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Surgical management of posterior petrous meningiomas

Leczenie operacyjne oponiaków tylnej ściany piramidy kości skroniowej

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Abstract

Background and purpose: The aim of the study is to present our experience in the surgical treatment of posterior petrous meningiomas in regard to clinical presentation, surgical anatomy, complications and long-term functional postoperative results.
Material and methods: A series of 48 consecutive patients operated on for posterior petrous meningiomas at the authors' institution between 2002 and 2011 is reported. The main symptom on first admission was hypoacusis, impairment of the fifth cranial nerve and cerebellar ataxia. The tumour was found to be attached to the premeatal dura in 46%, the inframeatal dura in 29% and the postmeatal dura in 25% of cases. Tumour resection was categorized as grade I in 16 patients, grade II in 29 patients, grade III in 1 patient and grade IV in 2 patients, according to the Simpson classification system. The petrosal approach and retrosigmoid approach were suitable for posterior petrous meningiomas.
Results: Postoperative facial nerve dysfunction appeared in 8 and further deteriorated in 2 patients. Hearing function deteriorated after surgery in 8 and improved in 2 cases. Perioperative death occurred in two patients. Tumour recurrence was observed in two patients, and both underwent a second operation and postoperative stereotactic radiotherapy.
Conclusions: Surgical treatment of posterior petrous meningiomas has become increasingly safe but these tumours still remain a surgical challenge because of the relatively high incidence of permanent complications associated with their removal. The site of displacement of the cranial nerves depending

Streszczenie

Wstęp i cel pracy: Celem pracy jest przedstawienie własnych doświadczeń w leczeniu operacyjnym oponiaków tylnej ściany piramidy kości skroniowej z uwzględnieniem objawów klinicznych choroby, anatomii chirurgicznej, powikłań pooperacyjnych i odległej oceny stanu neurologicznego.
Materiał i metody: Materiał kliniczny obejmuje kolejnych 48 chorych leczonych operacyjnie w naszym ośrodku w latach 2002–2011 z rozpoznaniem oponiaka tylnej ściany piramidy kości skroniowej. W badanej grupie były 44 kobiety i 4 mężczyzn, a średnia wieku pacjentów wyniosła 55 lat. Najczęstszymi objawami stwierdzanymi przy przyjęciu pacjenta były niedosłuch, zaburzenia funkcji nerwu trójdzielnego i ataksja móżdżkowa. Przyczep guza zlokalizowany był do przodu, poniżej i do tyłu od otworu słuchowego wewnętrznego odpowiednio u 46%, 29% i 25% pacjentów. Guz usunięto całkowicie w 45 przypadkach (Simpson I i II), a subtotalnie u 3 pacjentów (Simpson III i IV). Guzy usuwano drogą dostępu podpotylicznego zasutkowego i dostępu przezskalistego.
Wyniki: Po operacji u 8 pacjentów wystąpiło porażenie nerwu twarzowego, a u 2 chorych nasilił się niedowład uprzednio istniejący. U 8 pacjentów zaobserwowano pogorszenie słuchu po operacji, a u 2 chorych nastąpiła poprawa w tym zakresie. Dwóch pacjentów po operacji zmarło. W 2 przypadkach stwierdzono w dalszej obserwacji wznowę guza. Obu pacjentów operowano ponownie i poddano stereotaktycznej radioterapii.
Wnioski: Oponiaki tylnej ściany piramidy kości skroniowej mogą być leczone operacyjnie z dobrym wynikiem, niemniej

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on the dural origin of the tumour has the most influence on the related difficulties in its removal.

Key words: posterior petrous meningiomas, surgical treatment, results, operative technique.

jednak istnieje ryzyko zgonu i wystąpienia istotnych deficytów z zakresu nerwów czaszkowych. Najistotniejsze znaczenie dla oceny ryzyka leczenia ma lokalizacja przyczepu oponowego na podstawie czaszki, decydująca o kierunku przemieszczenia nerwów czaszkowych.

Słowa kluczowe: oponiaki tylnej ściany piramidy kości skroniowej, leczenie operacyjne, wyniki leczenia, technika operacyjna.

Introduction

Posterior fossa meningiomas account for 10% of all intracranial meningiomas [1]. The most common ones in this group are posterior petrous meningiomas [2]. Yasargil *et al*. [3] classified posterior fossa meningiomas into five groups: clival meningiomas, petroclival meningiomas, sphenopetroclival meningiomas, foramen magnum meningiomas and cerebellopontine angle meningiomas. However, it has been pointed out that meningioma location within the cerebellopontine angle is not precise enough for it does not indicate dural attachment location, thus rendering impossible cranial nerves (CNs) displacement assessment along with surgical risk assessment [4]. Samii and Ammirati [5] itemized posterior petrous meningiomas distinguishing locations anterior and posterior to the internal acoustic meatus. Still, the main criterion for classification of the tumour into the posterior petrous meningiomas group was the main tumour mass location regardless of dural attachment location; accordingly tentorial meningiomas accounted for a major part of the group. In order to ensure precise evaluation of dislocation of CNs, Bricolo and Turazzi [6] divided meningiomas of the posterior fossa base into petroclival meningiomas, posterior petrous meningiomas located anterior and posterior to the internal acoustic meatus, meningiomas located between the internal acoustic meatus and jugular foramen, and foramen magnum meningiomas.

