ON THE ROLE OF THE SPINAL CORD IN THE REGULATION OF LYMPH FLOW

I. A. Potapov

From the Laboratory on Lymph Circulation (Head— Candidate of Medical Sciences A. M. Beketaev) of the Institute of Physiology (Dir.— Academician A. P. Polosykhin) of the Akad. Nauk of the Kazakh SSR
(Presented by Active Member of the Akad. Med. Nauk SSSR V. V. Parin)
Translated from Byulleten' Eksperimental'noi Biologii i Meditsiny, Vol. 52, No. 9, pp. 24-27, September, 1961
Original article submitted November 10, 1960

Many authors have worked on the problem of neuro-humeral regulation of the lymphatic system [9, 10, 11, 15, etc.].

According to the data of certain investigators [7, 8, 10, etc.], the regulation of lymph circulation is apparently accomplished by one common vasomotor center. However, studying the influence of the nervous system on lymphatic vessels, several experimentors [15] suggested the possibility of local changes in lymph circulation, analogous to the regional changes in the blood circulation; this would imply a multiplicity of sources for the tonic innervation of the lymphatic vessels. This is partly confirmed by the observation of reflex changes in the lymph flow with stimulation of the interoceptors in the mesenteric vessels and the kidney, seen in trials with a transected spinal cord [12]. In addition, a number of investigators [6, 14, etc.] have shown that the rhythmic activity of the lymphatic "pumps" in the frog is dependent upon the effects of spinal nerves; these effects are realized by means of a nerve center, located in the spinal cord [5 et al.].

The above suggests that, in addition to formations in the medulla oblongata, a part is played by the spinal cord in the regulation of lymphatic vascular tonus in warm blooded animals. In this report we present an attempt to experimentally verify this hypothesis.

EXPERIMENTAL

In all, we carried out 25 short term experiments, using dogs weighing from 10 to 20 kg under morphine-hexenal narcosis. In 20 experiments, judging by the naked eye, we transected the spinal cord at the level of the I, II, III, IV, VI, and VII cervical vertebrae and the V, VI, VIII, and IX thoracic. In 7 of these trials we also transected the vagosympathetic trunks in the neck. In 5 of the trials, after transection of the spinal cord at the level of the I, V, VI and VII thoracic vertebrae, the caudal segment of the spinal cord was removed through a trephinated aperture made in the croup. In the experiments we recorded the lateral pressure in the common carotid artery, respiration, the pressure in the left femoral and left external jugular veins, and the flow of drops of lymph from the thoracic duct. In 12 of the trials we simultaneously recorded the lateral pressure in the thoracic lymphatic duct by a method developed by us, the essence of which is the following: a canula is inserted into the thoracic duct, connecting an elastic tube to a canula T-joint, at the site where the thoracic duct leads into the venous system; the elastic tube is joined to a linear water-air manometer via the T-joint. Both before transection or removal of the spinal cord and after these manipulations (15 min after the operation), stimuli were applied to the central portion of the sciatic nerve from time to time over the course of $3\frac{1}{2}$ hours, using an induction current from a du Bois Raymond coil, supplied by a 5 volt storage battery. Before transection of the spinal cord we selected the current intensity (distance of the secondary coil equal to 25-40 cm) which caused clearly observed changes in the recorded indices without producing a motor reaction in the animal. This current intensity served as the starting point for the stimuli after the operation on the spinal cord. During the run of the experiment the body temperature of the animal was controlled. Heparin was used as the anticoagulant, with a dosage of 208 m.u. per kg.

According to the data in the literature [1, etc.], after transection of the spinal cord the tonus of the lymphatic vessels decreases (the terminal pressure in the thoracic duct falls), which is evidence of central influences on the lymphatic system. In our investigations, recording the pressure in the thoracic duct at the moment of transection of the spinal cord, in 9 out of 12 trials, after a transient increase, the pressure fell below the original level. In 1 of the trials it remained unchanged; in 2 trials, where the arterial pressure increased following transection of the spinal cord and remained at this level up to the end of the experiment, the lymph pressure also exceeded its original figure, although in one of the cases it decreased after 2 hours.

In Fig. 1 we present the changes in the arterial and venous pressure and pressure in the thoracic duct, characteristic for our experiments, following transection of the spinal cord. Recordings of the lymph flow in this period demonstrate its initial increase, replaced by a deceleration.

