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ORIGINAL ARTICLE

Sphenoid wing meningiomas: peritumoral brain edema as a prognostic factor in surgical outcome

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Abstract
Sphenoidal meningiomas constitute 18% of intracranial masses, and still present a difficult surgical challenge. PTBE has been associated with several complications and future recurrence. This study aims to evaluate the outcome of the operatively treated sphenoid wing meningiomas in relation to PTBE as a prognostic factor in a series of 65 patients. The clinical materials of 65 patients with SWM treated microsurgically between 2007 and 2020 were analyzed retrospectively. Follow-up ranged from 6 to 156 months (median, 86). Clinical outcomes include postoperative major neurological deficit, quality of life using KPS, recurrence, and mortality rates. The mean age of patients was 53.9 years (range 20–74), males 24.6% and females75.4%. An edema index (EI) of 1 (40%) was considered as absent edema, and EI > 1 (60%) indicated present edema. Total resection (Simpson I–II) was achieved in 64.6% and subtotal (Simpson IV) in 13.8%. Postoperative complications included vision impairment in 3 patients, motor weakness 6, third nerve palsy 6, intraoperative bleeding and edema 5, and MCA infarct 2, recurrence in 17% and 7.7% died. In univariate analysis, we found that the PTBE is one of the serious risk factors in the immediate surgical outcomes and complication, though more data is needed to support this claim, while having a negative effect on postoperative KPS at short-term follow up ($\chi^2 = 6.44$, $p = 0.011$). PTBE was associated with decline in KPS and quality of life in the early postoperative period (three months) while showing no significant effect at long-term outcomes.

Keywords Sphenoid wing meningioma · Quality of life · Peritumoral brain edema · Mortality

Introduction

Meningioma is a benign, neoplastic lesion most often originating from arachnoid cells [1]. The SWMs account for 20% of intracranial meningiomas and represent a great surgical challenge due to their invasion of the bone and, especially, to their close relationship with internal carotid artery (ICA), middle cerebral artery (MCA), and cranial nerves [2]. Neuroradiological imaging is essential in the diagnosis and management of meningioma, and includes conventional and advanced imaging techniques like computed tomography (CT), magnetic resonance imaging (MRI), and nuclear medicine [3]. Meningiomas of the sphenoid wing and frontobasal regions are frequently associated with edema in the adjacent brain, which may be seen in 46 to 92% of cases as a low-density area surrounding the lesion on CT. Vasogenic edema surrounding tumors is often not well visualized on CT and can be better seen on MRI sequences [4]. PTBE not only causes intra- and post-operative difficulties but also has been implicated as an important factor for causing post-operative recurrence [5, 6]. Traditional microsurgical approaches for resection of SBMs involve open microscopic craniotomy with fine tumor microdissection. The World Health Organization (WHO) grade and extent of resection using the Simpson scale are still the most important prognostic factors for meningioma [7, 8].

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Materials and methods

Between January 2007 and December 2020, a total of 74 patients with SWM were treated in Uzhhorod Regional Center of Neurosurgery and Neurology. Nine patients were lost to follow-up and were thus excluded from statistical analysis. The clinical data of 65 patients were reviewed retrospectively. Sixteen male (24.6%) and 49 female (75.4%) patients were included in our study, with an age range of 20–74 years (mean 53.9 years, median 54 years). Tumor presented with impaired vision in 20 patients (30.8%), headache in 48 patients (73.8%), third nerve dysfunction in 5 (7.7%), exophthalmos in 5 (7.7%), motor weakness in 8 (12.3%), and aphasia in 7 (10.8%) cases. Each patient's preoperative and postoperative quality of life was assessed using KPS. Preoperative KPS was 80–100% in 11 patients (16.9%), and KPS 50–70 in 54 patients (83.1%); no patients had KPS ≤ 40. We enrolled patients with complete clinical data regarding patients' demographics, clinical history, radiographic findings, operative details, anesthetic record, tumor characteristics, and pathological record. In this study, the WHO Classification of Tumors of CNS and Simpson Grade for extent of tumor resection were used.

