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The Effect of the Pulse upon the Flow of Lymph.*

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In the course of some observations upon the receptaculum chyli, we were impressed by the fact that its position is such that it is ideally located for receiving the transmitted pulsations of the aorta. It lies between the aorta and the vertebral column, being intimately attached to the posterior wall of the aorta. The intercostal vessels form its lateral boundaries. A search of the literature shows that others have believed that the pulsations of arteries may be transmitted to the lymphatic system but positive demonstration of this is lacking.

This paper deals with the results of attempts to register pulsations in lymphatic vessels in several locations in dogs.

Large dogs were used in all experiments. In some instances, cream was given 3 hours before beginning the studies. Approximately 0.1 g of morphine was injected an hour prior to the operation. A slow pulse rate was desired and this was accomplished by using morphine. It was supplemented by ether during the operative procedures except in those instances in which the thoracic duct was exposed in the neck, when local anesthesia was employed. Heparin was used as an anti-coagulant in some of the experiments. A glass cannula as large as the vessel would accommodate was placed in the lymphatic trunk and it was connected by a rubber tube to a Jaquet recording tambour with an air valve and the oscillations were recorded. Four different sites were chosen in the various experiments for the exposure of the large lymph vessels. The most satisfactory of these was that in which the upper part of the cysterna chyli and the lower end of the thoracic duct were exposed through a transpleural incision between the 12th and 13th ribs. Positive pressure anesthesia was used in this procedure. A large right angle cannula was inserted into the uppermost part of the cysterna. The cannula was introduced until it was felt that the tip was in the sub-diaphragmatic portion of the cysterna. An air-tight closure of the chest around the cannula was then performed.

Using this method, oscillations in the column of lymph in the tube which were synchronous with the pulsations in the femoral artery could be seen and recorded. These pulsations did not seem to be de-

* Aided by a grant from the Division of Medical Sciences of the Rockefeller Foundation.

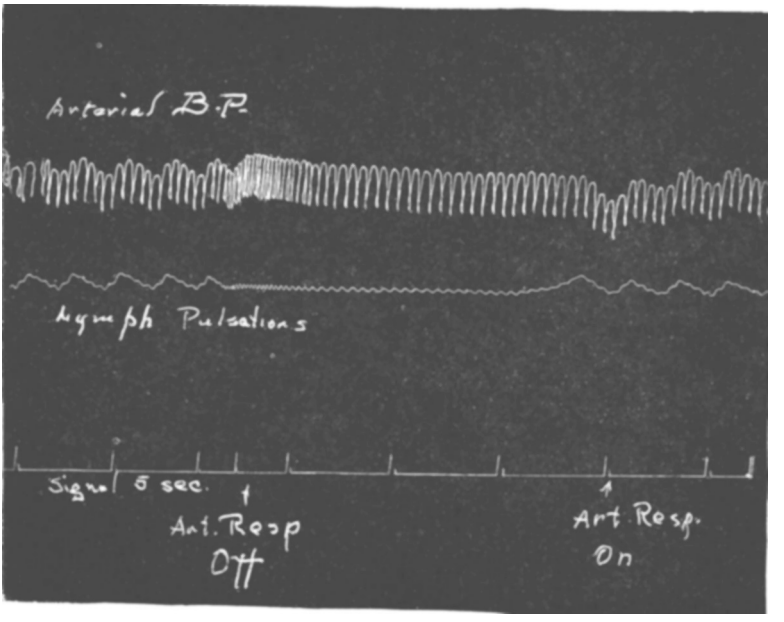

FIG. 1.

