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Anatomical Patterns of Hypoplastic Posterior Communicating Arteries and their Implications for Cerebrovascular Diseases

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Summary. A total of 114 undersized posterior communicating arteries (PCoA-s, external diameter less than 1 mm) and 126 larger ones were investigated histologically. Microscopic examination of hypoplastic PCoA-s revealed five different structural patterns. Two of them showed microscopic appearances characteristic of intracranial arteries seen in adults or newborns without vascular disease. Two other types resembled the histologic picture of Moya Moya disease. The last type was thin-walled and dilated. All PCoA-s larger than 1 mm displayed the adult pattern. The PCoA-s with the Moya Moya-like structure and the thin-walled, dilated pattern contained unusually few reticular fibers. It is supposed that Moya Moya disease may be restricted to the PCoA-s. Further, the types of hypoplastic PCoA-s with reticular fiber deficiency are most probably the source of the so-called unexplained subarachnoid hemorrhage regardless of the presence of infundibular widening. The latter statement stems from the observation that the structure of junctional dilatation does not differ from that of other segments of the artery that exhibit this alteration.

Key words: Cerebrovascular disease – Hypoplasia – Microscopic patterns – Posterior communicating artery

Introduction

It is well-known that the caliber of the posterior communicating arteries (PCoA-s) may display considerable variation [7, 27]. In addition asymmetry in their size is the usual pattern [6, 7, 27]. Remarkably small caliber of PCoA can be seen in approximately 12%–32% of adults [7, 24, 25].

In spite of the familiarity of this condition to pathologists no systematic investigations on the microscopic appearance of undersized PCoA-s appear in the literature.

Materials and Methods

Out of 952 individuals who died in our Department over a 5-year period 88 patients had a PCoA with an external diameter of less than 1 mm unilaterally (62 patients) or bilaterally (26 patients). The external diameter of the PCoA-s in the other individuals ranged from 1 to 4 mm. (The external diameter of the PCoA-s were measured grossly after fixation of the brain in 10% formalin for 1 week.)

All hypoplastic and 126 normal (i.e., larger than 1 mm) PCoA-s were subjected to microscopic investigation. In the latter group 26 normal PCoA-s originated from the vasculature contralateral to unilateral hypoplastic PCoA. The other 100 arteries were dissected from 50 patients without vascular diseases excluding hypertension and marked atherosclerosis. The age of patients with both hypoplastic and normal PCoA-s varied between 18 and 84 years (with a mean age of 52.4 and 53.1 years, respectively).

To make comparisons reliable, representative segments of the entire circle of Willis were also investigated histologically in each case. The PCoA-s were divided into 3 parts and sectioned serially in every case. Sections from all arteries were stained with hematoxylin-eosin, orcein, elastic-van Gieson and Gömöri's method for reticulin.

Results

Five basic patterns of microscopic structure emerged from studies on the hypoplastic PCoA-s.

Normal Adult Pattern

The structure characterizing undersized PCoA-s in this group corresponded in every respect to the well-known microscopic appearance of intracranial arteries seen in normal adults (Fig. 1 A). Therefore there is no need for further description. With advancing age the intima tended to show the changes which are held to be characteristic of aging and occasionally exhibited eccentric or concentric thickening of various degrees. The media always comprised a dense, rather evenly distributed network of reticular fibers which also participated in the development of intimal thickening (Fig. 2 B). With increasing age the fine reticular fibers, having a spiral appearance in younger individuals, became thicker and gradually straightened out without any decrease in their density. In advanced age progressive replacement of reticular fibers by collagen fibers also occurred.

