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ORIGINAL ARTICLE

Spinal Meningiomas Prognostic Evaluation Score (SPES): predicting the neurological outcomes in spinal meningioma surgery

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Abstract

Among many factors leading to a worse functional prognosis in spinal meningioma (SM) surgery, in a previous study, we recognized anterior/anterolateral axial topography, sphincter involvement at first evaluation, surgery performed on a recurrence, and worse preoperative functional status. The purpose of this paper is to evaluate the cumulative weight of these factors on prognosis through a multinomial logistic regression model performed on an original evaluation scale designed by the authors on the ground of the experience of the neurosurgical departments of our University. The original SM database composed of 173 cases was classified in regard to sex, age, symptoms, axial and sagittal location, Simpson grade resection, and functional pre/postoperative status. Fine presurgical and follow-up reevaluations were available. The authors propose a scale (Spinal Meningiomas Prognostic Evaluation Score (SPES)) of preoperative evaluation to assess the surgery-related risk of neurological worsening experienced by the patients included in the present cohort. The authors describe a strong statistical association between the SPES and the follow-up Frankel and McCormick scores ($r = -460$ and .441, p .001, both). Through a univariate ANOVA analysis, we disclosed that patients presenting scores 2 and 3 had a significantly higher association to lesser Frankel and McCormick postoperative scores, in respect to patients presenting SPES scores 0–1 (univariate ANOVA, p .008 and .011). Anterior or anterolateral axial location, operating on a recurrence of SM, sphincter involvement, and worse functional grade at onset present, along with the SPES scores are fairly predictive and reliable in respect to the long-term results of patients suffering from SM.

Keywords Intradural · Extramedullary · Meningioma · Multinomial logistic regression · Spinal cord

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Introduction

Background

The 25–46% of all primary spinal tumors are spinal meningiomas (SMs) [1, 2, 10], a relatively rare entity which exact incidence has been estimated to be 0.193 per 100,000 individuals [34], which are usually intradural extramedullary lesions [6, 14]. SMs are slowly growing, generally circumscribed tumors, which lead to symptoms when they compress the spinal cord [2, 8, 13, 23], presenting with local pain; nevertheless, the diagnosis is often not achieved until gait disturbances, altered sensibility, or sphincter dysfunctions become evident. Surgery is considered the only valuable treatment for this condition [13, 27] and aims to get a successful resection,

while minimizing the risk of spinal cord damage, and accordingly, the postoperative morbidity. Since a long time, it has been recognized and it is, to date, widely accepted that SMs carry a typical oncologic and neurological excellent prognosis [9, 15], and the current major improvement in modern neuroimaging techniques, intraoperative neuromonitoring, and surgical tools provided further advances in the management of this conditions. Nevertheless, cases presenting features such as anterior/anterolateral topography, recurrent lesions (in which there is violation of the arachnoidal layer and encasement of vascular structure), or patients presenting a poor neurological preoperative status (including sphincter dysfunctions) are to be considered as possibly doomed to have worse outcomes. This is the reason why functional outcomes have previously been deeply investigated by many authors [3, 16, 18, 25, 26, 29, 37], including the experience developed at the neurosurgical departments of Sapienza University [24], in order to focus on factors leading to a postoperative worsening in SM surgery and infer the possible outcome on the ground of the preoperative information.

Objective

It has become, at present, of growing practical, clinical, surgical, and medico-legal interest to reliably identify the cases that imply a higher probabilistic risk of postoperative worsening. Based on the data coming from the analysis of the relevant literature and on their experience, the authors propose a novel and simple evaluation scale based on preoperatively known features to easily predict and assess the risk of functional postoperative worsening, in order to shape the real expectancies about surgical results both of surgeons and patients.

Materials and methods

In neurosurgical departments of Sapienza University of Rome ("Umberto I" Hospital, "Sant'Andrea" Hospital, "Santa Maria Goretti" Hospital), a total of 224 spinal meningiomas were operated on in a period ranging between 1976 and December 2011. For a total of 51 patients, we applied the following exclusion criteria: (1) incomplete or wrong clinical and surgical reports, (2) patients lost to or who did not reach a minimum of 4 years of follow-up, (3) patients suffered from SM involving foramen magnum and craniocervical junction.

For all the patients, age, sex, presenting symptoms and their duration, a detailed physical preoperative and an in-depth postoperative follow-up examination, axial (location of dural attachment) and sagittal topography of the lesion, and histology (including "recurrent" lesions) are the final cohort demographic data. All the relevant details concerning the final cohort demographic data are expressed in Table 1.

The entire database was made up of a prospectively maintained database (1976–2003). In the period ranging from 2003 to December 2011, this database was updated with the cases operated on in these years.

Since it is a historical institutional database, not all the patients included were referred to surgery after an MRI scan. Particularly, in the period between 1976 and 1983, we used myelography; in the period between 1983 and 1991, an iodine-enhanced spinal CT; and from 1991 to now, a preoperative MRI scans which are considered the unavoidable gold standard in defining this pathology. To date, CT scans are currently used in case of unsuitability of the patient to MRI scan or extensively calcified lesions.

All the cases included underwent a standard laminotomy (or hemilaminectomy), dural opening, and microsurgical lesionectomy. A CUSA (Cavitation Ultrasonic Aspirator) debulking was performed to avoid any surgical traction on the cord whenever necessary; CUSA systems have been introduced and routinely employed in our institution since 1991. As a general principle, CUSA has been traditionally reserved for anterior/anterolateral and lateral lesions, lesions presenting vascular encasement, violation of the arachnoidal layer, and recurrent lesions in order to avoid any traction on the spinal cord. In the present cohort, the use of the CUSA system (including exclusively the cases in which, in the operative report was clearly described its use, therefore the following number could suffer from an underestimation bias) involved a total of 56/173 (32.3%) patients. For the aforementioned subgroup of patients, the CUSA, in our experience, is a precious instrument that definitely allows the surgeon to prevent any possible traction on the spinal cord, and therefore in our opinion, its use should be regarded as mandatory. Conversely, in all the SM presenting no such features as violation of the arachnoidal layer, or encasement of the vascular structures, with a posterior/posterolateral dural attachment, after dural opening, the dissection is usually simply performed, and there is generally no unquestionable advantage of its use. Total removal was the target in all posterior/posterolateral lesions, dural attachment was removed, and duraplasty completed the procedure. For anterior/anterolateral lesions, dural excision cannot be performed; therefore, a generous and cautious coagulation of the dural attachment completed the procedure.

