POSTERIOR APPROACH TO VENTRALLY AND DORSALLY LOCATED SPINAL MENINGIOMAS

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Objective. To analyze the outcomes of posterior approach in the surgery of intradural extramedullary meningiomas located ventrally and dorsally in relation to the spinal cord denticulate ligaments.

Material and Methods. The study included 29 patients with spinal intradural meningiomas operated on using posterior approach. Patients were divided depending on the tumor location relative to the denticulate ligaments into ventral (n = 13) and dorsal (n = 16) groups. The surgery duration, the degree of tumor resection, clinical outcomes, the presence and nature of complications, and the frequency of recurrence were assessed.

Results. The average follow-up period was 29 (6 to 61) months. Total tumor removal was performed in 93.1 % of cases: 11 cases (84.6 %) in ventral group and 16 cases (100.0 %) in dorsal group. The average duration of surgery was 136 minutes for dorsal meningiomas and 181 minutes for ventral meningiomas ($p < 0.05$). Complications in the form of CSF leakage were registered in two patients (6.9 %). In 11 (84.6 %) patients with ventral meningiomas and 15 (93.7 %) patients with dorsal meningiomas, an improvement or preservation of neurological functions at the pre-surgery level was observed. Recurrences were observed in two patients (6.9 %).

Conclusion. Patients with spinal meningiomas have a favorable neurological outcome and a low recurrence rate. Surgery is more complicated in patients with ventral meningiomas. In most cases, unilateral posterior approach is applicable for both ventral and dorsal meningiomas.

Key Words: spinal meningioma, posterior approach, intradural extramedullary tumor.

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Meningiomas are some of the most common spinal tumors and account for 25–45 % of all intradural extramedullary lesions [1]. The rate of spinal meningiomas is significantly less than that of intracranial meningiomas and amounts to about 1.2 % of all meningiomas of the central nervous system [2]. They are localized more often in the thoracic spine (67–84 %) and less often in the cervical (14–72 %) and lumbar (2–14 %) spine [3]. The gold standard for treating these tumors is surgical resection. Usually, resection provides a favorable neurological outcome and a low recurrence rate [4–6]. According to studies [3, 6–8], total resection is achieved in 82–99 % of cases and involves removal of the tumor with dural attachment resection (Simpson grade I) or coagulation (Simpson grade II) [9–11]. In contrast to intracranial meningiomas, the recurrence rate of spinal meningiomas after total removal is 1.3–25.0 % [8, 10, 12].

In our opinion, spinal meningiomas located anteriorly (ventrally) to the denticulate ligaments are a specific surgical challenge; they can be considered separately due to the complexity of a surgical approach and possible perioperative and postoperative complications. There are relatively few studies on removal of ventral spinal meningiomas through a unilateral (without laminectomy) posterior approach [2, 13, 14]. In this study, we review our experience in treatment of 29 patients with ventral and dorsal intradural extramedullary meningiomas who were operated on using a posterior approach.

The study objective was to analyze the outcomes of surgery for intradural extramedullary meningiomas located ventrally and dorsally to the denticulate ligaments using a posterior approach.

Material and Methods

In 2014–2019, 41 patients with extramedullary meningiomas were operated on. We retrospectively assessed the demographic data, radiological findings, clinical manifestations, and outcomes in patients with spinal meningiomas. The severity of neurological symptoms was assessed using the Klekamp-Samii scoring system [15] proposed in 1993 to evaluate patients with impaired spinal cord function (Table 1).

Depending on the tumor location relative to the denticulate ligaments, the patients were divided into 2 groups: ventral group (n = 13) and dorsal group (n = 16). The mean age of patients was 61.4 ± 17.8 years (29 to 84 years), with females predominating among the patients: 22 (75.9 %) of 29. The groups did not differ significantly in the age and gender. General characteristics of patients are presented in Table 2.

At the stage of preoperative planning, all patients underwent contrast-enhanced MRI for detailed assessment of the tumor location in the spinal canal relative to the dura mater, spinal cord

substance, and, separately, denticulate ligaments. Meningiomas located anterior to the denticulate ligaments were considered ventral (n = 13; Fig. 1a, b), and those located posterior to the ligaments were considered dorsal (n = 16; Fig. 2a, b). Tumor calcification was assessed by CT.