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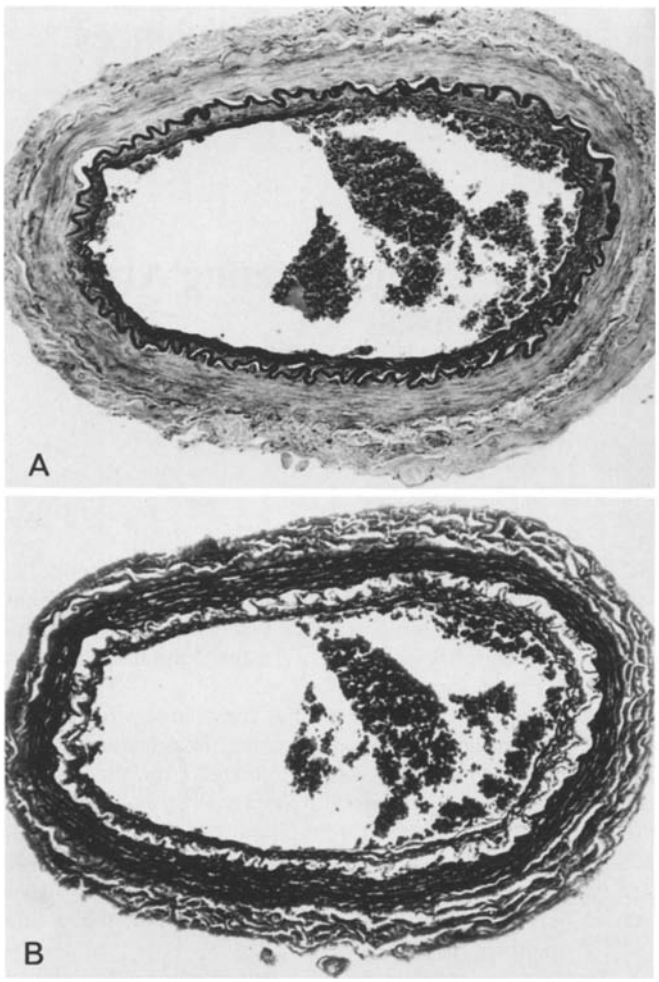

Fig. 1 A, B. The left PCoA of a 49-year-old man shows the adult pattern. Original magnification × 100. **A** elastic-van Gieson; **B** Gömöri's method for reticulin

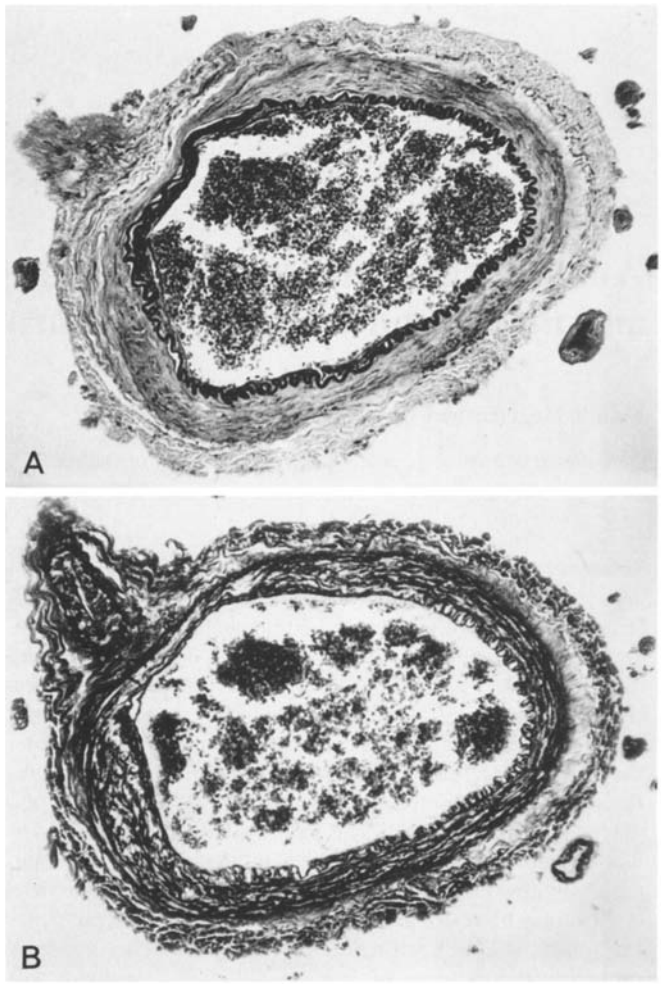

Fig. 2 A, B. The left PCoA of a 72-year-old woman displays the infantile pattern. Original magnification × 100. **A** elastic-van Gieson; **B** Gömöri's method for reticulin

