قسم : التشـــريح والهســـتولوجيـــا .
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المدد الدموى الشرياني للحبل الشـوكـي في الأرانب

أحمـد قنـــاوى

يصل المدد الدموى الشرياني للحبل الشوكي في الارانب عن طريـــــق التفرعات الشوكيه للشرايين الفقاريه ، بين الضلعيه الهابطه ، القطنيه والشرايين العجزية الى جانب الشريان الشوكي البطني والشريانان الشوكيان الظهريـــان للايمن والايسر .

ويمثل الشريان الشوكي البطني وعائا شريانيا غير منتظم يبدأ باتحـــــاد الشريانان الجذريان البطنيان الأيمن رقم واحد والايسر رقم واحد والنابعـان من الشـريان الفقـارى .

هذا ويتكون الشريانان الشوكيان الظهريان في منطقة الرقبة باتحـــــاد الشريانان الجذريان الظهريان الايمن رقم واحد والايسر رقم واحد والنابعان من الشريان الفقـارى .

هذا ويتميز المدد الدموى الشرياني للحبل الشوكي في الأرنب بوجـــــود الشريان الجذرى البطني الكبير وكل من الشريانان الجذريان الظهريان الكبـيران الايمن والايسر وذلك للاشتراك في تغذية التضخم القطنـي .

ومن الملاحظ أن المدد الدموى الشرياني للتضخم القطني أكثر غزارة مـــن المدد الدموى الشرياني للتضخم العنقي ويرجع ذلك الى نمو الاطراف الخلفية في الارانب بدرجة أكبر من نمو الاطراف الأماميـة .

هذا وقد نوقشت نتائج هذا البحث مع مثيلاتها في الحيوانات الأخـــــرى والانســـان .

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ARTERIAL BLOOD SUPPLY OF THE SPINAL CORD OF RABBIT

(With 6 Figures)

By
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SUMMARY

The arterial blood supply of the spinal cord of the rabbit is derived from the single ventral spinal artery and the two dorsal spinal ones, in addition to the well developed A. radicularis magna ventralis and the Aa. radiculares magnae dorsales dextra and sinistra.

The ventral spinal artery is represented by an irregular longitudinal arterial vessel which is formed by the union of the two caudally directed Aa. radiculares ventrales I dextre and sinistra. The right and left dorsal spinal areries are well developed in the cervical region and originates from the caudally directed branches of the first right and left Aa. radiculares dorsales.

The caudal portion of the spinal cord specially the lumbar enlargement, is richly supplied by the single A. radicularis magna ventralis, in addition to the right and left Aa. radiculares magnae dorsales. The stereo-microscopic examination of the spinal cord revealed that its texture is vascularized by five groups of marginal arteries, in addition to the Aa. fissuro-commissurales of the ventral spinal artery and the Aa. sulci of the dorsal spinal ones.

INTRODUCTION

The arterial blood supply of the spinal cord was described in a comparative manner by HOFFMANN (1900), HAFFERL (1933) and JELLINGER (1966). Moreover, the arteries of the spinal cord in man were studied by GILLILAN (1958), ROLL (1958) and TURNBULL/ BRIEG/ HASSLER (1966); in cat by BRADSHAW (1958); in dog by MILLER/ CHRISTENSEN/ EVANS (1964) and JENKINS (1972) and in pig by WISSDORF (1970).

The arterial supply of the spinal cord is derived from the segmental arteries which reach the spinal cord along its cervical, thoracic, lumbar and sacral regions and join the single median ventral spinal artery. However, not all these segmental arteries join the ventral spinal artery specially in mammals as stated by HAFFERL (1933). This desegmentation is little in rodents and domestic animals and reach its maximum in primates and man as described by JELLINGER (1966).

The present work was carried out to study the formation of the ventral and dorsal spinal arteries, the distribution of the dorsal and ventral radicular arteries and the fine arborization of their branches within the texture of the different regions of the spinal cord in rabbit.

MATERIAL and METHODS

This work was carried out on 17 native rabbits of the species Oryctolagus cuniculus of both sexes and of different ages (from 5 monthes to 3 years). The animals were anaesthetized by chloroform in a glass box, bled through the common carotid artery then injected with 10% formalin solution in order to fix the spinal cords. Ten of these animals were then injected by red coloured gum-milk Latex through the common carotid artery after puncturing the external jugular veins. To be sure that the spinal vessels are well injected, the abdominal aorta was re-injected in a cranial and caudal direction. Additional two specimens were injected by Latex-indian Ink. Another three animals were injected by 1 : 1 bovine serum-indian Ink solution, thenafter the spinal cords were dehydrated by ascending grades of alchol, cleared in benzin, then 1 :1 mixture of benzin and methyl benzoate followed by pure methyl benzoate. Two more animals were injected by Technovit 7001* then treated by conc. Hcl to obtain a Resin-cast of the injected arteries. The Nomenclature used is that adopted by the NOMINA ANATOMICA VETERINARIA (1983), however, the NOMINA ANATOMICA, HISTOLOGICA and EMBRYOLOGICA (1977) was taken in considration.

RESULTS

The arterial blood supply of the spinal cord in rabbit comes essentially from the spinal branches of the vertebral artery in the cervical region and the spinal branches of the segmental dorsal intercostal, lumbar and sacral areries. Each spinal branch passes along the cranial border of the corresponding spinal nerve within the vertebral canal, pierces the spinal dura mater and divides into dorsal and ventral radicular arteries.

