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THE BLOOD SUPPLY OF THE NERVES IN THE LOWER EXTREMITY

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We were aimed to study blood circulation in the nerves of the lower extremity, anatomically, histologically and histophysiologically. Since the blood supply of peripherical nerves was not investigated formerly in a proper way and scarce data are to be found in literature hereupon, a methodical study of this subject seems to be of some value, especially if connections to the medical practice are taken into consideration.

The blood supply of the nerves in the lower extremity is closely connected with trophical disturbances and inflammations of these nerves. In the clinical evaluation of ischialgia, of other neuralgies and of neuritis-cases attention is to be paid to the nutritional status of the nerve involved, i. e. to its blood supply also.

Practical connections of the blood supply of the nerves are obvious with reconstructive surgery, since in reestablishing nervous conduction, the blood supply is of a determinant importance. Circulation in the nerves has some importance in the propagation of infections also, and in the doctrines of nervism, dealing with distant reflectory effects. Obviously, in the mutual influence of pathogenic bacteria and peripherical nervous system, a considerable role is to be attributed to the blood supply of the latter.

The neurosurgical volume of the *Kischner—Nordmann* textbook states that blood supply and vascularisation of the peripherical nerves are nearby totally unknown though knowledge hereupon would be of a great practical and theoretical importance.

Being aware of this unsatisfactory knowledge, we were aimed to study the blood supply and vascularisation of the nerves in the lower extremity, as the first part of a more extensive research.

In order to demonstrate the nerve-vessels, liquid rubber, X ray contrast and India ink injections were made.

For injecting fine vessels, liquid rubber proved to be very suitable. Rubber readily dissolves in diluted ammoniumhydroxyde, the solution is a milky fluid that can further be diluted arbitrarily. Addition of different dyes is permissible. We are not compelled to wash the vessels prior to injecting ; injection can be performed without further preparatory measures. Since the vascular walls of fresh corpses offer a considerable resistance, corpses after a few days standing were preferably used. The fine vessels are totally filled by the injected dissolved rubber that intrudes occasionally into the veins too. In our opinion, filling of the veins occurred by pre-

capillary arterio-venous anastomoses rather than through the capillaries (on a transcapillary way). After the relapse of an interval, the rubber becomes hardened, elastic, and in this stage the vessels are easily prepared anatomically since the elastic rubber fibers are rarely cut.

The finer vascularisation of the peripherical nerves is easily studied roentgenologically. Iodine or an other contrast material is mixed to the liquid rubber, and in this way the injected stuff is suitable for X-ray examinations too. Well suited for this purpose proved turpentene oil mixed with minium. The contrast material filles finer branches of the vessels that are not filled by the more viscous rubber. In this way, finer vascularisation is demonstrable than by simple injections technics.

Injection of India ink proved recently to be a suitable method of demonstrating vascularisation. India ink is one of the most useful injection materials ; it completely fills even the finest vascular nets. As advantage of the India ink injection we have to mention that from closed canalicular systems it is not given off, it is suitable for preparing microscopic specimens too, and the filling of the vessels remains constant. Greater vessels are not be filled with India ink, since the injected fluid is distributed in the single branches, while the finer vessels are totally filled because of the lacking viscosity of the fluid. By India ink even the veins of the nerves can be well filled. It is our opinion that the India ink comes into the veins by a transcapillary way. Filling the veins adds to demonstrating the density of the small vascular channels.

