Predicting the Probability of Meningioma Recurrence in the Preoperative and Early Postoperative Period: A Multivariate Analysis in the Midterm Follow-Up

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ABSTRACT

We reviewed the clinical, radiological, surgical, and histopathological features of patients with meningiomas to identify factors that can predict tumor recurrence after “microscopic total removal,” to improve preoperative surgical planning, and to help determine the need for close radiological observation at shorter intervals or the need for radiotherapy as an adjuvant treatment in the early postoperative period. Clinical data, magnetic resonance imaging studies, angiographic data, operative reports, and histopathological findings were examined retrospectively in 137 patients with a meningioma treated microsurgically and with no evidence of residual tumor on postoperative MR images. Based on univariate analysis, tumor size, a mushroom shape, proximity to major sinuses, edema, osteolysis, cortical penetration, signal intensity on T2-weighted MRIs, pial-cortical arterial supply, presence of a brain-tumor interface in surgery, Simpson’s criteria, and histopathological classification were significant predictors for recurrence. However, age, gender, location of tumor, dural tail, calcification, signal intensity on T1-weighted images, and histopathologic subtypes in the benign group were not significant predictors. By Cox regression analysis the most important variables related to the time to recurrence were mushroom shape, osteolysis, dural tail, and proximity to major sinuses. Aggressive surgical therapy with wider dural removal should be considered in the presence of the preoperative predictors of a recurrence. Close radiological observation at shorter intervals or radiotherapy should be considered as adjuvant therapy in high-risk patients

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based on surgical findings predicting recurrence related to the brain-tumor interface, Simpson's criteria, and histopathological findings in the early postoperative period.

KEYWORDS: Angiography, magnetic resonance imaging, meningioma, tumor recurrence

Even after complete removal, meningiomas have been estimated to recur in 10 to 32% of the cases within 10 years.^{1,2} Except for the degree of tumor removal, other risk factors for recurrence are not well understood in the cases with benign meningioma. Regional multicentricity has been suggested as a cause of recurrences.³ Surgical cleavability of meningiomas from the adjacent parenchymal tissue has been reported as a significant prognostic factor⁴ and can be predicted from preoperative magnetic resonance imaging (MRI) and angiographic studies.⁵ The relation between tumor recurrence and radiological features on MRI and angiography indicating a brain-tumor interface (surgical cleavability) has not yet been studied.

We therefore investigated the relationships between tumor recurrence and the following parameters: age, gender, tumor size and shape, proximity to major sinuses, edema, bone changes, calcification, cortical penetration, dural tail, signal intensity on T1- and T2-weighted MRIs, pial-cortical arterial supply, brain-tumor interface at surgery, Simpson's criteria, and pathology. Our main goal was to identify high-risk groups preoperatively, to improve surgical planning, and to decide whether to perform close radiological observation at shorter intervals or radiotherapy as an adjuvant therapy by estimating the risk of recurrence via surgical and histopathological findings in the early postoperative period.

CLINICAL MATERIALS AND METHODS

Between 1989 and 2000, 201 patients underwent treatment for intracranial meningiomas at our Neu-

rosurgical Department. Sufficient data for analysis were available from 169 patients. Of 169 patients, 14 were excluded from the study due to radiographic evidence of residual tumors. At least 1 year of follow-up was deemed necessary since the volume doubling time in rapidly growing meningiomas, including in atypical or anaplastic and benign forms, is faster⁶ than would be expected in the average meningioma⁶⁻⁸ and to calculate time to recurrence correctly. Eighteen patients were excluded because their follow-up period was less than 1 year long. In this group, 2 patients died postoperatively and 4 patients died from unrelated diseases during the follow-up period with no evidence of tumor recurrence. The remaining 12 patients were lost to follow-up with less than 1 year without recurrence. All together, 137 cases had no evidence of residual tumor and suitable data for analysis. Their medical charts and radiographic files were reviewed retrospectively for clinical, radiographic, operative, and pathological data. None of the patients had undergone a previous operation or had received prior radiotherapy.

