Dept. of Anatomy and Histology,
Faculty of Veterinary Medicine,
Head of Dept. Prof. Dr. A. Hifny.

A DEVELOPMENTAL STUDY ON THE ANGIOARCHITECTURE OF THE SPINAL CORD IN DOG

(With 12 Figures)

By
A.K. AHMED and M.N.K. MOUSTAFA

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دراسة عن تطور الأوعية الدموية في الحبل الشوكى في أجنة الكــلاب

أحمد قنــاوى ، نبيل كامــــــــل

تم في هذا البحث دراسة تطور وتوزيع الأوعية الدموية المغذية للحبل الشوكــى فــي مراحل التطور الجنينية المختلفة . وقد تم إجراء هذا البحث على ستة وعشرون جنينـاً تتراوح أطوالها بين ٧ إلى ٢٥ سنتيمتر ، هذا وقد تم حقن الأجنة التى تراوحت أطوالهـا بين ٩ إلى ٢٥ سنتيمتر بالمصل المخلوط بالحبر المثينى . وقد أجرى الفحص الميكروسكوبى للعينات التى تم إعدادها لهذا الغرض إن الأوعية الدموية المغذية للحبل الشوكى قد إنتظمـت في ثلاث مجموعات رئيسية للأجزاء الظهرية والجانبية والبطنية الخاصة بالمادة السنجابيـة للحبل الشوكى . وقد أظهر هذا البحث التغذية الدموية الغزيرة التى تتلقاها أجزاء الحبـل الشوكي المشتركة في تكوين الضفائر العصبية العنقية والقطن ـ عجزية . كما تمت الإشـارة إلى الأوعية الدموية المغذية للعقد العصبية الخاصة بالجزر الظهرى للأعصاب الشوكية .

SUMMARY

The distribution of the spinal branches to the developing spinal cord in dogs from 7-25 cm CVR length was examined in injected and non-injected specimens. This study revealed that the grey mater is richly supplied than the white mater, also the segments of the spinal cord entering into the formation of the Intumescentiae cervicalis and lumbalis are richly vascularized in comparison to the segments other than those of the enlarg-ments.

The spinal branches forming the angioarchitecture of the spinal cord are arranged at first in three groups which correspond to the dorsal, inter-mediate and ventral grey horns of the cord. This study pointed also to the vasculature of the spinal ganglia.

INTRODUCTION

The arterial and venous blood supply of the spinal cord was examined in dogs by MILLER/ CHRISTENSEN/ EVANS (1964), in cat by BRADSHAW (1958), in pig by

WISSDORF (1970) and in rabbit by AHMED (1986). The vasculature of the spinal cord was also described in a comparative manner by HAFFERL (1933) and SEIFERLE (1975). The morphogenesis of the spinal cord was studied in domestic animals by MICHEL (1972) and SCHNORR (1985) and in man by AREY (1965). The distribution of the arterial and venous spinal branches was described by HOUSE/PANSKY (1960), JENKINS (1972), NOESKE (1958), GILLILAN (1958) and TRUEX/CARPENTER (1969). The functional anatomy of the spinal cord in dog and other domestic animals was studied by HOERLEIN (1978) and DE LAHUNTA (1983). The combination of all these subjects was important and necessary to discuss the results of this study.

MATERIAL and METHODS

The morphogenesis of the blood vascular pattern of the spinal cord studied in this work was carried out in 26 dog fetuses of both sexes, ranging from 7-25 cm CVR length. The fetuses were obtained from pregnant Egyptian-land race bitches sacritificed at various periods of gestation. The fetuses were recovered shortly after evisceration. The crown-to-rump [CVR] length was measured and calculated to the nearest (centimeter. Embryos of 7 and 8 cm CVR length were fixed entirly in 10% formalin soultion, serial paraffin sections were made at about 7 Um thickness and stained with Haematoxylin and Eosin.

The fetuses ranging from 9-25 cm CVR length were injected with a mixture of .Indian ink and Bovine serum (FATH EL-BAB, SCHWARZ and GODYNICKI, 1983). The injection was done through the umblical vessels or through the thoracic aorta after ligature of its cordial end. The injected fetuses were fixed in 10% formalin solution, the cervical, thoracic, lumbar and sacral segments of the spinal cord together with the surrounding vertebrae were cutted, decalcified, dehydrated and cleared using the routine method. Thick serial paraffin sections were made at about 20-150 Um, other free hand sections were also made at about 150-200 Um, the sections were examined by the light and stereo-microscops.