Radiologic examination and follow-up

All patients underwent MRI preoperatively with and without gadolinium. MRA and/or CTA were performed in majority of cases. In all operated cases, a CT scan was performed the next day after surgery. After discharge from the hospital, patients were followed up from 6 to 156 months (median — 86 months). In all cases, serial MRI was performed during follow-up. Information about the postoperative quality of life and recurrence was collected by telephone interviews or via clinical examination and imaging.

Tumor volume and brain edema

Brain edema is defined as an expansion of the brain volume due to increased water and sodium content [9]. Though the exact mechanism involved in the development of PTBE is not clearly understood, there are several factors directly included in PTBE pathophysiology such as tumor size, localization, histological grade, venous thrombosis, vascularization, gender, hormone receptor expression, growth factor expression, and microcortical invasion [10, 11]. However, none of these factors have convincingly established a role in the development of PTBE.

Tumor volume and volume of edema were measured by independent neuroradiologists on preoperative T1 contrast-enhanced and T2-weighted MRI sequences. Three maximal diameters of the tumor were measured using axial (A), sagittal (B), and coronal (C) T1 contrast-enhanced scans, and tumor volume was calculated: $V = A \times B \times C/2$. The volume of edema was calculated using the same approach on T2-weighted sequences. The extent of PTBE was assessed by the first author, measuring the edema index (EI): EI = (V tumor + V edema) / (V tumor).

An EI of 1 was considered as absent edema, an EI more than 1 as present edema. The degree of PTBE was classified as follows:

- EI = > 1– < 2 — mild PTBE
- EI = 2– < 3 — moderate PTBE
- EI = 3 and more — severe PTBE

Surgical techniques

The initial goal of the surgical management of all SWMs was complete resection with the preservation of surrounding neurovascular structures and their function. In cases where complete resection posed a great risk of injury to surrounding structures, the goal was modified to maximum safe removal of the tumor. Majority of tumors were removed via classic pterional approach, and in cases of large SWMs with bone invasion or severe PTBE, an extended pterional approach was used. Since 2015, an extradural anterior clinoidectomy was routinely performed for medial sphenoid wing meningiomas. No significant dynamic changes of the extent of resection and surgical complication rate throughout the study period were noted.

Perioperative management

Seizures were managed with anticonvulsants after the first seizure, and patients were closely followed with the prescribed medication for at least 3 months after surgery. PTBE was not routinely managed with steroids before surgery, but according to institution protocol they were prescribed in the postoperative period. The dosage of dexamethasone after surgery was 8–16 mg per day for the period of 5 to 10 days. In cases of symptomatic edema after surgery, a standard protocol of treatment was used. The impact of dosage and duration of steroid treatment on the outcome was not assessed.

Pathologic studies

After the resection of the tumor, histopathological and immune histochemical analysis was performed. Meningiomas were classified according to WHO classification of tumors of the central nervous system. Fifty-two tumors were grade I (80.0%), subdivided into endothelial type (35 cases, 53.8%), fibrous (7 cases, 10.8%), transitional (3 cases, 4.6%), angiomatous (6 cases, 9.2%), and psamomatous type found in a single patient. Grade II or atypical type was found in 11 cases (16.9%), and grade III or anaplastic type was found in 2 cases (3.1%).

Statistical analysis

All data transformations and analysis were carried out in R4.0.0. The difference in proportions of nominal variables has been evaluated with Pearson χ^2 test with Yates continuity correction or Fisher's exact test regarding if the smallest count is greater or less than 5 in the contingency table. The difference in ordinal variable (edema severity, outcomes, KPS) between two groups was studied with cumulative link logistic regression (R package "ordinal"). In order to assess the effect of the edema index on pre- and post-operative outcomes, censored regression (Tobit model) was used with left censoring at 1 (R package censReg). The univariate analysis of the total number of symptoms was carried out with Poisson regression. The statistical significance of all regression models was evaluated with the likelihood ratio test. The Wilcoxon-Mann–Whitney test was used to compare the age of patients between groups, since age distribution violates the normality assumption.

Results

Majority of cases were females (49 cases, 75.4%) as compared to males (16 cases, 24.6%); the F/M ratio was 3.1:1. There was no statistical difference between median age of male (58, IQR = 5.5) and female (53, IQR = 12) patients ($W = 293$, $p = 0.13$). The edema was found in 39 (60.0%) cases with rather even distribution across genders (Table 1).

