



Management of Meningiomas Involving the Major Venous Sinuses: A Single-Institution Experience

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BACKGROUND: In the management of meningiomas invading the major venous sinuses, balance between tumor control and complication prevention is desirable. The aim of this study was to describe an institutional experience in management of meningiomas involving major venous sinuses.

METHODS: A retrospective study was carried out over 18 years, between 1999 and 2017, in patients with meningiomas involving major venous sinuses. Clinical features, operative strategy, histology, postoperative complications, adjuvant therapy, and long-term follow-up were studied.

RESULTS: The study included 84 patients. Neurologic deficits were seen in 26 (31%) patients at presentation. The recurrence rates in Simpson grade I, II, and III excision were 7.6%, 25%, and 29.4% at a mean follow-up of 45.4 months (range, 1–192 months). No intervention of the involved sinus was done in 64 (76%) cases, venotomy was done in 3 (3.5%) cases, sinus resection without graft was done in 14 (16.6%) cases, and sinus reconstruction with patch was done in 3 (3.5%) cases. There were 53 (67.0%) patients with World Health Organization grade I histology and 25 (31.6%) patients with World Health Organization grade II histology. Fifteen recurrences were treated with Gamma Knife radiosurgery. In univariate analysis using Cox proportional hazards model, World Health Organization grade ($P = 0.036$, hazard ratio 2.90, 95% confidence interval = 1.07–7.87) and Simpson grade ($P = 0.017$, hazard ratio 2.90, 95% confidence interval = 1.18–5.29) were found to be significant factors to predict tumor recurrence.

CONCLUSIONS: Management of meningiomas involving major venous sinus with microsurgical techniques and adjuvant Gamma Knife radiosurgery achieves a good tumor control rate with an acceptable complication rate.

INTRODUCTION

According to Simpson,¹ “innocence” and “malignancy” are relative terms in describing meningiomas that invade surrounding structures. Meningiomas, although benign, pose problems due to their location and invasion of surrounding structures. Cushing began his surgeries for meningiomas with the conviction that meningiomas are benign tumors. In 43 of his 295 cases, reoperation was necessary for recurrence, and 76 patients died at home as a result of incompletely removed tumors.¹ Whereas gross total resection (GTR) remains the gold standard for most meningiomas, the treatment strategy for meningiomas invading venous sinuses has undergone significant evolutionary change. The fundamental question challenging the neurosurgeon in managing meningiomas invading the venous sinuses is what needs to be done with the venous sinus. Aggressive resection of involved venous sinus was favored by several authors previously.² Venous sinus resection without reconstruction has been shown to result in significant neurologic deterioration following surgery.³ On one hand, resection and opening of venous sinus to remove the invaded tumor is associated with significant postoperative morbidity.^{1,4} On the other hand, incomplete removal is associated with higher recurrence rates.^{3,4} With the tremendous advances in

Key words

- Meningiomas
- Parasagittal
- Surgery
- Venous sinus

Abbreviations and Acronyms

- GTR:** Gross total resection
MRI: Magnetic resonance imaging
SSS: Superior sagittal sinus
WHO: World Health Organization

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imaging and radiotherapy techniques, many centers now are in favor of a less aggressive resection strategy for these cases. Avoidance of complications with preservation of quality of life is the priority at the present time. This study is a retrospective analysis of our management strategy for such venous sinus meningiomas.

MATERIALS AND METHODS

Patients and Data

The study was approved by the institutional review board. At the Department of Neurosurgery, Louisiana University Health Center, Shreveport, the records of all patients with meningioma were reviewed from the years 1999–2017. Cases of meningiomas with involvement of venous sinus were selected after reviewing the historical charts and imaging details of the patients. The cases with clear evidence of involvement of the venous sinus (evaluated by magnetic resonance imaging [MRI], digital subtraction angiography, and operative notes) were included in the study. Data were evaluated retrospectively. Various demographic parameters, operative details, postoperative complications, pathology reports, and follow-up details were collected. The tumor size was measured from preoperative MRI along the longest dimension and recorded. The involvement of venous sinus was graded according to the Sindou grading system.⁴ Grade I is defined as attachment to the lateral wall of the sinus, grade II is invasion of lateral recess, grade III is invasion of lateral wall of sinus, grade IV is involvement of lateral wall and roof, grade V is complete occlusion of sinus, and grade VI is invasion of the opposite wall of the sinus with complete occlusion. The extent of resection was graded by Simpson grade. Grades I and II were considered as GTR. The pathologic grading was according to World Health Organization (WHO) grade. Ki-7 index was not available in 35 patients. Follow-up MRI was obtained at 6 months after surgery and thereafter at 1-year intervals. Recurrence was defined as new contrast-enhancing lesion in the area of previously completely resected region or new growth in the residual lesion >20% of the baseline size. Tumor control was defined to be present in tumors that remained stable and tumors that regressed from the initial baseline size. Postoperative Karnofsky performance scale score was evaluated.

