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Canine Cardiac Lymph Potassium, pH and Flow after Experimental Myocardial Infarction[1] (39162)

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(Introduced by M. Friedman)

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In recent years there has been increased awareness of the possible role of the cardiac lymphatics in various pathologic states (1–5). We have recently demonstrated an anatomic relationship between the canine subendocardial lymphatics and the cardiac conduction system and suggested a possible role of the lymphatics in the genesis of conduction disturbances and arrhythmias (6). The postulated mechanism involves transport of substances, such as intracellular products, from a damaged to a vulnerable area via the lymph system. Accordingly, it was the purpose of this investigation to study the changes in canine cardiac lymph potassium, pH and flow after producing acute myocardial infarction.

Methods. Nine healthy mongrel dogs weighing 16 to 25 kg were used in this study. They were anesthesized with intravenous pentobarbital (26 mg/kg) and respirations were maintained with an endotracheal tube and an intermittent positive pressure respirator. A right lateral thoracotomy incision was made through the fourth intercostal space. The cardiac lymphatics were visualized after 0.5–1 ml 0.5% solution of Evans blue dye (T-1824) was injected subepicardially into the right ventricle near the pulmonary conus. Visualization of the lymphatics was aided by the use of a Zeiss operating microscope (Model HL 5024). A small polyethylene catheter (PE 50) was inserted into a cardiac lymphatic in the mediastinum at or near the aortic arch (3). Lymph was allowed to drain directly into micro-blood collecting tubes (150 mm long, 3 mm diameter, 1.5 mm bore). Collection was made with tubes on ice and sealing was done immediately using tube sealer.

Cardiac lymph was collected and measured at 30-min intervals for 1 hr. A small myocardial infarction was produced by ligating the left anterior descending artery and adjacent vein approximately 4 cm from the apex, and the electrocardiograms were monitored for characteristic changes. Cardiac lymph samples were collected at 30-min intervals for 2 hr. Arterial blood was collected from a cannula in the carotid artery at the end of each 30-min interval. Lymph flows were measured and samples of lymph and blood were analyzed for potassium (Instrumentation Lab., Model 1434 Flame Photometer), pH (Corning Instruments Model 165 Blood Gas Machine), and the data were tested for statistical significance using the paired t test.

Results. The lymph potassium concentration (mEq/liter) did not significantly change under the conditions of this experiment (Table I.A).

The potassium content of the lymph (concentration times flow) increased and generally subsequently decreased in these studies (Table I.B). The increase of mean lymph potassium from 0.112×10^{-3} mEq/min in the 60-min control group to 0.153×10^{-3} mEq/min in the 30-min postligation group was significant at a level of $P < 0.05$.

The changes in serum potassium before and after ligation and for the remaining experimental groups were not significant (Table II.A), however, the slight drop between the 30- and 60-min control groups was significant.

The mean of the cardiac lymph pH decreased in the course of the study (Table I.C). The mean pH was significantly changed from 7.53 in the 60-min control group to 7.47 in the 30-min postligation group. The changes between the 30- and 60-min control, 30- and 60-, 60- and 90-, 90-

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TABLE I. LYMPH

	Time (min)	Control		Experimental			
		30	60	30	60	90	120
A. Potassium concentration (mEq/liter)	Mean	3.667	3.556	3.538	3.663	3.689	3.656
	SEM ±	0.176	0.181	0.236	0.186	0.172	0.176
	range	2.9–4.5	2.8–4.3	2.4–4.7	2.5–4.3	2.8–4.4	2.8–4.3
B. Potassium content ($\times 10^{-3}$ mEq/min)	Mean	0.103	0.112 $P < 0.05$	0.153	0.150	0.143	0.141
	SEM ±	0.028	0.023	0.031	0.027	0.023	0.020
	Range	0.040–0.292	0.058–0.280	0.055–0.315	0.045–0.283	0.079–0.271	0.064–0.240
C. pH	Mean	7.58	7.53 $P < 0.05$	7.47	7.45	7.43	7.43
	SEM ±	0.04	0.02	0.03	0.02	0.02	0.02
	Range	7.80–7.44	7.66–7.42	7.58–7.28	7.54–7.36	7.53–7.31	7.51–7.31
D. Flow (ml/30 min)	Mean	0.92	0.94 $P < 0.05$	1.33	1.32 $P < 0.02$	1.20	1.12
	SEM ±	0.25	0.18	0.23	0.21	0.21	0.22
	Range	0.31–2.50	0.37–2.00	0.44–2.20	0.62–2.50	0.50–2.20	0.15–2.12

