

EFFECT OF INCREASED SYSTEMIC VENOUS PRESSURE ON THORACIC DUCT AND PERIPHERAL LYMPH FLOW IN DOGS

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ABSTRACT

In congestive heart failure, lymph flow from the cannulated thoracic duct is greatly increased. However, there has been scant data on lymph flow in the intact lymphatic system with systemic circulatory congestion. In the present study, thoracic duct and peripheral lymph flow were qualitatively determined using heated cross-thermocouples in seven mongrel dogs. Central venous pressure was raised artificially by infusing large volumes of crystalloid solution equivalent to a maximum of 30% of body weight. Although both thoracic duct and peripheral lymph flow increased with an intact (closed) lymphatic system, the increase was notably less than with a transected (opened) cervical thoracic duct. With systemic circulatory congestion, cannulated thoracic duct lymph flow circumvents a major lymph impediment to lymph flow (i.e. high central venous pressure) and therefore considerably overestimates in vivo central lymph flow in this condition.

In congestive heart failure, a raised venous pressure favors greater capillary filtration and formation of edema. In this situation, lymphatics are typically dilated and creation of an external thoracic duct fistula not only demonstrates increased central lymph flow, but also relieves the signs and symptoms of circulatory congestion (1,2). On the other hand, this salutary clinical response also suggests that cannulation of the thoracic duct artificially circumvents restricted lymph drainage at the thoracic duct-subclavian vein junction from elevated central venous pressure (3-6). Ac-

cordingly, cannulated thoracic duct lymph flows with circulatory congestion may not be comparable to central lymph flow with an intact lymphatic system.

To pursue this possible discrepancy we used heated cross-thermocouples to determine qualitatively lymph flow in both an intact (closed) and transected (opened) lymph circulatory system, in dogs with raised systemic venous pressure after large volume infusion.

MATERIALS AND METHODS

Seven mongrel dogs weighing 10-17kg were anesthetized intravenously with sodium pentobarbital (30 mg/kg) and for muscle relaxation pancuronium bromide (0.08 mg/kg). A cuffed endotracheal tube was inserted and dogs ventilated in the supine position with a positive pressure respirator. Catheters were inserted into the left jugular vein and femoral artery, and central venous and arterial pressure continuously recorded using a pressure transducer (Nipponkoden, LPU-0.1A and Statham, P23ID) with the mid-axillary line of the chest taken as a zero reference level. A large bore catheter was also placed into the right femoral vein for fluid infusion and administration of drugs. After cannulae placement, 1000 units of heparin were administered intravenously. The cervical thoracic duct and a peripheral lymphatic in the lower leg were exposed (7). In two dogs,

the thoracic duct was opened to the ambient atmosphere by transection in the neck adjacent to the left internal jugular vein ("open" lymph system).

The plate-type elements (MT Giken, P-3L) of the heated cross-thermocouples (MT Giken, CTM-101) were attached to the cervical thoracic duct wall and leg lymphatic just above the ankle with surgical glue. Lymph vessels were freed from the underlying tissue and an adiabatator laid beneath them. The relative change in lymph flow was continuously monitored as the difference in thermo-electromotive voltage, with control lymph flow calibrated as zero voltage.

After 30 minute "equilibration" warmed Ringer's solution was infused continuously at an average rate of 10-15 ml/kg/min to a maximum of 30% of body weight to raise the central venous pressure in increments. During this "experimental period" changes in central venous and arterial pressure, and qualitative changes in lymph flow in both the "closed" and "open" lymph circulatory systems were determined.

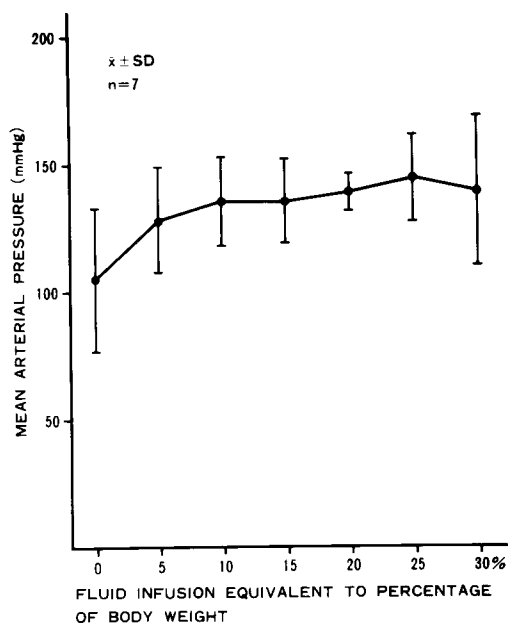


Fig. 1: Mean arterial pressure after incremental volumes of fluid infusion to a maximum of 30% body weight.

