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Postoperative irradiation for subtotally resected meningiomas

A retrospective analysis of 140 patients treated from 1967 to 1990

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The authors retrospectively analyzed 140 patients treated at the University of California, San Francisco, from 1967 to 1990 to evaluate the results of radiation therapy (median 5400 cGy) given as an adjuvant to subtotal resection of intracranial meningioma. Of the 140 meningiomas, 117 were benign and 23 were malignant. The median follow-up period was 40 months. The overall survival rate at 5 years was 85% for the benign and 58% for the malignant tumor groups ($p = 0.02$); the 5-year progression-free survival rates were 89% and 48%, respectively ($p = 0.001$). For patients with benign meningioma, the 10-year overall and progression-free survival rates were 77%. An improved progression-free survival rate in that group was not related to tumor size but was associated with a younger age ($p = 0.01$) and treatment after 1980 with innovative technologies ($p = 0.002$); none of those variables affected the progression-free survival rate in the patients with malignant meningioma. Increased progression-free survival in the benign tumor group was also significantly associated with increasing the minimum radiation dose ($p = 0.04$). The 5-year progression-free survival rate for patients with benign meningioma treated after 1980 (when computerized tomography or magnetic resonance imaging was used for planning therapy) was 98%, as compared with 77% for patients treated before 1980 ($p = 0.002$). There were no second central nervous system tumors. Morbidity (3.6%) included sudden blindness or cerebral necrosis and death. When total resection of benign meningioma is not feasible, subtotal resection combined with precise treatment planning techniques and adjuvant radiation therapy can achieve results comparable to those of total resection.

KEY WORDS • **meningioma** • **radiation therapy** • **subtotal resection** • **survival analysis**

For intracranial meningioma, total resection is the optimum approach to management as it provides long-term disease-free survival for more than 90% of patients treated.[1,3,4,6,20,26] Not all meningiomas can be totally resected without an unacceptable risk of morbidity, however. Attempted total resection of petroclival, parasellar, cavernous sinus, and orbital tumors is often associated with postoperative neurological deficits, particularly cranial nerve palsies.[13,18,22] As a consequence, surgeons must choose between aggressive resection (with its substantial risk of morbidity) and subtotal resection (with the higher rates of tumor recurrence and progression that subtotal resection entails).[11,13,19,20,26,28] In such cases, the role of radiation therapy is controversial.

Several retrospective studies have shown that radiation therapy after subtotal resection is beneficial for patients with benign meningioma.[3,5,9,10,19,26,28] Despite the evidence that radiation therapy reduces the rate of local recurrence, some authors advocate a policy that regards either further surgery or observation as a reasonable alternative to immediate postoperative irradiation.[24] Their rationale for such a course is that many subtotally resected tumors recur despite radiation therapy and that, whereas lesions recurring after surgery can be treated surgically, irradiation has significant toxicity and may itself induce malignancies.[2,7,21]

We have previously reviewed our experience with patients treated from 1968 to 1978.[3] All of the patients in that study had undergone surgery at the University of California, San Francisco (UCSF), but some of those patients receiving radiation therapy had previously undergone irradiation at another facility. In extending the review of our experience to the present, we proposed that a population of patients treated by the same group of clinicians, using the same therapeutic techniques and equipment, and with radiation therapy regimens that were consistent in mode and quality, would permit

us to define better the appropriate role for irradiation in the management of meningioma. By analyzing separately a cohort of patients evaluated with computerized tomography (CT) or magnetic resonance (MR) imaging and managed with radiation therapy planning and surgical techniques available since 1980, we also assessed whether these innovations have improved the outcome for patients with meningioma. This series therefore includes all patients with meningioma who underwent both subtotal resection and radiation therapy at UCSF over the 23-year period from 1967 to 1990.

Clinical Material and Methods

Patient Population

The population for this retrospective study consisted of 140 patients (46 males and 94 females) with subtotally resected intracranial meningioma who were treated postoperatively with external-beam megavoltage photon radiation at the UCSF Department of Radiation Oncology between August, 1967, and July, 1990. The patients ranged in age from 3 to 80 years (mean and median age 49 years). Data for the analysis were collected through May 15, 1991.