Our cohort includes only patients with posterior petrous meningiomas according to above-mentioned classification that aims at precise distinction of them from other posterior fossa base meningiomas, petroclival meningiomas in particular. Petroclival meningiomas involve the clivus, posterior petrous wall and tentorial incisure with dural attachment within the upper 2/3 parts of the clivus, the junction between the clivus and petrous part of the temporal bone and medially to the trigeminal nerve. In contrast to posterior petrous meningiomas petroclival meningiomas present with a dural attachment at the level or medially to the CNs V to XI foramina, i.e. CNs are located between the surgeon and the tumour, thus rendering the highest surgical risk for these tumours amongst all of the posterior fossa base meningiomas. On the other hand, posterior petrous meningiomas comprise a diverse group of tumours with clinical symptomatology and surgical risk closely related to dural attachment localization relative to internal acoustic meatus.

The aim of our study was to present our experience with posterior petrous meningiomas treatment based on homogeneous, relatively large clinical material that involves patients treated in a single centre over last ten years. The main problems related to diagnostics and outcome in this group of meningiomas will be discussed. The literature on the posterior fossa base meningiomas either present cerebellopontine angle meningiomas or describe petroclival meningiomas in greater detail. For that, the presented analysis seems to be of particular value.

Material and methods

A retrospective analysis of 48 consecutive patients who underwent surgical treatment in our department between 2002 and 2011 for posterior petrous meningiomas was performed. Cerebellopontine angle meningiomas as well as those with different dural attachments (i.e. petroclival meningiomas, tentorial meningiomas) were excluded from our cohort.

Meningioma diagnosis was established based on tumour histopathology. In 4 cases histopathological analysis proved a higher degree of malignancy (WHO grade II) (Table 1). Tumour location was determined after meticulous analysis of preoperative magnetic resonance imaging (MRI) along with intraoperative remarks. We distinguished 22 meningiomas with dural attachment anterior to the internal acoustic meatus (premeatal), 12 with dural attachment posterior to the internal acoustic meatus (postmeatal), and 14 meningiomas with an attachment localized between the internal acoustic meatus and jugular foramen (inframeatal). Radiographic evaluation included brain MRI scans as well as temporal bone computed tomography (CT). In order to assess venous sinuses patency, two patients underwent additional cerebral digital subtraction angiography (DSA) and another 8 magnetic resonance angiography (MRA). Based on brain MRI the size of the tumours was evaluated and classified as small tumours with the largest dimension below 2.5 cm (14 cases), midsize meningiomas that varied between 2.5 and 4 cm (20 cases) and large tumours that exceeded 4 cm (14 cases). Computed tomography scans of the temporal bone revealed calcifications within the tumour in 8 cases, hyperostosis at the dural attachment site in 7 cases, slight expansion of the internal acoustic meatus in 2 cases and jugular foramen expansion in another 2 cases. Digital subtraction angiography and MRA examination revealed occlusion of the bulb of the jugular vein in 2 patients and restriction of the sigmoid sinus in another three.

Table 1. Histopathological diagnosis of studied posterior petrous meningiomas

Histopathology	Number of tumours
Atypical meningioma (WHO grade II)	2
Chordoid meningioma (WHO grade II)	1
Clear cell meningioma (WHO grade II)	1
Fibroblastic meningioma (WHO grade I)	14
Meningothelial meningioma (WHO grade I)	12
Psammomatous meningioma (WHO grade I)	2
Transitional meningioma (WHO grade I)	16

WHO – World Health Organization

Table 2. Age and sex of the studied patients

Patients' age (years)	Male	Female	Total
< 40	1	2	3
41-50	0	9	9
51-60	2	14	16
61-70	1	16	17
> 70	0	3	3
Total	4	44	48

Table 3. Initial symptoms and signs

Symptoms and signs	N
Facial dysaesthesia	4
Trigeminal neuralgia	4
Diplopia	3
Hemifacial spasm	2
Hypoacusis	15
Headache	7
Cerebellar symptoms	13

Patients' age varied from 26 to 78 years (mean 55 years), the majority of them in their sixth or seventh decade (Table 2). Our cohort included 44 women and 4 men. The most common first sign of the disease was hypoacusis (Table 3); duration of symptoms prior to diagnosis exceeded one year in 13 cases while in 26 patients they lasted less than 6 months. Table 4 presents clinical signs prior to admission. Audiology examination with pure tone audiometry and auditory brainstem response (ABR) was performed in 38 patients, and 8 patients had additional speech audiometry. Deafness was found in 8 patients, while another 8 had unserviceable hearing. In 5 patients, obturative hydrocephalus with regular papilloedema was diagnosed. None of the patients had a ventriculo-peritoneal shunt implanted, however.

