

Surgical resection of cerebral arteriovenous malformation combined with pre-operative embolisation

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Summary To assess the importance of pre-operative embolisation, 27 cases of cerebral arteriovenous malformation (AVM) treated in this institute between July 1994 and October 1998 were analysed. The patients' ages ranged from 3 to 70 years (average 36.9) with a follow-up period of 1–41 months (average 19.2). The patient presented with haemorrhage in 21 cases and seizure in five. In 21 of 27 cases, surgical resection of a nidus was performed, gamma knife therapy was applied in three and conservative therapy was chosen in three. Of 21 cases treated surgically, total removal was achieved in 19 cases and a residual nidus was seen in one (a large basal ganglia AVM). In the remaining case, postoperative angiography was not available. Pre-operative embolisation followed by surgical resection of the nidus was performed in seven cases in which there was a large AVM. A volume index was calculated to indicate the size of the nidus using $X \times Y \times Z$, where X is the maximum diameter (cm) of the nidus on the lateral angiogram, Y is the diameter (cm) perpendicular to X and Z is the maximum diameter (cm) on the anteroposterior angiogram. The index averaged 45.9 for the cases in which pre-operative embolisation was performed, while it was 5.6 in the cases without embolisation. Pre-operative embolisation was performed to reduce the nidus flow as much as possible, to prevent overload to the surrounding structures. At surgery, the nidus was resected from the surrounding tissue and care was taken not to enter the nidus. Postoperatively, the systolic blood pressure was maintained at 90–100 mmHg for several days in the intensive care unit. The results were excellent in 15 cases, good in three (hemiparesis due to the initial haemorrhage remained in all three), fair in one (a patient with a severe subarachnoid haemorrhage). Two patients died (acute pulmonary oedema and severe meningitis). Minor postoperative bleeding or oozing was seen in three cases. In conclusion, reducing the shunt flow through a nidus in a step-wise fashion with pre-operative embolisation of a large AVM seems to be quite helpful in preventing postoperative haemodynamic overload to the surrounding brain. It is also important not to enter the nidus when it is removed at surgery. This helps to prevent intraoperative and/or postoperative bleeding, and led to successful total removal of the nidus with a good postoperative course. © 2000 Harcourt Publishers Ltd

Keywords: arteriovenous malformation, pre-operative embolisation, microsurgery, overload phenomenon

INTRODUCTION

Surgical removal of an arteriovenous malformation (AVM) is still considered to be one of the most difficult neurosurgical procedures. In recent years, with the introduction of interventional techniques and gamma knife surgery, the indications for surgery in AVM have changed significantly and multidisciplinary treatment has been instituted.^{1–5}

Recently, the authors have utilised pre-operative embolisation in large AVMs to reduce the bleeding during surgery and decrease the risk of postoperative overload to the surrounding brain.^{6–11}

This paper describes the surgical results obtained in treating AVMs and analyses the significance of pre-operative embolisation.

CLINICAL MATERIALS AND METHODS

Between July 1994 and October 1998, 27 patients (20 males and 7 females) aged 3–70 years (mean 36.9) with angiographically confirmed cerebral AVMs were treated in this institute. The patient presented with haemorrhage in 21 cases and seizures in five; the remaining case was found incidentally. Surgical resection was performed in 21 of 27 cases, a gamma knife was used in three and

conservative therapy was chosen in three. Before surgical resection of the nidus, embolisation of larger AVMs was performed. As an index of nidus size, the volume index (VI) was calculated using $X \times Y \times Z$, where X is the maximum diameter (cm) of the nidus on the lateral angiogram, Y is the diameter (cm) perpendicular to X and Z is the maximum diameter (cm) on the anteroposterior angiogram.^{8,11}

Pre-operative embolisation was performed 1 week before surgery using Aviten® powder as a particle material. When the nidus was large, the embolisation procedure to reduce the size of the nidus was performed two or three times at 1 week intervals. Surgical resection of the nidus was then carried out. During and after the surgical procedure, the systolic blood pressure was kept between 90 and 100 mmHg for several days, to prevent bleeding from the nidus or the surrounding brain. During this period, the patient was kept in the intensive care unit.

