate comparisons between patient groups were made using the χ^2 test or Fisher exact test for categorical variables and Student t test or Mann-Whitney U test for quantitative variables, as appropriate. A 2-tailed P value ≤ 0.05 was considered statistically significant. Statistical analysis was performed with IBM SPSS Version 23.0 software (IBM Corp., Armonk, New York, USA).

RESULTS

Patient and Tumor Characteristics

This study included 130 patients. The mean (SD) age at surgery was 54.3 (17.7) years with a female prevalence (58.3%) and no significant demographic differences stratifying patients by tumor location.

Tumors were left-sided in 77 patients (59.2%) and categorized as type A in 61 cases (46.9%), type B in 40 cases (30.8%), type C in 20 cases (15.4%), and type D in 9 cases (6.9%). The maximum tumor diameter was >30 mm in 87 cases (66.9%). Tumors >30 mm were found more frequently ($P = 0.017$) in type A (54 [88.5%]) and type D (10 [90.9%]) PPMs compared with type B (22 [55.0%]) and C (1 [5.0%]) PPMs. According to histology, 119 tumors (91.5%) were classified as World Health Organization grade I, and the remaining 11 (8.5%) as World Health Organization grade II meningiomas.

As detailed in **Table 1**, the clinical picture at presentation was different between tumor types. Headache ($P = 0.003$), hydrocephalus ($P < 0.001$), and cerebellar deficits ($P < 0.001$) were significantly more common in type A and type D PPMs. By contrast, the rates of preoperative hypoacusia/anacusia and trigeminal hypoestehesia/anesthesia were significantly higher in type B (87.5%; $P = 0.042$) and type C (85.0%; $P = 0.001$) tumors, respectively. Lower CNs' deficits were identified in 14 patients (10.8%), all with type A and type D PPMs.

Surgical Outcomes

Surgical Morbidity. The mean (SD) length of follow-up was 26.5 (13.2) months. Surgical complication rates (**Table 2**) were not significantly different between PPM groups. Postoperative intracranial hemorrhages occurred in 3 cases (2.3%), one of which required surgical evacuation. Hydrocephalus developed in 2 patients (1.5%) who underwent ventriculoperitoneal shunt placement. There were 5 cases of CSF leakage; surgical revision was needed in 1 case, and the leakage resolved after lumbar drainage in the remaining 4. All cases of wound infection (3 [2.3%]) and meningitis (2 [1.5%]) were successfully treated with antibiotics. Deep vein thrombosis was diagnosed in 6 patients (4.6%), all of whom completely recovered after a course of anticoagulation therapy.

Specific pictures of neurological sequelae surfaced after surgery for each tumor category (**Table 2**). Patients presenting with type A and type D PPMs were at higher risk to develop lower CNs (6.6%

Table 1. Clinical Presentation

Presenting Signs/Symptoms	Overall	Type A	Type B	Type C	Type D
Incidental diagnosis	11 (8.5)	7 (11.5)	2 (5.0)	2 (10.0)	0 (0.0)
Headache	45 (34.6)	36 (59.0)	2 (5.0)	2 (10.0)	6 (66.7)
Hydrocephalus	30 (23.1)	23 (37.7)	1 (2.5)	0 (0.0)	6 (66.7)
CN deficits					
CN IV deficit	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
CN V deficit	36 (27.7)	5 (8.2)	11 (27.5)	17 (85.0)	3 (33.3)
CN VI deficit	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
CN VII deficit	9 (6.9)	1 (1.6)	4 (10.0)	0 (0.0)	4 (44.4)
HB grade 2	8	1 (1.6)	4 (10.0)	0 (0.0)	3 (33.3)
HB grade 3	1	0 (0.0)	0 (0.0)	0 (0.0)	1 (11.1)
CN VIII deficit	77 (59.2)	34 (55.7)	35 (87.5)	3 (12.5)	5 (55.6)
CNs IX—X—XI deficit	14 (10.8)	8 (13.1)	0 (0.0)	0 (0.0)	6 (66.7)
Cerebellar deficits	33 (25.4)	30 (49.2)	0 (0.0)	0 (0.0)	3 (33.3)

Values are presented as number (%).
CN, cranial nerve; HB, House-Brackmann.

and 11.1%, respectively) and cerebellar (11.5% and 22.2%, respectively) deficits. Higher rates of postoperative facial weakness (15.0%) and hypoacusia/anacusia (12.5%) were recorded in patients with type B PPMs, while rates of trigeminal hypoestehesia/anesthesia (10.0%) were higher in patients with type C PPMs.