Operative Strategy for Involved Venous Sinus

The goal of surgical management was safe GTR of the tumor. Sinus resection was not performed in cases of tumor involving the middle and posterior one third of superior sagittal sinus (SSS), transverse sinus, sigmoid sinus, or torcular Herophili. Resection of the sinus was performed when the tumor was invading the anterior one third of sagittal sinus. In most cases, the tumor within the sinus was not pursued. No intervention to the sinus was done in 64 cases. A small venotomy was performed to remove tumor fragment in 3 cases. Sinus reconstruction was done using a small patch in 3 cases. In 14 cases, the sinus was resected along with the tumor. In all these cases, the tumor was located in the anterior one third of SSS. The residual tumor was observed for any growth with serial MRI, and cases that demonstrated growth were given radiation treatment with Gamma Knife (Elekta AB,

Table 1. Patient Characteristics and Clinical Features

Characteristic	Value
Number of patients	84
Age, years, mean \pm SD	63 \pm 15.6
Sex, male/female	29/55
Preoperative KPS score, mean \pm SD	87 \pm 6.9
Size, mm, mean \pm SD	43.77 \pm 18.65
Anterior one third principal dural attachment	23
Middle one third principal dural attachment	45
Posterior one third principal dural attachment	5
Transverse sinus	4
Torcula	6
Sigmoid sinus	1
Length of sinus involved, mm, mean \pm SD	30.33 \pm 19.93
Follow-up, months, mean (range)	45.48 (1–192)
Number of cases with bone involvement	5
Number of cases with multiple meningiomas	5
Preoperative symptoms	
Headache	60 (71.4%)
Seizure	25 (29.8%)
Neurodeficit	26 (31%)
Psychiatric symptoms	6 (7.1%)
Vertigo	6 (7.1%)
Visual	8 (9.5%)
KPS, Karnofsky performance scale.	

Stockholm, Sweden). Re-exploration was done in cases where the recurrence was causing mass effect or neurologic deficit.

Statistical Analysis

Continuous variables were analyzed with mean and SD. Progression-free survival was calculated by using the Kaplan-Meier survival analysis, and comparison was done using log-rank test. The Cox proportional hazards model was used to identify factors responsible for recurrence in the univariate and selected multivariate settings. IBM SPSS Version 24 software (IBM Corporation, Armonk, New York, USA) was used for statistical analysis. A *P* value <0.05 was considered significant.

RESULTS

Patient Characteristics and Clinical Presentation

The study included 84 patients. The demographic profile and clinical features of the patients are summarized in **Table 1**. There were 29 men and 55 women. The mean age of the study population was 62.8 \pm 15.5 years. The mean size of the tumor was 43.7 \pm 18.6 mm. Giant meningioma, defined as

Table 2. Details About Management of Tumor

Tumor Details	Number of Patients
Simpson grade of resection	
I	26 (32.9%)
II	36 (45.5%)
III	17 (21.5%)
IV	0 (0%)
V	0 (0%)
Sindhou grade	
I	49 (59.7%)
II	3 (3.6%)
III	1 (1.2%)
IV	0 (0%)
V	11 (13.4%)
VI	18 (21.9%)
WHO grade	
I	53 (67.0%)
II	25 (31.6%)
III	1 (1.2%)
Recurrence WHO grade	
I	7
II	9
Management of involved sinus	
No intervention	64
Venotomy	3
Sinus resection without graft	14
Sinus reconstruction with patch	3

WHO, World Health Organization.