The Aa. radiculares ventrales I dextra and sinistra originate separetely from the caudal aspect of the vertebral artery - as the latter lies ventral to the spinal cord - and unite with each other forming the initial part of the ventral spinal artery (a/ 1A; 2/2). This initial part is charectrized by the presence of an arterial circle in the half of the examined specimens and in the form of an arterial plexus in the rest.

The Aa. radiculares dorsales I dextra and sinistra arise also separetely from the cranial aspect of the vertebral artery - as the latter just pierced the spinal dura mater -. The first dorsal radicular artery passes inrelation to the cranial aspect of the 1st cervical spinal nerve within the vertebral canal and divides into a small cranial branch which distributes in the first cervical spinal cord segment and a larger caudal branch which unites with the cranially directed branch of the A. rdicularis dorsalis II to form the initial part o the dorsal spinal artery (3/2).

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* : Technovit 7001 is a Resin, cold-curing produced by Kulzer and Co. Gmbh, D 638 Bad Homburg, West germany.

ARTERIES OF THE SPINAL CORD

Each of the rest of the ventral radicular arteries either divides into a cranial and caudal branches which join the caudal and cranial branches of the neighbouring ventral radicular arteries to continue the course of the ventral spinal artery, or distributes in the corresponding spinal cord segment and the root of the corresponding spinal nerve.

A. spinalis ventralis :

The ventral spinal artery (1/1; A/3) is represented by an irregular longitudinal caudally directed arterial vessel. Its initial part is formed through the union of the Aa. radiculares ventrales I dextra and sinistra. Along its course in the ventral median fissure, the ventral spinal artery is strong in the cervical region and receives 6 (left) and 7 (right) strong ventral radicular arteries of the vertebral artery, while in the thoracic region the artery is weak and receives 8 (left) and 6 (right) poorly developed ventral radicular arteries of the segmental dorsal intercostal arteries. An irregular arterial circles are formed at the points where the ventral spinal artery receives the ventral radicular arteries, these circles may have three (c/ 1) or four sides (b/ 1). The ventral spinal artery continues as a weak vessel caudad along the ventral median fissure till the fifth lumbar spinal cord segment where it receives the strong A. radicularis magna ventralis (3/ 1; B/3). This artery - which represents the right 5th lumbar ventral radicular artery in all examined cases - continues the course of the ventral spinal artery caudad along the ventral aspect of the Cauda equina.

Aa. spinales dorsales :

The right and left dorsal spinal arteries (3/ 2) originate from the caudally directed branch of the right and left Aa. radiculares dorsales I. Each artery forms an irregular longitudinal anastomotic vessel along the shallow dorsolateral groove and results from the union of the cranial and caudal branches of the dorsal radicular arteries of the vertebral and first two dorsal intercostal arteries. Each of the rest of the dorsal radicular arteries divides into a cranial and caudal branch which distribute within the corresponding spinal cord segment; dorsal root and the ganglion of the corresponding spinal nerve. Side-anastomoses between the neighbouring branches were not observed in the thoracic and lumbar regions; so a continuous dorsal spinal arteries are not found.

The Intumescentia lumbalis is richly supplied by the Aa. radiculares magnae dorsales dextra and sinistra (2,1/ 4) which originate from the corresponding spinal branches of the 5th lumbar segmental arteries in 6 examined cases. The left major dorsal radicular artery arose from the 3rd lumbar spinal branch in other 4 examined specimens, while the right one originates from the 5th lumbar spinal branch as described vid supra.

Stereo-microscopy :

The stereo-microscopic examination of the texture of the spinal cords injected with 1 : 1 bovine serum and indian Ink showed that the marginal arteries which are detached from the dorsal and ventral radicular arteries, in addition to the central branches of the ventral and dorsal spinal arteries can be divided into the following groups :

1- The central dorsal group (2/ 5,6) which supplies the dorsal funiculus and originats from the cranial and caudal branches of the dorsal radicular arteries or from the right and left dorsal spinal arteries in the cervical region.

2- The dorsal cornual group (3/ 5,6) which supplies the dorsal grey column and the Substantia gelationsa, its twigs are derived from the dorsal radicular arteries and their terminal branches.

2- The dorsal cornual group (3/ 5,6) which supplies the dorsal grey column and the Substantia gelationsa, its twigs are derived from the dorsal radicular arteries and their terminal branches.

3- The lateral group (4/ 5,6) distributes in the lateral funiculus and originates from both the dorsal and ventral radicular arteries.

4- The ventral cornual group (5/ 5) supplies the ventral grey column and they are plenty distributed at the cervical and lumbar enlargements (B/ 5,6). The twigs of this group originate from the Aa. radiculres ventrales and the A. radicularis magna ventralis.

5- The central ventral group (6/ 5) vascularizes the ventral funiculus and its twigs originate from the ventral radicular and the fissuro-commissural arteries of the ventral spinal.

6- The sulcal arteries (1/ 5,6) whcih are derived from the dorsal spinal arteries or the terminal branches of the dorsal radiculr arteries. They descend in a serpentine course within the dorsal median sulcus till reaching the dorsal commissure where each divides into a right and a left branch.