The average duration of follow-up was 50.8 ± 9.3 months. In the original database, both the preoperative and the follow-up physical examinations were recorded in detail. For the previous study, we re-coded in a more effective and comparable way the results of these re-evaluations with the aid of the "Frankel" and "McCormick" scales. In the final database, we reviewed accurate pre- and postoperative evaluations. On the ground of a thorough revision of the follow-up physical examination, we inferred another three-step ordinal "functional status at follow-up" variable (Improved-Stable-Worsened) which was meant to work as a control variable in respect to

Table 1 Details of the final cohort

Total no. of patients	173
Sex	
Women	138 (79.8%)
Men	35 (20.2%)
Age	55.6 ± 13.1 years
Clinical presentation	
Pain	57 (32.9%)
Motor or gait disorders	55 (31.8%)
Paresthesias	53 (30.6%)
Sensory deficit	8 (4.6%)
Mean duration of preoperative symptoms	20.01 ± 18.86 months (range 0–120 months)
Axial topography	
Posterior	11 (6.4%)
Posterolateral	42 (24.3%)
Anterolateral	73 (42.2%)
Anterior	15 (8.7%)
Lateral	32 (18.5%)
Neurological status at follow-up	
Improved	150 (86.7%)
Stable	11 (6.4%)
Worsened	12 (6.9%)
Sagittal topography according to biomechanical levels of the spine	
Subaxial cervical	14.4%
Cervicothoracic junction	15.6%
Thoracic spine	68.8%
Thoracolumbar junction	1.2%
WHO grading of the lesions	
I	170 pts. (98.3%)
II	2 pts. (1.15%)
III	1 pt. (0.58%)
Spinal Meningiomas Prognostic Evaluation Scale	
0	32 pts. (18.5%)
I	75 pts. (43.4%)
II	48 pts. (27.7%)
III	17 pts. (9.8%)
IV	1 pt. (0.58%)
Anterior/anterolateral dural attachment	
Yes	88 pts. (50.8%)
No	85 pts. (49.2%)
Worse preoperative neurological status (ambulatory patients)	
Yes	120 pts. (69.4%)
No	53 pts. (31.6%)
Recurrent lesion	
Yes	4 pts. (2.3%)
No	169 pts. (97.7%)
Sphincter impairment at first evaluation	
Yes	93 pts. (53.8%)
No	80 pts. (46.2%)

Frankel and McCormick scores and also as a key variable for the statistical analysis included in the present paper.

On the ground of statistical observations extensively discussed and justified in "Results" paragraph and previously reported elsewhere [24], we observed that (1) location of dural attachment, (2) sphincter involvement at first evaluation, (3) worse preoperative functional status, and (4) surgery performed on a recurrent lesion were found to be statistically associated to a worse postoperative outcome. We therefore extracted the aforementioned variables and computed them from a nominal or ordinal variable to a dichotomous one:

Location of dural attachment. On the first ground, axial topography has been codified as a five-step nominal variable (anterior, anterolateral, posterior, lateral, and posterolateral); subsequently, for statistical purposes, we have codified such important variable in a dichotomous scale: anterior/anterolateral location of dural attachment (0/1–No/Yes).

Sphincter involvement at first evaluation (0/1–No/Yes). This feature included urinary and fecal incontinence. Generally, urinary incontinence was the presenting symptom for what sphincter function impairment is concerned.

Surgery performed on a recurrence (0/1–No/Yes). The subset of patients harboring a spinal meningioma recurrence was more likely to have a worse functional postoperative result; therefore, we included this dichotomous variable to the multinomial logistic regression analysis.

Worse preoperative functional status (0/1–Yes/No). We re-coded, as previously mentioned, all the neurological evaluations of the patients included in the final cohort with the aid of the Frankel and McCormick Scale. In our previous study, their scores were proven to be strongly negatively associated (Pearson's Bivariate correlation $p = .01$; $r = -.820$ McCormick pre-Frankel, Frankel $-.934$ McCormick at follow-up). As far as the neurological and functional status is concerned, class II on McCormick and class D on Frankel both cross-represent an ambulatory and functionally more independent patient. We subsequently extracted from such scales a dichotomy between ambulatory (0) and a non-ambulatory patient (1).

The aforementioned subscales established an arithmetic sum, thus obtaining a variable (with values ranging between 0 and 4—Table 2) we called "Spinal Meningiomas Prognostic Evaluation Scale" (SPES). This scale was meant to work as a "score system" for the multinomial logistic regression model of postoperative worsening prediction. The dependent (or "outcome") variable for the regression analysis was the "functional status at follow-up" variable, based, as previously mentioned, on the results of the follow-up physical examination (Improved-Stable-Worsened).

Table 2 Details of the "Spinal Meningiomas Prognostic Evaluation Scale" (SPES) system

Anterior/anterolateral location of dural attachment	
No	0 pt.
Yes	1 pt.
Worse preoperative status (ambulatory patients)	
No	0 pt.
Yes	1 pt.
Recurrent lesion	
No	0 pt.
Yes	1 pt.
Preoperative sphincter impairment	
No	0 pt.
Yes	1 pt.
SPES	Total pts.
Scores 0–4	0 to 4

The sample was analyzed with SPSS v18, in order to outline potential correlations between the investigated variables. On the first step, the comparison between outcome variables has been made with paired sample *t* test and Wilcoxon signed rank test, if the variables were dichotomous or nominal were investigated with chi-square analysis. Concerning neurological prognosis, we compared means with univariate ANOVA analysis. Multinomial logistic regression was used to assess the risk of postoperative neurological worsening. Continuous and ordinal variable correlations have been investigated with bivariate correlation according to Pearson and Spearman. Threshold of statistical significance was considered $p < .05$.

