

## The Perivenous Technique of Resection of Arteriovenous Malformations from Vital Areas of the Brain

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**A total of 17 patients with arteriovenous malformations (AVMs) in sensitive areas of the brain were operated on and the AVMs were completely resected using perivenous techniques. No patient suffered a new neurological deficit following surgery. The perivenous surgical technique is most suitable for small AVMs in sensitive cortex. It differs from the standard approach in that it places emphasis on perivenous microsurgical dissection, identification of the nidus before major arterial feeders, and early ligation of selected venous channels. Three different types of venous drainage—single, multiple, and dual—were identified. Each different type of venous drainage requires a different surgical approach for the best results.**

**KEY WORDS:** Arteriovenous malformation; Perivenous resection; Transvenous technique; Microsurgery; Subarachnoid hemorrhage; Intracranial hemorrhage

The recent introduction of magnetic resonance imaging (MRI) and increasingly more sensitive computed tomography (CT) scanning devices, together with digital subtraction angiography, have led to the discovery of many arteriovenous malformations (AVMs) on routine work-up prior to their rupture. As a result, the question of surgical resection is often raised in patients who were previously considered inoperable. Due to better technical skills, radiographic delineation, and modern anesthesia, the resection of "silent" or "polar" AVMs is becoming a routine procedure. However, the resection of AVMs from sensitive areas such as motor cortex, speech area, or deep white matter abutting on essential neural structures still presents formidable technical difficulties [1,3-5,8,9,18-20], as resection of any brain tissue surrounding an AVM in sensitive areas during the course

of surgery, or occlusion of blood supply to normal brain surrounding the malformation, will lead to a permanent neurological deficit.

A basic principle of surgery for AVMs has been the early occlusion of its arterial supply. The venous drainage has always been scrupulously protected, as an inadvertent injury to the system necessitating its early ligation would lead to a catastrophe. While this principle can be met readily in large AVMs, particularly in polar or less eloquent areas, where the search for arteries feeding the AVM early during the resection is better tolerated, a similar search in a sensitive area will expose the brain to excessive and perhaps intolerable trauma. With the evolution of microsurgical techniques we have become increasingly aggressive and have been able to resect AVMs in eloquent areas by dissecting around veins draining the AVMs leading to the nidus. The occlusion of major arterial supply (MAS) has been left until an opportune time, and no effort has been made to search for the MAS early, unless it was readily accessible. However, to take full advantage of this technique one must recognize the specific types of venous drainage and tailor a specific technique to the type of venous drainage pattern. This report, with illustrative case presentations, describes the salient points of this technique.

### Materials and Methods

A total of 17 patients were operated on with AVMs in the following areas: motor area (8), speech area (8), and close vicinity of the internal capsule (1). All patients were followed by a neurologist both preoperatively and postoperatively. Postoperative angiograms demonstrating a total resection of the AVMs were performed on 15 patients and reviewed by a neuroradiologist. Two patients refused a postoperative angiogram. The resection in these patients was judged to be complete by the operating surgeon. Age, sex, location of the AVM, and postoperative results at 6 months are summarized in Table 1. The following is the classification of the main venous draining patterns of different AVMs with a de-

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**Table 1.** *Patient Data*

Patient No.	Age (years)	Sex	Preoperative signs and symptoms	Location	Postoperative (6 month activity)
1	46	F	TIA, speech arrest, SAH	Left angular middle temporal gyrus	No deficit, normal activity
2	42	M	SAH, transient expressive aphasia	Left middle frontal gyrus	No deficit, normal activity
3	12	M	Intracerebral hematoma, aphasia, complete flaccid right hemiplegia and coma	Left middle frontal gyrus	No dysphasia on routine testing, (3/4) upper and (4/5) lower extremity paresis, normal mental status
4	32	M	TIA, SAH 4/5 right upper extremity paresis	Left posterior frontal parietal lobes	Mild (4/5) right upper extremity paresis
5	28	F	Intracerebral hematoma, right lower extremity plegia	Left posterior frontal lobe	Minimal (5-/5) right lower extremity paresis
6	56	M	Intracerebral hematoma, left hemiplegia coma	Right posterior frontal, parietal lobes	Left upper extremity (1/5) and left lower extremity (4/5) paresis
7	56	M	Seizures, headaches	Left temporal parietal lobes	Asymptomatic, no aphasia
8	14	M	SAH, intracerebral hematoma, right homonymous hemianopsia, right sixth nerve palsy	Left posterior periventricular parietooccipital regions	Right homonymous hemianopsia
9	46	M	SAH	Left posterior frontal lobe	Asymptomatic
10	42	F	Intracerebral hematoma, SAH, right lower extremity plegia	Left medial posterior frontal	Right lower extremity paresis
11	52	M	SAH	Left middle temporal gyrus	No deficit, normal activity
12	28	F	SAH	Left insular region	No deficit, normal activity
13	22	M	Intracerebral hematoma	Left insular region	Mild dysphasia, no motor weakness
14	30	F	Intracerebral hematoma, right hemiplegia	Left motor cortex	Mild right hemiparesis
15	42	F	SAH	Right motor cortex	No deficit, normal activity
16	18	M	SAH, mild right hemiparesis (4/5)	Left motor cortex	No deficit, normal activity
17	21	M	SAH	Right motor cortex	No deficit, normal activity

