A proposed scheme for grading intracranial arteriovenous malformations

YU-QUAN SHI, M.D., AND XIAN-CHENG CHEN, M.D.

Department of Neurosurgery, Hua Shan Hospital, Shanghai Medical University, Shanghai, People's Republic of China

A four-grade classification scheme for intracranial arteriovenous malformations (AVM's) is proposed. Grading is based on 1) the size of the AVM; 2) its location and depth; 3) its arterial supply; and 4) its venous drainage. Each of these aspects is divided into four grades with respect to the difficulty it poses for surgical excision. A description of the grading system and its application is given. This grading scale has been correlated with the operative morbidity and mortality in 100 cases of excised intracranial AVM's. The results show that the higher the grade of AVM, the greater the risk of surgical morbidity and mortality. This grading scale is simple and easy to apply. It can guide neurosurgeons in selecting AVM patients suitable for operation, in determining the best type of operation to perform, and in predicting operative difficulties as well as postoperative results.

KEY WORDS arteriovenous malformation grading system surgical resection prognosis

The five-grade scheme for ruptured intracranial aneurysms formulated by Botterell, et al., in 1956 has facilitated the selection of cases suitable for operation, the choice of the optimal time for surgery, and the prediction of the results of operation. There is no comparable grading system available for intracranial arteriovenous malformations (AVM's). In 1977, Luessenhop and Gennarelli suggested a grading method for supratentorial AVM's based on the anatomic nature of their feeding arteries as an initial resolution of this problem.

Since 1979, we have performed microsurgery on intracranial AVM's of various types and have found that the operations differed a great deal in both their difficulty and their results. In some cases the operations were simple and easy, and the patients recovered uneventfully with no postoperative neurological deficits. In other cases the operations were extraordinarily difficult, and various degrees of neurological deficits or permanent disability developed postoperatively. A simpler unified clinical grading method for intracranial AVM's would be of extreme value. Based on the surgical difficulty that might be anticipated during excision of the AVM, we propose a grading scale that can be mastered easily with a little practice (YQ Shi and XC Chen, unpublished data, 1983). Our method of grading AVM's is presented.

Grading System

Description of System

Four factors were considered to determine the difficulty of AVM excision, namely: 1) the size of the AVM; 2) its location and depth; 3) the complexity of its feeding arteries; and 4) the complexity of its draining veins. Each of these factors has been classified into Grades I through IV as shown in Table 1.

For grading AVM's, angiograms should be obtained to show the arterial and venous phases in both anteroposterior and lateral views. In some cases unilateral angiograms are not adequate to show the entire vascular nidus because of a drop in perfusion pressure due to vascular steal, and angiograms of the opposite side or total intracranial angiography must be used. The size of the AVM is determined by measuring the largest dimension of the vascular nidus appearing in the angiogram, excluding remote portions of its draining veins. By matching each AVM with the grading scale, item by item, its grade can be determined. Thus, a score consists of four digits, each of which represents the grade of the respective item. If all four digits are 1, the grading score is 1111 and the AVM is a Grade I. If one of the four digits is 2 (such as 2111 or 1211), the AVM falls between Grades I and II and is designated as Grade I-II. If two or more of the four digits are 2 (such as 2211 or 2121),
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**TABLE 1**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Grade I</th>
<th>Grade II</th>
<th>Grade III</th>
<th>Grade IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>diameter &lt; 2.5 cm</td>
<td>diameter 2.5–5.0 cm</td>
<td>diameter 5.0–7.5 cm</td>
<td>diameter &gt; 7.5 cm</td>
</tr>
<tr>
<td>Location &amp; Depth</td>
<td>superficial &amp; non-crucial areas</td>
<td>superficial, in functional areas</td>
<td>deep, e.g., interhemispheric, deep part of cerebrum or cerebellum, corpus callosum, basal ganglia, etc.</td>
<td>deep, involving vital structures of brain, e.g., brain stem, diencephalon, etc.</td>
</tr>
<tr>
<td>Arterial Supply</td>
<td>single superficial branches of MCA or ACA</td>
<td>multiple superficial branches of MCA &amp;/or ACA</td>
<td>branches of PCA or deep branches of MCA &amp;/or ACA; branches of vertebral artery</td>
<td>main branches of all 3 major cerebral arteries or vertebrobasilar artery</td>
</tr>
<tr>
<td>Venous Drainage</td>
<td>single, emptying into superficial dural sinuses</td>
<td>multiple; all drainage into superficial dural sinuses</td>
<td>deep cerebral vein emptying into vein of Galen, straight sinus; possible superficial venous drainage</td>
<td>deep cerebral vein with huge dilatation or aneurysm-like structures</td>
</tr>
</tbody>
</table>