Most neurological postoperative complications fully resolved during follow-up except for hypoacusia/anacusia, which remained stable. Diplopia was transiently registered in 2 cases (1.5%) following trochlear nerve deficit in a case of type C PPM and abducent nerve deficit in a case of type D PPM. Trigeminal hypoestehesia/anesthesia resolved in 3 out of 5 cases (60.0%). Seven patients (5.4%) developed new-onset facial weakness, and 4 (3.1%) experienced worsening of a preexisting deficit, showing a 3-month recovery rate of 72.7%. Postoperative dysphonia and/or dysphagia improved but persisted at last follow-up in 2 of 6 cases (33.3%). Cerebellar deficits were transient in all cases.

No case of intraoperative complications or perioperative death was registered.

Tumor Resection Rates. Tumor resection rates are presented in Table 3. Overall, Simpson grades 1 and 2 were achieved in 68.5% of cases (Figure 2). Simpson grade 1 was achieved more frequently in type A tumors (65.6%), and Simpson grade 2 in type D tumors (44.4%). The global NTR rate was 86.2% with the best results in type A PPMs (91.8%), followed by type B (82.5%), C (80.0%), and D (77.8%) PPMs. A total of 22 patients (16.9%) with tumor recurrence or growing remnant underwent fractionated radiotherapy or stereotactic radiosurgery according to tumor features.

DISCUSSION

Primary Posterior Petrous Meningioma Definition and Classification

The literature review on PPMs is hampered by the lack of standardized definition and classification of these tumors. We provided an anatomical characterization of PPMs as tumors arising from the dura of the posterior surface of the petrous bone laterally to the petro-occipital fissure within the area delimited by the superior petrosal, sigmoid, inferior petrosal, and cavernous sinuses.[1-8] Accordingly, we excluded from our analysis CPA meningiomas originating from the tentorium, clivus, jugular foramen or tubercle, and foramen magnum as well as PPMs extending to Meckel cave, and cavernous sinus.[5,8] By contrast, most of the studies in the literature included CPA meningiomas extending beyond these anatomical limits. Consequently, various surgical approaches have been described to resect tumors involving different anatomical compartments, with extremely variable postoperative outcomes.[2,11,14,23]

The classification of PPMs we propose is grounded on 3 principles: 1) the location of dural implant relative to the IAM, as previously reported[2,3,8,10-12,30,41]; 2) the direction of tumor growth; and 3) the displacement of CPA CNs. Every tumor type presents specific clinical and intraoperative features.

Type A and D PPMs are typically larger at diagnosis than type B and C PPMs. This difference can be explained by their clinical presentation. Type A and D PPMs generally manifest with mass effect signs and symptoms that reveal large-sized tumors. By contrast, patients with type B and C PPMs seek clinical attention more frequently because of CNs VII—VIII and CN V deficits, respectively, that appear with small-sized lesions.[2,3,8,10]

Table 2. Postoperative Surgical and Neurological Complications

Postoperative Complications	Overall	Type A	Type B	Type C	Type D
Surgical					
Intracranial hemorrhage	3 (2.3)	2 (3.3)	0 (0.0)	0 (0.0)	1 (11.1)
Hydrocephalus	2 (1.5)	1 (1.6)	0 (0.0)	0 (0.0)	1 (11.1)
CSF leakage	5 (3.8)	2 (3.3)	1 (2.5)	1 (5.0)	1 (11.1)
Infections					
Wound infections	3 (2.3)	2 (3.3)	1 (2.5)	0 (0.0)	0 (0.0)
Meningitis	2 (1.5)	0 (0.0)	1 (2.5)	0 (0.0)	1 (11.1)
Venous thromboembolism	6 (4.6)	3 (4.9)	1 (2.5)	1 (5.0)	1 (11.1)
Neurological*					
CN deficits					
CN IV deficit	1 (0.8)	0 (0)	0 (0)	1 (5.0)	0 (0)
CN V deficit	5 (3.1)	1 (1.6)	1 (2.5)	2 (10.0)	1 (11.1)
CN VI deficit	1 (0.8)	0 (0)	0 (0)	(0)	1 (11.1)
CN VII deficit	11 (8.5)	2 (3.3)	6 (15.0)	2 (10.0)	1 (11.1)
HB grade 2	7 (5.4)	2 (3.3)	4 (10.0)	1 (5.0)	0 (0.0)
HB grade 3	4 (3.1)	0 (0.0)	2 (5.0)	1 (5.0)	1 (11.1)
CN VIII deficit	7 (5.4)	1 (1.6)	5 (12.5)	0 (0.0)	1 (11.1)
CNs IX—X—XI deficit	6 (4.6)	4 (6.6)	1 (2.5)	0 (0.0)	1 (11.1)
Cerebellar deficits	11 (8.5)	7 (11.5)	1 (2.5)	1 (5.0)	2 (22.2)