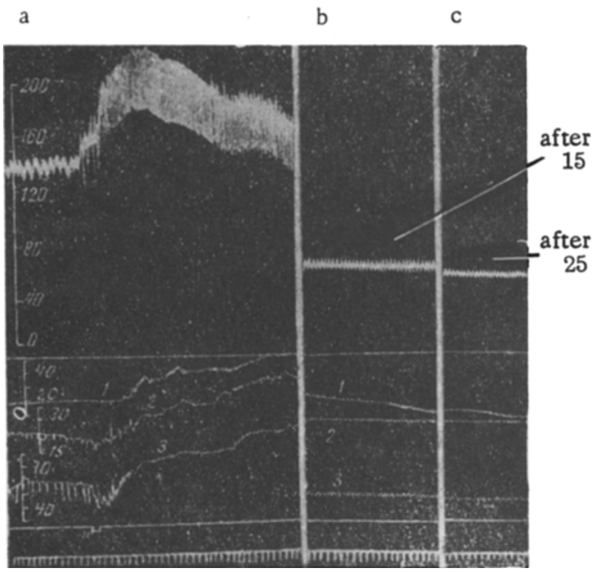

Fig. 1. Changes in the recorded indices following transection of the spinal cord at the level of the I cervical vertebra. a) Immediately after transection; b) the same after stopping the kymograph for 15 min; c) the same after stopping the kymograph for 25 min. Meaning of the curves (from above downward): arterial pressure; zero line; pressure in the femoral vein; pressure in the jugular vein; pressure in the thoracic duct; marking of the transection of the spinal cord; time markings (5 sec); artificial respiration.

The fall in pressure in the thoracic duct following transection of the spinal cord is probably a result of removal of the central neural influences on the lymphatic vessels and a transitory suppression of the lower regulatory mechanisms. However, the low level established for the lymph pressure during the period of spinal shock is inconstant, since with painful stimuli it is possible to decrease the pressure in the thoracic duct even further.

As we have already shown in the preliminary series of experiments on animals with an intact spinal cord, a pain stimulus can cause a pressor, depressor, or mixed type of reaction in the lymphatic vessels. These types of reactions, with a relative increase in the depressor and mixed, can also be observed following transection of the spinal cord.

Stimulation of the central portion of the sciatic nerve with an induction current during the period that the arterial pressure was depressed did not cause any apparent reflex responses, regardless of whether the current intensity exceeded the starting level or was below it. A pain stimulus, applied 40-50 minutes after transection of the spinal cord (53 observations, with recordings of the outflow of lymph drops from the thoracic duct), gave rise to a decrease in lymph flow in 24 cases, a weakening in the flow with subsequent increase in 12 cases, and an increase in lymph flow in 11 cases; in 6 cases there were no changes. In 5 observations the reactions in the lymph flow were noted to be simultaneous with changes in the pressure within the femoral vein (a fall), while in three of these we also recorded a minimal elevation in the arterial pressure (from 2 to 5 mm Hg).

In connection with the fact that in the majority of cases changes in the lymph flow at the moment of stimulation were not accompanied by changes in the arterial and venous pressure, respiration, or muscle tension (Fig. 2), it can be postulated that these lymph flow changes were the results of changes in the lumina of the lymph vessels, which occurred reflexively via the lymphomotor centers located in the spinal cord. In order to confirm this hypothesis, we carried out a series of supplementary experiments. In particular, in a number of experiments aimed at more complete removal of the central influences, following transection of the spinal cord we severed the vagosympathetic trunks in the neck. In all cases, following this supplementary transection of the vagosympathetic trunks, we observed reflex changes in the lymph flow with the application of pain stimuli; sometimes these were more apparent than before the latter transection.

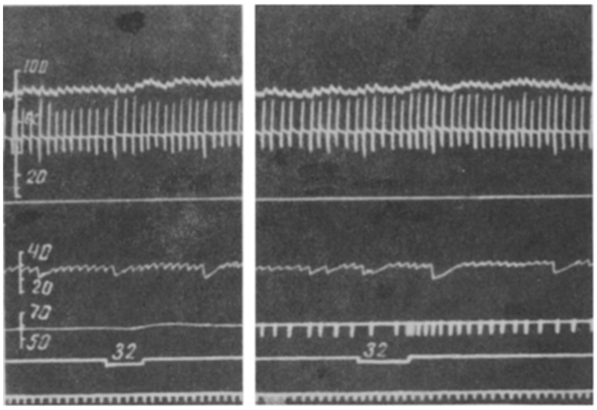

Fig. 2. Changes in the pressure within the thoracic duct and in the outflow of lymph drops from it associated with stimulation of the central portion of the sciatic nerve with an induction current (DC – distance between the induction coils. DC = 32 cm) one hour after transection of the spinal cord at the level of the VI thoracic vertebra. Meaning of the curves (from above downward): arterial pressure; respiration; zero line; pressure in the jugular vein; pressure in the thoracic duct (on the right half of the figure – markings of the outflow of lymph drops from the thoracic duct); stimulation markings; time markings (5 sec).

Taking into consideration the evidence in the literature on the presence of sympathetic fibers in the composition of somatic nerves [3, etc.], as well as data [2, 3, etc.] on the possible transfer of impulses by indirect routes in higher portions of the central nervous system, in 5 of the experiments we removed the caudal segment of the spinal cord after its transection. In these experiments we failed to observe reflex changes in the lymph flow even in a single case when we stimulated the central portion of the sciatic nerve with increasing current intensities.

The absence of a reflex response in this case cannot be explained by depression of the nerve centers above the transection of the spinal cord [4, 13, etc.], since, with stimulation of the central portion of the median nerve with an induction current, changes in the lymph flow typical for pain stimulation were noted, against a background of changes in the arterial and venous pressure and respiration.

