Lymphology 11 (1978) 37–41

Comparison of Lactate, Pyruvate and Potassium Concentration in the Cardiac Lymph and, Arterial and Coronary Sinus Plasma in Dogs

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Summary

Lactate (LA), pyruvate (PYR) and potassium (K) concentration in the cardiac lymph were compared with those in the arterial and coronary sinus plasma in dogs. In each substance, there was a good correlation between the plasma and cardiac lymph level in the control period. In respect to LA and PYR, the concentration in the cardiac lymph correlated more with that in the arterial plasma than in the coronary sinus one. During the infusion of isoproterenol, LA and PYR in the plasma increased, while K decreased. Each substance in the cardiac lymph changed to the same degree as in the plasma in mean values. Good correlation was also observed between the arterial plasma and cardiac lymph level during the administration of the agent. However, there was no correlation of PYR between the coronary sinus plasma and the cardiac lymph. During the administration of dipyridamole LA in the coronary sinus plasma increased and that in the arterial plasma decreased. LA in the cardiac lymph did decrease as in the arterial plasma. It is concluded that the concentrations of LA, PYR and K in the cardiac lymph can be changed depending upon changes in those in the plasma and the former two parameters seem to change depending upon those in the arterial plasma rather than the coronary sinus one.

Introduction

It has been recognized that the composition of lymph resembles that of plasma (1) and can be changed following changes in the plasma composition (2). It seems also important, however, to know which of the concentration of some substances in the arterial plasma and venous one correlates to more extent with that in the lymph, when the substance has a significant arterio-venous difference.

Lactate and pyruvate have a significant arterio-venous difference in coronary circulation, since these substances are well extracted by the heart as a substrate. In the present experiment, we examined whether there was a correlation in these substances between the cardiac lymph and, arterial and coronary sinus plasma, and then evaluated which of the concentrations in the arterial plasma and coronary sinus one had a better correlation with that in the cardiac lymph. It was also studied on the potassium concentration, which showed no significant arterio-venous differences.

Methods

Mongrel dogs weighing from 14 to 22 kg were anesthetized with intravenous administration of sodium pentobarbital (30 mg/kg), intubated and artificially ventilated with room air and supplementary oxygen to maintain the arterial oxygen tension within the normal value. The thoracotomy was performed through the left fourth intercostal space and the heart was exposed. The pericardium was incised about 3 cm at the portion just above the great cardiac vein. Small amount of T-1824 dye (0.05 to 0.1 ml) was injected into the left ventricle with tuberculin needle (27 G) and the cardiac lymphatic vessels were made visible. Teflon tube of small diameter (OD 1 mm) was inserted into the great cardiac vein carefully not to damage the cardiac lymphatic vessels and the tip of the tube was advanced about 3 to 4 cm toward the coronary sinus. Cardiac lymph node (3) was dissected free from the surrounding connective tissue and all the lymphatics entering the lymph node were ligated. A polyethylene tube (PE-10 or 50) was cannulated into one of the afferent lymphatic vessels stained with T-1824 dye. The lymphatic fluid flowing out

0024–7766/78 1300–0037 $ 04.00

from the cannula was collected in an ice cold polyethylene tube containing one drop of heparin solution (1,000 units/ml). Collecting period was varied from 15 to 60 min to obtain a desired volume of lymph. Arterial and coronary sinus blood were sampled at the starting- and end-point of the collecting period of the cardiac lymph. The blood and lymph were centrifuged at 0°C for 10 min at 3,500 rpm and the supernatant was used for chemical analysis. Potassium ion was measured by atomic absorption spectrometer (Perkin-Elmer 403). Lactate and pyruvate concentration were determined by the enzymatic method (Biochemica Combination Test, Boehringer Mannheim).

Arterial blood pressure was measured from the left internal thoracic artery using an electronic manometer and lead II of electrocardiogram was also monitored. In six dogs, isoproterenol was infused intravenously in doses of 0.1 μg/kg/min and sampling of the blood and lymph was done before and during the agent. In three dogs dipyridamole (30 μg/kg/min) was administered to decrease the arterio-coronary sinus differences of lactate concentration. Throughout the experiment, 5 % of glucose solution was infused intravenously (5 to 6 drops/min). Statistical analysis was done using the Student's unpaired or paired t-test.