Abbreviations: SAH, subarachnoid hemorrhage; TIA, transient ischemic attack; 0/5, no function; 5/5, normal motor function.

scription of the surgical techniques most suitable for their resection and illustrative case reports.

Three main types of venous drainage patterns have been recognized: single, multiple, and dual.

### Single

In this type of pattern, there is only one venous draining channel. This can be either superficial (cortical) or deep (galenic).

*Superficial.* This AVM is usually small and located in the subcortical white matter (Figure 1). The only draining channel is a singular cortical vein draining into either the midline or lateral sinuses.

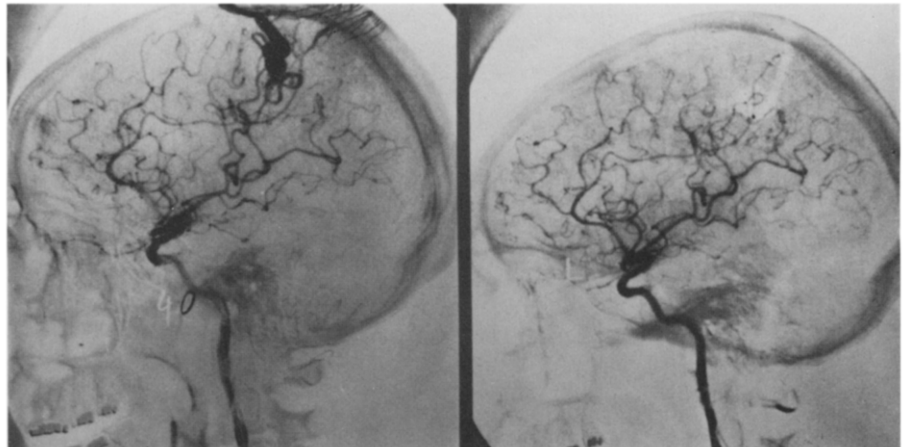
*Deep.* The primary drainage is into the internal cerebral vein and the vein of Galen. The AVM is located in

deep white (periventricular) matter (Figure 2). There is no recognizable cortical draining vein.

*Single-A Type (Superficial): Case 1.* A 32-year-old black woman was admitted after the sudden onset of severe headaches and the rapid development of a flaccid, left lower-extremity monoplegia with only minimal drift of the left upper extremity and total sparing of the face. A CT scan showed a hematoma in the medial aspect of the hemisphere and an AVM (Figure 1).

At surgery, the main draining vein was followed from the cortical surface to the nidus of the AVM in retrograde fashion. The whole AVM was identified and totally resected. After surgery, the patient awoke rapidly with a total hemiplegia on the left; including face, arm, and leg equally. The full return of function to the face and the upper extremity was complete within 24 hours, and she could walk unaided in 2 weeks. At 6 months,

**Figure 1.** Single, superficial venous drainage. Preoperative (left) and postoperative (right) angiograms.



her findings were limited to a minimal weakness of the lower extremities, characterized primarily by a 5-/5 left iliopsoas weakness, hyper-reflexia, and an upgoing toe on that side. Functionally, there was only a barely noticeable limp.