Normal Infantile Pattern

The microscopic picture of undersized PCoA-s with this pattern was very similar to that of intracranial arteries which can be seen in newborns. The internal elastic lamina (IEL) was densely and fairly regularly folded (Fig. 2 A). These arteries showed a minor degree of intimal thickening usually confined to branching points. The consistently fine and spiral reticular fibers of the muscular layer uniformly showed a dense regular distribution (Fig. 2 B). The hypoplastic PCoA-s with the infantile pattern generally did not show age-related changes, i.e., they retained the morphologic features mentioned above in advanced age as well.

The Moya Moya Pattern

The hypoplastic PCoA-s with this pattern always displayed an unusually thick IEL thrown into elaborate folds with frequent breaks in its continuity (Fig. 3 A). The thickness of the media markedly varied because of deep folds of the IEL. In general, eccentric or concentric intimal proliferation considerably narrowed the lumen especially in advanced age. The reticular fibers of the muscular layer were coarse and deficient either in bands or in relatively circumscribed areas (Fig. 3 B). The thickened intima also contained reticular fibers in variable amounts.

The Infantile Form of Moya Moya Pattern

The folds of the IEL were usually irregular and in some places very deep (Fig. 4 A). The thickness of the IEL was generally not uniform and small defects could be detected in the depth of the folds. At the branching sites intimal proliferation to a minor degree could be encountered. Because of the occasional deep folds of the IEL, the thickness of the media was extremely variable in cross-sections in this group also. The reticular fibers surrounding the smooth muscle cells of the media were fairly coarse and showed irregular distribution (Fig. 4 B). These fibers were generally lacking in wide bands especially close to the adventitia.

Thin-Walled, Dilated Pattern

The arterial wall was remarkably thin in relation to the diameter of the lumen, though the thickness of every single layer was proportional (Fig. 5 A). The IEL was moderately convoluted and showed the characteristic changes related to aging. Gaps of various size were common, particularly associated with branching sites. Concentric or eccentric intimal proliferation could occasionally be observed. Reticular fibers could generally be found only in the outer part of the muscular layer (Fig. 5 B) and they were either fine or coarse depending on the age of the patient.

