ORIGINAL RESEARCH

Increased prevalence and rupture status of feeder vessel aneurysms in posterior fossa arteriovenous malformations


ABSTRACT

Background Posterior fossa arteriovenous malformations (AVMs) are considered to have a higher risk of poor outcome, as are AVMs with associated aneurysms. We postulated that posterior fossa malformations may be more prone to associated feeder vessel aneurysms, and to aneurysmal source of hemorrhage.

Objective To examine the prevalence and hemorrhagic risk of posterior fossa AVM-associated feeder vessel aneurysms.

Methods A retrospective review of AVMs was performed with attention paid to location and presence of aneurysms. The hemorrhage status and origin of the hemorrhage was also reviewed.

Results 571 AVMs were analyzed. Of 90 posterior fossa AVMs, 34 (37.8%) had aneurysms (85% feeder vessel, 9% intranidal, 15% with both). Of the 481 supratentorial AVMs, 126 (26.2%) harbored aneurysms (65% feeder vessel, 29% intranidal, 6% both). The overall incidence of feeder aneurysms was higher in posterior fossa AVMs, which were evident in 34.4% of infratentorial AVMs compared to 18.5% of supratentorial malformations (p<0.01). The presence of intranidal aneurysms was similar in both groups (9.2% vs 8.8%). Feeder artery aneurysms were much more likely to be the source of hemorrhage in posterior fossa AVMs than in supratentorial AVMs (30% vs 7.6%, p<0.01).

Conclusions Posterior fossa AVMs are more prone to developing associated aneurysms, specifically feeder vessel aneurysms. Feeder vessel aneurysms are more likely to be the source of hemorrhage in the posterior fossa. As such, they may be the most appropriate targets for initial and prompt control by embolization or surgery due to their elevated threat.

INTRODUCTION

Brain or cerebral arteriovenous malformations (AVMs) are vascular lesions that have abnormal direct connections between the arterial and venous systems, without intervening parenchymal-perfusion small vessels. They are relatively rare—estimated to have a prevalence of 0.002–0.5%.—and associated aneurysms have been reported from 2.7% to 21% of the time. These can further be subclassified as feeder (or pedicle) aneurysms or intranidal aneurysms. This excludes aneurysms on the venous drainage side of the malformation. The aneurysm location has differing implications for treatment and outcome. The literature conflicts as to whether intranidal or feeder aneurysms carry the higher risk of a hemorrhagic presentation or re-rupture before treatment, although there is generally consensus that these are high-risk features compared with those AVMs without associated aneurysms.

Posterior fossa AVMs have been reported to be an independent predictor of increased morbidity and mortality. The percentage of AVMs presenting with hemorrhage ranges from 30% to 82%. Initial presentation with hemorrhage can lead to mortality rates as high as 10–30%. The increased morbidity and mortality of posterior fossa AVMs has also been illustrated, even though they represent only 5–15% of all intracranial AVMs. This may be due to more frequent presentation with hemorrhage, or to the more dire consequence of hemorrhage in an enclosed space with highly eloquent functional areas despite often smaller hematoma volumes after rupture. We hypothesize that posterior fossa malformations are also more prone to associated aneurysms—specifically feeder vessel aneurysms—and, when present, are more frequently the source of hemorrhage.

METHODS

After institutional review board approval, a retrospective review of AVMs treated at our institution from 1995 to January 2015 was evaluated. Demographic data, radiologic characteristics, and clinical parameters were collected, with attention paid to location and presence of associated aneurysms. These associated aneurysms were designated as feeder vessel aneurysms, intranidal aneurysms, or both. The hemorrhage status and origin of the hemorrhage was also reviewed. Two endovascular neurosurgeons determined the site of hemorrhage origin by radiologic review of the presentation CT scan and cerebral angiogram. An extensive literature review was performed for comparison of results with published reports.

