ADRENERGIC INNERVATION OF PIAL ARTERIES OF VARIED DIAMETER IN MAN AND ANIMALS

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UDC 611.133.33-018.83-019

KEY WORDS: cerebral arteries; adrenergic innervation; quantitative characteristics.

Morphological criteria of the degree of innervation of arteries remain a debatable topic in histochemical investigations of vasomotor innervation. Until now, the absolute number or concentration of vascular nerve fibers has generally been regarded as such a criterion [1, 2, 5]. However, the fact that transmitter secretion takes place only from varicosities (specialized thickenings formed along the course of axons [6]) makes the correctness of the conclusions based on the results of counting nerve fibers questionable.

The aim of the present investigation was to estimate the degree of innervation of arteries of the pia mater of different diameters in man and animals by comparing the concentration of adrenergic fibers and varicosities of nerve axons.

EXPERIMENTAL METHOD

The adrenergic innervation was studied by the method of Furness and Costa [7] on branches of the posterior cerebral artery 450-300, 300-200, 200-100, 80-60, and 50-30 μ in diameter. Material was obtained from medicolegal autopsies, from cadavers of persons killed in road traffic accidents, aged 22-24 years (12 cadavers), 55-64 years (seven), 65-74 years (six), and 75-86 years (seven), and also from adult animals: dogs (eight) and cats (nine). Samples of tissue were studied not later than 4 h after death, when changes in adrenergic nerve plexuses are insignificant [2]. The pia mater was removed together with its blood vessels, stretched out on glass, dried, and treated with a 2% solution of glyoxylic acid. The preparations were studied under the ML-2 luminescence microscope, using DS-1 and SZS-7 filters. To estimate the degree of innervation of the arteries the absolute number of nerve fibers per 0.84 mm length of the vessels, the concentration of nerve fibers per mm^2, and the concentration of varicosities per 0.1 mm^2 of vessel wall were counted. The results were subjected to statistical analysis.

EXPERIMENTAL RESULTS

The structure of the adrenergic nerve plexuses on pial arteries of equal caliber in man and animals of adult age is in many respects uniform in type. A dense double-layered fine-looped plexus, formed by fluorescent fibers running longitudinally, obliquely, or transversely, could be detected on arteries from 450 down to 300 μ in diameter (Fig. 1a). With a reduction of the diameter of the vessels to 100 μ the nerve plexuses became single-layered in structure (Fig. 1b) and the absolute number of nerve fibers per 0.84 mm length of the vessels was reduced about by half (Fig. 2a). In the adrenergic plexuses of pial arteries of smaller caliber longitudinal fibers began to predominate, and approaching the precortical arteries, the number of transverse connections between them became progressively smaller (Fig. 1c, d). On account of the rapid decrease in the absolute number of fibers (Fig. 2a) the loops of nerve nets became wider. On arteries from 80 to 60 μ in diameter not more than 5-8 fluorescent fibers could be counted, and on small precortical arteries (50-30 μ in diameter) only from two to five nerve fibers remained. It can be concluded from these counts that the importance of nervous control in the regulation of functions of the pial vessels declines sharply with a reduction in

Department of Histology, Cytology, and Embryology, Vladivostok Medical Institute. (Presented by Academician of the Academy of Medical Sciences of the USSR V. V. Kupriyanov.) Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 103, No. 2, pp. 215-218, February, 1987. Original article submitted March 10, 1986.