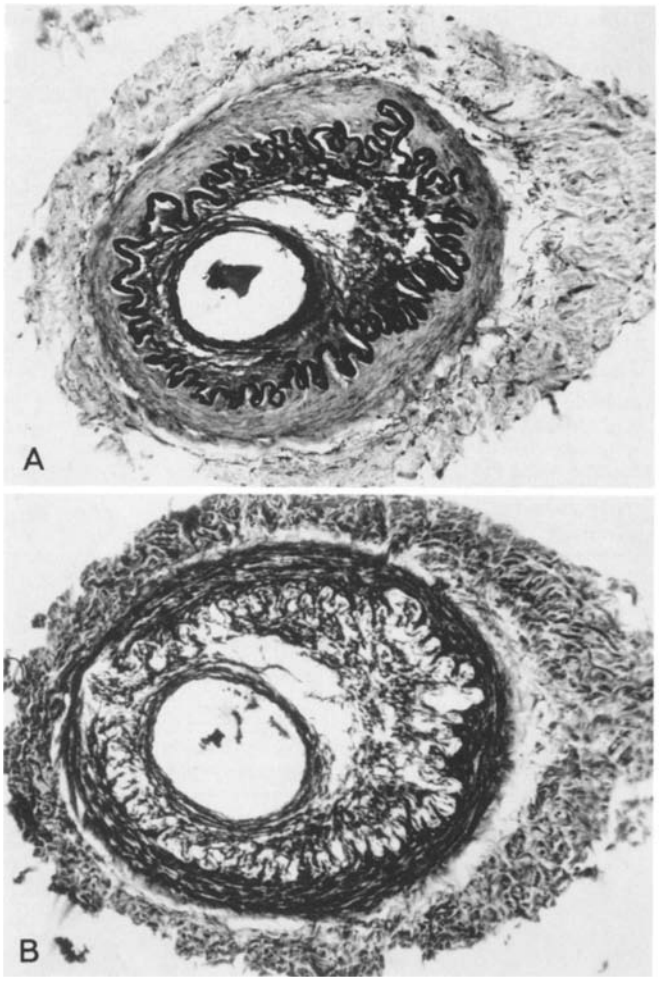

Fig. 3A, B. The right PCoA of a 32-year-old woman exhibits the Moya Moya pattern. Original magnification × 100. **A** elastic-van Gieson; **B** Gömöri's method for reticulin

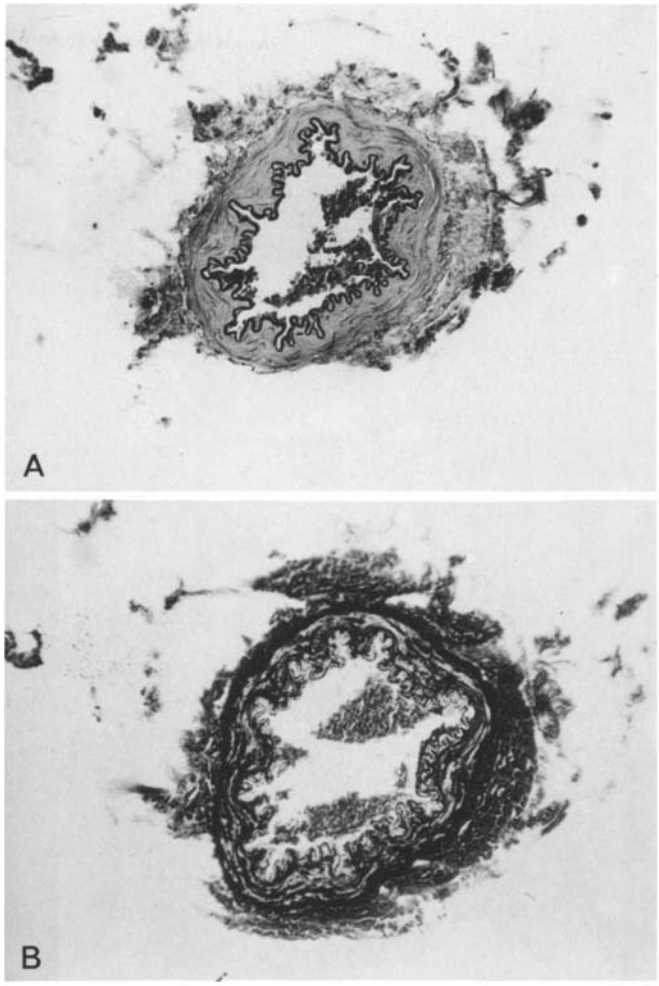

Fig. 4A, B. The infantile form of the Moya Moya pattern in the left PCoA of a 60-year-old woman. Original magnification × 100. **A** elastic-van Gieson; **B** Gömöri's method for reticulin

All PCoA-s larger than 1 mm proved to be of the adult type by microscopic investigation and their morphologic characteristics were identical with those seen in hypoplastic PCoA-s with the adult pattern.

Among the 114 undersized PCoA-s, 6 showed infundibular widening (i.e., junctional dilatation) macroscopically at their origin (3 with the adult pattern, 2 with the infantile form of Moya Moya pattern, and 1 with the thin-walled, dilated pattern). Similar alteration was found in 11 of the 126 PCoA-s larger than 1 mm. The microscopic structure of infundibular widening corresponded in every detail to the overall pattern of the involved PCoA. The diameter of both the hypoplastic and normal-sized PCoA-s was usually not totally uniform in their entire length, however, neither circumscribed ectasia nor marked dilatation could be observed in our material apart from the junctional dilatations.

