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A New In-Situ Heart-Lung Preparation to Study Cardiac Metabolism*

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Introduction

To the present time heart-lung preparation or modifications of it have been used to investigate physiologic, hemodynamic and pharmacological specifications of the myocardium.[1] Many authors have used artificial apparatus to study cardiac functions, to study materials used by the heart, and to study the amount and effects of cardiac metabolics. The action of individual ions on the heart has been studied by perfusing the isolated heart using Langendorff preparation.[1] Results of these studies depend to a great deal on the number and amount of these artificial materials, such as pump, oxygenetor, tubing, etc..

It has been shown that artifical apparatus and materials may cause qualitative and quantitative changes upon red-blood cells, thrombocytes and serum proteins.[2] Many substances, which may be released from damaged blood corpuscles, may stay in the artificial apparatus and may effect the chemical reactions of the materials whose effect upon the myocardium is to be studied.

The purpose of this paper is to present a new heart-lung preparation which is entirely in the body, contains no artificial materials, and is not denervated. The first part of this study is planned to prove that such a preparation is technically possible.

The blood sugar level and PO_2, PCO_2, and PH of the circulating blood in the preparation were also studied.

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Material and Method

10 Mongreal dogs weighing 13 to 35 kg. (average 24 kg.) were operated on.

All dogs were anesthetized using 25 mg/kg. Nembutal and were connected to a Mark 8 Bird ventilator. Respirations of the animals were assisted by a mixture of 40 % O_2 and 60 % air until the chest was open and controlled respiration was obtained by using the same mixture after the chest was opened.

The thorax was entered through the right 4th intercostal space. The azygos vein was distally ligated and a catheter was passed through the proximal end into the right ventricle via the superior vena cava and right Ventricle. The pericardium was opened with a longitudinal incision and both vena cava were surrounded by umbilical tape. A second catheter was inserted into the left ventricle directly and pressures of both ventricles measured simultaneously. Another tape was passed around the ascending aorta near the truncus brachiocephalicus. A Potts clamp was applied to the right atrial appendage and a Satinsky clamp was applied to the ascending aorta. Incisions of 2 cm. were made above the clamps and anastomosis was performed using 5-0 Ti-cron suture material and continuous technique (Figure 1).