*Single B-Type (Deep): Case 2.* An 11-year-old boy presented with the sudden onset of severe headache, difficulty with speech, and rapidly progressing right hemiplegia. When seen after a transfer from another hospital, he had aphasia, right hemiplegia, and did not follow verbal stimuli. An angiogram showed a deep AVM in the left frontal region with only a deep draining vein (Figure 2). At surgery, a cortical incision was made, and a hematoma encountered at about 2 cm below the cortex was evacuated. Arterial feeding vessels were identified and occluded. The deep draining vein was occluded last.

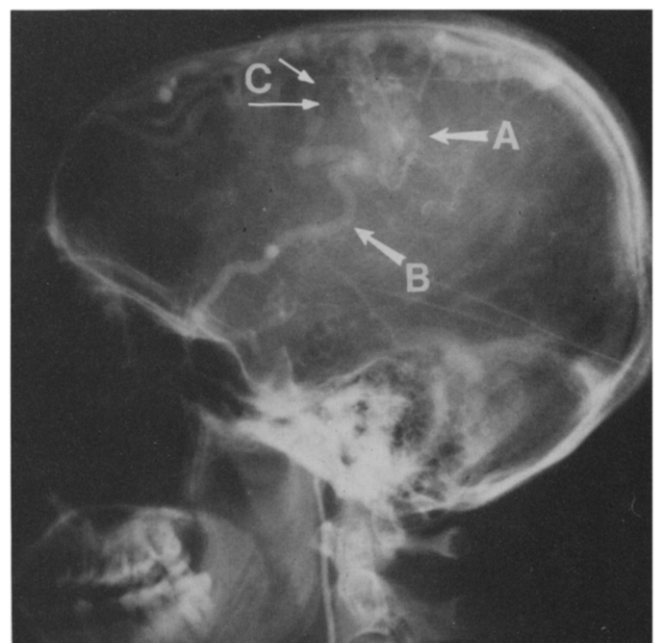
**Figure 2.** Single deep venous drainage.

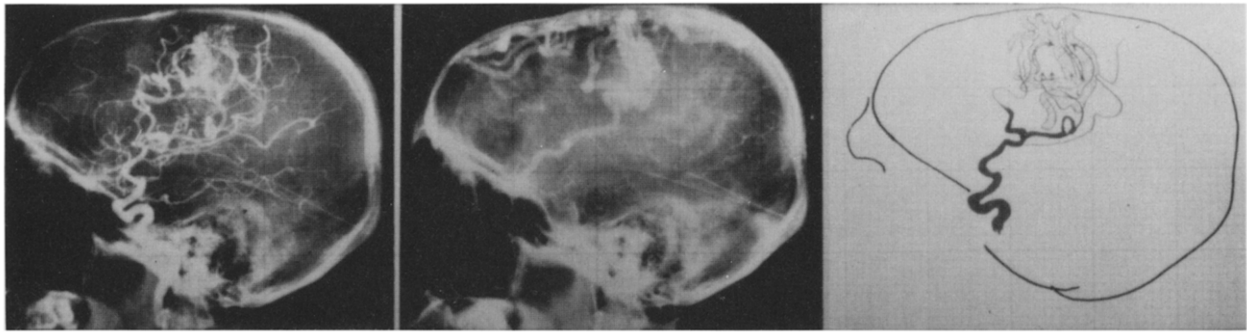


Postoperatively, the patient had right hemiplegia and aphasia. His state of consciousness gradually improved, and he started to utter simple words about 7 days after surgery. His recovery was excellent, and he eventually returned to school. He plays recreational soccer although he has a significant 3/5 upper and 4/5 lower extremity spastic hemiparesis and mild dysphasia demonstrable through specific neuropsychological testing.

In cases of a single superficial draining vein, the technique of perivenous resection as described by Malis is utilized [12]. In the case of a single deep draining vein, the precise localization of an AVM is essential as no visible marks are present on the cortical surface. This