MRI was performed mainly with a 1.5 T machine (General Electric, Milwaukee, WI, USA). Precontrast T1-weighted MRIs were obtained with 600–800/20/1–2 (repetition time/echo time/excitation) and T2-weighted images with 2800/90/1. Typically, slice thickness was 5 mm with a 2.5-mm interval between slices. Gadolinium-DTPA (0.1 mmol/kg) was used in 92 cases. T1-weighted MRIs were obtained in various planes depending on the location of the tumor. Tumors were categorized according to their location: parasagittal, falx, convexity, anterior fossa, middle fossa, or posterior fossa. They were also categorized into a near a major sinus (NS) group and a distant from major

sinus (DS) group. In the former group, the attachment margin of the tumor was located within 1 cm of the major sinuses, including sagittal, transverse, sigmoid, and cavernous sinuses. The size of the tumors was categorized as large (> 4 cm) or small (< 4 cm) by calculating its mean diameter on MRI. Signals from the lesions were evaluated for their intensity relative to cortical gray matter on a scale from 1 to 5 or both T1- and T2-weighted MRIs (Table 1).⁹ Calcification of the tumor was categorized as none, focal, and diffuse. Tumor shape, bone changes, and existence of a dural tail on MRIs were recorded. Tumor shape was categorized as round, lobulated, and mushroom.¹⁰ The extent of associated cerebral edema was graded mild (Grade 1) indicating absent edema or a small halo around the perimeter of the tumor, moderate (Grade 2) indicating extensions along white matter tracts for variable distances without involving the entire

hemisphere, and severe (Grade 3) indicating holohemispheric or almost holohemispheric edema.

On the basis of findings on selective angiography, we classified tumors into three groups in 83 cases. In Group 1, tumors with a tumor stain mainly received dural arterial supply without staining from pial-cortical arterial supply. In Group 2, the pial-cortical arterial supply provided less blood supply than the meningeal dural supply. In Group 3, the pial-cortical arterial supply was at least equal to that of the meningeal dural supply in staining of the tumor. Patients undergoing preoperative embolization were excluded from the study because the dural and/or pial-cortical arterial supply was one of the parameters investigated.

Surgical Approach

We used classic microsurgical dissection techniques, including the surgical microscope, microinstruments, and bipolar forceps. To avoid affecting the statistical results negatively, we excluded the few cases in which laser or ultrasonic aspiration were used. Based on microsurgical observations, the brain-tumor interface was graded as follows⁵: Type I, smooth; Type II, intermediate; and Type III, invasive.

The extent of tumor removal was graded according to Simpson's criteria.¹¹

Based on the schema of Russell and Rubinstein,¹² tumors were classified into their predominant histological subtypes as meningothelial (syncytial), fibroblastic, transitional, and angioblastic. If mitotic figures were present, tumor had infiltrated the surrounding brain tissue, nuclear atypia or necrosis was present, and differentiation was poor, these tumors were classified as atypical or malignant.¹³

Statistical Analysis

The SPSS version 10.1 and SAS version 8.1 statistical packages were used for data analysis.

Table 1 Visual Scoring of Meningioma Signal Intensity

Features	Score
T1-weighted images	
Markedly hypointense to gray matter, almost as dark as CSF	1
Mildly hypointense to gray matter but easily distinguished from it	2
Almost isointense with cortical gray matter, may be difficult to distinguish	3
Mildly hyperintense to gray matter but easily distinguished from it	4
Markedly hyperintense to gray matter, almost as bright as fat	5
T2-weighted images	
Markedly hypointense to gray matter, almost as dark as cortical bone	1
Mildly hypointense to cortical gray matter but easily distinguished from it	2
Almost isointense with cortical gray matter, may be difficult to distinguish	3
Mildly hyperintense to gray matter, easily distinguished	4
Markedly hyperintense to gray matter, almost as bright as CSF	5

CSF, cerebrospinal fluid.

