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BLOOD SUPPLY OF THE GANGLIA

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The present study about the angioarchitecture of the peripheral ganglia has the purpose of completing our previous investigations into the blood supply of the peripheral nerves. The question has a practical importance, because everywhere in the central and peripheral nervous system there exists a close correlation between blood supply and functional importance, and because attention is being directed more and more to the vascular pathology of the ganglia and to the examination of clinical manifestations connected with their changes.

The problem of the vascular supply of the ganglia has received little attention in the literature. Beside older descriptions of their visible blood supply, the most notable are *Bergmann*'s studies on the microscopical vascular conditions of the spinal ganglia, the coeliac ganglion and Gasser's ganglion. While *Nonidez* confined his investigations mainly to the arterio-venous anastomoses in the sympathetic ganglia of the dog, *Lattes* described hypertensive changes in the sympathetic ganglia without, however, discussing normal vascular conditions.

We are of the opinion that, to obtain a clear view of the ganglionic circulation, first the vascular supply of various human ganglia and their individual conditions must be examined, with special regard to the topography and architecture of the vessels. In addition, phylogenetical investigations are needed, comparing the blood supply of the ganglia according to species. Finally, after evaluating the results thus obtained, it should be established how can the circulation of the ganglia be influenced experimentally. Investigations of this kind would make it possible to elucidate a number of unsolved problems arising in the course of examinations exclusively concerned with the vascular pathology of the ganglionic blood supply.

In the present paper the first of the above points will be discussed, i. e. the vascular supply of the ganglia in human subjects, with especial regard to comparing the vascular system of the sympathetic and the spinal ganglia.

Material and Methods

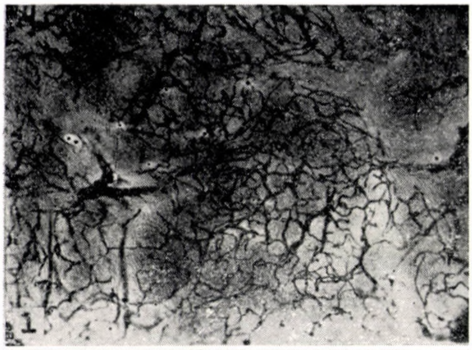
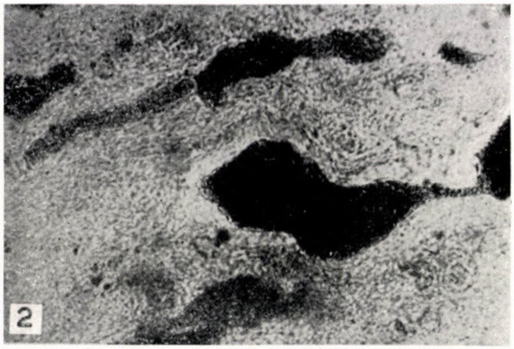
The sympathetic and spinal ganglia of 4 newborn and 6 adult humans were examined. The infants were injected through the heart with Prussian blue according to the specification in Romeis' manual. The vessels of the ganglia have been examined in sections 100 micra thick. In adults, the superior and inferior cervical ganglia, the thoracic ganglia, the coeliac ganglion, the lumbar and the spinal ganglia have been subjected to examination in sections 150 micra thick treated with peroxidase.

Blood supply of the sympathetic ganglia

Investigating the macroscopic blood supply of the sympathetic ganglia, *Delamare* and *Tanasesco* found that the superior cervical ganglion collects its vascular supply from the ascending pharyngeal artery ; the medium cervical ganglion from the inferior thyroid ; and the inferior cervical ganglion, from the deep cervical artery, these arteries serving as permanent trunks of supply. At least one branch of the corresponding intercostal arteries supplies the blood to each of the thoracic ganglia. The supplying trunk is the one lying immediately above the ganglion. The abdominal and lumbar ganglia collect their blood supply likewise from the corresponding segmental vessel trunk, while the supply of the coeliac ganglion comes from the smaller branches of either the abdominal phrenic, renal, suprarenal or lumbar arteries. According to the authors cited, the macroscopic blood supply of the sympathetic ganglia is independent from that of the spinal ganglia, in spite of their common development.