Posterior petrous meningiomas have been most often accessed via suboccipital retrosigmoid craniotomy (Fig. 1). In 7 patients with premeatal tumours, a combined approach, subtemporal and suboccipital with posterior petrosectomy (translabyrinthine in 2 patients, retrolabyrinthine in the other 5), was performed (Fig. 2). A combined translabyrinthine approach with posterior petrosectomy was also implemented in one case of inframeatal meningioma while in two other patients with a meningioma in this location that encompassed the jugular foramen surgical access was extended with a far-lateral transcondylar approach (Fig. 3). Facial nerve function was monitored in 40 patients during surgery; 8 patients had hearing organ function monitored as well. Additionally, in 4 patients CNs IX, X and XII function was monitored.

The extent of resection of tumours in particular locations is summed up in Table 5. Their radicality was assessed with the Simpson grading scale [7] based on intraoperative findings, postoperative early CT with contrast (7 days after surgery) and late postoperative brain MRI (3 months after surgery) owing to actual diagnostic options available (no early MRI evaluation with-

Table 4. Clinical symptoms and signs on admission in relation to tumour localization

Clinical symptomatology	Premeatal meningiomas (22 cases)	Inframeatal meningiomas (14 cases)	Retromeatal meningiomas (12 cases)	Total
Facial dysaesthesia	11	0	0	11
Trigeminal neuralgia	4	0	0	4
Abducent nerve palsy	3	0	0	3
Facial nerve palsy	2	2	0	4
Hemifacial spasm	2	0	0	2
Hypoacusis	12	10	2	24
Dysphagia	1	3	0	4
Cerebellar symptoms	7	4	6	17
Headache	1	4	4	9
Hydrocephalus	0	2	3	5

in the first forty-eight hours was performed). In three patients tumour resection was non-radical. In two patients with good swallowing and expectoration a tumour layer tightly adjacent to the lower group of cranial nerves was left owing to the high risk of severe postoperative deficits: in one of them it was a wide en plaque meningioma, while in the other one it was a small remnant of the meningioma within the jugular foramen. In the third case tumour infiltration encompassed the tentorial incisure, where a piece of meningioma was left behind.

The patient's condition was assessed on admission and at discharge from the department along with a long-term follow-up (at the department or in an outpatient clinic) based on neurological examination and brain MRI in all of the patients. In selected cases, facial nerve EMG and pure tone audiometry were also performed.

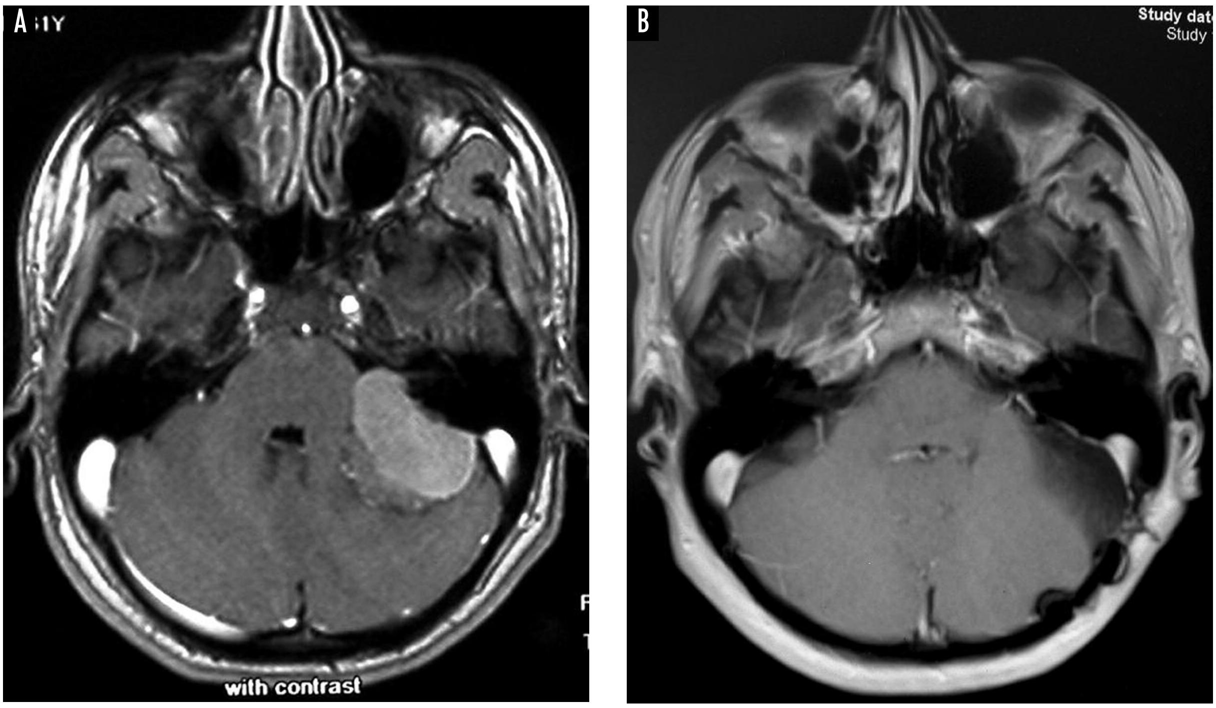

Fig. 1. A) T1-weighted Gd-enhanced MR image demonstrating tumour located posteriorly to the IAC (postmeatal). B) T1-weighted Gd-enhanced MR image revealing total resection of the tumour via the retrosigmoid approach