Showing the arterial blood pressure and the lymph pulsations as recorded in the receptaculum chyli through a cannula introduced just above the diaphragm. Incision in chest had been closed, animal still anesthetized. Only the oscillations synchronous with the arterial pulse were present when the apparatus producing artificial respirations was disconnected temporarily.

pendent upon the development of back pressure in the lymph trunks. As long as artificial respiration was used and the chest was open, other oscillations were not usually visible. When artificial respiration was suspended temporarily after closure of the chest, no other oscillations appeared. Artificial as well as normal respiratory movements caused definite alterations in the height of the column of lymph when the chest was closed. The effects of the arterial pulsations were superimposed upon these. As stated, the tip of the cannula was located at or below the attachment of the diaphragm. Quiet inspiration was associated with an elevation in the column of lymph and expiration with a decline, exactly the opposite of the alterations in pressure in the pleural cavity. On the other hand, forced expiration resulted in a marked increase in pressure. Some of these findings are shown in Figs. 1 and 2.

Results of a similar character were obtained when the receptaculum chyli was cannulated through an incision in the flank. It was more difficult under these circumstances to prevent leakage around the cannula. An attempt was made to determine whether or not pul-

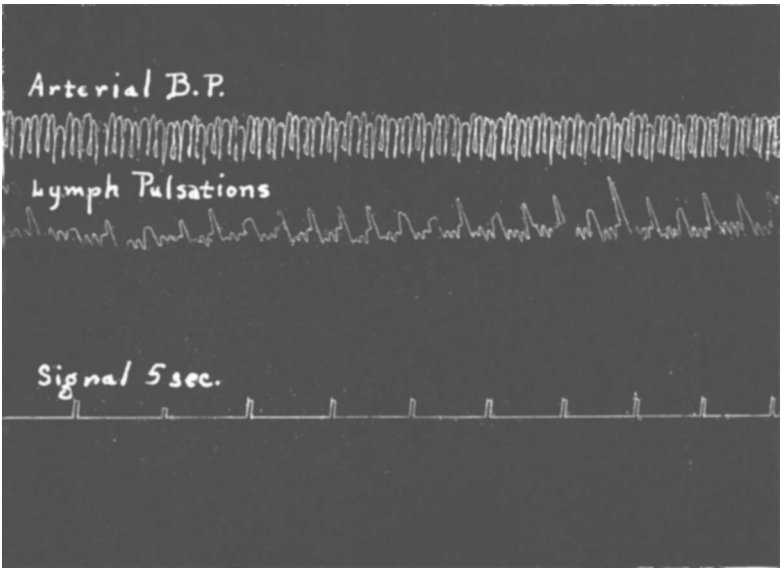

FIG. 2.
Showing the arterial blood pressure and the lymph pulsations as recorded in receptaculum chyli. Animal breathing normally, quiet respirations. The larger alterations in lymph pressure are due to respiratory movements and the smaller ones to arterial pulsations.

sations synchronous with those in arteries are present in the smaller lymph vessels. A cannula which was directed peripherally was placed in a lymph vessel lying anterior to the aorta and similar pulsations were recorded. Due to the proximity of this lymph vessel to the aorta, it is likely that the pulsations were transmitted from it.

Another approach consisted of cannulating the thoracic duct in the neck and similar pulsations synchronous with those in the large arteries were found. This was true also when a vein pocket[1] including the entrance of the duct was used instead of direct cannulation of the duct itself. Ligation of the subclavian artery did not abolish the pulsations. Ligation of the thoracic duct in the lowermost part of the chest caused a diminution but not a total disappearance of the pulsations. Expiration was associated with a rise and inspiration with a fall in the lymph pressure.

According to Poirier, Cuneo and Delamere,[2] the lymphatics are usually grouped together in the neighborhood of blood vessels, which they accompany in almost a straight line. A difference of opinion

