CHANGES IN REACTIVITY OF PIAL MICROVESSELS OF RATS DURING ONTOGENY

V. I. Kozlov, I. O. Tupitsyn, and F. B. Litvin

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Acute deficiency of the blood supply leads to functional adjustment of the microcirculatory bed aimed at maintaining the cerebral circulation at a constant level [1-3, 13]. High functional lability of the pial microvessels is determined by their specific geometry and by the presence of numerous arteriolo-arteriolar and venulo-venular anastomoses. The reactivity of the pial microvessels reflects compensatory changes in the intracranial circulation and is an informative parameter of the activity of its regulatory mechanisms [10]. Precortical arterioles, and sphincter in the region of their branching and microanastomoses are regarded as the principal regulatory component in the pial vascular system [11]. Meanwhile the possible participation of the venules in the supply of nutrients for the maintenance of brain activity cannot be ruled out [2]. With age changes have been shown to take place in the compensatory-adaptive mechanisms of maintenance of organ and tissue nutrition [5, 7, 8]. In view of the importance of the study of ontogenetic morphological and functional transformations of the microcirculatory system, it was decided to study changes in reactivity of the microvessels of the pial system occurring at different stages of postnatal ontogeny in rats after bilateral occlusion of the carotid arteries.

EXPERIMENTAL METHOD

The investigation was conducted on 140 Wistar rats aged 7, 30, 45, 60, and 90 days. Preparations for biomicroscopy of the pial vessels were made by the method described previously [6]. To assess reactivity of the pial microvessels, the common carotid arteries were occluded bilaterally for 6 min in animals aged 1 week and for 9 min in rats of the other age groups. Changes in the microcirculation were recorded intravitally by photomicrography, which was carried out 15, 30, 60, 90, 120, 180, 360, and 540 sec after the beginning of occlusion of the carotid arteries, and again for 9 min during the recovery period after removal of the occluding device. During biomicroscopy the time of onset of the microcirculatory changes — the appearance of a granular blood flow — and the time of its arrest, were recorded. The intensity of the response of the microvessels was judged by changes in the diameter of the arterioles and venules expressed as a percentage of their initial values.

EXPERIMENTAL RESULTS

Occlusion of the common carotid arteries induces associated changes in all components of the microcirculatory bed of the pia mater (Fig. 1). The velocity of the blood flow decreases initially in the large arterioles and venules, later in the precortical arterioles and postcortical venules, in which the blood flow becomes granular. A relatively long block of the blood flow (up to 2 min) is observed in arteriolo-arteriolar anastomoses. In the venules, reduction of the blood flow velocity is accompanied by a marked fall in the hematocrit index and the appearance of a well-marked juxtamural plasma layer in some venules. Compression of the carotid arteries is accompanied by closing of some capillaries in the pia mater of the young rats and by their plasmatization.

After occlusion of the carotid arteries two consecutive phases of changes in the microcirculation in the rat pia mater took place. First, constriction of the pial microvessels was observed, and was followed by their dilatation (Fig. 2). The duration of the phases changed with age: the duration of constriction of the arterioles was reduced from 60-70 sec in animals aged 7 days to 5-7 sec in adult rats. Meanwhile the duration of the dilator reaction increased. The first phase of the initial changes was due mainly to a fall of

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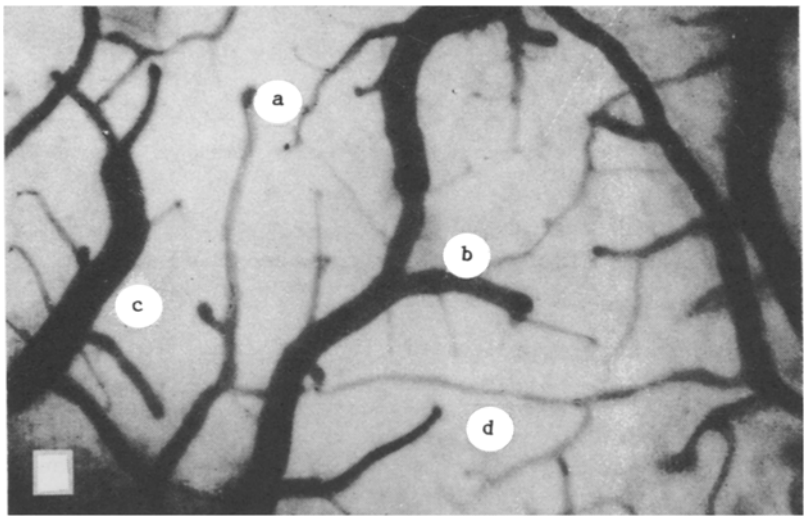

Fig. 1. Response of pial microvessels of 45-day-old rats to occlusion of common carotid arteries. Photomicrographs. Magnification 50 ×. a) Precortical arteriole; b) postcortical venule; c) venule; d) arteriolo-arteriolar anastomosis.

