Arteriovenous malformations in the basal ganglia and thalamus: management and results in 101 cases

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Object. Because arteriovenous malformations (AVMs) in the basal ganglia and thalamus are difficult to treat, the authors conducted a retrospective study to determine the best management strategy for these lesions.

Methods. The authors reviewed the management and outcome in 101 patients with AVMs treated between 1971 and 1995. In 15 conservatively treated patients, hemorrhage occurred in 71.4% (annual rate 11.4%), and the morbidity and mortality rates were 7.1% and 42.9%, respectively, during a mean follow-up period of 6.6 years. Total microsurgical resection was performed in 15 patients with no mortality resulting, but motor function deteriorated permanently in three of them (20%). Postoperative morbidity correlated well with the location of the AVM and with preoperative motor function. In cases of lenticular AVMs without motor weakness, a postoperative decrease in motor function was significantly more common than in the remaining patients. In patients with motor weakness before surgery, AVMs in the thalamus or caudate nucleus were successfully resected. Among 66 patients treated with gamma knife radiosurgery, three had permanent radiation-induced neurological deficits, and three others experienced bleeding (new bleeding in one case and rebleeding in two). The treatment-associated morbidity rate was 6.7%, and the actuarial rate of complete obliteration was 85.7% at 2.5 years. In five patients treated with embolization alone, the morbidity and mortality rates associated with the procedure or bleeding were 40% and 20%, respectively. The morbidity and mortality rates in the pre–gamma knife era were 22.2% and 22.2%, whereas those for the post–gamma knife era are currently 10.4% and 1.5%, respectively.

Conclusions. These results indicate that conservatively treated AVMs are more likely to bleed and thus produce a high incidence of patient mortality. Multimodal treatment including radiosurgery, microsurgery, and embolization improved clinical outcomes by making it possible to treat difficult cases successfully.

Key Words • arteriovenous malformation • basal ganglion • thalamus • radiosurgery • surgery • natural history

Arteriovenous malformations (AVMs) in the basal ganglia and thalamus present special management challenges.11,28 Some evidence indicates that deep-seated AVMs are more likely to rupture, a life-threatening event with lesions in this location.20 However, the natural history of AVMs in the basal ganglia and thalamus is unclear because of the limited number of reports on this subject, and surgery for these lesions entails considerable risk to critical areas of the nervous system. Thus, AVMs located in the deep nuclei of the brain represent a dilemma for neurosurgeons.

In recent years, advances in microsurgical techniques and endovascular procedures and the development of stereotactic radiosurgery have led to the successful removal or obliteration of an increasing number of AVMs in this location.5,6,10,13,14,16,18,24,26,30–32,34 However, most of these have involved highly selected cases, such as small or thalamic AVMs, and the methods used are still not without limitations and risks. To gain a better understanding of the indications for surgery, it is important to know the long-term follow-up results for potential surgical complications such as motor weakness, speech disturbance, or loss of visual field, but these have not been precisely documented. At present, several treatment options are available, including observation, microsurgery, embolization, stereotactic radiosurgery, and multimodal treatment. However, the best management strategy for these lesions has not been established. Therefore, we reviewed our experience with AVMs in the thalamus and basal ganglia to determine the best treatment options.

Clinical Material and Methods

We assessed 101 patients (58 males and 43 females) aged 4 to 58 years (mean 27.8 ± 12.2 years) treated between 1971 and 1995, who had angiographically confirmed AVMs in the basal ganglia or thalamus. Basal ganglia AVMs included those located in the caudate nucleus, lenticular nucleus, internal capsule, and amygdala. Twenty-eight patients were treated before 1990, when a...
gamma knife was installed at the University of Tokyo Hospital, and 73 were treated after its installation (Table 1). Based on the final treatment modality, the patients were divided into four groups: observation, microsurgery, embolization, and radiosurgery (gamma knife). The number of patients; their age and sex; the location, side, and Spetzler–Martin grade of their AVMs; and the mean follow-up period in each group are shown in Table 2. Of the 101 patients, 15 were conservatively treated. Another 15 underwent microsurgical resection alone (13 patients) or in combination with conventional radiotherapy (one patient) or embolization (one patient). Embolization alone was performed in five patients, and 66 patients were treated with the gamma knife alone or after embolization and/or microsurgery. Because this study is retrospective and not a cooperative study including many centers, we cannot exclude the possibility of bias in patient selection.