The anatomical location in this study was classified into 3 groups: lateral and middle — in 34 (52.2%) cases, medial — 23 (35.4%), SOM — 8 (12.4%). The SOM location was associated with a lesser risk of PTBE ($p = 0.10$) and smaller overall edema index ($\chi^2 = 4.48$, $p = 0.034$). The correlation between edema and anatomical location is summarized in Table 2.

Symptoms and signs

The preoperative clinical symptoms and signs included headache, visual acuity impairment, motor weakness, seizure, proptosis, dizziness, vomiting, and cognitive decline (Table 3). Of these symptoms and signs, headache was found in 48 (73.8%) cases, followed by seizures in 14 (21.5%) cases. During the early postoperative period, headache significantly improved in the vast majority of patients 45 (93.7%). However, full headache relief has been obtained in 13 (44.8%) PTBE patients versus 18 (94.7%) patients without PTBE. The difference has been found to be statistically significant with $\chi^2 = 13.4$, $p = 0.00025$. Long-term headache status does not differ in patient groups with or without PTBE ($\chi^2 = 1.45$, $p = 0.48$).

Preoperative seizures were recorded in 14 (21.5%) patients. The prevalence of seizure symptoms in PTBE patients was 28.2% (11 patients) while only 3 patients without PTBE (11.5%) had seizures ($p = 0.13$). In the early postoperative period, 9 patients were seizure-free (64.3%) patients. All 5 unimproved cases were found in the PTBE

Table 1 Incidence of edema according to age and gender

	Gender		Statistical significance
	Male ($n = 16$)	Female ($n = 49$)	
Age (median, quartiles)	58, 55.25–60.75	53, 48–60	$W = 293$, $p = 0.13$
< 40	1 (6.3%)	5 (10.2%)	
40–49	1 (6.3%)	12 (24.5%)	
50–59	10 (62.4%)	18 (36.7%)	
60–69	4 (25.0%)	11 (22.5%)	
> 70 years and more	–	3 (6.1%)	
Edema	8 (50.0%)	31 (63.2%)	$\chi^2 = 0.42$, $p = 0.52$
Mild	4 (50.0%)	18 (58.1%)	$\chi^2 = 0.91$, $p = 0.34$
Moderate	2 (25.0%)	5 (16.1%)	
Severe	2 (25.0%)	8 (25.8%)	

Table 2 Incidence of edema according to anatomical location

Anatomical location	Number of cases	Present edema	Statistical significance
Lateral and middle	34 (52.2%)	23 (67.4%)	0.10 (Fisher's exact test)
Medial (clinoid)	23 (35.4%)	14 (60.8%)	
Spheno-orbital (SOM)	8 (12.4%)	2 (25%)	

Table 3 Preoperative common symptoms and signs

Preoperative symptoms and signs	Edema ($n=39$)	No edema ($n=26$)	Statistical significance
Headache ($n=48$)	29 (74.4%)	19(73.1%)	$\chi.^2=0.0$, $p=1$
Outcomes 3 months			
Cured	13 (44.8%)	18 (94.7%)	$\chi.^2=13.4$, $p=0.00025$
Improved	14 (48.3%)	-	
Unimproved	2 (6.9%)	1 (5.3%)	
Outcomes 3–24 months			$\chi.^2=1.45$, $p=0.48$
Cured	25 (86.2%)	18 (94.7%)	
Improved	2 (6.9%)	-	
Unimproved	2 (6.9%)	1 (5.3%)	
Seizures ($n=14$)	11 (28.2%)	3 (11.5%)	$p=0.13$*
Outcomes 3 months			
Cured	1	-	$\chi.^2=2.86$, $p=0.24$
Improved	5	3	
Unimproved	5	-	
Outcomes 3–24 months			
Cured	11	3	
Improved	-	-	
Unimproved	-	-	
Memory deficit ($n=5$)	3 (7.7%)	2 (7.7%)	
Behavior change ($n=3$)	2 (5.1%)	1 (3.8%)	
Vertigo ($n=4$)	3 (7.7%)	1 (3.8%)	
Diplopia ($n=3$)	-	3 (11.5%)	

*Fisher's exact test

group, though the difference does not reach statistical significance ($\chi^2=2.86$, $p=0.24$). Long-term follow-up shows seizure relief in all patients. Other minor symptoms and signs such as vomiting, vertigo, and cognitive decline (behavior, memory) were cured within the 2-year follow-up period.