Histological Diagnosis

The diagnosis of a malignant histology was based on the presence of frequent mitoses (> 1/high-power × 400 field) and at least two of the following characteristics: increased cellularity, necrosis, large atypical (pleomorphic) nuclei, and increased cytoplasmic mass. Infiltration of tumor into brain parenchyma was considered *prima facie* evidence of malignancy.

Radiation Therapy Protocols

Radiation was delivered in conventionally fractionated median doses of 5400 cGy (range 1261 to 5940 cGy) for the benign and 5400 cGy (range 4462 to 6926 cGy) for the malignant meningiomas by using either arc or two- or three- field static treatment plans. From 1967 through 1980, treatment volumes were defined on the basis of the surgeon's description of the site and the extent of tumor. From 1981 to 1990, treatment volumes were based on both the radiographic data obtained from CT and/or MR imaging and the surgeon's description. In general, for benign meningiomas, the treatment volume included the gross tumor remnant after subtotal resection and a 1- to 2-cm margin of adjacent brain. For malignant meningiomas, the volume generally included the preoperative tumor volume and a 1- to 3-cm margin.

Survival Analysis

Rates of actuarial overall survival, intercurrent disease-specific survival, and progression-free survival were calculated (using the life-table method[17]) from the date of initial subtotal resection to the date of either tumor progression or the patient's death. Intercurrent disease-specific survival was defined as the time from initial subtotal resection to death from an intercurrent illness, even though the tumor was controlled. Progression was defined as either tumor growth observed on CT or MR imaging or, if those results were not available, as clinical neurological decline not attributable to other causes, such as complications of therapy. The curves obtained for overall survival and intercurrent disease-specific survival rates were compared with survival curves in a normal (control)[16] background population matched for age and sex. The Mantel-Haenszel log-rank test[17] was used to compare survival curves.

Selected demographic and clinical variables were subjected to univariate analysis as a continuous and/or as a dichotomous variable. Variables that could be categorized into two mutually exclusive groups were analyzed as dichotomous variables only. All others were analyzed as continuous variables and also as dichotomous variables divided into two groups that best distinguished between good outcome and poor outcome. To test the association between these variables and long-term progression-free survival, a Wald chi-squared test was used for both the continuous and the dichotomous variables. Relative risk of progression was also calculated. For the benign tumor group, variables that were shown to have a significant or borderline-significant association with survival were then used in a Cox proportional hazards model to determine which of the demographic and clinical variables were most predictive of long-term progression-free survival. All analyses were performed using the SAS statistical package.*

Demographic and Clinical Variables

The six variables evaluated for prognostic significance were: histological analysis of the tumor, tumor site, tumor size, minimum radiation dose to the tumor, patient age, and date of treatment. All but the histology variable were evaluated separately within the benign and malignant tumor groups.

Histology. Dichotomized into benign and malignant groups, histology of the meningioma was evaluable in all cases.

Tumor Site. Meningiomas were categorized according to location into six intracranial sites: orbital, occipital, posterior fossa, parasellar, frontal/olfactory, and temporal/parietal. Each site was evaluated with respect to each other site and to all other sites combined. Tumor site was evaluable in 114 of 117 cases of benign histology. Site analysis was confined to the histologically benign meningiomas because an analysis of the few malignant meningiomas, when divided into the six site categories, would permit no meaningful conclusions.

Tumor Size. Most of the patients in this series did not have evaluable CT or MR imaging studies that delineated the tumor volume before they underwent radiation therapy. Therefore, tumor size for all patients was approximated by the cross-sectional area of the treatment volume, defined as length × width of the largest radiation therapy portal at the isocenter of the tumor. This variable was evaluable in 123 of 140 pa-

* SAS statistical package, version 5, developed by SAS Institute, Inc., Cary, North Carolina.

