The Cardiac Lymphatics After Ligation of the Coronary Sinus[1] (34987)

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Although there are a number of excellent anatomic studies of the cardiac lymphatics, relatively few physiologic studies have been made due to technical difficulties in the cannulation of small channels. The cardiac lymph flow and composition has been studied in normal dogs and under some abnormal conditions (1–4). The effect of obstruction of the cardiac lymphatics on the structure and function of the heart has also been investigated (5, 6). A recent report from this laboratory on the cardiac lymphatics in experimental congestive heart failure (4) suggests that in chronic congestive failure the mediastinal channels which drain the cardiac lymph are grossly enlarged but the cardiac lymph flow is not significantly increased.

The effect of obstruction of the veins of the heart on the cardiac lymph flow and composition is the subject of this paper. Venous congestion was produced by partial or complete ligation of the coronary sinus which principally obstructs the veins of the left ventricular myocardium (7).

Methods. Healthy mongrel dogs weighing 10–20 kg were anesthesized with intravenous sodium pentobarbital (29 mg/kg). Respirations were maintained with an endotracheal tube and an intermittent positive-pressure respirator. A right lateral thoracotomy incision was made through the 3rd or 4th intercostal space and a small polyethylene catheter (PE 10) inserted into a cardiac lymphatic in the mediastinum at or near the aortic arch. Visualization of the lymphatics was aided by the injection of Evans blue dye (T 1284) (1–2 cc, 0.5% solution) subepicardially into the right ventricle near the pulmonary conus and magnification with the Zeiss operating microscope. The cardiac lymph was collected at 15-min intervals for 1 hr followed by ligation of the coronary sinus. Cardiac lymph was again collected at 15-min intervals for 1 hr. Determinations were made on each hourly specimen of collected lymph of WBC, GOT, LDH, Na, K, Cl, and total proteins. The composition of the blood was similarly determined after the lymph studies were completed.

A separate right thoracotomy incision was made through the 5th intercostal space for exposure of the coronary sinus and to pass a ligature around it. A large bore (⅛ in. id) stiff polyethylene catheter was passed into the coronary sinus through a stab wound in the right atrium and connected to a recording manometer. The pressure was measured before and after ligation of the coronary sinus over the rigid catheter. The site of ligation was about a centimeter from the right atrium in an area without tributaries. In a few animals one or two venous channels emptied into the coronary sinus between the ligature and the orifice of the coronary sinus in the right atrium. The blood pressure in the chambers of the heart and in the great vessels was recorded at the end of eight of the experiments.

Results. Forty-five dogs were used and cardiac lymph-flow studies completed in 20 (Table I). The mean cardiac lymph flow of 20 normal anesthesized dogs was 1.2 ml/hr (range 0.4–2.1). After complete ligation of the coronary sinus in 17 experiments, the mean cardiac lymph flow rose to 4.4 ml/hr (range 0.6–10.0). The coronary sinus was partially ligated in three dogs and an intermediate rise in mean cardiac lymph flow from the control level of 1.63 to 2.53 ml/hr

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TABLE I. Cardiac Lymph Flow and Coronary Sinus Pressure Before and After Complete Ligation of Coronary Sinus. Number of experiments in parentheses.[a]

		Cardiac lymph flow (ml/hr)		Coronary sinus mean pressure (mm Hg)	
	Weight (kg)	Before	After	Before	After
Mean	(20) 16.7	(20) 1.2			
	(17) 17.0	(17) 1.14	(17) 4.4	(11) 8.3	(15) 45.6
Range	(20) 10.4–20.4	(20) 0.4–2.1			
	(17) 10.4–20.4	(17) 0.4–2.1	(17) 0.6–10.0	(11) 5.0–12.0	(15) 20.0–87.5
SE		(20) ±0.13	(17) ±0.71	(11) ±0.7	(15) ±5.4

[a] In three experiments partial occlusion of the coronary sinus was followed by an increase of the mean cardiac lymph flow from 1.63 to 2.53 ml/hr. The mean body weight was 16.4 kg.

was observed. The mean coronary sinus pressure was 8.3 mm Hg (range 5.0–12.0) in 11 normal anesthetized dogs and rose to 45.6 mm Hg (20.0–87.5) after ligation of the coronary sinus in the 15 dogs in which it was measured.

Control samples of cardiac lymph, collected before ligation of the coronary sinus, contained both erythrocytes and leukocytes. WBC, RBC, electrolytes, and total protein determinations of lymph were not altered appreciably by coronary sinus ligation (Table II). The GOT and LDH were roughly half the control value in five of the six experiments. The GOT and LDH doubled in one experiment after ligation of the coronary sinus.

The composition of blood samples drawn after the lymph flow studies were completed (*i.e.*, after 2½–3 hr of anesthesia) are shown in Table III. The GOT and LDH were considerably higher in the cardiac lymph than in the blood, the electrolyte values were similar, and the protein content of cardiac lymph was lower than that of blood serum.

At the end of eight of the experiments the blood pressure in the RA, RV, LA, LV, and innominate artery were recorded. These were within normal limits implying that there was no gross deterioration in the general condition of the animals.

Clotting of cardiac lymph in the small polyethylene tubes used for cannulation was notably absent. This is in contrast to the frequency of clot formation in drainage of both the thoracic duct and right duct. However, when cardiac lymph is left overnight in a test tube a clot will form.