Statistical Analysis

The data were statistically analyzed using the chi-square test. Fisher’s exact probability test was used when there were fewer than four variables. The data are reported as the mean ± the standard deviation (SD) of the mean.

Results

Clinical Findings

The clinical findings are summarized in Table 2. There were significantly more females in the gamma knife group than in the observation group. The AVM grade was significantly higher in both the observation and transarterial embolization groups than in the microsurgery or gamma knife groups. Although the gamma knife group showed a trend toward a higher frequency of AVMs on the dominant side and in the basal ganglia than was observed in the microsurgery group, neither difference was statistically significant (both p = 0.07).

Observation Group

Fifteen patients 6 to 44 years of age (mean 26.4 ± 10.9 years) at the time of the initial event were treated conservatively because there was no history of hemorrhage or because the nidus was large or was located in the lenticular nucleus and caused no major neurological deficits. The mean follow-up period for this group was 6.6 ± 4.6 years. The follow-up results in these patients are summarized according to the initial symptoms in Table 3.

Hemorrhage. Of the 10 patients who presented with hemorrhage, eight experienced rebleeding during the follow-up period, which ranged from 2 to 16 years (mean 6 ± 5.2 years). Five of these patients died, one became bedridden, and only two have resumed working; four had large AVMs (Grade V) and the other four had small lesions (Grade III). The two patients who did not rebleed have returned to work.

Seizures. Of the four patients with epileptic seizures, one died following new bleeding episodes that occurred 5 years after the onset of the initial symptom. Two patients who did not have bleeding episodes are working. The remaining patient was lost to follow up, and her outcome is unknown.

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td><strong>observation</strong></td>
<td>15</td>
</tr>
<tr>
<td><strong>surgery</strong></td>
<td>12</td>
</tr>
<tr>
<td>conventional radiotherapy + surgery</td>
<td>0</td>
</tr>
<tr>
<td>embolization + surgery</td>
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</tr>
<tr>
<td><strong>embolization</strong></td>
<td>0</td>
</tr>
<tr>
<td><strong>gamma knife</strong></td>
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</tr>
<tr>
<td>surgery + gamma knife</td>
<td>6</td>
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<tr>
<td>embolization + gamma knife</td>
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<tr>
<td>embolization + surgery + gamma knife</td>
<td>3</td>
</tr>
<tr>
<td>total</td>
<td>28</td>
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<td>73</td>
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</table>

* Words in **boldface** type indicate treatment group used for outcome analysis.

<table>
<thead>
<tr>
<th>Treatment Modality</th>
<th>Observation (15 patients)</th>
<th>Surgery (15 patients)</th>
<th>Embolization (5 patients)</th>
<th>Gamma Knife (66 patients)</th>
</tr>
</thead>
<tbody>
<tr>
<td>age (yrs, mean ± SD)</td>
<td>26.4 ± 10.9</td>
<td>29.2 ± 10.6</td>
<td>25.2 ± 10.2</td>
<td>28.0 ± 12.8</td>
</tr>
<tr>
<td>sex (female/male)</td>
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<td>7:8</td>
<td>2:3</td>
<td>32:34</td>
</tr>
<tr>
<td>AVM location (BG/Th)</td>
<td>7:8</td>
<td>9:6</td>
<td>6:9</td>
<td>4:1</td>
</tr>
<tr>
<td>AVM side (rt/lt)</td>
<td>10:5</td>
<td>6:9</td>
<td>4:1</td>
<td>43:23</td>
</tr>
<tr>
<td>Spetzler–Martin grade</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>II</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>III</td>
<td>7</td>
<td>13</td>
<td>2</td>
<td>55</td>
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<td>IV</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>V</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>follow-up (yrs, mean ± SD)</td>
<td>6.6 ± 4.6</td>
<td>8.0 ± 4.2</td>
<td>3.7 ± 2.1</td>
<td>1.7 ± 1.0</td>
</tr>
</tbody>
</table>