TABLE 1

*Variables evaluated for potential prognostic significance on progression-free survival in 140 patients with subtotally resected meningioma**

Variable	Univariate Analysis†		Relative Risk‡	Cox Proportional Hazards Model (Multivariate Analysis)†
	Dichotomous	Continuous		
histology (benign vs. malignant)	0.001	NA	NA	NA
tumor site (benign)				
frontal/olfactory vs. all others	0.004	NA	4.5	NA
all other comparisons	NS	NA	NA	NA
tumor size				
benign	0.09	0.04	↑ 2.2/100 sq cm	0.38
malignant	NS	NS	NA	NA
minimum radiation dose				
benign	0.04	0.03	↓ 0.5/1000 cGy	0.43
malignant	0.01	0.10	NA	NA
patient age				
benign	NS	0.005	↑ 2.3/10 yrs	0.01
malignant	NS	NS	NA	NA
treatment date after 1980 vs. earlier				
benign	0.002	NA	0.09	0.01
malignant	NS	NA	NA	NA

* NA = not applicable or not evaluated.

† Analyzed by Wald chi-squared test. Results are p values; NS = not significant.

‡ ↑ = increased; ↓ = decreased.

tients. It was analyzed as a continuous variable, and also as a dichotomous variable based on two subgroups divided according to tumor size and constructed to differentiate between progression and freedom from progression. The dichotomous division value was calculated as the average of the median size of all tumors that progressed and the median size of all that did not progress.

Minimum Radiation Dose to the Tumor. Defined as the minimum isodose that fully encompassed the treatment volume, the minimum radiation dose to the tumor was evaluable in 137 of 140 cases. It was analyzed as both a dichotomous and a continuous variable.

Patient Age. This variable was evaluable in all cases and was analyzed as both a dichotomous and a continuous variable.

Treatment Date. Evaluable in all cases, this variable was analyzed as a dichotomous variable, divided between the period of MR- and CT-assisted treatment planning after 1980 and the earlier period from 1967 through 1980.

Results

Of the 140 patients in this study, 117 had benign and 23 had malignant meningiomas. The median follow-up period was 40 months (range 2 to 213 months, mean 49 months). More than 80% of the patients were followed for more than 12 months. During the follow-up period, 24 patients died. In the group with benign meningioma, the cause of death was uncontrolled meningioma in 11 cases, pneumonia in three, and cardiac causes in three. In the group with malignant histology, the cause of death was uncontrolled meningioma in six cases and acute respiratory failure in one case in which no autopsy was performed. The variables evaluated for potential prognostic significance are summarized in Table 1.

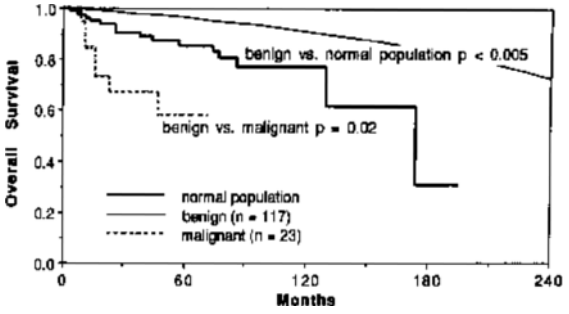

FIG. 1. Graph showing overall survival rates after subtotal resection and postoperative external-beam irradiation for meningioma in 140 patients and in a normal background (control) population[16] matched for age and sex. n = number of cases.

Histology

Overall 5-year survival rates were 85% for patients with benign and 58% for patients with malignant meningioma (p = 0.02, univariate analysis of the dichotomous variable, Fig. 1). The 5-year progression-free survival rates were 89% for the benign and 48% for the malignant tumor group (p = 0.001, univariate analysis of the dichotomous variable, Fig. 2).

The 10-year overall and progression-free survival rates were each 77% for patients with benign menin-

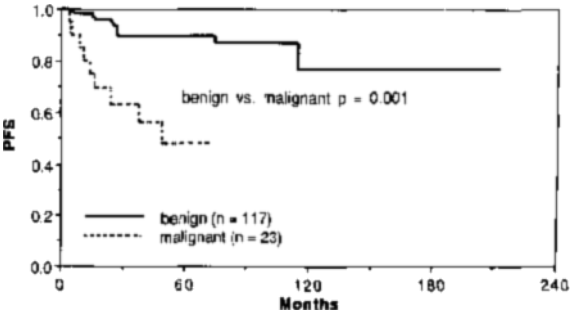

FIG. 2. Graph showing progression-free survival (PFS) rates after the subtotal resection and postoperative external-beam irradiation of benign or malignant meningiomas in 140 patients. n = number of cases.

