The Pathology of Vascular ("Arteriovenous") Malformations

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Introduction

VASCULAR malformations of the central nervous system have been known for at least three hundred years (Olivecrona and Ladenheim '57), but are still surrounded by considerable confusion and associated with a complex classification. Detailed morphologic studies of large numbers of cases are rare. Reviews of the many classifications can be found in the works of Evans and Courville '39, Noran '45, Olivecrona and Ladenheim '57, and Raynor and Kingman '65.

While the relationship of vascular malformations to vascular neoplasms is still less than completely clear (Raynor and Kingman '63), it seems relatively certain that arteriovenous malformations are true developmental malformations and not neoplasms (Wolf and Brock '35, Noran '45, Manuelidis '50, Olivecrona and Ladenheim '57, Zülch '57, Russell and Rubinstein '59, Bailey '61, Kaplan et al. '61, McCormick and Nofzinger '66). Zülch '57 states that the distinction between vascular malformations and vascular neoplasms is difficult, and distinguishes between the two groups on the basis of the autonomous growth seen in the latter group. However, as Russell and Rubinstein '59 and others have noted, "in common with the true neoplasms, it is clear that some [malformations] at least are not static but grow and inflict progressive destruction on the adjacent brain." Noran '45 considered that the presence of brain parenchyma between the vessels of the angioma was of "paramount importance" in concluding that it is a malformation rather than a vascular neoplasm. Clearly, however, this does not hold for all malformations, most notably the cavernous angiomas. In spite of these difficulties, one considers the malformations to be distinct from the true neoplasms, and to be caused by faulty embryologic development.

Our purpose is to present a reasonable classification of these lesions and to illustrate the various anatomic types. While the generic term "arteriovenous malformation" is commonly used, by no means all vascular malformations are composed of a mixture of arteries and veins, and thus strict delineation of the terms is necessary. The basic features of this classification are quite similar to those given by Evans and Courville '39, Noran '45, Olivecrona and Ladenheim '57, and Russell and Rubinstein '59.

Classification

Vascular malformations (congenital malformations of intracranial blood vessels, excluding berry aneurysms) consist of:
1. Telangiectasias (Including some cases of Sturge-Weber syndrome)
2. Varix (Including some vein of Galen malformations)
3. Cavernous malformation ("Angioma")
4. Arteriovenous malformation ("Angioma")
5. Venous malformation ("Angioma")
   (Including some cases of Sturge-Weber syndrome)

All of the 70 vascular malformations personally encountered can be classified into one of the five types (McCormick and Nofzinger '66). Moreover, at least the great majority of the well-documented malformations illustrated in the literature would seem to fall easily into one of these groups. The proper classification of the "hemangioma" of the nervous system is not completely clear. Kernohan and Sayre '52 considered them as true neoplasms. Cases (Burke et al. '64) in which multiple cutaneous and C.N.S. "hemangiomas" were found defy my attempts at precise classification, since no satisfactory photomicrographs of the C.N.S. lesion were shown. Although the term "angioma" is used, it should be clearly understood that it does not mean, as here used,

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a true neoplasm. A brief description of each of these five types of malformations is given.

**Telangiectasias (Capillary Angiomas)**

These are relatively common, typically small, solitary malformations, usually encountered incidentally at necropsy. In my experience, they have been found most commonly in the pons (Fig. 1). Grossly, they present as small areas of red softening, usually with ill-defined borders. Less often, they may appear as a group of dilated vessels resembling a cluster of petechiae (Fig. 2). These malformations seem to be uncommonly associated with massive hemorrhages.

Microscopically, telangiectasias are composed of thin-walled capillaries which are devoid of smooth muscle or elastic fibers. The capillaries may vary greatly in size, and may resemble cavernous spaces in some areas (Fig. 3). More or less normal brain parenchyma is present between the dilated capillaries, although at times the parenchyma becomes gliotic or even heavily mineralized (Fig. 4). In the Sturge-Weber syndrome, such mineralization and gliosis are almost constant (Greenwald and Koota '36, Wohlwill and Yakovlev '57, Roizin et al. '59). Due to common saccular dilatations of the capillaries in telangiectasias ("capillary microaneurysms"), beautifully demonstrated by Russell and Rubinstein '59 and by Courville '63, distinction between some of these malformations and cavernous angiomas may be somewhat difficult. Russell and Rubinstein '59 have stressed this point,
and distinguish between the two by the presence of the neural parenchyma between the vessels.

**Varix**

The varix of the central nervous system consists of a single, or occasionally several, dilated veins. They may appear grossly as a petechia, but in post mortem material are more commonly not visible grossly. These small lesions may occur in either the parenchyma or in the leptomeninges, but have been found more often within the parenchyma in my material. The anomalous vessel is a vein, usually with a relatively thin wall (Fig. 5). Hemorrhage, occasionally massive, has been seen associated with these malformations. Calcification and gliosis are not usually present. Some of the vein of Galen malformations (Gold et al. '64, Russell and Newton '64) would appear to be examples of simple varix, while others are arteriovenous malformations.