Results

The initial cohort of patients suffering from SM amounted to 224 patients. Fifty-one patients met the aforementioned exclusion criteria; thus, the residual cohort counted a total of 173 individuals. The cohort was composed of 138 female (79.8%) and 35 males (20.2%). The average age was 55.6 ± 13.1 years (range 16–80).

The most common presenting symptoms were pain (32.9% of cases, 57 patients), motor and gait disorders (55 patients 31.8%), paresthesias (30.6%, 53 patients), and sensory disturbance (4.6%, 8 patients); 18.5% of patients complained a single disturbance at onset. A clear sphincter disturbance was found to be the second appearing disturbance in 10 patients (5.8%).

In Table 1, we included a brief description of the involved biomechanical segments according to SINS classification, (1) subaxial cervical mobile spine (14.4%; C3-C6), (2) cervicothoracic junction (15.6%; C7-T2), (3) thoracic semi-rigid spine (68.8%, T3-T10), and (4) thoracolumbar junction

(1.2%, T11-L1). No case of pure lumbar meningioma (lower than L1) was present. Thoracic spine is more commonly involved (chi-square test, p .001). All the relevant demographic details are included in Table 1.

Preoperative functional status

As extensively exposed, functional evaluations were "recoded" in terms of Frankel and McCormick scales. These scales appeared to be strongly associated (Pearson's bivariate correlation p.01; $r = -.820$ McCormick Pre-Frankel, Frankel −.934 McCormick at follow-up), validating each other. The worst functional preoperative status was as usual associated to a lesser improvement both on Frankel and McCormick scales (Pearson's Bivariate correlation, both p .01, $r = .511$ and .618). The ability to walk was regarded as the "cornerstone" of functional independence. It corresponds with grade II on McCormick and D on Frankel scale. Therefore, the scores of these two variables have been dichotomized, for further analysis, according to the principle of walking ability.

Location of dural attachment

The most common axial location was anterolateral (73 patients, 42.2%); posterolateral location was represented in 42 patients (24.3%, details in Table 1). Patients presenting lesions with an anterior/anterolateral topography were more likely to have poor functional outcome on Frankel and McCormick scales (ANOVA analysis, p. 001 and .021 respectively). This topography was less often associated with clinical improvement (ANOVA analysis, p .016).

As previously reported by other authors [5, 8, 15, 24, 29], anterior/anterolateral topography is a quite common location for the dural attachment of the SMs (range reported in literature (38.5–65.2%).

Recurrence

Statistical analysis showed a statistical association between recurrence (4/173 cases), Simpson grade of resection and tumor histology (ANOVA analysis, p .043 and .002 respectively). These four patients had a dedicated follow-up in outpatient services of our departments, with a periodic 6-month MRI scan. In two out of these four patients, recurrence has been detected during postoperative follow-up and has proven stable, respectively for 72 and 120 months, and thus, these patients are still included in dedicated follow-up program. In the remaining two cases, respectively at 42 and 76 months after the first procedure, a second surgical procedure was performed to remove recurrent tumor; in particular in the first of the two cases, a second relapse at 36 months after the second procedure was detected and a third surgical procedure proved necessary. In both patients operated on for recurrent SM excision and spinal cord decompression, scarring caused by the first surgical procedure and violation of arachnoidal layer were found intraoperatively. These two patients experienced a worsening of neurological condition. This feature was found to be statistically associated to the ordinal three-step control variable (ANOVA analysis, p .001); however, due to the underrepresentation of this subgroup of patients, we cannot state that present data would be confirmed in a larger cohort. In regard to the first surgery of patients suffering from recurrent lesions, the underrepresentation of the subset of patients' lesion prevented the disclosure of strong statistically significant correlation between Simpson grade of resection and recurrent lesions.

Patients suffering from recurrent SM were also more likely to have postoperative complications and a worse functional and neurological outcome; a statistical association between recurrent lesion and neurological worsening was found (ANOVA analysis, p .003), although the association between complications and neurological outcome, burdened by the underrepresentation of this subgroup of patients, did not reach statistical significance (ANOVA analysis, p .090).

The duration of preoperative disturbances was negatively correlated with the probability of having a good functional class expressed in Frankel and McCormick scales at follow-up (Pearson's bivariate correlation, p .05, $r = .175$ and .161).

Sphincter impairment at fist evaluation

The definition of "sphincter disturbance" comprised urinary and fecal incontinence. These features were found to be statistically associated with a worse outcome (ANOVA analysis, p .006).

Besides, it was possible to identify an "effect modification" linked to a statistical interaction between the axial topography (location of dural attachment) and recurrence status: anteriorly/anterolaterally located lesions which were recurrent lesions were found to be statistically associated to worse outcomes in all the three outcome variables, McCormick and Frankel scores at follow-up, and the neurological status as described with the aid of the Improved-Stable-Worsened ordinal scale (multivariate ANOVA analysis p .001, .003, and .002 respectively).

Multinomial logistic regression

Lastly, a variable derived from the arithmetic sum of dichotomous variables, (1) location of dural attachment, (2) sphincter involvement at first evaluation, (3) surgery performed on a recurrence, and (4) worse preoperative functional status (see Table 2 and "Materials and methods"), was meant to work as

score system and used to stratify classes of patients according to a prediction model of postoperative functional status worsening. We called this score "Spinal Meningiomas Prognostic Evaluation Scale" (SPES) and could assume values between 0 and 4.

We performed a univariate ANOVA to investigate the impact of SPES scores on "functional status at follow-up" variable, Frankel and McCormick at follow-up scores. In order to improve the statistical reliability of the analysis, we excluded from the univariate ANOVA the single case presenting a SPES score of 4, so to be able to perform the post hoc tests. The results of this analysis disclose that patients presenting scores 2 and 3 had a significantly higher association to lesser Frankel and McCormick postoperative scores, in respect to patients presenting SPES scores 0–1 (univariate ANOVA, p .008, and .011; Fig. 1a, b).

