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THE BLOOD SUPPLY OF THE GANGLION SYSTEM OF THE BRAIN STEM IN THE LIGHT OF PHILOGENESIS

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Compared to cyto- and myeloarchitecture, the angioarchitecture of certain areas of the brain is less known. The angioarchitecture of the ganglion-system of the brain stem, which is an area of the brain that is of great practical importance, is not known even in man. As regards comparative studies, this angiostructure has been worked out to an even lesser extent.

It was the aim of our investigations to gain closer insight into the angio-structure of the ganglionsystem of the brain stem.

We consider philogenetical investigations to be of importance, because these suport results obtained in man and point out those correlations which explain the role and significance of the different vascular systems.

To our investigations practical significance can be attributed in three directions:

a) We may follow up the philogenesis of the vascular structure of the stem-ganglionsystem, which enables us to draw conclusions to various problems connected with the role and significance of the ganglionsystem of the stem and in addition it presents an opportunity for making general observations concerning the vascular supply of the nervous system.

b) On basis of macro- and microscopical evidence obtained in connection with the vascular structure of the ganglionsystem of the stem, duely considering philogenetical viewpoints as well, we may draw conclusions elucidating the histophysiology — in the first place the normal hydrodynamics — of the described vessels, which may get us nearer to the determination of the role played by the ganglion- system of the brain stem.

c) Evidence obtained in connection with the vascular structure may serve as morphological basis in investigations concerned with vascular diseases of the ganglionsystem of the stem, first of all with apoplexy.

Method of Investigations

The problem was approached macro- and m'croscopically. To corroborate histophysiological conclusions animal experiments were done. For macroscopical studies the brain was injected with red lead hyperoxide (minium) suspended in terpentine oil (terebenthene) and X-ray pictures were taken of the brain containing contrast medium.

For microscopic studies 1 : 2 dilutions of china ink were injected. Injected material was in part examined in thick sections without staining; other specimens were stained in addition with methylene blue.*

RESULTS OF THE INVESTIGATIONS

1. Fish

As compared to the blood supply of the prosencephalom, the vascularization of the ganglionsystem of the brain stem is materially better developed. An extremely high number of perforating vessels can be seen, which run from

Fig. 1

China ink injection. 300 microns. Fish (carp) Vessels of the ganglia of the stem. In the middle veins with large diameters. *a)* wide veins. *b)* perpendicular arteries. Magnification : 40 x.

without into the stem and which are considered to be arteries. In certain areas distended veins can be visualised. — In the fish there are permanent connections between the two hemispheres. In a few sections enormous perpendicular vessels can be seen. As regards the diameter of the vessels, there are no significant differences between the vessels of the prosencephalon and those of the ganglionsystem region. In the areas corresponding to those of the diencephalon and mesencephalon the vessels are more densely arranged. The thickest vessels, considered to be veins, are of about 30 microns in diameter. The diameters of medium vessel vary from 10 to 20 microns, those of the smaller ones are

* For the microfotograms I am grateful to Mr. M. Müller.

5 microns or less. — In contrast to frogs, in bony fish (carps) that are of higher order philogenetically than the formers, more circumscribed vascular areas develop already. In these animals we may also find a few veins of greater (30 — 40 microns) diameter which are wavy, bulgy and resemble the branch of a tree. In Fig. 1. the aa. striatae can be seen ; in the middle several bigger vessels (veins) can be noted.

2. *Frogs*

In the region of the ganglia of the stem the vessels are bigger and vascularization is more dense than in the prosencephalon. The strongest are the aa. striatae, penetrating from the basis. Bigger vessels can be observed arround the ventricles as well. These vessels — on the ground of their arrangement — are considered to be partly veins and partly arteries. The vessels — as shown in Fig. 2. — form a rather homogenous network ; we cannot speak here of areas

Fig. 2
China ink injection, 300 microns. Frog. Posterior part of prosencephalon Complete hemisphere. Relatively homogenous vascular net. Magnification : 40 x

of flow. The vessels are quite thin. The thicker ones have a diameter of about 10 microns. These can be considered to be veins, inasmuch as the law of Roux can be applied to living beings of such low order. The thinner vessels do not exceed 2—3—5 microns in thickness. The aa. striatae themselves, resp. the basal perpendicular vascular stems have a diameter of 20 microns. In the peripheral parts areas of rather poor vascularization can be seen. From the point of view of philogenesis it is of interest that the brain-vessel system of the frog is considerably more homogenous than that of living beings of higher order.