7- Fissural and fissuro-commissural arteries (7/ 5,6) which originate from the dorsal aspect of the A. spinalis ventralis and A. radicularis magna ventralis (3/ 1). The fissuro-commissural arteries ascend within the ventral median fissure till reaching the ventral commissure where each divides into an obliquely directed two diverging branches (B/ 3; 7/ 5,6 B). These branches distribute within the Substantia intermedia centralis, in addition to the area of the ventral cornu-commissural and medial motor nuclei (7/ 5 A,B).

The capillaries are richly distributed in the grey mater of the spinal cord than the white (5/ A,B), moreover, they are also more plenty at the cervical and lumbar enlargements than elswhere.

DISCUSSION

All the segmental spinal arteries are present in fishes, amphibians and birds and they share in the formation of the ventral spinal artery as described by HAFFERL (1933). However, in rodents and domesticated animals the segmental spinal arteries show a little degree of desegmentation which reaches its maximum in primates and man; in which the reduction of the arterial supply of the spinal cord reaches about 75% as reported by JELLINGER (1966). TRUEX/ CARPENTER (1969) stated that 5 - 8 posterior radicular arteries join the posterior spinal artery in man, while the anterior spinal artery receives 6 - 8 anastomosing vessels from the anterior radicular arteries. Moreover, WILLIAMS/ WARWICK (1980) stated that most of the anterior radicular arteries in man are small and terminate within the ventral nerve roots or in the plexus in the pia around the cord. They added that a variable number of the anterior radicular arteries (usually 4 - 9) situated mainly in the lower cervical, lower thoracic and in the upper lumbar regions are larger than the remainder and anastomose with each other and with the anterior spinal artery above to form a longitudinal vessel of uneven calibre along the anterior median sulcus.

WISSDORF (1970) observed complete segmental arrangement of the Aa. radiculares dorsales in the examined pigs, while the distribution of the Aa. rdiculares ventrales shows a percentage of desegmentation which reaches 45.72% on the right side and 54.28% on the left in 70 examined pigs.

The complete segmental arrangement of the dorsal radicular arteries was also observed in rabbit, however, the desegmentation of the vetnral radicular arteries in this animal reaches about 52% in the left and 48% in the right side.

The development of the ventral spinal artery in ovine, swine and human embryos was studied by TORR (1957), who stated that the artery develops from a bilateral capillary network. Moreover, NOESKE (1958) in man and WISSDORF (1970) in pig described the ventral spinal artery as a longitudinal anastomose found ventral to the spinal cord. There are islands in the course of the ventral spinal artery in fishes, amphibians, reptiles, birds and frequently found in mammals as described by HAFFERL (1933). The same author considered the Circulus arteriosus willisi (cerebri) as analoge to the island formation of the ventral spinal artery. He added that the island formation which found in the course of the basilar artery corresponds aslo to that found in the spinal cord. However, NOESKE (1958) considered the island formation in the course of the ventral spinal artery as a sign of the double origin of this vessel.

The Aa. comitantes described by WISSDORF (1970) in young pigs may have an important physiological action in regulating and controlling the pressure of the arterial blood passing into the texture of the spinal cord and to offer a regular blood streem indirectly from the ventral spinal artery in the sulcal vessels. However, such mechanism for controlling the spinal blood pressure and ensuring a continuous regular arterial blood flow may be obtained in rabbit through the irregular arterial circles found at the points where the ventral spinal artery receives the before-described ventral radicular arteries, resembling the mechanism of the cerebral arterial circle in regulating the cerebral blood pressure.

WILLIAMS/ WARWICK (1980) desribed an A. radicularis magna which arises in man from one of the intersegmental branches of the descending aorta in the lower thoracic or upper lumbar vertebral levels. This artery arises in two-thirds of cases on the left-hand side and may be responsible for most of the blood supply of the lower two-thirds of the spinal cord. Moreover, an A. rdicularis magna ventralis was found to originate on the left side at a level of L_4 in cat by BRADSHAW on the right side at the same level in guinea pig by JELLINGER (1966). The A. radicularis magna ventralis described in this work at the level of L_5 on the right side was found by JELLINGER (1966) in rabbit at the same level but in an alternating side.

The Aa. radiculres dorsales in rabbit have a smaller calibre than those of the Aa. radiculares ventrales as described also in pig by WISSDORF (1970), however, the dorsal radicular arteries form two Aa. spinales dorsolaterales (Aa. spinales dorsales) as stated by WISSDORF (1970). The dorsal branches of the spinal arteries in dog follow the dorsal nerve roots to the spinal cord where they are dissipated without forming a continuous dorsolateral trunk (MILLER/ CHRISTENSEN/ EVANS, 1964) or a difinitive dorsal or lateral spinal artery (JENKINS, 1970). However, HOFFMANN (1900) found this artery only in the cervical region in the dog. WISSDORF (1970) stated that the A. spinalis dorsolateralis is not complete in the thoracic region in rodents, however, it forms a lateral chain in pig. The formation of the Aa. spinales dorsales in the cervical and most cranial part of the thoracic region in rabbit may be explained by the presense of the cervical enlargement which is richly supplied by the strong A. spinalis ventralis ventrally and the Aa. spinales dorsales dorso-laterally.