Moreover, in case of SPES score 3, a total observed and predicted worsening rate was 23.5 and 48.0% respectively, compared to SPES scores 0, 1, and 2 presenting observed and predicted postoperative worsening rate ranging between 4.2 and 6.3% (Table 3). Conversely, for patient presenting a SPES score of 1, the predicted and observed improvement rate is as high as 93.8 and 91.6% respectively, as opposed to score 3 patients presenting an improvement rate of 64.7% (observed) and 42.6% (predicted) respectively.

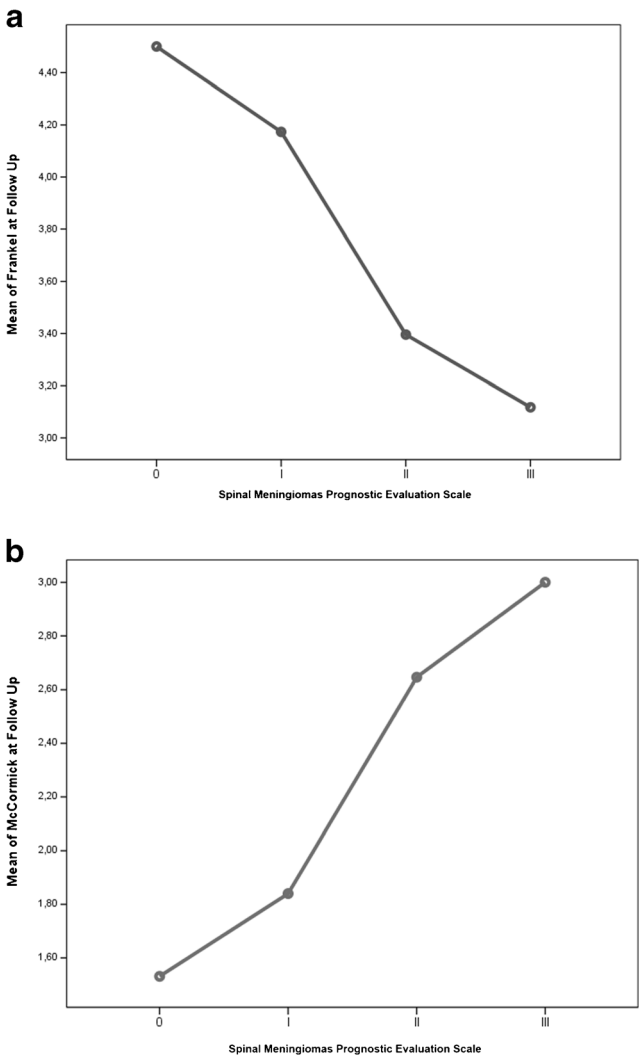

Fig. 1 Univariate ANOVA analysis demonstrating the different **a** Frankel and **b** McCormick scores at follow-up for the different SPES classes

We coded the SPES (0–1 vs 2–3) Frankel (A-B-C vs D-E) and McCormick (I-II-III vs IV-V) scores in a dichotomous fashion in order to perform a chi-square analysis to confirm the finding retrieved with the univariate ANOVA (Fig. 2a, b). SMCS scores 2–3 disclosed a clear statistical association with lower Frankel and McCormick scores (p .004 and .001 respectively).

Finally, we confirmed the statistical association between the SPES and the follow-up Frankel and McCormick scale through a bivariate correlation, confirming the predictability of the SPES in respect to the long-term functional results ($p < .05$ $r = -460$ and 441, Sig. > .001, both).

Furthermore, we performed a ROC curve to estimate the reliability of the SPES score in respect to the spinal cord function at follow-up as described by the scores of the "Frankel" and "McCormick" spinal cord function scales at follow-up and the functional status at follow-up (Improved-Stable-Worsened) either. The Frankel and McCormick scores at follow-up were strongly and reliably predicted by the SPES scores ($p = .003$ and .005 respectively Fig. 3), while the functional status at follow-up missed to reach the statistical significance. This could be explained because a vast amount of the investigated patients were definitely improved or stable, and therefore, the ROC analysis did not perform as accurately as it did with the more complex Frankel and McCormick scoring system.

Discussion

Spinal meningiomas are relatively rare and benign tumors arising from arachnoid cells, accounting for 1.2% of all CNS meningiomas (Fig. 4) with a global incidence as low as 0.193 per 100,000 individuals [26, 34]. SMs have been considered, since the historical work by Cushing, as lesions implying a typically favorable oncologic and surgical prognosis [9]. However, direct surgical experience and literature, through papers reviewing large institutional experiences, outlined that certain pathological features of the SMs can harbor a dismal neurological prognosis [18, 25–27, 37], especially those affecting the younger individuals, which present a more common anterior/anterolateral location of dural attachment and favor cervical spine, causing an increased risk of unsatisfactory results [8].

In our opinion, it was of great importance to focus the attention on the functional and neurological prognosis, and not only on surgical/oncologic outcomes, and by means of a further thorough review of our past institutional experience, to

Table 3 Multinomial logistic regression model for postoperative functional worsening prediction

SMCS	Improved	Frequency			Percentage	
		Observed	Predicted	Pearson residual	Observed (%)	Predicted (%)
0	Worsened	2	1.958	0.031	6.3	6.1
	Stable	0	0.729	−0.864	0.0	2.3
	Improved	30	29.313	0.438	93.8	91.6
I	Worsened	3	3.361	−0.202	4.0	4.5
	Stable	7	7.512	−0.197	9.3	10.0
	Improved	65	64.127	0.286	86.7	85.5
II	Worsened	2	2.212	−0.146	4.2	4.6
	Stable	2	2.141	−0.099	4.2	4.5
	Improved	44	43.647	0.178	91.7	90.9
III	Worsened	4	8.162	−2.020	23.5	48.0
	Stable	2	1.601	0.331	11.8	9.4
	Improved	11	7.238	1.846	64.7	42.6
IV	Worsened	1	1.000	0.003	100.0	100.0
	Stable	0	0.000	−0.001	0.0	0.0
	Improved	0	0.000	−0.003	0.0	0.0

conceive a reliable tool to preoperatively identify which cases are more likely to experience worse neurological result after surgical treatment in order to gain the opportunity for both patients and surgeons to define an effective and realistic expectancy about postoperative results.