3. *Chicken*

The brain stem of the chicken is similarly richer in vessels then is the prosencephalon. Here we can find a greater number of veins which in certain areas show bulgy dilation. Vessels of such characteristical distension can be seen in Fig. 3. Certain veins are tree-branch and cascade-like. In certain areas remarkably big vessels can be seen. — This vascular system of poultry is in general

Fig. 3
China ink injection, 300 microns. Chicken. Vessels of the ganglia of the stem. Very wide veins. Magnification : 40 x

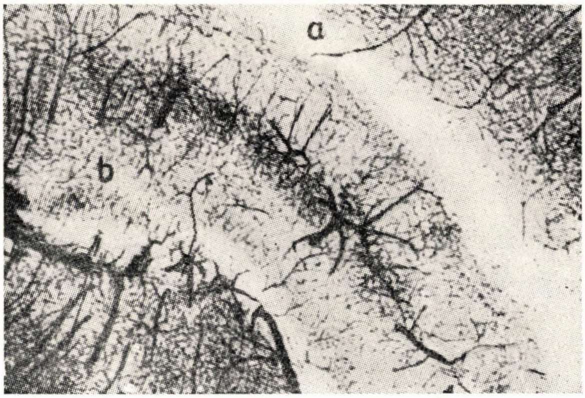

Fig. 4
China ink injection, 300 microns. Rat. Vessels of the ganglia of the stem. Cortical and stem ganglion structures are markedly differentiated from each other. *a)* vessels of the cortex. *b)* vessels of the ganglia of the stem. Magnification : 40 x

much more differentiated into separate areas of flow than that of the brain of fish. Individual larger vessels are found to be of even 60 to 70 microns in diameter. Medium vessels are 20 to 30 microns in diameter, that of the smaller ones varies between 10 to 20 microns. Veins are present in very great numbers and show extensive arborisation.

4. *Rat*

On comparing the vascularisation of the prosencephalon resp. of the cortical area it can be seen that the vessels of the stem are on the one hand more aboundantly present ; on the other hand, some of them exhibit quite different forms. (Fig.4.) Even in the low power view ve may note the considerably wide, ampoullary veins that are more marked than those in the brains of fish and chicken. (Fig. 5.). The medium size veins are 30—40 microns in diameter. The diameter of the arteries averages 20 to 25 microns. There is already marked differentiation in the angio-architecture of the cortical substance and ganglion-system of the stem in rat. (Fig. 4.) In certain areas — relatively infrequently —

Fig. 5
China ink injection, 300 microns. Rat. Wide, large vein in the ganglion system of the stem. Magnification of region b. of Fig. 4. Magnification : 100 x

sinuslike, distended veins (100 microns) can be demonstrated. The aa. striatae are 30 microns in diameter. Generally speaking in rats arteries preponderate to a greater extent than in poultry and fish.

5. *Cat*

In cat we find denser vascularisation in the area of the stem than in the cortico-medullary region. Characteristical are the extremely thick, arborising veins. Larger vessels are 30—40—50 microns in diameter. Ampoullary distensions can be observed in the larger veins, there are well defined sinuses as well. The diameter of these sinuses is around 50 microns. It is the veins that dominate in the region of the nuclei of the stem ; this is similar to the relations in the cortical areas, only even more marked. These veins are characterized by ampoul-like distensions, by their varying arborizing pattern as well as by their very large size as compared to other vessels. Medium vessels are 10 to 20 microns in diameter.