* MCA = middle cerebral artery; ACA = anterior cerebral artery; PCA = posterior cerebral artery.

**TABLE 2**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Total Cases</th>
<th>Operative Morbidity</th>
<th>Operative Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>Percent</td>
<td>No.</td>
</tr>
<tr>
<td>I</td>
<td>6</td>
<td>6.0</td>
<td>0</td>
</tr>
<tr>
<td>I-II</td>
<td>13</td>
<td>100.0</td>
<td>0</td>
</tr>
<tr>
<td>II</td>
<td>28</td>
<td>28.0</td>
<td>0</td>
</tr>
<tr>
<td>II-III</td>
<td>18</td>
<td>18.0</td>
<td>3</td>
</tr>
<tr>
<td>III</td>
<td>30</td>
<td>30.0</td>
<td>6</td>
</tr>
<tr>
<td>III-IV</td>
<td>5</td>
<td>5.0</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100.0</td>
<td>13</td>
</tr>
</tbody>
</table>

* AVM = arteriovenous malformation.

We applied this grading scale retrospectively to a series of 100 patients whose AVM's had been completely excised, in order to correlate their operative results with the grades we assigned to them (Table 2). In this series, 13 patients had postoperative morbidity and one died immediately postoperatively. With the exception of the death, all the operative results were assessed at least 3 months after the operation with careful comparison of the patients' preoperative neurological function. We divided the operative results into three categories as follows: "excellent" indicates essentially normal neurological function or noticeable improvement of preoperative deficits; "good" indicates maintenance of preoperative neurological function; and "poor" indicates development of new neurological deficits or increase of preoperative deficits.

We considered a poor result as operative morbidity, either minor or major. A patient with "minor morbidity" is able to live independently, while a patient with "major morbidity" requires help from the family or a nurse, or must be institutionalized. Our 13 cases of operative morbidity included two major and 11 minor designations; all of these patients had AVM's classified as Grade II–III or above. No Grade IV AVM was subjected to complete resection in our series.

**Illustrative Cases**

**Case 1**

This 25-year-old woman was admitted because of subarachnoid hemorrhage (SAH) confirmed by lumbar puncture 3 months prior to admission. Neurological examination showed that she was slightly dysphasic. Left carotid angiography revealed a small AVM in the anterolateral portion of the temporal lobe, fed from the anterior temporal artery and draining into the inferior cerebral vein (Fig. 1). The grading score was 1111, so it was designated a Grade I AVM. Complete excision was performed without difficulty. Postoperative recovery was uneventful, and neurological function became essentially normal with clearing of the speech disturbance.

**Case 2**

This 41-year-old woman had a history of severe headache associated with vomiting, loss of consciousness, and dilatation of the right pupil 6 months before admission. She was referred to our hospital after the above symptoms had resolved. On admission, she was found to have papilledema, and a 0.4-cm midline shift to the left on echoencephalography. There was an upper-quadrant visual field defect in the left nasal side. Right carotid angiography revealed a medium-sized AVM in the posterior portion of the right temporal lobe. The lesion was fed by a dilated posterior temporal artery, and drained through cortical veins to the right
transverse sinus. The grading score of this AVM was 2111, so it was designated a Grade I-II AVM. Complete excision of the lesion was performed without difficulty. The patient recovered uneventfully with no additional neurological deficit. She resumed her original work in a factory 6 months after surgery.

