Functional outcome and morbidity after microsurgical resection of spinal meningiomas

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OBJECTIVE The aim of this study was to evaluate functional outcome, surgical morbidity, and factors that affect outcomes of surgically treated patients.

METHODS The authors retrospectively analyzed patients who underwent microsurgical resection for spinal meningiomas between 2009 and 2020. Patient data and potential variables were collected and evaluated consecutively. Functional outcomes were evaluated using univariate and multivariate analyses.

RESULTS A total of 119 patients underwent microsurgical resection of spinal meningioma within the study period. After a mean follow-up of 25.4 ± 37.1 months, the rates of overall complication, tumor recurrence, and poor functional outcome were 9.2%, 7.6%, and 5%, respectively. Age, sex, revision surgery, and tumor recurrence were identified as independent predictors of poor functional outcome. Obesity and surgeon's experience had an impact on the complication rate, whereas extent of resection and tumor calcification affected the rate of tumor recurrence.

CONCLUSIONS Microsurgical resection of spinal meningiomas remains safe. Nevertheless, some aspects, such as obesity and experience of the surgeons that result in a higher complication rate and ultimately affect clinical outcome, should be considered when performing surgery.

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KEYWORDS spinal meningiomas; clinical outcome; complications; tumor recurrence

MENINGIOMAS are the most common type of tumor that arise from arachnoid cells in the CNS. Spinal meningiomas account for approximately 12% of all meningiomas and are one of the most common intradural extramedullary spinal tumors, representing 25%–30% of all spinal tumors. The overall incidence of spinal meningioma is approximately 0.31–0.35 per 100,000 population. Meningiomas occur more often in women than in men and have a peak incidence in the 6th through 8th decades of life.^{1–6}

Risk factors, such as hereditary syndromes, environmental exposure to high-dose ionizing radiation, especially in childhood and prior trauma, are discussed to be associated with occurrence of meningiomas.^{7,8} Progressive spinal cord compression caused by spinal meningiomas leads to neurological deficits and influences functional outcome and quality of life. In this study, we report our experience with surgically treated patients for microsurgical resection of spinal meningiomas.

Methods

The study included all patients who underwent microsurgical resection of spinal meningioma between 2009 and 2020. Based on the aim of the study, only meningiomas below the foramen magnum were included and evaluated.

Information, including patient characteristics, radiological features, diabetes mellitus, arterial hypertension, BMI, initial symptoms, tumor location, number of affected spinal levels, surgical approach, surgeon experience (defined as < 10 and > 10 procedures having been previously performed), American Society of Anesthesiologists (ASA) Physical Classification, surgical time (time from skin incision to wound closure), length of hospital stay, and functional neurological status at admission and during the course of treatment, was recorded and further analyzed. The neurological status pre- and postoperatively at discharge as well as at follow-up at least 6 months postoperatively and at a later follow-up, were assessed using the Eastern Cooperative Oncology Group (ECOG) score

ABBREVIATIONS ASA = American Society of Anesthesiologists; ECOG = Eastern Cooperative Oncology Group; EOR = extent of resection.

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TABLE 1. ECOG performance status

Grade	ECOG
0	"Fully active, able to carry on all pre-disease performance without restriction"
1	"Restricted in physically strenuous activity but ambulatory and able to carry out work of a light or sedentary nature, e.g., light house work, office work"
2	"Ambulatory and capable of all selfcare but unable to carry out any work activities. Up and about more than 50% of waking hours"
3	"Capable of only limited selfcare, confined to bed or chair more than 50% of waking hours"
4	"Completely disabled. Cannot carry on any selfcare. Totally confined to bed or chair"
5	"Dead"

From Oken, Martin, Creech, Richard, Tormey, Douglass, et al. Toxicity and response criteria of the Eastern Cooperative Oncology Group. *Am J Clin Oncol*. 1982;5(6):649–656. Cited in: Journals@Ovid Full Text at <http://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=reference&D=ovfta&NEWS=N&AN=00000421-198212000-00014>. Accessed March 16, 2021.