1. The sciatic nerve

The blood supply of the upper portion was examined in connection with the vessels of the sacral plexus. The artery, supplying with blood the upper part of the lumbo-sacral plexus (called truncus lumbo-sacralis), together with the initial part of the sciatic nerve, is the a. glutaea superior, coming from the a. hypogastrica. A branch coming off from the superior gluteal artery, anastomosing with a branch of the inferior gluteal one, is generally called a. comitans nervi ischiadici. The middle portion of the upper part of the nerve is supplied by a nerve branch of the a. glutaea inferior. There is often an anastomosis between this branch and that from the superior gluteal artery. On the nerve surfaces, ascending and descending rami are formed by the inferior gluteal artery. The lower third of the upper portion of the sciatic nerve receives its blood supply through the a. perforans I., coming from the deep femoral artery. Though this artery gives off some rami on the nerve-surface, its ramification is less dense than that of the aforementioned superior and inferior gluteal ones. The veins are adjacent to the arteries ; occasionally thicker branches are found between the nerve fiber bundles. Accordingly, reflux occurs through the superior and inferior gluteal veins to the hypogastric vein, and through the first perforant vein into the femoral one (Figs. 1/a and 1/b).

The lower portion of the nerve, in the posterior femoral region, is supplied by the first, second and third perforant arteries. The nerval branches of these arteries are divided into a stronger ascending and smaller descending ramus. Here the veins are adjacent to the arteries.

The finer vascular distribution is demonstrated in roentgenograms and microphotograms. Within the sciatic nerve, a rich vascular net is visible, situated at different levels. The superficial vessels are stronger, and in some instances division into an ascending and descending branch is quite obvious (Fig. 5/a

and 5/b). In 500—600 micra thick sections of specimens injected with India ink, stronger trunks are seen between nerve fiber bundles (Fig. 6). These stronger trunks are situated between the fiber bundles, in loose perineural tissue. However, within the nerve fiber bundles a few vascular channels can be seen of wider or narrower lumen, running partly perpendicularly, partly obliquely to the nerve fibers. In stained specimens and in longitudinal sections it has been clarified that by the injection arteries as well as veins were completely filled. Veins are differing from arteries by their wider lumen, typical arborisation and diverse width of lumen, as stated by *Roux* and *Pfeiffer*. Around stronger arteries several veins are seen, while smaller arteries and veins are found in an approximately equal number within the nerve, being situated adjacently.

In the sciatic nerve, two areae of vascular supply are to be distinguished : a peripherical and a central one. The peripherical area displays generally smaller vessels, while in the central one stronger trunks are found (Fig. 7). A central main artery was demonstrated in all specimens, being accompanied by a main central vein. Laterally, in most specimens 2—3 stronger arteries were seen too, with adjacent veins.

2. Posterior tibial nerve

The vascular supply of this nerve has been examined macroscopically in three regions : where it is coming off, in the popliteal fossa and in the posterior crural region. At the first commencement arteries are coming from the third perforant one and from the articular ramus of the a. poplitea. In the popliteal fossa the arteries are branches of the third perforant artery (in the upper part), and of the middle section of the popliteal one (in the central and lower part (Fig. 2/b). The vascular branches entering the nerve display a regular distribution into an ascending and descending ramus, continuing this type of distribution — and giving off additionally lateral branches too— between the nerve fibers. In the cranial part of the posterior crural region arteries are entering the nerve at two sites, coming off from the posterior tibial artery, forming ascending and descending rami. In the lower part of the same region, two stronger trunks are coming to the nerve from the posterior tibial artery ; these are distributed into ascending and descending rami also. The veins are mostly adjacent to the arteries. At the inner ankle, there is a rich vascular supply of the nerve, receiving branches at three sites from the adjacent posterior tibial artery.

X rays reveal a vascular net, consisting of stronger and finer branches within the tibial nerve.

In specimens injected with India ink it has been demonstrated that in the cross section of the tibial nerve there are a less number of vessels than in the sciatic. In the center, a central artery and vein are seen in this nerve too. Stronger vessels are found in the perineurium, between nerve fiber bundles.