The Nomenclature used in this study is that adopted by the Nomina Anatomica Veterinaria (1983); the Nomina Anatomica, Histologica and Embryologica (1977) was taken also in consideration. The Nomenclature used for the fine spinal vessels is that givin by TRUEX and CARPENTER (1969), WISSDORF (1970) and AHMED (1986).

RESULTS

The developmental process of the complete distribution of the arterial and venous branches of the spinal cord in dog fetuses could be divided into four different stages.

The first stage which was studied in embryos having 7-8 cm CVR length. At this time of intrauterine life the specimens were difficult to be generally injected through the umblical vessels, so this age was examined without injection. Both of the ventral spinal and dorsolateral spinal vessels were already formed at this age.

ANGIOARCHITECTURE OF THE SPINAL CORD

The ventral spinal vessels (Figs. 1,2) are found coursing longitudinally ventral to the developing ventral median fissure within a condensation of pia mater. At this area, the pia mater sends a vascular fold which carries the ascending branches of the ventral spinal vessels into the ventral median fissure (Figs. 1,2). The dorsolateral spinal vessels attain a dorsolateral position (Figs. 1,2) however, these vessels or one of their branches can be also demonstrated in a dorsal position (Fig. 1 A).

In fetuse of 12 - 15 cm CVR length, the ventral median fissure became much enlarged and encloses the branches of the ventral spinal vessels (Fig. 3). These branches represent the minor and major sulcal in addition to the sulco-commissural vessels (Fig. 3).

The areas developing from the alar plate of the spinal cord are vascularized by branches arising from the dorsolateral spinal vessels (Fig. 3). These branches are represented by the interfunicular vessels (Fig. 3), Rr. cornue dorsales (Fig. 3) and Rr. marginales (Fig. 5), in addition to the Aa. fissurae which descend within the dorsal median sulcus.

The areas developing from thebasal plate of the spinal cord are supplied branches derived from the ventral spinal vessels. These branches comprise the Rr. cornue ventrales (Figs. 3, 4) and the Aa. sulci major which ascend within the ventral median fissure to continye as Aa. sulco-commissurales.

The segments of the spinal cord entering into the formation of the Intumescentiae cervicalis and lumbalis are richly vascularized in comparison to the segments other than those of the enlargments as seen in Fig. (3).

The spinal ganglia in embryos of 12 - 15 cm CVR length are large in relation to the developing spinal cord. Each ganglion is divided into a dark outer zone and an inner lighter one (Fig. 6). The vessels supplying the outer part are arranged in a regular manner dividing the outer zone into regular areas. The inner portion is richly supplied with irregularlly distributed branches. The somatoafferent fibers forming the the dorsal spinal nerve root leave the inner lighter portion of the spinal ganglion toward the dorsolateral sulcus of the spinal cord, while the ventral spinal nerve root passes ventral to the spinal ganglion to join the dorsal branch at the other end of the spinal ganlion (Fig. 6 B).

The developing spinal cord in dog fetuses at the stage of 16 - 20 cm CVR length showed most of the morphological features of the spinal cord of newly born animals, however the central canal appeared large as in Fig. (7). The distribution of the branches of the spinal arteries and veins within the spinal cord of dog full term fetuses at the stage of 21 - 25 cm CVR length are similar to that described vide supra. The complete distribution of these vessels are explained in Figs. (8,9,10,11,12) at different levels of the spinal cord.

LEGEND OF FIGURES

Fig. (1): Cross section in T_2, 7cm CVR length, A[X6.3], B[X16] a dura mater and arachnoid, b pia mater, c pial vascular fold, d lateral grey horn, e dorsal funiculus, f lateral funiculus, g ventral funiculus, h central canal.
1 ventral spinal, 2 dorsolateral spinal vessels, 3 branches from 2, 4 internal vertebral venous plexus.

Fig. (2): Cross section in L_2, 7cm CVR length [X6.3] a dura mater and arachnoid, b pia mater, c pial vascular fold, d dorsal grey mater, e dorsal commissure, f ventral grey horn, g ventral commissure, h central canal.
1 ventral spinal, 2 dorsolateral spinal, 3 ventral radicular vessels.

