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Aneurysms Related to Cerebral Arteriovenous Malformations: Superselective Angiographic Assessment in 58 Patients

Francis Turjman, Tarik F. Massoud, Fernando Viñuela, James W. Sayre, Guido Guglielmi, and Gary Duckwiler

PURPOSE: To report the comprehensive superselective angiographic characteristics of aneurysms associated with cerebral arteriovenous malformations. **METHOD:** One hundred consecutive patients referred for cerebral arteriovenous malformation embolization underwent preembolization superselective angiography. Superselective angiograms were obtained after microcatheterization of arteriovenous malformation pedicles, and assessed for number and location of aneurysms related to the malformation. A χ^2 test was conducted to correlate these parameters with the onset of intracranial hemorrhage. **RESULTS:** Aneurysms were demonstrated in 58 of 100 patients. Single aneurysms were found in 24 patients and multiple aneurysms in 34. Presence and number of aneurysms were found to correlate significantly with a clinical presentation of hemorrhage. **CONCLUSION:** Superselective angiography was found to be of paramount importance in elucidating the precise and detailed angioarchitecture of brain arteriovenous malformations.

Index terms: Aneurysm, cerebral; Arteriovenous malformations, cerebral; Cerebral angiography

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The association of cerebral arteriovenous malformations (AVMs) and aneurysms has been widely reported. This association has been described with an incidence varying from 2.7% to 23% (1, 2). Two categories of aneurysms have been identified (3). In one category the aneurysms are located on feeding arteries of the malformation and are therefore termed *related* aneurysms. In the second category, the aneurysms are located on arteries independent of the AVM feeders and are called *remote* or *dysplastic* aneurysms. The systematic use of superselective angiography before embolization of brain AVMs provides optimal anatomic and dynamic information for analysis of AVM angioarchitecture. This technique does not, however, help in the identification of remote aneurysms usually depicted on selective angiography. The purpose of this paper is to assess the incidence of aneurysms related to AVMs when displayed by superselective angiography and to discuss the therapeutic implications of these data.

Materials and Methods

One hundred consecutive patients referred to our institution for treatment of brain AVMs underwent preembolization superselective angiography. There were 55 male and 45 female patients, ranging in age from 8 to 82 years. Forty patients presented with hemorrhage, 47 with epilepsy, and 13 with progressive neurologic deficits or headaches. Various pedicles of each AVM were catheterized before embolization using microcatheters with calibrated leak balloons or, more recently, supple flow-directed microcatheters (Balt, Montmorency, France). Superselective angiograms were obtained in orthogonal planes. The angiograms were retrospectively reviewed to assess the number and the location of aneurysms related to the malformation. A χ^2 test was conducted to correlate these parameters with the onset of hemorrhage. The level of statistical significance was $P = .05$.

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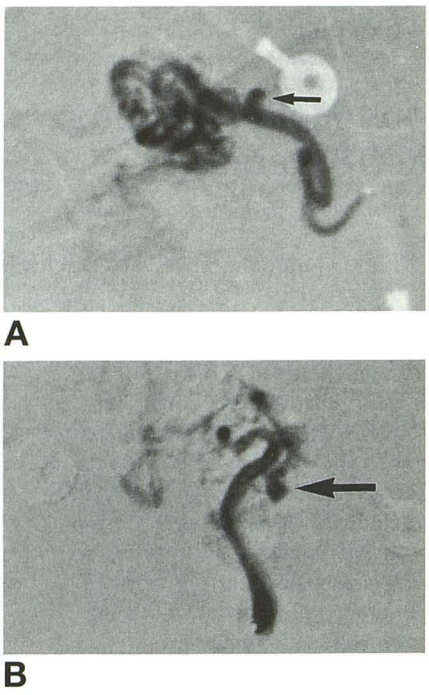

Fig 1. *A*, Left superselective angiogram, lateral view in a 32-year-old man with an AVM located in the left basal ganglia. After superselective catheterization of a medial lenticulostriate artery, the angiogram showed an aneurysm on a feeding pedicle to the malformation (*arrow*).

B, Lateral view after microcatheterization of another feeder to the nidus. An intranidal aneurysm is demonstrated.

Results

Aneurysms were demonstrated in 58 of 100 patients. Single aneurysms were found in 24 patients and multiple aneurysms in 34. Depending on their sites, related aneurysms have been classified into aneurysms proximal to the AVM (Fig 1A) and aneurysms within the nidus (intranidal) (Figs 1B, 2, and 3). Among aneurysms located proximal to the AVM, lesions on superficial feeding arteries and on perforators were identified. The number and location of related aneurysms are summarized in Table 1. Presence and number of aneurysms were found to correlate significantly with a clinical presentation of hemorrhage ($P = .001$). A χ^2 test for linear trend between the number of aneurysms and hemorrhage was demonstrated ($P = .0003$); it showed that the frequency of a presentation with hemorrhage increases with the number of aneurysms. There was a low incidence of hemorrhage in patients who had AVMs without aneurysms (19%) compared with patients with aneurysms (55.1%). An intranidal aneurysmal location was also significantly as-

