Stereotactic radiosurgery for postgeniculate visual pathway arteriovenous malformations

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Arteriovenous malformations (AVMs) that are located within the postgeniculate optic radiations or striate cortex are difficult to resect without creating postoperative visual defects. To reduce the risk of an AVM hemorrhage and to enhance the possibility of preserving visual function, the authors performed stereotactic radiosurgery in 34 patients with newly diagnosed or residual AVMs of the visual pathways. The mean AVM volume was 4.7 ml, and the average radiation dose to the AVM margin was 21 Gy. The median follow up was 47 months (range 16–83 months). Two (6%) of 34 patients had documented new visual field defects (central scotoma in one, and partial hemianopsia in one) after single-stage radiosurgery, but no patient developed a new permanent homonymous hemianopsia. Angiography was performed in all patients at a median of 26 months after radiosurgery: 22 (65%) had complete obliteration, 10 (29%) had a significant decrease in AVM volume, one (3%) had only a persistent early draining vein without residual nidus, and one (3%) had no change in the AVM. Thirteen (81%) of 16 patients with AVMs less than 4 ml had complete obliteration. Five patients had second-stage stereotactic radiosurgery after angiography revealed a persistent AVM nidus; two patients eligible for follow-up angiography had complete obliteration, thereby increasing the overall series obliteration rate to 71%. The calculated annual risk of AVM bleeding (before radiographic evidence of obliteration) was 2.4%. No patient bled after angiographically confirmed obliteration.

In most patients stereotactic radiosurgery obliterates visual pathway AVMs and also preserves preoperative visual function. Multimodality management (embolization, microsurgery, or staged radiosurgery) enhances AVM obliteration and visual preservation rates.

KEY WORDS • arteriovenous malformation • patient outcome • stereotactic radiosurgery • visual field
assessed at a multidisciplinary AVM conference and their treatment options (observation, microsurgical resection, embolization, stereotactic radiosurgery) were discussed by physicians experienced in managing patients with AVMs. A clinical summary of these patients is shown in Table 1. All patients had formal visual field testing prior to radiosurgery; one (3%) had a homonymous hemianopsia, and six patients (18%) had quadrantanopsias. Twenty-seven patients (79%) had normal preoperative visual fields. The median age was 33 years (range 11–66 years).

**Radiation Dosimetry**

Radiosurgery was performed according to a standard protocol.17,22 The mean AVM volume was 4.7 ml (range 0.4–10.5 ml). All patients were treated at the 50% or greater isodose at the margin of the AVM nidus as determined by stereotactic angiography. The mean dose to the AVM margin was 21 Gy (range 15–25 Gy). The selection of the radiosurgical dose was based on accumulated prior experience2,17 and the risk of radiation-induced complications predicted by the integrated logistic formula.6

**Follow-Up Evaluation**

Postradiosurgical physical examinations and magnetic resonance (MR) images were obtained at 6-month intervals for the first 2 years. If the MR image at 2 years suggested AVM obliteration (absence of flow-void signal, usually associated with gadolinium enhancement), follow-up angiography was performed. However, if the MR image at 2 years revealed persistent blood vessel flow-void signal, follow-up angiography was delayed until 3 years. If after 3 years the AVM was not obliterated on angiography, repeat stereotactic radiosurgery was generally recommended. Patients were contacted by telephone for additional clinical information concerning activity level, headaches, and seizures. The median patient follow up was 6.3 ml (range 3.6–10.3 ml). Two patients were eligible for follow-up angiography 2 years after second-stage radiosurgery. Two of five patients were eligible for follow-up angiography 2 years after second-stage radiosurgery. Fifty-six (56%) of nine patients with vascular headache syndromes had resolution or improvement of their headaches. Seven (78%) of nine patients with seizures had no further epileptic activity (five patients) or had a marked reduction (> 50% decrease) in their seizure frequency (two patients). Four patients had their anticonvulsant medications discontinued.

