The respected radiosurgical group at the University of Florida provides a well-written, concise report on the tumor control rate and complications of radiosurgical treatment of meningiomas performed using the linear accelerator (LINAC). Their patient population consisted of 210 patients, and none was lost to follow-up review. Data were accumulated prospectively in these patients, although, of course, the analysis was retrospective. Tumor control was defined as no growth on a neuroimaging study and the duration of follow up was defined as the interval between radiosurgical treatment and the last follow-up imaging study. Of the 210 patients, 93 had undergone previous surgery during which histological confirmation of the type of tumor had been obtained. In this group, there were 18 atypical meningiomas and 11 malignant meningiomas. In the remaining patients there was no histological confirmation of the diagnosis and all the patients were assumed to harbor benign meningiomas. The actuarial local control rate (no growth on the follow-up imaging study) for benign tumors was 100% at 2 years and 96% at 5 years; the 10-year actuarial control rate could not be determined given the relatively small number of patients who participated in follow up for longer than 5 years (35 patients). The 5-year control rate for atypical meningiomas was 77% and that for malignant meningiomas only 19%, but the number of patients with atypical or malignant tumors was too small to generate meaningful statistics.

In terms of complications attributable to radiosurgery, the authors recorded temporary complications in 13 patients (6.2%). All these complications resolved during the follow-up period after a brief (time or doses not recorded) course of steroid medications. Five patients (2.3% of the total) experienced permanent complications and malignant tissue was identified in all of them; however, all of these patients had previously undergone fractionated conventional radiation therapy, thus, the role radiosurgery played in the complications is not clear.

As expected, only patients with relatively small tumors were treated with radiosurgery. There were 121 patients with tumors of 8 cm$^3$ or smaller, 59 patients with tumors larger than 8 to 16 cm$^3$, and only 30 patients with tumors larger than 16 cm$^3$. The median tumor volume for the entire series was 7 cm$^3$.

This is an important report. Although there have been several other large series of patients with meningiomas treated with radiosurgery, this is the largest series of patients treated at a single institution with a LINAC. The results clearly confirm that a LINAC, at least when used by experts in a specialized center, achieves results with meningiomas that are similar to those achieved using the Gamma Knife.

Limitations of the Study

Given the importance of this topic, it is appropriate to discuss the limitations of this study as well as its clinical implications. The following limitations should be noted:

1) There was no independent observer. The senior author himself determined the tumor control rate by comparing neuroimages obtained at the time of treatment with those obtained at the time of the follow-up examination. Clearly, the senior author is a very experienced observer and there is no question about his objectivity; however, the value of the observations to the readership would have been enhanced had an independent observer performed the evaluations.

2) Follow-up neuroimaging after 5 years was only available in 35 patients and very few patients participated in follow up for 10 years. Given that meningiomas are generally benign slow-growing tumors, 10-year follow-up data on a sufficient number of patients would have been very valuable. I am sure that the authors will provide us with these data once they are available. Note, however, that the 5-year tumor control rate cited in this paper is comparable and perhaps superior to the 5-year control rate that is achieved following a Simpson Grade I or II resection.

3) The number of patients with atypical and malignant tumors is insufficient for us to gain insight into the value of radiosurgery for tumors whose histological characteristics are other than benign. Certainly, the 5-year tumor control rates for atypical and malignant tumors are too low to indicate any meaningful value of radiosurgery in the treatment of these tumors; however, at 2 years posttreatment a control rate of 100% for the few malignant tumors and 92% for atypical tumors compares favorably with what we generally obtain using radical surgery followed by conventional fractionated radiotherapy. Nevertheless, it should be noted that...
the complication rates associated with both conventional fractionated radiotherapy and radiosurgery in the treatment of malignant tumors are high enough to raise a flag against the use of these two modalities in the same patient.