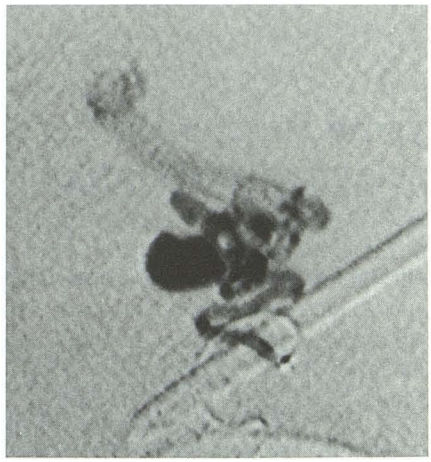

Fig 2. Superselective angiogram, oblique view, in a 8-year-old boy with a left AVM in the basal ganglia. After microcatheterization, the opacification of a lateral lenticulostriate artery showed a large intranidal aneurysm.

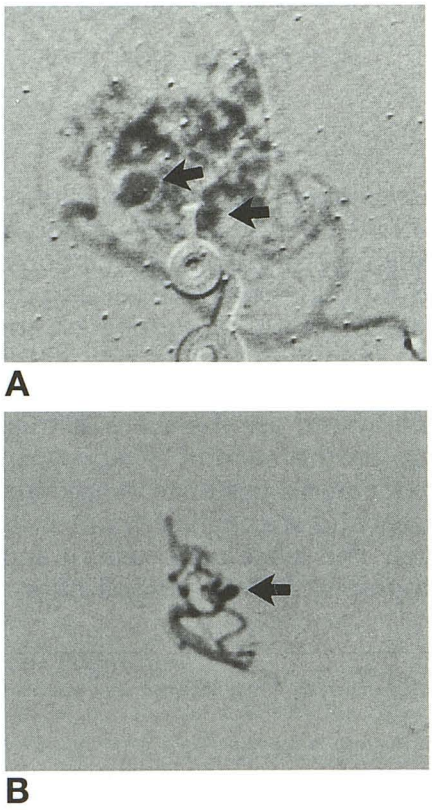

Fig 3. A 37-year-old woman with an AVM located on the midline and right basal ganglia.

A, Superselective angiogram, oblique view, after catheterization of the right middle cerebral artery trunk showed two intranidal aneurysms (*arrows*).

B, Angiogram, anteroposterior view, obtained after catheterization of the superior branch demonstrated an intranidal aneurysm not seen previously (*arrow*).

TABLE 1: Number and location of aneurysms related to AVMs

Location	Number of Aneurysms (%)	Single Aneurysms (%)	Multiple Aneurysms (%)
Nidus	25 (43.10)	11 (18.96)	14 (24.13)
Perforators	3 (5.17)	2 (3.44)	1 (1.72)
Superficial feeders	11 (18.96)	11 (18.96)	. . .
Nidus + perforators	13 (22.41)	. . .	13 (22.41)
Nidus + feeders	3 (5.17)	. . .	3 (5.17)
Perforators + feeders	2 (3.44)	. . .	2 (3.44)
Nidus + perforators + feeders	1 (1.72)	. . .	1 (1.72)
Total	58	24 (41.4)	34 (58.6)

TABLE 2: Location of related aneurysms and incidence of hemorrhage

Location	Patients with Hemorrhage (%)
Nidus	16 /25 (64)
Perforators	0 /3
Superficial feeders	4 /11 (36)
Nidus + perforators	9 /13 (69)
Nidus + feeders	0 /3
Perforators + feeders	2 /2
Nidus + perforators + feeders	1 /1
Total	32 /58 (55.1)
All nidus	26 /42 (62)
All perforators	12 /19 (63)
All superficial feeders	7 /17 (41)

TABLE 3: Number of aneurysms in patients with clinical presentation of hemorrhage

Aneurysms in Each Patient	Number of Patients	Number of Patients with Hemorrhage
Single	24	9
Multiple	34	23
Total	58	32

sociated with hemorrhage ($P = .004$). The relationship between aneurysm location and incidence of hemorrhage is summarized in Table 2; that between number of aneurysms and incidence of hemorrhage is summarized in Table 3.