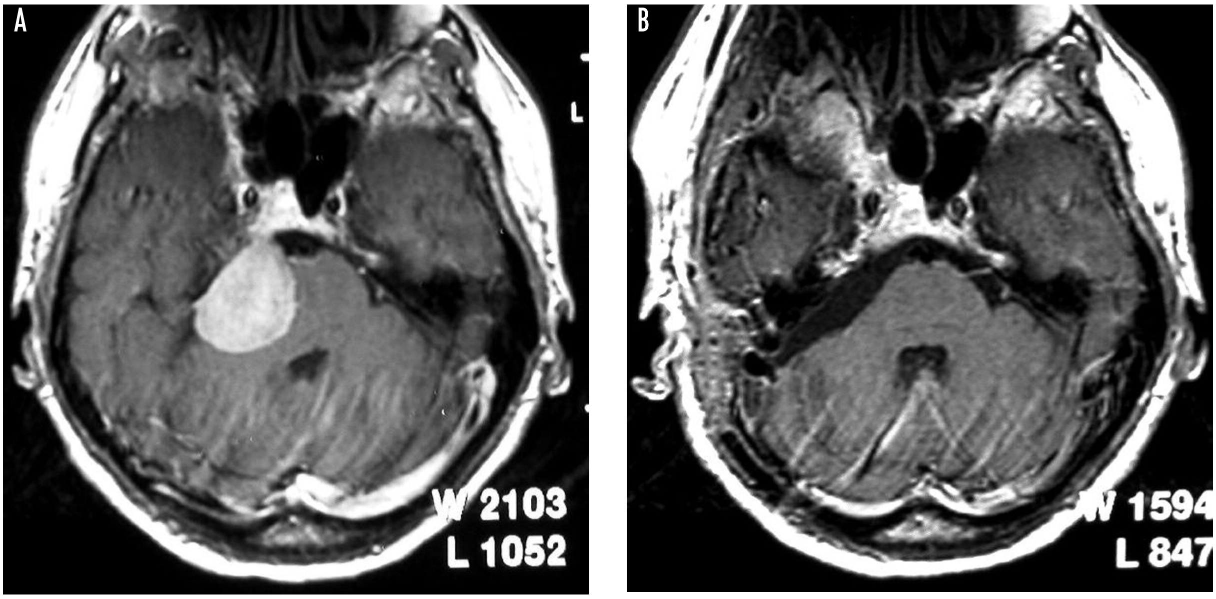

Fig. 2. A) Preoperative T1-weighted Gd-enchanced MR image revealing posterior petrous meningioma located anteriorly to the IAC (premeatal). B) Postoperative T1-weighted Gd-enhanced MR image obtained after total resection via the retrolabirinthine approach