**Case 3**

This 19-year-old man, 3 months before admission, suffered a sudden left-sided seizure followed by left hemiplegia, and later lapsed into coma lasting more than 1 week. Neurological examination on admission revealed that there was spastic paralysis of the left upper extremity, weakness of the left lower extremity, exaggeration of all tendon reflexes on the left side, and positive Hoffmann and Babinski signs. Right carotid angiography showed a medium-sized AVM in the central region of the cerebral hemisphere. Its feeding arteries derived chiefly from branches of the middle cerebral artery, with a minor part from branches of the anterior cerebral artery. Its draining vein emptied into the superior sagittal sinus. The grading score of this lesion was 2221, so it was designated a Grade II AVM. Complete excision was performed without much difficulty. Postoperatively, the left-sided hemiparesis persisted for about 2 weeks and then gradually resolved over a 3-month period. The patient returned to his original work as a shop clerk 1 year later.

**Case 4**

This 29-year-old man was admitted because of SAH 3 months previously. Neurological examination on admission was essentially normal. Left vertebral angiograms revealed a medium-sized AVM in the left occipital lobe, fed by a dilated posterior cerebral artery. Its draining veins emptied into both the superior sagittal and left transverse sinuses (Fig. 2). The grading score of this lesion was 2232, so it was designated a Grade II-III AVM. Complete excision of the AVM was performed, and the patient recovered without neurological deficit. He resumed his original work as a fisherman 6 months later.

**Case 5**

This 28-year-old woman was admitted because of recurrent attacks of SAH resulting in right-sided hemiplegia, hemianesthesia, and hemianopsia over the previous 2 months. Left carotid angiography showed a small AVM, about 2 cm in diameter, deep in the left cerebral hemisphere. The lesion was fed by a dilated lenticulostriate artery, and by the anterior choroidal artery, branches of the middle cerebral artery, and Heubner's artery of the anterior cerebral artery. The draining veins emptied into the superior thalamostriate and internal cerebral veins. The grading score of this lesion was 1333, so it was designated a Grade III AVM. Complete excision of the lesion was performed by the transventricular route. The patient remained in the same neurological condition as before surgery for 1 year, and then improved very slowly. She can now take care of herself and is doing simple housework.

**Case 6**

This 37-year-old woman was admitted because of repeated focal seizures on the right side for 6 years that became worse 6 months before admission. She had a right-sided hemiplegia with dysphasia of 9 months' duration. Left carotid angiography showed a huge AVM, 8 cm in diameter, in the left frontal lobe. Its feeding arteries mainly derived from dilated middle and anterior cerebral arteries. The draining veins emptied into both the superior sagittal sinus and the deep cere-
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**Fig. 2.** Case 4. *Left and Center:* Vertebral angiograms, lateral view (left) and anteroposterior view (center), showing a Grade II-III arteriovenous malformation (AVM). *Right:* Vertebral angiogram, lateral view, after excision of the AVM.

The grading score of this lesion was 4233, and it was designated a Grade III-IV AVM. Complete excision was followed by slight increase in her symptoms, particularly speech dysfunction in the immediate postoperative period. However, her condition gradually improved, and she returned to part-time work 1 year later.

**Case 7**

This 26-year-old woman was admitted with a history of left hemiplegia for 15 years and repeated generalized grand mal seizures for 13 years. Neurological examination showed she had mental retardation, with sluggish response to commands and poor calculation. There was a bilateral choked disc, left-sided hemiparesis, hemianesthesia, and hemianopsia. Right carotid and left vertebral angiograms (Fig. 4) revealed a huge AVM in the posterior part of the right cerebral hemisphere as well as the central part of the brain stem. All the three major cerebral arteries were involved in its blood supply. The venous drainage emptied into both the superficial sinuses and the deep cerebral veins, which showed aneurysmal dilatation. The grading score of this lesion was 4444. As a case of Grade IV AVM, she was not operated on because we thought this lesion could not be helped either by extravascular or by intravascular

**Fig. 3.** Case 6. *Left and Center:* Carotid angiograms, lateral view (left) and anteroposterior view (center), showing a Grade III-IV arteriovenous malformation (AVM). *Right:* Carotid angiogram, lateral view, after excision of the AVM.
surgery. This patient was not included in the series of 100 cases but is presented here as an example of a Grade IV AVM.