Results

In 11 dogs, we successfully cannulated into the cardiac lymphatic vessels and great cardiac vein, and obtained an enough volume of the cardiac lymph for chemical analysis. During the sampling period of the cardiac lymph in control, which was varied from 15 to 60 min, the blood pressure, heart rate and lead II of electrocardiogram showed no change. The flow rate of cardiac lymph in the control period was 2.2 ± 0.2 ml/hr (mean ± SE, n = 11).

Table 1 shows the results of chemical analysis of the cardiac lymph and, arterial and coronary sinus plasma in the control period. In all parameters there were no significant differences between the values of plasma obtained at the starting- and end-point of the sampling period of the cardiac lymph. Lactate and pyruvate concentration were significantly higher in the cardiac lymph than in the coronary sinus plasma and when it was compared in each case, the lactate and pyruvate concentration were higher in the cardiac lymph than in the arterial plasma in most cases. There was no significant difference in potassium concentration between the plasma and cardiac lymph.

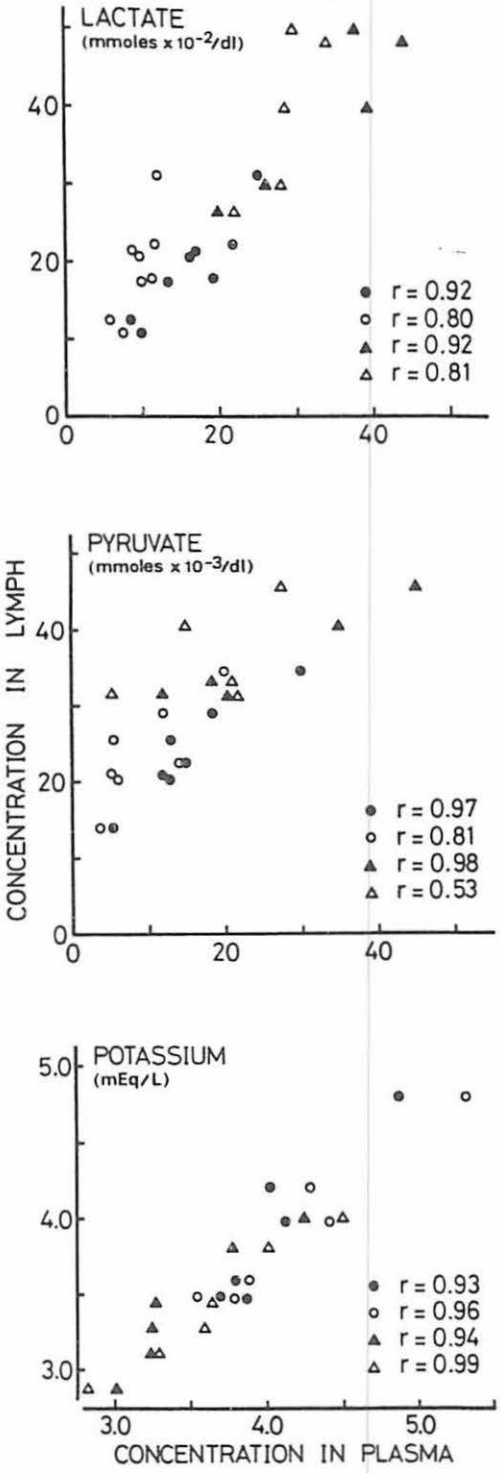
The mean values of the plasma samples obtained at the starting- and end-point were calculated. Each value of lactate, pyruvate and potassium concentration in the cardiac lymph was plotted against the mean plasma value (Fig. 1, closed and open circles). There was a good correlation between the cardiac lymph and, the arterial or coronary sinus plasma in each three parameter. In respect to the lactate and pyruvate concentration, higher corelation coefficient was observed between there correlation cardiac lymph and arterial plasma than between the cardiac lymph and coronary sinus one.