describing patient ability and level of neurological independence (Table 1).⁹

Surgery was performed using a standard dorsal approach with laminectomy or hemilaminectomy. In selected cases with multilevel tumor involvement, a laminoplasty was performed instead. The extent of resection (EOR) was classified according to the Simpson grading system.¹⁰ The amount of tumor resection was rated as total resection (Simpson grade I or II), subtotal resection (Simpson grade IV), or biopsy (Simpson grade V); no case of Simpson grade III resection was seen on review of the surgical reports. The EOR was assessed by the surgical report as recorded by the surgeon and on early postoperative MRI (< 72 hours). Somatosensory evoked potentials and motor evoked potentials were routinely monitored throughout surgery. Important variables of interest in the present study were functional outcome, complications, and recurrence rate. Good outcome was defined as stable ECOG score or improvement in ECOG score in comparison with the condition at admission. Complications were defined as any adverse event that resulted in a surgical procedure to revise or treat the complications, including superficial or deep wound infection, epidural and/or subdural hematoma, CSF leak, deep venous thrombosis, pulmonary embolism, and postoperative mortality. The recurrence rate was analyzed to define predictive factors influencing the recurrence rate. This study was approved by the local ethics committee at our institution.

Statistical Analysis

All statistics were performed using IBM SPSS (version 21, IBM Corp.); $p < 0.05$ was considered significant. Comparison of important differences between the study groups was made using Fisher's exact test for categorical variables. Nonparametric tests included the Mann-Whitney U-test and Kruskal-Wallis test to compare groups of data that did not follow the normal distribution. Tests for normality were performed using the Shapiro-Wilk test. Univariate analysis was performed to determine the effect of clinical variables on long-term outcome. In a second step, a multivariate analysis was performed to find independent predictors of long-term outcome after surgical treatment of intraspinal meningiomas by using a backward stepwise binary logistic regression analysis. For this step, the dependent variables

of functional outcome and neurological outcome, complications, and tumor recurrence were dichotomized.

Results

Patient Characteristics

Ultimately, 119 patients (mean age 59.9 ± 14.8 years, range 25–85 years) were included for final analysis. The sex distribution revealed a female predominance, consisting of 70.6% females, with a female-to-male ratio of 2.5:1. The mean follow-up was 25.4 ± 37.1 months. The most frequently involved location was the thoracic region (68.9%), followed by the cervical region (24.4%). Furthermore, in more than 70% of patients, the tumor affected only 1 spinal level and in 28.6%, 2 spinal levels; multilevel extension of more than 2 levels was only seen in 1 patient. The most common symptom that led to patient presentation was sensory deficit (34.5%), followed by gait instability (26.9%) and motor deficit (21%). Back pain and radicular pain were apparent in 27.7% of patients. Regarding initial symptoms and complaints, almost 72% of patients revealed a good status according to their ECOG grade (0 and 1); ambulatory and capable of all self-care but unable to carry out any work activities induced by spinal meningiomas was seen in almost 23% patients, whereas only 5% were capable of only limited self-care. The meningioma was accessed by a laminectomy in 78.2%, by a hemilaminectomy in 19.3%, and by a laminoplasty in 2 patients. Complete resection (Simpson grades I and II) was achieved in 86.6% and subtotal resection (Simpson grades IV and V) in 13.4%. Data regarding tumor calcification were obtained from surgical reports; 87% of patients had no calcification, 10.9% had partial calcification, and 1.7% had complete calcification. An overview is given in Table 2.

Complications

The overall complication rate in our investigated patient population was 9.2% (11 patients). In detail, postoperative complications consisted of postoperative infection in 2 patients (18.2%), CSF leak in 7 patients (63.6%), and postoperative epidural hematoma with subsequent need for revision surgery and postoperative pulmonary embolism in 1 patient each (0.8%). Because of postoperative