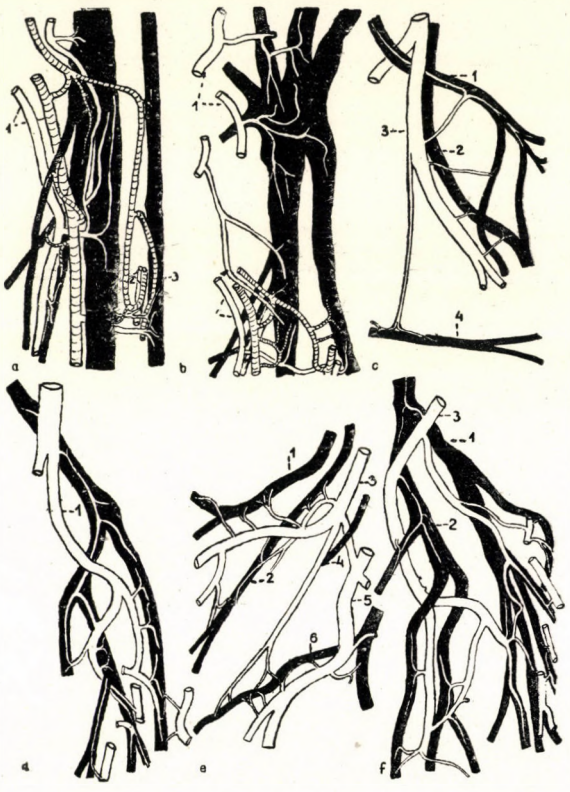


Fig. 1.

a) Arteries and veins of the great sciatic nerve.
1. Aa. et vv. gluteae inferiores.
2. A. et v. perforantes primae.
3. N. cutaneus femoris posterior.

b) The vessels of the sacral plexus and of the upper third of the great sciatic nerve.
1. Vv. gluteae superior et inferior.
2. A. et v. perforantes primae.

c) N. peroneus superficialis, n. peroneus profundus, n. saphenus.
1. N. peroneus profundus.
2. N. peroneus superficialis
3. A. tibilais anterior
4. N. saphenus.

d) The vessels of the medial plantar nerve.
1. A. plantaris medialis.

e) The vessels of the nerves on the dorsum pedis.
1. N. cutaneus dorsalis pedis medialis.
2. N. cutaneus dorsalis pedis intermedius.
3. A. tibialis anterior.
4. N. peroneus profundus.
5. A. peronea.
6. N. suralis.

f) The vessels of the nerves in the planta pedis.
1. N. plantaris medialis.
2. N. plantaris lateralis.
3. A. tibialis posterior.

Within the bundles, no stronger vessels are seen. A peripherical and central vascular supply area is found in the tibial nerve too, yet less markedly than in the sciatic.

3. Superficial and deep peroneal nerve (anterior tibial)

The common peroneal nerve trunk (n. peroneus communis) is less vascularised than the posterior tibial nerve. Arteries are coming from the third perforant and posterior tibial ones, displaying typical fork-like distribution into ascending and descending ramus, within the nerve.

In the upper portion of the anterior crural region an artery, coming from the anterior tibial one, is running parallelly to the deep peroneal nerve, without giving off any branches, visible macroscopically, to it (Fig. 2/c). In the same region, the superficial peroneal nerve receives its supply from the peroneal artery. In the lower portion of this region, some branches are given off by the anterior tibial artery to the deep peroneal nerve, and to the superficial peroneal nerve by the peroneal one. In the external malleolar region the deep peroneal nerve receives three thin arterial branches from the a. dorsalis pedis ; these branches divide on the nerve surface further (Fig. 1/c). Blood supply of the superficial peroneal nerve comes from the anterior tibial artery.

Within the common peroneal nerve a rather mighty arterial trunk has been demonstrated roentgenologically, without displaying any interruption. Seemingly, this arterial trunk comes into the nerve in two branches in the inferior portion. Occasionally, anastomosing collaterals are seen also. Division of the vessels into ascending and descending rami is obvious, and net formation in a few areae also (Fig. 5/c).

In India ink injected specimens the central artery and vein are clearly visible. In the single fiber bundles, a system of a main central and small peripheral arteries is obvious. A similar system was demonstrated in the vascular supply of the deep peroneal nerve too.