**Angiographic Follow-Up Studies**

Angiographically confirmed obliteration rates are shown in Table 2. The median time until follow-up angiography after single-stage radiosurgery was 26 months (range 11–44 months). Twenty-two (65%) had complete obliteration confirmed on angiography; 10 (29%) had significant reduction in both the size and flow of the AVM nidus. One patient had no evidence of residual nidus but only an early draining vein. One patient had no change in the AVM. Angiographically confirmed obliteration was inversely related to AVM volume: four (100%) of four AVMs less than 1 ml were obliterated, compared to nine (75%) of 12 AVMs 1 to 4 ml, and nine (50%) of 18 AVMs greater than 4 ml. The mean volume of AVMs that were obliterated was 3.9 ml, which was significantly less than the mean volume of AVMs (5.9 ml) that did not reach complete obliteration (p = 0.04, Student’s t-test). Five patients underwent second-stage stereotactic radiosurgery at a mean of 40 months (range 37–44 months) after their initial procedures. The mean AVM volume of these five patients was 6.3 ml (range 3.6–10.3 ml). Two patients were eligible for repeat angiography 2 years after second-stage radiosurgery (at 24 and 26 months), and both had complete AVM obliteration (Fig. 1). At the time of this analysis, 24 (71%) of 34 patients had complete obliteration confirmed on angiography.

**Visual and Neurological Outcomes**

Two patients complained of new visual field defects

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**Results**

**Clinical Outcomes**

Thirty-one (91%) of 34 patients returned to their previous employment or activity level after radiosurgery. Two patients had a reduced activity level because of persistent, debilitating headaches that did not improve with radiosurgery. One patient had worsening of a preexisting hemiparesis and was unable to continue full-time employment. Five (56%) of nine patients with vascular headache syndromes had resolution or improvement of their headaches. Seven (78%) of nine patients with seizures had no further epileptic activity (five patients) or had a marked reduction (> 50% decrease) in their seizure frequency (two patients). Four patients had their anticonvulsant medications discontinued.

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**TABLE 1**

Clinical summary of 34 patients with postgeniculate visual pathway arteriovenous malformations

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No. of Patients (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>presentation</td>
<td></td>
</tr>
<tr>
<td>hemorrhage</td>
<td>17 (50)</td>
</tr>
<tr>
<td>seizure</td>
<td>9 (26)</td>
</tr>
<tr>
<td>headache</td>
<td>9 (26)</td>
</tr>
<tr>
<td>other</td>
<td>4 (12)</td>
</tr>
<tr>
<td>prior treatment</td>
<td></td>
</tr>
<tr>
<td>incomplete resection</td>
<td>4 (12)</td>
</tr>
<tr>
<td>clot evacuation</td>
<td>1 (3)</td>
</tr>
<tr>
<td>embolization</td>
<td>6 (18)</td>
</tr>
<tr>
<td>location</td>
<td></td>
</tr>
<tr>
<td>occipital</td>
<td>21 (62)</td>
</tr>
<tr>
<td>temporal/occipital</td>
<td>6 (18)</td>
</tr>
<tr>
<td>parietal/occipital</td>
<td>7 (20)</td>
</tr>
</tbody>
</table>

**TABLE 2**

Angiographic follow up and outcome in 34 patients after stereotactic radiosurgery

<table>
<thead>
<tr>
<th>Procedure</th>
<th>No. of Patients</th>
<th>Complete Angiographic Obliteration (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>single-stage*</td>
<td>34</td>
<td>22 (65)</td>
</tr>
<tr>
<td>second-stage</td>
<td>5</td>
<td>2 (100)†</td>
</tr>
<tr>
<td>total</td>
<td>34</td>
<td>24 (71)</td>
</tr>
</tbody>
</table>

* Angiographic follow up at a median of 26 months (range 11–44 months).
† Two of five patients were eligible for follow-up angiography 2 years after second-stage radiosurgery.
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that developed 10 and 18 months after radiosurgery. Formal visual field testing revealed that one patient had a central scotoma; the second patient had a right homonymous hemianopsia that later improved to a partial hemianopsia. Both patients underwent MR imaging and were found to have a region of increased signal on long repetition time images surrounding the irradiated AVM. Three patients complained of visual hallucinations and had formal visual field testing performed (at 12, 20, and 24 months). No new visual defects were found in these patients. Ten asymptomatic patients had formal visual field testing performed at a median of 72 months after radiosurgery (range 21–93 months); no new visual defects were discovered in these patients. Nineteen patients had no visual complaints and normal visual fields on confrontational testing after radiosurgery; however, they did not have formal visual field testing. Overall, two (6%) of 34 patients had documented new visual field defects after radiosurgery. No patient sustained a new permanent homonymous hemianopsia after radiosurgery. One patient developed a new mild hemiparesis, and one patient had worsening of a pre-existing hemiparesis.

