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Comparison of Renal and Cardiac Lymph Constituents

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Summary

The concentration of various substances were measured in renal and cardiac lymph and arterial and venous plasma to determine if lymph constituents might indicate events occurring at the cellular level in these two organs. The study utilized anesthetized dogs. Magnesium, calcium, pyruvate and glucose concentrations were similar in the four fluids. Cardiac lymph contained significantly higher concentrations of creatine phosphokinase, lactic dehydrogenase and lactate. Renal lymph contained lower concentrations of zinc and protein while both renal and cardiac lymph contained less copper than arterial plasma. Venous plasma contained more copper than the other fluids. It is concluded that lymph composition reflects events occurring in the cells, especially for substances that are not readily diffusable through blood capillary endothelium.

Introduction

Lymph represents the best estimate of the composition of interstitial fluid from any organ (1). Many authors speak of interstitial fluid and lymph interchangeably. These authors examine lymph and plasma similarities and conclude that lymph or interstitial fluid is not too much different from plasma except for protein concentration and electrolyte concentration, the latter as altered by the Donnan equilibrium (2). This idea has recently been criticized by *Haljamae* (3). Also of interest is the relation of lymph to intracellular composition. For example, *Bergofsky* et al. (4) found the average pO_2 of anaerobically collected lymph was 7.2 mmHg which closely approximates the myocardial cell pO_2 of 6.9 mmHg found by *Whalen* (5) in cat ventricules *in vivo*. The pO_2 of lymph and myocardial cell was always far less than that of coronary sinus blood.

If this relation exists for oxygen, might there be other lymph constituents whose concentrations would indirectly give information on what is going on inside the cell?

To help answer the question, we compared the concentrations of several constituents in renal and cardiac lymph with arterial and venous plasma. We chose these two organs since the heart and kidney have similar lactic dehydrogenase (LDH) activities but the heart has much greater total activity (6). The heart is very rich in creatine phosphokinase (CPK) while the kidney is poor in this enzyme (7). Normally, in the heart, glucose and pyruvate are utilized for metabolism with little pyruvate reduced to form lactate (8). In the kidney, glucose is produced in the cortex and utilized in the medulla (9). Further, there is a large lactate gradient maintained between the cortex and medulla in the kidney (10).

In respect to electrolytes, the concentrations of magnesium and copper in heart and kidney are similar while calcium is maintained much higher in the kidney as is zinc but to a lesser degree (11).

Methods

Ten mongrel dogs of either sex, which had fasted 24 hours with water ad libitum, were anesthetized with intravenous sodium pentobarbital (30 mg/kg). The left kidney was exposed through a flank incision. Hilar lymphatic vessels were located around the renal artery and the largest of these vessels was ligated and catheterized with polyethylene tubing. The animal was placed on a respirator and the left thorax was entered through the fourth

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intercostal space. A small amount of fluorescein was injected into the left ventricular myocardium. The fluorescent lymphatic vessels leaving the heart were traced to the cardiac lymph node lying medial to the brachiocephalic artery. The larger lymphatics were ligated and the largest was catheterized with polyethylene tubing. The femoral artery and vein were catheterized for measuring blood pressure or collecting blood and infusion or collecting blood respectively. The animal was heparinized and an infusion of 0.9 % NaCl at 0.13 ml/kg/min was begun and continued for the duration of the experiment. After a 30 minute equilibration period, two 1 ml lymph samples were collected together with midpoint blood samples. One lymph sample was used for the determination of lactate, pyruvate, glucose, total protein, lactic dehydrogenase (LDH) and creatine phosphokinase (CPK) while the other was used for electrolytes. The order of analysis was reversed every other experiment. Protein was determined with American Optical refractometer and/or the Biuret reaction (12). Glucose, lactate and CPK were determined with Calbiochem Reagents modified from (13), termined with Sigma Chemical Co. Reagents modified from (16). LDH was determined by the method of *Wilson* et al. (17). Mean concentration values were determined for lactate and pyruvate in whole blood and other constituents in blood plasma and lymph. Values were compared with the one way analysis of variance and the Newman-Keuls multiple range test. The calci-Newman-Keuls multiple range test. The calcium concentrations were corrected for protein by the method of *Parfitt* (18).