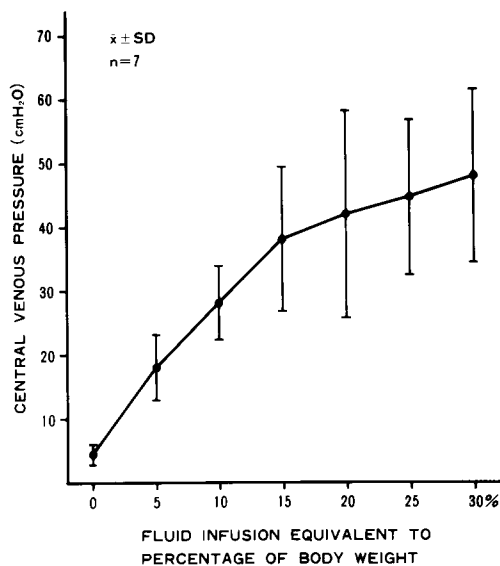


Fig. 2: Progressive rise in central venous pressure, after infusion of large volume of fluid.

RESULTS

After volume overload dogs uniformly showed both marked generalized and pulmonary edema. Mean arterial pressure (105.2 ± 25.0 mmHg) also increased to 135.6 ± 15.6 , 138.8 ± 6.4 , and 138.6 ± 26.1 mmHg after infusion volume to 10%, 20% and 30% of body weight respectively, with the major rise occurring after infusion of 1-1.7 liters of fluid (10% body weight). Central venous pressure (4.4 ± 1.5 cmH₂O), on the other hand, uniformly showed a progressive incremental rise with volume infusion to 28.1 ± 5.3 , 41.9 ± 15.1 , and 47.8 ± 12.7 cmH₂O after fluid overload of 10%, 20% and 30% of body weight respectively (Fig. 2). In the intact ("closed") lymph circulatory system, thoracic duct flow also showed a qualitative rise (13.8 ± 14.2 , 24.1 ± 12.4 and 35.9 ± 17.4 V) with infusion volume equivalent to 10% 20% and 30% of body weight, (Fig. 3) but the rise was considerably less when compared to the open circulatory system (100-300 V, Fig. 4). By comparison, peripheral lymph flow (10.2 ± 7.2 , 29.4 ± 7.4 and 26.9 ± 3.1 V) (after in-

fusion of 10%, 20% and 30% body weight respectively) was similar in "closed" and "open" lymphatic system (Fig. 5). A direct correlation was observed between central venous pressure and thoracic duct flow in the "closed" lymph circulatory system (Fig. 6).

Although peripheral lymphatics were widely dilated, no streamer formation was seen, and therefore, he presumed that rhythmic contractility of dermal lymphatics played little or no role in propelling lymph forward. In contrast, tissue clearance of subcutaneously injected radioiodinated serum

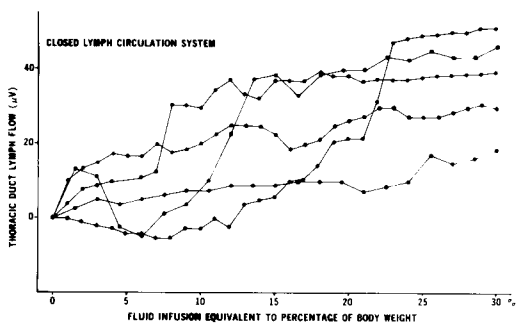


Fig. 3: Thoracic duct flow in the intact ("closed") lymph circulatory system increased significantly when fluid infused is equivalent to more than 15% of the body weight ($p < 0.05$). Thoracic duct flow is shown as the difference in the thermo-electromotive voltage.

