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Original Article

Factors associated with improved Karnofsky performance status after surgery for petroclival meningiomas: a 10-year follow-up retrospective study

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Abstract: Objectives: Petroclival meningiomas, generally, have a good prognosis. However, neurological dysfunction, complications, and recurrence/progression after surgery seriously affect the long-term quality of life of patients. The aim of the current study was to determine factors involved in improvement of Karnofsky performance scores (KPS) after surgery for petroclival meningiomas. Methods: A retrospective study of 163 patients with petroclival meningiomas was conducted. Patients underwent surgery between May 2006 and October 2015 at Sanbo Brain Hospital (China). According to changes in KPS during long-term follow-ups, the patients were divided into improvement and no improvement groups. Prognostic factors associated with improvements in KPS were identified. Results: Compared with the no improvement group, the KPS improvement group had lower preoperative KPS scores ($P < 0.001$), higher postoperative KPS scores ($P = 0.021$), and higher frequencies of cranial nerve 1 involvement ($P = 0.029$). Compared with the no improvement group, the improvement group showed higher postoperative KPS scores ($P < 0.001$), as well as higher rates of gross total resection, subtotal resection + radiotherapy, and subtotal resection (all $P < 0.001$). Multivariable analysis revealed that duration of symptoms (OR = 0.985, 95% CI: 0.972-0.998, P = 0.021), preoperative KPS (OR = 0.798, 95% CI: 0.710-0.860, P < 0.001), and postoperative KPS (OR = 1.153, 95% CI: 1.092-1.218, P < 0.001) were independently associated with improvements in long-term KPS after treatment. Cranial nerve involvement, surgical approach, and extent of resection were not associated. Conclusion: Present results suggest that duration of symptoms, preoperative KPS, and postoperative KPS are associated with improved long-term KPS after surgery for petroclival meningiomas.

Keywords: Petroclival meningioma, recurrence/progression, surgical treatment, prognostic factors, quality of life, Karnofsky performance score

Introduction

Petroclival meningiomas account for approximately 3-10% of posterior fossa meningiomas [1]. These tumors have a total surgical resection rate of 32-61%, mortality rate of 0-1.2%, complication rate of 31-65.9%, and neurological dysfunction rate of 22-37.8% [1-7]. Indeed, surgical resections of petroclival meningiomas are extremely difficult and challenging due to tumor characteristics, the deep anatomical location in the skull base, and proximity to complex and important nerves and blood vessels. Petroclival meningiomas, generally, have a good prognosis. However, long-term neurological dysfunction and severe complications after surgery seriously affect the long-term quality of life of patients.

Individualized treatment plans are particularly important for treatment of patients with petroclival meningiomas. These plans should be able to achieve maximal tumor resections. They should preserve important nerves and blood vessels, reduce postoperative complications and neurological dysfunction, and improve the long-term quality of life of patients. Reasonable treatment plans should be based on patient age, physical conditions, tumor characteristics, neurologic status, and surgeon experience [1]. Many studies have shown that tumor characteristics, surgical approach, adjuvant therapy, and postoperative neurological dysfunction/complications can affect the long-term quality of life of patients. These studies, however, had several limitations, including small sample sizes, short follow-ups, and incomplete observation factors [3, 5, 7-9]. These studies also lacked detailed comparisons of neurological dysfunction and analysis of complications before and after surgery.

Therefore, the present retrospective study aimed to analyze general conditions, tumor characteristics, treatment modality, and short- and long-term prognostic indicators of patients with petroclival meningiomas, determining factors involved in improvement of long-term Karnofsky performance scores (KPS) [10]. Current results should help clinicians in employing optimal individualized treatment strategies, aiming to achieve maximum tumor resections while preserving important neurovascular structures, reducing postoperative complications and neurological dysfunction, and improving the long-term quality of life of patients.

Materials and methods

Study design

The current retrospective study was conducted for patients undergoing surgery for petroclival meningiomas, between May 2006 and October 2015, at Sanbo Brain Hospital (China). The study design complied with ethical principles of the Declaration of Helsinki and was approved by the Sanbo Brain Hospital Medical Ethics Committee of Capital Medical University.

Patients

Inclusion criteria: 1) age ≥ 18 years old; 2) confirmed diagnosis of petroclival meningiomas; and 3) underwent scheduled surgery. Patients with incomplete data were excluded.

Grouping

According to changes in KPS during follow-ups, the patients were divided into improvement and no improvement groups.