Postradiosurgery Hemorrhage

Two patients (6%) had an AVM hemorrhage (at 6 and 16 months, respectively) after single-stage radiosurgery. Both patients were treated conservatively and recovered without additional neurological or visual deficits. A third patient had persistent visual hallucinations 24 months after radiosurgery for a 5.5-ml AVM. Formal visual field testing at that time was normal. Incomplete resection was performed by the referring physician and a new partial hemianopsia developed postoperatively. This patient declined further treatment and sustained a fatal hemorrhage 52 months after radiosurgery and 28 months after microsurgery. We calculated the annual risk of AVM hemorrhage in this series of 34 patients to be 2.4% until angiography confirmed obliteration and 0% afterward.

Discussion

The optimum treatment of patients with AVMs located within the visual pathways should stress protection from the risk of hemorrhage and preservation of visual function. In the present series, 34 patients had stereotactic radiosurgery of AVMs located in the postgeniculate optic radiations or the striate cortex. No patient developed a permanent homonymous hemianopsia after radiosurgery. At last follow up (median 47 months), only two (6%) of 34 patients had confirmed new partial visual field defects after radiosurgery. Two patients had an AVM hemorrhage after radiosurgery during the latency interval before obliteration. Both patients sustained no additional neurological deficits. A third patient died of an AVM hemorrhage 52 months after unsuccessful radiosurgery and delayed microsurgery. Twenty-four (71%) of 34 patients had cerebral angiography that showed complete obliteration. The overall obliteration rate in this series is less than that reported (80%) from our overall AVM experience and is related to the larger volumes of AVMs treated in this group of patients. Stereotactic radiosurgery was effective in reducing the predicted hemorrhage rate in these patients and in preserving their preoperative visual function.

Surgical Resection of Visual Pathway AVMs

Relatively few studies have reported outcomes after surgical resection of visual pathway AVMs. Kattah, et al., described two patients with occipital AVMs that were resected completely using a planned two-stage procedure. During the first operation, the major feeding arteries were coagulated or clipped. Both patients developed a complete homonymous hemianopsia postoperatively. At reoperation, the AVM nidus was resected and both patients regained normal vision. More recent studies have reported new permanent visual field defects in 15% to 33% of patients after excision of visual pathway AVMs (Table 3). However, most surgical series (including the present radiosurgical series) have based their postoperative visual outcomes on gross confrontation rather than formal visual field testing. Only Martin and Wilson reported complete pre- and postoperative visual field testing. They stated that nine (56%) of 16 patients had temporary new or worsened visual field defects postoperatively; five (31%) of 16 patients devel-

Fig. 1. Anteroposterior (left) and lateral (right) angiograms obtained in a 31-year-old women revealing an arteriovenous malformation (AVM) in the right occipital lobe. Upper: Angiograms at the first stage radiosurgery. Center: Angiograms obtained 38 months later at the second-stage radiosurgery. Lower: Angiograms obtained 32 and 70 months after radiosurgery showing complete obliteration of the AVM.
TABLE 3
Selected series reporting management results for AVMs of the optic radiations or striate cortex\

<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>No. of Patients</th>
<th>New or Worsened Visual Field Defects Postop</th>
<th>No. of Patients (%) With Complete Resection/Obliteration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Martin &amp; Wilson, 1982†</td>
<td>16 (56)</td>
<td>9 (56)</td>
<td>2 (12.00)</td>
</tr>
<tr>
<td>Solomon &amp; Stein, 1987‡</td>
<td>28</td>
<td>NR</td>
<td>6 (21.00)</td>
</tr>
<tr>
<td>Batjer &amp; Samson, 1987§</td>
<td>15</td>
<td>NR</td>
<td>5 (33.00)</td>
</tr>
<tr>
<td>Korosue &amp; Heros, 1990</td>
<td>65</td>
<td>NR</td>
<td>13 (20%)</td>
</tr>
<tr>
<td>Barrow &amp; Dawson, 1994</td>
<td>26</td>
<td>NR</td>
<td>4 (15%)</td>
</tr>
<tr>
<td>Present study</td>
<td>34</td>
<td>2 (6)</td>
<td>2 (6)</td>
</tr>
</tbody>
</table>

* Abbreviations: AVMs = arteriovenous malformations; NR = not reported.
† The only series in which patients had formal pre- and postoperative visual field testing.
‡ Excludes five patients with infratentorial AVMs.
§ Ten of 15 patients had AVMs greater than 3 cm in diameter.