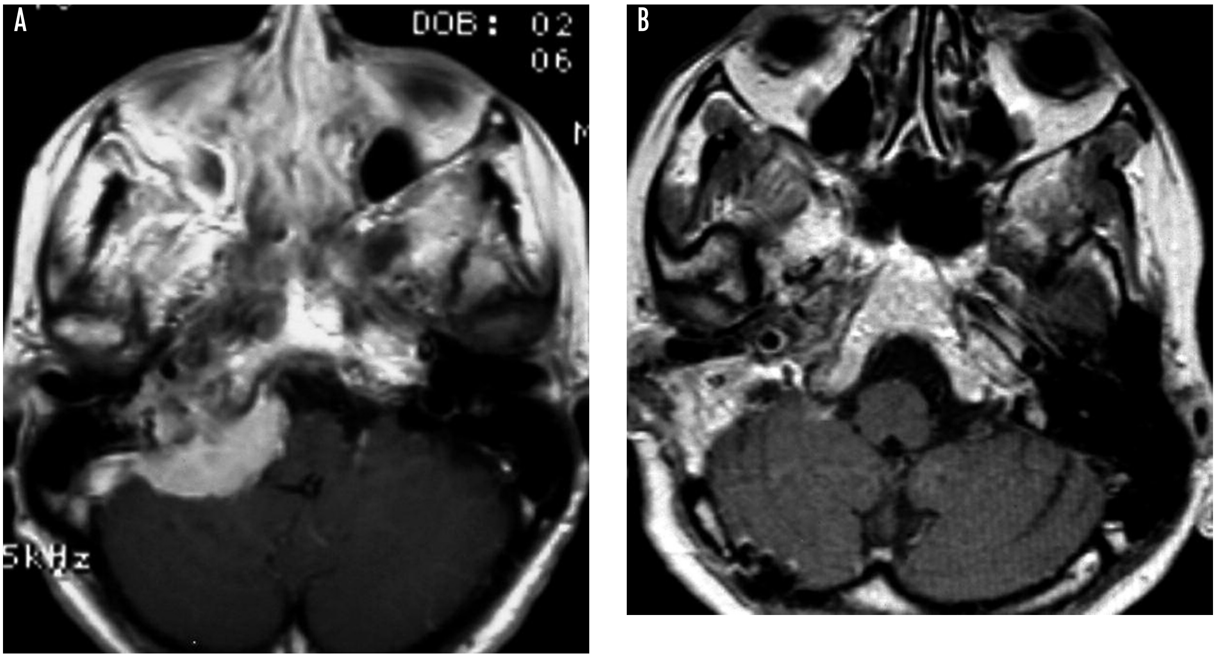

Fig. 3. A) Preoperative T1-weighted Gd-enchanced MR image revealing tumour located inferiorly to the IAC (inframeatal). B) Postoperative T1-weighted Gd-enchanced MR image revealing total resection of the tumour via far-lateral transcondylar approach

For facial nerve function evaluation, the House-Brackmann scale was implemented [8]; accordingly for hearing evaluation we applied the Gardner-Robertson scale [9]. Follow-up times varied from 12 to 120 months; for 24 patients it exceeded 24 months. Catamnesis was available for 44 out of 46 patients recruited for the study (95%).

Results

Two patients died after surgery (4.2%). The first one with an extensive inframeatal meningioma was admitted to the department in poor general condition, recumbent with cranial nerve VII, IX and X deficits and deafness

Table 5. Extent of resection of meningioma relative to its localization and size

Extent of resection (according to Simpson grading scale)	Tumour location			Tumour size			Total
	Premeatal meningiomas (22 cases)	Inframeatal meningiomas (14 cases)	Retromeatal meningiomas (12 cases)	< 2.5 cm (14 cases)	2.5-4 cm (20 cases)	> 4 cm (14 cases)	
Simpson I	4	5	7	5	7	4	16
Simpson II	17	8	4	9	12	8	29
Simpson III	0	1	0	0	1	0	1
Simpson IV	1	1	0	0	0	2	2

present. After surgery his swallowing and expectoration deficits intensified and the patient succumbed to massive pneumonia. The other one had an extensive premeatal tumour that encompassed the tentorial incisure and was admitted in a good general condition. During surgery, a severe adhesive reaction of the arachnoid was present along with related brain oedema; after surgery the patient remained comatose and died a few days later. Postoperative CT revealed venous infarction within the brainstem and cerebellum. Another patient who fully recovered after surgery for a jugular foramen meningioma developed consciousness deficits and severe cerebellar ataxia 5 days later. Control CT revealed ischaemic stroke within the anterior inferior cerebellar artery (AICA) region. Decompressive resection of the cerebellar hemisphere was performed, resulting in gradual improvement of neurological status. Still, moderate cerebella ataxia remained.

A significant proportion of postoperative deficits relates to CN injuries, facial and acoustic nerves in particular. Detailed data with pre- and postoperative evaluations of the CN VII and CN VIII function are

Table 6. Preoperative and postoperative facial nerve function during 12-month follow-up

Meningioma localization	Preoperative function		Postoperative function	
	Without deficit	Deficit (grade)[a]	Without deficit	Deficit (grade)[a]
Premeatal meningiomas (21 cases[b])	19	1 (gr. IV) 1 (gr. II)	15	1 (gr. V) 2 (gr. IV) 2 (gr. III) 1 (gr. II)
Inframeatal meningiomas (12 cases[c])	10	2 (gr. II)	7	2 (gr. IV) 3 (gr. III)
Retromeatal meningiomas (11 cases[d])	11	0	11	0

[a]According to House-Brackmann scale, [b]One death during postoperative period, [c]One death during postoperative period, one patient without catamnesis, [d]One patient without catamnesis

Table 7. Preoperative and postoperative auditory function during 12-month follow-up

Meningioma localization	Preoperative function			Postoperative function		
	Without deficit	Functional hearing[a]	Non-functional hearing[b]	Without deficit	Functional hearing[a]	Non-functional hearing[b]
Premeatal meningiomas (21 cases[c])	9	8	4	7	5	9
Inframeatal meningiomas (12 cases[d])	4	4	4	3	2	7
Retromeatal meningiomas (11 cases[e])	9	2	0	11	0	0

[a]Functional hearing is equivalent to grade II on the Gardner and Robertson scale, [b]Non-functional hearing is equivalent to grade III to V on the Gardner and Robertson scale, [c]One death during postoperative period, [d]One death during postoperative period, one patient without catamnesis, [e]One patient without catamnesis

Table 8. Preoperative and postoperative facial nerve and auditory functions relative to the tumour size during 12-month follow-up