4. N. cutaneus surae medialis, n. cutaneus surae lateralis, n. suralis

The n. cutaneus surae medialis receives its vascular supply from the adjacent muscle arteries, mainly from the muscular branches of the gastrocnemius muscle, thus indirectly from the posterior tibial artery. Only smaller vessels enter the substrate of the nerve, forming within a more or less marked fine network. The main nerval branches of the arteries are on the nerve surface and enter the nerve substrate segmentally, dividing into an ascending and descending ramus. Between the latters anastomoses exist and, thus, a continuity of the vascular canalisation is demonstrable. (Fig. 2/d).

The vessels of the n. cutaneus surae lateralis are coming off from the third perforant artery and from articular branches of the popliteal one. The vasa nervorum are mostly running on the surface of the nerve rather than within the substrate, between the fiber bundles (Fig. 2/a).

The sural nerve, being formed by union of the aforediscussed ones, receives an artery coming from the peroneal one. This rather large trunk describes a forke-like course cranially, partly between the fibers, partly on the surface of the nerve. From the one belly of the gastrocnemic muscle a branch of the muscular artery is coming off that runs initially on the surface of the tendon and then enters the nerve substrate, dividing into an ascending and descendind ramus. This type of vascularisation is a transitory one, between the types characteristical for large and small nerves.

5. The femoral nerve

To the first commencement a rather small artery is going, entering the nerve substrate. This artery is coming off from the pelvis, it is a branch either of the a. circumflexa ilei profunda or of the a. epigastrica inferior. From the anastomosis between the a. iliolumbalis and a. circumflexa ilei profunda, a second branch is often running to the upper portion of the femoral nerve (Fig. 2/f). An other nerval artery comes off from the deep femoral one, and after having entered the nerve, it divides whisk-likely into the single branches of the femoral nerve. The type of vascularisation resembles that typical in smaller nerves : the artery runs on the nerve surface and enters in some area the fibers. Each nerve branch seems to have an artery proper. The veins belong mainly to the great saphenic one (Fig. 2/e).

Microscopically, a considerably richer vascularisation is revealed than is found in the peroneal and tibial nerves. A central vascular trunk is demonstrated in the femoral nerve too. In the single nerve fiber bundles, central and peripherical vessels are seen here too ; however, peripherically more and larger vessels are found than centrally. In the connective tissue layers between the bundles stronger vasa are seen. As regards their direction, most vessels within the fiber bundles are running perpendicularly to the nerve fibers.

6. The anterior cutaneous femoral nerve

Rather thin vessels enter the substrate of the nerve, coming off from cutaneous arteries, mainly from the cutaneous femoral ones. Vascularisation is of the small nerve type : the vessels enter at some sites — coming from the adjacent connective tissue — the nerve substrate.

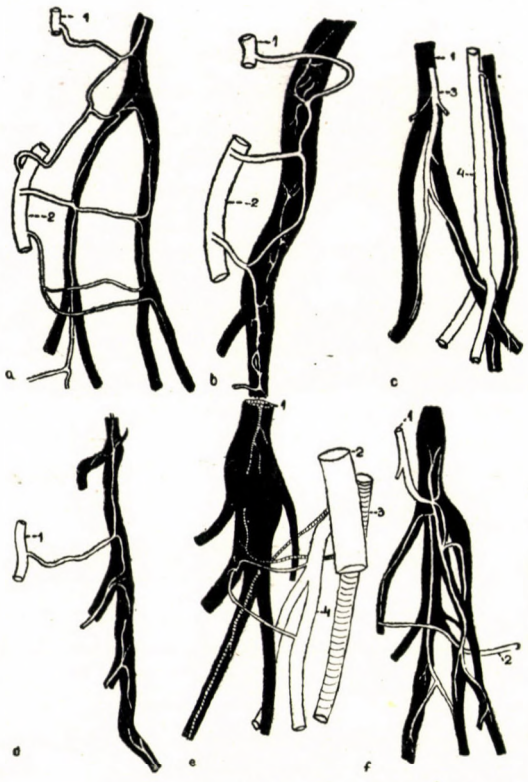


Fig. 2.