It can be seen in Fig. 3 that stimulation of the central portion of the sciatic nerve with a successively increasing current intensity (first stimulus – with a coil distance DC = 20 cm, sec– DC = 10 cm, third– DC = 0), 2 hours after transection of the spinal cord at the level of the I thoracic vertebra and removal

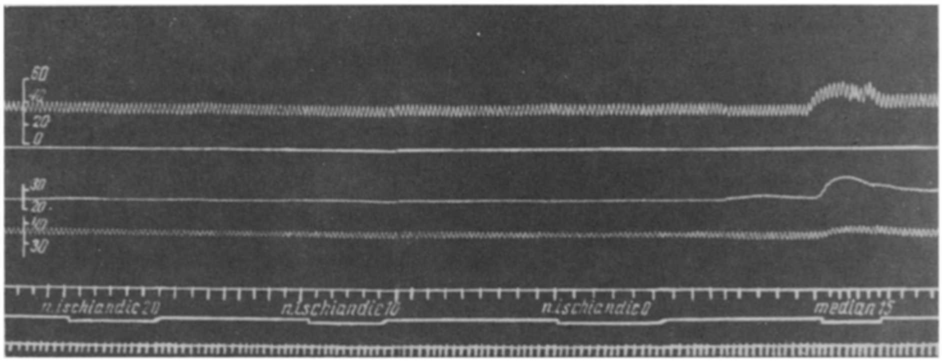

Fig. 3. Results of stimulating the central portions of the sciatic and median nerves with a successively increasing current intensity 2 hours after transection of the spinal cord at the level of the I thoracic vertebra and removal of its caudal portion. Meaning of the curves is the same as in Fig. 1 (instead of the pressure in the thoracic duct we recorded the outflow of lymph drops from it). Figures above the stimulus marking – distance between the induction coils (in centimeters).

of its caudal portion, did not cause changes in the indices recorded; stimulation of the central portion of the median nerve with an induction current (DC = 15 cm) led to changes in the arterial and venous pressure and lymph flow.

Thus, stimulation of the central portion of the sciatic nerve with an induction current, following transection of the spinal cord at various levels, can cause reflex changes in the lymph flow and lateral pressure in the thoracic lymph duct in the absence of changes in the arterial pressure, venous pressure, and respiration. These changes disappear after removal of the spinal cord, which suggests the existence of lymphomotor centers in the spinal cord of warm blooded animals. Further verification of this hypothesis will serve as the subject of our subsequent investigations.

SUMMARY

Stimulation of the central section of the sciatic nerve with induction current following division of the spinal cord in dogs at the level of the first cervical vertebra to the XI thoracic can provoke reflex changes in the lymph flow and the lateral pressure in the thoracic lymph duct; with no alterations in the arterial, venous pressure and respiration. After removal of the spinal cord no such changes were observed; Thus, a conclusion can be drawn as to the presence of lymphomotor centers in the spinal cord of warm-blooded animals.

LITERATURE CITED

1. Val'dman, V. A., Vascular Tonus [in Russian] (Leningrad, 1960).
2. Golub, D. M., in the book: Problems in the Morphology of the Peripheral Nervous System [in Russian] (Minsk, 1949), p. 7.
3. Grinshtein, A. M., Pathways and Centers in the Nervous System [in Russian] (Moscow, 1946).
4. Durmish'yan, M. G., On the Mechanisms of the Effects of Afferent Stimuli [in Russian] (Moscow, 1955).
5. Esakov, A. I., A study of the Processes Lying at the Root of the So-Called Automatic Activity of the Lymph Pumps [in Russian]. Avtoref. Diss. Kand. (Moscow, 1958).
6. Itina, N. A., Functional Properties of the Neuro-Muscular Apparatus in Lower Vertebrates [in Russian] (Moscow-Leningrad, 1959).
7. Kovanov, K. V., Works of the All-Union Soc. of Physiologists, Biochemists, and Pharmacologists [in Russian] (Moscow, 1954), vol. 2, p. 77.
8. Kotova, G. N., Fiziol. Zhurn SSSR, 1957, No. 5, p. 428.
9. Kokhanina, M. I., Humoral-Reflex Regulation of Lymph Flow [in Russian]. Diss. Kand., (Alma-Ata, 1943).
10. Petrovskii, V. V., Fiziol. Zhurn. SSSR (1954) No. 3, p. 323.
11. Polosukhin, A. P., in the book: Neural Regulation of Blood Circulation and Respiration [in Russian] p. 234.
12. Uryupov, Yu. S., Works of the All-Union Soc. of Physiologists, Biochemists, and Pharmacologists [in Russian]. (Moscow, 1954), vol. 2, p. 64.
13. Frol'kis, V. V., Reflex Regulation of Cardio-Vascular System Activity [in Russian] (Kiev, 1959).
14. Bernar-Klod, Lectures on the Physiology and Pathology of the Nervous System [in Russian]. SPb. (1866) vol. 1.
15. Camus, L., Gley, E., C. R. Acad Sci (Paris, 1895) v. 120, p. 747.

All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of this issue.