Discussion

Since the first description of intravascular catheter navigation in cerebral arteries by Serbinenko (4) and Debrun et al (5), technical improvements have led to safer, quicker, and more accurate diagnostic and therapeutic procedures. Superselective angiography is routinely performed before brain AVM embolization, providing important anatomic, functional, and dynamic information. Such angiography allows a comprehensive study of AVM angioarchitecture by avoiding the angiographic superimposition of different feeders and of their venous drainage and helps in the recognition of aneurysms on feeding arteries and within the nidus itself. It also permits the differentiation between intralesional aneurysms and venous ectasia. Based on a systematic analysis of our data, we have demonstrated a high rate (58%) of aneurysms related to AVMs. Interestingly, this rate is close to that found by Anderson and Blackwood (55.5%) in pathologic specimens (6). Therefore, despite their small series of autopsied patients, we can hypothesize that superselective angiography provides as close an assessment as possible of the true number of aneurysms related to AVMs. We demonstrated a greater number of intranidal aneurysms than previous studies: 42% of our patients versus 12% and 19%, respectively, in the studies of Marks et al (7) and Lasjaunias et al (2). We also have observed a higher rate of multiple aneurysms (56.6% of the total number of related aneurysms) in these AVMs. The previously reported rate of multiple aneurysms associated with AVMs varied between 13.3% and 48% (2.7).

Three theories have been suggested to explain the association between aneurysms and AVMs: (*a*) hemodynamic factors, (*b*) a common developmental abnormality resulting in the onset of both AVM and aneurysm, and (*c*) a coincidental association of the two lesions. As is often the case, a combination of factors from these different theories probably contributes to the pathogenesis of these lesions. Okamoto et al (8) has suggested that remote aneurysms are only coincidental findings. Their incidence in most series is consistent with the expected incidence of aneurysms in the general population (8–11). Related aneurysms seem to be AVM flow dependent. This opinion is shared by several authors (12–17). They appear on arteries hemodynamically related to the AVM, and their location tends to be unusual in comparison with most other intracranial aneurysms. They represent from 37% to 69.2% of the total number of aneurysms associated with AVMs (9, 12, 15, 16). Okamoto et al (8) have demonstrated that the distribution of aneurysms on feeding arteries to an AVM was greatly in excess of the expected distribution in the absence of an AVM. This hypothesis is supported by several clinical and

laboratory data. There are, however, several criticisms regarding this hypothesis, namely: (*a*) the low frequency of aneurysms observed in other high-flow brain fistulas and vein of Galen malformations; (*b*) the results of the study of Brown et al (18), who demonstrated no correlation between associated aneurysms and parameters of high flow in AVMs such as size and velocity of the shunt; and (*c*) the relatively low overall number of aneurysms related to AVMs reported by Yasargil (10). This last criticism is based on investigations that used selective angiography only. As evidenced by our results, the use of superselective angiography increases substantially the number of aneurysms seen and suggests that these lesions are much more commonly associated with AVMs than previously thought.

Among patients with AVM rupture and hemorrhage, 80% harbored associated aneurysms. This association of a hemorrhagic clinical presentation and an AVM associated with aneurysms seems to be a constant finding in the literature (19, 20). In our experience, this association is even stronger in the presence of multiple aneurysms (71.9% of these hemorrhaged). This was demonstrated by a χ^2 test for linear trend. Our data are consistent with previously reported results of intranidal aneurysms and hemorrhage (7). We found this association in 62% of patients. A previous study by Marks et al (20) suggested no correlation between the location of aneurysms on feeding arteries and hemorrhage. In the present study, however, aneurysms located on deep feeding arteries (perforators) were found to be associated with hemorrhage more frequently (63% of patients) than aneurysms located on superficial feeding arteries (41%).

Our data have important therapeutic implications for endovascular therapy. The surgical treatment of aneurysms associated with AVMs usually focuses on remote and proximal aneurysms, because intranidal aneurysms are removed with the nidus itself. As suggested by Marks et al (7), these considerations are different for the endovascular therapist. The therapeutic occlusion of a nidus compartment increases the intravascular pressure in the nonoccluded vessels supplying the AVM (21, 22). Because intranidal aneurysms are thin-walled structures, they are likely to rupture after sudden intravascular hypertension, as occurs in embolization of a pedicle supplying a different compartment of the nidus. We have encountered this situation (unpublished data). The same process could occur in AVMs that have associated aneurysms on feeding pedicles. Consequently, the embolization of brain AVM pedicles should be first performed through branches with aneurysms, either intranidal or on feeding arteries, if at all possible.

In a recent report (23), 9 (4.9%) arterial pseudoaneurysms were diagnosed in a series of 189 patients with AVMs who bled. These lesions were irregular-shaped aneurysmlike vascular cavities and were demonstrated on angiography only after AVM hemorrhage. Although angiograms performed before bleeding were usually not available in the present study, most of the aneurysms depicted were thought to be true aneurysms and not pseudoaneurysms. Furthermore, the low incidence of pseudoaneurysms is unlikely to affect our statistical analysis.

This study confirms that superselective angiography is of paramount importance in elucidating the angioarchitecture of brain AVMs. This technique allows the demonstration of a high rate of aneurysms, probably closely matching the correct anatomic rate. Consequently, superselective angiography increases the validity of correlations between angioarchitecture and clinical presentation and furthers our understanding of the role of associated aneurysms in AVM symptoms.

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