Meningioma localization	Tumour size (cm)	Preoperative function				Postoperative function			
		CN VII		CN VIII		CN VII		CN VIII	
		Without deficit	With deficit	Functional hearing[a]	Non-functional hearing[b]	Without deficit	With deficit	Functional hearing[a]	Non-functional hearing[b]
Premeatal meningiomas (21 cases[c])	< 2.5	8	0	8	0	8	0	7	1
	2.5-4	9	1	9	1	7	3	5	5
	> 4	2	1	0	3	0	3	0	3
Inframeatal meningiomas (12 cases[d])	< 2.5	5	0	5	0	3	2	3	2
	2.5-4	4	0	3	1	3	1	1	3
	> 4	1	2	0	3	1	2	0	3
Retromeatal meningiomas (11 cases[e])	< 2.5	1	0	1	0	1	0	1	0
	2.5-4	4	0	4	0	4	0	4	0
	> 4	6	0	6	0	6	0	6	0

CN – cranial nerve

[a]Functional hearing is equivalent to grade II on the Gardner and Robertson scale, [b]Non-functional hearing is equivalent to grade III to V on the Gardner and Robertson scale, [c]One death during postoperative period, [d]One death during postoperative period, one patient without catamnesis, [e]One patient without catamnesis

presented in Table 6 and Table 7. Four patients had preoperative facial nerve palsy; in one case the deficit was severe. Every patient with severe, postoperative facial nerve palsy (grade V or VI on the House-Brackmann scale) had a golden plate implanted into the upper lid in the early postoperative period in order to facilitate eye closure. Whenever a lower degree of facial palsy occurred (grade IV on the House-Brackmann scale), the eye was initially protected with a humid chamber while the decision on golden plate implantation was deferred conditional on the results of early postoperative facial nerve rehabilitation. Anatomical continuity of the facial nerve was not compromised in any case; patients with postoperative palsy showed gradual improvement of the nerve function. None of the patients required delayed facial to hypoglossal nerve anastomosis. The highest percentage of new permanent postoperative facial nerve deficits occurred in patients with inframeatal meningiomas (4 out of 10 patients, i.e. 40%). Concurrently, in one case preoperative facial nerve palsy subsided during postoperative follow-up in the same group. Moreover, the highest percentage of patients with pre- and postoperative hearing impairments was also related to the same location of meningiomas. Essentially, a significant deterioration to the non-functional level occurred (group III, IV and V according to the Garner and Robertson scale) in 3 out of 22 patients with well-preserved preoperative hearing. Conversely, 5 out of 14 patients with preoperatively impaired yet functional hearing (grade II according to the Garner and Robertson scale) deteriorated after surgery while in two patients hearing disturbances withdrew. The size of a meningioma was another risk factor for preoperative hearing disturbances as well as postoperative facial palsy (Table 8).

Four patients presented with CNs IX and X palsies on admission; in two of them surgery had no significant effect on it, in one patient it subsided postoperatively while in the last one it deteriorated significantly and the patient required tracheotomy. Likewise, new CN IX and CN X palsy occurred in 6 patients after surgery and then withdrew completely in 3 patients and significantly diminished in the other three during follow-up.

Abducent nerve palsy was found preoperatively in 3 patients with premeatal tumours and after surgery it subsided in one of them. A new abducent nerve deficit occurred in five patients after surgery; it proved permanent in one of them.

In the group of four patients who presented with trigeminal neuralgia, the pain subsided in all of them. Preoperative deficits of touch sensation were stable after surgery, however.

No hydrocephalus developed during the postoperative period. In the group of four patients with a higher degree of malignancy (WHO grade II), one patient underwent early postoperative radiotherapy. For the remaining three patients, in two of them the tumours recurred after 14 and 27 months, respectively. They underwent reoperation with subsequent radiotherapy. Radiotherapy was also elected for one patient with a small fragment of the tumour left within the jugular foramen (WHO grade I). All of them received stereotactic radiotherapy with LINAC.

Discussion

Approximately 5-8% of all intracranial meningiomas are located within the cerebellopontine angle [2]. Still, schwannomas are the most common in this location, accounting for 70-80% of tumours, while meningiomas of the cerebellopontine angle constitute 10-15% of them; the third most common tumours in this location are epidermoid cysts with their frequency at 4-5% [10,11]. However, meningioma location within the cerebellopontine angle is not precise for it encompasses a plethora of tumours with different locations of dural attachments and thus with different growth direction and CN dislocation, different relationships to venous sinuses of the skull base and different clinical presentation. Importantly, it translates into various degrees of surgical difficulty and frequency of surgery-related complications. The group of meningiomas discussed differs from other tumours of the posterior fossa skull base by the location of the dural attachment on the posterior wall of the petrous part of the temporal bone [6]. Still, a precise location of the attachment related to the internal acoustic meatus is equally important [9,12]. Primarily, premeatal and retromeatal localizations were distinguished which highlighted worse outcome of premeatal tumours, despite their relatively small dimensions and earlier clinical presentation [13]. Additionally, dural attachment location between the internal acoustic meatus and jugular foramen (inframeatal) was also distinguished [6] while the others introduce other locations, i.e. above the internal acoustic meatus and those with a dural attachment within the internal acoustic meatus [14,15]. Another classification of posterior petrous meningiomas was introduced by Desgeorges *et al*. [16], who divided the area into A, M and P zones and stressed the variable extensiveness of the dural attachment, which might encompass more than one zone. In this classification A (anterior) type encompasses meningiomas of the petrous apex, M (middle) type includes tumours with an attachment in the vicinity of the internal acoustic meatus, and P (posterior) type involves meningiomas located between the posterior wall of the internal acoustic meatus and the sigmoid sinus. Zhe Bao Wu *et al*. [17] proposed a similar classification that distinguishes type I (meningiomas located posteriorly to the internal acoustic meatus), type II (attachment located anterior to the internal acoustic meatus) and type III that encompasses extensive meningiomas with a wide dural attachment to the posterior wall of the petrous part of the temporal bone where a precise location of dural attachment was not possible. They classified as many as 27% of posterior petrous meningiomas in this group but the others do not report such a high number of meningiomas with uncertain location of the dural attachment. In our cohort we had no particular doubts regarding dural attachment localization except for a single case of en plaque meningioma that was partially dissected.

