4. B. N. Shavyrin, E. L. Andreev, N. V. Bulgakov, et al., in: Central Regulation of the Hemodynamics [in Russian], Kiev (1973), pp. 232-234.
5. V. M. Khayutin, V. M. Danchakov, and V. L. Tsaturov, Byull. Eksp. Biol. Med., No. 2, 117 (1958).
6. V. Smieško, J. Kožik, and E. L. Meschersky, Physiol. Bohemoslov., 29, 278 (1980).
7. M. Bullivant, J. Physiol. (London), 280, 141 (1978).
8. S. Rodbard, Perspect. Biol. Med., 13, 507 (1970).

TIME COURSE OF LYMPH PRESSURE IN SOMATIC AND MESENTERIC LYMPHATICS AT REST AND AT THE PEAK OF DIGESTION

Yu. I. Borodin,* P. M. Tryasuchev, and E. P. Voityuk

UDC 612.323 + 612.333]-018:612.423

KEY WORDS: lymph pressure; lymph nodes; functional activity.

In this investigation the time course of lymph pressure in the popliteal and mesenteric lymph nodes and their efferent lymphatics was studied in 20 intact dogs when the drained organs were in a state of physiological rest and also, in the case of the mesenteric nodes, at the peak of digestion.

EXPERIMENTAL METHOD

The hydrodynamic lymph pressure was measured by means of a pressure transducer developed by E. P. Voityuk, the sensitive element of which is a profiled silicon membrane, 36-60 μ thick, on which a tensoresistive Wheatstone bridge with temperature stabilization elements is formed by means of planar diffusion technology [1]. The transducer has the following parameters: dynamic range 0-200 mm Hg, sensitivity 1 mV/mm Hg, zero drift ≤1%/°C, nonlinearity ≤1%. The intrinsic frequency of mechanical resonance is 20 kHz, and with a fluorine plastic catheter with internal diameter of 1 mm and length 20 cm it is 300 Hz. The pressure recording chamber, one wall of which is formed by the membrane with resistance strain gauges, communicates with an injection needle through the fluorine plastic catheter. This space is filled with physiological saline containing heparin. The lymph pressure in the lymphatic space to be studied, into which the needle is inserted, was thus transmitted through the liquid to the membrane of the transducer. Unbalance of the Wheatstone bridge, proportional to pressure changes, was recorded in the form of strain graphs.

The lymph pressure was recorded in this way for periods of 30 sec, separated by intervals of 2 min. Observations on each organ were made for between 30 and 60 min. The blood pressure in the external iliac artery was recorded synchronously by means of another transducer, and respiration was recorded by an MT-64 thermistor. The injection needle connected to the transducer was inserted into the lymph node to a depth of 2 mm. The two cases in which subcapsular bleeding was observed, resulting in high values of the pressure inside the node, were excluded from the study. A much more frequent complication was entry of the needle into the connective-tissue hilar body. In such cases the pressure record corresponded to a uniform curve characteristic of that obtained when the transducer needle was inserted into the perinodal cellular tissue.

If the pressure curve recorded with the needle inserted into the perinodal cellular tissue (control) was similar to that recorded with the needle inside the node, the latter was discarded. Operative access to the lymph nodes was obtained under morphine—thiopental anes-

*Academician of the Academy of Medical Sciences of the USSR.

Laboratory of Functional Morphology of the Lymphatic Circulation, Institute of Physiology, Siberian Branch, Academy of Medical Sciences of the USSR, Novosibirsk. Department of Normal Anatomy, Novosibirsk Medical Institute. Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 93, No. 6, pp. 10-12, June, 1982. Original article submitted December 16, 1981.

 0007-4888/82/9306-0702$07.50

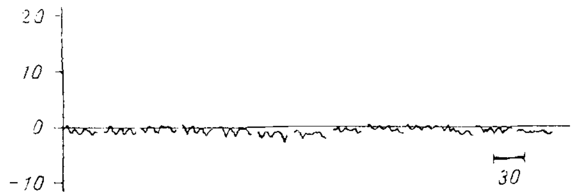

Fig. 1. Pressure in mesenteric lymph node of a fasting dog (in cm water). Time marker (below) 30 sec.

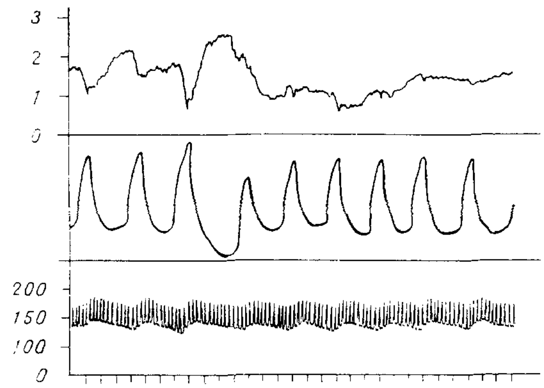

Fig. 2. Synchronized recordings of lymph pressure in mesenteric lymph node (in cm water, top trace), respiration (middle trace), and arterial pressure (in mm Hg, bottom trace).