Neuroradiological imaging evaluation

All patients underwent computed tomography (CT) and magnetic resonance imaging (MRI) scans before surgery. Based on the tumor equivalent diameter (TED) formula [$(D1 \times D2 \times D3)^{1/3}$], the maximum diameter of the tumor on the sagittal, coronal, and axis planes was defined as D1, D2, and D3, according to the enhanced MRI. Petroclival meningiomas were divided into four categories, including small (< 1.0 cm), medium (1.0-2.4 cm), large (2.5-4.4 cm), and giant (≥ 4.5 cm) [1]. Brain CT with a bone window can be used to determine osteoproliferation or tumor invasion at the skull base, as well as the severity of cerebellar tonsil herniation. Contrast-enhanced brain MRI scans can identify the origin of the tumor base. This can be used to divide petroclival meningiomas into the three regions, including clival, petroclival, and sphenopetroclival portions [1, 8]. T1-weighted MRI images can determine tumor blood supply and consistency. T2-weighted images can determine the presence of peritumoral brain edemas and the tumor border, particularly the arachnoid border between the brainstem and the tumor. Postoperative enhanced MRI images were obtained for extent of resection (EOR) determination in each patient within 1 month of surgery. EOR was divided into gross total resection (GTR), subtotal resection (STR), and partial resection (PTR).

Treatment strategies

Before admission, treatment strategies included surgery, surgery plus radiotherapy, surgery plus gamma-knife treatment, and careful observation. Most patients received conservative careful observation. All patients underwent surgical treatment after admission. A small number of patients underwent a second surgery. Adjuvant radiotherapy or gamma-knife treatment was given due to postoperative residual tumor tissues within 3 months of surgery. Patients undergoing STR or PTR (Simpson Grade III-IV) and GTR (Simpson Grade I/II) with a pathological grade II-III meningiomas, according to the 2016 World Health Organization (WHO) classification of tumors of the central nervous system [11], received adjuvant radiotherapy or gamma-knife treatment within 3 months of surgery. No adjuvant radiotherapy or gamma-knife treatments were given to patients that underwent GTR (Simpson Grade I/II) with a pathological grade I meningioma.

Surgical treatment

The use of various surgical approaches to reach petroclival meningiomas was guided by the origin of the tumor base relative to the dura mater of the skull base, size of the lesion, skull base portion involved, relationships between neurovascular structures and tumor, and preoperative imaging evaluations (CT/MRI). Indications for selection of the surgical approach were as follows. A temporooccipital craniotomy sub-temporal transtentorial petrosal apex approach was used for the removal of petroclival meningiomas originating from the upper third of the clivus or the lower edge of the petroclival fissure base, not lower than the level of the plane of the internal auditory canal and extending toward the interpeduncular fossa, side of the brain stem, the anterior or posterior petrous apex, the superior or inferior tentorial notch, and the posterolateral wall of the cavernous sinus. A frontotemporal craniotomy pterional or orbitozygomatic approach was used for the removal of tumors extending toward the suprasellar cistern, optic chiasm, superior and inferior orbital portion, lateral wall of the orbit, dorsum sellae, parasellar, lateral wall of the cavernous sinus, or the base of the middle cranial fossa. A suboccipital retrosigmoid approach or superior and inferior tentorium transpetrosal presigmoid approach was used for the removal of tumors originating from the upper two-thirds of the clivus or the lower edge of the petroclival fissure base, not lower than the level of the jugular foramen and extending toward the ventral pons, cerebellopontine angle and prepontine cistern, dorsum of the petrous bone, and inferior tentorial notch. A far-lateral transcondylar approach was used for the removal of tumors that extended below the level of the jugular foramen to the inferior clivus or the foramen magnum. A combined subtemporal transtentorial and suboccipital retrosigmoid approach or combined suboccipital retrosigmoid and far-lateral transcondylar approach was used for the removal of giant or large petroclival meningiomas that had a wide base and involved two or more cranial fossa.

Operative time was defined as the time from incision of the scalp to closure of the scalp. Fluids were aspirated into a reservoir bottle for blood recycling. The amount of intraoperative blood loss was determined as the fluid amount in the reservoir bottle subtracted from the amount of rinsing fluid. Adhesive drapes were used to cover the operative field and surgical sheets were used to avoid the outflow of blood or blood absorbance by surgical sheets. The bag below the operative field completely collected the blood and rinsing fluid.