ARIENS KAPPERS/ HUBER/ CROSBY (1965) stated that the spinal cord in rabbit extends into the sacral region, whereas in Chiropteres and Insectivores the spinal cord is very short. They added that this difference in extent of the cord is associated with the greater development of the posterior extremities in the rabbit. Consequently, the lumbar enlargement - which appears to be associated with the comparative size of the posterior

extremities (ARIENS KAPPERS et al., 1965) - is richly supplied in rabbit with arterial blood through a large A. radicularis magna ventralis and two considrable Aa. radiculares magnae dorsales.

GILLILAN (1974) considered that the quantities of blood delivered to various parts of the brain are related to the functional importance of those parts, consequently, the functional importance of the spinal cord in fishes, amphibians, reptiles, birds and lower animals is much more essential to those animals than it in man. Moreover, PALMER (1965) reported that the short chain relay system in the cord subserving both sensory and motor function is much more important in the lower animals than in man. HOLMES (1975) mentioned that the spinal cord is relatively independent of the brain in the lowest vertebrates, while in higher verebrates, the cord becomes progressively more dependent upon the brain.

The steremicroscopic examination of the fine arborization of the arteries of the spinal cord is of great importance for the field of the pathological anatomy and for the clinical and surgical perposes.

HOUSE/ PANSKY (1960) divided the texture of the spinal cord in man into 7 areas depending upon the distribution of the arterial branches of the spinal arteries. However, the arterial branches suppling the texture of the spinal cord in rabbit are divided into 5 groups which distribute in five corresponding areas, in addition to the sulcal and fissurocommissural arteries.

Depending upon the results of GILLILAN (1958); WILLIAMS/ WARWICK (1980) mentioned that the central ranches of the anterior spinal artery are responsible for the supply of as much as two-thirds of the cross-sectional area of the spinal cord. These entral branches comprise the sulcal and sulco-commissural arteries described by TRUEX/ CARPENTER (1969) and WISSDORF (1970). The sulcal arteries described by WISSDORF (1970) include minor and major ones which supply the white mater around the Fissura mediana ventralis and join each other, however, TURNBULL/ BRIEG/ HASSLER (1966) and WILLIAMS/ WARWICK (1980) stated that anastomoses were not observed within the cord itself.

BRADSHAW (1958) stated that each sulcal artery divides in cat ino a right and left branches in opposition to the mode of branching found in man, in which the artery turns completely to one side in an alternating manner which described by GILLILAN (1958) and TRUEX/ CARPENTER (1969). However, WISSDORF (1970) mentioned that the sulco-commissural arteries ascend within the Fissura mediana ventralis and each divides into a cranial and caudal banch either before or after its enterance into the Commissura alba. The same author added that the caudal branch can join the cranial branch of the following suclo-commissural artery close to the central canal.

The white mater of the spinal cord is divided in man into Funiculus dorsalis (poterior), Funiculus lateralis and Funiculus ventralis (anterior) as stated by the NOMINA ANATOMICA, HISTOLOGICA and EMBRYOLOGICA (1977) and WILLIAMS WARWICK (1980); in dog and other domestic animals by MILLER et al. (1964) and the NOMINA ANATOMICA VETERINARIA (1983). However, SEIFERLE (1975) divided the white mater in the animals into the Funiculus dorsalis and the ventrolateralis.

The branches of the anterior spinal i.e. ventral spinal artery were named sulcal and sulco-commissural arteries by TRUEX/ CARPENTER (1969) and WISSDORF (1970); although these branches course within the Fissura mediana ventralis " anterior " (NOMINA ANATOMIC, HISTOLOGICA and EMBRYOLOGICA, 1977) i.e. Fissura mediana " ventralis " (NOMINA ANATOMICA VETERINARIA, 1983). Moreover, WISSDDRF (1970) named the branches of the dorsolateral i.e. dorsal spinal artery as Aa. fissurae; although these fissural arteries descend within the

Sulcus medianus dorsalis. It is more suitable to name the branches of the dorsal spinal arteries which descend within the Sulcus medianus dorsalis as Aa. sulci, and those of the ventral spinal artery which pass within the Fissura mediana ventralis as Aa. fissurae and Aa. fissuro-commissurales; however, these names are proposed to the international Committee on veterinary Gross Anatomical Nomenclature.