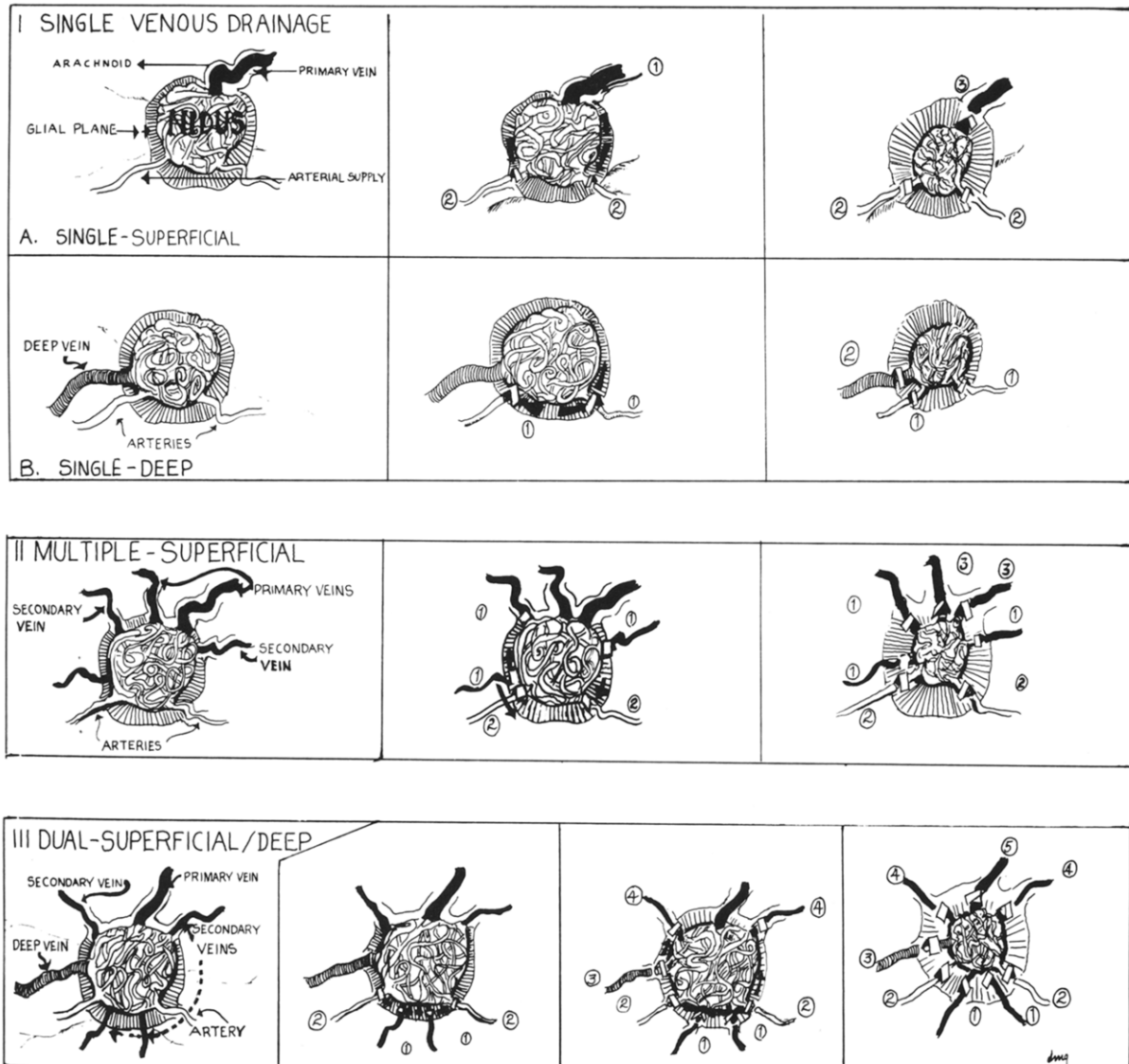
**Figure 3.** Multiple superficial venous drainage. *A*, primary vein; *B*, lateral and *C*, medial secondary draining veins.

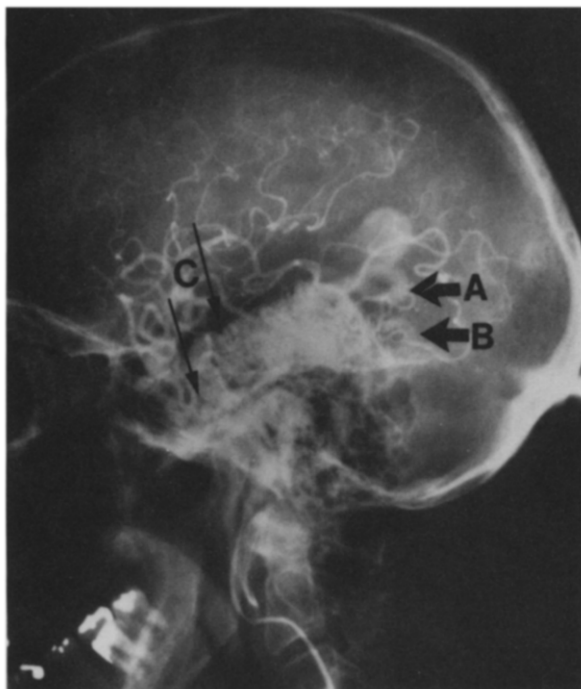




**Figure 4.** Preoperative preparation. Arterial phase (left), venous phase (middle), and the composite sketchings (right) showing the relative relationships of arterial and venous structures.