Our own examinations were concerned with the microtopography and architecture of the vessels of the sympathetic ganglia. Lying in separate groups, these vessels form a number of vascular beds within the ganglia, an arrangement observable both in infants and adults. This pattern is especially marked in the superior cervical (Fig. 1) and the coeliac ganglia, while the vessels seem to be less sharply delimited in the stellate ganglion. An entirely different picture is presented by the vessels of the nerve fibres interweaving the ganglia, inasmuch as they form a fine network of anastomosing ascending branches, as has been reported in our previous papers on the blood supply of peripheral nerves. The vascular supply of the ganglionic cells is considerably richer than that of the nerve fibres passing through the ganglia, this difference being so conspicuous that in thick unstained preparations the areas with cell groups may be sharply distinguished from the nerve fibres on the basis of the number of vessels present (Fig. 1). The ratio of the vascular structure of the ganglionic cells to that of the surrounding nerve fibres is approximately the same as the ratio of the vessels in the basal nuclei to the angioarchitecture of the capsula interna.

The angioarchitecture of the sympathetic ganglia presents many a characteristic feature. The capillaries are thin. Apart from the large vessels in the centre of hilun-like vascular beds, no significant vascular dilatation is observable in infants, whereas in adults there are quite marked ampullary, cisternlike vascular dilatations in each sympathetic ganglion: most of these wide vessels correspond in size to postcapillary veins. Their diameter is especially large in the superior cervical ganglion (Fig. 2) where the average diameter of

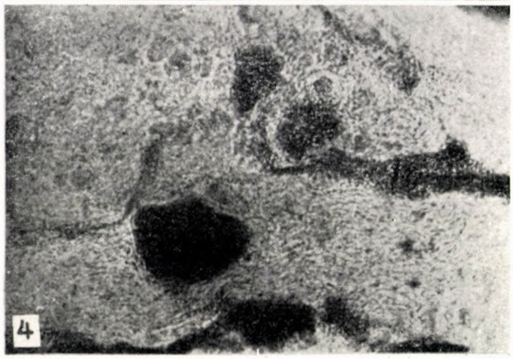



Fig. 1. Strongly detailed vascular system of ganglion cervicale superius. Gelatine injection ×80. Infant
Fig. 2. Broad venous sinusoids of superior cervical ganglion. Peroxidase reaction. ×120. Adult
Fig. 3. Dense, homogeneous vascular structure of spinal ganglion. Gelatine injection. ×80. Infant
Fig. 4. Sinusoids in spinal ganglion: though broad, they are considerably smaller than the sinusoidal vessels in the sympathetic ganglia. Peroxidase reaction. ×120. Adult
Fig. 5. Venous sinusoids in the caudate nucleus. China ink injection. ×40. Adult

100 ampullary vessels is 102,4 micra, while that of the venous sinusoids in the thoracic ganglia amounts to 90,9. These sinusoids can be found only among the densely packed vessels in the area of the ganglionic cells. The vascular pattern of the nerve fibres corresponds to the angioarchitecture of other nerves. The sinuses of the sympathetic ganglia are generally wider than those seen in the human spinal system and in hypothalamic nuclei.

Blood supply of the spinal ganglia

The blood supply of the spinal ganglia has been studied by *Bergmann* in some detail. He found the macroscopic blood supply of these ganglia to be collected from the spinal branch of the dorsal trunk of the segmental arteries, the venous blood being drained into the venous vertebral plexuses. The microtopographical conditions of the vessels in the spinal ganglia have not been examined by *Bergmann*.

Our own studies made in this respect have revealed that the vascular arrangement of the spinal ganglia was much more homogeneous than that of the sympathetic system, in harmony with the similar arrangement of the cells (Fig. 3). A separation of the vessels to distinct groups, similar to those described in the sympathetic ganglia, could not be observed (Fig. 3). The distribution of the nerve fibres in the spinal ganglia are perfectly identical with the general vascular conditions of the surrounding nerves, the situation in this respect being analogous to that described for the sympathetic system.

It has further been found that the vessels of the spinal ganglia are coarser, thicker, and their arborification more angular than those of the sympathetic ganglia. Small ampullary vessels can be observed in infants already. As regards adults, the spinal ganglia, too, contain marked ampullary venous sinusoids, as has been reported also by *Bergmann*. These sinusoids are however, considerably smaller than those in the sympathetic ganglia (Fig. 4). Whereas the diameters of the latter average 102,2 and 90,9 micra, respectively, the average diameter of the spinal sinusoids does not exceed 53,3 micra, approximately one half of the value found for sympathetic sinusoids. We have further observed that whereas the number of capillary loops was 123 per square mm in the sympathetic ganglia, this number averaged 231 in the spinal ganglia*. The capillary density in spinal ganglia is therefore approximately the double of the density in sympathetic ganglia.