In a previous study [24], we recognized, among others, the following factors leading to a worse functional prognosis in SM surgery:

1. Anterior/anterolateral location of dural attachment
2. Surgery performed on a recurrence
3. Sphincter involvement at the first evaluation
4. Worse preoperative functional status (ambulatory versus not ambulatory patients)

We selected the aforementioned features, because of their strong statistical association with the long-term outcomes, and of course, because of their simple and plain presurgical recognizability.

Our previous experience, and some relevant papers by other authors, underlines that a late diagnosis with a long duration of preoperative symptoms and a severe preoperative neurological impairment is associated to a worse prognosis [17, 35]. However when firstly evaluating a patient suffering from SM, it is common to retrieve a "long lasting" history of back pain with uncertain onset time; therefore, we excluded this feature from the multinomial logistic regression analysis.

Maiti et al. [18] reported, in their interesting paper, the association of radiological features as retrieved with the aid of the preoperative MRI such as "dural tail" and T2 hyperintensity of the spinal cord as predictors of worse functional outcomes. Since not all the patients included underwent a preoperative or postoperative MRI, we decided to focus our attention on purely clinical and surgical features. Besides, the MRI allowed the formulation of more accurate anatomical classification for SM, which brought to a deeper knowledge of such condition [5].

Sandalcioglu et al. [26] (similarly to the report of Levy et al. [17]), in their review of 131 surgically treated patients, described as a factor of surgical morbidity the extensive tumor calcification, especially in elderly patients (76–80 years). Calcification of SM turned out to be a relevant factor for a negative prognosis also in the Roux et al. review of 54 cases of intraspinal meningiomas [25], together with the presence of anterior dural attachment; however, recent evidences question strongly this finding [2]. Although it is possible to preoperatively assess with high accuracy through a spine CT the calcification of a SM, this feature remains extremely rare, not statistically associated to a worse outcome (in our experience [24]), and it is still not possible, on the sole ground of the preoperative radiological examinations, to correlate it with the real key variable: the *consistency of the tumor*.

Operating an anteriorly located spinal cord meningioma represents a surgical challenge with a risk of subtotal resection and also postoperative worsening [1, 5, 8, 19, 21, 24] SM surgery usually reaches a total resection, but if the tumor has a ventral localization and is calcified, surgical treatment may be risky and may lead to spinal cord damage [11, 26].

The group of Zham [37] focused the attention on the influence of histologic subtype of SM on the postoperative outcome of their cohort of 39 patients, founding out the role of psammomatous type (further confirmation of the possible implication of calcified elements), grade III meningiomas, and the cervical location of the tumor. WHO grading may be

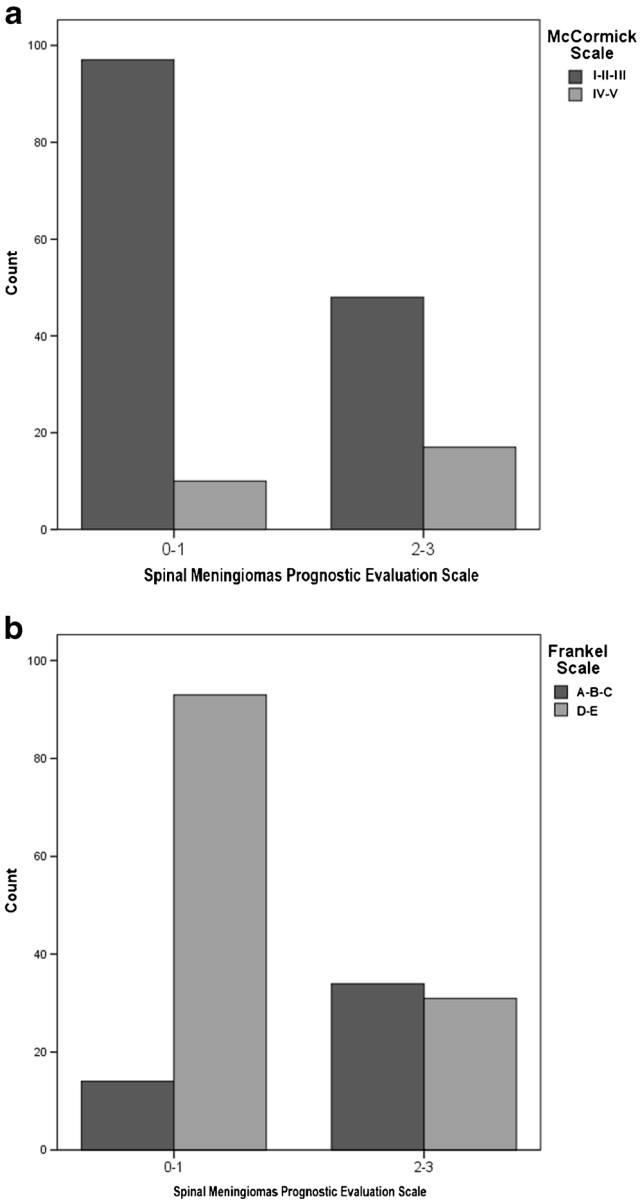

Fig. 2 Chi-square analysis demonstrating the different **a** Frankel and **b** McCormick scores at follow-up for the different SPES classes as expressed by means of dichotomous variables (high versus low SPES classes 0–1 versus 2–3 and high versus low Frankel and McCormick classes at follow-up)

associated with long-term functional outcome, but it was excluded from the regression analysis because it is not possible to accurately assess this feature before surgery. Besides, through high impact experiences [28, 33], the role of grading on has been extensively questioned.