size >5 cm in the largest dimension, was seen in 13 cases. The most common venous sinus location was in the middle one third of SSS. The number of cases with principal dural attachment to anterior one third of SSS, middle one third of SSS, posterior one third of SSS, transverse sinus, torcular herophili, and sigmoid sinus was 22, 45, 5, 4, 6, and 1. Presenting symptoms included headache in 71.4% of cases, seizures in 29.8% of cases, and neurologic deficits in 30.9%. Tumor removal was Simpson grade I in 26 (32.9%), grade II in 36 (45.5%), and grade III in 17 (21.5%) (Table 2). Mean follow-up time was 45.4 months. There were 53 (67.0%) patients with WHO grade I histology, 25 (31.6%) patients with WHO grade II histology, and 1 patient with WHO grade III histology. One patient with prior grade III astrocytoma who had received radiotherapy had subsequently developed meningioma. Prior history of prostate cancer, thyroid cancer, skin cancer, and meningiosarcoma were noted in 1 patient each.

Risk Factors for Recurrence

A number of factors influencing recurrence rates were analyzed (Table 3). In the univariate analysis using the Cox proportional hazards model, WHO grade ($P = 0.036$, hazard ratio 2.90, 95% confidence interval = 1.07–7.87) and Simpson grade ($P = 0.017$, hazard ratio 2.90, 95% confidence interval = 1.18–529) were found to be significant factors predictive of tumor recurrence. Similar results were graphically obtained using Kaplan-Meier analysis (Figures 1 and 2).

Age >65 years, sex, length of the sinus involved, tumor size >4 cm, sinus surgery versus no sinus surgery, and location of the tumor were not found to be statistically significant factors predicting tumor recurrence. Sindou grade was not found to statistically affect the recurrence rate in this study ($P = 0.941$). Seven cases (13.2%) with WHO grade I histology and 9 cases (36%) with WHO grade II histology recurred. The recurrence rates in Simpson grade I, II, and III excisions were 7.6%, 25%, and 29.4%. Five cases had multiple intracranial meningiomas. All patients received surgical treatment. There were 17 recurrences, and 15 patients received Gamma Knife radiosurgery. Gamma Knife treatment as given for tumor recurrence was documented on follow-up evaluation. Two patients received Gamma Knife therapy for the second time for tumor recurrence.

None of the patients who had Simpson grade I excision and WHO grade I histology experienced recurrence. The mean time for recurrence was 7.4 years (range, 2–26 years). Fifteen patients underwent reoperation for recurrences. Three patients underwent re-exploration twice.

Management of Involved Sinus

No intervention was done to the involved sinus in 59 cases. Sinus resection without graft was done in 14 cases. This was done most commonly for tumors invading the anterior one third of SSS. A conservative approach was used in tumors involving other areas of major venous sinus. The residual fragment inside the sinus was not pursued and was observed with serial MRI. Recurrence of the tumor was subjected to Gamma Knife radiosurgery. Small venotomy to remove the invaded tumor was done in 3 cases in which the tumor was minimally invading the venous sinus. Sinus reconstruction with a small dural patch was done in 3 cases after tumor removal. No serious side effects were noted in these patients. Aggressive sinus resection with reconstruction was not performed in this series.

Complications

Eight patients (9.5%) developed wound-related complications (Table 4). New postoperative neurologic deficits were noted in 8 (9.5%) patients, which recovered in 3 patients. There was 1 death, which was not related directly to the surgical treatment. Six patients (7.1%) developed postoperative hydrocephalus and were treated with ventriculoperitoneal shunt. All patients with preoperative seizures were seizure-free after surgery. Postoperative seizures developed in 1 patient who did not have preoperative seizures. Mean preoperative Karnofsky performance scale score was 87.9 ± 6.9 , and mean postoperative Karnofsky performance scale score was 88.04 ± 11.4 . No patients developed venous thrombosis or venous infarct. There were no cases of

Table 3. Factors Predicting Tumor Recurrence Using the Cox Proportional Hazards Model

Factor	Univariate			Multivariate		
	HR	95% CI	P Value	HR	95% CI	P Value
Age >65	1.060	0.361–3.117	0.915	—	—	—
Male sex	0.298*	0.095–0.932*	0.037*	0.407	0.106–1.561	0.190
WHO grade	3.115*	1.032–9.404*	0.044*	6.366*	1.34–30.24*	0.020*
Sindou grade V and VI	0.453	0.100–2.053	0.305	—	—	—
Simpson grade	3.942*	1.101–14.11*	0.035*	5.378*	1.344–21.51*	0.017*
Tumor left in sinus after surgery	0.735	0.212–2.541	0.626	—	—	—
Tumor in anterior one third of SSS	1.766	0.364–8.573	0.481	—	—	—
Length of sinus involved	0.995	0.957–1.035	0.818	—	—	—
Sinus surgery versus no sinus surgery	2.012	0.771–5.249	0.153	—	—	—
Tumor size >4 cm	2.021	0.670–6.095	0.212	—	—	—

HR, hazard ratio; CI, confidence interval; WHO, World Health Organization; SSS, superior sagittal sinus.