opened permanent new visual field defects postoperatively. In the present series, 15 (44%) of 34 patients had postradiosurgical formal visual field testing performed at a median of 51 months (range 10–93 months) after radiosurgery. The assessment of postradiosurgical visual field defects was therefore limited by the lack of formal visual field testing in all patients. The remaining 19 patients had no visual complaints after radiosurgery. Thus, the rate of formal visual field testing in the present series is similar to the published rate after microsurgery for visual pathway AVMs.1,2,16,25

Most authors recommend a direct approach to the AVM that reduces retraction and minimizes violation of the optic radiations. Heros§ recommended a transcortical approach through the inferior temporal gyrus for AVMs located in the medial temporal lobe. Batjer and Samson1 based their operative approach on the location of the AVM in relation to the trigone of the lateral ventricle. For AVMs located lateral to the trigone (lateral to the P2–3 junction of the posterior cerebral artery (PCA)), a middle or inferior temporal gyrus approach was used. For AVMs located medial to the trigone (medial to the P2–3 junction of the PCA) resection was achieved via a parietal interhemispheric approach. Martin and Wilson18 advocated an occipital parafalcine approach for resection of AVMs that were located in the medial occipital lobe. Today, multiplanar MR imaging defines the exact location of the AVM and is essential in planning the microsurgical approach. Stereotactic techniques also facilitate resection of AVMs that are located deep in the brain.24

Contemporary AVM Radiosurgery

Stereotactic radiosurgery is often regarded as appropriate only for those patients with AVMs who are at high risk or unwilling to undergo microsurgical resection. The same factors related to good outcomes after AVM resection (small size, noncritical location)19,23 are also predictive of good outcomes after AVM radiosurgery.7,8,17,22 We recently reported the clinical outcomes of 65 patients who underwent radiosurgery for Spetzler–Martin Grade I or II AVMs.22 Overall, 60 (92%) of 65 patients returned to their preoperative level of functioning without additional deficits. Two patients hemorrhaged and died during the latency interval prior to obliteration. Patients with larger, critically located, and complex AVMs (Spetzler–Martin Grade III–VI) may require multimodality treatment (microsurgical resection, embolization, or radiosurgery) to eliminate the AVM and to ameliorate symptoms. At our center, conventional biplanar stereotactic angiography routinely supplements stereotactic MR imaging and stereotactic MR angiography so that we can define the irregular three-dimensional volume of the AVM.3

Patients continue to be at risk for AVM hemorrhage for a period of time after radiosurgery. Recent reports observed that the annual risk of hemorrhage may be increased (from 7.7% to 8.4%) during the 1st year,2,22 although even AVMs incompletely obliterated after radiosurgery may be less likely to bleed than untreated AVMs.3,28 In the absence of a prospective trial, all comparisons of AVM bleeding risks after radiosurgery and the natural history of untreated AVMs are flawed. The usually quoted 3% to 4% annual risk of hemorrhage includes AVMs of all sizes,5,20 whereas radiosurgery is most often advocated for small (< 3 cm average diameter) AVMs. Kader, et al.,12 and Spetzler, et al.,26 suggest that small AVMs have a higher risk of hemorrhage. The reported risk of latency-interval hemorrhage after stereotactic radiosurgery of small AVMs may in part reflect the natural history of such AVMs if left untreated.

Effect of Visual Field Defects

Patients with visual field defects have a poor rehabilitation outcome according analysis of activities of daily living and functional status outcome.23 Many are unable to be gainfully employed. Patients with visual field defects generally show slow, disordered visual search in their blind fields, and tend to neglect that space.11,19 Such defects may make complex sensorimotor activities such as driving impossible.21 Elderly patients appear to be especially vulnerable and unable to compensate for visual field defects.29 In a report by Kerkhoff, et al.,14 on their efforts to develop compensatory eye movement strategies in hemianoptic patients; 12 (54%) of 22 patients developed visual field increases, and 20 (91%) of 22 patients were able to return to at least part-time employment. It appears that some patients with visual field defects can be rehabilitated successfully using saccadic eye movement strategies to compensate for their visual field defect.

Conclusions

We believe that stereotactic radiosurgery is an effective strategy to reduce visual defects in patients with AVMs of the visual pathways. For patients whose employment is dependent on normal vision, stereotactic radiosurgery may be preferable to microsurgical resection of AVMs within the visual pathways. Future radiosurgery and microsurgery series should examine those AVM factors that better predict the risks in an individual patient including...
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age, AVM volume, location, presence of venous outflow restriction or related aneurysms, and the expected morbidity related to the specific surgical approach.

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References


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