TABLE 2. Patient characteristics

	Value
Sex	
Female	84 (70.6)
Male	35 (29.4)
Mean age, yrs	59.9
Tumor location	
Cervical	29 (24.4)
Cervicothoracic	4 (3.4)
Thoracic	82 (68.9)
Thoracolumbar	1 (0.8)
Lumbar	3 (2.5)
Affected level	
1	84 (70.6)
2	34 (28.6)
>2	1 (0.8)
Symptoms & signs	
Back pain	11 (9.2)
Radicular pain	22 (18.5)
Sensory deficit	41 (34.5)
Motor weakness	25 (21.0)
Bladder/bowl dysfunction	9 (7.6)
Gait ataxia	32 (26.9)
Incidental finding	3 (2.5)
Lower-limb spasticity	6 (5.0)
Diabetes	14 (11.8)
Hypertension	49 (41.2)
Obesity	21 (17.6)
Mean BMI, kg/m ²	27.0
Prior surgery	9 (7.6)
ECOG grade on admission	
0	38 (31.9)
1	48 (40.3)
2	27 (22.7)
3	6 (5.0)
Histology	
WHO grade I	0
Meningothelial	93 (78.2)
Psammomatous	9 (7.6)
Transitional	4 (3.4)
Fibrous	3 (2.5)
Choroid	2 (1.7)
Angioma	1 (0.8)
WHO grade II	7 (5.9)
Calcification	
None	104 (87.4)
Partial	13 (10.9)
Complete	2 (1.7)
EOR	
GTR	103 (86.6)
STR	16 (13.4)

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TABLE 2. Patient characteristics

	Value
Mean surgical time, mins	185
Surgical approach	
Laminectomy	93 (78.2)
Hemilaminectomy	23 (19.3)
Laminoplasty	2 (1.7)
Mean LOS, days	7.7
ASA class	
I	8 (6.7)
II	76 (63.9)
III	33 (27.7)
IV	1 (0.8)
Dural attachment	
Ventral	8 (6.7)
Ventrolateral	24 (20.2)
Lateral	73 (61.3)
Dorsolateral	9 (7.6)
Dorsal	2 (1.7)
Surgeon's experience	
<10 procedures	14 (11.8)
>10 procedures	105 (88.2)
ECOG grade at end of FU	
0	94 (79)
1	19 (16)
2	5 (4.2)
3	0
4	1 (0.8)
Neurological status	
Improved	72 (60.5)
Stable	41 (34.5)
Deteriorated	6 (5.0)
Recurrence	9 (7.6)

FU = follow-up; GTR = gross-total resection; LOS = length of stay; STR = subtotal resection.

Values represent the number of patients (%) unless stated otherwise.

complications, 9 revision surgeries were necessary. There was no 30-day postoperative mortality (Table 3).

Obesity ($p = 0.04$), surgeon experience with performing < 10 previous procedures ($p < 0.001$), previous surgery ($p = 0.009$), and revision surgery ($p < 0.001$) were significantly different in patients with and those without postoperative complications. Further analysis revealed that the mean initial surgical time in patients with a postoperative CSF leak was significantly longer than that in patients without a postoperative CSF leak (219.6 vs 181.6 minutes, $p = 0.003$; Mann-Whitney U-test; Fig. 1).

We conducted a multivariate logistic regression analysis to identify independent predictors. The multivariate analysis identified surgeon experience (OR 1.1, 95% CI 0.3–13.1) and obesity (OR 3.2 CI 1.1–8.9) as indepen-

TABLE 3. Complication rate

	No. of Patients (%)
30-day mortality	0
Postop infection	2 (1.7)
CSF leakage	7 (5.9)
Postop hematoma	1 (0.8)
Neurological deterioration	6 (5.0)
Pulmonary embolism	1 (0.8)

dent predictors for having a postoperative complication (Nagelkerke $R^2 = 0.51$; Table 4).

Outcome

After a mean follow-up of 25.5 months, 94 patients (79%) had an ECOG grade of 0, 19 patients (16%) had an ECOG grade of 1, and 5 patients (4%) had an ECOG grade of 2 (restrictions in activities of daily life). Only 1 patient had an ECOG grade of 4 (completely disabled) at the end of the follow-up period. Comparing the neurological status at admission and at the end of follow-up, an improvement was observed in 72 patients (60.5%), stable neurological status was recorded in 41 patients (35%), and deterioration in neurological status occurred in 6 patients (5%).