In this study, we excluded tumors located at the C2 level or higher, as representing a separate problem (surgery of the craniovertebral region), as well as completely lateral meningiomas (n = 12) that could not be attributed to the ventral or dorsal group.

In patients included in the study, meningiomas were located mainly in the thoracic spine (n = 19; 65.5 %); cervical and lumbar meningiomas were found in 7 (24.1 %) and 3 (10.4 %) cases, respectively.

The linear tumor dimensions were calculated in the sagittal, axial, and coronal planes in millimeters. A part of the spinal canal lumen occupied by the tumor (in percent) was calculated separately. The degree of tumor resection was analyzed based on intraoperative data and control MRI scans using the Simpson classification. The duration of surgery as well as perioperative and postoperative surgical and neurological complications were analyzed. To assess outcomes, we used changes in the neurological status in accordance with the Klekamp – Samii scoring system and control MRI images.

Most (n = 24; 82.8 %) tumors were removed using a posterior unilateral approach. In this case, hemilaminectomy was performed in 17 cases, and the margins of the adjacent laminae were resected at the tumor level in 7 cases. The length of a skin incision was about 4 cm in all cases. The Caspar retractor was used to retract the paravertebral soft tissues. The surgical corridor for tumor removal was enlarged by complete resection of the yellow ligament in the interlaminar space and under the resected bone structures; additionally, the lamina was resected medially under the base of the spinous process. The dura mater was opened by making a longitudinal linear incision; the dural edges were fixed with temporary ligatures. After opening the capsule, the tumor was reduced in size intracapsularly using an ultrasonic aspirator. The dural attachment was excised together with the tumor during Simpson grade I resection or coagulated in the case of Simpson grade II. In the case of small ventrally located tumors, the spinal cord was retracted using the denticulate ligament that was delicately dissected from the dura mater and tightened medially with a ligature. In the case of tumors of the thoracic region, the denticulate ligament together with the root can be transected to allow sufficient rotation of the spinal cord and visualization of the tumor.

At present, we have relatively rarely used a bilateral approach with laminectomy, mainly in cases of severe calcification of ventral meningiomas with compression of the spinal cord and tight adherence to it. In this series of patients, this approach was performed in 5 (17.2 %) cases.

Removed tumors were fixed with formalin; histological examination was performed in pathological departments of clinics; the histological findings were presented in accordance with the WHO classification (2016).

The data were statistically processed using the calculation of descriptive statistics. The distribution of data in the groups is presented as mean with standard deviation (M ± SD). The significance of differences between the compared mean values was assessed using the nonparametric Mann – Whitney U test; the significance of differences in the rate of neurological disorders in the postoperative period was assessed using the Fisher test. Differences were considered significant at $p < 0.05$.

Table 1
Klekamp – Samii neurological scoring system [15]

Score	Sensory deficit, pain, dysesthesia	Paresis	Gait	Bladder function	Bowel function
5	No symptoms	Full power	Normal	Normal	Normal
4	Present, not significant	Movement against resistance	No aid	Slight disturbance, no catheter	Slight disturbance, full control
3	Significant, function not restricted	Movement against gravity	Mobile with aid	Residual, no catheter	Laxatives, full control
2	Some restriction of function	Movement without gravity	Few steps with aid	Sometimes catheter	Sometimes loss of control
1	Severe restriction of function	Contraction without movement	Standing with aid	Often catheter	Often loss of control
0	Incapacitation of function	Plegia	Wheel chair	Permanent catheter	No control

Table 2
General characteristics of patient groups

Parameters	Patients with ventral meningiomas	Patients with dorsal meningiomas
Number, n (%)	13 (44.8)	16 (55.1)
Mean age, years	60.6 ± 14.6	62.4 ± 15.3
Gender (males : females)	1.0 : 3.3	1.0 : 3.0
WHO grade I tumors, %	100.0 (n = 13)	93.7 (n = 15)
WHO grade II tumors, %	0.0	6.3 (n = 1)
Mean hospital stay, days	6.2 ± 2.3	5.9 ± 2.1