None of the preoperative symptoms alone was found to be significantly prevalent in SWM patients with PTBE. The greatest attributable to PTBE risk is 16.7% for seizure symptom (risk ratio = 2.45); however, it is still insignificant in Fisher's exact test ($p=0.13$). The univariate analysis of preoperative seizures versus edema index using censored (Tobit) regression shows a significant association with $\beta=2.28$, $\chi^2=5.50$, and $p=0.019$.

The median number of preoperative common symptoms was 2 (LQ = 1, UQ = 2), and there was no difference in the number of preoperative common symptoms in patients with or without PTBE ($\chi^2=0.01$, $p=0.91$). The edema index had no effect on the number of general preoperative symptoms as well producing the same statistics value ($\chi^2=0.01$, $p=0.91$).

Vision impairment was the most common preoperative major neurological deficit (MND) in SWM patients with 30.7% prevalence (20 patients), followed by motor weakness (12.3%, 8 patients), aphasia (10.7%, 7 patients), third cranial nerve deficit (7.7%, 5 patients), and exophthalmos (7.7%, 5 patients). Preoperative neurological symptoms are summarized in (Table 4).

On early postoperative follow-up (3 months), vision improved in majority of cases 13 (65%). SWM patients without PTBE were more likely to report their vision symptom improvement in the early postoperative period (87.5%) compared to PTBE cases (50.0%). Due to the limited number of cases, the difference does not reach the statistical significance cutoff ($\chi^2=3.2$, $p=0.072$). Within 2 years of follow-up, 8 cases of vision impairment completely recovered, 7 cases improved, and 5 cases left unimproved. Among the unimproved patients, one became blind, one underwent eye evisceration, and two died. SWM patients with PTBE show inferior outcomes in terms of vision impairment, but the number of cases is too low to be statistically meaningful.

Third cranial nerve palsy completely resolved in 2 cases and has not improved in 3 cases within the follow-up period. Of note, patients who underwent evisceration of the eye due to infection and one of the patients who died in the early postoperative period were among the three patients without improvement. Within the first 3 months of follow-up, motor weakness symptoms improved in 4 patients (50%). The results of the 2-year follow-up demonstrate 5 cases with complete resolution of motor symptoms, 2 cases of partial recovery, and one patient who died. All cases of aphasia completely resolved during the long-term follow-up period.

Table 4 Preoperative major neurological deficit (MND)

Preoperative major neurologic deficit	Edema ($n=39$)	No edema ($n=26$)	Statistical significance
Vision impairment ($n=20$)	12 (30.8%)	8(30.8%)	$\chi^2=0.0$, $p=1$
Outcomes 3 months			
Cured	-	-	$\chi^2=3.2$, $p=0.072$
Improved	6 (50.0%)	7 (87.5%)	
Unimproved	6 (50.0%)	1 (12.5%)	
Outcomes 3–24 months			$\chi^2=0.14$, $p=0.71$
Cured	5 (41.7%)	3 (37.5%)	
Improved	3 (25.0%)	4 (50.0)	
Unimproved	4 (33.3%)	1 (12.5%)	
III cr. nerve deficit ($n=5$)	2 (5.1%)	3 (11.5%)	$p=0.38$*
Exophthalmos ($n=5$)	1 (2.6%)	4 (15.4%)	$p=0.15$*
Behavior change ($n=3$)	2 (5.1%)	1 (3.8%)	$p=1$*
Motor weakness ($n=8$)	7 (17.9%)	1 (3.8%)	$p=0.13$*
Aphasia ($n=7$)	5 (12.8%)	2 (7.7%)	$p=0.39$*