6. Dog

The vascular system in the brain stem of the dog strongly resembles that of the cat ; this fact is obviously explainable by the close philogenetical relation existing between these two species. At the same time there are marked differences in the cortical vascular structures ; in cat the number of veins is higher than that of the arteries, while in the dog it is the arteries that dominate. There are no such differences between the two spcies in the vascular structures of the nucleus system of the stem. This fact, together with others, also shows

Fig. 6
China ink injection. 300 microns. Dog. Wide vein in the area of the caput nuclei caudati. Magnification : 40 x

that the vascular structure of this area is a philogenetically old formation. In the cat and in the dog marked ampoullary, wide venous system can be demonstrated already in this area, with sinuslike bulges at certain sites, as it is shown in Fig. 6.

7. Infant (human)

In the newly born child very thin, homogenous vascular network can be found in the brain stem. In certain areas thicker, but not too branching vessels can be seen:, that are about 20 microns in diameter. Thin vessels are 2—5 microns in diameter. They are loosely distributed as compared to the corresponding areas is smaller animals. At certain sites bulges resembling the sinuses of the nucleus systems of the grown man's brain stem are found ; these represent an early form of the latter. In Fig. 7. the materially more homogenous angio-structure of the newborn is shown.

Fig. 7
China in injection, 300 microns. Newborn child. Caput nuclei caudati. As compared to the adult, relatively homogenous angiostructure. Magnification : 40 x

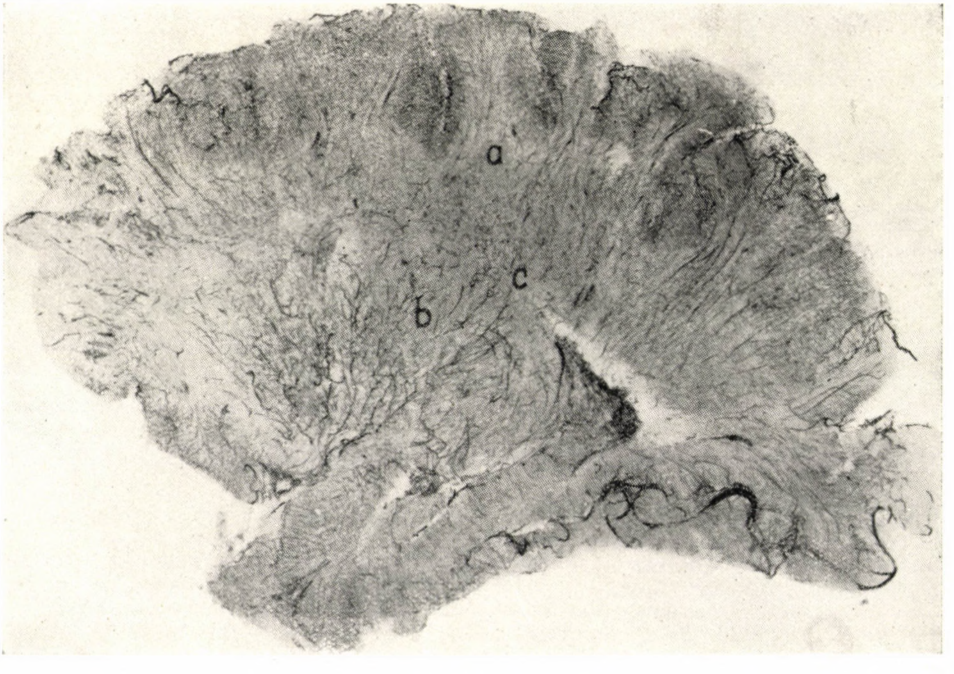

Fig. 8
Man. Connection of aa, striatae with the cortico-medullary vessels. (2 cm thick section, minium-therebenthene injection.) Roentgenogram, natural size. *a)* aa cortico-medullares. *b)* aa. striatae externae. *c)* anastomosis between the two vascular systems

8. Human adult

Roentgonological examination of the brain stem arteries of man has shown that the aa. striatae can be divided into two groups : aa. striatae externae and internae on the basis of their length and topographical distribution. Fig. 8. The external striated artries are considerably longer than the internal ones and they communicate only in man with the aa. corticales longae, which fact