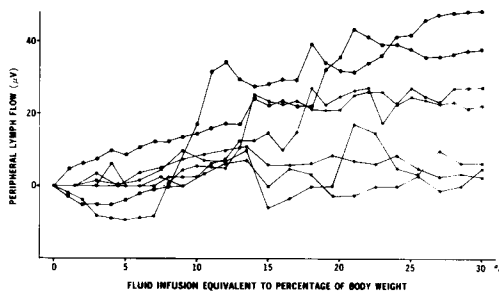


Fig. 5: Peripheral lymph flow in the leg increases significantly when the fluid infused is equivalent to more than 15% of body weight ($p < 0.01$).

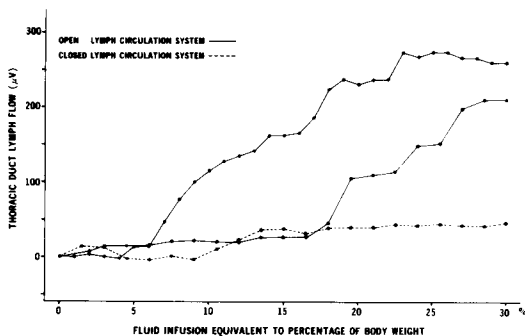


Fig. 4: Thoracic duct flow in the opened lymph circulatory system (2 dogs) is much greater than thoracic duct flow in the closed system (mean 5 dogs).

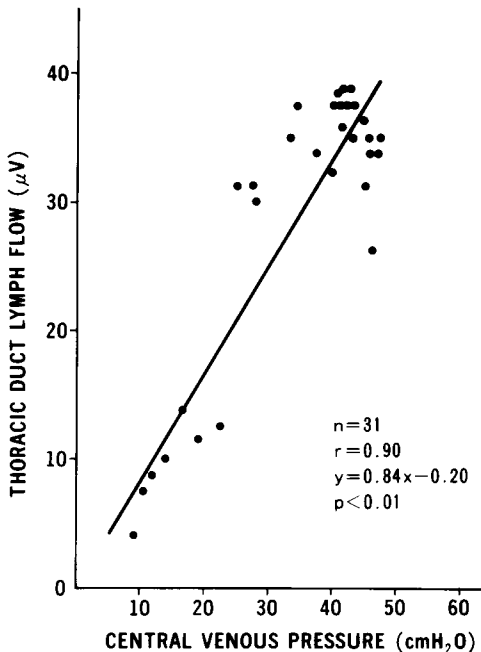


Fig. 6: A direct correlation is found between central venous pressure and thoracic duct flow in the closed lymph circulatory system.

DISCUSSION

In longstanding cardiac edema, McMaster (8) examined lymph flow in cutaneous lymphatics of the leg by injecting small amounts of dye intradermally.

albumin in cardiac edema was found to be rapid (9,10) suggesting that lymph flow was increased.

The effect of increased systemic venous pressure on drainage of lymph from the thoracic duct has been investigated previously (4-6), but seldom where the lymphatic system was undisturbed (11). In this study, thoracic duct flow increased with an intact "closed" lymph circulatory system after central venous pressure was raised by massive fluid infusion and presumably greater net capillary filtration and lymph formation. Moreover, there was a direct correlation between elevation in central venous pressure and rise in thoracic duct flow suggesting that propulsion of thoracic duct lymph partially overcame greater resistance from central venous hypertension. On the other hand, thoracic duct flow in the "open" lymph circulatory system increased multifold over that in the "closed" system, suggesting that not only is central venous hypertension a major barrier to free flow of lymph, but that cannulation of the thoracic duct during circulatory congestion yields a flow rate that is not a true indicator of flow *in vivo*.

Although massive volumes of fluid were infused to raise central venous pressure and the dogs exhibited pulmonary and generalized edema, overhydration is characteristic of patients with congestive heart failure and therefore the experimental findings resemble the clinical condition (12).

Heated cross-thermocouples have previously been used to assess regional blood flow in a variety of tissues and organs (13). The chief advantages of this method are its simplicity with attachment to a vessel without extensive damage and the ability to monitor fluid flow on-line. Nonetheless, this technique only provides qualitative data by change in electromotive voltage and does not yield information regarding volume flow per minute.

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