* We have used the following method for ascertaining these figures. The capillary loops seated in the ganglia were, for simplicity's sake, assumed to form rectangles, and using the average lengths of their longer and shorter sides, respectively, the average area of the loops expressed in square micra was obtained. From this value was computed the number of capillary loops over an area of 1 square mm.

Discussion

Hagen has reported in a recent paper on the vascular pathology of the sympathetic ganglion that in cases of a spontaneous gangrene of the vessels, the ganglionic cells were destroyed over certain areas. He has also described the histopathological changes occurring in the ganglia in connection with obliterating endarteritis. Concerning these pathological processes we want to point out that the vessels in the sympathetic ganglia form separate groups around each of the larger vessel-trunks. If we compare this vascular arrangement with the more uniform vascular structure found in the spinal system where there is a marked anastomosis even between the larger vessels we are inclined to regard the sparsely anastomizing separate vascular groups of the sympathetic ganglia as functional terminal blood channels. These morphological observations might serve as a base for the appreciation of the vascular-pathological lesions in the sympathetic ganglia. It also deserves attention that the vascular supply of the spinal ganglia is about twice as rich as that of the sympathetic ganglia. Our previous investigations into the blood circulation of the nervous system have repeatedly confirmed that the degree of the vascular supply of any particular nervous area is in direct proportion to its functional importance. The motor cortex possesses many more vessels than, for instance the polar area ; the rich vascular structure of the hypothalamic neurocrine nuclei contrasts vividly with its surroundings ; in birds the functionally important cerebellum is the area most abundantly vascularized ; the areas of the peripheral nerves exposed to mechanical stress are likewise rich in blood vessels. The abundant vascularization of the spinal ganglia might also be explained by functional differences.

Before concluding the problem of the sinusoidal broad vessels observed in the ganglia should be discussed. Describing venous sinusoids of this kind in the spinal ganglia and in the coeliac ganglion, *Bergmann* suspected them to be pathological structures substituting ganglionic cells which gradually disappear with advancing age. He supposed that, filled with blood, these broad vessels exerted a pressure on their surroundings thus leading to degeneration and destruction of the adjacent neurons. Reporting on hypertensive vascular lesions in the ganglia, *Lattes* considered the system of venous sinusoids as arteriovenous anastomoses with the function of regulating the blood pressure. *Nonidez*, too, described the venous sinusoids in the sympathetic ganglia of the dog as the venous part of arterivenous anastomoses. None of the authors mentions a difference in size between the sinuses of the two systems. We cannot completely agree with either of the authors as regards the problem of venous sinusoids. We believe that the special structure in question cannot be explained unless vascular conditions in other nervous areas too are taken into account. The sinuses in the ganglia show a striking resemblance to the sinusoidal vessels as found in the spinal system of man and of the members of the phylogenetic row (Fig. 5), as also to the sinuses of the neurocrine nuclei in the hypothalamus, it being characteristic of these sinuses that, absent in infants, they appear in adult age. As the cytoarchitecture, so also the angioarchitecture of the phylogenetically more remote nervous areas presents a different pattern in so far as they are provided with large, broad, in some places sinusoidal vessels. We suggest that, apart from possible functional uses, the large sinusoids form a normal part of the sympathetic ganglia as phylogenetically ancient nervous areas. This would explain the smaller size of the sinusoids in the phylogenetically more recent spinal ganglia.

Summary

(i) The vessels of the sympathetic ganglia form separate groups. Such vascular groups surround larger vessels which may be considered functional terminal arteries. The vascular pattern of the spinal ganglia is more homogeneous.

(ii) The capillaries in the spinal ganglia are twice as densely packed as those in the sympathetic system. This phenomenon might be explained by functional differences.

(iii) Broad, venous sinusoids are observable both in the sympathetic and the spinal ganglia. The width of sinuses in the sympathetic ganglia considerably exceeds that of the sinuses in the spinal system.

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