Table 2 Clinicopathological Data of 16 Patients with Recurrent Meningiomas

Case Number	Age (y)/Sex	Surgical Cleavage [†]	Simpson Grade	Histological Characteristics	Location	Interval to Recurrence (mo)
1*	38/F	III	I	malignant	anterior fossa	68
2	38/F	II	II	angioblastic	parasagittal	28
3	53/F	II	II	transitional	anterior fossa	114
4*	25/M	III	I	malignant	convexity	35
5	48/F	II	II	angioblastic	anterior fossa	41
6*	48/F	III	I	atypical	convexity	52
7	48/M	II	III	transitional	parasagittal	81
8*	62/M	II	I	atypical	anterior fossa	43
9*	48/M	III	I	atypical	convexity	32
10*	56/M	III	III	atypical	parasagittal	28
11	60/F	II	III	fibrous	middle fossa	84
12	64/F	III	I	transitional	parasagittal	71
13	50/F	III	I	meningothelial	convexity	60
14	37/M	III	I	fibrous	parasagittal	61
15	28/M	III	III	angioblastic	convexity	48
16	25/M	II	I	transitional	posterior fossa	38

*Patient underwent radiotherapy after surgical removal of tumor.

[†]I: smooth type; II: intermediate type; III: invasive type.

Recurrence-free times were estimated by the non-parametric method of Kaplan-Meier and compared by the log rank test. The association between the two categorical variables was assessed by the chi-squared or the Fisher's exact test. Finally, Cox regression, with a stepwise selection procedure, was used to evaluate time to tumor recurrence.

RESULTS

Of the 137 patients, 2 had malignant, 4 had atypical, and 131 had benign meningiomas. Sixteen patients developed a recurrent meningioma (Tables 2 and 3). The mean time to recurrence was 60.5 ± 27.9 months (range, 28 to 114 mos) for benign meningiomas and 39 ± 14.5 months (range, 28 to 68 mos) for malignant meningiomas. The other 121 patients had no recurrent symptoms or radiological evidence of a recurrence (mean follow-up, 68 ± 28.7 mos; range, 12 to 128 mos).

Of the 47 patients under 40 years old, 10.6% had a recurrence compared with 12.2% of the 90 patients over 40 years old. Neither patient age ($p = 0.92$) nor gender ($p = 0.50$) was significantly related to tumor recurrence (Table 4).

Tumor size was significantly related to recurrence. Larger tumors were significantly more likely to recur than smaller tumors ($p = 0.05$). Kaplan-Meier plots of recurrence-free time for patients with large tumors were significantly shorter than those associated with small tumors ($p < 0.05$) (Fig. 1).

The location of a tumor was not significantly related to recurrence ($p = 0.5$; data not shown). However, the recurrence rate in the NS group was significantly higher than in the DS group (20.0% versus 5.19%) ($p = 0.04$). Recurrence-free time was significantly longer in the DS group ($p < 0.04$) (Fig. 2) than in the NS group.

Tumor shape was also significantly related to recurrence. Four of the six (66.6%) mushroom tumors, 7 of the 28 (25.0%) lobulated tumors, and 5 of the 103 (4.8%) round tumors recurred. Time to recurrence was significantly longer for round and

Table 3 Radiological Results of Recurrent Meningiomas in 16 Patients

Case Number	Signal Intensity		Edema Grade	Angio Class	Penetration on MR	Location	Calcification	Size	Shape	Bone Change	Dural Tail
	T1 Class	T2									
1	3	5	2	NA	+	DS	-	S	R	O	NA
2	1	2	3	1	+	NS	F	L	L	-	+
3	2	4	2	1	+	NS	-	S	R	-	NA
4	4	5	2	3	+	DS	-	L	M	H	+
5	2	4	2	2	+	NS	-	S	R	-	+
6	2	4	3	2	+	NS	-	S	M	-	+
7	2	2	2	NA	+	NS	F	L	L	O	-
8	2	2	2	2	+	DS	-	L	M	O	+
9	2	4	3	3	+	NS	-	S	M	O	-
10	3	4	3	3	+	NS	-	S	R	-	+
11	3	3	2	NA	+	DS	-	L	L	-	+
12	3	5	3	3	+	NS	-	L	L	-	-
13	3	5	3	NA	+	NS	-	L	L	-	+
14	3	5	2	3	+	NS	-	L	L	-	-
15	3	5	3	NA	+	NS	-	L	L	H	+
16	3	3	2	NA	+	NS	-	L	R	-	NA

NS, near a major sinus; DS, distant from a major sinus; +, present; -, absent; F, focal calcification; D, diffuse calcification; S, small; L, large; R, round; L, lobulated; M, mushroom; O, osteolysis; H, hyperostosis; Class, classification; NA, not available.