*Fisher's exact test

Surgical complications

A total of 85 surgeries were performed during the study period on 65 patients with SWM. None of the patients died during the preoperative period or immediate postoperative period. Three (4.6%) patients died within 30 days after surgery due to bleeding, pulmonary embolism, and infection. Other surgical complications consisted of 3 cases of postoperative bleeding, 2 cases of CSF fistula, and one case of empyema. On long-term follow-up, recurrence was diagnosed in 11 (17%) cases, and 3 patients had second recurrence. Gross total resection (Simpson I–II) has been achieved in 42 cases (64.6%), subtotal resection (Simpson III) in 14 cases (21.6%), and partial resection (Simpson IV) in 9 cases (13.8%). After the resection of the tumors, the specimen were sent for histological study.

Postoperative complications were classified as new major neurological deficit (NMND — vision deterioration, third cranial nerve palsy, motor deficit, and aphasia) and other complications (bleeding, infarction, infection and death). The most common complications among SWM patients were motor weakness and oculomotor nerve deficit, which occurred in 6 patients (9.3%). The patients with PTBE show greater risk of motor weakness as postoperative complication (12.8% versus 3.8%, $p=0.39$). All cases of postoperative motor weakness and oculomotor nerve deficit were temporary and have resolved in a period from few weeks up to 2 years. Postoperative optic nerve damage was found in 3 (4.6%) of SWM patients. All of these patients had PTBE, though it is still insufficient to draw any conclusion ($p=0.26$). New-onset postoperative seizures were found in 5 (7.7%) patients (Table 5). None of the NMND happened to be significantly correlated with PTBE presence. The highest risk ratio (RR = 3.37) was found for motor weakness, though the corresponding p value is 0.39. Post-operative bleeding and edema were found in 5 (7.7%) patients.

Table 5 Postoperative new major neurological deficit and other complications

Postoperative complications	Edema ($n=39$)	No edema ($n=26$)
Vision impairment ($n=3$)	3 (7.7%)	-
III cranial nerve deficit ($n=6$)	4 (10.3%)	2 (7.7%)
Motor weakness ($n=6$)	5 (12.8%)	1 (3.8%)
Aphasia ($n=1$)	1 (2.6%)	-
Seizures ($n=5$)	3 (7.7%)	2 (7.7%)
Bleeding and edema ($n=5$)	3 (7.7%)	2 (7.7%)
MCA infarction ($n=2$)	1 (2.6%)	1 (3.8%)
Infection /F/E ($n=4$)	3 (7.7%)	1 (3.8%)

Quality of life

KPS has been utilized to evaluate the quality of life in SWM patients in both the pre- and postoperative periods. Preoperative scores of 80 to 100 were found in 11 (16.9%) cases (Table 6). These patients were able to carry on normal activities and work with no special care needed. The preoperative Karnofsky Performance Scores of 50 to 70 were found in 54 (83.1%) cases. These patients were unable to work but could live at home with assistance needed. There were no KPS values of 0 to 40 in the preoperative time. Patients with PTBE tend to show lower values on the KPS scale, though the difference was insignificant ($\chi^2=2.26$, $p=0.13$).

In the early postoperative period, the status of most patients improved, with 46 (70.8%) patients in the 80–100 KPS range, 15 (23.0%) patients in the 50–70 KPS range, and 4 (6.2%) patients who died in that period. There is a statistically

Table 6 Correlation between PTBE and KPS in the pre and postoperative f/u

Karnofsky Performance Scores (KPS)	Total ($n=65$)	Present edema ($n=39$)	No edema ($n=26$)	Statistical significance
Preoperative				$\chi^2=2.26$, $p=0.13$
80	11 (16.9%)	5 (12.8%)	6 (23.1%)	
70	36 (55.4%)	21 (53.8%)	15 (57.7%)	
60	17 (26.2%)	12 (30.8%)	5 (19.2%)	
50	1 (1.5%)	1 (2.6%)	-	
40 and less	-	-	-	
Post op f/u 3 months				$\chi^2=6.44$, $p=0.011$
100	3 (4.6%)	1 (2.6%)	2 (7.7%)	
90	19 (29.3%)	8 (20.5%)	11 (42.3%)	
80	24 (36.9%)	15 (38.4%)	9 (34.6%)	
70	14 (21.5%)	11 (28.2%)	3 (11.6%)	
60	1 (1.5%)	1 (2.6%)	-	
50	-	-	-	
40 and less	4 (6.2%, died)	3 (7.7%)	1 (3.8%)	
Post op f/u 2 years				$\chi^2=1.07$, $p=0.30$
100	28 (43.1%)	15 (38.4%)	13 (50.0%)	
90	17 (26.2%)	11 (28.2%)	6 (23.1%)	
80	8 (12.3%)	4 (10.3%)	4 (15.4%)	
70	7 (10.7%)	5 (12.8%)	2 (7.7%)	
60	-			
50	-			
40 and less	5 (7.7%, died)	4 (10.3%)	1 (3.8%)	