a) Nervus cutaneus surae lateralis and its ramifications.
1. A. perforans tertia.
2. A. poplitea.

b) The tibial nerve within the popliteal fossa.
1. A. perforans tertia.
2. A. poplitea.

c) Nervus peroneus superficialis et profundus.
1. N. peroneus superficialis.
2. N. peroneus profundus.
3. A. peronea.
4. A. tibialis anterior.

d) Nervus cutaneus surae medialis.
1. Muscular branch of the posterior tibial artery.

e) Arteries and veins of the femoral nerve.
1. Ramus arteriae circumflexae ilei profundae.
2. V. femoralis.
3. A. femoralis.
4. V. profunda femoris.

f) Nervus femoralis.
1. Anastomosis between the a. iliolumbalis and a. circumflexa ilei profunda.
2. Ramus arteriae profundae femoris.

7. The obturator nerve

Arterial branches are coming to this nerve from the deep femoral artery. Veins are going to the deep femoral vein. Anatomically, the venous net of this nerve has been prepared.

8. Saphenic nerve

Blood supply is provided by cutaneous branches of the anterior tibial artery, and in the lower portion, where the nerve runs along the inner border of the foot, by the a. dorsalis pedis (Fig. 1/c).

Microscopically, between the nerve fibers, forming small bundles, several vessels are seen, giving off small branches to the fibers themselves. This nerve is abundantly vascularised, within the fiber bundles several vascular channels were observed. They are in the bundle rather peripherically and are going perpendicularly to its center.

9. Nn. cutanei dorsi pedis — medius, intermedius and lateralis

These nerves of the dorsum pedis are supplied segmentally by branches of the adjacent arteries. Several fine branches are seen, being given off from the main trunks, running to the nerves, and than mainly on the nerve surface longitudinally or displaying a fork-like division. There is a continuity between the ascending and descending rami of these different vessels (Fig. 1/e).

10. Nn. plantares — medialis et lateralis

The plantar nerves are small ones and display a vascularisation typical for small nerves. The nerval vasa are running on the surface, display a fork-like division into ascending and descending rami, with multitudinous anastomoses, giving off supplying small branches at nearby every site to the nerve substrate. The vasa nervorum are coming from the medial and lateral plantar artery, segmentally, to the adjacent nerves (Figs. 1/d, 1/f).

Conclusions

Vascularisation of the peripherical nerves is — according to our observations — segmental in every instance ; thus, the nerves receive their blood supply from adjacent and near arteries. Nerval arteries proper, described anatomically in connection with some nerves, as e. g. with the great sciatic one, consist in reality of anastomoses between several segmental arteries. Arteries entering the peripherical nerve, divide into an ascending and descending ramus. In well prepared specimens anastomoses are seen between these rami

and those of the adjacent segments. Lateral and collateral branches are given then off from these first ascending and descending rami, entering deeper parts of the nerves, dividing similarly into ascending and descending rami, and form-