* BG = basal ganglia; Th = thalamus.
† p = 0.02 compared to observation group.
‡ p = 0.01 compared to observation group.
§ p = 0.04 compared to microsurgery group.
|| p = 0.01 compared to gamma knife group.
** p = 0.003 compared to observation group.
Arteriovenous malformations in the basal ganglia and thalamus

TABLE 3

<table>
<thead>
<tr>
<th>Initial Symptom</th>
<th>Follow-Up Period (yrs)</th>
<th>Bleeding Episodes</th>
<th>Outcome</th>
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<tr>
<td>hemorrhage (10)</td>
<td>2–16</td>
<td>no rebleeding (2)</td>
<td>working (2)</td>
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<td></td>
<td></td>
<td>rebleeding (8)</td>
<td>working (2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>bedridden (1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>dead (5)</td>
</tr>
<tr>
<td>seizure (4)</td>
<td>2–12</td>
<td>no bleeding (2)</td>
<td>working (2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>bleeding (1)</td>
<td>dead (1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>unknown (1)</td>
<td>unknown (1)</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>bleeding (1)</td>
<td>working (1)</td>
</tr>
</tbody>
</table>

* Values in parentheses are numbers of patients. Unknown means lost to follow up.

Headache. The patient with headaches had new bleeding 8 years after the onset of the initial symptom but recovered without major neurological deficits.

Outcome. Over the total of 88 observation years, 71.4% of the patients (10 of 14) in this group suffered rebleeding or new bleeding. The annual bleeding rate and the actuarial 10-year bleeding risk were 11.4% and 81%, respectively. Among the patients who presented with hemorrhage as the initial symptom, eight (80%) of 10 suffered rebleeding. The annual rebleeding rate (13%) and actuarial 10-year rebleeding risk (86.7%) were higher in these patients than for the entire group. The annual rates of bleeding and rebleeding during the first 3 observational years, a period corresponding to the latency interval after radiosurgery, were 10% and 14.3%, respectively. The morbidity and mortality rates in the observation group were 7.1% (one of 14) and 42.9% (six of 14), respectively.

Microsurgery Group

All 15 patients in the microsurgery group had a history of hemorrhage; five had suffered intracerebral hemorrhage (ICH) and 10 intraventricular hemorrhage (IVH). The patients’ ages at the time of the hemorrhagic event ranged from 12 to 57 years (mean 29.2 ± 10.6 years). Nine AVMs were located in the thalamus, four in the lenticular nucleus, and two in the head of the caudate nucleus. All of the lesions were completely resected, and no rebleeding occurred during a mean follow-up period of 8 years.

TABLE 4

<table>
<thead>
<tr>
<th>Preop Function</th>
<th>Postop Function</th>
<th>Follow-Up Period (yrs, mean ± SD)</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>weakness (8)</td>
<td>improved (1)</td>
<td>8.0 ± 4.8</td>
<td>working (5)</td>
</tr>
<tr>
<td>ICH (5)</td>
<td>unchanged (7)</td>
<td></td>
<td>independent (2)</td>
</tr>
<tr>
<td>IVH (3)</td>
<td></td>
<td></td>
<td>bedridden (1)</td>
</tr>
<tr>
<td>no weakness (7)</td>
<td>unchanged (4)</td>
<td>8.0 ± 4.1</td>
<td>working (5)</td>
</tr>
<tr>
<td></td>
<td>deteriorated (3)</td>
<td></td>
<td>independent (2)</td>
</tr>
<tr>
<td>IVH (7)</td>
<td>lenticular AVM (2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>thalamic AVM (1)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Values in parentheses are numbers of patients.

Preoperative Disturbance of Consciousness. Three patients who suffered a large ICH showed disturbance of consciousness preoperatively. After the operation, this disturbance improved in all three patients.

