Treatment of Cerebral Arteriovenous Malformations by Preoperative Embolization and Microsurgery

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Abstract

Objectives To determine the role of preoperative embolization on postoperative neurological outcome in the treatment of cerebral AVMs, we retrospectively evaluated an effectiveness of combining preoperative embolization and microsurgery for arteriovenous malformations(AVM) of the brain.

Methods Two groups(10 patients who underwent preoperative superselective embolization and surgery versus 27 patients who underwent surgery only) were compared and categorized by Spetzler- Martin grade, the size of AVM and postoperative clinical outcome using Glasgow Outcome Scale. The 37 patients included 23 males and 14 females, ranging in age from 11 to 74 years(mean 36 years).

Results The arteriovenous malformations in preoperative embolization and surgery group had a larger average greatest diameter(4.45cm versus 3.83cm) and were of higher Spetzler- Martin grade(80% versus 52% grade III through V). At 1 week after surgery, the preoperative embolization and surgery group represented a better outcome(60% versus 44% with Glasgow Outcome Scale score of 5). And over 6 months after surgery, the embolization and surgery group displayed more favorable clinical outcome(80% versus 63% with Glasgow Outcome Scale score of 5).

Conclusion Combined treatment with superselective preoperative embolization using N- butyl cyanoacrylate and direct surgery may help neurosurgeon treating the high grade AVMs thus improving the postsurgical outcome.

KEY WORDS Arteriovenous malformation- Superselective embolization- Microsurgery.

Introduction

Microneurosurgery has been the principal method for the treatment of intracranial arteriovenous malformations(AVMs). Even though the recent development of modern therapeutic modalities including intravascular neurosurgery and stereotactic radiosurgery has expanded the therapeutic options, each modality itself created some controversies as to the best management strategy(27)(28). However, proper combination of these modalities would provide the maximum clinical benefits(6)(12)(13)(16)(19).

Preoperative embolization is felt to improve surgical results by reducing the size of the AVM, eliminating deep or inaccessible feeding vessels, decreasing blood loss, lowering the frequency of complications related to normal perfusion pressure breakthrough, and facilitating a surgical resection plane(16)(19). The recent development of new microcatheters has markedly improved intracranial endovascular navigation beyond the circle of Willis and decreased morbidity related to catheterization of cortical or deep AVM feeders(7).

In this study, we have attempted to determine the influence of preoperative embolization on postoperative neurological outcome in the treatment of cerebral AVMs.

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Clinical Materials and Method

The clinical data and imaging findings of 37 consecutive cerebral arteriovenous malformation patients who were treated in our department of neurosurgery from March, 1992, to December, 1998 were retrospectively evaluated. Of these, the study group consisted of 10 patients who underwent preoperative N-butyl cyanoacrylate embolization and surgical resection and the control group consisted of 27 patients treated with direct surgery alone. The 37 patients included 23 males and 14 females, ranging in age from 11 to 74 years (mean 36 years).

Endovascular embolization was performed in the angiographic suite under neuroleptic analgesia through a femoral catheter. A 6F or 7F guide catheter was inserted through the femoral artery and positioned as close as technically feasible to the skullbase. The guide catheter was continuously flushed with heparinized saline (4,000U/L) via an infusion bag. Systemic heparinization was done with 5,000 Units in an intravenous bolus, followed by 1,000U/hr throughout the procedure. A flow-guided microcatheter (1.8 F Magic, Balt Co., Montmorency, France) was then inserted through the guiding catheter and the tip of microcatheter was positioned within the nidus of the AVM or at the entrance of a fistula. After superselective angiogram for evaluating adequate position of the microcatheter tip, the microcatheter was irrigated with 5% dextrose solution before glue injection. A 25% or 33% mixture of N-butyl-2-cyanoacrylate (Histoacryl, B Braun Melsungen, Germany) in Lipiodol (Guerbet, Aulnay-sous-Bois, France) was injected slowly until proximal reflux of glue begins to extend along the microcatheter, or until the nidus has filled and there is no more progression of glue (Fig. 1). Several embolization procedures proved necessary in three cases (up to 5 in one case). Embolization was discontinued when complete or sufficient occlusion of the nidus for surgery was achieved or when further embolization was judged impossible or too risky. To determine the influence of preoperative N-butyl cyanoacrylate embolization on postoperative neurological outcome, we categorized both groups by Spetzler-Martin grade (Table 1). Distribution of Spetzler and Martin grading system comparing pre- and postembolization is presented in Table 2. All of the cases showed a one- or two grade improvement after the embolization. The 10 embolization and surgery patients under-

Results

Relative to surgery only patients, the AVMs in surgery and embolization group had a larger average greatest diameter (4.45 cm versus 3.83 cm) and tended to be of a higher Spetzler-Martin grade (80% grade III through V versus 52% grade III through V) (Table 1). Distribution of Spetzler and Martin grading system comparing pre- and postembolization is presented in Table 2. All of the cases showed a one- or two grade improvement after the embolization. The 10 embolization and surgery patients under-