Statistical analysis

The demographic data and proportion of AVM patients with feeder aneurysms were compared between a supratentorial and infratentorial location using the χ² test. ORs were used to evaluate the source of bleeding from a feeder aneurysm in infratentorial AVMs compared with supratentorial AVMs. Statistical analyses were performed using SAS software V9.4 (SAS Institute, Cary, North Carolina, USA).
Hemorrhagic stroke

RESULTS
Patient characteristics
A total of 571 AVMs that had identifiable locations were analyzed. The age range of the patients was 19 days to 87 years (average 41 years) and the gender was evenly distributed, with 288 women and 283 men. Two hundred and eighty-four (49.6%) of these AVMs initially had a hemorrhagic presentation. One hundred and sixty AVMs (28.0%) had associated aneurysms, 120 (21.0%) of which had associated feeder aneurysms. Of the 571 AVMs, 90 were infratentorial.

Incidence of feeder aneurysms
Of the 90 AVMs located in the posterior fossa (including cerebellar and brainstem locations), 34 (37.8%) had aneurysms: 29 (85%) with at least one feeder vessel aneurysm, 3 (9%) with intranidal aneurysms, and 5 (15%) with both. Of the 481 supratentorial AVMs, 126 (26.2%) harbored aneurysms, 82 (65%) of which were feeder aneurysms, 37 (29%) intranidal, and 7 (6%) both. The overall incidence of aneurysms was appreciably higher in posterior fossa AVMs. This association was most pronounced for feeder aneurysms, which were evident in 34.4% of infratentorial AVMs compared with 18.5% of supratentorial malformations (p<0.01). The incidence of intranidal aneurysms was similar in supratentorial and infratentorial locations (9.2% vs 8.9%; table 1).

Feeder aneurysm rupture status
When evaluating for rupture site, 18 of 60 hemorrhages in the posterior fossa could be attributed to a feeder aneurysm, yielding a 58% rupture incidence for those aneurysms, and account for 30% of ruptures among infratentorial AVMs. In comparison, 17 of 224 supratentorial hemorrhages could be clearly attributed to a feeder aneurysm, yielding a 7.6% aneurysm rupture incidence and accounting for 7.6% of total supratentorial AVM hemorrhages (p<0.01). This amounts to an OR of rupture from feeder aneurysms at the time of presentation of 5.86 (CI 2.4 to 14.2; p=0.001) for infratentorial versus supratentorial hemorrhages.

Illustrative case
A middle-aged patient with no past medical history presented with 1 week of unremitting headache, which had initially occurred postcoitally. Initial head CT demonstrated a hemorrhage measuring 2 cm×8 mm around the cerebellar vermis and he was admitted to the neurosurgical service (figure 1A). CT angiography (CTA) showed an underlying vermian AVM, and the initial angiogram demonstrated a Spetzler–Martin grade II, Spetzler–Ponce grade A malformation measuring 2 cm and fed by the superior cerebellar artery (SCA) and posterior inferior cerebellar artery (PICA) (figure 1B). It drained into the straight sinus, as well as the transverse sinus and torcular herewith. There were associated feeder and intranidal aneurysms on the SCA (figure 1C) and PICA. Embolization of all feeder aneurysms was performed using n-butyl cyanoacrylate (n-BCA) (Codman Neuro, Raynham, Massachusetts, USA) in one session (figure 1D). Postembolization angiographic images demonstrated occlusion of all aneurysms. Two weeks later, suboccipital craniotomy was performed for resection of the residual malformation with no resultant complications or symptoms (figure 1E).