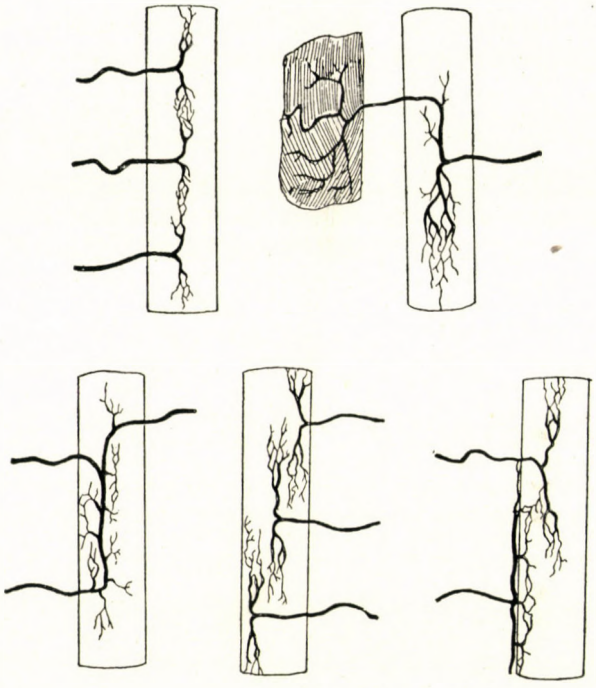


Fig. 3.
Schematic sketch of ascending and descending ramification of the vessels in large nerves.

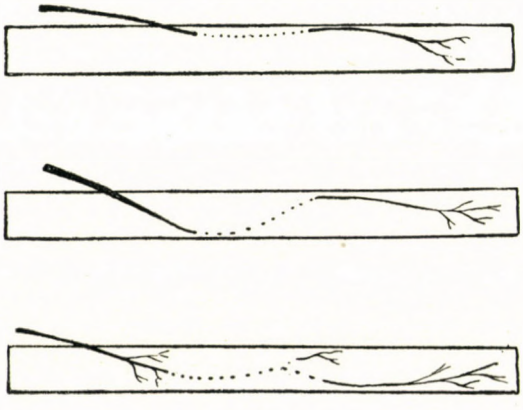
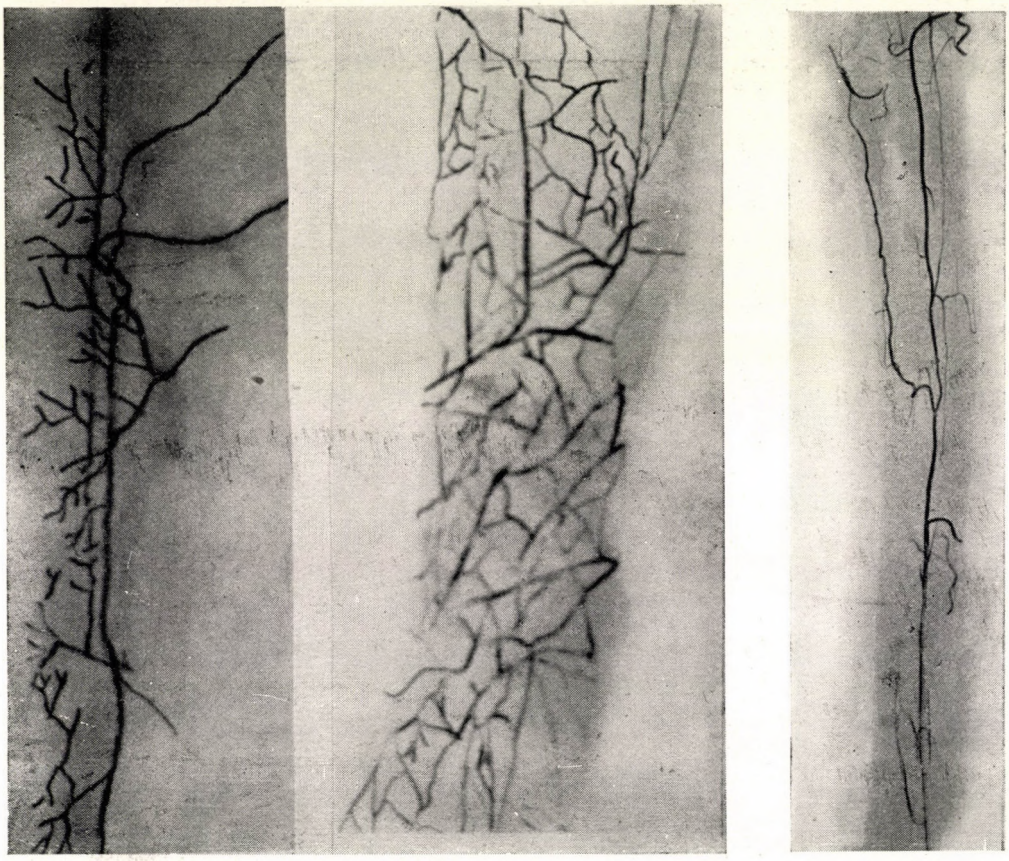