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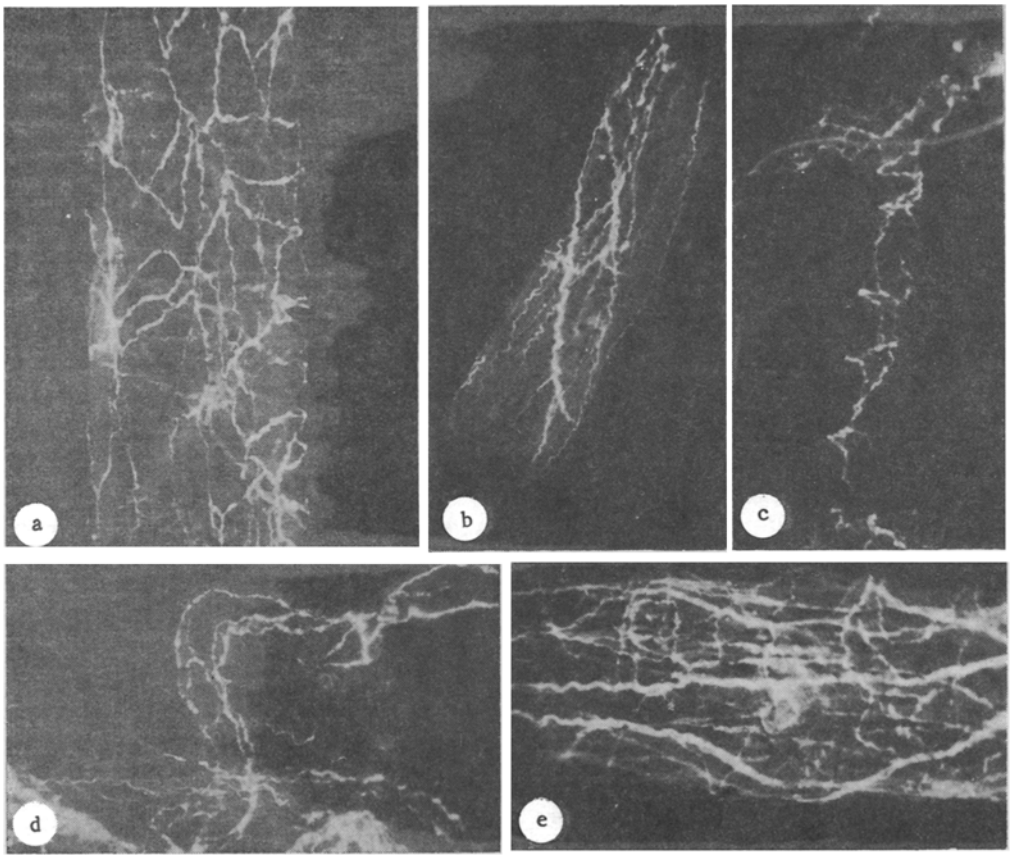

Fig. 1. Adrenergic nerve plexuses of pial arteries in man and animals. a) Artery of a 27-year-old man, 356 μ in diameter; b) dog's artery 197 μ in diameter; c) artery of a 39-year-old man 80 μ in diameter; d) cat's artery 75 μ in diameter; e) artery of a 63-year-old man 400 μ in diameter. Method of Furness and Costa. 200×).

their caliber. The concentration of fluorescent fibers on different segments of the vascular bed likewise varied (Fig. 2b), but no significant difference was observed in the values of this parameter between arteries from 450 to 100 μ in diameter in man and from 300 to 80 μ in diameter in animals ($P > 0.05$). In other words, the response of vessels of this caliber to nervous influences ought to be virtually identical, with the exception of arteries thinner than 50 μ, in which the concentration of nerve fibers was significantly less ($P < 0.05$–0.01) than values obtained for pial arteries over 100 μ in diameter (Fig. 2b).

A different pattern was observed when the degree of innervation of the arteries was estimated from the number of varicosities per unit area of vessel wall. Varicosities were identified along the course of nerve fibers in adrenergic plexuses of pial arteries of every caliber (Fig. 1a, b, c). However, the number of these thickenings varied considerably not only in vessels of different diameter, but also in individual nerve fibers of the same arteries. In some fibers the varicosities formed a continuous chain of fluorescent bead-like thickenings, whereas in others they were very rare. Calculations showed that the highest concentration of varicosities was present in the wall of arteries from 200 to 100 μ in diameter in man and from 80 to 60 μ in diameter in animals (Fig. 2c). It is important to note that in both dogs and cats, the parameter remained significantly higher ($P < 0.05$) in pial arteries 50–30 μ in diameter than in arteries of larger caliber. This agrees on the whole with the results of physiological investigations [3] indicating greater changes in the lumen of the small pial vessels during stimulation of vasomotor fibers.