1 Lee, F. C., *Am. J. Physiol.*, 1924, **67**, 498.

2 Poirier, P., Cuneo, B., and Delamere, G., *The Lymphatics*, W. T. Keener and Co., Chicago, 1904.

exists as to the agencies responsible for the flow of lymph and as to the relative importance of these. Luciani[3] stated, "At each systolic efflux the whole arterial tree is dilated by the passage of the pulse wave, in consequence of which the whole of the perivascular lymphatics immediately receive an impulse to centripetal evacuation of the lymph which they contain." However, Luciani considered active and passive movements of skeletal muscles and the respiratory mechanism as the most important agencies in promoting the flow of lymph. After enumerating many factors which aid in the flow of lymph, Lee[4] stated that he had observed small fluctuations in lymph pressure, not entirely synchronous with the heart beat, and which he believed to be due to intra-thoracic pressure changes associated with the contraction of the heart. As a result of studies on lymph pressure, Beck[4] stated, "It is probable that the pulsation of the blood-vessels may be transmitted to the adjacent lymph vessels and on account of the numerous valves present in the lymph vessels force the lymph forward and become a factor in the production of the pressures obtained in this study." Sainsbury[5] expressed the belief that the pulse wave is the most important factor in promoting the flow of lymph. Clark and Clark[6] describe the movement of lymph as a "bobbing" back and forth synchronous with the heart beat or respiration, with only a sluggish forward movement.

Since the present experiments were initiated, Parsons and McMaster[7, 8] have reported the results of an extremely interesting study in which it seems to have been proven conclusively that a pulsating stream of blood is an important factor in maintaining a flow of lymph. The ears of rabbits were perfused with defibrinated rabbits' blood in such manner that pulsation could be imported to the perfusate or withheld from it at will. It was found that pulsation of the blood vessels leads to greater formation and flow of lymph, to greater interstitial spread of dye injected into the tissues and to the more rapid absorption of dye. Even though the flow of the perfusate was less and the pressure was lower, pulsating perfusions yielded larger lymph flows and greater spread of dye in the tissues.

The competency of the valves in lymphatics was confirmed by our futile attempts to pass a small catheter through the thoracic duct

3 *Luciani's Human Physiology,* Macmillan and Co., 1911, 1, 519.

4 Beck, C. S., *Johns Hopkins Hosp. Bull.,* 1924, **35**, 206.

5 Sainsbury, Harrington, *The Cardiac Cycle,* William Wood and Co., 1931.

6 Clark, E. R., and Clark, E. L., *Am. J. Anat.,* 1933, **52**, 273.

7 McMaster, P. D., and Parsons, R. J., *J. Exp. Med.,* 1938, **68**, 377.

8 Parsons, R. J., and McMaster, P. D., *J. Exp. Med.,* 1938, **68**, 353.

into the cysterna chyli. It is obvious that the pulsations of arteries would be without influence on the effective lymph flow were it not for the valves which allow the fluid to flow in only one direction. The experiments reported do not allow one to state with certainty that the arterial pulsations are an important agency in promoting the flow of lymph. However, the fact that the lymph pulsations were present even when the ducts did not appear to be distended is highly suggestive. It seems likely that the arterial pulsations are an important factor in promoting the flow of lymph when the subject is completely relaxed or sleeping. Even under these conditions, the respiratory movements aid materially. However, the effect of the respiratory movements is probably exerted in the main on large lymphatic trunks and only indirectly on most of the smaller ones, whereas the arterial pulsations probably influence directly the lymph flow throughout the body. The work of Parsons and McMaster suggests this very strongly. During activity, whether it be of the skeletal or intestinal systems, the muscular movements probably exert a major influence on the flow of lymph. The many factors which promote the flow of lymph vary quantitatively under different conditions.

Summary. Pulsations in lymphatics synchronous with those in arteries have been recorded. The possible effect of the pulse upon the flow of lymph has been discussed.

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Optimal Conditions for Recovery of Antibody from Immune Precipitate of Type I Pneumococcus.

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In a previous paper[1] we have shown that the liberation of antibody from immune precipitate of Type I Pneumococcus by the action of dilute alkali is due to a shift of antigen-antibody equilibrium as follows:

$$B_mG_n \underset{\text{neutral}}{\overset{\text{alkaline}}{\rightleftharpoons}} B_{m-x}G_n + xB$$

[1] Liu, S. C., and Wu, H., *Chinese J. Physiol.*, 1938, **13**, 449.