Results

Table 1 (p. 160) shows constituent concentration in arterial and venous plasma and in renal and cardiac lymph. It can be seen that cardiac lymph contained greater total CPK and LDH activity. The ratio of LDH in the presence of .33 mM pyruvate and 10 mM pyruvate is a measure of LDH-H since high concentrations of pyruvate inhibit the LDH-H but not the LDH-M (6). As can be seen there was no difference among the four fluids.

There were no differences in the concentration of either Mg^{++} or Ca^{++} while Zn^{++} was lower in renal lymph. Cu^{++} in both renal and cardiac lymph were lower than in arterial plasma but higher in venous plasma than in the other three fluids.

Lactate concentration was greater in cardiac lymph but there were no differences with pyruvate and glucose.

Discussion

Magnesium, calcium, pyruvate and glucose concentrations were similar in arterial and venous plasma and renal and cardiac lymph.

CPK was much higher in cardiac lymph than plasma with a lymph/plasma of about 5.0. This value compares favorably with *Feola and Glick* (198) who reported a L/P of 7.0. These L/P ratios are considerably higher than the 1.5 reported by *Szabo* (20). Total LDH was much higher in cardiac lymph than plasma with concentrations very similar to those reported by *Uhley* et al. (21) but higher than found by *Szabo* (20). The higher concentration of lactate in cardiac lymph is very similar to that reported by *Araki* et al. (22) and *Kluge* (23).

The finding of low zinc and copper concentrations in renal lymph was no surprise since these metals are tightly bound to proteins (24, 25) and the data indicate that the lymphatic-venous gradient is the same order of magnitude and direction for zinc, copper and protein.

The low concentration of copper but not of zinc in cardiac lymph is probably a result of the much larger concentration of zinc in myocardial tissue (26). This would allow a greater gradient for the diffusion of zinc in contrast to copper, from cells into lymph.

The data would support the hypothesis that lymph composition reflects events occurring in the cells, especially for substances that are not readily diffusible through blood capillary endothelium.

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Table 1 The mean concentration ± SE of constituents of arterial and venous plasma and renal and cardial lymph

	Arterial	*Venous*	*Renal*	*Cardiac*
CPK mU/ml	285 ± 32	272 ± 31	94 ± 21	1357 ± 306*
LDH (mU/ml) with .33 pyruvate	55 ± 6.6	60 ± 6.8	30 ± 6.3	785 ± 250*
LDH (mU/ml) .33/10 mM pyruvate	2.10 ± .19	2.14 ± .19	2.72 ± .46	2.44 ± .09
Mg (mEq/L)	1.36 ± .05	1.36 ± .05	1.36 ± .06	1.36 ± .09
Ca (mEq/L)	4.74 ± .19	4.79 ± .20	4.80 ± .19	4.60 ± .20
Zn (μg%)	60 ± 5	74 ± 7	40 ± 6*	71 ± 8
Cu (μg%)	58 ± 4	75 ± 4*	30 ± 3++	40 ± 3++
Lactate (mg%) WB	11.5 ± 2.1	14.4 ± 3.0	9.4 ± 1.3	21.0 ± 4.2*
Pyruvate (mg%) WB	1.07 ± .16	1.11 ± .19	1.05 ± .28	1.59 ± .26
Glucose (mg%)	100 ± 7	92 ± 6	85 ± 11	85 ± 9
Protein (mg/ml)	53 ± 6	55 ± 6	20 ± 4+	48 ± 7

*Higher than other means; + Lower than other means; ++ Lower than arterial and venous; no difference between cardiac and renal lymph; WB whole blood

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