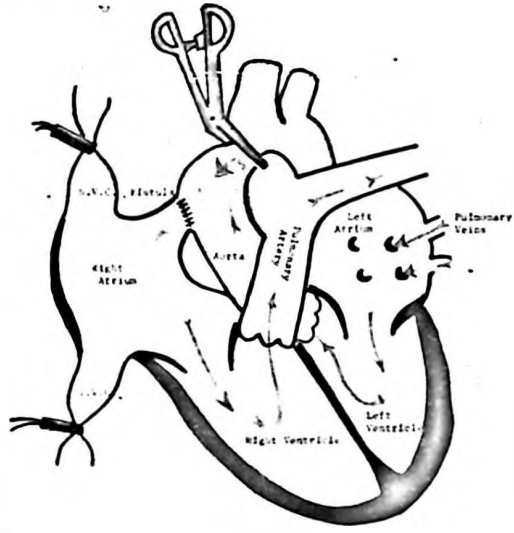

Figure 1
I.V.C.: Inferior Vena Cava
S.V.C.: Superior Vena Cava

TABLE I

TIME AND SAMPLE TABLE OF HEART-LUNG PREPARATION

Dog No:	Samples	PO_2 mm Hg	PCO_2 mm Hg	PH	Base Excess m.eq/l	HCO_3 m.eq/l	Total CO_2 M. mol/ Plasma	Duration of heart lung preparation in min.
1	Control	197.1	23.7	7.456	- 5.5	-16.5	-17.2	10
	Fifth minute	251.6	12.0	7.619	- 7.5	11.9	-12.3	
	At the end	166.8	8.2	7.725				
	Control	167.4	19.8	7.460	- 8	-13.9	-14.5	
2	Fifth minute	230.3	5.6	7.738	—	—	—	8
	At the end	197.3	4.5	7.63	—	—	—	
	Control	110.2	32.6	7.271	-11	-14.7	-15.8	
3	Fifth minute	167.5	10.9	7.663	- 8	-11.5	-12	8
	At the end	113.7	6.5	7.518	-16	- 5.7	- 6.2	
	Control	132	10.7	7.358	-13	-11.3	-12	
4	Fifth minute	177.4	8.2	7.753	- 6	-11.8	-12.1	10
	At the end	133.5	5.2	7.658	—	—	—	
	Control	105.4	11.3	7.493	-14	- 8.3	- 8.7	
5	Fifth minute	292.4	4.5	7.585	-15	- 6.8	- 7.3	10
	Control	122.3	24.0	7.297	-14	-11.3	-12.2	
6	Fifth minute	285.4	10.7	7.680	- 7.5	-11.8	-12.2	7
	At the end	87.6	20.4	7.425	-10	-12.8	-13.4	
	Control	159.5	8	7.494	-16	- 6.3	- 6.7	
7	Fifth minute	238.1	7.5	7.543	-15	- 6.6	- 7.1	8
	At the end	183.6	7.5	7.474	-17	- 5.7	- 6.3	
	Control	102.2	33.1	7.370	- 9	-15.6	-16.4	
8	Fifth minute	177.4	8.2	7.573	-13	- 7.6	- 8.1	9
	At the end	134.5	5.2	7.650	—	—	—	
	Control	140.4	22.3	7.423	- 9	-14	-14.7	
9	Fifth minute	230.5	10.2	7.540	-13	- 8.4	- 8.8	10
	At the end	130.5	4.5	7.590				
	Control	150.6	23.1	7.339	-12.5	-11.9	-12.6	
10	Fifth minute	200.8	10.7	7.510	-14	- 7.8	- 8.3	8
	At the end	170.5	4.3	7.550				

The ascending aorta was clamped distal to the anastomosis immediately before closing both vena cava and removal of the Satinsky clamp. At this moment, heart lung preparation begins to work: Blood pumped by the heart to the ascending aorta flows into the right atrium through the anastomosis and circulates through the right ventricule, pulmonary artery and lungs; and after oxygenation, returns to the pulmonary veins, left ventricule and again is pumped to the aorta making a closed circulation.

Once the anastomosis was opened and the aorta was clamped and closed circulation began; E.C.G., right and left ventricular pressures were monitored constantly. To check blood suqar and gases, blood samples were taken every five minutes and when the heart stopped. These samples were compared with the samples which were taken prior to the beginning of closed circulation in the preparation.

Results

Table I shows that the average time interval from the beginning of the funsction of the preparation until the heart stops is 8,8 minutes. At the end of 5 minutes there is a considerable elevation in the PO_2 and PH. Meanwhile POC_2 is decreased. PO_2 remains high in samples taken after the heart stops.

Table II shows that blood-sugar levels are low at the end of the fifth minute and at the end of the study. Average blood-sugar level is 66.9 mg % before the preparation works. At the end of the fifth minute it is 58.8 mg % and when the heart stops, it is 50.6 mg %.

TABLE II

BLOOD SUGAR CHANGES BY TIME IN THE HEART-LUNG PREPARATION

Dog No.	Control (% mg.)	5th Minute	At the end	Duration of heart-lung preparation (min.)	Amount of blood in the preparation at the end of study
1	73	60	56	10	200
2	52	48	40	8	200
3	61	59	49	8	220
4	72	70	60	10	190
5	74	62	44	10	210
6	64	54	45	7	200
7	56	48	38	8	200
8	64	59	44	9	210
9	78	63	55	10	200
10	75	65	45	8	200
Average	66.9	58.8	50.6	8,8	203

The average amount of blood in the preparation at the end of the experiment is 203 cc. with a minimum of 190 cc. and a maximum of 220 cc.