After starting the infusion of isoproterenol, the blood pressure tended to decrease slightly, from 134 ± 10 to 127 ± 9 mmHg at 5 min, and then returned to the control value and maintained the constant value throughout the experiment. The heart rate increased from 165 ± 10 to 192 ± 14 beats/min ($p < 0.05$)

Table 1 Comparison of composition between cardiac lymph and, arterial and coronary sinus plasma in control.

		Arterial Plasma		*Cardiac*	*Coronary Sinus Plasma*	
	No.	starting-point	end-point	*Lymph*	starting-point	end-point
Lactate, mmoles x 10^{-2}/dl	8	16.9 ± 2.4	16.2 ± 1.6	19.3 ± 2.2	9.9 ± 0.9**	9.6 ± 0.7**
Pyruvate, mmoles x 10^{-3}/dl	7	16.8 ± 3.4	13.6 ± 2.7*	23.9 ± 2.5	10.0 ± 2.4**	9.1 ± 2.2**
Potassium, meq/liter	6	3.91 ± 0.14	4.21 ± 0.24	3.92 ± 0.22	4.11 ± 0.28	4.29 ± 0.28

Values are mean ± SE. * $p < 0.05$, ** $p < 0.01$, compared with cardiac lymph.



and sustained the high value during the infusion period of isoproterenol. The flow rate of the cardiac lymph increased from 2.0 ± 0.4 to 2.3 ± 0.5 ml/hr ($p < 0.05$). Fifteen minutes after the infusion of isoproterenol, the concentration of lactate and pyruvate in the plasma increased and that of potassium decreased significantly. These concentration in the plasma showed a further change following the passage of time up to 75 min after the starting of isoproterenol administration, in spite of the constant hemodynamic parameters. The mean value of the plasma samples obtained at the starting- and end-point was calculated as in the control and the effect of isoproterenol on the composition of plasma and lymph was summarized in Table 2. The concentration of lactate and pyruvate increased significantly in the cardiac lymph and that of potassium decreased. The degree of changes of each substance in the cardiac lymph was almost similar with that in the plasma. Each value in the cardiac lymph after the agent was also plotted against the mean value of plasma in Fig. 1 (closed and open triangles). As in the preinfusion period, there existed significant correlations between the cardiac lymph and, arterial and coronary sinus plasma in the lactate and potassium concentration. Each regression line, however, was different to some extent from that in the control period. In pyruvate concentration, there was no significant correlation between the cardiac lymph and coronary sinus plasma, while good correlation existed between the cardiac lymph and arterial plasma.

In order to change the arterio-coronary sinus difference of lactate concentration, intravenous infusion of a potent coronary vasodilator, dipyridamole (4), was done in three dogs (Fig. 2). During the infusion of the agent the value in the coronary sinus plasma increased

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Fig. 1 Correlation between the concentration of lactate, pyruvate and potassium in the plasma and that in the cardiac lymph. ● ; arterial plasma values in control. ○ ; coronary sinus values in control. ▲ ; arterial plasma values after isoproterenol. △ ; coronary sinus values after isoproterenol.

Table 2 Effects of isoproterenol on the composition of cardiac lymph, arterial and coronary sinus plasma.

		Control			*Isoproterenol*		
	No.	Artery	Lymph	Cor. Sinus	Artery	Lymph	Cor. Sinus
Lactate, mmoles x 10^{-2}/dl	5	14.7 ± 2.6	16.2 ± 2.1	9.3 ± 1.2	33.3 ± 4.5**	39.3 ± 4.7**	28.2 ± 2.0***
Pyruvate, mmoles x 10^{-3}/dl	5	16.4 ± 4.0	25.1 ± 2.9	11.1 ± 2.9	26.3 ± 6.0	36.6 ± 2.8**	18.6 ± 3.5*
Potassium, meq/liter	6	4.06 ± 0.17	3.92 ± 0.21	4.20 ± 0.25	3.47 ± 0.19***	3.43 ± 0.17**	3.64 ± 0.24*

Values are mean ± SE. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, compared with control.