Follow-ups

Thirteen patients (7.4%) were lost to follow-up. Their mailing addresses or phone numbers had changed. One hundred sixty-three out of the 176 patients (92.6%) completed follow-ups in July 2016. The median follow-up was 38.5 months (interquartile range: 44.8 months). Follow-ups were performed via outpatient visits, phone calls, and mailed questionnaires. Follow-up visits mainly included an assessment of enhanced brain MRI scans, clinical symptoms, and signs. The function of the facial nerves was evaluated using the House and Brackmann (HB) score grading system.

Quality of life was assessed using KPS, preoperative KPS, postoperative KPS, and final KPS (the last follow-up). KPS improvement indicates that the final KPS was higher than the preoperative KPS. No KPS improvement indicates that the final KPS was lower than or equal to the preoperative KPS.

Tumor recurrence is defined as any newly identified enhancement after GTR (Simpson Grade I/II). Tumor progression is defined as any amount of increase of enhancing tumor volume after STR (Simpson Grade III/IV) or PTR (Simpson Grade IV) [12].

Statistical analysis

Data analysis was performed using SPSS 21.0 (IBM, Armonk, NY, USA). Microsoft Office Excel 2007 (Microsoft Corporation, Redmond, WA, USA) was used to record data. Continuous data were analyzed using Kolmogorov-Smirnov tests, determining their distribution. Normally distributed data are presented as mean ± standard deviation with 95% confidence intervals (CI). They were analyzed using ANOVA with the LSD post-hoc test. Non-normally distributed data are presented as medians and interquartile ranges. They were analyzed using Mann-Whitney U-tests. Categorical variables are presented as frequencies and were analyzed using Chi-square tests. Multivariable logistic regression analysis was used to assess multiple factor effects, including variables found to be significant in univariable analyses. P-values < 0.05 indicate statistical significance.

Results

Patient characteristics

Clinical data of 227 patients that underwent surgical treatment for petroclival meningiomas, between May 2006 and October 2015, was retrieved. Fifty-one patients were excluded according to the diagnostic criteria of occurrence and origin of petroclival meningiomas. Thirteen patients were excluded because of loss to follow-up. Therefore, 163 patients were included in this study. Based on KPS, the patients were classified as KPS improvement (n = 85) or no KPS improvement (n = 78) (**Table 1**). There were no differences between the two groups regarding age, gender, duration of symptoms, hospital stay, preoperative neurological dysfunction, symptoms, previous treatments, present treatments, extent of resection, operative time, and intraoperative bleeding (all P > 0.05). Compared with the no improvement group, the KPS improvement group had lower preoperative KPS scores (P < 0.001), higher postoperative KPS scores (P = 0.021), and higher frequencies of cranial nerve 1 involvement (P = 0.029).

Tumor characteristics

Table 2 shows tumor characteristics. There were no differences between the two groups regarding tumor size, peritumoral edema, AB between tumor and NVS, tumor consistency, tumor vascularity, skull base bone changes, tumor differentiation, and tumor histology (all P > 0.05).

Postoperative clinical characteristics

Table 3 shows postoperative characteristics of the patients. Compared with the no improvement group, the improvement group showed higher postoperative KPS scores (P < 0.001), as well as higher rates of gross total resection, subtotal resection + radiotherapy, and subtotal resection (all P < 0.001). There were no differences between the two groups regarding recurrence/progression (P = 0.383) and facial nerve function (P = 0.577).

Multivariable analysis

Factors associated with KPS improvement in univariable analyses were included in multivariable analysis. Duration of symptoms was included to adjust results. It may affect outcomes since it is associated with the aggressiveness of the disease [13]. Multivariable analysis revealed that duration of symptoms (OR = 0.985, 95% CI: 0.972-0.998, P = 0.021), preoperative KPS (OR = 0.798, 95% CI: 0.710-0.860, P < 0.001), and postoperative KPS (OR = 1.153, 95% CI: 1.092-1.218, P < 0.001) were independently associated with improvements in KPS after treatment. Cranial nerve involvement, surgical approach, and extent of resection were not associated (**Table 4**).