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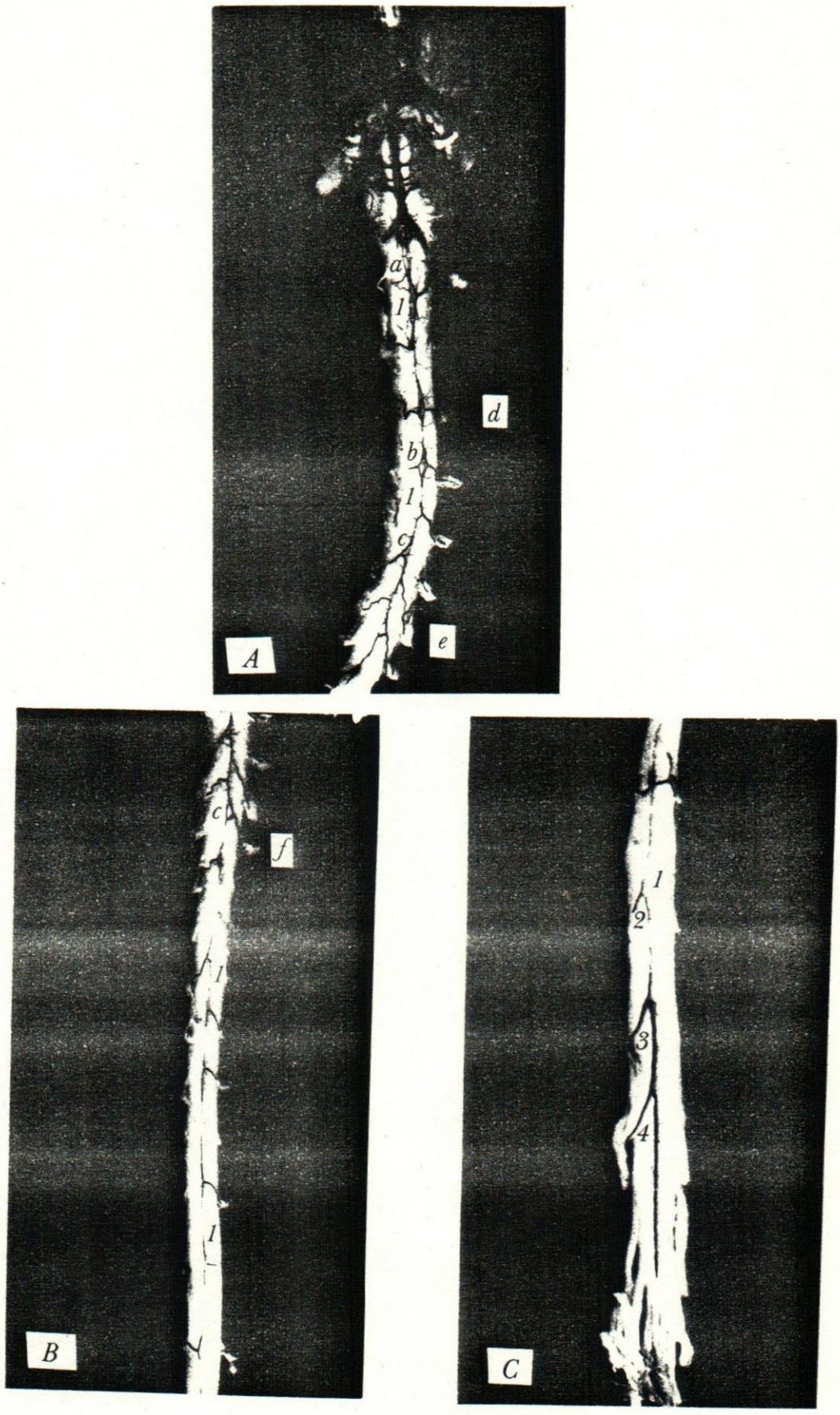

Fig. (1): Latex-indian Ink injected spinal cord of rabbit:
A. cervical region, B. thoracic, C. lumbar region and Cauda equina, ventral view.
a. initial part of the ventral spinal artery (plexifor),
b. four-sided arterial circle, c. three-side circle,
d. 4th cervical, e. 8th cervical, f. 1st thoracic spinal nerves with the corresponding ventral radicular artery,
1) ventral spinal artery, 2) 4th right lumbar ventral radicular artery,
3) A. radicularis magna ventralis, 4) 6th right lumbar ventral radicular artery