*Statistically significant.

postoperative deep venous thrombosis. Two patients developed postoperative cerebral edema after resection of tumor.

DISCUSSION

The Simpson grade and histologic grade are 2 of the most important determinants of meningioma recurrence.⁵ The controversy lies in treatment of the invaded portion of the sinus and the management of involved sinus. Leaving the tumor behind would lead to recurrence, and radical resection may increase chances of venous infarction. A balance between tumor control and venous complications is needed. The location of the tumor also has implications in the management of the sinus. The anterior one third of SSS can be resected completely along with the involved tumor without serious consequences.^{6,7} None

of the patients in whom the anterior one third of SSS was resected along with the tumors showed postoperative venous infarct or edema in our series.

Case for Aggressive Resection

Aggressive resection of middle one third and posterior one third SSS has been reported by some centers with increased rate of complications (Table 5). In their series of 100 patients, Sindou et al.³ attempted sinus reconstruction in 45 patients in whom the tumor had invaded the wall or the lumen of SSS. They found a 3% mortality rate due to brain swelling. A further 8 patients developed permanent neurologic deficits. The study by DiMeco et al.⁸ reported radical sinus resection in 30 patients. They reported 2 perioperative deaths and brain swelling in 8.3%

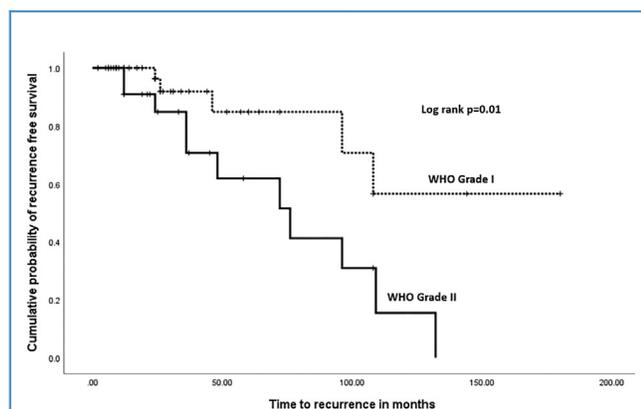


Figure 1. Kaplan-Meier graph showing the cumulative probability of recurrence-free survival with World Health Organization grade I versus World Health Organization grade II. WHO, World Health Organization.

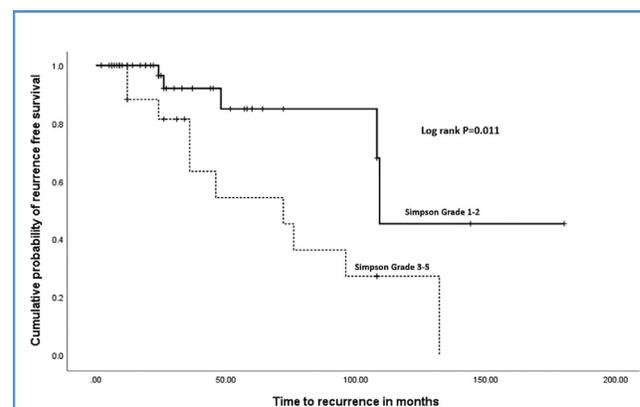


Figure 2. Kaplan-Meier graph showing the probability of recurrence-free survival with Simpson grade I–II versus Simpson grade III–V.