Many studies [17, 18] reported that a complete resection is a predictor of a good prognosis; moreover, in a cohort of 130 meningiomas [18], en plaque and recurrent meningiomas [7, 16, 26] represent challenges because of their complete resection that is difficult to achieve due to infiltration of spinal cord parenchyma and violation of the arachnoidal layer due to surgical scarring. Patients, whose surgeries were performed on recurrent lesions, were found to be associated with a worse functional and neurological long-term outcome [24]. The rate of late recurrence was reported to be 1.3% by Solero et al. [31] and 4% by Levy et al. [17], with a difference in terms of recurrence for lesions with Simpson grades I and II [17, 21]. Mirimanoff et al. [20] reported that, after a total resection, the recurrence-free rate at 15 years was 68%, in comparison to 9% after a subtotal resection. However, the main limitation of the study of Mirimanoff et al. is the limited number of patients included in the cohort. Besides, subtotal resection (Simpson grade IV) was reported to be more associated to recurrence than total resection also by Yoon et al. [36]. The behavior of "recurrence" in SMs surgery has been considered as a puzzling issue because of the extremely slow growth of these tumors [9, 12, 24, 26, 27]; probably, concerning this topic, the most accurate analysis available to date is the one of Setzer et al. [29] who stratified the risk of recurrence according to the WHO grading, rather than extent of resection; they reported a recurrence rate of 1.4% for the WHO grade I lesions (similarly to other reports [32]) and respectively of 50 and 100% for lesions grade II and III in relatively long follow-up period (43.5 ± 24.8 months).

Truth is, as far as we can currently understand, that SMs are relatively rare tumors [26, 31, 34] of which the vast majority is WHO grade I lesions (more than 96% in most of the published series [34]), presenting an exceedingly low recurrence rate (1.3–2.3%) and presenting a very slow rate of regrowth; therefore, not even cooperative longitudinal studies could easily overcome the technical issues of describing, in an accurate fashion, the problem of "recurrences" from oncologic, surgical, and neurological point of views. Nevertheless, many reports converge on identifying surgery on recurrent lesions as frequently harsh and ungenerous.

In a recent notable retrospective trial, Bayoumi et al. [4] developed a multivariate analysis model to outline the potential positive neurological prognostic factors in SM surgery. The authors identify three variables with a statistically significant odds ratio and associated to improved outcomes: presurgical motor deficit, presurgical sensory disturbance, and presurgical myelopathy. These factors could be associated (from a statistical point of view) to the functional prognosis in our experience as well: the most of those patients are indeed complaining just pain at the diagnosis (32.9% of patients), with minor or no neurological impairment of the motor functions; they are likely statistically result stable or worsened at follow-up. Conversely, patients presenting motor impairment and/or a clear myelopathy are more likely to show a more significant improvement. Sensory deficit can preoperatively be found alone or in association with gait ataxia, caused by the impairment of the posterior aspect of the spinal cord. Lesions with a posterior location of the dural attachment are more likely to present a fair-to-excellent prognosis at follow-up.

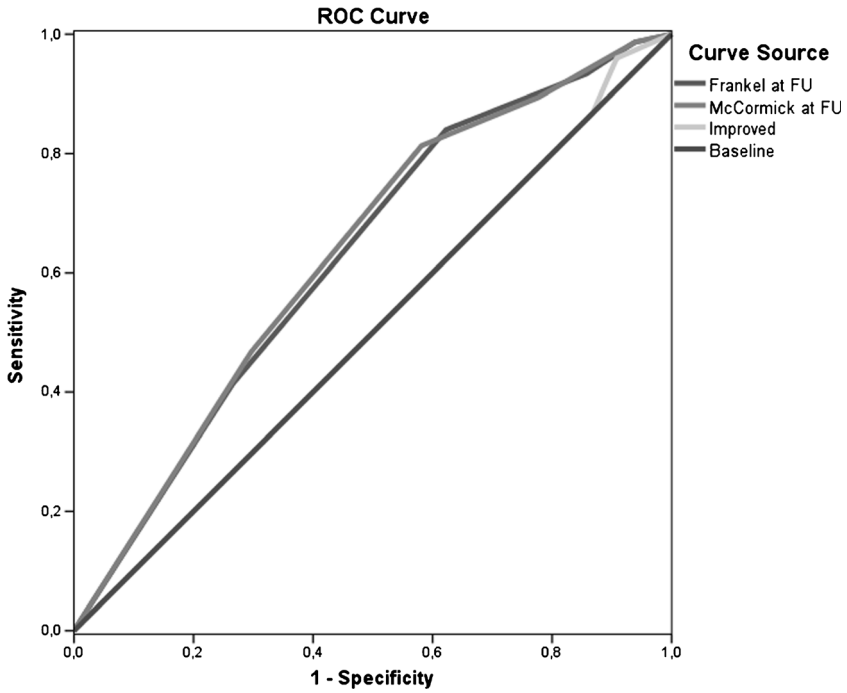

Fig. 3 ROC curve demonstrating the specificity and sensitivity parameters of the SPES score system in respect to Frankel and McCormick scores and the three step ordinal variable (Improved-Stable-Worsened)

We decided to summarize our institutional experience with SMs surgery, proposing a scale based on preoperatively evaluable features which could assess the risk of surgery on functional and neurological outcomes for each single patient affected by SM undergoing a surgical treatment. We created a scale, obtained by the arithmetical sum of dichotomous variables obtained by the analysis of the aforementioned factors, and used it to retrospectively assess their impact on the predictable functional and neurological prognosis by means of a univariate ANOVA analysis with post hoc tests and a multinomial logistic regression model.