4) The authors obtained histological confirmation of the diagnosis only in the 93 patients who had undergone resection before radiosurgery. In the other 117 patients the presumed diagnosis of benign meningioma was based on evaluations of neuroimaging studies only. Some readers may consider this a deficiency of the study; however, if anything, it leads to a bias against radiosurgical results due to the presumption that all of these tumors were benign. In other words, presumably the results could have been better if all patients had undergone a biopsy and those patients harboring more aggressive tumors had been excluded from the analysis. Because at times it is difficult to differentiate schwannomas residing in the petroclival region or cavernous sinus from meningiomas, it is also possible that some of the tumors were schwannomas. Nevertheless, we know from other series that radiosurgery seems to be approximately as effective in treating schwannomas as it is in treating meningiomas; therefore excluding the few schwannomas that may have been treated in this series would not have changed the results significantly. The authors discuss the important series of Flickinger, et al., in which meningiomas were diagnosed in 219 patients on the basis of neuroimaging criteria alone and only 2.3% of the patients were discovered to harbor a tumor that was not a meningioma during a 10-year follow-up period. Similarly in the series reported by Friedman and colleagues, only two patients were found to harbor tumors that were not meningiomas: one had a dura mater–based metastasis and the other had a hemangiopericytoma.

5) Another important caveat, which is not a deficiency of this series but rather a limitation intrinsic to radiosurgery, is that the tumors treated in this series were small. There were only 14 tumors larger than 20 cm³ and the median tumor volume was 7 cm³. Interestingly, the authors found no difference in tumor control between the different size categories. This contrasts with the results of radiosurgical treatment of cerebral arteriovenous malformations, in which there is an inverse correlation between the size of the lesion and the chances of a cure. That such a correlation in tumor control was not evident in this series may be related to the relatively small number of patients in each tumor size category or to the relatively short follow-up period, considering the fact that meningiomas are relatively slow-growing tumors. Notwithstanding these considerations, it is of paramount importance for clinicians to understand that radiosurgery is a treatment applicable only to relatively small tumors.

6) This series does not help the clinician decide whether it is best to observe or treat asymptomatic or minimally symptomatic patients with small meningiomas when they are first seen. No information is provided as to how many patients were symptomatic before treatment, how many were treated at the initial diagnosis, or how many were observed and treated only when tumor growth had been documented. How different is the natural history of a small asymptomatic meningioma from the results reported in this series?

7) As in the case with previously untreated tumors, this series provides us no information about whether it is preferable to treat a small residual tumor with radiosurgery after resection or to observe the patient and treat the tumor only after growth is confirmed on follow-up images. The patients in this series were treated immediately on discovery of residual tumor after surgery and, therefore, we do not know whether waiting for signs of growth before radiosurgery may save some patients whose tumors may not grow the possible side effects of radiosurgery.

Clinical Implications of the Report

I will conclude by analyzing the clinical implications of this report from the standpoint of a neurosurgeon who encounters these tumors frequently and who, incidentally, does not personally perform radiosurgery.

1) The results of this series offer support to the notion that stereotactic radiosurgery (SRS) performed with a LINAC is as effective and safe as gamma knife surgery in the treatment of intracranial meningiomas.

2) The study results offer strong confirmation of the value of SRS as the primary treatment for small intracranial meningiomas. The results are good enough to indicate that SRS is the treatment of choice in older patients facing a relatively high surgical risk because of comorbidities or because of the location of the lesion, who harbor a small meningioma that has been shown to grow during observation. Furthermore, the results indicate that even in younger, otherwise healthy patients with small meningiomas, SRS could be considered a valid treatment alternative provided the patients experience no or only minimal symptoms from the tumor. Before any of us can suggest that radiosurgery is the preferred treatment in these younger patients, we must have confirmation of high tumor control rates at 10 years and beyond, which this series does not offer. For the time being, I admit that I will continue to consider excision as the treatment of choice in younger, otherwise healthy patients who harbor small meningiomas in locations where surgery is expected to carry a low morbidity rate. Clearly, it is also reasonable to observe some of these tumors for evidence of growth and then recommend excision once growth is noted. I have frequently recommended surgery rather than observation when I first examine a patient in whom the tumor is located in an area in which further growth would render removal more risky or the tumor impossible to cure; this situation occurs frequently in parasagittal meningiomas lying close to but not yet involving the superior sagittal sinus, and in medial sphenoid wing meningiomas lying close to but not yet involving the cavernous sinus, to name just two locations.

3) The findings of this and other radiosurgical series do not change our current thinking about the need for excision or decompression in patients harboring tumors larger than the maximum size usually considered for radiosurgery or in patients who are symptomatic due to a mass effect from the tumor on the brain or cranial nerves. Nonetheless, the results of this and similar studies provide us with the important take-home message that when such surgery is undertaken, it does not need to be so radical that it subjects the patient to significant morbidity. Clearly, small tumor remnants that are left behind because of their involvement with the cavernous sinus, adhesion to cranial nerves (other than the optic nerves) or the brainstem, or their involvement