Discussion

Most petroclival meningiomas are benign tumors. However, neurological dysfunction, complications, and recurrence/progression after surgery seriously affect the long-term quality of life of patients. Therefore, the aim of the present study was to determine factors involved in improvement in KPS after surgery for petroclival meningiomas. Compared with the no improvement group, there was significant correlation between the KPS improvement group and lower preoperative KPS scores (P < 0.001), higher postoperative KPS scores (P = 0.021), and higher frequencies of cranial nerve 1 involvement (P = 0.029). Regarding postoperative characteristics, the improvement group showed higher postoperative KPS scores (P < 0.001), as well as higher rates of gross total resection, subtotal resection + radiotherapy, and subtotal resection (all P < 0.001), compared with the no improvement group. In KPS improvement and no-improvement groups, 17.6% and 6.4% of the patients, respectively, experienced tumor adhesion or engulfment of one cranial nerve. Obviously, patients with intraoperative tumor adhesion or engulfment of a cranial nerve had better postoperative neurological function recovery and long-term quality of life levels. However, there were no significant differences between patients with tumor adhesion or engulfment of two or more cranial nerves in the two groups. Therefore, preoperative image evaluations and intraoperative location of cranial nerves and tumors are very important. They might influence postoperative neurological function recovery and long-term quality of life. Compared with the KPS no-improvement group, the KPS improvement group had higher KPS scores after the operation. This suggests that higher KPS scores after the operation were closely related to improvements in

Table 1. Baseline characteristics

Variables	KPS improvement n = 85	No KPS improvement n = 78	P
Age (years)	48.1 ± 12.3	49.5 ± 11.9	0.326
Gender, female, n (%)	61 (71.8)	52 (67.5)	0.481
Duration of symptom (months)	25.3 ± 27.6	35.4 ± 49.8	0.108
Asymptomatic patients (n)	0	4	
Duration of admission (days)	25.7 ± 11.2	30.0 ± 31.6	0.233
Preoperative KPS	68.7 ± 9.9	77.5 ± 14.1	< 0.001
Postoperative KPS	67.4 ± 15.3	60.9 ± 20.2	0.021
Preoperative neurological dysfunction and symptoms, n (%)			
M/H	15/85 (17.6)	12/78 (15.6)	0.698
CNs involved, n (%)			0.066
1	15/85 (17.6)	5/78 (6.4)	0.029
2	9/85 (10.6)	12/78 (15.4)	0.361
3	11/85 (12.9)	18/78 (23.1)	0.091
≥ 4	44/85 (51.8)	40/78 (51.3)	0.951
Ataxia	25/85 (29.4)	21/78 (27.3)	0.724
Dysarthria	5/85 (5.9)	2/78 (2.6)	0.511
Gait	24/85 (28.2)	24/78 (31.2)	0.723
Dizziness	27/85 (31.8)	22/78 (28.6)	0.621
Epilepsy	5/85 (5.9)	2/78 (2.6)	0.511
Headache	30/85 (35.3)	29/78 (37.7)	0.802
Hydrocephalus	34/85 (40.0)	29/78 (37.7)	0.712
Previous treatment, n (%)			
Surgery	7/85 (8.2)	6/78 (7.8)	0.898
Surgery + radiotherapy	2/85 (2.4)	1/78 (1.3)	1.000
Surgery + GKS	9/85 (10.6)	8/78 (10.3)	0.729
Observation	67/85 (78.8)	63/78 (80.8)	0.757
Present treatment, n (%)			0.391
Surgery	60/85 (70.6)	54/78 (70.1)	
Surgery + radiotherapy	5/85 (5.9)	9/78 (11.7)	
Surgery + GKS	20/85 (23.5)	15/78 (19.5)	
Surgical approach, n (%)			0.124
Frontotemporal/orbitozygomatic osteotomy	3/85 (3.5)	4/78 (5.2)	
Presigmoid	14/85 (16.5)	11/78 (14.3)	
Retrosigmoid	23/85 (27.1)	21/78 (26.0)	
Subtemporal transtentorial petrosal apex	30/85 (35.3)	32/78 (41.6)	
Far-lateral transcondylar	9/85 (10.6)	1/78 (1.3)	
Frontotemporal + subtemporal transtentorial petrosal apex	0	3/78 (3.2)	
Subtemporal transtentorial petrosal apex + retrosigmoid	6/85 (7.1)	5/78 (6.4)	
Retrosigmoid + far-lateral transcondylar	0	1/78 (1.3)	
Operative time (minutes)	436 ± 172	435 ± 142	0.972
Intraoperative bleeding (ml)	1099 ± 750	1089 ± 889	0.935

KPS: Karnofsky performance status; M/H: monoplegia or hemiplegia; CN: cranial nerve; GKS: gamma knife surgery.

