VASCULAR MALFORMATIONS OF THE BRAIN
AN ANATOMICAL STUDY*
HARRY A. KAPLAN, M.D., STANLEY M. ARONSON, M.D., AND
E. JEFFERSON BROWDER, M.D.
Department of Neurosurgery, State University of New York,
Downstate Medical Center, Brooklyn, New York
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MUCH has been written concerning congenital vascular malformations of the brain, but little has been recorded regarding their anatomical organization. This paper, limited to consideration of lesions within the forebrain, will attempt to define the component design of cerebral arteriovenous malformations on the basis of embryogenesis and adult vascular anatomy. Roentgenograms of vascular malformations in the living patient and dissection of specimens obtained at autopsy bear out the contention that arteriovenous anomalies represent a defect in capillary development with formation of gross arteriovenous shunts and resulting in enlargement of the related arterial and venous channels.

ANATOMICAL CONSIDERATION

Embryogenesis reveals the mechanism of production of the arteriovenous malformation in the adult. The evolution of the vascular system of the brain is sequential and follows the environmental influences placed upon it through formation of progressively newer structures. The growing embryo, as it passes through what appears to be ancestral phases, demonstrates constant formation of new elements and the dropping out of older ones.

The embryologic development of the vascular system of the brain may be subdivided into a series of arbitrary periods. During the first period the primordial endothelial blood-containing channels appear, which are neither arteries nor veins, but rather a germinal bed of endothelium at the base of the brain. This germinal bed grows dorsally as a sprouting meshwork between the ectoderm and brain wall to cover ultimately the neural structures. Blood channels, appearing first as solid cords, develop into tubes by flattening of the outer cells and dissolution of the inner ones. A capillary mesh precedes the more definable vascular system. During the second period veins, arteries, and capillaries are distinguishable. The larger vessels, arteries and veins, form through the fusion of some of the channels of the capillary mesh and dissolution of others. The portion of the plexus lying against the brain wall remains and spreads out as a flattened capillary sheet and the more superficial part develops into definite arteries and veins. Connections are present between the capillary sheet and the more superficial trunks. According to Evans arteries and veins always have their origin in a multiple capillary anlage rather than in single trunk-like forms and function only as source and draining channels for the capillaries. The final phases of blood-vessel development of the brain to the adult pattern are recognized relatively early. An immature vascular circuit becomes functional in the 3-to-5-week embryo. The stems of origin of all cerebral arteries in the 2-month-old embryo are similar to those of the adult. The veins reach maturity somewhat later. The adult pattern of most venous sinuses and cerebral veins can be recognized in the 3-month-old embryo. However, changes in the venous system of the brain continue until birth. It, therefore, becomes apparent that a relatively minute aberration occurring early in development may be responsible for the gross vascular deformity seen in the adult.

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Knowledge of the adult basic vascular pattern reveals the component structural organization of the fully developed arteriovenous malformation. Despite the multiple transformations and the myriad of vessels involved in the final development of the normal vascular system of the brain, a well-organized neurovascular pattern results. It readily becomes apparent that particular regions of the brain are always related to specific arteries and veins and in a definite design. This paper deals primarily with arteriovenous malformations of the forebrain and consequently a description of only the vascular anatomy of the forebrain is presented.

If one, for purposes of clarification, views the central nervous system in its original neural-tube form with a base and suprasegmental cell masses, then the cerebral cortices can be seen to arise as a mantle of cells which had ballooned dorsally from the rostral segment of the forebrain (Fig. 1A). Each cerebral cortical cell mass is divided arbitrarily into four large areas: the frontal, parietal, occipital, and temporal regions. Four large arteries, as branches of the internal carotid artery, irrigate each cerebral cortex (Fig. 1B). The most rostral part of the cortex, the rostral frontal lobe, receives its blood through the distal branch of the internal carotid artery, the anterior cerebral artery. Proceeding caudally along the cortex,