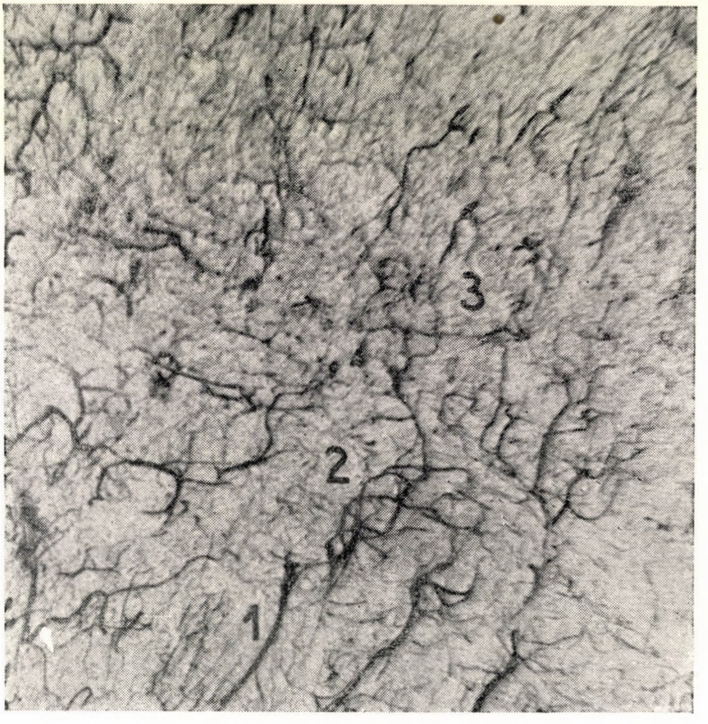

Fig. 8/a

Roentgenogram. Anastomosis between the two vascular systems. 1. aa. striatae externae ; 2. anastomosis ; 3. aa. cortico-medullares. Area c. in Fig. 8

proves beyond doubt that the aa. striatae cannot be called terminal arteries. The aa. striatae externae, apart from their relative length, are also present in greater numbers than the aa. striatae internae, which is a fact that may have to be considered in cases of surgical interference. Fig. 8. shows the aa. striatae externae and their anastomosis with the aa. cortico-medullares. In Fig. 8/a high power view of these communications is presented.

Roentgenological examination of the veins in this region reveals that the veins do not run parallel with the arteries at all, but they take, in the majority

of cases, a course of outward direction toward the insula. In the subinsular region we always find a large, connective vein that communicates abundantly with the insular veins. (Fig. 9.)

Fig. 9
Man. Venae striatae and their connections with the insular veins. (Section of 2 cm thic kness. Minium-therebenthene injection. Roentgenogram.)

Together with macroscopical findings, histological studies have also revealed that the ganglionsystem of the human brain stem has a special vascular structure. This vascular structure can be differentiated from that of other regions even in animals, but it is in man that its special character is most markedly seen. In this area, in accordance with the rule of Roux, the veins dominate. The veins are extremely wide and have a great number of branches. Their diameters are so large that the term : »sinusoid vascular system« is suggested for proper terminolgy. (Fig. 10).

These wider veins are 80 to 100 microns in diameter. Occasionally they may be even wider. The maior vessels have many branches, in general they resemble the branches of a tree. They bear strong resemblence to the similar vessels of fish, rats, chickens etc., from which they differ only in size. This angioarchitecture is another proof of the fact that the ganglion system of the brain stem is a philogenetcally old part of the nervous system. In certain areas the veins show pond-like distensions; this is most often seen at sites where the individual tree-branch veins join each other. These bulges are, beside the smaller