Motor Function. The effects of microsurgery on motor function are summarized in Table 4. Eight patients, five with ICH and three with IVH, exhibited moderate hemiparesis before the operation. Only one patient, who had ICH, improved postoperatively. Nevertheless, five of these patients have only slight weakness and have returned to work; two are independent, and one is bedridden. The latter patient had been doing well until a hypertensive ICH occurred. Thus, motor weakness was improved by microsurgery and rehabilitation in most cases. One representative case is illustrated in Figs. 1 and 2. Of the seven patients who had IVH without paresis, three (two with a lenticular AVM and one with a thalamic AVM) deteriorated after the operation. Fortunately, one patient who harbored a lenticular AVM is now working, and the other two are independent.

To identify good candidates for microsurgery, we analyzed the relationship between postoperative motor function and the location of the nidus (thalamus, caudate nucleus, or lenticular nucleus) and between the surgical results and the presence or absence of motor weakness preoperatively. Patients harboring AVMs in the thalamus or caudate nucleus showed a trend toward better results than those with AVMs in the lenticular nucleus (p = 0.15). Patients with no preoperative motor weakness were significantly more likely to develop motor weakness after the operation (p = 0.04). Decreased motor function postoperatively was significantly more likely in patients who harbored lenticular AVMs and had no preoperative motor weakness than in the remaining patients (p = 0.03).

Verbal Function. Verbal function was evaluated using the Japanese edition27 of the Western Aphasia Battery.8 Five of six patients with dominant-side AVMs had postoperative speech impairment. Two of three patients in whom an interhemispheric transventricular approach was used experienced postoperative speech disturbance. One of these two patients suffers from motor aphasia and right hemiparesis, which have persisted for 15 years; presumably, brain tissues around the AVM including the internal capsule were damaged by the operation. In the other patient, the speech disturbance resolved 5 weeks postoperatively. All three patients who underwent a transtemporal transventricular procedure exhibited postoperative speech disturbances that resolved completely within 3 months, 4 months, and 1 year, respectively. Thus, postoperative speech disturbances resolved completely, except in one early case. A representative case is shown in Figs. 3 and 4.

Surgical Approaches and Postoperative Visual Field Defects. Postoperative visual field defects occurred in four of six patients in whom a transtemporal approach was used and in one of two in whom a transtemporal approach was used. None of these defects showed significant improvement during the follow-up period. The seven patients who underwent interhemispheric or transsylvian procedures had no postoperative visual field defects.

Disconnection Syndrome. In three patients in whom the nidus was resected via an interhemispheric approach,
there was a potential risk of disconnection syndrome. However, no patient in our series was seriously impaired by this syndrome.

**Surgical Outcome.** Of 15 patients who underwent surgical resection, 10 (66.7%) are working and four (26.7%) are living independently (Table 4). One patient, who suffered a hypertensive ICH during rehabilitation, is bedridden. There were no deaths.

**Radiosurgery Group**

Sixty-six patients, aged 4 to 58 years (mean 28 \pm 12.8 years), underwent gamma knife irradiation. Sixty-two patients (93.9%) presented with hemorrhage, three had ischemic neurological deficits, and one suffered epileptic seizures. We observed a preoperative neurological deficit (for example, hemiparesis, hemihypesthesia, or speech disturbance) in 55 patients (77.3%). Most of the AVMs were Grade III (83.3%), and 35 (53%) were less than 2 cm in diameter. Of these, 47 were treated by means of gamma knife radiosurgery alone, whereas the remaining 19 underwent multimodal treatment (Table 1). Transarterial embolization was undertaken to reduce the AVM size in 13 patients before radiosurgery; in five cases, the lesion was successfully reduced in size, from Grade IV to Grade III. The actuarial rate of complete obliteration was 28.8% at 1 year and 85.7% at 2.5 years (Table 5). Neuroimaging studies showed radiation-induced edema in 12 patients (20%). Eight patients (13.3%) suffered symptomatic radiation-induced neurological deficits, which were permanent in three (5%). Three patients experienced bleeding (new bleeding in one and rebleeding in two) from the partially obliterated nidus 6, 12, and 22 months after radiosurgery, respectively. In one of these three patients, a chronic expanding hematoma formed, and his hemiparesis and visual acuity deteriorated. The annual bleeding rate before angiographically demonstrated cure was calculated as 3.3%; lower than that in the observation group. These results may give an impression that radiosurgery lowered the risk of bleeding. However, clinical characteristics, especially the AVM grade, differed between the two groups and therefore it is hard to draw such a conclusion from the present study. The permanent treatment-associated morbidity in this group was 6.7%. As for the final outcome, 44 patients (73.3%) are working, 12 (20%) are living independently, and four (6.7%) are dependent (Table 6). There were no deaths, and no patient is bedridden. Six patients were lost to follow up.