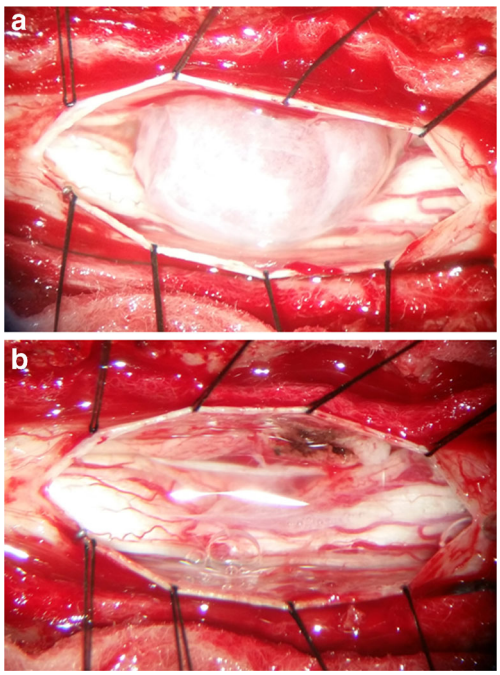

Fig. 4 An intraoperative microsurgical picture disclosing a purely lateral thoracic spinal meningioma (**a**) before and (**b**) after a complete surgical excision with coagulation of the dural attachment (Simpson grade II resection)

We are increasingly aware that the presurgical information to the patients has become one of the central moment of our entire activity. In a contemporary clinical setting, in which simply no mistake and no wrong prediction is accepted, the patient, before expressing his written consent, has, in most of the cases, already independently retrieved an outstanding amount of information about his condition and his prognosis. Most of the patients, receiving surgical treatment in our departments, have already received previous consultations, sometimes optimistic, misleading, or inaccurate.

This scale, therefore, addresses the urgent concern of providing a simple and clear stratification of the predictable outcomes, on the ground of features that can be easily evaluated before surgery, in order to identify and confront the real expectancy about the early and long-term outcomes of SMs surgery.

Limitations

The main limitations of this study lie in the extremely low incidence of this condition; moreover, its typically slow growth jeopardizes the statistical impact of the analysis concerning the recurrences. Many of these lesions presented a favorable neurological outcome and therefore, the subgroup of patients presenting a dismal outcome may be underrepresented. Furthermore, because

of the benign behavior of this condition, the subset of patients presenting combined critical features such as recurrences, compromised neurological preoperative status, and preoperative sphincter impairment, was naturally underrepresented in the present paper, our conclusions, although deriving from a very large series of SMs, may result affected by an unavoidable bias concerning the exact statistical prediction of the neurological results of the high SPES classes (such as classes II and III).

Purpose of the investigation

The present paper grounds its roots in the contemporary framework of the "shared decision-making process" [22, 30, 32]. We, as any other clinical and research groups throughout the entire world, became increasingly aware that patients receiving a thorough, clear, and effective preoperative (and in general pre-treatment) information by their health professionals are more likely to experience a better affective-cognitive, behavioral, and health outcomes [30]. A relatively recent Cochrane review demonstrates that in comparison with patients, a standard information and care, who were thoroughly informed with decision aids, presented increased awareness, stronger compliance through a more accurate risk perception. Thus, internal conflict about decisions is decreased, conversely increased the probability of receiving treatments reflecting the patient values of "Appropriate Healthcare" [32].

Conclusions

Patients suffering from anteriorly or anterolaterally located lesions, or who undergo surgeries for recurrent SMs, or who are affected by a worse functional status and/or sphincter impairment in the preoperative period usually experience, in the long run, a worse functional and neurological prognosis. It is, in our opinion, of uttermost importance to take advantage of all the information the surgeon has, in the preoperative period, to reliably identify who are less likely to experience a good and complete neurological recovery after surgery, in order to be able to provide a precise presurgical information to the patient and to be able to handle to such a prediction in order to plan the safer and most effective surgery for the single patient himself. Therefore, the authors propose an evaluation scale, they called SPES which scores are fairly predictive of the long-term results of patients suffering from SM.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval The present paper contains results obtained from a retrospective study. For this type of study, formal consent is not required.

Informed consent Informed consent was obtained from all individual participants included in the study. No identifying information about participants is available in the article.

References

1. Aboul-Enein HA, Khidr WM, Abdeen KM, Madawi AA (2015) Surgical management of ventrally based lower cervical (subaxial) meningiomas through the lateral approach: report on 16 cases. Clin Neurol Neurosurg 139:152–158
2. Alafaci C, Grasso G, Granata F, Salpietro FM, Tomasello F (2016) Ossified spinal meningiomas: clinical and surgical features. Clin Neurol Neurosurg 142:93–97
3. Arima H, Takami T, Yamagata T, Naito K, Abe J, Shimokawa N, Ohata K (2014) Surgical management of spinal meningiomas: a retrospective case analysis based on preoperative surgical grade. Surg Neurol Int 5(Suppl 7):S333–S338
4. Bayoumi AB, Laviv Y, Karaali CN, Ertilav K, Kepoglu U, Toktas ZO, Konya D, Kasper EM (2017) Spinal Meningiomas: 61 cases with predictors of early postoperative surgical outcomes. J Neurosurg Sci. https://doi.org/10.23736/S0390-5616.17.04102-9
5. Bayoumi AB, Laviv Y, Yokus B, Efe IE, Toktas ZO, Kilic T, Demir MK, Konya D, Kasper EM (2017) Proposal of a new radiological classification system for spinal meningiomas as a descriptive tool and surgical guide. Clin Neurol Neurosurg 162:118–126
6. Bettaswamy G, Ambesh P, Das KK, Sahu R, Srivastava A, Mehrotra A, Jaiswal A, Jaiswal S, Behari S (2016) Extradural spinal meningioma: revisiting a rare entity. J Craniovertebr Junction Spine 7(1):65–68
7. Caroli E, Acqui M, Roperto R, Ferrante L, D'Andrea G (2004) Spinal en plaque meningiomas: a contemporary experience. Neurosurgery 55(6):1275–1279
8. Cohen-Gadol AA, Zikel OM, Koch CA, Scheithauer BW, Krauss WE (2003) Spinal meningiomas in patients younger than 50 years of age: a 21-year experience. J Neurosurg 98(3):258–263
9. Cushing H, Eisenhardt L (1938) Meningiomas. Their classification, regional behaviour, life history, and surgical end results. Bull Med Libr Assoc 27(2):185
10. Davies S, Gregson B, Mitchell P (2017) Spinal meningioma: relationship between degree of cord compression and outcome. Br J Neurosurg 31(2):209–211
11. Freidberg SR (1972) Removal of an ossified ventral thoracic meningioma: case report. J Neurosurg 37(6):728–730
12. Gezen F, Kahraman S, Çanakci Z, Bedük A. (2000) Review of 36 cases of spinal cord meningioma. Spine 25(6):727–731
13. Goldbrunner R, Minniti G, Preusser M, Jenkinson MD, Sallabanda K, Houdart E, von Deimling A, Stavrinou P, Lefranc F, Lund-Johansen M, Moyal EC (2016) EANO guidelines for the diagnosis and treatment of meningiomas. Lancet Oncol 17(9):e383–e391
14. Grimm S, Chamberlain MC (2009) Adult primary spinal cord tumors. Expert Rev Neurother 9(10):1487–1495. https://doi.org/10.1586/ern.09.101
15. King AT, Sharr MM, Gullan RW, Bartlett JR (1998) Spinal meningiomas: a 20-year review. Br J Neurosurg 12(6):521–526
16. Klekamp J, Samii M (1999) Surgical results for spinal meningiomas. Surg Neurol 52(6):552–562
17. Levy WJ Jr, Bay J, Dohn D (1982) Spinal cord meningioma. J Neurosurg 57:804–812