Table 4 Association of Clinical, Radiological, Surgical, and Histological Parameters with Recurrence in Meningiomas*

Variable	Incidence of Recurrence (%)	Incidence of Recurrence (N)	p Value
Patient age			
< 40 years	10.6	47	= 0.92
> 40 years	12.2	90	
Patient gender			
Male	10.9	64	= 0.50
Female	12.3	73	
Tumor size			
Small	6.7	90	= 0.05
Large	21.3	47	
Location			
NS	20.0	60	= 0.04
DS	5.2	77	
Tumor shape			
Round	4.9	103	= 0.0001
Lobulated	25.0	28	
Mushroom	66.7	6	
Tumor calcification			
None	14.6	96	= 0.12
Focal	8.9	24	
Diffuse	0	17	
Edema			
None or minimal	0	61	= 0.001
Marked	14.5	55	
Severe	38.1	21	
Bone change			
Hyperostosis	3.3	61	= 0.001
Osteolysis	80.0	5	
None	14.8	71	
Cortical penetration			
Absent	0	69	= 0.001
Present	23.5	68	
Dural tail			
Absent	9.8	41	= 0.15
Present	19.6	51	
Intensity			
T1			= 0.85
1	16.2	37	
2	10	10	
3	10	90	
4	NA	NA	
5	NA	NA	
T2			
1	0	15	
2	6.5	46	

Table 4 (con't)

Variable	Incidence of Recurrence (%)	Incidence of Recurrence (N)	p Value
3	2.7	37	= 0.001
4	23.8	21	
5	38.9	18	
Angiographic class			
1	5.6	36	= 0.12
2	11.5	26	
3	23.8	21	
Surgical cleavage			
I	0	60	= 0.001
II	12.2	49	
III	35.7	28	
Simpson Grade			
I	6.6	121	= 0.001
II	36.4	11	
III	80	5	
Pathology			
Benign	7.6	131	= 0.0001
Nonbenign	100	6	

*According to univariate analysis (Cox-Mantel test). The study is based on 137 patients. Some data related to angiography and dural tail are lacking.

NS, near a major sinus; DS, distant from a major sinus; NA, not available.

lobulated tumors ($p < 0.001$) (Fig. 3) than for mushroom-shaped tumors.

None of the tumors recurred in the patients with diffuse calcification. In contrast, tumor recurred in 14.6% of the patients without calcification and in 8.9% of the patients with focal calcification. However, there was no significant difference among these recurrence rates ($p = 0.12$).

The peritumoral edema grade was associated with the tumor recurrence ($p = 0.001$). Kaplan-Meier plots of recurrence-free time for Grades 1 through 3 edema showed increasingly negative slopes of recurrence-free time curves as edema grade increased ($p < 0.001$) (Fig. 4).

The recurrence rate was lowest (3.3%) in the patients with hyperostosis and highest (80.0%) in patients with osteolysis and in the patients without bone changes (14.8%, $p < 0.001$). Kaplan-Meier plots of recurrence-free time in the cases with

Figure 1 Kaplan-Meier plots showing the percentages of patients who were recurrence-free after surgical excision over time in the groups according to tumor size ($p < 0.05$).

Figure 2 Kaplan-Meier plots showing the percentages of patients who were recurrence-free after surgical excision over time based on proximity to a major sinus ($p < 0.04$).

Figure 3 Kaplan-Meier plots showing the percentages of patients who were recurrence-free after surgical excision over time according to tumor shape ($p < 0.001$).

osteolysis compared with those with hyperostosis and those without bone change showed a significant difference in favor of hyperostosis and no bone change ($p < 0.001$) (Fig. 5).