**Figure 5.** Three different types of surgical approaches dictated by the type of venous drainage from the AVM. The sequence of steps taken in occluding the vascular channels is indicated by numbers and arrows.





**Figure 6.** Dual venous drainage. A, deep draining channel; B and C, superficial draining channels.

venous pattern is obviously not suitable for the perivenous technique and the classical technique should be used.

In both of these types of AVMs, it is obvious that utmost care be taken not to occlude the draining veins prior to a complete resection of the AVM. This is con-

trary to all other types of AVMs where early occlusion of selected draining veins is performed deliberately and where such occlusion facilitates the AVM resection.

*Multiple*

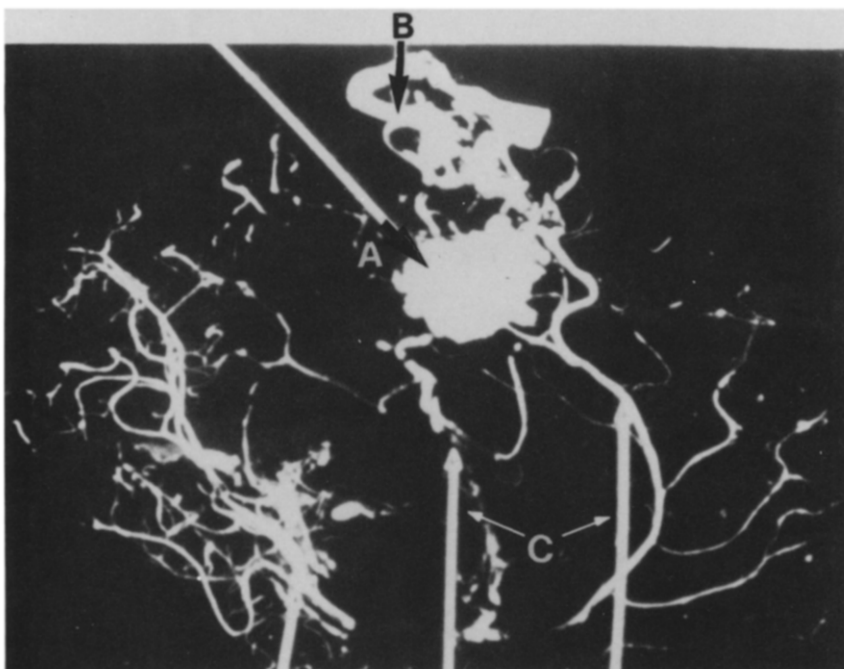
In this type of AVM there are two or more major draining veins from the AVM. Depending on circumstances, these can be one of the following.

*Type A—Superficial.* Primary drainage is into either *medial* or *lateral* sinuses, usually both (Figure 3).

*Type B—Deep.* We have not yet encountered an AVM with purely deep multiple draining veins. The technique for single-deep draining veins would be used if this was encountered.

*The Multiple Type A (Superficial): Case Report.* A 33-year-old right-handed man presented with a history of several years of headaches and a seizure disorder. A recent subarachnoid hemorrhage necessitated his admission.

On admission, he had only a mild hemiparesis (4/5) in the proximal muscles of the right upper extremity, hyperreflexia, and minimal spasticity. There was, however, a significant degree of functional impairment of the hand, specifically, clumsiness of the fingers and thumb during rapid alternating movements. His angiogram and the relationship of the AVM to the motor strip is seen in Figure 4. At surgery, a total resection of the AVM was achieved. After surgery, the patient exhibited a total



**Figure 7.** Corrosion preparation of AVM showing that dissection along a draining vein (B) will lead directly to the nidus of the AVM (A). The more deeply located arterial supply comes from both the anterior and middle cerebral arteries (C). (Courtesy Dr. H. Kaplan.)

hemiplegia of the arm, face, and leg, although he was fully awake. The initial return of function began in the legs and proximal muscles of the upper extremity on the fourth day; and in 2 weeks the patient was able to walk with minimal assistance and lift his arm about 40°. At 6 weeks, he had findings similar to the preoperative ones except for the hand, but he was able to feed himself. At 6 months, his neurological examination was virtually the same as it was preoperatively, although the hyperreflexia and the spasticity were somewhat greater than before surgery.