Fig. 4.
Schematic sketch of the piercing type of vascularisation, met with in nerves of small size.



a) b) c)

Fig. 5.

a) X-ray of the vessels of the great sciatic nerve. They are situated at different levels. The superficial ones are thicker ; their distribution into ascending and descending branches is obvious, similarly the vascular net, formed by further division of the primary branches.

b) X-ray of the one radix of the sacral plexus. Ascending and descending branches of the vessels are clearly demonstrated. The further arborisation occurs in a whisk-like manner.

c) X-ray of the common peroneal nerve. A large vessel is running parallelly to the nerve trunk. Some branches are given off, distributing into ascending and descending rami.

ing amply anastomoses. Finally, a vascular net results (Fig. 3). Vascularisation consisting of parallel branches and interim cross branches is characteristical for longitudinal organs, like the spinal medulla, ureter, etc. The spinal cord receives everywhere additional cross-running vessels. The main arteries are the anterior and posterior ones, receiving anastomoses segmentally from the deep cervical artery, from the intercostal ones, etc. ; as a result of these anastomoses the spinal arteries display an equal width through the total length of the spinal medulla. Branches entering the medulla divide into ascending and

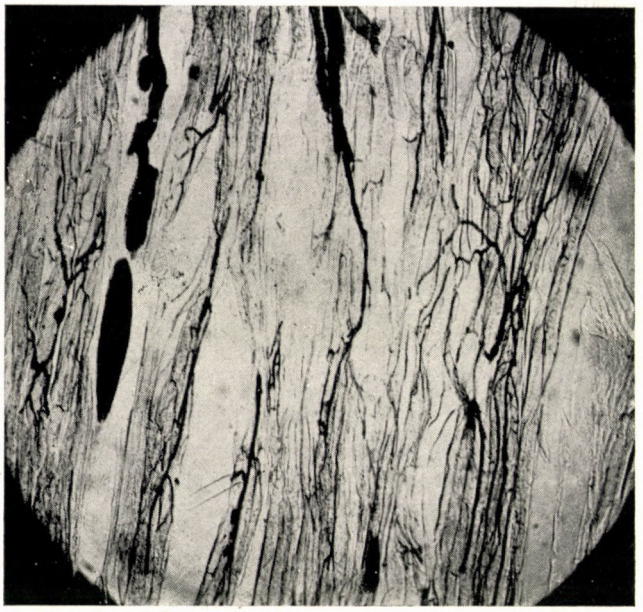


Fig. 6.
Longitudinal section of the great sciatic nerve. Vascular net of parallel constituents.

descending rami; by the latters cross branches are given off. In this way, a vascular net is formed in the spinal medulla. In a similar segmental way the ureters are vascularised too. While the ureters are running on the posterior wall of the abdomen and then of the pelvis, their main supply comes from

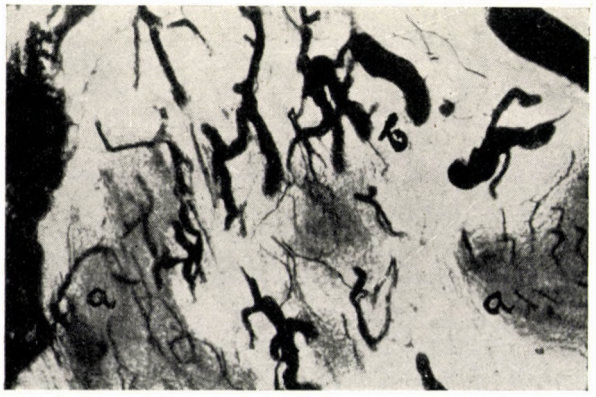


Fig. 7.
Cross section of the great sciatic nerve.
a) peripherical zone, containing small vessels;
b) central zone, containing large vessels.