The classification initially elected that divides meningiomas into premeatal, inframeatal and postmeatal tumours proved to be practical and facilitated the determination of CN displacement. This classification determines differences in relationships between CNs and the tumour that might be later appreciated intraoperatively. Premeatal meningiomas displace CN V anteriorly, the complex of CNs VII and VIII posteriorly or inferiorly, and the lower group of nerves (IX, X, XI) inferior to the tumour. Postmeatal meningiomas displace CN V anteriorly and superiorly, CNs VII and VIII anteriorly (seldom inferiorly) and CNs IX-XI inferior to the tumour, while inframeatal meningiomas displace CN V anteriorly, the complex of CNs VII and VIII superiorly or posteriorly and CNs IX-XI inferior to the tumour [14].

Hearing disturbances along with cerebellar ataxia were leading symptoms on admission and the most frequent first sign of the disease. Literature on cerebellopontine angle meningiomas as well as those that distinguish posterior petrous meningiomas reports hearing disturbances in 60 to 75% of cases [11,14,18]. In contrast to acoustic schwannomas, hearing disturbances in posterior petrous meningiomas are not the sole leading clinical sign. Half of the patients with premeatal tumours presented with signs of trigeminal nerve injury such as dysaesthesia on the face and some patients also reported trigeminal neuralgia. According to Rhoton [19] dysaesthesia often precedes hearing disturbances in this group of patients. It seems that this particular symptom is often neglected by patients; in our cohort only 4 patients reported aforementioned disturbances as a first sign of the disease. For all of the symptomatic trigeminal neuralgia cases, the symptoms withdrew after surgery; the others reported similar observations [11,14]. Other CN deficits are rare prior to the operation. Premeatal meningiomas might cause facial and abducens nerves' palsy. Ninth and tenth nerve deficits rarely occur in various locations of posterior petrous meningiomas; moreover they are usually transient [17]. Rare, primary meningiomas of the jugular foramen are an exception for dysphagia prior to surgery can be found in half of the patients [20]. Every case with severe dysphagia and expectoration impairment should be considered a candidate for elective perioperative tracheotomy and percutaneous endoscopic gastrostomy.

Brain MRI is a study of choice for preoperative diagnostics for it allows, in the majority of cases, localization of the dural attachment and assertion of internal acoustic meatus or jugular foramen involvement. It is worth mentioning, however, that small alterations such as small hyperostosis or thinning and enlargement of skull base foramina are clearly visible on CT examination of the temporal bones, which is helpful in determination of tumour type [14]. For that, we always perform CT scans for all skull base tumours.

The most common surgical access for the tumours in question regardless of dural attachment localization involves the suboccipital retromastoid (retrosigmoid) approach. A number of authors state that this approach enables removal of all meningiomas in this location including those located anterior to the internal acoustic meatus [3,5,11,14]. The retromastoid (retrosigmoid) approach facilitates hearing preservation, early opening and drainage of arachnoid cisterns in order to assure cerebellum relaxation as well as early visualization of the lower group of cranial nerves. In selected cases, a petrosal approach with posterior petrosectomy, most commonly retrolabyrinthine, was implemented in order to preserve hearing [21]. This approach allows early identification and preservation of the facial nerve and diminishes cerebellar retraction, which is of particular importance in large premeatal tumours, extending beyond the midline and dislocating the brainstem posteriorly. Choice of surgical access in those cases depends on individual preferences and the surgeon's experience. In our hands, the petrosal approach, successfully implemented in early cases from our series of patients with premeatal meningiomas, has been replaced by the suboccipital, retromastoid (retrosigmoid) approach.

The suboccipital, retromastoid (retrosigmoid) approach, owing to the frequency of use and familiarity with surgical anatomy, appears to be much simpler, less time-consuming and with a proper modification facilitates efficient tumour removal up to the level of Meckel's cave. The underlying idea for an extended approach involves intradural drilling of the bone above and anterior to the internal acoustic meatus along with resection of the posterior part of the petrous apex with a diamond bite [22].