In this type of AVM there are several cortical draining veins of various sizes. One or two large ones are termed primary. They are identified on angiogram by their size and how early the dye enters during angiography. During surgery they are protected, while all the others are transected and followed toward the nidus in a sequential manner. The main arterial feeders are clipped in depth after the cortical (secondary) venous drainage channels are transected. These maneuvers result in a substantial decrease in size of the AVM which is then delivered on the last remaining large draining vein toward the sinus (Figure 5).

#### *Dual (Superficial and Deep)*

The AVM has two or more major draining channels, one draining into superficial, lateral, or medial sinuses, and another into the galenic system. There are usually several draining veins (Figure 6).

*Case Report.* A 58-year-old man presented with a history of several years of headaches and seizures that had recently increased in frequency. The seizures necessitated the performance of a CT scan which demonstrated a large AVM located in the left temporal lobe (Figure 6). Cerebral angiogram had confirmed the presence of an extensive AVM in both the temporal and parietal lobes. At surgery, total removal of the AVM was achieved. Postoperatively the patient did well, was afebrile, but had a significant receptive dysphasia. Computed tomography scan showed evidence of postoperative swelling which persisted for several weeks. The dysphasia gradually improved, but 6 weeks after surgery, a drainage from the wound was noted. The cultures were positive, and an infected bone flap was diagnosed. At surgery, an epidural collection of pus communicating with a small intracerebral extension was evacuated and the bone flap was removed. Postoperatively his dysphasia rapidly improved and he was discharged. Four months later he was readmitted for a cranioplasty. His postoperative course was uneventful and cosmetic results were excellent. There

was no evidence of dysphasia or any other neurological impairment at the time of discharge.

In this instance, as in all types with dural venous drainage, the resection was started superficially in the temporal tip where there were several draining veins emptying into the sphenoparietal sinus. The resection then proceeded towards the lateral aspects up to the vein of Labbé, which was preserved. The veins were transected in a gradual fashion and retrograde dissection was continued until the edge of the AVM was identified. Dissection was then directed towards the medial aspect where both deep venous drainage as well as the main arterial supply entering the AVM were identified and ligated. The AVM was then delivered on the vein of Labbé, which was then transected before entering the sinus (Figure 5).

#### **Discussion**

Recently several excellent reviews have summarized the natural history of AVMs. It is generally thought that about 5 million people in the United States and Canada harbor AVMs [5]. Serious neurological disability is generally produced by either a hemorrhage, which takes place in approximately 50% of all patients, or by a dementia-like syndrome related to a combination of relative ischemia of the normal tissue due to shunting through the AVM and its pulsatile force [5,7,10,13]. Even though the relative risks of dying from cerebral hemorrhage in patients with AVMs are less than in those harboring aneurysms, they still remain formidable. It is estimated that in those patients where hemorrhage was the initial presenting symptom, the likelihood of further bleeding is between 4% and 6% per year. In those where the initial symptom was either headache, seizure, or progressive neurological deficit, the likelihood of further bleeding is 1%–2% per year [5,10]. It is further reported that approximately half of those that suffered a non-fatal hemorrhage are left with a fixed neurological deficit. It is clear, therefore, that the best surgical candidates in prevention of morbidity and severe disability are young patients whose longer life expectancy makes them statistically more likely to suffer fatal hemorrhage. Similarly, patients where the AVM is located in a vital area and where even a small hemorrhage leads to a significant fixed neurological deficit are theoretically the best candidates. This is the group of patients, however, where the risks are the greatest.