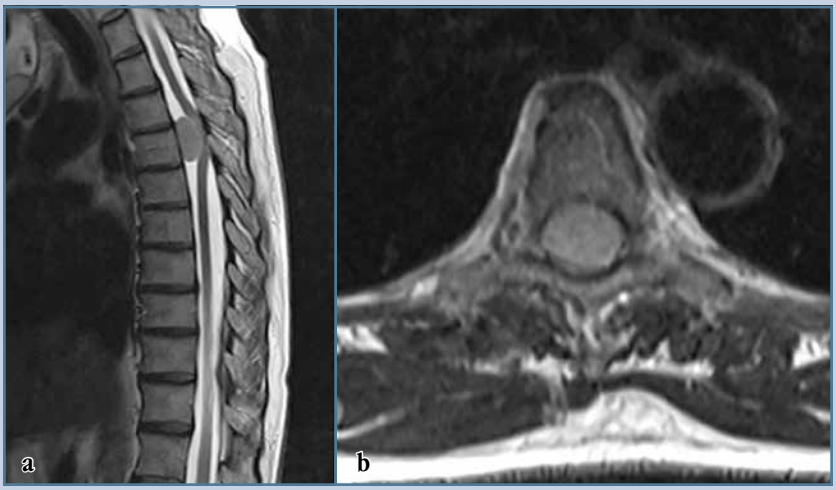

Fig. 1
MRI scans (T2–WI) of a female patient with a ventral meningioma at the T5 level in the sagittal **(a)** and axial **(b)** projections

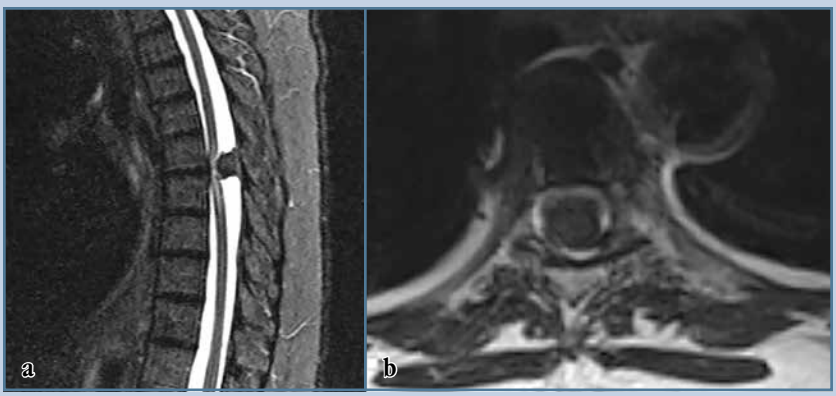

Fig. 2
MRI scans (T2–WI) of a female patient with a dorsal meningioma at the T4–T5 level in the sagittal **(a)** and axial **(b)** projections

Results

The mean follow-up period was 29.0 ± 14.7 months. (6 to 61). During the follow-up period, all patients underwent postoperative MRI at 3 to 6 months, then once a year.

At the time of diagnosis, the mean tumor size was 19.0 ± 5.2 mm, 13.0 ± 3.8 mm, and 18.0 ± 6.7 mm in the sagittal, axial, and coronal planes, respectively. There was no significant difference in size between the groups of patients with ventral and dorsal meningiomas. The mean part of the spinal canal lumen occupied by the tumor in the axial plane was 62 % (15 to 96 %), without significant differences between the groups.

At admission, clinical symptoms in patients with ventral meningiomas were represented by local back pain (46.1 %), motor dysfunctions (38.5 %), sensory disorders (31.0 %), sensory ataxia (23.1 %), and pelvic disorders (15.4%). Symptoms in patients with dorsal meningiomas included local back pain (43.8 %), sensory disorders (37.5 %), sensory ataxia (31.2 %), motor dysfunctions (18.7 %), and pelvic disorders (12.5 %).

The duration of symptoms to admission to the hospital was less than 3 months in 6 (20.7 %) cases, 3 months up to 1 year in 15 (51.7 %) cases, and more than one year in 8 (27.6 %) cases. The duration of symptoms was different in the groups of patients with ventral (less than 3 months – 15.4 %; 3 to 12 months – 46.1 %; more than 1 year – 38.5 %) and dorsal (less than 3 months – 25.0 %; 3 to 12 months – 56.2 %; more than 1 year – 18.8 %) meningiomas and significantly differed: the duration of symptoms was less in the group of patients with ventral meningiomas ($p < 0.05$). WHO grade I meningiomas were present in 28 (96.5 %) patients, and 1 (3.5 %) patient had grade II meningioma (atypical meningiomas). Comparative data for ventral and dorsal meningiomas are given in Table 3.