We could not establish any significant correlation between the morphologic features of the hypoplastic PCoA-s and the age of individuals. Table 1 shows a close relationship between the external diameter and the morphologic properties of the hypoplastic PCoA-s. Table 2 summarizes the microscopic appearances of bilaterally hypoplastic PCoA-s and indicates that the microscopic characteristics of undersized PCoA-s were not always uniform on both sides.

The intracranial major arteries of all patients, independently from the presence of any form of hypoplastic PCoA-s showed only the age-related changes, including alterations of reticular fibers, depicted in PCoA-s with the adult pattern. It must be emphasized that patients with hypoplastic PCoA-s that contained smaller amounts of reticular fibers than usual, did not exhibit reticular fiber deficiency in their large intracranial arteries.

Discussion

There is no generally accepted quantitative definition of PCoA hypoplasia. In agreement with Saeki and Rhoton [24] we regard those PCoA-s hypoplastic which are smaller than 1 mm in external diameter.

Our observations indicate that the structure of undersized PCoA-s may present five different microscopic patterns. This finding raises two important questions: (1) what kind of factors are responsible for the development of the hypoplastic PCoA-s with various microscopic pictures, and (2) do these altered vessels have any clinical importance?

According to data in the literature [10, 23] the PCoA-s develop from the posterior division of the internal carotid ar-

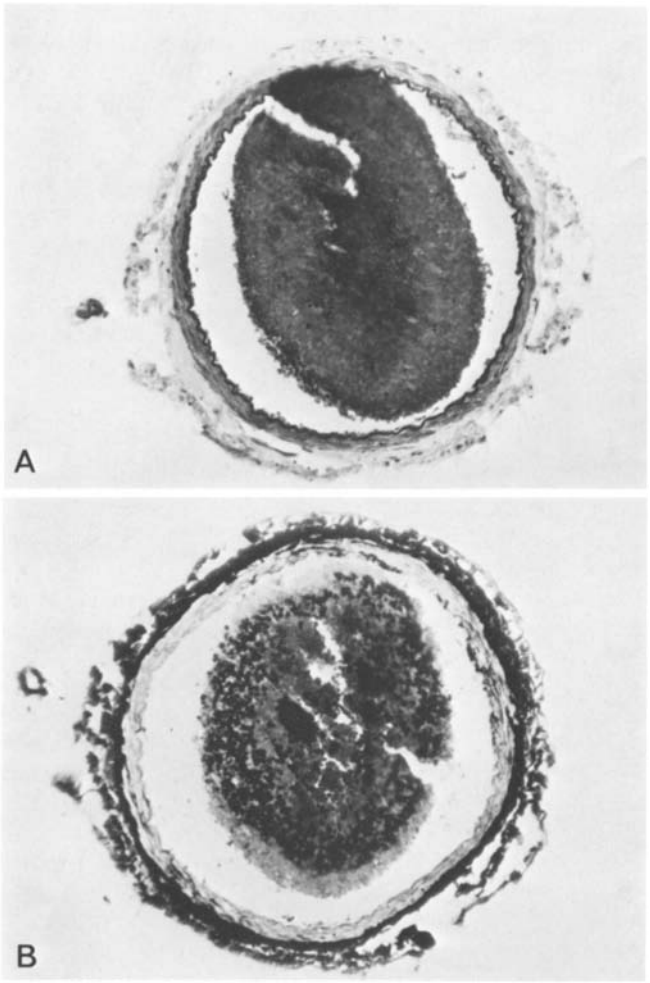

Fig. 5 A, B. The left PCoA of a 21-year-old woman is thin-walled and dilated. Original magnification × 100. **A** elastic-van Gieson; **B** Gömöri's method for reticulin

Table 1. The relationship between the microscopic appearance and the caliber of the undersized posterior communication arteries (PCoA-s) occurring on one side