Surgical risks can be divided into two main groups. The risks to life have been significantly reduced, although not totally eliminated, in recent years. In the larger series, Drake [4] reported the mortality rate of 3% for supratentorial AVMs in 166 cases; and there

were several smaller series where no mortality was reported [8,11,18]. The risks to neurological function have attained greater significance as the risks to life have lessened and surgeons become bolder in attempting to resect AVMs from more and more sensitive areas of the brain. While it is clear that resection of AVMs from vital areas of the brain is possible without producing a new neurological deficit, such surgery remains technically difficult. Several authors reported such results several years ago, and the number of neurosurgeons capable of duplicating those results has increased recently with the widespread application of microsurgical techniques [3,4,6,8,11,17,19-22]. The main causes of mortality are the development of uncontrollable bleeding which takes place upon unplanned entry into the AVM, tear of major AVM channels, inadvertent occlusion of the main venous drainage channel, or as reported recently, the so-called "breakthrough" bleeding [2,15,16]. While the former causes could, at least theoretically, be eliminated with improved techniques, the breakthrough bleeding is thought to be due to a loss of autoregulation caused by a sudden change in the pressure and blood flow through normal brain upon rapid clipping of the AVM. Some authors, however, suggested that in some cases such bleeding may be due to an incomplete removal of the AVM [14].

At surgery, in most instances, the draining veins are encountered first as they lay more superficially than the arterial blood supply. In some instances, no vessels are visible on the cortex, or the remaining visible structure is the only draining vein, premature occlusion of which would result in a "blow out" of the AVM.

The basic technique of occluding the feeding artery first is both a logical and time tested procedure. In some instances, however, such a procedure results in undue retraction or blind section of the cortex, which in itself may produce an irreversible neurological deficit. In such instances, primary dissection of veins has been recommended [12].

Our current technique is as follows: After the angiogram is reviewed, a line drawing of the major arteries and veins is completed on transparent paper. This composite picture utilized sequential arteriograms in both early arterial and late venous phases to include as many details as possible about both the normal and abnormal vessels. This careful tracing sometimes reveals important relationships that may have escaped notice during a routine review of the angiogram. Outlines of the skull are also included with the drawing. This allows for a more precise placement of the bone flap (Figure 4). The recent availability of a rapid sequence of computerized pictures obtained with intraarterial digital subtraction angiography allows a repeated review of stored angiograms. Although this is often helpful in clarifying specific points

on the angiogram, it does not fully replace the line drawing described above [8].

Retrograde dissection along the draining vein into the nidus allows dissection to be limited to the AVM (Figure 7). Such an approach is particularly useful in dealing with smaller AVMs in the motor strip or speech area where surrounding cortical structures carry essential neurological function. In both dual and multiple types, there is an early, deliberate occlusion of some of the draining vessels when more than one of each type (superficial/deep) is present. Following a review of an angiogram, the largest draining vein is termed primary, and all others are termed secondary draining channels. The first step is a retrograde perivenous dissection along one of the secondary veins. Once the edge of the AVM is identified, the vein is occluded, transected, and used as a handle to resect the rest of the lesion. The glial plane is entered, and resection is continued towards another secondary vein. The arterial feeders and small vessels entering the AVM from the surrounding brain are identified and coagulated using bipolar cautery or surgical clips depending on the size of the vessel to be occluded. The primary draining channel is left for last and the AVM is delivered upon it as on a stalk. The dissection is carried out using either a microscope or magnifying surgical loops, bipolar cautery, and gentle traction if necessary. We no longer routinely use a microscope for resection of the entire AVM. Usually we reserve its use only for specific portions of the malformation such as dissection along a main draining vein, or if the AVM is very small.

In none of our cases did early occlusion of one or several draining veins result in a premature rupture of the AVM. In fact it appeared to have allowed a more direct access to the glial plane and feeding vessels. Similarly, we have not encountered a single instance of the so-called breakthrough bleeding. It appears that the sequential occlusion of several of the secondary venous draining channels causes a gradual increase in the resistance to the flow within the AVM and some return of autoregulation.

The utilization of the retrograde dissection of the proximal end of the draining vein leads to the nidus of the AVM in most instances. It can be used repeatedly at several sites, provided one or two main draining veins are preserved. The three different techniques that we have utilized according to the three different patterns of the venous drainage of the AVM are shown in Figure 5. We have reserved the classical approach for instances where the main feeding arteries are readily available for clip application, or where there is no visible pathology on the cortical surface. We feel that the utilization of the transvenous technique helps to achieve greater success in resection of AVMs from vital areas of the brain.

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