Fig. (3): Cross section in C_7, 13cm CVR length, A[X4], B[X6.3] 1 Rr. corni dorsales, 2 Rr marginales, 3 Rr corni ventrales, 4 R. interfunicularis, 5 major sulcal vessel, 6 Rr. sulco-commissurales, 7 internal vertebral venous plexus.

Fig. (4): Cross section in T_6, 14cm CVR length [X6.3] a dura mater, b subdural space.
1 Rr. corni dorsales, 2 Rr. marginales, 3 Rr. corni vetnrales, 4 sulcal branch.

Fig. (5): Cross section in T_{12}, 14cm CVR length [X6.3].
1 R. fissuralis, 2 R. interfunicularis, 3 Rr. corni dorsales, 4 Rr. marginales, 5 R. corni ventrales, 6 sulcal branch.

Fig. (6): Vertical section in T_6, 14cm CVR length, A[X4], B[X6.3] a dorsal sensory root, b ventral motor root, c spinal ganglion, d dura mater, e inner zone, f outer zone.

Fig. (7): Cross section in L_1, 20cm CVR length [X4] a dura mater, b arachnoid and pia mater, c dorsal root, d ventral root, e central canal.
1 dorsal, 2 ventral radicular, 3 interfunicular, 4 Rr. corni dorsales, 5 Rr. marginales, 6 Rr. corni ventrales, 7 sulcal branch, 8 ventral spinal, 9 dorsal lateral spinal vessels.

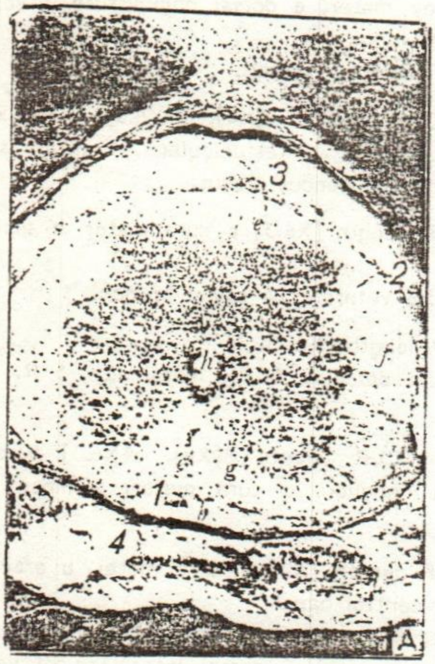
Fig. (8): Cross section in L_3, 21cm CVR length [X4].
1 R. interfunicularis, 2 Rr. corni dorsales, 3 Rr. marginales, 4 Rr. corni ventrales, 5 major sulcal vessel, 6 sulco-commissural vessel.

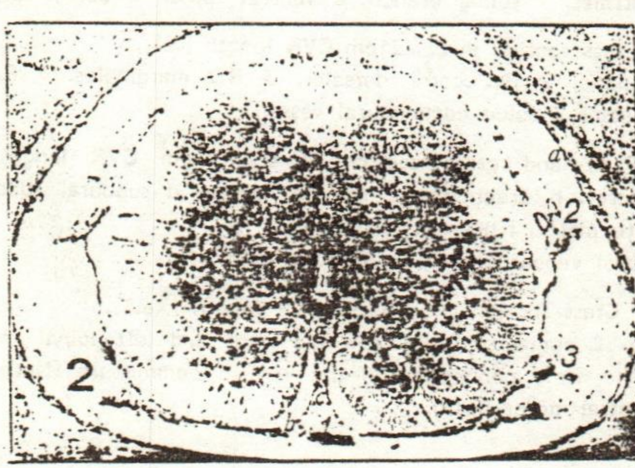
Fig. (9): Free-hand cross section in C_7, 24cm CVR length, Stereo-microspe. [X9]. a dura mater, b arachnoid, c epidural space, d subdural space, e body of C_7, f pedicle, h white mater, i grey mater.
1 internal vertebral venous plexus, 2 vertebral artery.