Microscopic patterns	External diameter (mm) (number of patients)			
	< 0.25	0.25–0.5	0.5–0.75	0.75–1.0
Adult pattern ($n = 27$)	–	–	2	25
Infantile pattern ($n = 18$)	2	3	12	1
Moya Moya pattern ($n = 5$)	–	3	2	–
Infantile form of Moya Moya pattern ($n = 8$)	5	3	–	–
Thin-walled, dilated pattern ($n = 4$)	–	2	2	–
Total number ($n = 62$)	7	11	18	26

Table 2. The microscopic picture of the PCoA-s in cases of bilateral hypoplasia (Number of patients: 26)

Microscopic patterns	Diameter of the bilaterally hypoplastic PCoA-s		
	Roughly equal ($n = 11$)	Different-sized ($n = 15$)	
		The difference is 0.49 mm or less $n = 9$	The difference is 0.5 mm or more $n = 6$
Concordant on both sides			
Adult	6	6	–
Infantile	3	2	–
Moya Moya	1	–	–
Infantile form of Moya Moya pattern	1	1	–
Discordant on the 2 sides			
Infantile and adult	–	–	3
Infantile and thin-walled	–	–	2
Moya Moya and its infantile form	–	–	1

teries in an embryo of 5.3 mm (29 days). The fetal development of the circle of Willis indicates that changes in hemodynamic demand during intrauterine life play a very important role in determining the size of the components of the arterial circle. It is known that at the early stage of development the vertebrobasilar system receives its arterial blood supply from the internal carotid arteries first mainly through the primitive trigeminal arteries and later through the PCoA-s because the vertebral arteries begin to develop relatively late ontogenetically. During fetal life the PCoA-s remain as large channels until the vertebral arteries have reached their full development. After this period the basilar artery generally contributes most of the blood to the distal segment of the posterior cerebral arteries and consequently the PCoA-s remain smaller as compared to the proximal segment of the posterior cerebral arteries. This configuration of the arterial circle is said to be normal [7, 24, 27]. It represents the maintenance of the early stage of development when in postnatal life the PCoA-s are larger than the proximal segment of the posterior cerebral arteries or the posterior cerebral artery arises as a major branch of the internal carotid artery [7, 10, 23, 24, 27]. Asymmetry in size of the PCoA-s is usually explained by the lack of simultaneous reduction of the primitive trigeminal arteries on the two sides [10, 23] that also refers to the importance of hemodynamic conditions in the determination of the size of an artery.

The dimension of the arteries can also be modified after birth [23, 27]: the proximal segment of the posterior cerebral arteries undergoes proportionally greater increase in size than the PCoA-s probably reflecting functional needs in the area of supply [27]. According to Stehbens the cerebellum increases in weight to a greater extent than either the cerebrum or the brain stem [27].

It is most likely that hemodynamic conditions influence not only the size of an artery but also determine the structure of the vessel wall. The relation between the structure and function of the blood vessels has been emphasized by Benninghoff [5] based on observations of an acardiac term infant with

retrograde blood flow in the aorta [4]. The structure of the aortic wall showed all the characteristics of peripheral arteries and differed significantly from underdeveloped aortas. Similar conclusions can be drawn from the structural transformation of vein grafts implanted into the arterial system.

The presence of pattern variations among the hypoplastic PCoA-s is not easily accounted for by the morphologic observations. The existence of the adult type appears to be obvious and requires no explanation. They usually undergo age-related changes affecting not only the intima which is well-known from the literature [3, 11, 18, 27] but also the reticular fibers of the muscular layer which become coarser, lose their spiral appearance with advancing age, and may gradually be replaced by collagen fibers [15, 17]. The age-related changes in the PCoA-s with the adult pattern – especially in those which are larger than 1 mm – may occur earlier and in a more severe form than in other intracranial arteries of the same patient. This finding is in good accordance with the observations of Baker and Jannone [3].