TABLE II. SERUM

	Time (min)	Control		Experimental			
		30	60	30	60	90	120
A. Potassium concentration (mEq/liter)	Mean	4.1 $P < 0.05$	4.0	4.1	4.2	4.0	4.1
	SEM ±	0.1	0.1	0.2	0.2	0.2	0.1
	Range	3.3–4.5	3.3–4.4	3.2–4.5	3.1–4.7	3.1–4.4	3.5–4.4
B. pH	Mean	7.44	7.44	7.45 $P < 0.05$	7.41	7.41	7.40
	SEM ±	0.05	0.06	0.06	0.06	0.05	0.05
	Range	7.64–7.34	7.66–7.27	7.63–7.33	7.62–7.30	7.60–7.29	7.60–7.28

and 120-min experimental groups were not statistically significant.

The pH of the serum remained relatively constant except for a significant drop between the 30- and 60-min experimental groups. The mean serum pH values were lower than the corresponding mean cardiac lymph values (Table II.B).

The cardiac lymph flow increased after ligation in all experiments and generally subsequently decreased (Table I.D). The mean lymph flow increased from 0.94 ml/30 min prior to ligation to 1.33 ml/30 min in the first sample group after ligation. This increase was significant at a level of $P < 0.05$. The mean lymph flow decreased significantly ($P < 0.02$) between the experimental 60- and 90-min groups. The changes between the two control samples, the experimental 30- and 60-, and 90- and 120-min groups were not statistically significant.

Discussion. Potassium. The concentration of potassium in local coronary veins draining an ischemic area increases after coronary occlusion (7), and Jennings *et al.* (8) have demonstrated that after about 90 min, potassium rapidly decreases in the infarction site. In this study, following ligation there was no significant increase in lymph potassium concentration (mEq/liter) although there was a significant increase in lymph potassium content (mEq/min) as a result of the increased lymph flow generated by the infarction. Thus the number of milliequivalents of potassium moving through the interstitial tissue to the collecting system at a given instant of time has increased after ligation.

Feola, Glick, and Pick (9) have reported an increase in lymph potassium concentration following experimental myocardial infarction, whereas Szabó, Magyar, and Réffy (10) reported no increase in lymph potassium concentration 6 hr after experimental myocardial infarction and a subsequent increase in lymph concentration 24 hr later. In Feola's experiments the circumflex artery was ligated, whereas in this study the distal anterior descending artery was ligated to provide a minimal size infarc-

tion. Accordingly, the sampling of lymph from a small infarction may fail to show rise in potassium concentration, especially if there is a concomitant increase in local fluid volume.

pH. Following experimental myocardial infarction the pH of the lymph significantly dropped. The serum pH, on the other hand, also significantly dropped, but the change became apparent at a later interval of time, suggesting that the local changes are first manifest in the lymph drainage system.

Lymph flow. This study indicates that ligation of the distal left anterior descending coronary artery results in an increase in cardiac lymph flow. Since the technique involved ligation of both a small coronary artery and its adjacent vein, it seems unlikely that the increased flow is due to outflow (venous) occlusion as the corresponding inflow was also occluded. It is quite likely that hypoxia produced certain changes within the cells which facilitated the release of substances to the interstitial space that mobilized fluid and subsequently enhanced lymph flow. The significant fall in lymph flow 1 hr after ligation suggests that the source of the fluid expends itself quickly.

Conclusions. Canine cardiac lymph was studied after acute experimental myocardial infarction. The lymph potassium concentration remained the same, the lymph potassium content increased, the lymph pH decreased, and the lymph flow increased while the serum potassium and pH remained the same. It is suggested that localized hypoxia may result in cellular changes that release substances, e.g., potassium, to the interstitial space where they mobilize fluid and enhance lymph flow.

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