DISCUSSION
Comparison of data in the literature on the topic of AVM-associated aneurysms can be difficult due to varying classification schemes and differing denominators for reported prevalence. As shown in table 2, the occurrence of associated aneurysms is listed as the percentage of total AVMs (ie, supratentorial and infratentorial) in some papers, while others only evaluated infratentorial malformations. Some only cataloged ruptured presentations while others reported all AVMs in an institution. The aneurysms themselves are described alternately as ‘feeder’, ‘proximal’, or ‘preterminal’ aneurysms to separate them from ‘intranidal’/‘nidal’ or ‘remote’/‘unassociated’ aneurysms. For instance, Platz et al19 classifies AVM-associated aneurysms as feeding (type 1), nidal (type 2), or unassociated (type 3), but further divides type 1 into 1a and b, where 1a is closer to the circle of Willis than the malformation itself while the opposite is true with type 1b. In contrast, Yu et al20 used a four-tier classification system where I was unassociated, II was flow-related but at the proximal portion of a feeding artery, III was ‘dissecting type’ on a feeding artery, and IV was intranidal. Some papers do not subclassify feeder, remote, or intranidal aneurysms at all. However, the overall incidence of aneurysms associated with AVMs from our literature review is 2.6–47%. In the posterior fossa specifically, the incidence is 20.8–47% (table 2).

Our results support previous implications that feeder aneurysms are more common infratentorially.21–24 The reason for this increased incidence and predilection for hemorrhage is unclear, although the differential impact of AVM hemodynamics in smaller posterior fossa vessels may be relevant. Increased wall shear stress (WSS) and, to some degree, smaller vessel size has previously been demonstrated as a risk factor for supratentorial feeder vessels to be associated with aneurysms;25–27 thus, smaller vessel feeders such as the PICA and SCA, as encountered in the posterior fossa, may be more prone to developing increased WSS in the setting of high AVM flows and, consequently, aneurysms.21–26

This study is drawn from one of the largest databases of AVMs reported. Only three other groups have reported on a volume of patients larger than this one, ranging from 600–662, some by joining data from multiple centers.6,8,23 In correlation with the majority of the literature, we demonstrate no statistically significant gender predisposition for hemorrhage or associated feeder aneurysms, although articles such as those by Platz et al19 and Thompson et al23 did find a difference, with increased associated aneurysms and hemorrhagic presentation, respectively, in women. In our study, slightly more men presented with hemorrhage, although more women had associated aneurysms.

Table 1 Distribution of patients with infratentorial versus supratentorial AVMs, with hemorrhagic presentation between the two groups

<table>
<thead>
<tr>
<th></th>
<th>Infratentorial</th>
<th>Supratentorial</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No of patients</td>
<td>%</td>
</tr>
<tr>
<td>Total</td>
<td>90</td>
<td>15.76</td>
</tr>
<tr>
<td>Cerebellar</td>
<td>78</td>
<td>13.66</td>
</tr>
<tr>
<td>Brainstem</td>
<td>12</td>
<td>2.10</td>
</tr>
<tr>
<td>Ruptured</td>
<td>60</td>
<td>66.67</td>
</tr>
<tr>
<td>Total aneurysms</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>Feeder</td>
<td>29</td>
<td>37.8</td>
</tr>
<tr>
<td>Intranidal</td>
<td>3</td>
<td>9.0</td>
</tr>
<tr>
<td>Both</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>Bleed from feeder</td>
<td>18</td>
<td>58.06</td>
</tr>
</tbody>
</table>

AVM, arteriovenous malformation.
However, we demonstrate, in a large single-center sample, an increased risk of hemorrhagic source specifically from AVM-associated aneurysms in the posterior fossa in comparison with supratentorial locations, with an OR of 5.86.

AVMs have been represented in the literature most recently due to controversy over the best treatment regimen, which has been heavily debated, especially for lower grade lesions. The ARUBA trial made sweeping recommendations to leave all of these malformations to conservative medical management only. There has been significant discussion as to whether low-grade lesions should, instead, be addressed using surgical resection as the primary modality. Many authors and experts advocate a multimodality approach to many of these malformations, especially high-grade lesions. The literature suggests that...
ruptured A VMs of this location. are signi
to associated aneurysms, but we have identi
statements as to the prospective risk of hemorrhage attributable
either from the aneurysm or the A VM itself
Only those that could be de
feeder aneurysms are, if anything, likely to be underestimated.
by the location of n-BCA liquid embolisate after embolization
by endovascular means, if it cannot be addressed during the sur-
orrhage was somewhat subjective as this could not be
elimination of the feeder aneurysm should be a priority, often
supratentorial A VMs, feeder vessel aneurysms are also more
likely to be the source of hemorrhage in the posterior fossa.