Table 4. Postoperative Complications

Complication	Number of Patients*
New neurologic deficits	8 (9.5%)
Postoperative seizures	1 (1.1%)
Wound-related complications	8 (9.5%)
Cerebral edema	2 (2.3%)
DVT	0
CVT	0
Hydrocephalus	6 (7.1%)
Death	1 (1.1%)
Postop KPS score, mean \pm SD	88.0 \pm 11.4
Reoperation	9
Recurrence	16 (19.04%)

DVT, deep venous thrombosis; CVT, cerebral venous thrombosis; KPS, Karnofsky performance scale.
*All values are number of patients except for postoperative KPS score.

of the patients. Mantovani et al.¹⁴ presented 21 patients with sinus resection and reconstruction. Postoperative sinus patency was present in only 52% of the operated cases. They noted 1 case with postoperative venous infarct and 5 cases of neurologic

deficits along with seizures in the postoperative period. Surgical management of the sinus depends on degree of sinus occlusion by the tumor and the development of collaterals. Caroli et al.⁹ described 328 patients with SSS-invading meningiomas. SSS was totally resected in 215 patients and partially resected in 113 patients. They performed complete resection of the involved venous sinus only when the sinus was fully occluded and performed incomplete resection if there was partial occlusion. With this approach, 10 patients developed postoperative motor deficits. The authors concluded that complete sinus occlusion with established collateral flow can be resected, whereas incomplete sinus occlusion of the tumor without collaterals may result in venous infarct.

Case Against Aggressive Resection

Sughrue et al.¹⁰ showed in their series of 135 parasagittal meningiomas that there was no difference in tumor control rates between patients with subtotal resection versus GTR in WHO grade I parasagittal meningiomas. Small tumor remnants left within and around the lesions generally remain stable for several years and can be followed. Treatment can be considered only on documented growth.¹⁰ Raza et al.¹¹ also did not find a positive correlation between the degree of sinus involvement and tumor recurrence. In their study of 67 patients with meningiomas invading SSS, Tomasello et al.¹² found a recurrence rate of 10.4% and mortality rate of 4.5% during long-term follow-up (mean 80 months). Colli et al.¹³ concluded after a study of 53 patients with parasagittal meningiomas that

Table 5. Studies with Aggressive and Nonaggressive Sinus Surgeries and Their Outcomes

Study	Patients	GTR	Follow-Up, Mean (Range)	Recurrence Rate	Complication Rate	Sinus Surgery
Aggressive resection						
Sindou and Alvernia, 2006 ³	100	93%	96 months (36–276)	4%	Mortality 3%, permanent neurologic deficit 8%	Sinus resection with reconstruction attempted in 65%
DiMeco et al., 2004 ⁹	108	92%	79.5 months (19–223)	13.9%	Brain swelling 8.3%, postoperative hematoma 1.8%	Sinus resection without reconstruction in 28%
Mantovani et al. ¹⁴	38	87%	26.05 months	5.3%	Brain swelling/venous infarction 2.6%, neurologic deficit 13%, mortality 0	Sinus resection with reconstruction with patch or direct suture in 21 (55%)
Caroli et al., 2006 ⁹	328	65%	25.4 years (3.5–34)	11.58%	Motor deficits 3%, mortality 0	Marginal sinus resection in patent sinus with reconstruction
Nonaggressive resection						
Sughrue et al., 2011 ¹⁰	61	62%	7.6 years (1.7–18.6)	4.91%	Neurologic deficits 3%, venous infarction 1.6%	Subtotal resection with immediate SRS; sinus resected only in 5 cases of complete occlusion
Raza et al., 2010 ¹¹	110	81%	41 months	11%	Venous infarction 3.6%, mortality 0.9%	Subtotal resection followed by radiosurgery
Tomasello et al., 2013 ¹²	67	86.5%	80 months	10.4%	Morbidity 10.4%, mortality 4.5%	Microsurgical resection without removal of intrasinus portion
Colli et al., 2006 ¹³	53	85%	98.7 months (2–261)	17.5%	Venous thrombosis 3.9%, operative mortality 1.9%, surgery-related mortality 5.4%	Radical resection not attempted in case of sinus invasion

GTR, gross total resection; SRS, stereotactic radiosurgery.

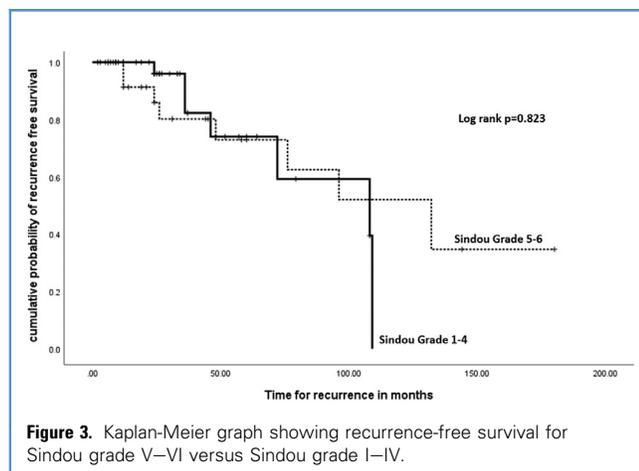


Figure 3. Kaplan-Meier graph showing recurrence-free survival for Sindou grade V–VI versus Sindou grade I–IV.