Discussion

The anticipated gains from complete excision of an AVM are elimination of the danger of further bleeding and improvement of the cerebral blood supply by correction of cerebral vascular steal. However, if the operation should carry a risk of morbidity or mortality higher than that of the natural history of the disease, there is no gain from surgery. Therefore, a method of predicting the difficulty that will be encountered during the operation, the surgical outcome, and the relative morbidity and mortality rates inherent in the operation would be of great value in deciding whether or not to operate. The criteria of grading in this proposed scheme relate to the type of AVM, its operation, and the outcome from operation.

In our series of 100 patients whose AVM had been totally excised, there was no mortality or morbidity associated with AVM’s of Grade II or under. For those cases above Grade II, morbidity occurred in increasing frequency as the grade increased. Thus, in Grade II–III the morbidity rate was 16.7%, in Grade III 20.0%, and in Grade III–IV 80.0%. In Grade III–IV, there was a mortality rate of 20.0%. This shows that the proposed scheme of grading meets the predetermined requirement of predicting the dangers of surgery. Therefore, this system may warrant wider clinical application.

In this grading scale we do not consider intracranial hematoma as a grading criterion for the following reasons. 1) The destructive effects to the brain of intracranial hemorrhage are caused by its size, location, duration, accompanying cerebral vascular spasm, and edema. All these elements vary a great deal in individual cases. It is difficult to categorize an intracranial hematoma, so we excluded it as a criterion in order to decrease the complexity of the grading system. 2) The presence of a sizable intracranial hematoma will usually facilitate the excision of the AVM. Furthermore, it is difficult to predict the results of removing an intracranial hematoma. In some cases removal will cause prompt resolution of neurological deficits, and in others recovery may be handicapped by the destructive effect to the surrounding brain caused by the hematoma before removal. Thus, the influence of a hematoma is hard to assess. A hematoma is sometimes difficult to identify even on angiography. This is because there is significant cerebral vascular steal, especially in cases of medium-sized and large AVM’s, which results in a blank zone due to poor focal cerebral perfusion. Computerized tomography scanning will help to diagnose hematomas in fresh cases, but may not be able to differentiate old hematoma from old cerebral ischemic atrophy.

The four grading criteria used in our scheme have a theoretical basis. The size of the lesion is intimately related to the degree of injury to the brain during excision. A small AVM can be excised with very little injury, while a large AVM presents more danger of injury during its excision. Therefore, large AVM’s are more likely to cause morbidity. The location of the lesion also has much to do with neurological symptoms and signs. If the AVM is located in a non-crucial area, its excision would seldom result in severe disability; if the AVM is located in a functional area or a vital center of the brain, its excision would inevitably result in severe neurological deficits.

Arterial blood supply is vital for the normal function of the brain. If the arterial supply to the AVM is simple and superficial (most likely from terminal branches) ligation would cause little or no effect. Sometimes, because of the eradication of the cerebral vascular steal, the patient may even show significant improvement after surgery. However, if too many arteries are involved in the blood supply to the AVM, ligation of all these arteries can result in inadequate cerebral blood flow. The central branches of the main cerebral arteries (such as the lenticulostriate arteries, anterior and posterior choroidal arteries, and all the deep perforating arteries at the base of the brain) are vital to the functioning of the brain. Their ligation can result in severe impairment of function of the vital structures such as the thalamus, basal ganglia, internal capsule, and brain.
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stem, causing serious neurological deficit and sometimes even death. Venous drainage is also of great importance to the symptomatology. Ligation of only a few tributaries of a superficial cortical vein has no effect on venous return in the brain; however, if many superficial vein tributaries or the main pathway of the deep cerebral vein are occluded, congestion and severe edema, sometimes even hemorrhagic infarction of that part of the brain, result.

Based on these perceptions, we consider this scheme of grading AVM's to be rational. It may provide a simple way to clarify surgical indications for treatment of AVM's, and it may be useful in comparing AVM's in one series and between series. We hope that this grading scale will promote progress in the treatment of AVM's of the brain.

References


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Address reprint requests to: Yu-quan Shi, M.D., Professor in Neurosurgery, Hua Shan Hospital, Shanghai Medical University, Shanghai 200040, People’s Republic of China.