Cortical penetration on MRI was one of the most important variables predicting recurrence after surgical excision. The difference in recurrence rate was statistically significant ($p = 0.001$). All the cases

Figure 4 Kaplan-Meier plots showing the percentages of patients who were recurrence-free after surgical excision over time according to edema grade on MRI ($p < 0.001$). All cases of complete resection with no or minimal edema were recurrence-free for the entire follow-up period.

Figure 5 Kaplan-Meier plots showing the percentages of patients who were recurrence-free after surgical excision over time according to bone changes ($p < 0.001$).

without cortical penetration were free from recurrence for as long as 123 months. The recurrence-free time was shorter (mean 103 ± 41 mos; $p < 0.001$; data not shown) in patients with cortical penetration.

Gadolinium-DTPA contrast material was used in 92 cases (67.1%). Ten of the 51 cases with dural tail signs (19.6%) and 4 of the 41 cases without dural tail signs (9.8%) recurred. The presence of dural tail affected neither recurrence rate ($p = 0.15$) nor time to recurrence ($p = 0.5$; data not shown) in univariate analysis.

The signal intensity of the tumor on T1-weighted MRIs was not significantly related to recurrence ($p = 0.85$). However, the signal intensity on T2-weighted MRIs was significantly related to recurrence ($p = 0.001$). There were no recurrences in patients with a score of 1. Recurrence rates based on T2-weighted signal intensity were 6.5%, 2.7%, 23.8%, and 38.9% in patients with scores 2, 3, 4, and 5, respectively. Superimposed Kaplan-Meier plots showed increasingly negative slopes of recurrence-free time curves

with increasing T2-weighted intensity scores ($p < 0.001$; data not shown).

Based on the angiographic findings, there were 36 cases in Group 1, 26 cases in Group 2, and 21 cases in Group 3. The recurrence rate was 5.6% in Group 1, 11.5% in Group 2, and 23.8% in Group 3. Although this rate increased as the pial-cortical arterial supply increased, we were unable to detect a significant difference because of the reduced number of the samples from 137 to 83 ($p = 0.12$). However, time to recurrence was affected by the type of arterial supply. Kaplan-Meier plots of recurrence-free time showed a significant difference in favor of Group 1 and Group 2 ($p < 0.01$) compared with Group 3 (Fig. 6).

Sixty (43.7%) cases had a Type I brain-tumor interface (smooth), 49 (35.7%) cases had a Type II interface (intermediate type), and 28 cases (20.4%) had a Type III interface (invasive type). The type of brain-tumor interface was significantly related to recurrence ($p = 0.001$). Kaplan-Meier plots of recurrence-free time showed a significant difference in favor of Type 1 cases ($p < 0.001$) (Fig. 7). All

Figure 6 Kaplan-Meier plots showing the percentages of patients who were recurrence-free after surgical excision over time according to angiographic classification ($p < 0.01$).

Figure 7 Kaplan-Meier plots showing the percentages of patients who were recurrence-free after surgical excision over time in groups according to the brain-tumor interface at surgery ($p < 0.001$). All Type 1 cases were recurrence-free for the entire follow-up period.

Figure 8 Kaplan-Meier plots showing the percentages of patients who were recurrence-free after surgical excision over time according to histopathologic classification ($p < 0.001$).

Type I cases were free from recurrence as long as 128 months. Recurrent tumors were associated with Type II and III cleavage planes.

Complete tumor excision (Simpson Grade I), including the dural attachment, was achieved microscopically in 121 (88.3%) cases. Eleven (8.0%) cases were classified as Simpson Grade II in which only unipolar coagulation of the dural attachment was accomplished. Complete tumor excision without resection or coagulation of dural attachments in Simpson Grade III was achieved in 5 cases (3.6%). Simpson Grade was significantly related to recurrence ($p = 0.001$). Kaplan-Meier plots of recurrence-free time showed increasingly negative slopes of recurrence-free time curves as Simpson Grade increased ($p < 0.001$; data not shown).

Recurrence rates differed based on histopathological classification ($p < 0.001$; data not shown). Histopathological classification in benign groups as transitional, meningothelial, fibroblastic, and angioblastic had no significant relationship with recurrences ($p = 0.30$; data not shown). However, when histopathological classification was re-analyzed as benign and nonbenign meningiomas

(atypical and malignant), a significant relationship was found ($p = 0.0001$). Kaplan-Meier plots of recurrence-free times showed a significant difference in favor of benign tumors ($p < 0.001$) (Fig. 8).

