THE NERVE SUPPLY OF THE DUCTUS ARTERIOSUS IN DOGS

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In their studies of the ductus arteriosus many workers have attempted to find the reason for its obliteration in the peculiar structure of the wall of the vessel [6, 11 and others] or in the topographical anatomical changes in the thoracic organs taking place after birth [7, 10]. The role of the nervous system in the function and obliteration of the duct has not been determined, and it would not be incorrect to say that it has been inadequately investigated. The exception is the work of Barcroft, Kennedy and Mason [4], who used physiological methods without preliminary anatomical investigation in an attempt to find nerves which brought about the closure of the ductus. By stimulation of the peripheral end of the left vagus nerve they succeeded in establishing a diminished blood flow through the ductus and, as assumed by these authors, its closure. They conclude from these findings that in guinea pigs the branches of the left vagus nerve must participate in the innervation of the ductus. However, more recent experiments by Kennedy and Clark [Clark, 1942] showed that destruction of the spinal cord and sympathetic ganglia with division of both vagus nerves, and also electrical stimulation of the vagus, phrenic, sympathetic and splanchnic nerves and of the stellate ganglion on the left side have no effect on closure of the ductus. The negative results of these experiments led these authors to the incorrect conclusion that the nervous system is not concerned in closure and function of the ductus. This problem is till unsolved at the present time even though a considerable amount of evidence has accumulated in the literature indirectly supporting the existence of receptor apparatus in the wall of the ductus arteriosus. Osseladore, Pezzuoli and Pietri [8], for instance, observed closure of the ductus arteriosus in guinea pigs immediately after injection into their blood vessels of a perfusing fluid saturated with oxygen, and relaxation of the ductus when the concentration of carbon dioxide in the blood was increased. Record and McKeown [9] observed constriction of the walls of the ductus when physiological saline was injected into the blood vessels of the animals.

T. A. Grigor'eva [1], studying the innervation of the vessels of the cat, discovered a large number of nerve cells in the region of the aortic orifice of the ductus arteriosus which, evidently, belonged to the vagus nerve. Similar observations were made by Boyd [5] and Jager and Wollenman [12].

The incomplete and contradictory accounts in the literature of the nerves of the ductus arteriosus impelled us, at Prof. B. M. Sokolov's suggestion, to carry out an experimental morphological investigation of the nerves of the ductus arteriosus in animals and especially in dogs.

EXPERIMENTAL RESULTS

The results of macro- and microscopic examination of the nerves of the ductus in 20 cadavers of puppies and fully-grown dogs showed that the nerves to the ductus arteriosus are formed from branches of the sympathetic trunk and the vagus nerve on the left side. In the course of the nerves to the ductus two forms can be distinguished – scattered, and combined in one main trunk. In the latter case ($^4/_5$ of all animals) the independent nerve to the ductus areteriosus (Fig. 1) is formed from branches of the left vagosympathetic trunk, the caudal cervical ganglion and the trunk of the left vagus nerve. The number of branches of the vagosympathetic trunk and the caudal cervical ganglion taking part in the formation of this nerve varies from 1 to 3, their thickness from 0.1-0.3 mm and their length up to 1.5 cm. The number of branches of the left vagus nerve is inconstant and varies from 1 to 4, their thickness from 0.1-0.3 mm, and their length up to 0.7 cm.

The branches are united into a nerve from the level of the VIth cervical to the IIIrd thoracic vertebra. In one case at the site of union of the branches we observed gangliar thickenings, oval in shape and measuring 1 × × 2 mm (Fig. 1).