Table 1. Spetzler-Martin grades

<table>
<thead>
<tr>
<th>Grade</th>
<th>Surgery and embolization</th>
<th>Surgery only</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>I, II</td>
<td>2 (20%)</td>
<td>13 (48%)</td>
<td>15</td>
</tr>
<tr>
<td>III-V</td>
<td>8 (80%)</td>
<td>14 (52%)</td>
<td>22</td>
</tr>
<tr>
<td>Total</td>
<td>10</td>
<td>27</td>
<td>37</td>
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went a total of 17 embolizations, maximum 5 embolizations per patient (Fig. 2), for an average of 1.7 embolizations per patient. Surgery was generally scheduled 3 to 5 days after the last staged embolization. All patients underwent postoperative angiography to document complete surgical removal of their AVM. Typical preembolization, postembolization and postresection angiograms are shown in Fig. 3.

The complete distribution of outcome scores for both the surgery and embolization group and surgery only group is displayed in Table 3. At 1 week after surgery (Table 4), the surgery and embolization group had better outcome scores (60% with Glasgow Outcome Scale score of 5) as compared with the surgery only group (44% Glasgow Outcome Scale score of 5). This 1-week delayed difference in outcome presumably reflects the resolution of more transient deficits in the surgery and embolization patients. The long term evaluation (over 6 months after surgery) (Table 5) continued to favor the surgery and embolization patients (80% with Glasgow Outcome Scale score of 5) relative to the surgery only patients (63% with Glasgow Outcome Scale score of 5), despite a significantly higher Spetzler-Martin grade AVMs in the surgery and embolization group.

The 10 patients underwent surgical resection of AVM lesions which result in total removal of nidus. There were two patients with surgical resection after embolization who experienced postoperative complication. One had aphasia and paralysis with recovery in four weeks after operation, and the other who has residual AVM after previous operation without preembolization suffered from wound infection with persistent vegetative state.

Within 1 week after embolization, surgical resection of

<table>
<thead>
<tr>
<th>Grade</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preembolization</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Postembolization</td>
<td>-</td>
<td>5</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Fig. 2. A 44-year-old man with spontaneous intracerebral hematoma (Spetzler grade IV). Right lateral internal carotid angiogram showing a large posterior parietal AVM supplied by enlarged middle cerebral arterial feeders (A). The AVM was embolized with five sessions (B, C, D) and post-embolization angiogram (D) showing the markedly reduced flow through the AVM with residual nidus.
totally or partially occluded lesion was done. The arteriovenous malformations that had occlusion of more than 75% of nidus appeared to be extensively thrombosed when inspected at surgery. And there were evidence of thrombosis of cortical draining veins as well as occlusion of deep or relatively inaccessible feeders, facilitating dissection of

**Fig. 3.** Initial left internal carotid arteriography(A) showing AVM in the parietal lobe with two feeding arteries. After superselective injection of lower(B) and upper(C) feeding arteries with N-butyl-2 cyanoacrylate, postembolization internal carotid arteriography shows nearly complete obliteration of the AVM with preserved flows of the adjacent normal arterial branch. Carotid angiogram after surgical resection(D) shows preservation of nutrient artery.

**Table 3.** Glasgow outcome patient distribution[1] surgery and embolization(SE) versus surgery only(SO)

<table>
<thead>
<tr>
<th>Score</th>
<th>Preoperative</th>
<th>1 Week after surgery</th>
<th>6 Months after surgery</th>
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<tbody>
<tr>
<td></td>
<td>SE</td>
<td>SO</td>
<td>SE</td>
</tr>
<tr>
<td>5</td>
<td>7</td>
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<tr>
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<td>3</td>
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<td>1</td>
<td>0</td>
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**Table 4.** Early postoperative gglasgow outcome scale scores (1 week)

<table>
<thead>
<tr>
<th>Score</th>
<th>Surgery and embolization</th>
<th>Surgery only</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>6 (60%)</td>
<td>12 (44%)</td>
<td>18</td>
</tr>
<tr>
<td>&lt;5</td>
<td>4 (40%)</td>
<td>15 (56%)</td>
<td>19</td>
</tr>
<tr>
<td>Total</td>
<td>10</td>
<td>27</td>
<td>37</td>
</tr>
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**Table 5.** Long term postoperative glasgow outcome scale scores (over 6 months)

<table>
<thead>
<tr>
<th>Score</th>
<th>Surgery and embolization</th>
<th>Surgery only</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>8 (80%)</td>
<td>17 (63%)</td>
<td>25</td>
</tr>
<tr>
<td>&lt;5</td>
<td>2 (20%)</td>
<td>10 (37%)</td>
<td>12</td>
</tr>
<tr>
<td>Total</td>
<td>10</td>
<td>27</td>
<td>37</td>
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superficial aspect of residual AVM with good control of small fragile deep feeding vessels.

