This paper on the risk of hemorrhage from arteriovenous malformations (AVMs) that appear obliterated on angiograms after stereotactic radiosurgery is an excellent and important article from the respected gamma knife surgery (GKS) group at the University of Tokyo Hospital. The authors observed the occurrence of hemorrhage in the area of the AVM nidus in patients treated by radiosurgery in whom angiography had confirmed complete obliteration of the AVM after GKS. This led the authors to perform a systematic retrospective study of all their patients who were treated for a cerebral AVM by using the Gamma Knife and in whom angiographic confirmation of obliteration had been obtained. There were 271 patients, of whom follow-up data could be obtained in 236; the follow-up period ranged from 1 to 133 months with a median of 77 months after angiographic confirmation of obliteration. Among these 236 patients, four experienced a hemorrhage in the area of the previously demonstrated AVM; the hemorrhage occurred from 16 to 51 months after angiographic confirmation of obliteration. Of considerable interest is the fact that two of these patients had undergone resection and, although the AVM was mostly obliterated, the authors found evidence of patent small vessels in both. The authors calculated that the risk of hemorrhage after angiographic demonstration of obliteration was 0.3% annually with a cumulative risk, according to a Kaplan–Meier analysis, of 2.2% over a 10-year period. Nevertheless, this risk is not zero. The 0.3% annual risk of bleeding found by the authors approximates the risk of bleeding from a small unruptured anterior circulation aneurysm.

In view of their findings, the authors recommend “continual follow up even after obliteration on angiography.” The problem is, what does this mean? Clearly, continual follow up would not have prevented the hemorrhages that occurred in this series. Should the follow-up review include periodic angiography? We do not know what angiography would have shown in these patients had it been performed immediately before the hemorrhage occurred. We know that the last angiograms obtained in these patients yielded negative findings, but would there have been a subsequent angiographically detectable recanalization of the lesion? Because we do not know the answer to this question, we do not know whether “continual follow up” should include angiography, particularly given the fact that there is a very small but present risk associated with angiography. I tend to agree with the authors’ presumption that the AVMs that bled after angiographic obliteration had been demonstrated essentially behaved like “angiographically occult vascular malformations.” I should add that, although the authors imply that angiographically occult vascular malformations are usually cavernous angiomas, we have histological evidence of “true” AVMs that were angiographically occult and yet looked like typical “cavernous angiomas” on preoperative MR images. This is the reason why we prefer to call these lesions “angiographically occult vascular malformations” until proven histologically to be either a cavernous angioma or a small cryptic AVM. The issue then remains, if we are not going to recommend to these patients routine follow-up angiography after a nondiagnostic angiogram, what should constitute this “continual follow up?” Clearly, continual follow up, if systemically recorded at several large radiosurgery centers, would give us confirmatory data about the risk of hemorrhage after angiographic obliteration. From the point of view of the individual patient, however, it would probably not change the clinical course in any meaningful way.

See the corresponding article in this issue, pp 842–846.
way. An additional point is what to tell these patients. Of significance, all four hemorrhages in this series were relatively benign from the clinical point of view. This may allow us to reassure these patients by telling them that yes, there is a very small risk of hemorrhage in the future, even after the angiogram yields normal findings, but that if they do have a hemorrhage, the likelihood is high that the hemorrhage will be relatively small and unlikely to leave them with a major neurological deficit. As clinicians, however, we should not be completely reassured by the fact that all four of these hemorrhages were benign because we know that approximately 70% of hemorrhages from untreated AVMs are also relatively benign from the clinical point of view.

One consideration, not mentioned by the authors but brought about by their experience, is whether after radiosurgery and angiographic demonstration of obliteration of the nidus, we should consider resection of the nidus at least in patients who are relatively young and healthy and in whom the AVM had been located in an area where surgical excision would be unlikely to lead to a significant neurological deficit. Of course, it could be argued that if the AVM was located in an area of the brain where excision would be unlikely to lead to a neurological deficit, the lesion should have been excised in the first place rather than treated by radiosurgery. As we have stated repeatedly in the past, we certainly feel strongly that in patients who can tolerate excision well, small lesions located in noneloquent areas of the brain should be treated by excision rather than radiosurgery. Nevertheless, the fact remains that a significant percentage of patients treated at radiosurgical centers are treated for small lesions located in noneloquent areas of the brain (Spetzler–Martin Grades I and II AVMs). In all likelihood, the reason that these patients are treated with radiosurgery rather than by excision is because they choose this modality of treatment rather than the more invasive surgical procedure. Are these patients likely to agree to surgical excision after the nidus is obliterated? This series contains an important piece of information: continuous enhancement of the lesion on CT or MR images and located in a noneloquent area of the brain. Even when such lesions are relatively deeply located, using current frameless stereotactic methods, these lesions can be reached through a relatively benign trajectory with little or no morbidity. The overall 0.3% annual risk of hemorrhage, which may be considerably higher if we were to consider only lesions that show continued enhancement, in my opinion, justifies the recommendation of excision. After all, as mentioned earlier, this risk approximates that of a 6- or 7-mm unruptured aneurysm of the anterior circulation and most of us currently recommend treatment of such aneurysms in patients who are good surgical candidates.

In summary, these authors have provided substantial evidence that there is a persistent risk of hemorrhage after angiographic demonstration of complete obliteration of a radiosurgically treated AVM. Clearly, this risk is small and much smaller than the risk of hemorrhage of an untreated AVM. Additionally, it appears likely that when such hemorrhages occur, they tend to be relatively benign from the clinical point of view, although with only four patients we cannot be confident of this fact. The fact that there is a significant correlation between persistent enhancement of the nidus on CT and/or MR images and the risk of hemorrhage after angiographic obliteration, raises the question of whether young, healthy patients with AVMs in noneloquent areas of the brain should be advised to have their “obliterated” nidus removed when such a nidus continues to show enhancement at the time of angiographic obliteration.

References

Response: We appreciate the kind words and thoughtful comments, as always, offered by Dr. Heros about our paper. First of all, we would like to stress once more the importance of obtaining follow-up angiography studies in patients treated by GKS for AVMs. Angiography is obviously the imaging study that most convincingly can delineate a small residual nidus or a remnant arteriovenous shunt, and evidence of nidus obliteration on angiography should continue to be the first imaging goal to be achieved.2 As for successive measures of follow up, periodic MR imaging with Gd enhancement is our preference, because it carries practically no risk and can display residual enhancement of the angiographically confirmed obliterated nidus. Such a follow-up finding may not change the clinical course in an individual patient, but it might if it can detect changes possibly related to the risk of hemorrhage that we do not already know, such as regrowth of the enhancing lesion. Angiography should be an option saved for such cases.

As Dr. Heros suggests, it certainly is reasonable to consider resection of an angiographically obliterated nidus, es-