Discussion. The experiments reported here show that ligation of the coronary sinus with

TABLE II. Composition of Cardiac Lymph Before and After Ligation of Coronary Sinus. Number of experiments in parentheses.

	One-hr collection before ligation			One-hr collection after ligation		
	Mean	Range	SE	Mean	Range	SE
Wt (kg)	(9) 17.8	12.7– 20.4		(9) 17.8	12.7– 20.4	
WBC × 10^3	(9) 2.0	0.7– 4.5	± 0.442	(7) 2.2	.7– 6.0	± 0.555
RBC × 10^3	(9) 205	14 –1200	±126	(7) 289	40 – 600	±127
GOT	(6) 1840	624 –5250	±220	(4) 740	268 –1300	±155
LDH	(6) 1177	414 –2725	±329	(4) 725	285 –1096	±131
Na^+	(7) 162	151 – 188	± 5.0	(6) 152	149 – 155	± 1.0
K^+	(7) 2.6	1.9– 3.0	± 0.13	(6) 3.0	2.7– 3.7	± 0.13
Cl	(7) 129	113 – 151	± 4.6	(6) 122	106 – 126	± 2.5
Total protein	(6) 3.6	2.3– 5.0	± 0.46	(5) 3.6	2.2– 5.3	± 0.46

TABLE III. Composition of Blood After Lymph Studies Completed. Number of experiments in parentheses.

		Mean	Range	SE
Wt (kg)	(6)	17.4	12.7 – 20.4	
WBC $\times 10^3$	(6)	12.4	8.3 – 22	± 2.16
RBC $\times 10^6$	(6)	6.18	4.64– 7.02	± 0.85
SGOT	(3)	81	55 –100	±13.5
LDH	(3)	86	51 –126	±22.3
Na^+	(5)	152	147 –157	± 1.6
K^+	(5)	3.4	3.1 – 3.8	± 0.4
Cl^-	(5)	112	104 –115	± 1.8
Total protein	(5)	5.2	4.8 – 5.8	± 0.06

the production of venous congestion is followed by an increase in the cardiac lymph flow; however, gross edema of the myocardium was not observed. Symbas *et al.* (6) found evidence that obstruction of the cardiac lymphatics by ligation may impair myocardial contractility in some animals.

When lymph formation is accelerated by raising the venous pressure, it presumably would first collect in the interstitium. The demonstrated prompt increase in cardiac lymph flow after ligation of the coronary sinus suggests there is a limited capacity of the heart to accommodate expansion of an interstitial pool of lymph. The extensive network of lymphatics in the heart, notably described by Patek (8), would appear to aid in the ready egress of lymph and deter the development of cardiac edema. Furthermore, the histologic structure of the heart, which consists of closely knit muscle bundles with a minimum of areolar tissue, would not lend itself to extensive edema formation. The lungs, on the other hand, have a loose, expansible histologic framework into which edema fluid collects readily. We have demonstrated that acute obstruction of the pulmonary veins is followed by a small (nearly 4-fold) increment in pulmonary lymph flow (9). We have also shown that much larger increases in pulmonary lymph flow occur in chronic pulmonary edema associated with experimental congestive failure—as high as 25-fold or more (10, 11).

The observation that the cardiac lymph flow does not increase appreciably in experimental congestive heart failure (4) suggests that chronic venous congestion does not occur to any extent in the heart under the conditions of those experiments. In contrast are the present experiments in which the venous pressure of the heart was deliberately elevated to excessively high levels and a marked increase in cardiac lymph flow followed.

The relatively low GOT and LDH values in cardiac lymph, compared to the controls, may be explained by dilution of the enzymes by the increase in lymph formation. The low enzyme values in blood serum, compared to the GOT and LDH of cardiac lymph, are also explained by dilution of the cardiac enzymes when added to the blood stream of the animal.

The absence of clotting of cardiac lymph in the fine catheters used for cannulation is not readily explained. However, this may be evidence for a protective mechanism in the heart which prevents or delays coagulation of blood or lymph in that organ.

The relationship between venous pressure, capillary pressure, and lymph flow, clearly stated by Starling (12), has been demonstrated for many organs such as the lungs, liver, intestine, kidney, and the lower extremities. The present experiments further support Starling's statement and confirm its validity for the heart.

Summary. The cardiac lymph flow was measured in 20 dogs by cannulation at the level of the aortic arch of a mediastinal lymphatic which drains lymph from the heart. The mean flow was 1.14 ml/hr and this rose to 4.4 ml/hr after complete ligation of the coronary sinus in 17 experiments. After partial ligation of the coronary sinus in three experiments, there was a rise in cardiac lymph flow of lesser degree. The mean pressure in the coronary sinus in 11 experiments was 8.3 mm Hg and this rose in 15 dogs to 45.6 mm Hg after ligation of the coronary sinus. Thus the mean cardiac lymph flow increased 3.9-fold while the mean coronary sinus pressure increased 5.5-fold.

The WBC, RBC, Na, K, Cl, and total protein of the lymph were not altered appreciably by coronary sinus ligation. The GOT and LDH were roughly half the control value

in five of six experiments. The GOT and LDH were considerably higher in cardiac lymph compared to peripheral blood drawn after the lymph studies were completed.

The data suggest that an increase in the venous pressure of the left myocardium, which is produced by ligation of the coronary sinus, is followed by a significant 3.9-fold increase in the cardiac lymph flow. This confirms for the heart the relationship between venous pressure, capillary pressure, and lymph flow stated by Starling, which has been previous demonstrated in organs other than the heart.

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