Gamma knife surgery for dural arteriovenous fistula

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Advances in endovascular, radiosurgical, and microsurgical techniques have led to a better understanding of the pathogenesis, natural history, and treatment options for dural arteriovenous fistulas (DAVFs). First described in 1951, DAVFs represent approximately 15% of all intracranial malformations. Although this type of vascular malformation is neither new nor rare, it is not nearly as well understood as arteriovenous malformations (AVMs). Thus far, three main theories have been put forth to describe the pathogenesis of DAVFs. One major theory relates the formation of these fistulas to dural sinus thrombosis and subsequent venous hypertension. Another theory holds that DAVFs are formed as a result of increased angiogenic factors released from the brain or dura mater. The last major theory centers on an underlying hypercoagulable state as the causative factor in DAVF formation. A more comprehensive understanding of the pathogenesis of DAVFs could lead to the development of more appropriate treatment modalities or even strategies for prevention.

Just as the pathogenesis of DAVFs is not fully understood, the natural history and the long-term risks of these fistulas remain the subject of controversy. Borden, et al., proposed a classification system for DAVFs, according to which fistulas associated with retrograde leptomeningeal venous drainage (that is, Borden Types II and III) demonstrate a more aggressive natural history than those with purely venous drainage into a dural sinus. In recent series, hemorrhage rates have been reported to be as high as 19 to 35%. Pial venous drainage, deep venous drainage, and the presence of varices have also been associated with a higher risk of hemorrhage. Variability in the architecture and location of DAVFs may account in part for the aggressive nature of some and the indolent course of others. Differences in presenting symptoms and long-term risks affect treatment selection and patient expectations.

The Karolinska Institute has long been a luminary center for gamma knife surgery (GKS), and in the Acknowledgments section of the article by Söderman and colleagues, the authors call attention to the pioneering work of Christer Lindqvist and my colleague, Ladislau Steiner, in the field of GKS for DAVF. In that article, the authors demonstrate the effectiveness of GKS in the treatment of DAVFs. They retrospectively studied 53 patients with 58 DAVFs who had undergone GKS as part of their treatment. Of these patients, 28 had angiographically confirmed obliteration of the DAVF following GKS. Three patients had incomplete targeting of the DAVF, and therefore complete obliteration was not achieved or even expected in these cases. This latter point emphasizes the importance of accurate dose planning and a thorough understanding of the anatomy of each vascular malformation as part of any radiosurgical approach. Eleven patients reported symptomatic improvement in a DAVF-associated bruit, and “several” of the patients with cavernous sinus DAVFs noted improvement in ophthalmological symptoms. Two patients suffered intracranial hemorrhage during the follow-up period. There were two radiation-induced complications following GKS.

In the institutions where I have worked, the radiosurgical experience with DAVFs mirrors the results observed by Söderman and associates. Data from the University of Pittsburgh Medical Center indicated that 17 of 18 patients had substantial improvement in neurological symptoms associated with DAVF. Angiographic obliteration of the fistula was observed in eight patients, and a decrease in or an absence of the DAVF was noted on magnetic resonance (MR) imaging or angiography studies in seven other patients. At the University of Virginia Health System, 58 DAVFs have been treated with GKS. The incidence of obliteration decreased with the increasing length of the DAVF. Of 19 DAVFs less than 15 mm in length, 10 had angi-
graphic follow-up data, and seven of these were cured. Among the DAVFs between 15 and 25 mm in length, six had adequate follow-up data, and three of these were obliterated. There were 14 patients with lesions greater than 25 mm in length, and seven had angiography studies, which revealed that five had been cured. Three patients suffered a hemorrhage after GKS, but none demonstrated a new neurological deficit. The DAVFs in two of these patients remained patent following GKS. Radiosurgery followed by embolization (either transarterial or transvenous) appears to avoid the pitfalls of failing to target the entire DAVF with ionizing radiation and having that untargeted portion later recanalize.

If it is going to occur, obliteration following GKS is delayed. As such, radiosurgery seems best indicated for treating DAVFs that have a low likelihood of hemorrhage. A DAVF of the cavernous or transverse–sigmoid sinuses is often associated with a low incidence of hemorrhage and seems to be an ideal target for radiosurgical treatment. Radiosurgery offers a reasonable rate of obliteration, albeit typically during a 2- to 3-year period following the procedure. Moreover, radiosurgery affords a high degree of relief from such symptoms as tinnitus and can do so before or even without complete DAVF obliteration.

Radiosurgical obliteration seems durable. At the University of Virginia Health System, we have never observed the recanalization of an angiographically confirmed AVM or DAVF. Unfortunately, the same cannot be said of vascular lesions treated using endovascular approaches. We have observed subtotal obliteration of vascular malformations following GKS. In such cases, there is complete angiographic obliteration of the nidus but persistence of an early draining vein. Subtotal obliteration may not represent a premature stage of ongoing obliteration but rather an end point in and of itself. Subtotal obliteration may require repeated radiosurgery.

In patients with DAVFs, selecting and effecting the optimal treatment necessitates a multidisciplinary team. Members should have expertise in microsurgery, endovascular approaches, and stereotactic radiosurgery. The expectations of patients seem to be increasingly factored into the treatment equation. The varied presentation of patients with DAVF (for example, hemorrhage in some or more benign symptoms such as tinnitus in others) and the uncertainty regarding the natural history of these lesions make some patients unwilling to undergo invasive approaches such as extirpation. Although the exact indications for the radiosurgical treatment of a DAVF have yet to be fully defined, the article by Söderman, et al., and others previously published have firmly established the importance of this treatment option. Neurosurgeons must be vigilant in looking for complications in each of the three treatment options and be brutally honest when reporting them. Additional studies with open-ended clinical and radiological follow-up evaluations are required and will help to shed further light on the outcomes in patients with DAVF following radiosurgery.

References

Response: We truly appreciate the editorial comments by Drs. Heros and Sheehan. We also agree with the different perspectives on the management of these sometimes complex lesions, taking into consideration the nature of the fistula, its operability, patient preferences, risk factors, and so forth. We purposely chose not to compare GKS with other treatment modalities given that the aim of our paper was to relate our experience with GKS as a viable treatment option for these lesions and not necessarily to declare its superiority to other therapeutic options.

In regard to the criticism from Dr. Heros, his points are well chosen. It is truly a problem to assess the efficacy of radiosurgery based on angiography alone. More and more centers use MR imaging or MR angiography studies to screen patients for angiography, making the angiographically proven cure rate a parameter more related to the specificity of MR imaging or MR angiography rather than to the treatment response. His idea of expressing the cure rate as worst-case or best-case scenarios is one we agree with and have used. However, for such a small patient population as the one featured in our report, the 95% confidence interval is quite large (53–83%), thus including the best- and worst-case scenarios within it. Furthermore, the 2-year end point is an arbitrary and historical one, and the obliteration rate would presumably have increased had we monitored the patients for a longer period. We agree that the topics of target selection and dose optimization for these complex lesions are important and must be discussed. We are therefore planning to address these issues in a future paper. Finally, in regard to management decisions, we concur with the opinion that the safest treatment is not always the least invasive one. We believe that the treatment offering the best risk/benefit ratio should be recommended to the patient, independent of noninvasive, invasive, or minimally invasive aspects.