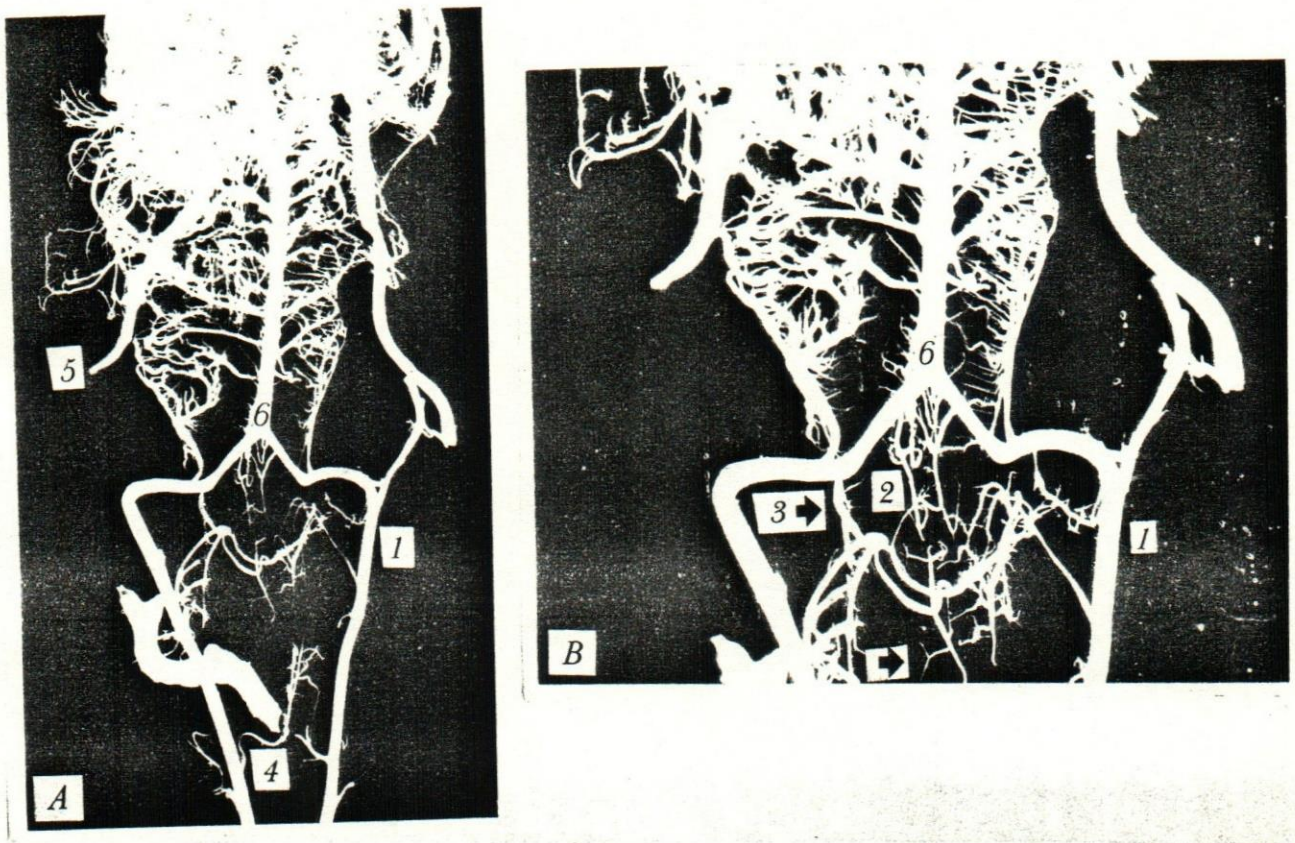

Fig.(2): Cast of a Technovit injected specimen, ventral view :

1. vertebral artery,
2. initial part of the ventral spinal artery,
3. initial part of the dorsal spinal artery,
4. 3rd right cervical ventral radicular artery (broken at its junction with the ventral spinal artery,
5. internal carotid artery,
6. basilar artery (Note a divided fissuro-commissural artery, arrow).

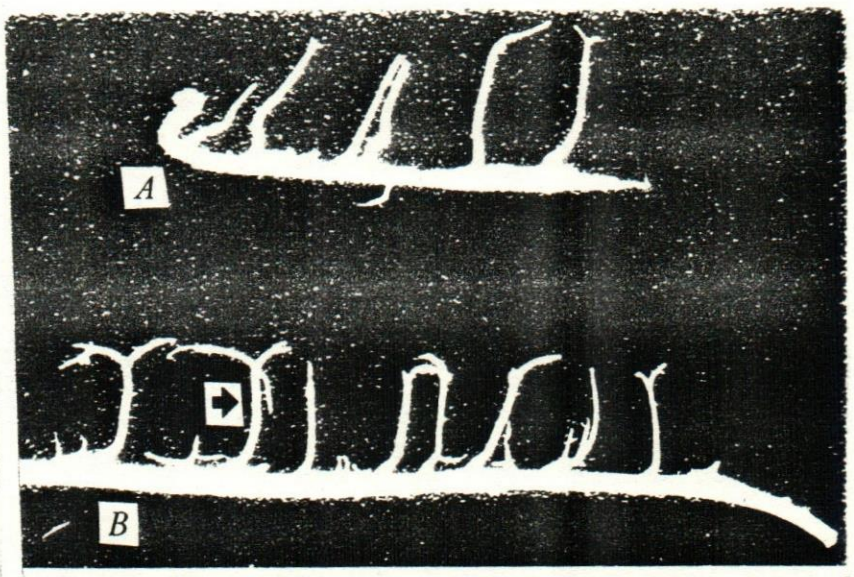

Fig. (3): Cast of Technovit for the ventral spinal artery in the cervical region (A) and of the A. radicularis magna ventralis (B), lateral view ; X 10. Note the fissural and fissuro-commissural arteries (arrow).