TABLE 2

*Impact of tumor site on progression-free survival rate for benign meningioma**

Intracranial Site	No. of Tumors		5-Year PFS
	Total	Progressed	
orbital	11	0	100%
occipital	6	0	100%
posterior fossa	27	2	96%
parasellar	44	4	88%
frontal/olfactory†	14	3	79%
temporal/parietal	12	2	76%

* Records were inadequate to determine the location of three tumors. PFS = progression-free survival rate.

† Only this group was at significantly higher risk for progression ($p = 0.004$, univariate analysis of the dichotomous variable) as compared to all other sites combined.

gioma. No patient with a malignant meningioma was followed for as long as 10 years. Overall survival for both the benign and malignant tumor groups was significantly lower than the expected survival in a normal (control) population.[16] With determinant cause of death censored, intercurrent disease-specific survival for each histological group did not differ significantly from survival in a normal population, indicating that the patients in this cohort could expect to live a normal life span as long as their tumor was controlled.

Tumor Site

There were too few malignant meningiomas in this series to permit meaningful conclusions about survival rates in regard to tumor site. For benign meningioma (Table 2), patients with tumor in the orbital or occipital region had 5-year progression-free survival rates of 100%, with declining rates for those with tumor in the posterior fossa and the parasellar, frontal/olfactory, and temporal/parietal regions. Only the subgroup with frontal/olfactory meningioma was at significantly greater risk than the other site subgroups for progression ($p = 0.004$, univariate dichotomous analysis), with a relative risk of progression 4.5 times greater than all other sites combined. Of 14 tumors in this site, three progressed, all of which were anterior fossa lesions not involving the olfactory nerve or cribriform plate. Two of those three tumors were treated before CT or MR imaging was available and were large tumors ($\geq$ 80 sq cm) that received less than 5400 cGy irradiation, all factors that may have contributed to local failure.

Tumor Size

For benign lesions, there was a trend of borderline significance toward decreased progression-free survival in association with larger tumor size; that is, the cross-sectional area of the treatment volume ($p = 0.09$, univariate analysis of the dichotomous variable of $\leq$ 60 sq cm vs. > 60 sq cm; $p = 0.04$, univariate analysis of the continuous variable). The relative risk of progression increased 2.2-fold for every 100-sq-cm increase in tumor size. For malignant lesions, the relationship between progression-free survival and tumor size was not significant ($p > 0.25$, univariate analysis of the dichotomous variable of $\leq$ 100 sq cm vs. > 100 sq cm; $p = 0.13$, univariate analysis of the continuous variable). We attribute the lack of significance to the small number of patients in the subgroup.

Minimum Radiation Dose to Tumor

For both benign and malignant meningiomas, improved progression-free survival rates were associated with increasing minimum radiation dose to the tumor. For benign lesions treated with a minimum tumor dose greater than 52 Gy the 10-year progression-free survival rate was 93%, as opposed to 65% for those treated with 52 Gy or less ($p = 0.04$, univariate analysis of the dichotomous variable; $p = 0.03$, univariate analysis of the continuous variable). The relative risk of progression decreased by a factor of 0.5 for every 1000-cGy increase in the minimum radiation dose to the tumor. For malignant lesions treated with a minimum tumor dose greater than 53 Gy, the 5-year progression-free survival rate was 63%, as opposed to 17% for those treated with 53 Gy or less ($p = 0.01$, univariate analysis of the dichotomous variable; $p = 0.10$, univariate analysis of the continuous variable). The relative risk of progression as a function of minimum tumor dose was not evaluated for malignant meningiomas because the relationship between progression-free survival rate and minimum radiation dose to the tumor was not significant for malignant lesions on univariate analysis as a continuous variable.