Table 7 Univariate analysis of various factors affecting mortality

Variables	Mortality	Statistical significance
Gender	$n=5$	
Female 49	4	$p=1$*
Male 16	1	
Simpson grade		
Grades I–II 42	1	$\chi^2=7.29$, $p=0.063$
Grade III 14	1	
Grade IV 9	3	
WHO Grade		
Grade I 52	2	$\chi^2=2.84$, $p=0.24$
Grade II 11	2	
Grade III 2	1	
PTBE		
Present 39	4	$p=0.64$*
Absent 26	1	

*Fisher's exact test

significant difference in 3-month KPS outcomes between patients with and without PTBE ($\chi^2=6.44$, $p=0.011$). In the late postoperative period, within 2 years of follow-up, 53 (81.6%) patients showed KPS values in the 80–100 range and 7 (10.7%) patients presented with disabilities (KPS 50–70). The total number of deaths in the 2-year follow up is 5 (7.7%). Late postoperative KPS outcomes still were slightly better in patients without PTBE, but statistically the difference is insignificant ($\chi^2=1.07$, $p=0.30$).

Mortality

The overall mortality rate was 7.7% (5 cases). Three patients died within the first month after surgery, with a 30-day postoperative morality rate of 4.6%. Two patients died between 3 and 6 months after surgery. Four (8%) patients were females (age range 44–74, median 58 years), and one is a 58-year-old male (6.3%). PTBE was found in 4 (80%) of these cases. The overall number of cases is too low to draw any statistical conclusion about the effect of PTBE, sex, Simpson Grade, or WHO Grade on mortality (Table 7).

Discussion

Meningiomas account for 14–19% of all primary intracranial tumors in adults, occur most commonly in females, and are the most common tumors of the sphenoid wing region [9, 12]. In this study, most of the patients (41.5%) were in the age category of 50–69 years which correlated with other studies [13]. Females were more than males in our study, with a female-to-male ratio 4:1. The latter finding corresponds with literature data — Violaris et al. found that females had 3 times the propensity to develop meningiomas as compared to males [14].

Our study showed PTBE in 60% of cases. Literature data indicates that most cases of meningioma that had PTBE were in the sphenoid ridge location — it has been found to be associated with more than half of the cases [15–17]. In other studies, PTBE is present in almost 60% of cases of supratentorial meningioma. It is caused by the secretion of vascular endothelial growth factor by the tumor and is closely associated with the presence of cortical pial blood supply of the tumor [18, 19]. The PTBE may limit operative exposure, increase the difficulty of surgical resection by restricting the amount of brain retraction possible, and increase the risk of post-op intracranial hematoma and hypertension [20, 21, 21]. This might be due to the fact that PTBE had significant lower cerebral blood flow and volume in neural tissue adjacent to tumor [22]. The presence of PTBE in meningiomas is linked not only with intraoperative complications and difficulty in resection, but also with postoperative seizures and future recurrence. Though meningiomas are classically benign tumors, arising from the arachnoid cap cells, approximately 10% of them tend to recur [10]. In this study, we aimed to establish the role of PTBE on surgical outcomes.