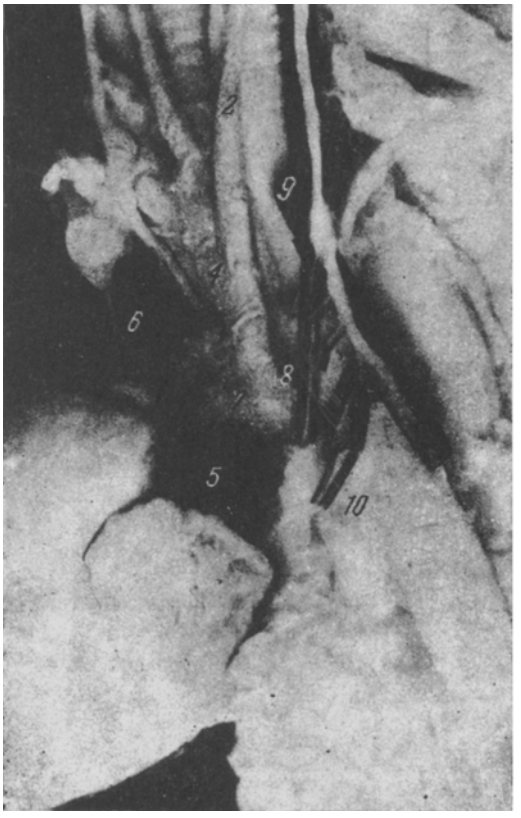

Fig. 1. Formation of the nerve of the ductus arteriosus in a two-day-old puppy: vagosympathetic trunk and left carotid artery (2), innominate artery (4), caudal cervical ganglion (9), nerve of the ductus arteriosus (8), ductus arteriosus (10).

Fig. 2. The nerve of the ductus arteriosus in a two-month-old puppy: arch of the aorta (1), innominate artery (2), carotid artery (3), subclavian artery (4), pulmonary artery (5), nerve of the ductus arteriosus (7), branch to the arch of the aorta (9).

The nerve thus formed is 0.75 mm in thickness and up to 2.2 cm in length and it usually proceeds alone ($^2/_3$ of cases), situated on the anterior surface of the aortic arch from the orifice of the left subclavian artery to the medial border of the aortic orifice of the ductus arteriosus. More rarely the nerve has connections with the cardiac branches of the left vagus nerve taking part in the formation of the left coronary cardiac plexus (1 case in 20), with the trunk of the left vagus nerve and with the deep part of the cardiac plexus (2 cases in 20). Two variants can be distinguished in the distribution of the nerve to the walls of the ductus.

In the first variant the nerve divides when still 0.2-0.5 cm from the ductus arteriosus into branches 0.1-0.2 mm in thickness and up to 1 cm in length which, uniting with each other, form anastomoses in the form of a loop (Fig. 2).

In the second variant (Fig. 1) the nerve proceeds alone to the ductus, and only after becoming completely buried in the adventitia does it divide into branches directed toward its orifices.

In $^1/_5$ of cases where the nerve consists of a single trunk, the nerve of the ductus arteriosus arises not from the combination of branches but directly from the left caudal cervical sympathetic ganglion, and it has a thickness of 0.3-0.5 mm and a length of 1.5-4.5 cm. The nerve is distributed not only to the walls of the ductus but also to the cellular tissue lying on the anterior surface of the arch of the aorta in direct proximity to the aortic orifice of the ductus arteriosus. These branches were shown particularly clearly in fully grown dogs with an obliterated ductus. In individual cases, in its course toward the ductus the nerve has connections in the form of trunks 0.1 mm

in thickness and up to 2 cm long, with the nerves of the thymus gland, the pericardium and with the cardiac branches.

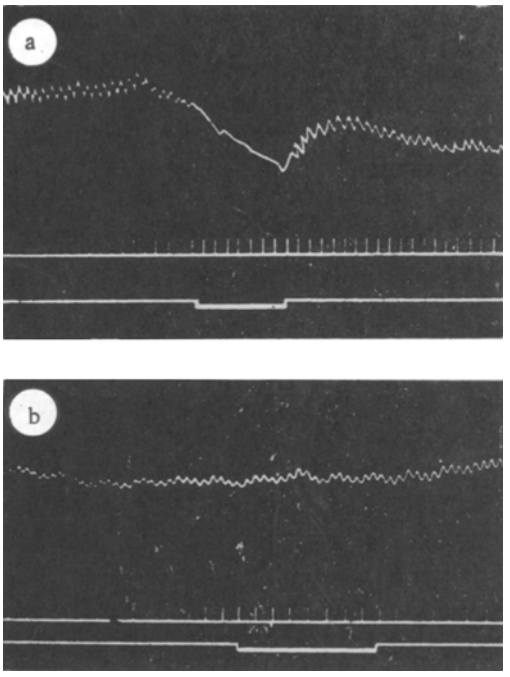

Fig. 3. Changes in the blood pressure of a two-day-old puppy during stimulation of the aortic orifice of the ductus arteriosus (a) and during stimulation of areas of the aorta adjacent to the orifice of the ductus arteriosus (b).