subtotal resections without sinus resections were adequate in most of the cases to achieve good tumor control with an acceptable morbidity. In our series, the degree of sinus invasion given by the Sindou grade did not affect tumor recurrence (Figure 3). We analyzed whether tumor left within the sinus could affect the recurrence rate. Cox proportional hazards model showed no statistically significant correlation ($P = 0.365$) for predicting the recurrence. The length of sinus involved, tumor size >4 cm, and removal of intrasinus portion of the tumor did not predict tumor recurrence. The length of sinus involvement by the tumor also did not correlate with tumor recurrence. Complete sinus resection does not guarantee tumor control. Microscopic tumor may still exist at the sinus resection margin and contribute to recurrence.⁹

The principles of surgical management of the sinus invaded by tumor have shown a gradual shift from aggressive resection toward conservative approach over the last few decades. In the present series, no intervention was done on the sinus in 64 cases. A small venotomy with direct suturing was done in 3 cases, and sinus reconstruction with a patch was done in 3 cases. Most cases of complete sinus resection were done for the anterior one third of SSS. We believe that aggressive sinus surgery is not essential for tumor control and would increase surgical morbidity.

The tumor control rates following radiosurgery for meningioma adjacent to venous sinuses were 67%–78% at 5 years.^{15–17} Just as radical sinus resection may leave microscopic disease behind at the resection margins, out-of-field recurrences can occur after treatment with radiosurgery. Radiosurgery has changed the way surgeons currently handle sinus invasion. Radiosurgery has been shown to achieve better tumor growth stabilization than the natural growth rate of meningioma.¹⁸ It can also be used for first treatment in small meningiomas.¹⁷

The WHO grade and Simpson grade were found to significantly predict recurrences in our study. We hypothesized that the

inclusion of meningiomas involving the anterior one third of SSS may confound the results. Meningiomas in the anterior one third of SSS can be completely resected without serious sequelae. The paucity of major draining veins in the anterior one third of SSS would give more margin for resection and translate into better tumor control. However, analysis with Cox proportional hazards model showed that the tumor location along SSS was not predictive of tumor recurrence ($P = 0.24$). Radical resection of the involved sinus does not necessarily translate to a good Simpson grade. The narrow corridor between the major draining veins may result in leaving significant microscopic disease at the edges. It is also not possible to coagulate the edges of resection in this difficult location. In other words, radical sinus surgery may not be the complete answer for achieving tumor control and could worsen the complications.

Management of Atypical Meningiomas

In the present study, there were 24 patients with WHO grade II histology and 1 patient with WHO grade III histology. The recurrence rate in atypical meningioma was 36% (9 patients). Eight patients underwent re-exploration for removal of tumors. Patients with atypical meningiomas who had undergone GTR did not receive radiation immediately after surgical resection. They were followed, and recurrences were treated with radiosurgery or re-exploration. Several controversies exist regarding postoperative radiotherapy for atypical meningiomas. One is the need for adjuvant radiotherapy after GTR. In patients who underwent GTR, local recurrence was decreased after radiation. Similar findings were noted by Aghi et al.¹⁹ and Komotor et al.²⁰ Mair et al.,²¹ in their study of 114 patients with atypical meningiomas, suggested that radiotherapy is not appropriate after surgical resection in which GTR has been achieved, as they did not find significant benefit regarding tumor recurrence. Hardesty et al.²² also advocated close observation after GTR.

Study Limitations

The limitations of a retrospective analysis apply to this study. MIB labeling index/Ki-67 analysis was not available for all patients. Analysis of this factor could help to define tumor recurrence more accurately. The mean follow-up period was close to 3 years; a longer follow-up could detect late recurrences. Whereas this study deals with surgically treated cases of parasagittal meningiomas, the data on parasagittal meningiomas followed conservatively or treated first with Gamma Knife radiosurgery have not been included.

CONCLUSIONS

Meningiomas invading major venous sinuses can be managed without aggressive sinus resection to give an acceptable recurrence-free survival with adjuvant radiation therapy.

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