The infantile pattern presumably persists owing to the lack of extreme hemodynamic stress since their structure seems to be independent of aging and appears to remain unchanged throughout life. PCoA-s with the infantile pattern were observed up to the 5th decade by Wright who investigated 12 peripheral arteries obtained from 59 patients of all ages [30]. In our material, however, this pattern was encountered in more advanced age, i.e., in the 8th decade. The hypoplastic PCoA-s with both adult and infantile pattern are most probably normal variations.

In the development of hypoplastic PCoA-s with the other patterns we have to attribute a more important role to local factors, i.e., the reactivity of the structural elements forming the arterial wall, than to the hemodynamic stresses. The appearance of IEL in the PCoA-s with both Moya Moya pattern and its infantile type does not belong to the common picture seen in intracranial arteries of patients without vascular diseases. Similar patterns were observed in numerous cases of Moya Moya disease [8, 12, 29], the occurrence of which cannot be traced back to usual hemodynamic factors acting during either intrauterine or postnatal life. However, the difference between the Moya Moya pattern and its infantile form proves that hemodynamic stress influences the microscopic appearance even in these cases. Published data indicate that Moya Moya disease may bilaterally involve various components of the arterial circle to variable extents [8, 12, 20, 22, 28, 29]. The PCoA-s may be either affected or free from pathologic changes. Our observations suggest that the pathologic process characteristic of Moya Moya disease may be restricted to the PCoA-s bilaterally. On the basis of this finding it seems likely that Moya Moya disease may exist in a localized, abortive form.

The cause of Moya Moya disease is still unknown. The abnormal IEL, the hypoplasia, and the partial lack of reticular fibers in PCoA-s with both forms of Moya Moya pattern suggest that this pathologic process may be traced back to a complex disturbance of histogenesis, the cause of which remains obscure and it cannot be solved by morphologic findings. One may suppose that some injurious effect acting during the histogenesis of PCoA-s – either in fetal life or during growth – is responsible for their development. To discuss the kinds of injurious factors which might play a role in the disturbance of histogenesis would be merely speculative. The reticular fiber deficiency that characterizes PCoA-s with both forms of Moya Moya patterns implies the presence of the same abnormality in more generalized Moya Moya disease as well. However, this presumption requires microscopic validation. This would explain the relatively high incidence of berry aneurysms [1, 2, 19, 21, 32] and dissecting aneurysms [31] in cases of Moya Moya disease. Our earlier observations have shown that in the intracranial arteries of patients with both berry [15] and dissecting aneurysms [16] poor supply in reticular fibers is characteristic and typical.

In the fifth type of hypoplastic PCoA-s the conspicuous reticular fiber deficiency was the most striking histologic alteration. It is most probably the cause of dilatation because the partial lack of reticular fibers decreases the strength of the arterial wall [15, 17].

Contradicting views can be found in the literature concerning the role of infundibular widening of PCoA-s (i.e., junctional dilatation = the enlargement of the most proximal part of PCoA) in the pathogenesis of the so-called unexplained subarachnoid hemorrhage (SAH). Hassler and Saltzman presumed that infundibular widening of PCoA-s occurring in approximately 7% of the cases are either aneurysmal or preaneurysmal lesions and can cause SAH [13, 14, 26]. In contrast, Epstein et al. believed that the junctional dilatation is a normal variation and does not predispose to bleeding or future true aneurysmal dilatation since according to them its histologic structure is normal [9]. According to our findings it seems reasonable to presume that the types of PCoA-s which have poor supply in reticular fibers – especially because it is associated with defects of IEL – may rupture under excessive hemodynamic stress regardless of whether infundibular widening is present or not. The junctional dilatations with normal microscopic structure most probably have no clinical significance related to the bleeding. We are therefore of the opinion that it is not the infundibular widening that has an important role as the possible source of unexplained SAH but the structure of the arterial wall which is the same in the whole artery irrespective of the presence of junctional dilatation.

Stehbens suggested that the thin PCoA-s should not be regarded as developmental faults but normal variations [27]. Our observations partly contradict this views. Only undersized PCoA-s with adult and infantile patterns can be considered normal variations.

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