pressure in the cerebral vessels. The diameter of the precortical arterioles was reduced in this phase from 18.7 ± 0.9 to 13.6 ± 1.5 μ, and diameter of the arterioles of the III order was reduced from 26.3 ± 1.3 to 23.7 ± 2.5 μ, respectively. In the venules these changes were less marked. The diameter of the postcortical venules decreased by 21%, and the diameters of the I order venules and collecting venules decreased by 12 and 9%, respectively. The second phase reflects compensatory changes in the arteriolar and venular components in response to occlusion of the carotid arteries. The diameter of the precortical arterioles increased under these circumstances from 24.4 ± 2.3 to 34.4 ± 2.3 μ, and the diameter of the arterioles of the III and II orders fell from 36.2 ± 1.0 to 48.0 ± 1.4 μ and from 46.2 ± 2.4 to 56.6 ± 3.2 μ. In the venular components the increase in the diameter of the postcortical and collecting venules and the venules of the I order was 15, 7, and 3%, respectively. Thus vessels with different diameters differ in their ability to dilate: the smaller the diameter of the arterioles and venules, the stronger their dilator reaction.

The time taken for dilatation of the pial microvessels to reach its maximum varied with age. In adult rats, for instance, it was shorter than in rats aged 7 to 30 days. Arterioles of rats aged 7 days reached maximal dilatation 120 sec after the beginning of occlusion, whereas in rats aged 45 days, the time taken to reach maximal dilatation was reduced by half, and in adult rats by three-quarters.

Besides the more rapid development of an adaptive compensatory response of the microvessels in adult animals, more marked dilatation of the arterioles also was found. In animals aged 7 days average dilatation of the arterioles amounted to 20-25% of the initial value, and in rats aged 30 and 45 days, it increased to 60-75%; however, at this stage of development the character of the response of the microvessels takes place in ontogeny by the 60th and 90th days of postnatal development, when the definitive shape of the microcirculatory channels is finally achieved. In the venular portion, the degree of dilatation decreases with age. From 7 to 90 days of development the degree of constriction of the postcortical venules after occlusion was reduced from 25 to 6%.

According to data in the literature, the arteriolo-venular coefficient (AVC) is an integral characteristic of the "input" and "output" vessels of the microcirculatory system [4, 9]. The time course of this parameter is complex and it depends on changes in structure and functional maturity [6]. Biomicroscopy showed that the almost twofold increase in AVC after occlusion is associated with marked changes in the parameters of the arteriolar component. In animals aged 7 days, throughout the period of occlusion, the response of the arterioles remained relatively low (Fig. 3), whereas in 30-day-old rats, a sharp increase in the value of AVC was observed in the first minutes, due to hyper-reactivity of the arterial vessels, and in adult animals AVC gradually increased and remained relatively constant

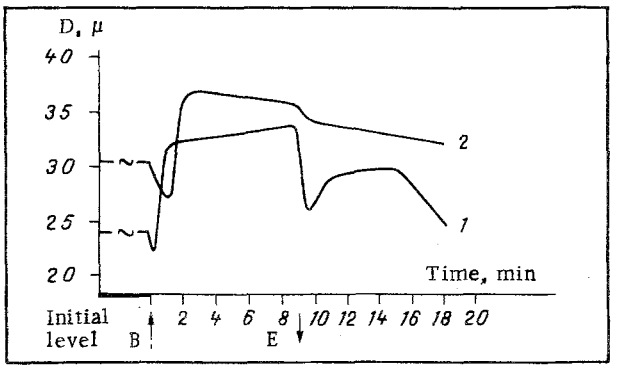

Fig. 2

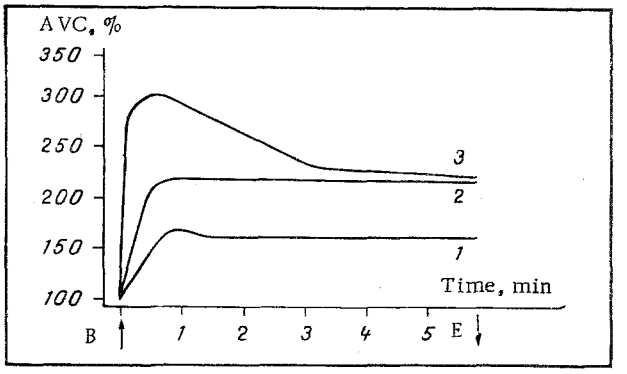

Fig. 3

Fig. 2. Changes in dialysis of precortical arterioles and postcortical venules of pia mater after occlusion of common carotid arteries in an albino rat aged 45 days. 1) Precortical arterioles; 2) postcortical venules. Here and in Fig. 3: B) beginning of occlusion; E) end of occlusion.

Fig. 3. Changes in arteriolo-venular coefficient (AVC) in pial system during occulsion of common carotid arteries in rats at different times of ontogeny. Age: 1) 7 days; 2) 30 days; 3) 90 days.

throughout occlusion, evidence of a switch of the pial microcirculatory system to a qualitatively different hemodynamic level.

Thus the investigations showed that structural modification of the pial microcircuitry system during ontogeny is associated with definite changes in reactivity of the vessels of the microcirculatory bed. The formation of stable compensatory and adaptive reactions of the microvessels is observed only in adult animals.

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