Patient Age

No distinction between good and poor outcome could be delineated for age groups by univariate analysis of this factor as a dichotomous variable. However, univariate analysis of patient age as a continuous variable showed a significant association between decreased progression-free survival rate and increased patient age ($p = 0.005$). The relative risk of progression increased 2.3-fold for every 10-year increase in age. Age was not a significant prognostic factor for malignant meningioma.

Treatment Date

In the benign meningioma group, patients treated during the period of MR- and CT-assisted treatment

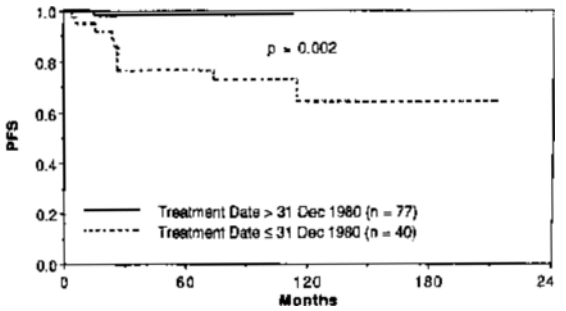

FIG. 3. Graph showing progression-free survival (PFS) rates after subtotal resection and external beam irradiation of benign meningioma as a function of treatment date. Data are divided between the period of magnetic resonance imaging-assisted and computerized tomography-assisted treatment planning after 1980 and the earlier period from 1967 through 1980. n = number of cases.

TABLE 3

*Results after postoperative radiation therapy for subtotally resected meningioma (retrospective reviews)**

Authors & Year	Survival Period & Type	Benign Tumor		Malignant Tumor	
		No RT	RT	No RT	RT
Forbes & Goldberg, 1984	4-yr RFS	—	72%	—	0/4
Barbaro, *et al.*, 1987	5-yr RFS	59%	77%	—	—
Taylor, *et al.*, 1988	5-yr PFS	43%	86%	—	—
Glaholm, *et al.*, 1990	5-yr DFS	—	84%	—	3/9
Miralbell, *et al.*, 1992	5-yr PFS	59%	88%	—	—
Goldsmith, *et al.*, 1994	5-yr PFS	—	89%	—	48%

* RT = radiation therapy; PFS = progression-free survival; DFS = disease-free survival; RFS = relapse-free survival.

planning after 1980 had a 5-year progression-free survival rate of 98%, whereas for those treated before or during 1980 the rate was 77% ($p = 0.002$, univariate analysis of the dichotomous variable, Fig. 3). Patients treated after 1980 had a relative risk of progression 0.09 times that of patients treated during 1980 or before. Treatment date had no significant impact on the progression-free survival rate of patients with malignant meningioma.

Multivariate Analysis

For the group with benign meningioma, the significant and borderline-significant variables from the univariate analyses — treatment date, patient age, tumor size, and minimum tumor radiation dose — were subjected to multivariate analysis with the Cox model. Only treatment date ($p = 0.01$) and patient age ($p = 0.01$) were significantly associated with progression-free survival rate (Table 1). Tumor site was not included in this analysis because there were too few patients with lesions in the frontal/olfactory region. For the group with malignant meningioma, no multivariate analysis with the Cox model was performed because no univariate associations were found.

Complications

Of the 140 patients in this series, five (3.6%) had complications that might have been attributable to irradiation. Three patients experienced sudden blindness from complications arising 20 to 22 months after the completion of radiation therapy. One patient treated in 1979 with a minimum radiation dose to the tumor of 5400 cGy (180 cGy per fraction; three-field technique, opposed laterals and anterior ethmoid field) developed retinitis and sudden right retinal hemorrhage; the retinae had been located at the field edge receiving approximately 2700 cGy at 90 cGy per fraction. Another patient who received 4923 cGy in 1974 (182 cGy per fraction; anterior/lateral wedge pair technique), had vitreous hemorrhage with probable radiation retinopathy; the dose to the retina was approximately 3700 cGy, at 137 cGy per fraction. Although these dose fractionation regimens have not been associated with retinopathy in the radiation oncology literature, for the purposes of this study we classify them as probable complications. The third patient, who experienced optic neuropathy after receiving 5400 cGy in 1989 (180 cGy per fraction; opposed lateral/vertex three-field technique), had received a maximum dose to the optic nerve of 5670 cGy (189 cGy per fraction).