The postoperative neurological and angiographic findings were evaluated. The follow-up period was 2–41 months (average 19.2).

RESULTS

The clinical findings are summarised in Table 1. The Spetzler-Martin grading² was I in 5 cases, II in 8, III in 10, IV in 3 and V in 1. In 15 of 27 cases, direct surgical removal was performed, in three cases gamma knife therapy was used and in the remaining three cases conservative therapy was chosen in accordance with the patients' requests (Table 2). The VI of the nidus of all 27 patients ranged from 1 to 112 (average 28.4). Pre-operative embolisation was carried out in 8 of 27 cases. Of 8 patients, embolisation was performed in one patient before gamma knife

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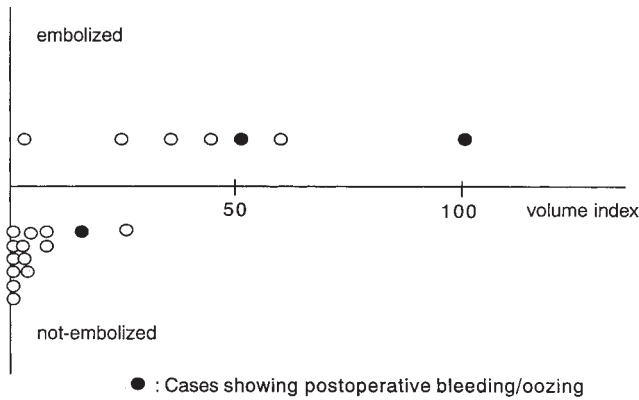


Fig. 1 Volume index and pre-operative embolisation; ●, cases with postoperative bleeding or oozing.

therapy. One patient underwent pre-operative embolisation three times and another two patients twice. The VI ranged from 3.4 to 101 (average 45.9) in the cases with pre-operative embolisation, and 1–26.3 (average 5.6) in those without embolisation (Fig. 1).

The results were excellent in 15 cases, good in 3 (hemiparesis due to the initial haemorrhage remained in all three) and fair in one (a patient with a severe subarachnoid haemorrhage). Two patients died (acute pulmonary oedema and severe meningitis) (Table 3). In three cases, intracerebral bleeding occurred after surgery (Fig. 1). Bleeding occurred in two cases with pre-operative embolisation the VI in these cases was 50.6 and 101 and in one case without pre-operative embolisation (the VI was 15.6). In all three cases, the bleeding was minimal and no fatal haemorrhage occurred.



Fig. 2 CT scan showing the subarachnoid and intraventricular haemorrhages.

Total removal of the nidus was achieved in 19 of 20 surgical cases (Table 4). A postoperative angiogram was not available for one surgical patient (case 8). This case is described later.

There were no complications related to the embolisation.