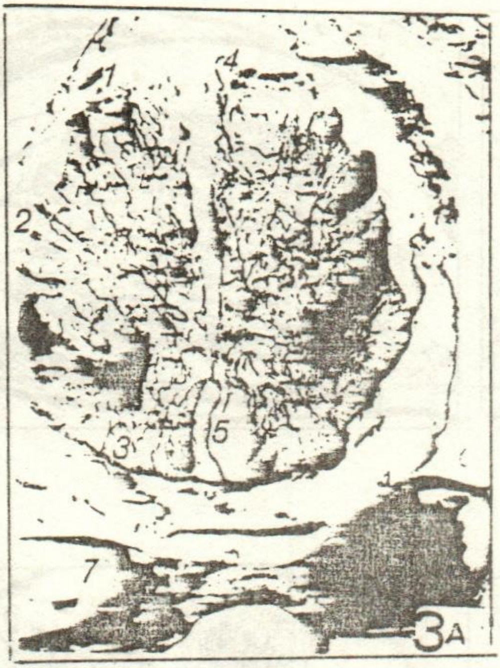
Fig. (10): Cross section inC_7, 24cm CVR length (X6.3).
1 marginal vein, 2 connection between the right and left spinal vessels in the dorsal commissure, 3 the same connection in the ventral commissure (Note the heavy vasculature in the ventral motor horn).

Fig. (11): Cross section in C_8, 24cm CVR length (X4).
1 dorsolateral spinal, 2 ventral spinal vessels (Note the vascular connection around the central canal).

Fig. (12): Cross section in L_4, 24cm CVR length (X4). a dura mater, b subdural space, c dorsal sensory roots, d ventral motor roots.
1 ventral spinal, 2 dorsolateral spinal artery, 3 Rr. corni dorsales, 4 Rr. marginales, 5 Rr. corni ventrales.



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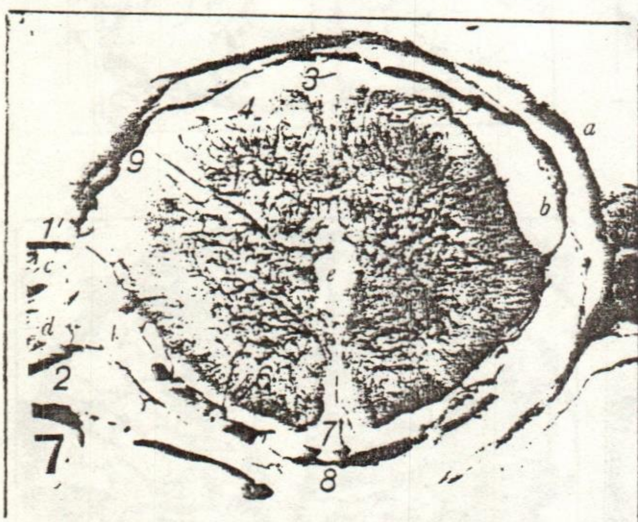
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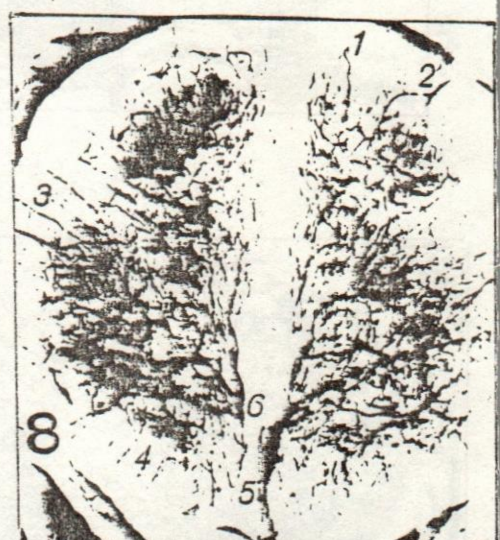
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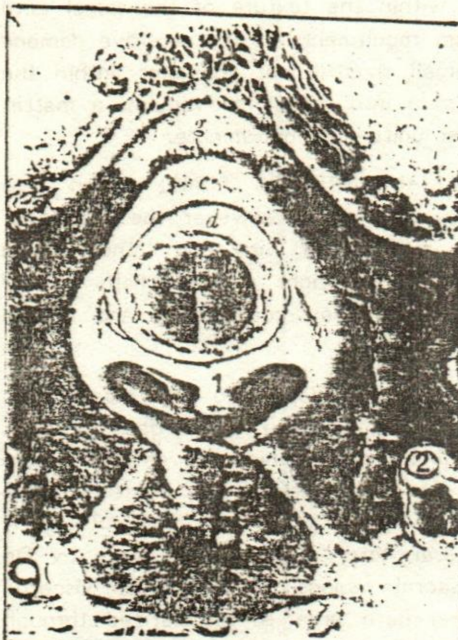
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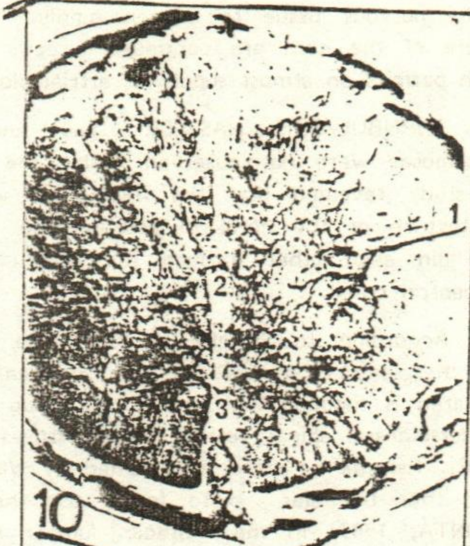
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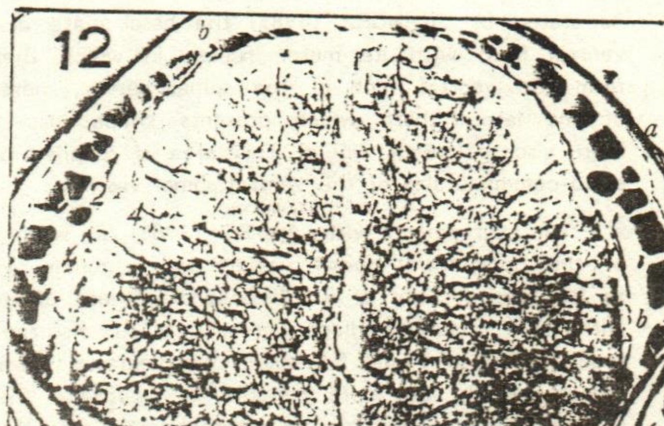
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DISCUSSION