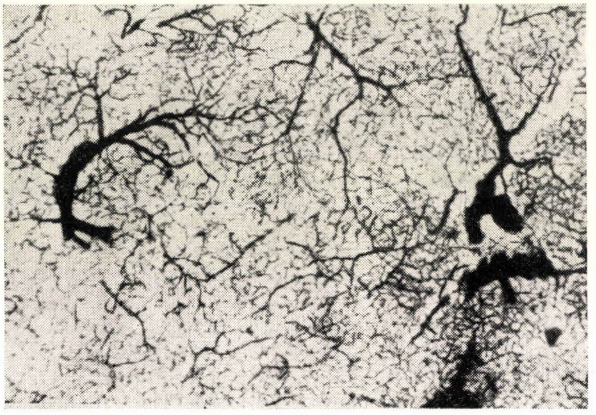

Fig. 10
China ink injection, 300 microns. Man. Vessels of the nucleus lentiformis. Ampoullary, sinusoid veins. Magnification: 40 x

or greater extravasates present in injected sections, with certainity not to be considered to be by-products, bearing in mind the following considerations:

a) We have found the same structures in six different injected brains.

b) Similar formations can be followed along the philogenetical line, where we have worked with more specimens, too.

c) Sinusoid angiostructures can be demonstrated in non-injected preparates as well.

d) To rule out extravasates and the suggestion that the described veins became distended as the result of injection it is mentioned in addition to the aforesaid facts that in the cortex of the same brain in which sinus-like veins could be demonstrated in the stem, no such dilated veins could be observed.

e) Similar veins have been described by Pfeiffer in the thalamus and in the corpus geniculatum laterale.

Topographical differences

In the ganglionsystem of the brain stem angiotopographical differences of some significance can be found in the arterial system, in connection with the described arrangement of the aa. striatae. Apart from the already described connective vena striata system, there are no marked differences in the venous system. On the other hand, it is of interest to study the vascular system connecting the stem ganglion structure with the capsula interna. Certain stem branches are continued in the internal capsule in the form of straight, elongated branches. As a result of this that part of the internal capsule that is nearest to the nuclei of the stem is relatively richer in vessels than the medullar substance in general. (Fig. 11.)

The special venous structure of the stem nuclei is in our opinion suggestive of the possibility that these veins may be praedilectional sites in cases of apolexy.

In order to investigate the behaviour of these veins when the speed of flow is pathologically reduced, the following experiment was performed :

The iugular veins on both sides were ligated in a cat. By this ligation we did not cut off completely the flow from the brain of venous blood, we only reduced it, since the plexus venosus vertebralis and venae cervicales etc. represent a collateral system of sufficient capacity for the maintenance of life. Eight days later, following the washing of the vessels of the brain with formalin, the animal was killed. When compared to a control animal we found that the stem veins operated upon were 2 to 5 times wider than those in the control brain. A loosening up in the walls of the veins in the region of the stem nuclei could also be observed in the operated animal.

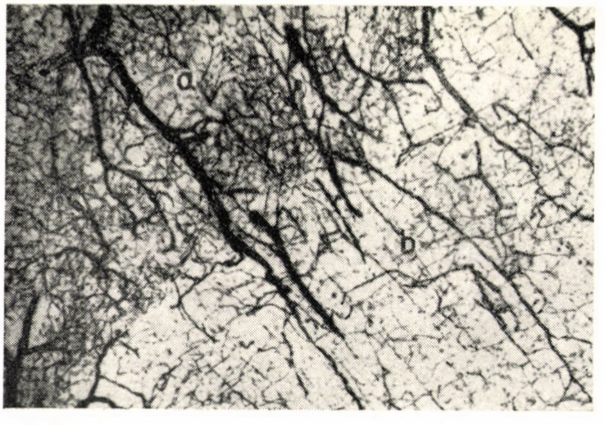

Fig. 11
China ink injection, 300 microns. Man. Transitory area between the angiostructure of capsula interna and nucleus caudatus

In the part of the internal capsule adjacent to the nucleus caudatus vessels of large diameters are still visible. Magnification : 40 x. *a)* Angio-structure of nucleus caudatus. *b)* Angio-structure of the internal capsule.