18. Maiti TK, Bir SC, Patra DP, Kalakoti P, Guthikonda B, Nanda A (2016) Spinal meningiomas: clinicoradiological factors predicting recurrence and functional outcome. Neurosurg Focus 41(2):E6
19. Maiuri F, De Caro MDB, de Divitiis O, Vergara P, Mariniello G (2011) Spinal meningiomas: age-related features. Clin Neurol Neurosurg 113(1):34–38
20. Mirimanoff RO, Dosoretz DE, Linggood RM, Ojemann RG, Martuza RL (1985) Meningioma: analysis of recurrence and progression following neurosurgical resection. J Neurosurg 62(1):18–24
21. Nakamura M, Tsuji O, Fujiyoshi K, Hosogane N, Watanabe K, Tsuji T, Ishii K, Toyama Y, Chiba K, Matsumoto M (2012) Long-term surgical outcomes of spinal meningiomas. Spine 37(10): E617–E623
22. Oshima Lee E, Emanuel EJ (2013) Shared decision making to improve care and reduce costs. New Engl J Med 368(1):6–8
23. Pena M, Galasko CS, Barrie JL (1992) Delay in diagnosis of intradural spinal tumors. Spine 17:1110–1116
24. Raco A, Pesce A, Toccaceli G, Domenicucci M, Miscusi M, Delfini R (2017) Factors leading to a poor functional outcome in spinal meningioma surgery: remarks on 173 cases. Neurosurgery 80(4): 602–609
25. Roux FX, Nataf F, Pinaudeau M, Borne G, Devaux B, Meder JF (1996) Intraspinal meningiomas: review of 54 cases with discussion of poor prognosis factors and modern therapeutic management. Surg Neurol 46(5):458–464
26. Sandalcioglu IE, Hunold A, Müller O, Bassiouni H, Stolke D, Asgari S (2008) Spinal meningiomas: critical review of 131 surgically treated patients. Eur Spine J 17(8):1035–1041
27. Saraceni C, Harrop JS (2009) Spinal meningioma: chronicles of contemporary neurosurgical diagnosis and management. Clin Neurol Neurosurg 111(3):221–226
28. Schaller B (2005) Spinal meningioma: relationship between histological subtypes and surgical outcome? J Neuro-oncol 75(2):157–161
29. Setzer M, Vatter H, Marquardt G, Seifert V, Vrionis FD (2007) Management of spinal meningiomas: surgical results and a review of the literature. Neurosurg Focus 23(4):E14, 1–12
30. Shay LA, Lafata JE (2015) Where is the evidence? A systematic review of shared decision making and patient outcomes. Med Decis Mak 35(1):114–131
31. Solero CL, Fornari M, Giombini S, Lasio G, Oliveri G, Cimino C, Pluchino F (1989) Spinal meningiomas: review of 174 operated cases. Neurosurgery 25(2):153–160
32. Stacey D, Bennett CL, Barry MJ, Col NF, Eden KB, Holmes-Rovner M, Llewellyn-Thomas H, Lyddiatt A, Légaré F, Thomson R (2011) Decision aids for people facing health treatment or screening decisions. Cochrane Database Syst Rev 10:CD001431–CD001431
33. Sun SQ, Cai C, Ravindra VM, Gamble P, Yarbrough CK, Dacey RG, Dowling JL, Zipfel GJ, Wright NM, Santiago P, Robinson CG (2015) Simpson Grade I-III resection of spinal atypical (World Health Organization Grade II) meningiomas is associated with symptom resolution and low recurrence. Neurosurgery 76(6):739–746
34. Westwick HJ, Shamji MF (2015) Effects of sex on the incidence and prognosis of spinal meningiomas: a surveillance, epidemiology, and end results study. J Neurosurg Spine 23(3):368–373
35. Westwick HJ, Yuh SJ, Shamji MF (2015) Complication avoidance in the resection of spinal meningiomas. World Neurosurg 83(4): 627–634
36. Yoon SH, Chung CK, Jahng TA (2007) Surgical outcome of spinal canal meningiomas. J Korean Neurosurg Soc 42(4):300–304
37. Zham H, Moradi A, Rakhshan A, Zali A, Rahbari A, Raee M, Ashrafi F, Ahadi M, Larijani L, Baikpour M, Khayamzadeh M. (2016). Does histologic subtype influence the post-operative outcome in spinal meningioma? Iran J Cancer Prev 9(2)