The distribution of the fine spinal vessels within the texture of the spinal cord appears to be of special pattern to fulfill the high requirments of the sensitive demand of the nervous tissue to oxygen supply. The small sized spinal arterioles within the texture of the cord are continued directly to drain into the spinal venules, a matter which permits an atmost supply of artrial blood per unite-area per minute.

TURNBUL/BRIEG/HASSLER (1966) and WILLIAMS/WARWICK (1980) stated that anastomoses were not observed within the spinal cord itself, however the results of this study revealed that the fine spinal vessels anastomose with each other within the texture of the cord. In addition the vessels of the right and left halfs of the cord join each other through the dorsal and ventral grey commissures and around the central canal.

According to SCHNORR (1985) the alar plate develops into the dorsal horn with the sensory area where the somatoafferent fibers of the spinal ganglia enter. This area is supplied with the dorsal group of spinal vessels which are detached from the dorsolateral spinal vessels and comprises the Rr. corni dorsales, Rr. interfuniculares and Rr. fissurae as were also named by WISSDORF (1970). Moreover, SCHNORR (1985) added that the alar plate forms also the lateral horn (intermediate horn by De LAHUNTA, 1983) in the thoracic, lumbar and sacral regions, at which the viscero-afferent fibers end in their neurons. The lateral horn area is vascularized through the Rr. marginales which spring from both the dorsolateral and ventral spinal vesseles, however the proper name of the marginal branches at this area is the Rr. corni laterales; as these vessels are responsible for the vasculature of the lateral grey horn. As stated by SCHNORR (1985) the basal plate of the spinal cord develops into the ventral horn with its motor nuclei, in which their somatoeffernt fibers develop to form the ventral root of the spinal nerves, moreover it develops the ventral part of the lateral horn which presents sympathetic and parasympathetic neurons with their visceroefferent fibers. This area is supplied by the Rr. corni ventrales and Rr. sulco-commissurales of the ventral spinal vessels.

