CHOLINERGIC AND ADRENERGIC INNERVATION OF MICROVESSELS OF THE SEROUS MEMBRANES

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The morphological substrate of dual (sympathetic and parasympathetic) innervation of the microblood-vessels was studied in the serous membranes of the cat. By the use of histochemical methods to demonstrate cholinergic (Koelle–Gomori) and adrenergic (Falck–Hillarp) nerve structures the architectonics of both components of the vasomotor innervation was described in the pericardium, pleura, and peritoneum. Adrenergic structures were more numerous than cholinergic in corresponding segments of the arterial system. The autonomic innervation of the terminal arterioles and capillaries was inconstant in character and was essentially confined to single synaptic contacts arising along the course of the adrenergic and cholinergic terminals. In the veins, including the post capillary venules and small collecting veins, the autonomic innervation (both adrenergic and cholinergic) was exceptionally poorly developed and sometimes impossible to detect.

Key words: innervation of microvessels; cholinergic nerve structures; adrenergic nerve structures.

The autonomic innervation of the terminal microvessels continues to attract close attention as a subject for research. This is explained primarily by the perennial importance of the microcirculation problem and of its most important aspect, the nervous mechanism controlling the terminal blood flow under normal and pathological conditions [4, 6]. Another factor accounting for the increased interest in autonomic vascular innervation is that reliable methods for the separate detection of cholinergic and adrenergic nerve structures are now available in modern neuromorphology. By the use of these methods in the last decade much research has been carried out into the morphological substrate of the dual (sympathetic and parasympathetic) innervation of the peripheral blood vessels. In addition to establishing the existence of complex topographical relations between the cholinergic and adrenergic components of the autonomic vascular innervation, these investigations at the same time provide evidence of the inadequate level of study of the morpho-functional principles governing the vasomotor innervation of the various orders of microvessels. In particular, there is a conflict of opinion regarding the presence or absence of direct synaptic contacts of autonomic nerve fibers with true capillaries and postcapillary venules [3, 8-11]. The relative contribution of cholinergic and adrenergic components in the different parts of the terminal system is not clear in its essentials. Much remains to be done in the study of their architectonics and structural differences.

Considering the great importance of these problems to the correct understanding of the histophysiology of the nervous mechanisms responsible for the control of the peripheral circulation it was decided to study the structural organization of the cholinergic and adrenergic components of the autonomic innervation in the microcirculation of the serous membranes.

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EXPERIMENTAL METHOD

Various parts of the serous membranes of the cat were studied: the pericardium, pleura, and peritoneum. These membranes have a rich blood supply with an intramural plexiform structure including all elements of the arterial and venous systems [2, 7]. Total microscopic investigation of total preparations of the serous membranes provide the facilities for the fullest study of three-dimensional neurovascular relations. Another important fact is that, besides possessing a rich blood supply, the serous membranes have no other contractile structures of the type that usually interferes with the study of the specialized vasomotor innervation.

To demonstrate cholinergic (more exactly, activated by cholinesterase) nerve structures the Koelle–Gomori thiocholine method was used with acetylcholine iodide as the action substrate. Incubation continued for 1.5-2 h at 37°C. The adrenergic nerve structures were revealed by the fluorescence-microscopic method of Falck and Hillarp. The duration of treatment of the specimens with gaseous formaldehyde (relative humidity 51%) was 1.5 h at 80°C and 3 h at 37°C. The specimens were examined and photographed in the ML-2 luminescence microscope.

EXPERIMENTAL RESULTS

Analysis of the specimens showed that most autonomic nerve fibers demonstrable in the serous membranes by the thiocholine and catecholamine methods belonged to the autonomic system. Comparison of the cholinergic and adrenergic components of this innervation showed characteristic differences in their architectonics and structural organization. In corresponding segments of the blood vessels the parasympathetic innervation was characterized by a mainly longitudinal arrangement of the nerve fibers and by polygonal loops stretched lengthwise along the vessel. In the structure of the sympathetic plexus, besides fibers with a longitudinal course there were thick and complex adrenergic networks (Fig. 1). As the blood vessels branched and the vascular innervation changed to the more terminal levels (precapillary arterioles) the above differences in the structure of the sympathetic and parasympathetic components gradually disappeared. In both cases groups of thin axons or single fibers showing high activity of the mediator (noradrenalin), in one case, or the enzyme (acetylcholinesterase), in the other case, were seen (Fig. 2).

The observations revealed a separate arrangement of the sympathetic and parasympathetic components of the autonomic innervation in the blood vessel walls. However, this does not rule out the possibility of close topographical relations between them or the formation of typical cable systems in the principal bundles of the paravascular plexus characteristic of the autonomic periphery as a whole [5].