After dichotomizing the variable of functional outcome (ECOG grade at the end of follow-up), significant differences were found in the univariate analysis for the following variables in comparing the good and poor outcome groups: obesity ($p = 0.05$), EOR (Simpson grade $\geq IV$, $p < 0.001$), ASA class ($p = 0.002$), tumor localization in the lumbar spine ($p < 0.002$), previous surgery ($p = 0.01$), revision surgery ($p = 0.03$), and male sex ($p = 0.03$). Moreover, an age-dependent influence on outcome was found (ECOG grade 0, mean age 56.8 years; ECOG grade 1, mean age 70.9 years; ECOG grade 2, mean age 74.6 years; and ECOG grade 4, mean age 59 years; $p = 0.002$, Kruskal-Wallis test; Fig. 2). The length of stay in patients with ECOG grade > 0

TABLE 4. Univariate and multivariate analysis of variables affecting overall complication rate, outcome, and tumor recurrence

	Univariate Analysis: p Value	Multivariate Analysis: OR (95% CI)
Complication		
Obesity	0.04	3.2 (1.1–8.9)
Surgeon's experience	<0.001	1.1 (0.3–13.1)
Previous surgery	0.009	
Outcome		
Obesity	0.05	
Simpson grade $\geq IV$	<0.001	
ASA class	0.002	
Tumor in lumbar spine	<0.002	
Previous surgery	0.01	
Revision surgery	0.03	23.8 (2.2–26.2)
Sex (male)	0.03	6.0 (0.8–56.7)
Age	0.002	1.1 (0.9–1.2)
Tumor recurrence		28.6 (2.2–37.4)
Tumor recurrence		
Calcification	0.006	16.3 (1.2–250)
Simpson grade $\geq IV$	<0.001	8.7 (0.9–87.5)

was significantly longer (7.2 days for grade 1, 8.0 days for grade 2, and 14.4 days for grade 3; $p = 0.04$; Fig. 3).

The multivariate relationships were analyzed for the dependent (dichotomized) variables of functional outcome and neurological outcome at the end of the follow-up. Among risk factors, the variables age (OR 1.1, 95% CI 0.9–1.2), sex (OR 6.0, 95% CI 0.8–56.7), revision surgery (OR 23.8, 95% CI 2.2–26.2), and tumor recurrence (OR 28.6, 95% CI 2.2–37.4) remained significant (Nagelkerke $R^2 = 0.43$) (Table 4).

FIG. 1. Boxplot showing the effect of surgical time on postoperative CSF leakage. The x indicates the mean. * $p = 0.003$.

FIG. 2. Boxplot showing age-dependent outcomes. The mean age for patients with an ECOG grade of 0 was 56.8 years; for ECOG grade 1, 70.9 years; for ECOG grade 2, 74.6 years; and for ECOG grade 4, 59 years. * $p = 0.002$.

FIG. 3. Boxplot showing the relationship between length of hospital stay and clinical outcome. ** $p = 0.04$.

FIG. 4. Boxplot showing the difference in surgical time between experienced and less experienced surgeons.

Meningioma Recurrence

The recurrence rate in the present study was 7.6% (9 patients) and occurred during a mean time of 10.1 years (range 1–29 years). In univariate analysis comparing tumor recurrence and no recurrence, calcification ($p = 0.006$) and EOR, namely Simpson grade IV in 15 patients and Simpson grade V in 1 patient ($p < 0.001$) were found to be statistically significant. Furthermore, recurrence was associated with significant impact on clinical outcome, ECOG grade > 1 during follow-up ($p = 0.05$), and poor clinical outcome ($p = 0.01$). Most recurrent meningiomas occurred during a longer follow-up period. Age, sex, obesity, diabetes, surgeon experience, dural attachment, localization, histology, and EOR had no impact on tumor recurrence.

In multivariate analysis, only the Simpson grade $\geq$ IV (OR 8.7, 95% CI 0.9–87.5) and tumor calcification, which was reported in 15 patients (OR 16.3, 95% CI 1.2–250), remained significant (Nagelkerke $R^2 = 0.31$) (Table 4).

Discussion

The aim of the present study was to evaluate the clinical outcomes after microsurgical resection of spinal meningiomas. Furthermore, we aimed to find predictive factors affecting the complication and recurrence rates of these benign, slow-growing tumors.

