Guest Editorial

Microsurgery and radiosurgery in brain arteriovenous malformations

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The parallel development of microsurgery, endovascular procedures, and radiosurgery, used alone or in combination, has widened the scope of surgery for arteriovenous malformations (AVM's). The paper presented by Sisti, et al., is a contribution to the evolving discussion concerning the present and future share of the three techniques in the management of brain AVM's. Sisti, et al., report the outcome of microsurgery in a series of 67 cases of AVM's less than 30 mm in largest diameter. They achieved complete resection of the AVM nidus in 94% of their cases, with a surgical morbidity rate of 1.5% and no mortality. In 24 superficially located AVM's, there was no morbidity or mortality. They compared these results, representative of those obtained by experienced vascular neurosurgeons, with the outcome in series with radiosurgical AVM treatment.

It was refreshing to note that, in contrast to the large majority of neurosurgeons, Sisti, et al., recognized the usefulness of a stereotactic guide. They used (as did Rieschel and also Guic, et al., 30 years ago) a probe to lead them to a deep-seated target. We prefer a guide with a laser beam. It is elegant andatraumatic, and thus fulfills its purpose better than a probe. The theoretical risk of brain shift with displacement of deep lesions following the lifting of the bone flap does not occur or is insignificant in our experience if the craniotomy is kept small.

The primary aim of Sisti, et al., was to compare the outcome of treating patients with AVM's by microsurgery to that achieved with using radiosurgery. Since they acknowledge the inherent flaws of the methods they used, we will not emphasize them. Instead, we will provide some facts for calm consideration.

Radiosurgery

The Latency Period

In our previous publications, we estimated the latency period between radiosurgical treatment and the onset of total obliteration of the AVM to be 1 or 2 years or more. This was based on angiographic follow-up studies, which used to be performed according to a strict protocol at 1, 2, or several years after the treatment. Hence, the real time of obliteration between two follow-up angiograms could not be established. With the introduction of magnetic resonance (MR) imaging, follow-up MR scans were carried out at 6 months, and occasionally at 3 and 9 months following treatment. Absence of flow-void areas on these images prompted early follow-up angiography which documented that, in a number of cases, the AVM is obliterated before 1 year. Hence, the problem of latency — and the risk of rebleeding during the latency period — should be reassessed.

AVM Volume and Dose

In our publications, we stressed that the best target for radiosurgery is a lesion of small volume. This did not mean that we managed only small AVM's. In our series, 450 AVM's were larger than 30 mm and 120 were larger than 40 mm in greatest diameter. Parenthetically, it should be mentioned that to give the size of only one of the diameters of an AVM is of doubtful value. In our series, some AVM's had one diameter larger than 40 mm and the other two diameters between 6 and 30 mm; some AVM's have two diameters over 40 mm, while the third diameter is between 5 and 25 mm; and some AVM's have all three diameters larger than 40 mm. Obviously, this wide variation in the size of the three diameters may influence the outcome both in microsurgery and in radiosurgery.

The incidence of total AVM obliteration is dose-dependent, and rises with an increase in minimum AVM margin dose. In large AVM's treated with similar doses, comparable obliteration rates can be achieved, but at the price of higher risk.

Patency of Irradiated AVM's and Rebleeding

The issue of possible protection against hemorrhage in irradiated but still patent AVM's is highly contro-
versal. Like the majority of neurosurgeons, we believe that patients, whether treated by microsurgery, radiosurgery, or endovascular techniques, remain at risk for a rebleed as long as the malformation is still patent. Nonetheless, in a recent study using the Kaplan-Meier life-table estimates, we found that the shape of the curve could be interpreted as an indication of a sustained decrease in the risk of hemorrhage late in the follow-up period. However, we emphasized that this should be confirmed by larger series followed beyond the period represented by the plateau at the right side of a life curve.

Another piece of information related to rebleeding was derived from the group of our patients having subtotal obliteration. We acknowledge subtotal obliteration in cases with nonvisualization of the nidus but continued early venous opacification, indicating that shunting is still present. In our series, 89 AVM's showed subtotal obliteration and no recurrence of hemorrhage was observed in this group. From the time of angiographic assessment of subtotal obliteration, the follow-up period was 496 patient-years, an average of 5 years per patient. If we assume a 2% or 4% yearly risk of rebleeding, the probable number of hemorrhages should have been nine (95% confidence interval 7.7 to 10.6, 99.9% confidence interval 6.7 to 11.7) or 17 (95% confidence interval 14.4 to 19.6, 99.9% confidence interval 12.5 to 21.4). The weakness in this reasoning is that we do not know whether any of these AVM's became obliterated after the last follow-up angiography. Therefore, let us assume that there were only 248 risk-years. Even in such a scenario, with a 2% assumed yearly risk the number of hemorrhages would be 4.8 (95% confidence interval 4 to 5.6, 99.9% confidence interval 3.5 to 6.1) and with a 4% assumed yearly risk the number of hemorrhages would be 9.3 (95% confidence interval 7.8 to 10.8, 99.9% confidence interval 6.8 to 11.7).

Thus, the zero incidence of hemorrhage in our material seems remarkable indeed compared to the incidence of hemorrhage in the natural history of the disease. These new observations require critical open-minded consideration; if they hold, it will be necessary to revise present views on possible protection against hemorrhage in irradiated but still patent AVM's.

**Location of AVM**

Sisti, et al., state that location alone is not commonly an indication for one form of treatment over the other. Nevertheless, they extirpated only three (50%) of six brain-stem AVM's. In our Fig. 1, we illustrate a mid-brain AVM before and after radiosurgery. In our series of 57 AVM's of the brain stem treated with the gamma knife, a 2-year follow-up evaluation was obtained in 28 cases; 20 (71.4%) were completely obliterated and five (17.9%) were substantially obliterated. We excluded from this group the malformations on the surface of the brain stem and included only those lesions directly in the midbrain, pons, perincule, and medulla. The results of gamma knife surgery in thalamic AVM's (Fig. 2) also compare favorably to the results with microsurgery.

**Aneurysms Associated With AVM's**

Sisti, et al., indicate as one of the advantages of microsurgery for AVM's, the clipping of associated arterial aneurysms during extirpation of the malformation. We certainly agree that microsurgery is the appropriate technique for managing arterial aneurysms; we (L.S. and C.L.) performed microsurgery on close to 1500 arterial aneurysms, 715 of them operated on between 1970 and 1980. Nevertheless, we have obliterated intracranial and perinidal aneurysms with the gamma knife (Fig. 3). Moreover, when for some reason microsurgery could not be performed, we have occasionally used the gamma knife to obliterate aneurysms at a distance from the AVM or aneurysms without an AVM.

**Clinical Outcome**

Sisti, et al., in their Table 3 summarize the clinical condition of their patients at the onset of symptoms, at the time of microsurgery, and at follow-up evaluation a mean of 50 months after treatment. Between time of surgery and follow-up review, improvement to their Grade I group (neurologically normal) was seen in only