Vision impairment was the most common symptom of SWM in our group (55% in medial SWMs), followed by headache, confirming the results of other studies [23–25]. We found no significant relationship between PTBE incidence, and the preoperative headache, seizures, and other general symptoms. Short-term symptom relief was correlated with edema ($p = 0.00025$ for headache, $p = 0.24$ for seizures, $p = 0.072$ for vision impairment). Brain edema shows no impact on the incidence of the preoperative vision impairment, III cranial nerve deficit, exophthalmos, behavioral changes, or aphasia but seems to increase the risk of motor weakness significantly ($p = 0.13$). In a remarkable number of patients with preoperative seizures, they persist postoperatively, severely reducing patients' quality of life and leading to the need of prolonged anticonvulsant treatment. Thus, in recent years, some studies addressed this topic with regard to risk factors for postoperative seizures. Interestingly, late postoperative seizures occur more frequently than early ones according to the literature [26–29]. Further research is still needed to clarify the effect of PTBE on neurological symptoms in SWM patients.

Moussa et al. described motor weakness, transient cognitive decline, and seizure as main postoperative complications [30]. The most common postoperative complications in our study were motor weakness, oculomotor nerve palsy, and new-onset seizure. New motor deficit and oculomotor palsy were observed in 6 cases each (9.3%), with 5 of them in both instances had preoperative PTBE ($p = 0.39$). Lieu et al. found strong evidence that cerebral edema is one of the most important risk factors for postoperative seizures independent of tumor size [31]. New-onset post-op seizure was seen in 5 cases from the present series, with 3 of them having PTBE.

Assessment of quality of life before surgery and continuously over the follow-up period is a hospital routine for patients with brain tumors. There was no statistically significant difference in preoperative KPS between PTBE and PTBE-free groups ($\chi^2 = 2.26$, $p = 0.13$). But we have found a negative role of PTBE on the postoperative KPS and quality of life within 3 months of follow-up ($\chi^2 = 6.44$, $p = 0.011$), while this correlation disappeared when assessing long-term results ($\chi^2 = 1.07$, $p = 0.30$). Steroids have been frequently used to counter the PTBE in primary parenchymal brain tumors to lower the surgical complication rate, but their usage in meningiomas remains inconclusive [32].

The overall survival of surgically treated SWM patients within a median of 86 months follow-up was 92.3%, and the recurrence rate was 16.9%. Of note, in 72.7% of recurrent cases PTBE was present during the initial treatment. This fact is explained by the difficulty of complete tumor resection in the presence of edema — 7 out of 9 patients (78%) with Simpson IV resection in the series had preoperative PTBE. Brain edema is a notorious factor for most surgeons, not only impacting the incidence of postoperative complications and higher risk of recurrence, but also as a factor for intraoperative complications and a significant predictor of morbidity. Most frequent intraoperative difficulties are loss of dissection plane at the brain-tumor interface leading to surgical difficulty during resection, new-onset post-operative seizures, and new neurological deficit. Moreover, PTBE has been associated with a higher risk of postoperative intracranial hematoma and subsequent intracranial hypertension, higher risk of blood transfusion, and prolonged hospital stay [22, 33–35]. Significant intraoperative bleeding was more frequent in patients with edema — 4 out of 5 cases (80%) in our series with intraoperative bleeding were from the PTBE group. Both patients who required secondary surgery due to intraoperative bleeding and subsequent intracranial hypertension had PTBE preoperatively. Three patients died within 30 days after surgery, two of them — from the PTBE group.

The present study highlights the negative effect of preoperative PTBE on short-term surgical outcome despite of the edema index score. Most likely, the increase in severity of edema would be associated with more complications; however, this could not be justified by our analysis. However, in our previous publication we found that PTBE is a negative predictor for recurrence and severity of edema is associated with shorter time to recurrence [36].

Conclusion

In this study, the PTBE was present in approximately 60% cases of SWM with rather even distribution across genders. The PTBE is one of the serious risk factors affecting the immediate surgical outcome and complication rate including mortality/morbidity in the early postoperative period, and the incidence of tumor recurrence within a long-term follow up. Presence of PTBE is associated with a negative effect on postoperative KPS and quality of life within the 3-month follow up, while it has no significant effect on long-term outcome.

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Data availability Data is presented in tables and figures, as it is a systemic review.

Code availability Not applicable.

Declarations

Ethics approval Not applicable.

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Consent for publication Not applicable.

Conflict of interest The authors declare no competing interests.

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