Values are presented as number (%).
CSF, cerebrospinal fluid; CN, cranial nerve; HB: House-Brackmann.
*Overall number of neurological complications including transient and permanent deficits.

Furthermore, intraoperative findings could be predicted by PPM classification.[12,13] Type A PPMs tend to dislocate cerebellum and brainstem contralaterally, CNs VII—VIII anteromedially, and CNs IX—X—XI inferiorly, particularly when they reach large sizes. Type B PPMs demonstrate strict contact with CNs VII—VIII, which can be encased, pushed superiorly or inferiorly depending on the site of origin at the IAM. Type C PPMs generally displace CN V anteromedially and CNs VII—VIII posterolaterally. Type D PPMs compress cerebellum and brainstem and demonstrate variable relationships with CNs V, VII, VIII, IX, X, and XI.

Table 3. Tumor Resection Rates

	Overall	Type A	Type B	Type C	Type D
Simpson grade					
1	56 (43.1)	40 (65.6)	8 (20.0)	7 (35.0)	1 (11.1)
2	33 (25.4)	11 (18.0)	12 (30.0)	6 (30.0)	4 (44.4)
Extent of resection					
NTR	112 (86.2)	56 (91.8)	33 (82.5)	16 (80.0)	7 (77.8)
STR	18 (13.8)	5 (8.2)	7 (17.5)	4 (20.0)	2 (22.2)

Values are presented as number (%).
NTR, near-total resection; STR, subtotal resection.