Table 1 Profile of 27 patients with arteriovenous malformations

| Case No. | Age (yrs.) Sex | Location | Initial Presentation | Size (mm) | V.I. | S-M grade | Treatment | Preop. Emb. | Residual Nidus | Outcome | Follow-up Period (mos) |
|----------|-------------------|-----------------|----------------------|-----------|------|-----------|-----------|-------------|----------------|-----------|------------------------|
| 1 | 56, M | parietal | seizure | 50*30*40 | 60 | 3 | op | + | – | excellent | 40 |
| 2 | 53, M | frontal | ICH | 10*10*10 | 1 | 1 | op | – | – | excellent | 41 |
| 3 | 24, M | thalamus | ICH | 10*10*10 | 1 | 3 | gamma | – | * | excellent | 27 |
| 4 | 27, M | temporal | seizure | 70*40*40 | 112 | 4 | cons | – | * | excellent | 39 |
| 5 | 22, F | occipital | seizure | 40*30*40 | 48 | 4 | gamma | + | * | excellent | 33 |
| 6 | 35, F | occipital | ICH | 20*20*20 | 8 | 2 | op | – | – | good | 37 |
| 7 | 53, M | parietal | ICH | 10*10*10 | 1 | 2 | op | – | – | good | 29 |
| 8 | 21, M | basal ganglia | ICH | 50*45*45 | 101 | 4 | op | ++ | N.A. | dead | 23 |
| 9 | 18, M | parietal | ICH | 40*30*30 | 36 | 3 | op | + | – | dead | 26 |
| 10 | 31, M | occipital | ICH | 15*15*15 | 3.4 | 3 | op | + | – | excellent | 23 |
| 11 | 19, M | temporal | ICH | 20*15*15 | 4.5 | 1 | op | – | – | excellent | 20 |
| 12 | 58, M | frontal | ICH | 25*25*25 | 15.6 | 1 | op | – | – | excellent | 20 |
| 13 | 3, M | frontal | ICH | 10*10*10 | 1 | 1 | op | – | * | excellent | 20 |
| 14 | 55, F | thalamus | ICH | 15*15*15 | 3.4 | 3 | gamma | – | * | excellent | 19 |
| 15 | 21, F | corpus callosum | ICH | 70*45*25 | 78.8 | 5 | cons | – | – | excellent | 20 |
| 16 | 46, F | frontal | ICH | 10*10*10 | 1 | 2 | op | – | – | excellent | 14 |
| 17 | 17, M | parietal | ICH | 25*10*10 | 2.5 | 2 | op | – | – | excellent | 13 |
| 18 | 18, M | temporal | ICH | 50*30*30 | 45 | 3 | op | +++ | – | excellent | 11 |
| 19 | 70, M | parietal | ICH | 20*10*10 | 2 | 2 | op | – | – | excellent | 11 |
| 20 | 26, M | frontal | ICH | 20*20*10 | 4 | 2 | op | – | – | excellent | 11 |
| 21 | 47, M | parietal | seizure | 45*45*25 | 50.6 | 3 | op | ++ | – | excellent | 9 |
| 22 | 49, F | parietal | ICH | 40*25*25 | 25 | 3 | op | + | – | excellent | 9 |
| 23 | 24, M | frontal | seizure | 50*50*50 | 125 | 3 | cons | – | * | excellent | 8 |
| 24 | 58, M | CM junction | SAH | 10*10*10 | 1 | 3 | op | – | – | fair | 6 |
| 25 | 62, M | parietal | ICH | 35*30*25 | 26.3 | 2 | op | – | – | good | 5 |
| 26 | 55, F | occipital | ICH | 10*10*10 | 1 | 2 | op | – | – | excellent | 2 |
| 27 | 27, M | cerebellum | incidental | 20*20*20 | 8 | 1 | op | – | – | excellent | 2 |

ICH: Intracerebral hemorrhage, IVH: intraventricular hemorrhage, SAH: subarachnoid hemorrhage, V.I.: volume index, op: direct surgery, cons: conservative therapy, Preop. Emb.: preoperative embolization, N.A.: not applicable

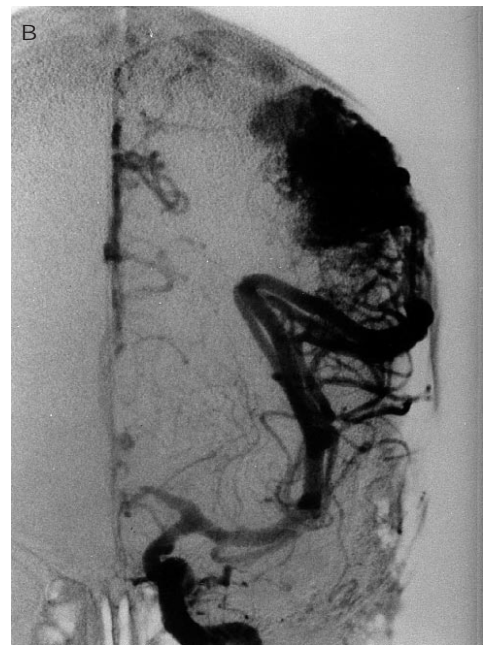


Fig. 3 Left carotid angiograms showing a nidus in the left parietal area fed by the middle cerebral artery. A: lateral view; B: anteroposterior view.