Based on Cox regression analysis, the most important variables affecting the time to recurrence of tumor were a mushroom shape, osteolysis, a dural tail, and proximity to major sinuses. See Table 5.

DISCUSSION

Several studies have reported higher recurrence rates for males than for females.^{14–17} However, other studies, including ours, have found no significant difference based on gender.^{1,16–20} Nakasu et al²¹ and several other authors found no association between tumor development in young patients (< 40 yrs) and a high likelihood of recurrence.^{2,21,22} However, Perry and associates¹⁷ found a significant difference between age and recurrence, while Adegbite and colleagues¹ could demonstrate no significant influence of sex and age on recurrence. In our

Table 5 Summary of the Multivariate Analysis of Time to Recurrence by Cox Regression Model

Variables	β	Se β	p	exp(β)	[CI_L	CI_U]
Tumor shape						
Lobulated	ref.					
Round	2.14	0.85	0.0100	8.50	1.61	44.97
Mushroom	1.85	0.88	0.0300	6.36	1.13	35.69
Bone changes						
Hyperostosis	ref.					
Osteolysis	-1.36	0.95	0.1500	0.26	0.04	1.65
None	2.55	0.77	0.0009	12.81	2.83	57.93
Dural tail						
Absent	ref.					
Present	1.98	0.88	0.200	7.24	1.29	40.64
NA	-0.72	1.01	0.4700	0.49	0.07	3.52
Tumor location						
DS	ref.					
NS	1.48	0.80	0.0600	4.39	0.92	21.07

NA, not applicable; NS, near a major sinus; DS, distant from a major sinus; Se, standard error; ref, reference value.

study neither gender nor age was a significant predictor of recurrence.

Increasing tumor size correlated closely with the increasing recurrence rate in our study. Bitzer and coworkers²³ and Ide and colleagues²⁴ reported that large tumors were associated with a higher incidence of tumor infiltration and adherence to arachnoid membrane and the adjacent brain tissue than smaller tumors. In our study tumor size was related to cortical penetration detected on MRI. However, there was no statistical correlation between tumor size and the type of brain-tumor interface at surgery.

Opinions on tumor location as a predictor of risk vary. Adegbite and associates¹ found that location had no significant influence on recurrence. In contrast, Palma and coworkers²⁵ found that tumor location was a significant predictor of recurrence when completeness of resection was not precisely controlled. In our study, the location of a tumor was not an important factor in predicting a recurrence. However, Nakasu and colleagues²¹ divided meningiomas into two groups as near a major sinus and distant from a major sinus and found that the recurrence rate was different between the two groups. We also found that tumors in the NS group

were more likely to recur than those in the DS group. Proximity to a major sinus reached significance in the univariate analysis and significantly affected the time to tumor recurrence.

In our series, mushroom-shaped meningiomas were associated with a significantly higher incidence of recurrence than those with smooth borders. Alvarez and colleagues²⁶ and Jääskeläinen and associates²⁰ support this theory, suggested by New et al,¹⁰ finding “mushrooming” on CT to be a significant prognostic sign for clinical and histological malignancy. Four of our six cases with a mushroom pattern were atypical or malignant; the other two were benign. In contrast, Nakasu and coworkers²¹ found that lobulated tumors recurred more often than round tumors. We, however, found no difference between lobulated and round tumors in terms of recurrence rates.

Nakasasu and colleagues²¹ reported no recurrence of meningiomas associated with calcification, which they had assumed might be an important predictor for nonrecurrence. Although two of our meningioma cases associated with focal calcification recurred, there was no significant relationship between presence of calcification and recurrence rate.