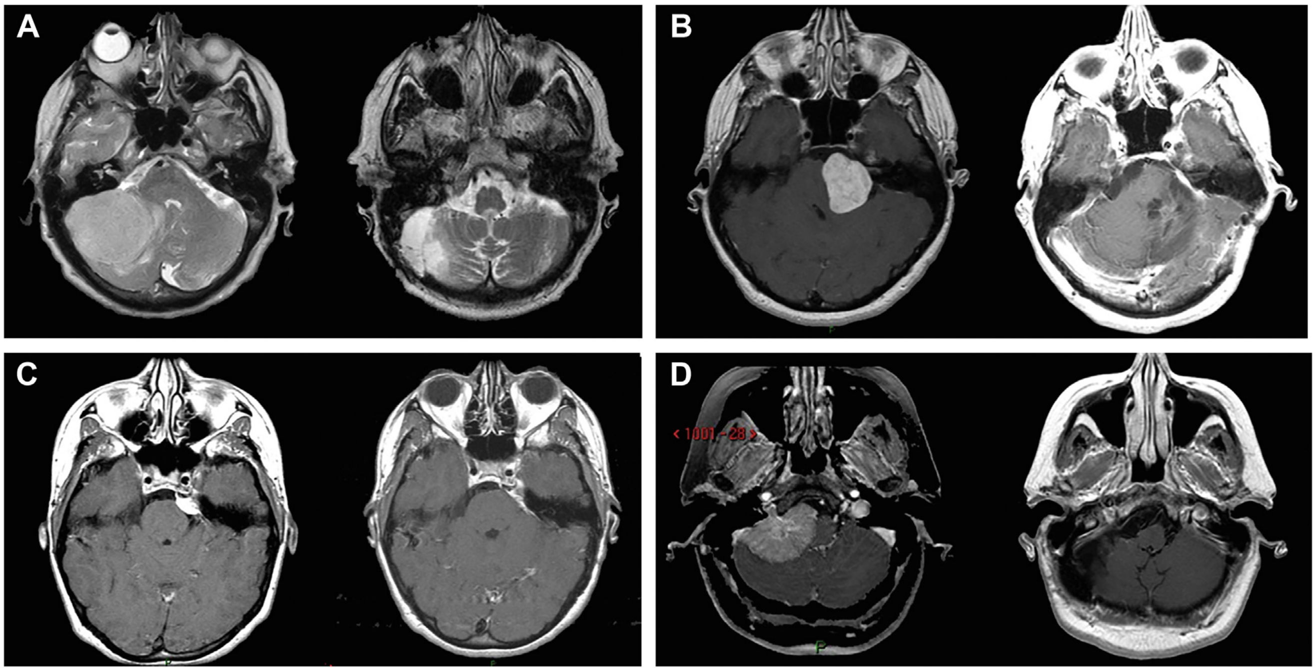

Figure 2. Magnetic resonance imaging of posterior petrous meningioma (PPM). (**A**) Type A PPM: preoperative (left) and 1-month postoperative (right) images showing near-total resection (Simpson grade 1). (**B**) Type B PPM: preoperative (left) and 1-month postoperative (right) images showing near-total resection (Simpson grade 2) and reactive linear dural enhancement. (**C**) Type C PPM: preoperative (left) and 1-month postoperative (right) images showing near-total resection (Simpson grade 2) and reactive linear dural enhancement. (**D**) Type D PPM with secondary invasion of the superior aspect of jugular foramen: preoperative (left) and 1-month postoperative (right) images showing gross total resection (Simpson grade 1).

Surgical Technique and Outcomes

The goal of surgery is to maximize the extent of tumor resection, while limiting the risks of neurological sequelae and deterioration of quality of life. Different surgical strategies have been suggested to remove PPMs: RSA, anterior transpetrosal approach (ATPA), posterior transpetrosal approaches (translabyrinthine, transotic, transcochlear), middle fossa approaches, and their combinations.[1-3,5,6,8,10-25] Skull base–trained neurosurgeons have to master all of them to select and tailor the approach that best suits a specific tumor.

We routinely adopted the RSA because of its operative advantages, flexibility, limited surgical risks, and low postoperative complication rates, particularly in expert hands.[10,12,13,16,33-35,42] The RSA is a straightforward, non–time-consuming approach that provides panoramic visualization and familiar exposure of the CPA.[6,18,22,23,34,35] It allows a direct vision of cerebellum, brainstem, CNs—at brainstem emergence and along their cisternal course—and CPA vessels, with their perforating branches to the brainstem, limiting the risk of intraoperative injuries to neurovascular structures. The RSA affords a lateral-to-medial and slightly caudal-to-cranial trajectory exposing 4 operative windows to work through: 1) between the tentorium and CN V; 2) between CN V and CNs VII–VIII; 3) between CNs VII–VIII and CNs IX–X–XI; 4) between CNs IX–X–XI and foramen magnum.[6,19,21,26] Early CSF drainage from the cerebellomedullary and cerebellopontine cisterns allows cerebellar relaxation, significantly reducing surgical manipulation and possible contusion, and favors subarachnoidal plane preservation during tumor dissection.[6,18,34,35]

The RSA is extremely versatile. According to PPM type and dimensions, it can be tailored in sizes, location, and extension. The transverse and sigmoid sinuses can be skeletonized, and the IAC, suprameatal tubercle, or inframeatal portion of the petrous bone can be drilled to improve surgical exposure and maneuverability.[6,22,33-37,43] Particularly in type C PPMs, the transverse sinus skeletonization and the suprameatal bone drilling expands the first and second surgical windows, respectively, enabling the mobilization of CN V and a straight view of the anatomical structures medial to the IAM up to the petrous apex.[26,33,36]

The RSA carries low morbidity.[6,12,13,17,18,33,34,43] The complication rates we described are in line with literature data on PPMs approached via the RSA (**Table 4**).[1,3,10,12,13,21] Every PPM category brings a specific spectrum of potential complications: type A PPMs are typically related to CNs IX–X–XI and cerebellar deficits; type B to CNs VII–VIII deficits; type C to CN V deficits; and type D to cerebellar deficits. Facial nerve preservation was reported to be between 77.5% and 90.2%, while postoperative serviceable hearing ranged from 36.3% to 76.0%.[1,3,12,13,21,44]

Table 4. Literature Review of Series Reporting Primary Posterior Petrous Meningioma Approached via the Retrosigmoid Approach