The duration of surgery in the groups significantly differed and was 189.2 ± 24.5 min and 136.7 ± 19.6 min, on average, for resection of ventral and dorsal meningiomas, respectively ($p < 0.05$). The main cause for choosing laminec-

tomy as an approach was pronounced tumor calcification and deformation of the spinal cord by the tumor with the formation of an area of altered MR signal (myelopathic lesion) according to preoperative MRI data, which indicated intimate tumor adherence to the spinal cord and the difficulty of intraoperative spinal cord traction. Total removal was performed in 11 (84.6 %) cases in the group of patients with ventral meningiomas (the tumor was resected with coagulation of the dural attachment, Simpson grade II) and in 16 cases in the group of patients with dorsal meningiomas: of these, 2 (12.5 %) patients had dural attachment resection and duraplasty (Simpson grade I), and 14 (87.5%) patients had Simpson grade II resection. Differences in the radicality of resection depending on the tumor location relative to the denticulate ligaments were statistically significant ($p < 0.05$).

Most patients quickly recovered after surgery; the mean hospital stay was 6.1 ± 2.2 days (6.2 ± 2.3 in the group of ventral meningiomas; 5.9 ± 2.0 in the group of dorsal meningiomas, without significant differences). Surgical complications were presented only by wound CSF leakage in 2 (6.9 %) patients. Of these, one female patient with a ventral meningioma was after Simpson grade II resection, and one female patient with a dorsal meningioma was after Simpson grade I resection. In both cases, CSF leakage regressed after placement of a lumbar drain and conservative measures.

After surgical treatment, most patients had a good neurological outcome. In the group of patients with ventral meningiomas, an increase in neurological deficit was observed in 2 (15.4 %) patients; in this case, aggravation of symptoms in one of them was temporary, manifested by numbness in the lower extremities and a moderate decrease in muscle strength, and completely regressed after 4 months. In 3 (23.0 %) patients in this group, the neurological status remained at the preoperative level; 8 (61.6 %) patients had an improvement. In the group of patients with dorsal tumors, 1 (6.2 %) patient developed transient deterioration, 5 (31.2 %) patients had no changes, and 10 (62.5 %) patients had an improvement. Final stabilization of the neurological picture occurred 14 weeks after surgery, on average. There was no significant difference between subgroups in the rate of neurological disorders ($p > 0.05$, Fisher's test). Changes in neurological symptoms, according to Klekamp – Samii, are shown in Figure 3.

Two patients developed recurrences. In one female patient with a WHO Grade II dorsal meningioma removed totally, recurrence was detected after 14 months; the patient was re-operated. The second female patient with a grade I ventral meningioma, who underwent subtotal tumor resection, had a recurrence after 20 months; she was also re-operated.

Discussion

We analyzed the surgical approaches, rate and type of complications, and treatment outcomes in patients with spinal meningiomas in accordance with their location relative to the denticulate ligaments. In our opinion, most meningiomas, even those located anterior to the denticulate ligaments, can be delicately and totally removed through the posterior unilateral approach. Enlarged posterior or anterior approaches for ventral meningiomas are used relatively rare, mainly in cases of tumor tissue calcification and significant compression of the spinal cord with tight adherence of the tumor to the cord.

For resection of ventral meningiomas, large and traumatic approaches have been developed and used: posterolateral or anterior approaches with single-level or multilevel corpectomy and instrumentation [16, 17]; in this case, the rate of postoperative approach-associated complications amounts to 27 % [16]. Compared to the outcomes reported in [2] where only posterior approaches were used, the rates of recurrences and unfavorable outcomes in the case anterior approaches are higher [18]. Posterior approaches do not require open-

Table 3

Comparative characteristics of ventral and dorsal meningiomas

	Ventral meningioma		Dorsal meningioma	
Mean size, mm				
Sagittal	18.3 ± 2.2		17.8 ± 2.0	
Coronal	13.5 ± 1.8		13.0 ± 1.5	
Axial	14.5 ± 1.3		13.9 ± 1.2	
Part of the spinal canal lumen occupied by the tumor, %	74.3 ± 12.3		69.1 ± 11.8	
Mean duration of surgery, min	189.2 ± 24.5		136.7 ± 19.6*	
	unilateral approach	laminectomy	unilateral approach	laminectomy
	181.1 ± 18.5	204.4 ± 26.9	132.8 ± 17.7	145,0 ± 21,8
Resection radicality, n (%)				
Simpson grade I	0		2 (12.5)*	
Simpson grade II	11 (84.6)		14 (87.5)	
Simpson grade III–IV	2 (15.4)		0*	