Kallio and associates²⁷ found that hyperostosis was associated with a high recurrence rate after apparently complete removal of benign meningiomas. We found no such relationship in our series. However, the incidence of recurrent meningiomas was significantly higher in patients with osteolytic changes in the skull bones.²⁸ The presence of osteolysis increased the risk of recurrence in our series. Younis and Sawaya²⁹ support the theory, originally proposed by Olmsted and McGee,²⁸ that meningiomas causing osteolysis and extending into the soft tissue should be considered malignant even when their initial histology seems benign. However, Alvarez et al²⁶ did not find that osteolysis was a significant factor in predicting malignancy in their series. In our series, osteolysis occurred in 3 (50.0%) of the six non-benign cases of meningioma.

Nakau and coworkers³⁰ reported tumor cells in the dural tails of five of nine meningiomas with dural tails. In contrast, Tokumaru and associates³¹ found no neoplastic involvement in the enhanced dura. Nakasu and colleagues²¹ reported that there was no significant relationship between tumor recurrence and the dural tail on MRI. In our series the presence of dural tail was not a predictor of recurrence in univariate analysis, confirming the findings of Nakasu et al. However, the presence of a dural tail was a significant variable affecting time to recurrence in the multivariate analysis.

Chen³² and Zee³³ and their associates suggested that tumor hyperintense to gray matter on T2-weighted MRI was correlated with microscopic hypervascularity, a soft consistency, and aggressivity, whereas other authors^{24,34} have found no significant difference between benign and anaplastic and aggressive tumors on MRI. In this study⁵ the MR signal intensity on T2-weighted MRI was correlated with recurrence.

Bitzer et al³⁵ and Tamiya and colleagues³⁶ reported that intrinsic cerebral arteries might play a significant role in the pathogenesis of meningioma-associated edema. Recently, however, the adherence of tumor to the surrounding brain tissue was found

to be strongly correlated with edema.²⁴ Therefore, we decided to analyze the relationship of pial-cortical arterial supply, peritumoral edema, and cortical penetration with recurrence. We found a significant relationship between peritumoral edema, cortical penetration, and recurrence, but there was no relationship between pial-cortical arterial supply and recurrence. However, time to recurrence was strongly affected by the type of arterial supply. Despite the recent rapid proliferation of literature on the early prediction of meningioma recurrence, an angiographically based series on the prognostic value of pial-cortical arterial supply for predicting the recurrence rate in meningiomas has not yet been published.

There is complete agreement in the literature that radical surgery is one of the positive factors influencing the prognosis of benign and malignant meningiomas.^{14,20,37-41} The Simpson grading system has been the best-accepted predictor of recurrence since publication of Simpson's landmark article in 1957.¹¹ The recurrence rate was reported to be twofold for Simpson Grade II as opposed to Grade I excision of benign meningiomas, evidently related to the regrowth of neoplastic cells escaping from dural coagulation.¹¹ Simple coagulation of the tumor base was one of the risk factors for recurrence. A significant difference in recurrence rate has been reported by comparing the combination of Grades I and II tumors with the combination of Grades III and IV.¹ Compared with those of Simpson Grade II and III in our series, Simpson Grade I were significantly more likely to recur.

CONCLUSIONS

Tumor size, mushroom shape, osteolysis, edema grade, proximity to a major sinus, cortical penetration and intensity on T2-weighted MRIs, pial-arterial supply on angiography, type of brain-tumor interface at surgery, Simpson Grade, and malignancy were significantly independent predictors for

recurrence. Aggressive surgical therapy with wider dural removal should be considered when these findings are present preoperatively. Close radiological observation with shorter intervals or radiotherapy should be considered as an adjuvant therapy for patients with a high risk of recurrence in the early postoperative period. Our findings provide convincing evidence about predictors for recurrence of meningiomas in midterm follow-up. However, since recurrence rates increase over time after complete excision, further long-term follow-up studies are needed to confirm these predictors.

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Commentary

İldan and coworkers studied the factors predicting recurrence after complete resection of meningiomas in the MRI era. Their findings are interesting and speak for themselves. It is important to note that there was a difference between Simpson Grade I and Grade II resection of meningiomas. The authors did not assess the value of radiosurgery or radiotherapy. It would be interesting to know if subtotal resection (Grade II or Grade III) followed by radiotherapy is associated with the same recurrence rate as a Simpson Grade I excision. This question, for instance, is pertinent for skull base meningiomas.

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