Two patients developed cerebral necrosis with associated clinical neurological decline. One case, treated in 1985, occurred 30 months after completion of radiation therapy for a left occipital malignant meningioma, with 6000 cGy minimum radiation dose to the tumor at 180 cGy per fraction (6667 cGy maximum brain dose at 200 cGy per fraction; opposed lateral/vertex three-field technique). The patient underwent a craniotomy for decompression and recovered. The other case, treated in 1984, occurred 13 months after completion of radiation therapy for a right frontoparietal benign meningioma, with a 5580-cGy midplane dose at 180 cGy per fraction (5735 cGy maximum brain dose at 185 cGy per fraction; opposed lateral technique). This patient died of bronchopneumonia associated with his chronic brain syndrome. In both cases, pathological examination revealed only cerebral necrosis and no tumor.

Discussion

The patients treated with radiation therapy in our series in general had a good outcome. For patients with a benign meningioma, the 5-year overall survival rate of 85% and progression-free survival rate of 89% compare favorably with results for similarly treated patients in reported series, and are considerably better than the 43% to 59% relapse/progression-free 5-year survival rates that are associated with subtotal resection followed by observation only (Table 3).[3,9,10,19,26]

Total resection is the standard treatment for meningioma. Documenting the results of total resection of benign meningioma, Barbaro, *et al.*,[3] reported a recur-

rence in two of 51 cases; Mirimanoff, *et al.*,[20] reported a 5-year progression-free survival rate of 93%; and Taylor, *et al.*,[26] reported an 82% rate of 5-year actuarial local control. The 5-year progression-free survival rate of 89% in patients with benign meningioma in our series indicates that, for patients in whom total resection is not feasible, adjuvant radiation therapy can achieve results approaching those obtained with total resection.

Although patients with malignant meningioma had significantly less favorable outcomes than those with tumors of a benign histology, their 5-year overall survival rate of 58% and progression-free survival rate of 48% compare favorably with previously reported results (Table 3).[9,10] While attempts to improve outcome of malignant meningioma with adjuvant chemotherapy have been disappointing to date,[15] and while the potential efficacy of approaches such as RU486 hormone therapy[12] and stereotactic radiosurgical techniques[8,14,27] is speculative, the finding that more than 50% of the patients treated with radiation therapy are alive 5 years after therapy indicates that malignant meningioma is a central nervous system (CNS) tumor for which appropriate adjuvant therapy can assure a substantial number of long-term survivors.

In our analysis of the intracranial site of benign meningioma as a prognostic factor, tumors of the orbit and of the parasellar region did not differ significantly from all other sites in terms of 5-year progression-free survival rates. As Barbaro, *et al.*,[3] have noted in regard to cases of subtotal resection, patients undergoing radiation therapy have more favorable outcomes than those not receiving irradiation, even though the tumors in the irradiated cohort are located in surgically more unfavorable sites[20] than tumors in the cohort not treated with irradiation. Such findings strongly support the conservative therapeutic approach of subtotal resection followed by radiation therapy for meningiomas in such critical sites as the petroclival or parasellar region, the cavernous sinus, or the orbit, when the surgeon deems the risk of morbidity associated with total resection to be unacceptably high.