Right and left ventricular pressure traces, E.C.G. shown in Figures 2, 3 and 4. There was some elevation at the beginning of the experiment, but pressures decreased gradually until the heart stopped.

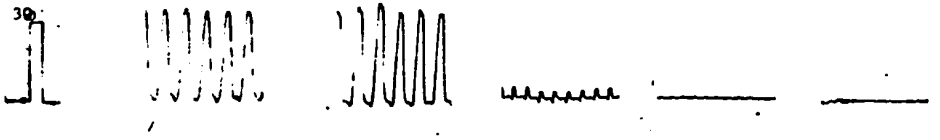

Figure 2
Right ventricular pressures

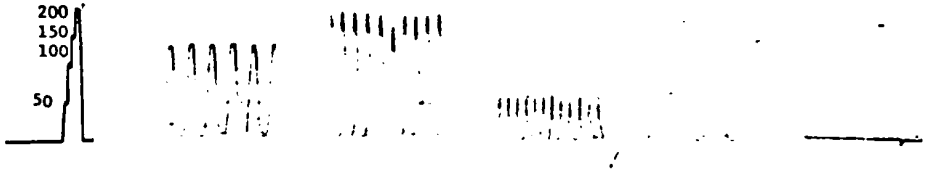

Figure 3
Left ventricular pressures

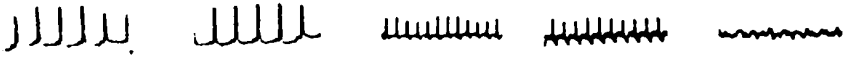

Figure 4
E.C.G.

Discussion

The disadvantage of heart-lung preparations which have been used to investigate cardiac functions, were mainly two:

1. The artificial elements included in the preparation.

2. The function of most of these preparations being outside the body. We believe their reactions to many factors are different when the organs (heart and lung) are taken outside the body.

J. Liedtke and friends[3] made a heart-lung preparation with the aid of pump and oxygenator. They studied the relationship between the cardiac metabolism and hemodynamic factors in pigs.

J. Neely[4] and T. Shea[5] studied cardiac functions in isolated mice hearts, also using artificial elements for the preparation.

J. Scheuer[6] used isolated mice heart preparations to investigate the effect of changes in high energy phosphate upon myocardium and electrocardium.

G. Marchetti and his friends[7] studied the effect of β adrenergic blocking drugs upon the myocardium using similar preparations. But the heart was not completely isolated and blood was circulating through detoxification organs causing side effects of these organs upon the material to be studied.

In our preparation, blood circulates only in the heart and lungs, therefore changes in the elements and any other material containing blood, can occur only in the heart and lungs.

In our preparation, there is a closed circulation and the heart gives metabolic residues into this circulating blood. The blood in our preparation never circulates through the kidneys and liver and no blood from other sources enters into this closed circulation. The average circulation time in preparation until th eheart stops is nine minutes. What is the main reason for the heart to stop at the end of the period? It is not myocardial anoxia since the PO_2 elevates. There are problems related to the elevation of CO_2. The decreased level of the blood sugar might be an important factor. The purpose of this preliminary report is to introduce a new preparation, to prove that it is technically possible, and to present initial findings.

At the second part of our study factors causing the heart to stop will be investigated.

We will also try and study different materials which may extend this period and make the heart function longer. For instance, our early impression is that solutions of glucose with insulin, extend this period and the heart beats much longer. It is obvious that many materials and drugs and their effect upon cardio-respiratory system can be studied with this preparation.

Summary

A new In-Situ Heart-Lung Preparation (İkizler - Aytaç Preparation) to study cardiac metabolism, has been described. Two main advantages of this new preparation over the previous ones in literature were discussed and it was proved that such a preparation is technically possible. Blood gases and blood sugar in the closed circulating blood of the preparation were also studied in the first section of this paper.

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