Series	Number of Patients	Mortality	Neurological Complications	Intracranial Hemorrhage	HCP	CSF Leakage	Wound Infections	Meningitis
Schaller et al., 1999[10]	31	0 (0%)	18 (58.1%)	1 (3.2%)	0 (0%)	0 (0%)	0 (0%)	1 (3.2%)
Selesnick et al., 2001[1]	6	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (16.7%)	0 (0%)	0 (0%)
Bassiouni et al., 2004[12]	51	0 (0%)	10 (19.6%)	NA	1 (2.0%)	5 (9.8%)	NA	NA
Nakamura et al., 2005[13]	347	2 (0.6%)	8 (2.3%)	12 (3.5%)	16 (4.6%)	16 (4.6%)	0 (0%)	0 (0%)
Qu et al., 2009[3]	42	0 (0%)	6 (14.3%)	2 (4.8%)	NA	1 (2.4%)	NA	NA
Sade and Lee, 2009[21]	58	NA	10 (17.2%)	NA	NA	4 (6.9%)	NA	NA
Mean (Min-Max)	89.2 (6—347)	0.12 (0—0.6)	18.6 (0—58.1)	2.9 (0—4.8)	1.7 (0—4.6)	6.7 (0—16.7)	0 (0—0)	1.1 (0—3.2)
Present series, 2022	130	0 (0%)	14 (10.7%)	3 (2.3%)	2 (1.5%)	5 (3.8%)	3 (2.3%)	2 (1.5%)

HCP, hydrocephalus; CSF, cerebrospinal fluid; NA, not available; Min, minimum; Max, maximum.

Furthermore, the PPM classification predicts surgical radicality.[10,12,13] We reported an overall NTR rate of 86.2%, which is in accordance with the literature rates between 84.0% and 100%.[1,3,10,12,13,21] We registered better results in type A PPMs than in types B, C, and D PPMs.

Some authors advocate the ATPA as the best surgical option for PPM. Although ATPA may be considered a valuable alternative in cases of premeatal meningiomas (type C PPMs) extending toward Meckel cave, cavernous sinus, middle cranial fossa, and clivus, there are limitations of its applicability to treat primary PPMs. The ATPA provides a narrow operative corridor between CN V and IAC with reduced surgical maneuverability around brainstem and CPA vessels, along with their perforating branches, and nerves, especially at brainstem emergence.[23,25] Moreover, it affords an anteromedial trajectory with a limited access to the inferior surgical corridors (the third and fourth) restricting its indications to tumors with prevalent medial extension toward the clivus and cavernous sinus, which are beyond the anatomical borders of PPM.[23,25,45] Finally, the ATPA requires extensive bony removal and manipulation of neurovascular structures—labyrinth; cochlea; CNs III—VIII; temporal lobe; inferior anastomotic vein; superior petrosal, sigmoid and cavernous sinuses—which are at risk of damage causing nonnegligible rates of approach-related complications (8.0%—76.0%).[25,35,36] Furthermore, the NTR rates reported for the ATPA are widely variable, fluctuating between 18.2% and 97.4%.[23,25]

Study Strengths and Limitations

We presented comparable results of a large series of patients operated on by 2 dedicated skull base neurosurgeons with the same surgical approach and microsurgical technique. However, this study brings all the limitations of a retrospective series, potentially reducing the generalizability of our findings.

CONCLUSIONS

We provided an anatomical characterization and surgical classification of PPMs based on a homogeneous large series of patients operated via the RSA. We highlighted the operative and prognostic relevance of our classification and analyzed the surgical outcomes, stressing the advantages of the RSA in safely and effectively removing PPMs. Multicenter studies including skull base reference centers, following standardized definition and classification of PPMs, should be conducted to compare different surgical approaches and confirm our findings on the RSA.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

Carmine Antonio Donofrio: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing — original draft, Writing — review & editing. **Filippo Badaloni:** Conceptualization, Data curation, Investigation, Methodology, Validation, Visualization, Writing — review & editing. **Lucia Riccio:** Conceptualization, Data curation, Investigation, Methodology, Validation, Visualization, Writing — review & editing. **Alessandro Morandini:** Writing — review & editing. **Alessandro Bertuccio:** Writing — review & editing. **Daniele Generali:** Writing — review & editing. **Fabio Calbucci:** Supervision, Writing — review & editing. **Franco Servadei:** Supervision, Writing — review & editing. **Antonio Fioravanti:** Conceptualization, Supervision, Writing — review & editing.

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