CONCLUSION
Posterior fossa AVMs are more prone to developing associated
aneurysms, specifically feeder vessel aneurysms. Compared with
supratentorial AVMs, feeder vessel aneurysms are also more
likely to be the source of hemorrhage in the posterior fossa.
These data support targeting posterior fossa feeder aneurysms
for initial and prompt control by embolization or surgery.

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Meeting of the Society of Neurointerventional Surgery in San Francisco, California,
USA in July 2015.

Table 2 Literature review presenting the incidence of associated aneurysms with AVMs with respect to location and hemorrhagic presentation

<table>
<thead>
<tr>
<th>Authors (reference)</th>
<th>Incidence (%) of feeder aneurysms in total intracranial AVMs</th>
<th>Incidence (%) of feeder aneurysms in supratentorial AVMs</th>
<th>Incidence (%) of feeder aneurysms in infratentorial AVMs</th>
<th>AVMs with feeders that presented with haemorrhage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abla et al[20]</td>
<td>31.8 (49/154)</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Kouznetsov et al[8]</td>
<td>6 (14/233)</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Lasjaunias et al[2]</td>
<td>13 (13/101)</td>
<td>–</td>
<td>–</td>
<td>57 of total AVMs with aneurysms</td>
</tr>
<tr>
<td>Lv et al[9]</td>
<td>7.9 (24/302)</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Magro et al[7]</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>47 (16/34)</td>
</tr>
<tr>
<td>Meisel et al[4]</td>
<td>27.8 (184/662)</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Platz et al[19]</td>
<td>35.2 (76/216)</td>
<td>–</td>
<td>–</td>
<td>59.3 (35/59) total</td>
</tr>
<tr>
<td>Schmidt et al[21]</td>
<td>–</td>
<td>5 (21/417)</td>
<td>25 (14/57)</td>
<td>–</td>
</tr>
<tr>
<td>Stapf et al[4]</td>
<td>17 (77/463)</td>
<td>–</td>
<td>–</td>
<td>55.8 (43/77)</td>
</tr>
<tr>
<td>Stein et al[22]</td>
<td>–</td>
<td>–</td>
<td>22.6 (12/53)</td>
<td>–</td>
</tr>
<tr>
<td>Westphal et al[44]</td>
<td>–</td>
<td>2.6 (5/196)</td>
<td>20.8 (5/24)</td>
<td>–</td>
</tr>
<tr>
<td>Yang et al[12]</td>
<td>–</td>
<td>–</td>
<td>32.8 (20/61)</td>
<td>–</td>
</tr>
</tbody>
</table>

AVM, arteriovenous malformation.

Contributors JO: design of the work, including the acquisition, analysis, and
interpretation of data, drafting the paper, revising it critically for important
intellectual content, and contribution to the final approval of the version to be
published. SA-H: design of the work, drafting the work, revising it critically for
intellectual content, and contribution to the final approval of the version to be
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version to be published. VA: design of the work, interpretation of the results,
drafting of the paper and final approval. FC: revising the manuscript and final
approval of results. AA: design of the work, drafting the work, revising it critically
for important intellectual content, and final approval of the version to be published.

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Data sharing statement All relevant data have been presented in this paper. The
entire data are protected and available from the principal investigator. More detailed
clinical and demographic data are unidentifiable and locked in the office of the
corresponding author and are available on request.

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posterior fossa AVMs represent an especially dangerous subset
of lesions, with associated aneurysms an especially high-risk
feature. We suggest, as have other authors,29 30 that immediate
elimination of the feeder aneurysm should be a priority, often
by endovascular means, if it cannot be addressed during the sur-


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