**Discussion**

The current treatment options for AVMs include observation, embolization, stereotactic radiation, and microsurgery or a combination of these techniques. The surgical resection of superficially located AVMs, Spetzler grade 1 through 3, has been shown to be associated with low surgical mortality and morbidity and remains the standard treatment option for these lesions\(^1\)\(^4\)\(^5\)\(^\text{(28)}\). But high-risk AVMs, large lesions with deep venous drainage and eloquent location (Spetzler grade 3, 4, 5), need to be managed with combined multimodality treatment, such as embolization followed by surgery or stereotactic radiosurgery. In the author’s series, we attempted preoperative embolization for relatively high grade lesions\(^8\)% rather than low grade ones\(^2\)% with no mortality and lower morbidity\(^\text{(Table 1)}\).

We believe that surgical excision is still the best treatment when it is technically possible to carry out without causing significant damage to adjacent brain. Preoperative embolization of AVMs improves surgical results by reducing the size of the nidus, decreasing flow through the AVM, and eliminating deep or surgically inaccessible arterial feeders and thereby decreases complication related to normal perfusion pressure breakthrough and facilitate surgery by decreasing operating time and blood loss\(^5\)\(^\text{(26)}\). Many authors emphasized that the risk of severe hyperemic complications which accompanies one-stage occlusion of large, high-flow AVMs\(^2\)\(^\text{(18)}\)\(^\text{(20)}\)\(^\text{(21)}\)\(^\text{(23)}\). Therefore, by using a staged preoperative AVM embolization, it is hoped that a progressive rather than abrupt change in cerebral hemodynamics will avoid sudden redistribution of blood flow, thus reducing the so-called normal perfusion pressure breakthrough\(^\text{(NPPB)}\). In our limited series of patients, preoperative staged embolization appears to have reduced the incidence of permanent morbidity and mortality\(^\text{(Table 5)}\).

Controversy remains concerning the safest and most effective embolic agent for preoperative embolization of AVMs\(^3\)\(^4\). The advantages of adhesive N-butyl cyanoacrylate include deep intranidal penetration, permanent occlusion, high thrombogenicity, and relatively easy of delivery through small microcatheters\(^5\). But nonadhesive agents such as coils, silk thread, and polyvinyl alcohol are subject to recanalization over time, making it difficult to treat large AVMs with multi-staged embolization over weeks to months.

Initially, the goal of endovascular embolization was complete occlusion of AVMs and some think that embolization as sole treatment, but the recent literature confirms that embolization of brain AVMs is not usually curative\(^9\)\(^\text{-}\)\(^\text{11}\)\(^\text{(18)}\). The chance to cure a brain AVM exclusively by endovascular means is in the range of 10-\% 20\%\(^1\). Like many authors, we accepted embolization as a reductive therapy to facilitate surgical resection of high grade lesions. Before we accept embolization as a routine presurgical procedure, we had the usual well-known morbidity and mortality for high grade AVMs, but now we think that prior embolization offers definite advantage for surgical resection of lesion. There is no general agreement on the time of the operation after embolization. If the interval between embolization and surgery is too long, the development of either leptomeningeal or deep collaterals may cause significant surgical difficulties\(^2\)\(^\text{(25)}\). The authors performed surgery within 3-5 days after embolization. But Pasqualin et al.\(^2\)\(^\text{(22)}\) stated that operative blood loss and postoperative hyperemic complications are possibly more common with shorter intervals between embolization and surgery. Development of new feeding arteries may occur after 2-3 months and probably 3-5 weeks is an optimal interval\(^\text{(25)}\). But as in author's series, if multi-staged embolization over weeks to months is needed, surgical resection should be done as soon as possible to prevent the possibility of recanalization. Further experience will be required to determine the most appropriate time interval between surgery and embolization in each individual patient.
Our results show an improved outcome in the surgery and embolization group which is first notable at 1 week after surgery (60% versus 44% Glasgow Outcome Scale score of 5) (Table 4). The long term outcome (over 6 months after surgery) score continue to favor the surgery and embolization group (80% versus 63% Glasgow Outcome Scale score of 5) (Table 5). The Glasgow Outcome Scale is most ideally suited for the evaluation of long-term outcome. Especially in this study, this type of outcome scale was felt to be the most useful considering primary goal of the study and limitations of patient follow-up.

Conclusions

For the best management of AVMs, it is essential to achieve complete elimination of abnormal arteriovenous shunting. The stepwise occlusion of relatively large AVMs by staged preoperative embolization and surgical resection appears to provide a means of transforming inoperable or hardly operable AVMs into operable lesions and to minimize the postoperative mortality and morbidity. The N-butyl cyanoacrylate embolization with superselective angiography appears to improve postsurgical outcome of patients with relatively high grade cerebral AVM.

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