Comparative analysis of specimens treated by the thiocholine and catecholamine methods showed quantitative predominance of elements of the adrenergic innervation over the cholinergic in corresponding

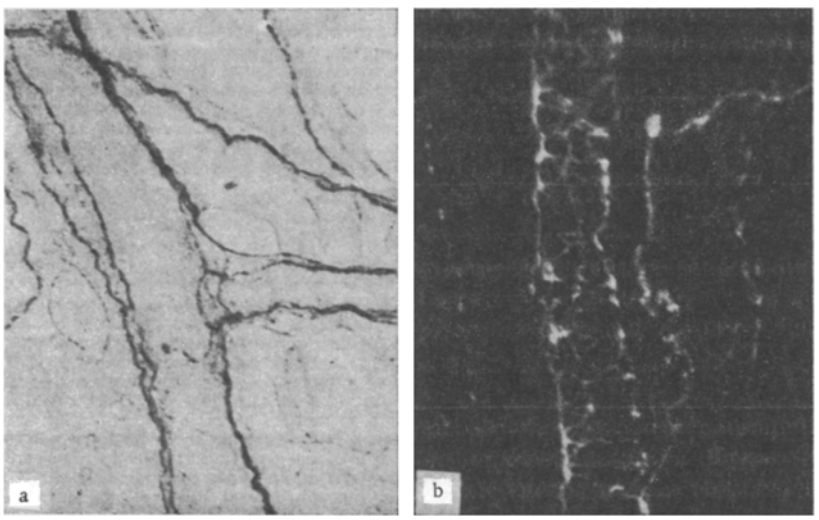

Fig. 1. Cholinergic and adrenergic innervation of blood vessels of the cat pericardium: a) Koelle–Gomori method; b) Falck–Hillarp method, 400×.

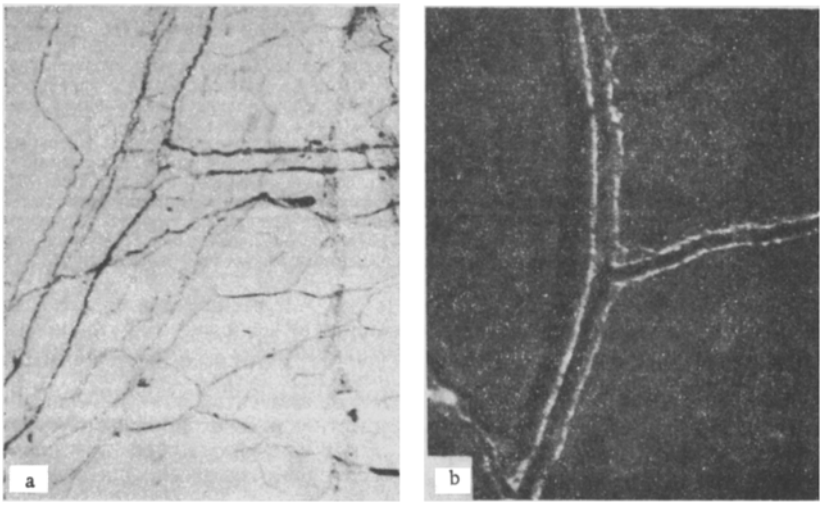

Fig. 2. Cholinergic and adrenergic innervation of vessels of the parietal pleura: a) Koelle–Gomori method; b) Falck–Hillarp method, 400×.

segments of the vascular system of the serous membranes. This suggests that peripheral vasoconstrictor mechanisms are represented preferentially in the walls of the vessels supplying them with blood. This applies chiefly to the arterial portions of the vascular system. So far as the venous portion is concerned, the adrenergic and cholinergic innervation of these vessels is extremely poorly developed. Microscopic examination of total preparations very often revealed a striking contrast between the powerfully developed adrenergic plexus in the wall of arteries of different caliber and the hardly perceptible single fibers accompanying the series of venous trunks. Often along the course of the small veins elements of the adrenergic innervation could not be found at all, a result not likely to be attributable to technical errors, for the arterial vessels lying immediately next to the veins invariably carried brightly luminescent perivascular plexuses (Fig. 2b). However, it must be emphasized that the nerve supply of the latter could be traced only as far as a certain limit, including the system of terminal arterioles and precapillaries, and that it did not spread to the overwhelming majority of capillaries. Only a few capillaries, these observations showed, were in contact with adrenergic terminals. These findings agree with reports in the literature of isolated discoveries of cross sections of axons and synapse-like structures close to the capillary wall [1, 11], and they can thus be contrasted with the views of those workers who totally deny the existence of any autonomic innervation of the capillaries [8-10].

The features of the structural organization of the cholinergic and adrenergic components of the autonomic vascular innervation were typical equally of all the serous membranes studied. Nevertheless, within the same membranes the intensity of innervation of the corresponding parts of the vascular system with vasomotor nerves varied within wide limits. In all probability this fact reflects the functional state of the innervated structures, which lies at the basis of the histochemical methods used to demonstrate them, rather than the true morphological picture of the vascular innervation. What these experiments primarily revealed was the enzymic or mediator activity of the nerve fibers, the degree of which can be reflected significantly in the morphological picture of the neurovascular relations, especially in the region of the capillaries where the innervation structures are represented by single, very thin axons.

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