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## The Outcome of Linear Accelerator Radiosurgery: Is an Early Angiogram Needed?

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In this issue of the *American Journal of Neuro-radiology* (page 475), Oppenheim et al document an extensive experience with linear accelerator radiosurgery for 197 patients over a 4-year period (January 1990 to December 1993). Of the 197 patients treated, 138 had what was defined as an "early" angiographic follow-up 6–18 months after treatment. The authors' stated aim was to determine if an early angiogram was predictive of patients' final outcomes.

The radiosurgical treatment parameters the authors list in Table 2 are consistent with previously published reports of linear accelerator radiosurgery with a median peripheral prescription dose of 25 Gy for small arteriovenous malformations (AVMs): median target volume 2.67 cc; medium maximum dimension of 2.2 cm. Of note, 73 (53%) of 138 patients had single isocenter surgeries, treatments that cannot be highly conformal to target and isodose target outlines. Previous investigators have identified incomplete nidus coverage as one of the main reasons AVM obliteration can fail after radiosurgery (1). The authors' overall obliteration rate (67.4%) is consistent with prior reports.

The predictive value of an early angiogram was determined by whether or not complete obliteration occurred with intermediate or late angiographic follow-up. The findings indicate that a lower percent-volume reduction on the "early" angiogram corresponded to a lower rate of complete obliteration. Only 10% of those in the 0–25% volume reduction group went on to complete obliteration. In this sense, the "early" angiogram appears to have predictive value regarding later outcome, and I would agree with the authors that in the nonresponding patients with a prior history of hemorrhage, other treatment techniques should be discussed. In this article, as with others, the rehemorrhage rate of

4.3% in nonresponding patients is not significantly different from the natural history of untreated AVMs. I am surprised that in those patients with a 50% reduction on the "early" angiogram, only 38.1% went on to complete obliteration. Was there any difference in AVM size, age, or treatment parameters for the patients in whom obliteration failed that was significantly different from those who went on to complete obliteration? Is a median time of 24 months after surgery a long enough interval to assess "complete obliteration" angiographically? For patients without a history of hemorrhage, or for larger AVMs, we generally use the 3-year angiogram to determine final outcome of radiosurgical treatment.

The authors question in their title, "is an early angiogram needed" to assess response, predict outcome, or both? I believe that current MR imaging with 3-dimensional time-of-flight or phase-contrast can provide information equal to angiography about percent reduction in AVM nidus volume, with less risk for the patient and at a lower cost. Pollock et al reported 100% specificity for MR prediction of angiographic obliteration in small AVMs after radiosurgery using conventional T1-weighted imaging (2). While MR imaging appears to be specific, to date we have still taken a "conservative" viewpoint and use angiography, as microsurgeons do, to confirm AVM obliteration after initial MR imaging.

Radiosurgery is an effective form of treatment for about 70% of patients harboring small- to medium-sized AVMs. The authors are to be commended for their review and for reiterating that in those patients who do not appear to respond to radiosurgery, especially those with a prior history of hemorrhage, other forms of therapy should be considered sooner rather than later.

### References

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2. Pollock BE, Kondziolka D, Flickinger JC, Patel A, Bissonette DJ, Lunsford LD. Magnetic resonance imaging: an accurate method to evaluate arteriovenous malformations after stereotactic radiosurgery. *J Neurosurg* 1996;85:1044–1049

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