Surgical Techniques for Arteriovenous Malformations in Functional Areas: Focus on the Superior Temporal Gyrus

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Abstract

Direct surgical intervention of arteriovenous malformations (AVMs) in functional areas has been accepted as a standard mode of treatment. However, safe and successful intervention requires that such factors as exact location, size, vascular supply, and drainage be considered. Importantly, surgical techniques must be individualized to each patient, based on hemodynamic anatomy of the AVM. This paper discusses AVMs in the superior temporal lobe, which have a complex neuronal anatomy and circulatory system; the authors present 22 patients with AVMs of various sizes and describe the surgical techniques specific for the indicated location. Surgical procedures adhered to the following principles: 1) avoid brain tissue removal; 2) preserve microcirculation; 3) maintain circulation of the isolated major draining vein to access the AVM core; 4) compartmental isolation; and 5) preservation of functional area cortex covering the AVM. All patients underwent total resection except one, who had a subtotal resection. Neurological and occupational recovery was remarkable except for partial hemianesthesia in one patient; two patients are still in rehabilitation. This is the first description of a direct surgical approach to AVMs in the superior temporal gyrus, where management is challenging because the lesions may extend elsewhere, such as to Broca's and Wernicke's areas. The results suggest that the procedure is promising.

Key words: arteriovenous malformation, direct intervention, superior temporal arteriovenous malformation, surgical technique, surgical results

Introduction

Surgical procedures for arteriovenous malformations (AVMs) located in functional areas of the brain require special techniques.3-5) The surgical principles include 1) skillful avoidance of brain tissue removal; 2) preservation of microcirculation by interrupting shunting arterioles and communicating venules that connect directly to venous loops of the AVM core or nidus; 3) circulatory maintenance of draining veins, one of which is isolated as the first step for access to the AVM; 4) preservation of cortical veins (not part of the AVM core) that are only passively dilated with arterial blood flow from the core; and 5) compartmental isolation of large AVMs.

There are several reports on surgery of temporal lobe AVMs.1,2,7) However, AVMs in the superior temporal gyrus are unique because of their anatomical relationship to functionally important areas. This relationship poses serious technical and neurologically related challenges. AVMs in this region extend into areas such as the frontal, temporal, and parietal opercula, lower sensorimotor area, Broca's area, Wernicke's area, basal ganglia, the island of Reil, internal capsule, and optic radiation. They often surround the middle cerebral artery and receive blood supply from several of its main branches, including the lenticulostriate artery.

This paper presents surgical techniques for safe resection of these AVMs. It also discusses the efficacy of surgery to control this often devastating anomaly.

Materials

Twenty-two patients are included in this series: nine males and 13 females, ranging from 9 to 59 years of age. AVMs were located on the left in 14 patients and on the right in eight. Six AVMs extended into Broca's area and eight extended into Wernicke's area. AVMs extended into the sensorimotor area in all patients except for four who had AVMs smaller than 3 cm; each of the latter featured a large hematoma extending to sensorimotor area. Patients present-
ed with the following signs and symptoms: hemor-
rhagic ictus (13 patients), temporal lobe seizures (7),
progressive neurological deficit (1), and repeated
transient neurological deficit (1). In addition, three
patients had both hemorrhagic ictus and seizures.
Volumes of the AVMs varied as follows: 1) small,
less than 14.1 cm$^3$ (equivalent to a sphere of 3 cm in
diameter) (4 patients); 2) medium A, between 14.1
and 33.5 cm$^3$ (3 and 4 cm in diameter) (4); 3) medium
B, between 33.5 and 65.5 cm$^3$ (4 and 5 cm in di-
ameter) (7); 4) large, between 65.5 and 113 cm$^3$ (5 and
6 cm in diameter) (5); and 5) giant, greater than 113
cm$^3$ (2). AVM volume was calculated by using the
equation $V = \frac{abc}{4\pi}$, where $a$, $b$, $c$ are the radii of
two dimensions (of an elliptical AVM). The di-
ameter is twice the cubic root of $abc$; i.e. twice the
radius of the sphere with the volume equal to the el-
liptical AVM. Therefore, the size of the AVM ex-
pressed by our calculated diameter is greater than
the AVM of the same diameter whose size is ex-
pressed by the largest of three dimensions.