CONCLUSIONS

We find no exact description of the vascularisation of the ganglion system of the brain stem in literature ; the most we can find is occasional allusions to this topic. Thus sinus-like veins have been described in the thalamus and corpus geniculatum laterale — being somewhat related to the ganglion system — by *Pfeiffer*. *Hoagh-Wolff*, studying the vessels of the ganglion system of the brain stem in cats, have found that the theory, according to which within the nervous system the blood supply is directly proportionate to the total surface of nerves, is valid in this region of the nervous system as well. In this connection we may confirm the statement that blood supply in general is proportionate to the greatness and importance of function. *Locchi* and *Scharrer* have dealt with the problem of the terminal arteries in the brain. According to the former there are no terminal arteries in the human brain, while the latter found terminal arteries in the brain of the opossum. In this respect we have found that the aa. stritae in the course of philogenesis come nearer and nearer to the aa. cortico-medullares and in man there are doubtlessly established communications between them.

The uniformity of the results obtained in different individuums on the one hand, the similar results obtained in different species of the philogenetical line on the other, with due consideration given to those we said earlier, appear to confirm the view that the special angiostructure of the ganglion system of the brain stem is no artificial product, but here we deal with a real sinusoid venous system that is most marked in man.

On basis of the phisical law of flow, according to which the speed of flow is in invers ratio to the diameter, it can be supposed that in the sinus-like venous bulges the flow is slower even under normal circumstances. This hydrodynamical condition renders these sinusoid veins a possible site for thrombus formation as well as for lesions to the wals of the vessels, if, due to pathological changes, the flow of blood becomes reduced.

It was in the light of this theora that we performed the animal experiment mentioned above.

Several ruptures due to injection could be observed in the area of the vessels of the stem ganglia. *Pfeiffer* considers these to be experimental apoplexies. These ruptures occur mainly in the described ampoullary veins, resp. in the venous cisternes.

We mention here that we do not consider these so called experimental apoplexies to be a sufficient investigation method and results concerning them have been mentioned for the sake of completeness only.

Summary

1. The vascularization of the ganglion system of the brain stem has been subject to macro- and microscopical investigations.

2. Investigations carried out in the vascular system of the brain stem in fish, fogs, chickens, rats, dogs and cats have revealed that the vascular structure of the stem ganglia shows a materially less marked development upward in the philogenetical line than that of the cortex. As we come, on the other hand, to species of higher and higher order, the veins in the region of the ganglia of the stem become wider and wider.

3. In man we have found that the aa.striatae externae are longer and more densely arranged than the internae and they communicate with the aa. cortico-medullares. The veins of the stem do not follow the course of the arteries. In the subinsular region a lerge vein can be found that communicates freely with the insular veins, and resembles a clasp in form. The human ganglion system of the brain stem has a special angiostructure consisting of ampoullary, cisterne-like, sinusoid veins.

4. From the morphological conditions we may draw histophysiological conclusions, according to which it may be assumed that the circulation in this system may be slower even normally ; in case of impaired circulation, on the other hand, this system may serve as a site of predilection for lesions to the walls of the vessels and for consecutive haemorrhages.

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КРОВОСНАБЖЕНИЕ УЗЛОВ МОЗГОВОГО СТВОЛА С ТОЧКИ ЗРЕНИЯ ФИЛОГЕНЕТИЧЕСКОЙ

Ф. Бэлэньи

Резюме

1. Мы исследовали макроскопически и микроскопически кровоснабжение системы узлов мозгового ствола.

2. При исследовании сосудов узлов мозгового ствола у рыб, лягушек, кур, крыс и у собак оказывается что система сосудов узлов ствола мозга развивается в ходе филогенетического развития в гораздо меньшей степени, чем система сосудов кори мозга, и что чем выше стоит данное животное в филогенетическом разряде, тем шире просвет вен узлов ствола мозга.

3. У человека мы находим, что aa. strictae externae более длинные и более богато разветвленные, чем aa. striatae internae, и что они анастомизируют со aa. corticomedullares. Вены узлов ствола не сопровождают ход артерий; в области под островом располагается большая вена скобко-образной формы, которая дает много анастомозов к венам острова.

4. На основе морфологических данных можно сделать тот гистофизиологический вывод, что кровообращение этой области является более медленным и в нормальных условиях, а что при ухудшении кровообращения на этом месте возникают легче всего повреждения стенки сосудов с последующими кровоизлияниями.