the a. spermatica interna, and more caudally from the a. renalis, hypogastrica vesicalis inferior. This type of vascularisation is indicative that we are not permitted to prepare the ureter or any other longitudinal organ free of adjacent structures in a longer portion, in operations. Similarly, separation of the supplying vessels is not permissible for longer sections. The excellent vascularisation of the nerves, described above, with numerous anastomoses, makes it obvious that nerves are permitted to be freed from the adjacent structures in regions not to extended, without the risk of damaging the blood supply. In thin nerves, the supplying artery is running on the nerve surface for longer sections twistedly traversing the nerve substrate at some sites. This type of vascularisation (Fig. 4) we denote as the piercing one.

As regards the nerves of the lower extremity, the blood supply was found proportional to their thickness on the one hand, and the area innervated on the other hand. The sciatic nerve whose neuralgiae are often due to some nutritional disturbance, receives the blood supply from several sources ; of blood circulation is interrupted in any of these supplying branches, a collateral circulation seems, thus, sufficient to satisfy metabolic requirements of the nerve.

The blood supply of peripherical nerves is an important factor in their normal activity. Some therapeutic measures are based upon a plentyful blood supply of the nerves involved, i. e. on their improved nutrition.

Summary

The blood supply in the nerves of the lower extremity has been examined by aid of liquid rubber, X ray contrast material and India ink injected.

Two main types of vascularisation were found :

1. In thick nerves and in those of medium size, like the great sciatic, anterior tibial, common peroneal, etc., segmental arteries enter the nerve and divide into ascending and descending rami. These latters form by cross and oblique branches a vascular net.

2. In thin nerves, like the cutaneous femoral, the deep and superficial peroneal one, etc., the vasa nervorum are running on the surface of the nerve, and enter at some sites its substrate, penetrating the peripherical nerve and appearing on the opposite side. This type of vascularisation authors denoted as the piercing one.

Diversities of these two main types of vascularisation are also seen.

The nerval vasa are situated in the peri-, epi- and endoneurium. The vascular trunks of the nerve fibers are in the adjacent connective tissue. Microscopically is was stated that in the substrate of thicker nerve trunks a peripherical and central vascular zone can be distinguished, the former containing the smaller, the latter greater vessels.

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КРОВОСНАБЖЕНИЕ НЕРВОВ НИЖНЕЙ КОНЕЧНОСТИ

З. Сабо—Ф. Бэленьи

Резюме

Мы исследовали кровоснабжение периферических нервов нижней конечности впрыскиванием в сосуды жидкой резины, контрастного вещества и туша.

На нервах нижней конечности можно различать два главных способа кровоснабжения :

1. Сосуды вступающие по участкам в толстые и средне толстые стволы, в роде седалищного нерва, большеберцового нерва и малоберцового общего нерва, разветвляются на восходящую и нисходящую ветви, которые, отдавая поперечные и косые разветвления, — образуют сосудистую сеть.

2. Сосуды более тонких нервов, как например кожного нерва бедра, глубокого и поверхностного малоберцовых нервов, и. т. д. идут по поверхности нервного ствола, местами проникают в вещество нерва, прободают нерв и опять выходят на поверность на противоположной стороне. Этот способ кровоснабжения называется нами »кровоснабжением путем прикаливания«.

Встречаются и способы кровоснабжения. Место, направление, и разветвление сосудов расположены в перинервальной, эпинервальной и эндонервальной соединительных тканях. Сосудистые стволы нервных волокон всегда расположены в межволокнистой соединительной ткани. На гистологических срезах можно установить, что в более толстых нервех имеется, содержащая мелкие сосуды, периферическая, и содержащая более крупные сосуды, центральная зона.