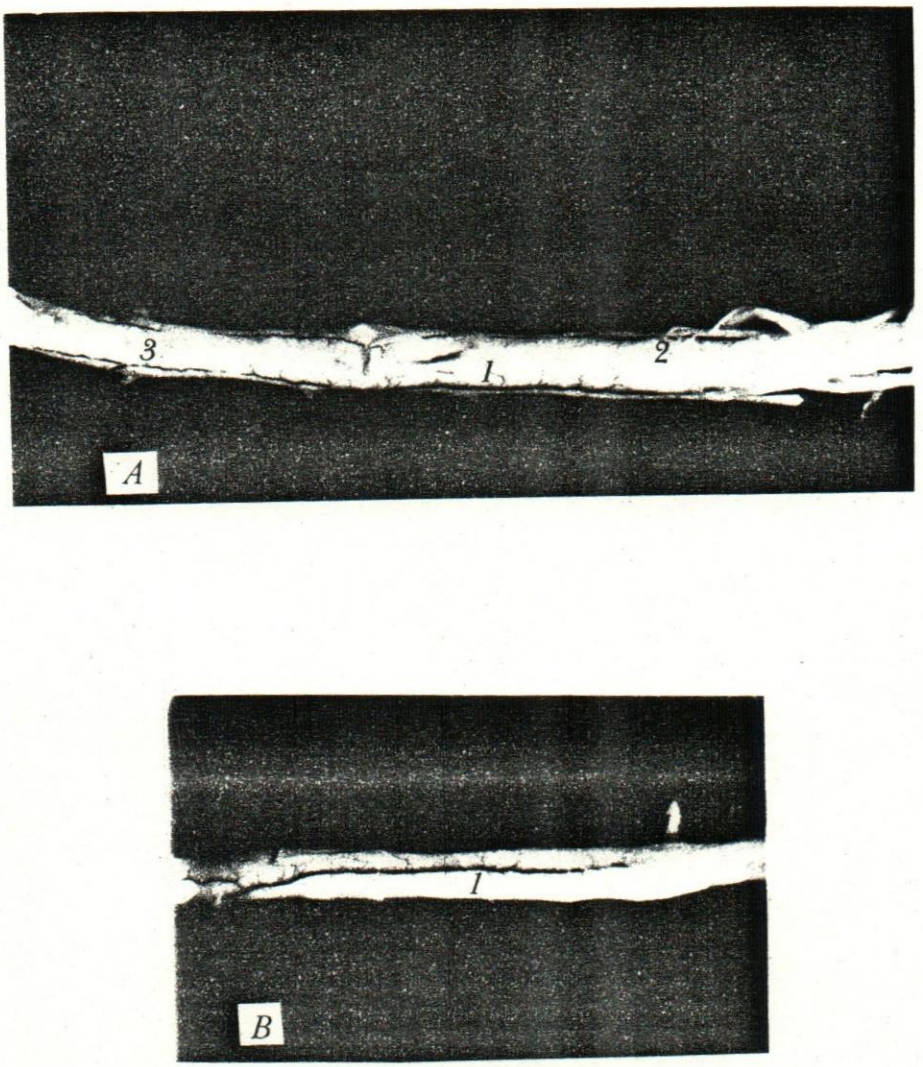

Fig. (4): Latex-indian Ink injected spinal cord of rabbit, lumbar region, A. dorsal view, B. left lateral view:

1 A. radicularis magna dorsalis sinistra, 2A. radicularis magna dorsalis dextra (5th right lumbar dorsal radicular artery),

3 2nd left lumbar dorsal radicular artery.

(Note the large caudal branch of the A. radicularis magna dorsalis sinistra in B).