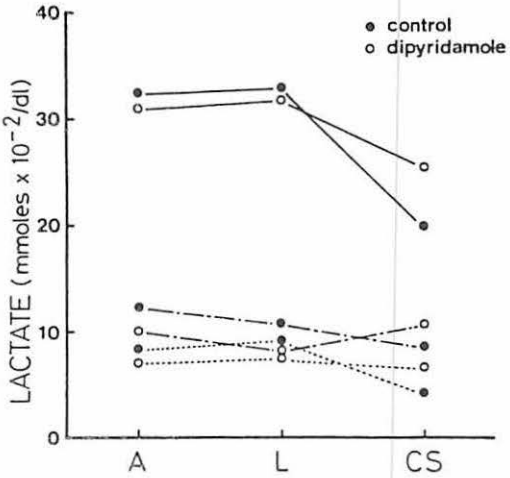

Fig. 2 Effect of dipyridamole on lactate concentration in the arterial plasma (A), cardiac lymph (L) and coronary sinus plasma (CS). Each line represents each case.

and that in the arterial plasma decreased in all cases. Thus, the arterio-coronary sinus difference diminished. The lactate concentration in the cardiac lymph did decrease as same as in the arterial plasma.

Discussion

In the present experiment, sampling of the arterial and coronary sinus blood was done both at the starting- and end-point of the sampling period of cardiac lymph. Since the sampling period of the cardiac lymph needs relatively long time, it seems necessary to check changes in the plasma level of each substance due to the passage of time alone, for the precise comparison of composition of the cardiac lymph and plasma. To examine the correlation between the plasma and cardiac lymph values, we used a mean value of plasma samples obtained at the starting- and end-point. There will be no problems when it was applied to the plasma samples in control and during the infusion of dipyridamole, since no significant change was observed between the starting- and end-point samples. During the infusion of isoproterenol, however, the plasma values of lactate, pyruvate and potassium obtained at the end-point showed a further change than that obtained at the starting-point. It would be also appropriate to use the mean value of these two plasma samples to compare the plasma value with the cardiac lymph, since our preliminary experiments showed that lactate, pyruvate and potassium concentration in the plasma changed just linearly within the sampling period of 15 to 75 min after the infusion of isoproterenol.

In the control period, a very high correlation was observed between the concentrations in the cardiac lymph and plasma in all three substances. During the infusion of isoproterenol, concentrations of these substances in the cardiac lymph changed to the same degree as in the mean plasma values in all three substances and the good correlation was also observed in most parameters. This indicates that the concentrations of these substances can be changed in the cardiac lymph depending upon changes in the plasma. The regression lines of these parameters after the agent were different to some extent from those in the control period. This might be caused by the changed cardiac metabolism itself due to the positive ino- and chrono-tropic action of isoproterenol. These results might indicate that the composition of the cardiac lymph was influenced not only by the plasma composition but also by the cardiac metabolism as already reported in experimental myocardial ischemia (5, 6).

When the correlation coefficient of these substances between the cardiac lymph and arterial plasma was compared with that between the cardiac lymph and coronary sinus plasma, higher correlation coefficient was observed in the former in lactate and pyruvate in the control period and also during the infusion of isoproterenol. Furthermore, the pyruvate concentration in the coronary sinus plasma showed no correlation with that in the cardiac lymph after the agent. These results were further confirmed in lactate after the administration of dipyridamole, where the lactate concentration in the cardiac lymph decreased as in the arterial plasma in spite of an increase in the coronary sinus level. In respect to potassium concentration, which had no arterio-coronary sinus difference, the correlation coefficient between the cardiac lymph and coronary sinus plasma showed a slightly higher value than that between the cardiac lymph and arterial plasma.

It is concluded that some substances in the cardiac lymph showing an arterio-coronary sinus difference, such as lactate and pyruvate, have a higher correlation with the arterial plasma level rather than the coronary sinus one.

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