long-term quality of life. On the other hand, age, intraoperative bleeding, symptomatic time, hospitalization time, preoperative neurological dysfunction and symptoms, pre-admission treatment, and surgical approach were not significantly different between the two groups. Size of the tumors, peritumoral edema, arachnoid interface between tumors and important cranial

Table 2. Tumor characteristics

Variables	KPS improvement n = 85	No KPS improvement n = 78	P
Tumor size (cm), n (%)			0.466
Small (< 1.0)	1	0	
Medium (1.0-2.4)	8	10	
Large (2.5-4.4)	54	44	
Giant (≥ 4.5)	15	19	
Peritumoral edema, n (%)	13/85 (15.3)	12/78 (15.6)	0.987
Brainstem	5/85 (5.9)	7/78 (9.1)	
Cerebellum	4/85 (4.7)	1/78 (1.3)	
Temporal lobe	4/85 (4.7)	3/78 (3.9)	
Thalamus	0	1/78 (1.3)	
AB between tumor and NVS, n (%)			0.296
Presence	23/85 (27.1)	13/78 (16.9)	
Absence between tumor and brainstem	21/85 (24.7)	22/78 (28.2)	
Absence between tumor and neurovascular structures	41/85 (48.3)	43/78 (55.1)	
Tumor consistency, n (%)			0.574
Soft	22/85 (25.9)	18/78 (23.4)	
Moderate	20/85 (23.5)	15/78 (19.2)	
Firm	43/85 (50.6)	45/78 (57.7)	
Tumor vascularity, n (%)			0.572
Moderate	22/85 (25.9)	17/78 (22.1)	
Hypervascularity	63/85 (74.1)	61/78 (76.9)	
Skull base bone erosion/osteoproliferation, n (%)	21/85 (24.7)	16/78 (20.8)	0.523
Tumor differentiation of regions involved, n (%)			0.847
Clival	5/85 (5.9)	5/78 (6.5)	
Petroclival	48/85 (56.5)	41/78 (51.9)	
Sphenopetroclival	32/85 (37.6)	32/78 (41.0)	
Tumor histology, n (%)			0.327
WHO Grade I	76	68	
Meningothelial meningioma	48/85 (56.5)	44/78 (57.1)	
Fibrous meningioma	5/85 (5.9)	4/78 (5.2)	
Transitional meningioma	18/85 (21.2)	14/78 (18.2)	
Psammomatous meningioma	2/85 (2.4)	2/78 (2.6)	
Angiomatous meningioma	2/85 (2.4)	1/78 (1.3)	
Secretory meningioma	1/85 (1.2)	3/78 (3.9)	
WHO Grade II	9	8	
Chordoid	2/85 (2.4)	1/78 (1.3)	
Atypical	7/85 (8.2)	7/78 (9.1)	
WHO Grade III	0	2	
Rhabdoid	0	1/78 (1.3)	
Anaplastic (malignant)	0	1/78 (1.3)	

KPS: Karnofsky performance status; AB: arachnoid border; NVS: neurovascular structures; WHO: World health Organization.

nerves and blood vessels and brainstem, tumor consistency, tumor blood supply, tumor erosion of skull base, and tumor location were not significantly different between the two groups. Two cases of malignant petroclival meningiomas (WHO Grade III) were included in the KPS no-improvement group, suggesting that the long-term quality of life of malignant petroclival meningioma patients is not good.

Patients with good long-term quality of life (KPS ≥ 80) accounted for 84.7% in the KPS improve-

Table 3. Final status and outcomes of the patients (n = 163)

Variables	KPS improvement n = 85	No KPS improvement n = 78	P
KPS score, n (%)			< 0.001
80-100	72/85 (84.7)	38/78 (48.7)	
50-70	13/85 (15.3)	25/78 (32.1)	
0-40	0	15/78 (19.2)	
Facial nerve function			0.577
Normal, no sign of facial nerve paresis	61/85 (71.8)	42/78 (53.8)	
Shallow FW, close eyes slightly, slight DOC while smiling	21/85 (24.7)	19/78(24.4)	
Shallow FW, close eyes with effort, slight DOC	3/85 (3.5)	4/78(5.1)	
Recurrence/progression	10/85 (11.8)	6/78 (7.7)	0.383
Gross total resection	34/85 (40.0)	2/78 (2.6)	< 0.001
Subtotal resection + radiotherapy	27/85 (31.8)	2/78 (2.6)	< 0.001
Subtotal resection	48/85 (56.5)	11/78 (14.1)	< 0.001
Deceased	0	13/78 (16.7)	NA
Surgery		4/78 (5.1)	
Postoperative complications		3/78 (3.8)	
Other disease		1/78 (1.3)	
Tumor recurrence/progression		5/78 (6.4)	

KPS: Karnofsky performance status; FW: forehead wrinkles; DOC: distortion of commissure.