*significant differences between groups, $p < 0.05$.

ing the chest and abdominal cavities and are minimally invasive. Among spinal surgeons, these are the most popular approaches for removal of intradural tumors [19–22]. Of course, these approaches are associated with limited visualization of the ventral surface of the spinal cord; also, working space does not always allow Simpson grade I resection [23]. In addition, tight tumor adherence to the dura mater significantly increases the risk of complications, such as spinal cord injury or CSF leakage [24]. Lonjon et al. [16] demonstrated that the classical posterior approach is usually performed to access soft ventrolateral tumors, while lateral enlargement is used for large and dense tumors. According to Kim et al. [25], anterior corpectomy or costotransversectomy should be used instead of the posterior approach in the case of ventral meningiomas tightly adhered to the dura mater.

In our opinion, a bilateral approach with laminectomy should be used to enlarge working space in the case of pronounced tumor calcification and significant compression of the spinal cord, which is usually associated with intimate adherence of the tumor capsule to the cord and potential technical difficulties of their separation, which was done in 5 (17.2 %) cases. Tola et al. [26] presented evidence that the posterior approach with hemilaminectomy was an effective surgical approach even in patients with ventral and ventrolateral meningiomas. Also, in their opinion, large and calcified meningiomas are limitations for this approach, which is consistent with our series of observations. According to our data, the posterior approach provides a convenient and safe access for removing spinal meningiomas, including those located ventrally to the denticulate ligament, with the possibility of complete tumor resection in 93.1 % of cases.

In surgical planning and approach selection, a preoperative surgical grading system proposed by Arima et al. [27] can be used to assess the difficulty of removing spinal meningiomas. In this system, a low score predicts a good surgical outcome, and a high score indicates serious surgical difficulties.

As in surgery for neoplasms in general, including benign spinal lesions [28] and other intradural extramedullary tumors [29, 30], surgery for spinal meningiomas should be aimed at their total removal. So far, the question of dural attachment resection or coagulation (Simpson grade I and Simpson grade II, respectively) remains controversial [2, 10, 21]. Often, especially in cases of ventral meningiomas with a high risk of intraoperative spinal cord injury, dura resection followed by its repair is a challenge; surgical treatment of spinal meningiomas is often limited to Simpson grade II resection. Nakamura et al. [31] reported a series of patients with spinal meningiomas (mean duration of 12 years). According to them, the recurrence rate at 11.5 years of follow-up was 0 (0/43) for Simpson grade I resection, while the recurrence rate at 12 years was 31.6 % (6/19) for Simpson grade II resection. Interestingly, patients under 50 years of age have a relatively high risk of recurrence (35.0 %). Thus, the authors recommend Simpson grade I resection for patients under 50 years of age. According to other published data, even Simpson grade I resection does not exclude recurrence of meningiomas. Solero et al. [32] reported two patients with recurrences after resection of the tumor with the dural attachment; Bostr m et al. [13] reported three such patients.

Yamamuro et al. [11] conducted a detailed histological study of 25 spinal meningioma specimens resected together with the dural attachment. Invasion of tumor cells through all layers of the dura mater was observed in 19 out of 25 cases. They presented evidence that the dural tail in preoperative MRI and