Intraoperative neurophysiological monitoring for posterior fossa skull base tumours is indispensable [4] and was implemented in each operation with an increased risk of CN injury with the exception of a few operations for meningiomas with a well-defined postmeatal dural attachment. Neurophysiological monitoring aims at intraoperative identification of cranial nerves and consequently at reduction of intraoperative injury. Facial nerve monitoring with intraoperative nerve stimulation and brainstem auditory evoked potentials is most commonly used. For selected cases, CN IX-XII function might be monitored as well; in some of the patients in the presented group we also implemented this form of intraoperative monitoring.

We achieved a gross total tumour removal (Simpson grade I and II) in 93.8% of cases. Others presented comparable series of patients with posterior petrous meningiomas with a slightly lower percentage of gross total removals that varied from 83 to 86% but without any mortality [4,14,17]. The authors of the above-mentioned reports stress that the reason for leaving tumour bits rose from tumour infiltration on CNs and the risk of their injury with simultaneous good neurological function on preoperative examination. There is general agreement that surgical treatment of postmeatal tumours does not carry any significant risk and the majority of the studies report gross total resections for all of the tumours in this group. A significantly lower percentage of gross total resections was recently reported by Roche *et al*. [23]. In their whole series the authors report gross total resection of a meningioma in only 39% of the tumours, while in the subgroup of premeatal tumours this percentage reached only 18%, with a relatively high mortality of 8.8% for the entire group. In our series, perioperative mortality was 4.2%.

The most crucial postoperative complications in this group of patients relate to facial nerve and auditory dysfunctions. In our series, 8 patients (18%) had permanent postoperative facial nerve palsy. Importantly, it developed in the group of patients with tumours located anterior to and below the internal acoustic meatus. In the series reported by Basiouni *et al*. [14], permanent facial palsy developed only in 3 patients (6%) and only in premeatal and suprameatal groups. Other authors report a wide range of permanent facial nerve palsies from 6 to 19% [4,17,23].

We found postoperative hearing deterioration in 8 patients (18%) while preoperative hearing deficits subsided in 2 patients. Hearing improvement concerned the patients with postmeatal tumours; other authors reported similar observations [14]. Yasargil [3], in his series of 30 patients with cerebellopontine angle meningiomas, reported hearing improvement in as many as 12 patients, with hearing deterioration in only one patient. Matthies *et al*. [18] in their study that encompassed 134 patients with cerebellopontine meningiomas observed hearing preservation or its improvement in 82 and 6% of cases, respectively. Series comparable to our cohort report considerably different degrees of hearing loss after surgery varying from 0 to 33% [4,14,17,23]. All the authors consequently emphasize the crucial role of tumour localization anterior and adjacent to the internal acoustic meatus for the risk of facial and acoustic nerve function deterioration. Meningioma size seems to have a significant effect on deterioration in particular tumour localizations [17,23] as well as a large influence on the occurrence of hearing loss prior to the operation; our study has confirmed these observations.

Recurrent tumours were found in two patients (4.3%) from our group, a finding similar to other authors' observations [14,17,23]. Histopathological evaluation revealed higher-grade meningiomas (WHO grade II) in both patients that were dissected radically but received no adjuvant radiotherapy. Some authors advocate adjuvant stereotactic radiotherapy such as gamma knife or, rarely, fractionated stereotactic radiotherapy in patients with even small bits of benign meningioma (WHO grade I) left [17,24]. According to others, there is no justification for radiotherapy in cases where only small fragments of meningioma that infiltrates CNs remain [14]. Nonetheless, there is general agreement regarding superiority of normal neurological function preservation over excessive and risky aspirations to achieve radicality of surgical resection [14,17,23]. A treatment protocol for cases with radical resection of higher-grade meningiomas (WHO grade II) is still a matter of debate. In our opinion, all cases with non-radical resection of meningioma should receive adjuvant stereotactic (gamma knife, LINAC) radiotherapy of the remaining tumour in the early postoperative period. We also think that stereotactic radiotherapy should be considered after surgery for higher-grade meningiomas.

Conclusions

1. It is feasible to achieve favourable outcomes in the treatment of posterior petrous meningiomas despite the large size they might attain and vital neuro-vascular structures in their neighbourhood. The suboccipital, retromastoid (retrosigmoid) approach is efficient as well as sufficient to ensure resection of the majority of posterior petrous meningiomas with various localizations of dural attachment.
2. It is imperative for safe planning of surgical resection to establish the exact location of a dural attachment of the tumour in progress of preoperative diagnostic workup.
3. It is particularly difficult to achieve radical tumour resection while preserving normal function of facial nerve and auditory function in cases with the dural attachment located anteriorly and inferiorly to the internal acoustic meatus.
4. In our opinion, non-radical dissection of a meningioma should be combined with early adjuvant, stereotactic radiotherapy.

Disclosure

Authors report no conflict of interest.

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