Surgical Procedure

Surgical procedures for AVMs less than 3 cm in di-
ameter, consisting of one compartment, and for
AVMs 3-4 cm in diameter, which have two compart-
ments (in which the smaller complements the larger),
were described in detail previously.\textsuperscript{5} This article
describes surgical procedures for AVMs larger than
4 cm in diameter.

AVMs larger than 4 cm in the superior temporal
 gyrus consist of 1) a large lateral compartment sup-
plied by many branches of the sylvian group, which
originate from the middle cerebral artery; 2) a
smaller anterior compartment supplied by the an-
terior temporal artery; and 3) a posterior compart-
ment supplied by the posterior cerebral artery.
These AVMs usually can be approached from the
lateral surface of the temporal lobe, in the following
order: 1) access to the lateral compartment, 2) lateral
and inferior dissection, 3) anterior and medioan-
terior dissection; 4) anterior-superior dissection un-
til the sylvian vein is reached, 5) interruption of
small feeding arteries and communicating venules
around the sylvian vein (laterosuperior dissection),
6) superior and mediusuperior dissection, 7) pos-
terior dissection, 8) exposure of the medially
located draining vein (connected to the basilar vein,
internal cerebral vein, or vein of Galen), and 9) inter-
ruption of all the laterally and medially located
major draining veins. Intraoperatively controlled
hypotension was used as needed to facilitate
hemostasis.\textsuperscript{6}

After frontotemporal or temporoparietal

craniotomy and dural opening (Fig. 1), the major
draining vein is identified and followed in the sulcus
by interrupting communicating venules of 200–300
$\mu$m.\textsuperscript{3–5} Approximately 2 cm deep from its external
end, this draining vein is found connected to the
lateral aspect (Fig. 2) of the large lateral compart-
ment. Dissection of this compartment proceeds later-
ally to anteriorly and then inferiorly. Finally, it pro-
ceeds posteriorly by interrupting shunting arterioles

\textbf{Fig. 1} The dural opening through a frontotemporal
 craniotomy is outlined in relation to the su-
 perior temporal gyrus, Broca's area
 (Broca's), and the premotor (Pre M), motor
 (M), and sensory cortices (S).

\textbf{Fig. 2} The drawing shows the sylvian vein and the
external end of the two draining veins that
are located at the junctions with cortical
veins, dilated with arterial blood.
Fig. 3 The arteriovenous malformation (AVM) core is dissected circumferentially from lateriorly and anteriorly underneath the superior temporal gyrus until the dissection reaches the sylvian vein.

(50–250 μm) and communicating venules (50–200 μm) (Fig. 3). The anterior compartment, if large enough to extend into the anterior temporal lobe, is approached separately and more safely by following another major draining vein than by retracting the cortex further forward from the first sulcal opening.

After interruption of shunting arterioles, the anterior portion of the core (anterior compartment supplied by the anterior temporal artery) is cauterized loop-by-loop, so that the shrunken venous loops can be transferred into the first sulcal opening.

As the anterior part of the sylvian vein is reached, numerous small draining veins (<1 mm) are found bridging the superior lateral edge of the AVM core and sylvian vein. An almost equal number of small feeding arteries (<1 mm) originating from the sylvian group of the middle cerebral artery may be seen connected to the superior lateral aspect of the core. A few of these arteries and veins are cauterized and sectioned simultaneously.

The superior and mediosuperior aspects of the AVM core (mainly lateral compartment) are now isolated. As the pulsatile expansion of the AVM core is diminished, the venous loops are cauterized to extend coagulation to include the anterior one-half or two-thirds of the AVM core.