In agreement with AHMED (1986) it is more suitable to name the branches of the dorsolateral spinal vessels which course within the Sulcus medianus dorsalis as Rr. sulci instead of Rr. fissurae and those of the ventral spinal artery whcih pass within the Fissura mediana ventralis as Rr. fissurae and Rr. fissuro-commissurales instead of Rr. sulci and Rr. sulco-commissurales. These proper names of the fine spinal vessels, which are more suitable in regard to their course, distributin and area of supply; are proposed to the International Committee on Veterinary Gross Anatomical Nomenclature and the Subcommittees of the international Anatomical Nomenclature Committee for the Nomina Anatomica, Histologica and Embryologica.

REFERENCES

Ahmed, A.K. (1986): Arterial blood supply of the spinal cord of rabbit. Assiut Vet. Med. J. Vol. 15, No. 30.

Arey, L.B. (1965): Developmental anatomy, Seventh Edition. W.B. Saunders Company, Philadelphia and London.

Bradshaw, P. (1958): Arteries of the spinal cord in the cat. J. Neurol. (London), 21, 284-289. (cited after Wisdorf, 1970).

De Lahunta, A. (1983): Veterinary Neuroanatomy and clinical Neurology. Second Edition. W.B. Saunders Company.

Fath El-Bab, M.R.; R. Schwarz and S. Godynicki (1983): The morphogenesis of the vasculature in bovine fetal skin. J. Anatomy, 136, 561-572.

Gillilan, L. (1958): The arterial blood supply of the human spinal cord. J. Comp. Neurol., 110, 75-104. (cited after Williams/Warwick, 1980).

Hafferl, A. (1933): Das arterien-system, Verlauf der Arterien des Halses und Kopfes in: L. Bolk, E. Goppert, E. Kallius und W. Lubosch: Handbuch der vergleichenden Anatomie der Wirbeltiere. Bd. VI, 577-602. Verlag Urban und Scharzenberg, Berlin-Wien.

Hoerlein, B.F. (1978): Canine Neurology, Third Edition. W.B. Saunders Company.

House, E.L. and B. Pansky (1960): Coverings and vascularization of the central nervous system in: Functional approach to Neuroanatomy. Mcgraw-Hill Book Company, New York, Toronto, London.

Jenkins, T.W. (1972): Blood supply and dural venous sinuses in: Functional mammalian Neuroanatomy. Lea & Febiger, Philadelphia.

Michel, G. (1972): Die Bildung des Ruckenmarkes in: Kompendium der Embryologie der Haustiere. Gustav Fischer Verlag. Stuttgart.

Miller, E.M.; G. Christensen and H. Evans (1964): The heart and arteries in: Anatomy of the dog. W.B. Saunders Comp., Philadelphia,London.

Nomian Anatomica, Histologica and Embryologica (1977): Prepared by the subcommittees of theInternational Anatomical Nomenclature Committee. Fourth Edition. Excerpta Medica, Amsterdam-Oxford.

Nomina Anatomica Veterinaria (1983): Published by the International Committee on Veterinary Gross Anatomical Nomenclature of the World Association of Veterinary Anatomists. Third Edition, Ithaca, New York.

Noeske, K. (1958): Uber die arterielle Versorgung des menschlichen Ruckenmarkes. Morph. Jb. 99, 455-497. (cited after Wissdorf, 1970).

Schnorr, B. (1985): Entwicklung des Nervensystems in: Embryologie der Haustiere. Ferdinand Enke Verlag, Stuttgart.

Seiferle, E. (1975): Ruckenmark in: R. Nickel, A. Schummer und E. Seiferle, Lehrbuch der Anatomie der Haustiere, Bd. IV, Nervensystem. Verlag P. Parey, Berlin - Hamburg.

Truex, R.C. and M.B. Carpenter (1969): Blood supply of central nervous system in: Human Neuroanatomy. Sixth Edition. Williams and Wilkins Comp., Baltimore.

Turnbull, I.M.; A. Brieg and O. Hassler (1966): Blood supply of thecervical spinal cord. J. Neurosurg., 24, 951-965.

Williams, P.L. and R. Warwick (1980): Angiology in: Gray's Anatomy, 36 Edition. Churchill Livingstone, Edinburg, London, Medlbourne and New York.

Wissdorf, H. (1970): Die Gefassversorgung der Wirbelsaule und des Ruckenmarkes von Hausschwein (Sus scrofa F. domestica 1., 1858). Zbl. Vet. Med. Beiheft 12, 1-104.