In comparison with previously published data, we found some similarities and differences. The peak incidence of meningiomas occurs between the 6th and 8th decades of life.^{11,12} Moreover, in contrast to other CNS tumors, there is a strong female predominance.^{8,13,14} The mean age in the present study was 59.8 years, with 54% of patients older than 60 years. Furthermore, there was no significant difference in mean age between males (60.3 years) and females (59.6 years). The female-to-male ratio in the present study was 2.5:1, which represents a relatively lower female-to-male ratio than that described in most published studies.^{6,15,16}

Complications

The overall complication rate in the literature has been

reported to range between 0% and 24%, and the most frequent complications are CSF leaks, fistulas, neurological deterioration, venous thromboembolic diseases, cardiac and respiratory complications, and infectious complications.^{8,12–14,17–25} We have provided additional information and show that obese patients experienced postoperative complications more often, and, more importantly, the amount of experience of the surgeon performing the procedure also affected the complication rate. These aspects have not previously been mentioned and should be considered when planning microsurgical resection. Additional training in spine and microsurgical technique may be helpful before performing surgery on spinal meningiomas. Nevertheless, the surgeon's effect and the level of experience remain an aspect that need special consideration.

Obesity influences outcomes of patients undergoing spine surgery, especially those with complications, such as surgical site infections, venous thromboembolism, major complications, prolonged length of surgery, and increased financial costs.^{26–28} Weight reduction prior to planned surgery, when appropriate, should be recommended for patients with mild or absent symptoms attributable to spinal meningiomas to ensure a reduced rate of postoperative complications. The length of surgery was associated with the occurrence of CSF leak. Patients with a longer surgical time significantly more often experienced postoperative CSF leakage. The mean surgical time for experienced surgeons was shorter but not significantly reduced compared with that of surgeons with less experience (182.8 vs 203.4 minutes) (Fig. 4).

Recurrence Rate

The recurrence rate of spinal meningiomas ranges from 1.3% to 6.4%. In our series, the recurrence rate was 7.6%; interestingly, all recurrences were in WHO grade I meningiomas, which is in contrast to previously published data, reporting a high recurrence rate for high-grade meningiomas.^{8,18,20} Many factors associated with tumor recurrence have been discussed in similar literature, including tumor location, Simpson resection grade, histol-

ogy, calcification, dural attachment, and proliferative activity.^{8,11,21,25} An increased incidence of tumor recurrence with a longer follow-up period has been reported in many studies evaluating long-term follow-up.^{22,29} In line with this finding, we can prove this aspect. Most recurrences happened during a longer follow-up period, which was significantly longer than that in patients without tumor recurrence. Considering this fact, the rate of tumor recurrence will be higher during a longer follow-up. We found no correlation with respect to dural attachment, localization of the tumor, number of affected spinal levels, BMI, diabetes, hypertension, and surgeon experience. The EOR, namely, subtotal tumor resection with remnant and calcification, was significantly different. Calcification of the tumor results in increased spinal cord manipulation, which should be considered when microsurgical resection is the goal. In planning the surgical procedure, CT can be very helpful to establish plans for a safe and optimal surgical approach. Tumor recurrence had an impact on clinical outcome and level of independency as expressed by a higher ECOG score.

Functional Outcome

Poor functional outcome has been reported to be between 2% and 20%.^{8,12–14,17–22} Moreover, factors leading to poor functional outcome after surgery were tumor calcification, anterior dural attachment, tumoral adherence to the spinal cord, poor preoperative status, and advanced age.^{8,13,14,18,19,21} Poor functional outcome in our investigated patient population was evident in 6 patients (5%). In addition to known variables such as localization, EOR, histology and thus rate of tumor recurrence, sex, and age, we found some additional factors affecting clinical outcome, namely, obesity, ASA score, and the effect of previous surgery. These aspects should be considered when performing surgery in patients with spinal meningiomas. Ultimately, we showed that patient outcome was associated with the length of hospital stay and was prolonged in patients with neurological deterioration, which is not only of medical interest but also of financial interest (Fig. 3).

Conclusions

Our results reflect a good functional outcome after microsurgical resection of spinal meningiomas. In addition to known factors, we found that obesity, surgeon experience, and surgical time affect functional outcomes and complication rates.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Behmanesh. Acquisition of data: Behmanesh, Kilinc. Analysis and interpretation of data: Behmanesh. Drafting the article: Kilinc. Reviewed submitted version of manuscript: Behmanesh, Marquardt. Approved the final version of the manuscript on behalf of all authors: Behmanesh. Statistical analysis: Setzer. Administrative/technical/material support: Setzer, Keil, Dubinski, Bruder. Study supervision: Seifert.

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