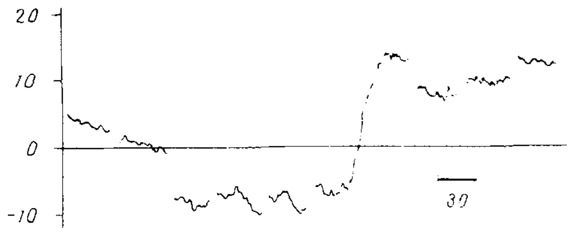

Fig. 3. Pressure in mesenteric lymph node at peak of digestion. Scales of pressure and time correspond to those in Fig. 1.

thesia. The needle of the transducer was inserted into the lymphatics against the lymph flow. As a rule, insertion into the large efferent vessel of the mesenteric conglomerate of lymph nodes did not block its lumen. The efferent vessel of the popliteal lymph node was discovered in the middle of the medial surface of the thigh in the composition of a plexus of lymphatics around the femoral vein. As a rule it collapsed on the needle proximally to the site of puncture. Distally to the puncture, however, the lumen of the vessel was visible and the lymph was transported by other vessels of the plexus.

EXPERIMENTAL RESULTS

The pressure in the popliteal lymph node in the stationary limb fluctuated with an amplitude of 2-5 cm water about the zero mark, and in some cases its value was negative. Periodic rises and falls of pressure with a cycle of about 12 min (waves of the 1st order) were observed. On these were superposed waves of the 2nd order, with a duration of 2-6 sec, and of the 3rd order, with a duration of 0.5-1 sec.

The time course of lymph pressure in the mesenteric lymph node in a state of reduced physiological activity of the gastrointestinal tract (the animals received no food for 24 h but could obtain water *ad lib.*) was similar to that of the hydrodynamic pressure inside the node. It also fluctuated slightly — with an amplitude of 2-5 cm — around zero (Fig. 1). In some cases the duration of the 1st order waves was longer than on the pressure curves of the popliteal lymph nodes, and reached 25 min. Synchronized recording revealed a genetic connection between the 2nd order waves and respiratory movements and between 3rd order waves and cardiac activity (Fig. 2).

The lymph pressures recorded in the efferent vessels of the mesenteric and popliteal nodes in some cases were higher than in the corresponding nodes themselves. For instance, a lymph pressure of 3 to 10 cm water (with an amplitude of 3 to 12 cm) was found in the efferent vessels of the popliteal nodes, and a pressure of 4 to 8 cm water (with an amplitude of 1 to 11 cm) in the efferent vessels of the mesenteric nodes. The duration of the 1st order waves was rather longer in the efferent vessels of the mesenteric nodes than in those of the popliteal node (12-15 min compared with 9-10 min).

In three cases the pressure was measured similarly in one of the two afferent lymphatics of the popliteal lymph node. It was found to be 9-14 cm water. Even gentle massage of the tissues of the foot led to a rapid (within 0.5-2 min) and considerable (up to 40-60 cm water, and in one case, up to 210 cm water) increase of pressure. After the massage was stopped the pressure fell to its original level within a few minutes. Incidentally, massage of the foot led to only a very small and slow (in several minutes) increase of pressure in the popliteal lymph node, without affecting the pressure in its efferent lymphatics.

At the height of digestion the pressure in the mesenteric lymph nodes rose considerably, to reach 15-17 cm water. The 1st-order waves on the lymph pressure curve became faster and their amplitude increased to 20-24 cm. Sudden pressure drops with an amplitude of 10-12 cm were observed (Fig. 3).

Similar changes also were observed in the efferent lymphatic of the mesenteric conglomerate of lymph nodes: The pressure in it increased to 15-20 cm water and the amplitude of the 1st-order waves reached 20-23 cm. A tendency also was found for the propulsive apparatus of the lymphatics to display greater acitivty: The 1st-order waves became shorter (9-12 min).

The 1st-, 2nd-, and 3rd-order waves can be regarded as periodic changes in the patterns of lymph flow. The 1st-order waves reflect the natural tonic activity of the smooth-muscle apparatus of the lymphatic vessels and nodes, the 2nd-order waves reflect respiratory movements, and the 3rd-order waves reflect cardiac activity. They were discovered previously during a study of the lymph flow in somatic lymphatics using thermistors [2, 3]. The present investigation shows that these phenomena are also typical of the mesenteric lymphatic pathways. The results are in agreement with those of an investigation [4] in which it was found that the pressure in the afferent lymphatic of the dog's popliteal lymph node is lower than in the efferent lymphatic. The results now obtained show that in the peritoneal cavity lymph passes into the efferent vessels of the lymph nodes against the pressure gradient.

The negative pressure levels thus revealed are evidence of a suction factor in the motor activity of the lymph nodes for peripheral lymph. The negative pressures on the lymph pressure curves are characterized by the same wavelike changes as the positive curves. In some experiments the pressure levels were observed to change from positive to negative and vice versa. The lymph pressure at any given moment of life is thus the resultant of influences of many different kinds on the lymph flow.

LITERATURE CITED

1. E. P. Voityuk, V. A. Gridchin, and A. P. Lisofenko, in: The Natural Sciences in Health Care [in Russian], Novosibirsk (1980), pp. 115-116.
2. V. V. Kamenskaya and Yu. I. Borodin, Izv. Sibir. Otd. Akad. Nauk SSSR. Ser. Biol. Med. Nauk, No. 4/1, 90 (1963).
3. V. G. Karmanov, "Measurement of the temperature of plant leaves during physiological research," Author's Abstract of Candidate's Dissertation, Leningrad (1956).
4. G. V. Tomchik, "The lymph flow in the regional lymph nodes and architectonics of the intramural vascular system under normal conditions and in venous stasis," Author's Abstract of Candidate's Dissertation, Novosibirsk (1974).