When the concentration of nerve fibers and varicosities in the pial arteries of persons of the older age group was studied, differences were found among the changes in these parameters (Fig. 3a, b). In human arteries from 450 to 300 μ in diameter quite dense nerve plexuses were discovered for a long time (Fig. 1e). It was only between the ages of 75 and 86 years that a significant decrease ($P < 0.05$) was observed in the concentration of fluorescent fibers in the pial arteries of this caliber compared with the corresponding value in persons between

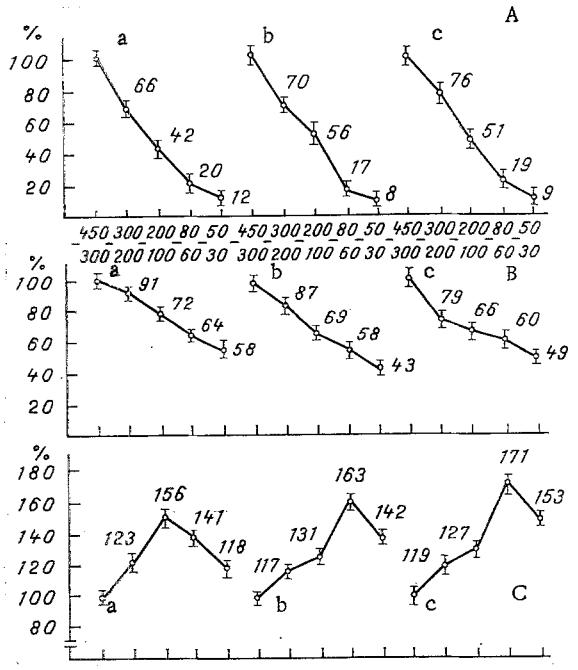

Fig. 2

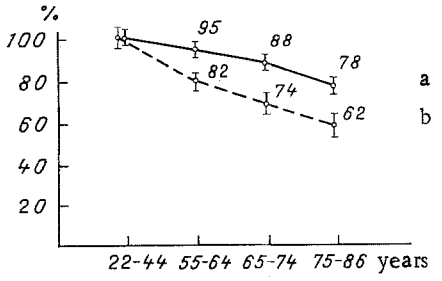

Fig. 3

Fig. 2. Absolute number (A), and concentration of nerve fibers (B) and varicosities (C) in adrenergic plexuses of pial arteries of varied diameter in man and animals of adult age. a) Man; b) dog; c) cat. Value of parameter in arteries 450-300 μ in diameter taken as 100%.

Fig. 3. Concentration of nerve fibers (a) and varicosities (b) in adrenergic plexuses of pial arteries with a diameter of 450-300 μ in persons of older age groups. Value of parameter in persons aged 22-44 years taken as 100%.

22 and 44 years of age. Consequently, taking the concentration of nerve fibers as the morphological criterion of the degree of innervation of the pial arteries, it must be concluded that it remains unchanged until 75 years of age. However, this contradicts the results of clinical and experimental investigations which show significant reduction of neurogenic influences on the intensity of the cerebral blood flow in the second period of adult life [4, 8]. The concentration of varicosities fell more rapidly than the concentration of nerve fibers (Fig. 3b). Initially the density of varicosities diminished on single fibers, but with age the number of these fibers in the pial vessels increased, thus giving rise to the corresponding changes in the value of this parameter. The concentration of varicosities at the age of 55-64 years was almost 20% below its value at the age of 22-44 years, and during the subsequent decade the differences became significant ($P < 0.01$).

The concentration of varicosities is thus a more accurate morphological indicator of the degree of neurogenic influences on the intensity of the cerebral blood flow.

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