Table 2 Treatment modality

| S-M grade | No. of cases | Treatment Modality | | |
|-----------|--------------|--------------------|-------------|--------------|
| | | direct surgery | gamma knife | conservative |
| I | 5 | 5 | 0 | 0 |
| II | 8 | 8 | 0 | 0 |
| III | 10 | 7 | 2 | 1 |
| IV | 3 | 1 | 1 | 1 |
| V | 1 | 0 | 0 | 1 |
| total | 27 | 21 | 3 | 3 |

Table 3 Operative result

| S-M grade | No. of cases | Operative Result | | | | |
|-----------|--------------|------------------|------|------|------|------|
| | | Excellent | Good | Fair | Poor | Dead |
| I | 5 | 5 | 0 | 0 | 0 | 0 |
| II | 8 | 5 | 3 | 0 | 0 | 0 |
| III | 10 | 5 | 0 | 1 | 0 | 1 |
| IV | 3 | 0 | 0 | 0 | 0 | 1 |
| V | 1 | 0 | 0 | 0 | 0 | 0 |
| total | 27 | 15 | 3 | 1 | 0 | 2 |

CASE STUDY

This 47-year-old man had a 10-year history of seizures because of a large left parietal AVM, and was followed-up in the outpatient clinic. His seizures were well controlled until 23 December 1997, when he developed a severe headache. A CT scan showed a mild hemorrhage in the left lateral ventricle (Fig. 2). An angiogram showed a large (4.5 × 4.5 × 2.5 cm) AVM in the left parietal lobe, with a VI of 50.6 and a Spetzler and Martin grade of III (Fig. 3). The nidus was fed mainly from the middle cerebral artery, with some flow from the anterior and posterior cerebral arteries. Two pre-operative embolisations were performed, with a 1-week interval between, to occlude the part of the nidus fed by the middle cerebral artery. This reduced the nidus volume by nearly 50%. Direct surgery was then performed. Since the nidus was located near the motor cortex, neuroelectrophysiological monitoring was performed and the motor area was confirmed during surgery, the the nidus was then removed. Postoperatively, the systolic blood pressure was kept between 90 and 100

Table 4 Removal of nidus

| S-M grade | No. of cases | nidus | |
|-----------|--------------|---------------|----------|
| | | total removal | residual |
| I | 5 | 5 | 0 |
| II | 8 | 8 | 0 |
| III | 6 | 6 | 0 |
| IV | 1 | 0 | 1 |
| V | 0 | 0 | 0 |
| total | 20* | 19 | 1 |

*: Postoperative angiogram is not performed in one case.

mmHg for several days, and the patient showed no neurological deficits. The postoperative angiogram showed complete disappearance of the nidus (Fig. 4). However, the postoperative CT scans showed minor bleeding in the cavity after nidus removal. The patient was discharged 1 month after surgery without neurological deficits.

DISCUSSION

The strategy for treating patients with cerebral AVMs has changed dramatically since the recent advent of intravascular and radio-surgery techniques; ^{1-3,5} however, direct surgical treatment of an AVM is still an important option.^{1,13} The goal of AVM surgery is to remove the nidus to prevent future haemorrhage and to improve the neurological status caused by the presence and effects of the AVM.

After adequate embolisation of the feeding arteries by an intravascular technique, the nidus is removed surgically. It is very important that the surgical exposure provides access to the major feeding arteries and draining veins. Therefore, pre-operative embolisation primarily targets the feeding arteries that are difficult to approach surgically or the major feeding arteries, to minimise intraoperative bleeding. Another important role of intraoperative embolisation is to reduce the postoperative vascular overload of the surrounding brain,^{4,6-9,11,14} although a case against staged operative resection of a cerebral AVM has been reported.¹⁵ The overload phenomenon may occur after total resection of the nidus. The rationale for step-wise therapy of the AVM is to reduce the vascular overload of the surrounding brain by gradually reducing