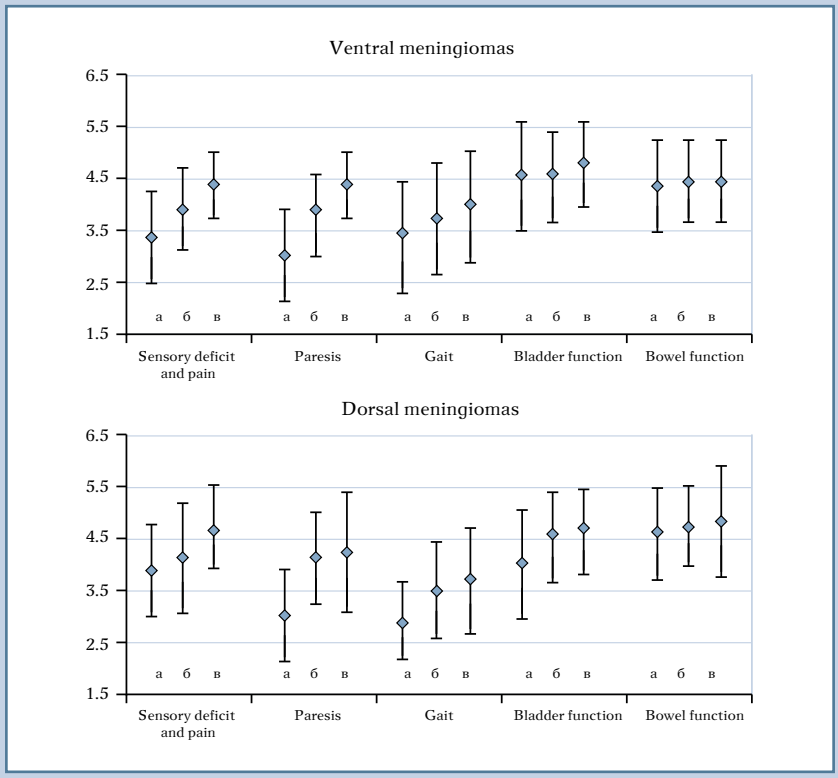

Fig. 3
Changes in neurological functions of patients before and after surgery (Klekamp–Samii neurological scoring system; M ± SD): *a* – before surgery; *b* – at discharge; *c* – follow-up

tumor calcification in CT scans were not predictors of tumor invasion into the dura mater. Nakamura et al. [31] reported tumor invasion into the dura mater in 35 % (15/43) of Simpson grade I resections. In addition, they concluded that tumor cells were partially preserved during Simpson grade II resections.

On the other hand, according to the data of many research groups [25, 33–35], good results are achieved in the case of Simpson grade II resection. Voulgaris et al. [34] reported a series of 10 ventral spinal meningiomas resected with dura mater coagulation (Simpson grade II) through the posterior approach without recurrences and deterioration of neurological functions with a mean postoperative follow-up period of 26 months. In a study by Kim et al. [25], seven large ventral meningiomas were removed through the posterior approach (2 cases of Simpson grade I and 5 cases of Simpson grade II) with a good outcome in all cases, without recurrence during an average follow-up period of 39 months. Notani et al. [21] reported a case of recurrent meningioma in an 87-year-old patient 11 years after Simpson grade II resection.

We performed total tumor resection (Simpson grade I–II) in 27 (93.1 %) cases. In most (25 out of 27; 92.6 %) cases of total resection, Simpson grade II resection was performed. Simpson grade I resection was used in two cases with dorsal tumors. In our opinion, the possibility of duraplasty depends on the location of dural attachment and tumor–spinal cord tissue relationships. Important factors are the baseline neurological status of the patient and tumor–spinal root relationships.

In patients who underwent total tumor resection, recurrence occurred only in a female patient with a histological structure of the WHO Grade II tumor. According to Klekamp and Samii [15], tumors with a similar histological structure recur in 100% of cases within 5 years. In another female patient with a recurrence, the first surgery involved subtotal tumor resection. The total recurrence rate was 6.9 %, which is consistent with the data reported by other authors [4, 16, 36–38]. A study by Onken et al. [2] reported that significant factors for recurrence were incomplete tumor resection and the histological structure of WHO grade II meningioma, which is consistent with our results. The localization of the tumor relative to the denticulate ligaments affects the recurrence rate because the rate of total resection is lower for ventral tumors.

In our series, the rate of neurological symptoms did not differ significantly between the groups. According to the data of Gilard et al. [39], the anterior tumor location and the histological structure of grade II meningioma are risk factors for neurological deficit aggravation after removal of spinal meningiomas. A study by Westwick et al. [38] analyzed a series of 131 patients with spinal meningiomas and revealed that factors increasing the risk of postoperative deterioration are age over 75 years, female gender, and calcification of grade I meningiomas.

Conclusion

In our series, patients with ventral and dorsal spinal meningiomas underwent surgery with a favorable neurological outcome and a low recurrence rate in most cases. The duration of surgery, degree of tumor resection, and clinical outcomes in the groups of ventral and dorsal meningiomas are characterized by their own features; the group of patients with ventral tumors is surgically more complex. The posterior unilateral approach is generally applicable for both ventral and dorsal meningiomas. In cases of large calcified tumors with significant compression of the spinal cord, more enlarged approaches may be required.

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