Table 4. Long-term prognostic factors for improved KPS

Factors	OR	95% CI	P
Duration of symptom (months)	0.985	0.972-0.998	0.021
Preoperative KPS	0.798	0.740-0.860	< 0.001
Postoperative KPS	1.153	1.092-1.218	< 0.001
CN (two CNs involved)	0.229	0.027-1.941	0.176
Surgical approach	12.938	0.523-3.283	0.118
Extent of resection (partial resection)	0.263	0.038-1.823	0.176

OR: odds ratio; CI: confidence interval; KPS: Karnofsky performance status; CN: cranial nerve.

ment group and 48.7% in the KPS no-improvement group. Additionally, patients with lower long-term quality of life (KPS 50-70) accounted for 15.3% and 32.1%, respectively. There was a significant difference between the two groups (P < 0.001). Patients with poor long-term quality of life (KPS ≤ 40) accounted for 19.2% in the KPS no-improvement group. Results showed that most patients in the KPS improvement group had good long-term quality of life, while most patients in the KPS no-improvement group had lower long-term quality of life. Comparing preoperative KPS scores, results indicated that most patients with improved KPS scores had good long-term quality of life and prognosis. There were no significant differences in long-term neurological function and tumor recurrence and progression between the two groups. The total resection rate of tumors was 40% in the KPS improvement group and 2.6% in the KPS non-improvement group. Subtotal resection plus radiotherapy represented 31.8% and 2.6%, respectively, while subtotal resection represented 56.5% and 14.1%, respectively. These differences were significant (P < 0.001). Compared with the KPS no-improvement group, the KPS improvement group had higher rates of total resection and subtotal resection. In addition, most patients with total or subtotal resections had good long-term quality of life and prognosis. Dead patients represented 16.7% in the KPS no-improvement group: Four cases of operation-related deaths (5.1%), 3 cases of postoperative complications deaths (3.8%), 5 cases of recurrence/progression-related deaths, and 1 case of unknown death (1.3%). When the KPS score decreased after the operation, the patients experienced poor long-term quality of life and prognosis, even death.

Multivariable analysis results suggest that duration of symptoms, preoperative KPS, and postoperative KPS were associated with long-term improved KPS after surgical treatment for petroclival meningiomas. Taken together, results suggest that patients with low KPS before surgery had a higher probability of significant improvement after surgery. On the other hand, the association between postoperative KPS and improvement is by definition. Multivariable analysis showed no significant effects of involvement of two or more cranial nerves, the extent of resection, and the surgical approach on KPS improvement. However, it indicated that predictive factors included shorter symptomatic time, lower KPS scores before the operation, and higher KPS scores after the operation. As a result, patients with these factors had improved KPS scores and lower neurological dysfunction and complications, leading to good long-term quality of life and prognosis.

In recent years, individualized surgical approaches and intraoperative neurophysiological monitoring have helped to reduce postoperative complications and various neurological disorders after surgery. The treatment strategy for petroclival meningiomas has, therefore, changed from performing a total resection or maximum extent of resection to protecting and improving the long-term quality of life and minimizing postoperative complications and neurosurgical dysfunction [2-5, 14-22]. In addition to total resection of tumors, subtotal or partial resections with adjuvant radiotherapy or stereotactic radiosurgery (gamma-knife treatment) have become more common. These methods avoid damage to blood vessels or nerves and control or delay tumor progression and recurrence [23-27].