**Embolization Group**

Only five patients, all with a history of hemorrhage, were treated with embolization alone. Their ages ranged from 11 to 37 years (mean 25.2 \pm 10.2 years). No lesion
was totally obliterated. In one case, the guidewire caused traumatic bleeding, and the patient is now dependent. One patient died of hemorrhage after embolization. Two other patients suffered hemiparesis after embolization; one recovered fully within 3 months and is working, whereas the other has persistent mild hemiparesis but is independent. One other patient who had no complications after embolization is working.

Comparison of Clinical Outcomes Between the Pre– and Post–Gamma Knife Eras

To determine how the introduction of the gamma knife contributed to the improvement of treatment results, clinical outcomes were compared between the pre– and post–gamma knife eras. Before the gamma knife was installed, 15 of 28 patients were treated conservatively, whereas all patients since then have received some kind of active treatment. The morbidity and mortality rates in 27 patients treated in the pre–gamma knife era and available for follow-up review were 22.2% and 22.2% (six patients each), whereas those for the post–gamma knife era are currently 10.4% (seven of 67) and 1.5% (one of 67), respectively. Thus, introduction of the gamma knife greatly improved the results of treatment for basal ganglia and thalamic AVMs (p = 0.0005). However, it must be noted that no Grade V AVMs have been treated since the gamma knife has been in operation.

Discussion

The natural history of AVMs in the basal ganglia and thalamus remains unclear because of the limited numbers of reports. Data from the present series, to our knowledge the largest in the literature, indicate that deep-seated AVMs are more likely to bleed, causing a high incidence of patient mortality. Ninety-two (91.1%) of 101 patients had a history of hemorrhage at presentation, and three of eight patients presenting with headaches or seizures (four in the observation group, excluding one lost to follow up, and four in the radiosurgery group) experienced rebleeding during the follow-up period. Thus, 95 (95%) of 100 patients experienced bleeding episodes as an initial event or during the follow-up period. In contrast, 67% of patients with convexity AVMs in the cooperative study and 74% of patients with AVMs in all locations in Yaşargil’s series presented with hemorrhage. The reason for this difference is not fully understood, but it may be because of higher perfusion or venous pressure or a higher incidence of associated arterial and venous aneurysms.

Our study also demonstrated a high risk of rebleeding among conservatively treated patients with a history of hemorrhage: the annual rebleeding rate was 13%, and the actuarial 10-year rebleeding risk was 86.7%. Four of eight patients with recurrent hemorrhage harbored large AVMs. These results indicate that deep-seated AVMs of any size have a greater propensity to rehemorrhage. The morbidity
and mortality rates in the eight patients who experienced rebleeding were 12.5% and 62.5%, respectively. Thus, the rupture of an AVM in the thalamus or basal ganglia can lead to catastrophic hemorrhage. These results indicate that patients who suffer a hemorrhage should be treated to prevent a second bleed, because the prognosis of these patients is extremely poor if they are conservatively treated.

Current treatment options for AVMs in the basal ganglia and thalamus include microsurgery, radiosurgery, embolization, and multimodal methods. However, deciding what is the best management strategy for these deep-seated lesions is difficult. The effectiveness of the treatment, postoperative morbidity and mortality, and long-term outcomes in terms of the complications that can occur with each method must all be considered. Microsurgical resection of these AVMs is a challenging operation, because the nidus is located near vital neural structures and in most instances the deep feeding vessels cannot be occluded before the nidus is dissected from the surrounding brain. However, surgical results have improved in recent years.