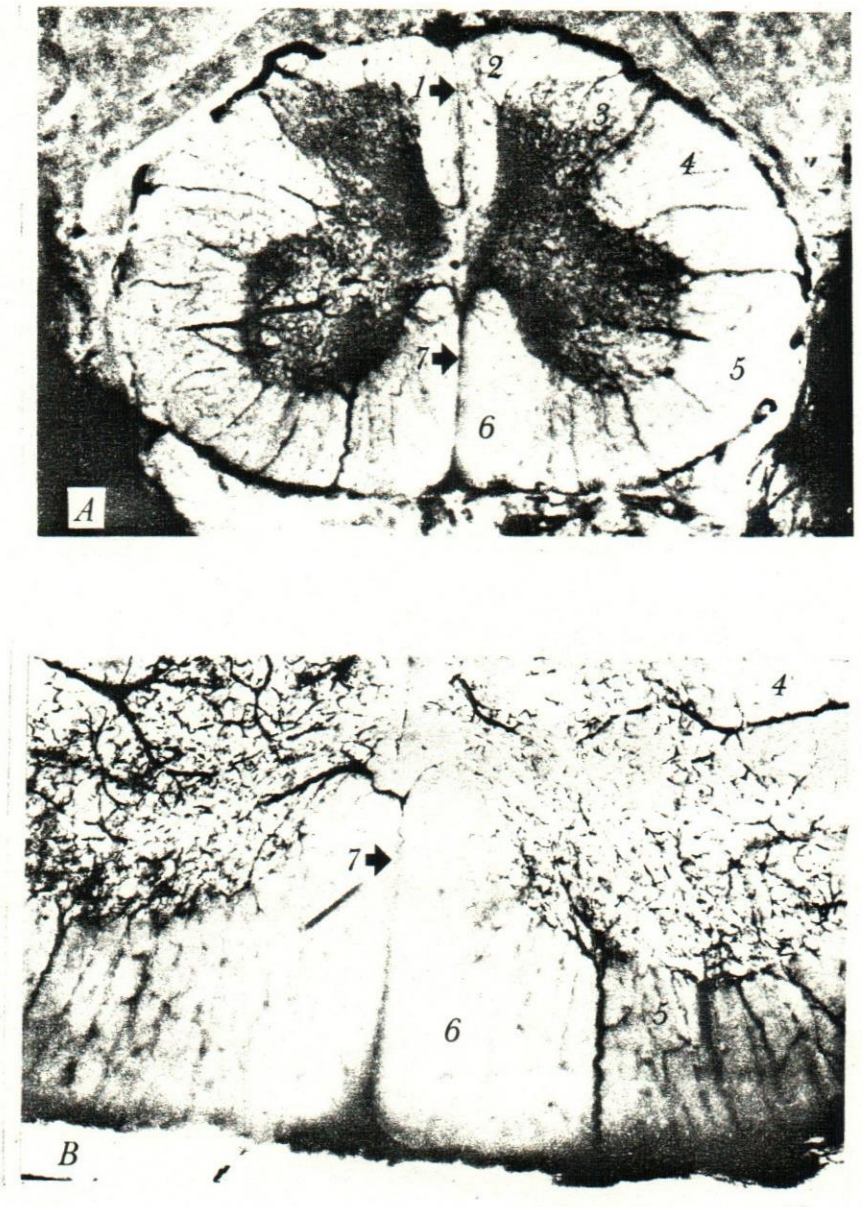

Fig. (5): Thick section of bovbine serum-indian Ink injected spinal cord, fixed and cleared.
A. section at the 4th cervical segment level, X 20
B. section at the 8th cervical segment level, X 50
1. sulcal artery of the dorsal spinal artery, 2. central dorsal group,
3. dorsal cornual group, 4. lateral group, 5. ventral cornual group,
6. central ventral group, 7. fissuro-commissural artery of the ventral spinal artery.
(Note the serpentine course of the fissuro-commissural artery and its diverging branches in B).

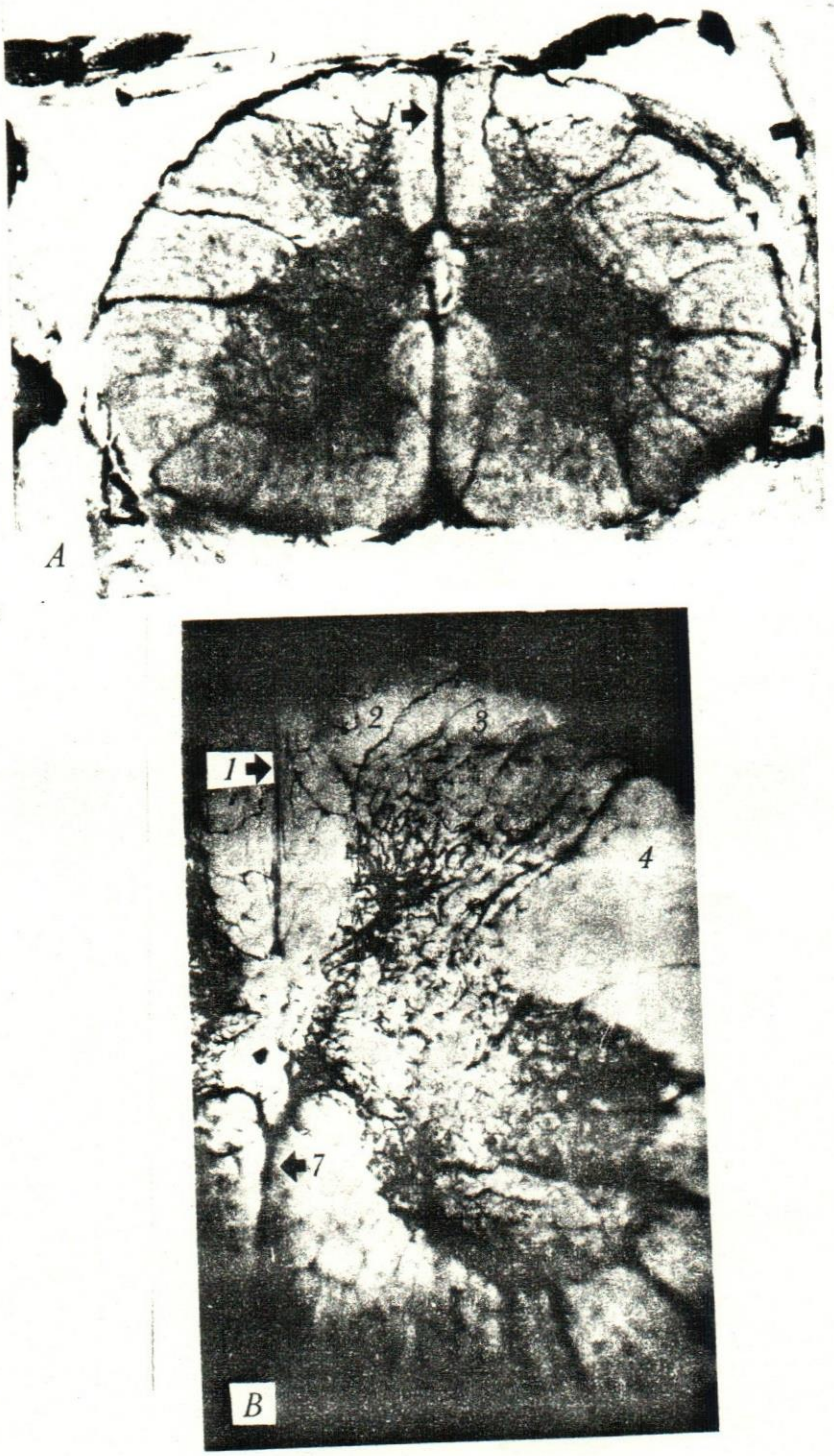

Fig. (6): Thick section of bovine serum-Indian Ink injected spinal cord:
A. section at the 2nd lumbar segment level.
(note the serpentine course of a sulcal artery and its diverging branches deep to a corresponding vein), X 20.
b. section at the level of 6th lumbar segment, X 50.
(note the serpentine course of the sulcal artery (1), and the diverging branches of the fissuro-commissural vessels), Legende as Fig. (5).