The long-term quality of life of patients with petroclival meningiomas is closely related to postoperative complications and recovery of neurological dysfunction. In the current series, the complications were similar to those previously observed [3, 4, 28-31]. Sekhar et al. [32] investigated the impact of preoperative and intraoperative factors on neurological function recovery in 75 patients with clival meningiomas that underwent surgery. Results showed that the following preoperative factors had a significant negative impact on postoperative neurological function: male gender, lower KPS scores, tumor size ≥ 2.5 cm, compression and edema of the brain stem, unclear arachnoid border, vascular encasement, and basilar artery blood supply. Difficult resections, absence of an arachnoid border, and partial resections had a negative impact on postoperative neurological function [32]. In addition, long-term follow-ups revealed that male gender, difficult resections, partial resections, basilar artery blood supply, and early postoperative neurological dysfunction were adverse prognostic factors for long-term neurological rehabilitation [32]. In the present series, the KPS improvement group showed that lower preoperative KPS scores were associated with KPS improvement, as in the study by Sekhar et al. [32]. However, there were no significant effects from gender, arachnoid border of tumor-to-brainstem, brainstem edema, and tumor size on KPS improvement. All patients in Sekhar's study had clivus meningiomas. The structural relationship between tumors and the ventral brainstem was close. Therefore, preoperative factors, such as the interface between tumors and brainstem, edema, and the size of tumors, directly affected neurological function after surgery. The present study showed that KPS improvement after surgery was significantly associated with lower KPS scores before surgery. Since most patients in the present series had mild symptoms before admission and conservative observations were performed, surgical treatment was not considered until the symptoms were severe. As a result, KPS scores were significantly lower than those before admission.

Little et al. [4] retrospectively reviewed 137 patients that underwent surgery for petroclival meningiomas, suggesting that preoperative factors cannot be used to sufficiently and accurately assess the risk of postoperative neurological disturbance. They found that intraoperative factors, such as adhesion between the tumor and the blood vessels and nerves, as well as the fibrous texture of the tumors, were independent predictors of a high incidence of postoperative neurological dysfunction. Neurovascular encasement and rich blood supply showed no negative effects on the rate of postoperative neurological deficits [4]. Thus, they concluded that intraoperative tumor characteristics could be used to more accurately assess neurological function and avoid the risk of postoperative neurological dysfunction. In the present study, tumor characteristics, such as tumor size, peritumoral edema, the arachnoid membrane interface between tumor and brain stem and important blood vessels and cranial nerve, tumor texture, and blood supply of tumors, were not significantly different between KPS improvement and no-improvement groups. Results indicated that these intraoperative factors had no significant effects on KPS improvement in patients after surgery. Obviously, current results are not consistent with the study by Little et al. [4]. Grouping might explain, at least in part, the discrepancies. Little et al. [4] analyzed the extent of tumor resection and neurological dysfunction after the operation with the criteria of whether or not to consider the characteristics of intraoperative tumors (fibrous texture of tumors and adhesion of tumors to nerves and vessels). This resulted in imbalanced groups (n = 31 vs. n = 106). For hard tumors with tight adhesion and unclear interface to the brain stem or important cranial nerve and vessels, present results are consistent with those of Little et al. [4]. To reduce neurological dysfunction after the operation, subtotal resections of the tumors is an appropriate choice. Therefore, the present study shows that the proportion of subtotal resections in the KPS improvement group was significantly larger than that in the KPS no-improvement group.

In the present study, multivariable analysis showed that duration of symptoms, preoperative KPS, and postoperative KPS were independently associated with improved KPS after treatment for petroclival meningiomas. Cranial nerve involvement, surgical approach, and extent of resection were not associated with improved KPS after treatment for petroclival meningiomas. Discrepancies among studies could be due to many factors, including surgical experience and skill, available techniques and technologies, radiotherapy planning, and postoperative management. Meningiomas are relatively indolent and slow-growing tumors [33]. Therefore, duration of symptoms is an indirect indication of tumor course, with longer durations likely to be associated with more advanced disease. However, this is not always the case since some tumors may display aggressive features [13]. Since the KPS indicates the extent of symptoms due to the compression of nervous and vascular structures by the tumor, patients with better preoperative KPS scores are more likely to have a long-term improved KPS and quality of life, compared with patients with worse KPS. Immediate postoperative KPS scores are also probably indicative of treatment success. They may be associated with better long-term KPS.

The present study had several limitations. It was a retrospective, non-randomized, and observational study. Therefore, present research results need to be improved. A prospective randomized cohort study is needed to investigate the trends of development and prognosis of petroclival meningiomas using multivariable analysis.

Duration of symptoms, preoperative KPS, and postoperative KPS were associated with improved KPS after treatment for petroclival meningiomas. Surgical treatment strategies for petroclival meningiomas must involve a trade-off between the extent of the resection, postoperative complications, and neurological dysfunction with long-time quality of life.

Disclosure of conflict of interest

None.

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