Some AVMs (for example, small lesions with hematoma in the thalamus or caudate nucleus) can now be resected with acceptably low morbidity and mortality rates. Although advanced microsurgical techniques as well as adjuncts to surgery (including preoperative embolization, intraoperative angiography, intraoperative sonography, electrophysiological monitoring, and induced hypotension) have greatly contributed to good outcomes, selecting suitable patients for microsurgical resection is critical to reducing surgical morbidity and mortality rates.
In the case of thalamic AVMs, our surgical treatment of large AVMs, embolization is a useful adjunct therapy. After embolization, the AVM should be promptly resected, because partial embolization does not protect against hemorrhage and early recanalization may occur. Together with previously reported cases, our surgical results indicated that patients with small-to-medium sized AVMs in the thalamus or caudate nucleus who experienced motor weakness before surgery would be good candidates for microsurgical resection.

Radiosurgery is a good option for treating deep-seated small AVMs, particularly in patients with no history of hemorrhage. In the present study, the actuarial rate of complete obliteration was 85.7% at 2.5 years posttreatment. This is similar to other reported results. 

Regarding the possibility of radiation injury, Tew, et al. 

Magnetic resonance (MR) imaging is especially useful for this purpose, because it provides important information about the relationship of the nidus to the internal capsule, the presence of hematoma and its anatomical location, and the condition of the surrounding brain in terms of edema and gliosis.

Microsurgery produced satisfactory results in our patients with ICH. Such patients often present with disturbance of consciousness and evacuation of the hematoma can be life-saving. In addition, surgical removal of an AVM that includes a hematoma is not very difficult because of the partial separation of the nidus from the surrounding brain tissue. Therefore, surgical extirpation of the AVM can be recommended in patients with ICH. In our patients presenting with hemorrhage and motor weakness, the risk of surgery aggravating preoperative motor weakness was small, and motor weakness could be improved by rehabilitation. If the AVM is small-to-medium sized, microsurgical resection is a good option in these patients. In the patients with lenticular AVMs and motor weakness, however, we have performed microsurgical resection in only two, and therefore we cannot draw conclusions about such cases. With regard to the surgical treatment of large AVMs, embolization is a useful adjunct therapy. After embolization, the AVM should be promptly resected, because partial embolization does not protect against hemorrhage and early recanalization may occur.

Deciding whether surgery is indicated in patients presenting with hemorrhage but with no neurological deficits is problematic. In these patients, surgical accessibility depends mostly on the location of the AVM. The lesions located in the basal ganglia, especially lenticular AVMs, are very difficult to approach because of their proximity to the internal capsule. In one reported series, direct resection of basal ganglia AVMs was performed in only five (33%) of 15 patients, whereas AVMs in the thalamus or caudate nucleus were successfully resected with low morbidity and mortality rates. In the case of thalamic AVMs, the whole nidus is not always located in the thalamus (Figs. 3 and 4). In many cases, large parts of the nidus consist of vessels feeding the choroid plexus in the lateral ventricle. In our series, three of seven patients with preoperative motor weakness deteriorated after the operation, and two of the three who deteriorated had lenticular AVMs. In patients with lenticular AVMs and without motor weakness before surgery, the risk of postoperative motor weakness was significantly increased (p = 0.03). Therefore, surgical indications for lenticular AVMs in patients with a history of hemorrhage but no neurological deficits must be carefully determined. For small AVMs or following embolization for large lesions, radiosurgery seems to be a reasonable alternative for such patients. Additionally, to previous reported cases, our surgical results indicated that patients with small-to-medium sized AVMs in the thalamus or caudate nucleus who experienced motor weakness before surgery would be good candidates for microsurgical resection.

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presented since the gamma knife was installed, multimodal treatment including radiosurgery, along with advances in microsurgical techniques and perioperative management, seem to have improved the clinical outcome by making it possible to treat difficult cases successfully.

**Conclusions**

Patients with AVMs in the basal ganglia and thalamus who suffer a hemorrhage should be actively treated to prevent a second hemorrhage because they bear a high risk of rebleeding with a high incidence of mortality if conservatively treated.

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