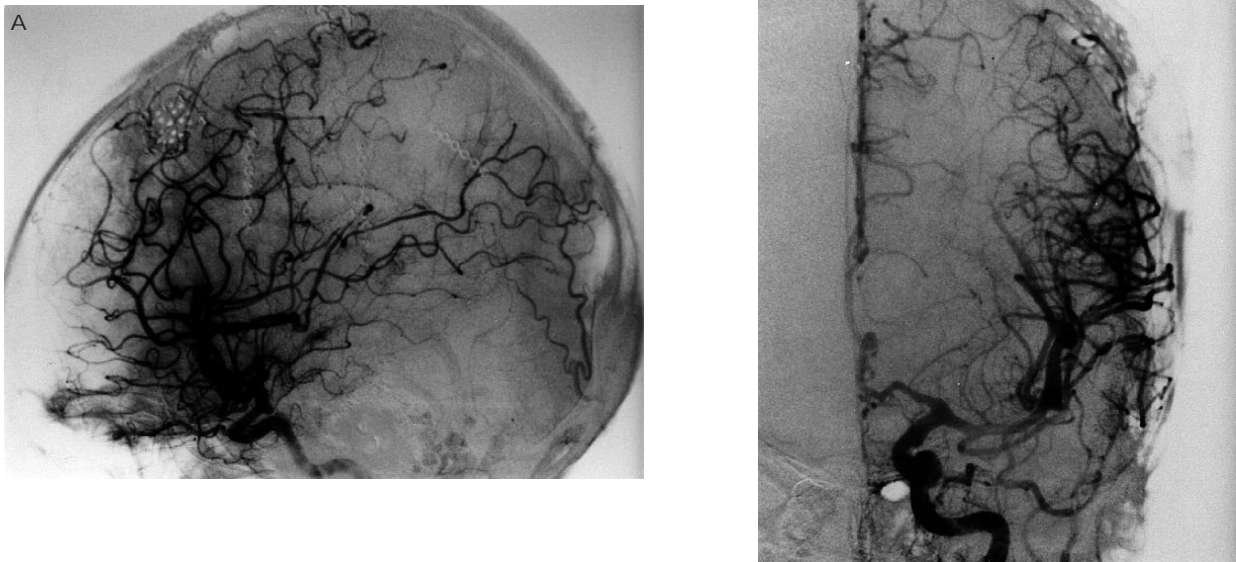


Fig. 4 Left carotid angiogram showing complete removal of the nidus. A: lateral view; B: anteroposterior view.

the shunt flow through the nidus, especially when the AVM is large. In the present study a large AVM was defined as one with a maximum diameter >5 cm or a VI > 60.¹¹

The authors used pre-operative embolisation mainly for large AVMs and ultimately the postoperative overload phenomenon did not occur. There were three cases with postoperative bleeding. In all three cases, the bleeding was minimal and occurred in the cavity left by removal of the nidus.

Collagen particle was used as an embolised material in this series. Particles cannot pass through vessels with a small diameter and are thought to be easily washed away by blood flow as compared with liquid materials, which plug a nidus immediately after injection.¹⁶ Recently, however, liquid material has been mainly used in this institute.

Postoperatively, it is essential to control the systolic blood pressure, maintaining it between 90 and 100 mmHg, for about 1 week after surgery.^{8,9,11,17} This is required to prevent both postoperative bleeding and the postoperative vascular overload phenomenon. Antihypertensive drugs or barbiturates can be used during the first few days after surgery to reduce the systolic blood pressure. Postoperative angiograms should be taken 1 week after surgery even in cases where complete resection of the nidus is confirmed by intraoperative angiography or immediate postoperative angiography. The induced hypotension should be maintained until there is no postoperative overload.

At surgery, it is important not to enter the nidus while dissecting it. Following this principle helps to prevent intraoperative and postoperative bleeding, and leads to successful total removal of the nidus with a good postoperative course.

In conclusion, reducing the shunt flow through a nidus in a step-wise fashion with pre-operative embolisation of a large AVM seems to be quite helpful in preventing the postoperative haemodynamic overload to the surrounding brain.

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