Finally, the posterior portion of the AVM core is isolated and core venous loops are cauterized safely, loop-by-loop, until this portion is shrunken. The medial aspect of the AVM then can be dissected from superiorly downward, to expose the medially located draining veins, which are then interrupted. Superficially located draining veins are also interrupted and the entire shrunken AVM is removed.

Fig. 4 The shrunken anterior compartment is seen anterior to the lateral compartment. The isolation of the superior aspect of the arteriovenous malformation core first begins laterally along the sylvian vein.

Fig. 5 The lateral angiogram demonstrates three draining systems: 1) through the vein of Labbé (arrow), 2) through the sphenoparietal sinus (thick arrow) (two of them draining into the lateral sinus), and 3) through the basilar vein of Rosenthal (arrowhead) into the vein of Galen and straight sinus.

The authors’ procedure saves the cortex of the superior temporal gyrus, the underlying white matter, and the pia and arachnoid covering the cortex. Neither a large excavation of the brain nor a large arachnoid opening is formed after such an AVM resection.

Case Report

A 28-year-old female, admitted on December 12,
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Fig. 6 The anteroposterior angiogram shows the arteriovenous malformation surrounding the middle cerebral artery and its branches, and the basilar vein (arrowhead) and the sphenoparietal sinus (arrow).

1990, was healthy until about one year prior to admission, when she had a sudden episode of inability to continue a train of thought for 10–15 seconds. Her friend noted that at that time, the patient was staring into space and unable to communicate. Ten similar episodes followed. About one week before admission, she had a generalized seizure that lasted for 2–3 minutes. On awakening she was aphasic. Since the age of 5 years, she had frequent episodes of severe throbbing headaches. Neurologically, she was intact after recovery from the postictal state. Angiography and magnetic resonance imaging showed a large (70 cm³) AVM in the superior temporal area extending to the posterior frontal area.

At surgery, draining veins above and below the sylvian fissure were isolated separately to reach the AVM core. Four compartments, i.e., the anterior, lateral, and posterior compartments (as described in the surgical note), and the superior compartment above the sylvian fissure were dissected separately and totally resected. Several small foci of hemosiderin-laden brain tissue were observed during AVM dissection, indicating repeated hemorrhages in the past.

Results

Patients were followed from 1 to 20 years. Total AVM elimination was achieved in 21 patients; subtotal elimination was achieved in one patient. All patients regained neurological functions or improved in comparison with presurgical neurological status except for one, who developed partial hemihypesthesia. Of the 22 patients, 19 returned to occupational capacity, two are in convalescence, and one retired with disability. All seven patients who presented with seizures are seizure-free without anticonvulsants; the three patients presenting with a history of hemorrhagic ictus and seizures gained seizure control with smaller doses of anticonvulsants.

Discussion

Neurosurgeons must refrain from old surgical principles, such as 1) removal of brain tissue during AVM dissection under the assumption that the AVM is always surrounded by gliotic brain; 2) an overzealous search for feeding arteries, which requires brain tissue removal in the functional area; 3) obliteration of feeding arteries that send many branches to the functional area; 4) the dictum "the draining vein should never be touched until the end of AVM dissection"; and 5) removal of the cortex and cortical veins that are passively dilated by communication with the draining veins and AVM core through juxtanidal veins.

Adherence to the surgical principles mentioned in the introduction is essential for safe resection of AVMs in the superior temporal gyrus. Our surgical results indicate satisfactory return to occupation in 86% of our patients. Seizure control has been excellent in all cases; this corresponds to postoperative results reported by others. Overall results of AVM resection in the superior temporal gyrus, including lesions that extend to speech and sensorimotor areas (underneath the cortex) or the capsulostriatothalamic area (with a compact type), are convincing for future surgical treatment.

References


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