**Cavernous Angioma (“Cavernoma”)**

In spite of the relative infrequency of these malformations, they have attracted considerable attention due to their occasional rupture with severe hemorrhage, their association with convulsions, and the relative

![Fig. 7. Sinusoidal, thin-walled vessels comprising a cavernous malformation. No neural parenchyma is present between the component vessels. (H. & E.; 38X)](image)

![Fig. 8. Photomicrograph taken at the edge of a cavernous malformation illustrating hyalinization and thickening of vessel walls, gliosis of adjacent neural parenchyma, and abundant hemosiderin deposition from previous minor hemorrhages. (H. & E.; 38X)](image)
ease of surgical removal (Evans and Courville '39, Noran '45, Penfield and Ward '48, Bodin and Heller '50, Manuclidis '50, Züllch '57, Schneider and Liss '58, Russell and Rubinstein '59). They may range greatly in size (1 mm. to many centimeters in diameter). The smaller ones may appear as a petechia (Fig. 6), while the larger angiomas may appear as a huge, purple-red, well circumscribed or even encapsulated mass. Multilobulation is common. They have been found in all parts of the central nervous system, but have been found most often in the cerebrum (Russell '54). These malformations may be multiple, but solitary lesions are more common. Encapsulation of these lesions has been particularly stressed by Schneider and Liss '58, but circumscription without encapsulation is much more common. Microscopically, these malformations are composed of large, sinusoidal vascular spaces forming compact masses which are not separated by parenchyma. Manuclidis '50, however, believes that small amounts of parenchyma can occur between the component vessels in the cavernous malformation. The walls of these dilated channels are relatively thin, with no smooth muscle or elastic tissue (Fig. 7). Calcification, at times dense, is a feature which has been stressed. Hyalinization of the vessel walls is very common, and thrombosis of all or part of the lesion may occur. Hemosiderin deposition in gliotic tissue about these malformations is common indicating minor hemorrhage (Fig. 8).

Arteriovenous Malformation

This lesion constitutes the best known, and most frequently described, vascular malformation, and the literature concerning this lesion is immense. They occur in all parts of the central nervous system, but the larger ones most often occur in the area supplied by the middle cerebral artery. At one time regarded as rare in other locations, they are being found with much greater frequency in the posterior fossa (McCormick and Nofzinger '66) and spinal cord. While apparently rare (McGuire et al. '54), arteriovenous malformations can occur in the choroid plexi, in which case hydrocephalus often develops. We have seen these lesions in the glomus of the choroid plexus in two patients.

The typical gross features of the large A-V malformations have been well described as a "bag of worms," with greatly dilated and thickened venous channels forming a wedge-shaped mass extending from the leptomeninges deep into the parenchyma, often reaching and even entering the lateral ventricle. The congeries of vessels are of all sizes, even exceeding a centimeter in diameter. The overlying leptomeninges are often thickened and opacified. Calcification is encountered in a significant number of A-V malformations, and may be present in large amounts (Penfield and Ward '48, Alexander '53, Mascherpa and Valentino '59). More commonly, the calcification is seen only microscopically (in gliotic parenchyma or in the vessel walls).
Microscopically, the variable and extremely complex nature of the lesion becomes evident (Fig. 9). The vessels may range from relatively well differentiated arteries and veins to malformed, thick and thin-walled, hyalinized vessels apparently neither artery or vein. Segmental dilatations of these vessels are often seen (Arieti and Gray '44, Russell and Rubinstein '59) (Fig. 10). Large, irregular nodules of hyalinized intima and smooth muscle often project into the lumens (Wolf and Brock '35, Russell and Rubinstein '59, Bailey '61) (Fig. 11). A peculiar, amyloid-like material is at times found in the vessel walls (Neumann '60, Peterson and Schulz '61). Figure 12 illustrates this material in one of our cases. Ossification may also occur, but is uncommon (Williams '50). Degeneration of the parenchyma about and within the malformation is almost constant, and may be the most conspicuous feature in some cases (Antoni '62) (Fig. 13). Hemosiderin pigment is commonly found, indicating at least minor hemorrhage from the malformation.

**Venous Angiomas**

These malformations quite closely resemble the more common arteriovenous lesions, except that arteries are not found.
Malformations composed entirely of veins are somewhat more common in the spinal cord than in the brain (Russell and Rubinstein '59), but do occur in the brain (Wolf and Brock '35, Noran '45, Zülch '57, Courville '62, Courville '63, McCormick and Nofzinger '66). Manuellidis '50 and Russell and Rubinstein '59 include the Sturge-Weber syndrome with venous angiomas, although its inclusion with the telangiectasias would seem preferable in some cases. In our experience, most venous angiomas are smaller than the A-V malformations, although minute ("cryptic") forms of both are encountered (McCormick and Nofzinger '66). "Capillary angiomas" are almost constantly found in these small malformations (Russell and Rubinstein '59, Courville '62, '63). As in arteriovenous malformations, but unlike cavernous angiomas, neural parenchyma is found (Fig. 14). The vessels comprising the malformations are devoid of large quantities of smooth muscle and elastic tissue. Hyalination and thickening of the walls are common (Fig. 15).

Summary and Conclusions

Vascular malformations of the nervous system can be, in almost all instances, classified as (1) telangiectasias, (2) varices, (3) cavernous malformations, (4) arteriovenous malformations, or (5) venous malformations. The distinguishing anatomic features of each of these types are given. The generic term "arteriovenous malformations" is often applied to the whole group, although this is incorrect. All types are regarded as developmental malformations and not true neoplasms.

References


DOTT, N. M. Intracranial aneurysms: cerebral arterio-


EPPINGER, H. Pathogenesis (Histogenesis und Aetio-


167.


FORSKHOLM, F., and ALPERS, B. J. Anatomical de-


HACKET, W. M. Über den Bau und die Altersverän-


TURNBULL, H. M. Intracranial aneurysms. Brain, 1918, 41:50-86.

ULLRICH, D. P., and SUGAR, O. Familial cerebral

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