Although a trend toward improved progression-free survival rate in association with increasing minimum tumor radiation dose was not significant on multivariate analysis, the 5-year progression-free survival rate of 93% in patients treated with greater than 52 Gy is comparable to the results reported for patients managed with total resection.[1,3,4,6,20,26] For patients with malignant meningioma, the minimum radiation dose to the tumor appears to be even more critical, as the 5-year progression-free survival rate in our study nearly quadrupled from 17% for patients receiving 53 Gy or less to 63% for those who received greater than 53 Gy. These data contrast with observations by Taylor, *et al.*,[26] in the only other study of meningiomas we know of that addresses the issue of radiation therapy dose-response relationship. Taylor, *et al.*, found no correlation between radiation dose and tumor control in their series with benign meningioma irradiated either immediately after subtotal resection or after recurrence. Their study was restricted to only 23 patients, however, 10 of whom were irradiated at the time of salvage therapy for recurrence. In addition, they noted that all of their patients who experienced a recurrence after receiving 6000 cGy had a large tumor volume at the time of irradiation and that their 17 patients with small tumors had an excellent control rate (88%) after receiving 5000 to 5500 cGy irradiation. Our current treatment policy is to use 54 Gy for benign meningiomas and 60 Gy for patients with malignant meningiomas. Our results indicate that the higher doses associated with an increased progression-free survival rate can be delivered safely.

The report by Al-Mefty, *et al.*,[2] suggesting that radiation therapy for benign CNS tumors, including meningioma, causes significant long-term complications has been criticized for its liberal use of the term "complication."[23] Despite careful long-term follow-up review of our series, we could not substantiate their view. Only five (3.6%) of 140 patients in our series, two of whom were treated before CT or MR imaging were in use, experienced complications that may have been attributable to irradiation.

Of three patients who became suddenly blind, two were treated before 1980. In neither case had the dose fractionation regimen used been associated with retinal injury in the radiation oncology literature. The third patient was treated in 1989. That case prompted an analysis from this institution of the reported cases of radiation-induced optic neuropathy,[11] which showed that conventionally fractionated (180 cGy per fraction) radiation therapy regimens should not exceed 5400 cGy to the optic nerve to assure a low risk of optic neuropathy. That is now our institution's policy. Based on the cases of two patients who developed cerebral necrosis after treatment in 1984 and 1985, one of whom died, our institution has established a policy to avoid using the high-dose opposed lateral technique for irradiation of the CNS whenever possible. No patient in our series developed a recurrent benign or malignant CNS tumor.

Although the delivery of irradiation is never without potential complications, we believe that the potential for serious morbidity is slight and that the risk of potential late effects of treatment is offset by the reduced likelihood of a recurrent neoplasm afforded by increasingly precise treatment planning techniques.

In our series, the 5-year progression-free survival rate of 98% for patients with benign meningioma who were treated after 1980 was significantly better than the 77% survival rate for patients treated before 1980 ($p < 0.002$). The difference in progression-free survival rates is very likely attributable to improvements in imaging modalities that have permitted more exact target localization and to improvements in surgical techniques that have resulted in much-reduced residual tumor burden at the time of radiation therapy.

Conclusions

Radiation therapy for subtotally resected meningioma is effective and safe, and the results are substantially superior to those obtained in patients followed only with observation after subtotal resection. For pa-

tients with benign meningioma, the results approach those obtained in patients managed with total resection, particularly since the introduction of technologically advanced CNS imaging techniques. While the disparate outcomes achieved for patients with malignant meningioma are discouraging, and while there is still a need for more effective adjuvant therapy of the malignant lesions, the data obtained in this series would appear to leave little room for continued controversy about the relative efficacy of radiation therapy following subtotal resection.

Radiation therapy should be considered the standard adjuvant care following subtotal resection of a meningioma. After subtotal resection, observation alone unnecessarily subjects the patient to an increased risk of recurrence with a concomitant risk of requiring a second craniotomy. Moreover, when irradiation is delayed until the time of recurrence, the efficacy of therapy may be jeopardized if the meningioma should undergo malignant transformation to a more aggressive tumor[25] and/or develop an increasing tumor burden.

The observation that patients with benign meningioma of the orbit and parasellar sites do not fare significantly worse than patients with such a tumor in any other site supports conservative subtotal resection followed by radiation therapy for lesions in critical sites when the surgeon deems the risk of morbidity associated with total resection to be unacceptably high. In such a case, we recommend a dose of 54 Gy for benign meningioma and a dose of 60 Gy for patients with malignant meningioma, with appropriate blocking of the optic apparatus. Our findings indicate that doses in this region can be delivered safely and are associated with increased progression-free survival.

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