When the branches to the ductus assume the scattered form they appear as 2-5 nerve trunks emerging from the left caudal cervical ganglion and the left vagus nerve. The thickness of the branches of the ganglion is 0.2-0.5 mm and their length 2-4.5 cm; the thickness of the branches of the vagus nerve is 0.1-0.2 mm and their length up to 1.2 cm. In their course to the ductus arteriosus the branches always cross the anterior surface of the arch of the aorta. Before burying themselves in the wall of the ductus, as a rule, they have connections between themselves. The largest branches leading to the ductus arteriosus in this scattered form are the nerve trunks which emerge from the caudal cervical ganglion.

The main nerve trunk leading to the ductus arteriosus is usually situated in the area between the origins of the innominate and the left subclavian arteries, among the loose cellular tissue, and is directed inferiorly and caudally. Its constancy, its topographical anatomical characteristics and its distribution in the wall of the ductus arteriosus justify its being called the nerve of the ductus arteriosus (Figs. 1, 2).

Besides the above-mentioned nerves, branches from the left augmentor nerve of I. P. Pavlov, studied in detail by I. M. Shvetsov [3], enter the wall of the ductus. These branches are 0.2 mm in thickness and are up to 1 cm in length, and are distributed to the middle part of the ductus arteriosus and to its pulmonary aperture.

A concentration of nerve branches may be observed in the wall of the ductus in the region of its aortic end, which is in agreement with the findings of Boyd, Wollenman, Barcroft, T. A. Grigor'eva and others.

Experiments carried out jointly with A. P. Dvoinina on 20 dogs, mainly puppies (from new-born to 2½ months of age), showed that the ductus arteriosus is a well-marked reflexogenic zone. The reflex is observed particularly clearly (fall in blood pressure in the greater circulation, slowing of the rate of the heart with intensification of the pulse pressure) during stimulation of the aortic orifice of the ductus (Fig. 3). We observed a similar reaction on stimulation of the nerve of the ductus arteriosus. Division of the nerve and subsequent stimulation of its central and peripheral ends demonstrated convincingly that this nerve is centripetal, since a depressor reaction is observed only on stimulation of its central end. As a control of these findings we stimulated the aorta adjacent to the ductus arteriosus, but we did not once observe a reaction of this sort in either puppies or fully grown dogs.

It is neccesary to point out that the reflex from the ductus arteriosus alters with age. It is particularly well marked in puppies in the first 5 days of life and is completely absent in adult dogs. Perhaps the anatomical changes in the ductus arteriosus (obliteration of the ductus and its exclusion thereby from the circulatory system) are connected with the age changes in the function of its nerves. It is possible that previous workers (I. Cion, K. Ludwig and others) who made extensive studies of the circulatory reflexes used for this purpose fully grown dogs and did not find the nerve of the ductus arteriosus, whose depressor function is timed to be shown in the first period of postembryonic development.

SUMMARY

The nerves of ductus arteriosus up to the present time were studied inadequately. The author performed experiments on 20 adult dogs and newborn pups in which he investigated the nerves of the ductus arteriosus by macro- and microscopic examination and physiological methods.

The results of these investigations demonstrated that the nerves passing in the direction of the ductus are formed from the branches of the truncus symphathicus and the vagus nerve of the left side. 2 variations of nerve distribution were found: scattered and magistral. In the last variant an individual nerve (the nerve of ductus arteriosus) approaches the duct. Its diameter reaches 0.75 mm in the newborn pups.

Experiments showed that the nerve of ductus arteriosus is a depressor. Its function changes with the age of dogs. It is especially pronounced in puppies during the first 5 days of life and is completely absent in adult dogs. The depressive function of the nerve of ductus arteriosus is meant to serve during the first period of postembryonic development when the depressive function of Ludwig-Cion's nerve is absent.

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