CONTINUOUS METHOD OF RECORDING HEAT PRODUCTION BY THE HEART

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The work of the heart and the metabolic processes in the myocardium associated with it are accompanied by the liberation of heat [2]. Heat is conducted away from the myocardium with the coronary blood and also by diffusion into the mediastinum and into the chambers of the heart [4]. A small quantity of heat is utilized in endothermic reactions, chiefly the deoxygenation of hemoglobin and interaction between carbon dioxide and the blood. Most of the heat from the myocardium is carried away by the coronary blood flow [5]. About 70% of the venous blood from the heart, mainly from the left ventricle, flows out through the coronary sinus [3]. Measuring the temperature of the blood flowing from the heart through the coronary sinus can therefore be used as an integral assessment of myocardial metabolism. Most investigations of myocardial heat production have been undertaken by direct calorimetry on isolated strips of heart, papillary muscles, and isolated hearts [2]. However, removal of the heart from the body disturbs the physiological mechanisms of humoral and nervous regulation of its activity and of myocardial metabolism as a result of denervation of the heart and disturbance of its humoral connections with the rest of the body. Release of heat by the myocardium also has been measured in experiments on the working heart with thoracotomy of the animal [5]. Thoracotomy also disturbs the conditions of work of the heart because of disturbances of external respiration and of the circulation, and it changes the pathway for the outflow of heat. More reliable information on the physiological correlation between function and metabolism of the myocardium can be obtained in experiments on the intact animal.

The aim of this investigation was to develop a continuous method of measuring the temperature of the blood in the coronary sinus and recording it in the course of physiological reactions of the circulation in experiments on animals with an intact chest and with preservation of natural breathing.

EXPERIMENTAL METHOD

Experiments were carried out on 15 dogs anesthetized with morphine and chloralose (2.5 and 50-100 mg/kg respectively), using a method of catheterization, extracorporeal perfusion and resistography of the coronary arteries, catheterization of the coronary sinus, the chambers of the heart, and the main vessels, and synchronized recording of arterial pressure, pressure in the chambers of the heart, the resistance of the coronary and peripheral vessels, respiration, etc. [1]. Parameters of the cardio- and hemodynamics, blood temperature in the coronary sinus, and other parameters were recorded on a Mingograf-81 polygraph. The catheter for catheterizing the coronary sinus (Fig. 1) is a radiopaque tube 4, with internal insulated leads 3, with a temperature transducer 1 on its curved ends, and with holes 2 for taking blood samples. On the other end of the catheter is a packing bush 7, a two-pin plug 5, and a connecting tube 6. An MT-54 "M" semiconductor microthermoresistor, designed by V. G. Karmanov, and made by the experimental workshop attached to the Agrophysics Research Institute (Leningrad), is used as the temperature transducer. The device for converting blood temperature readings into an electrical signal and recording it in reactions of the heart consists of a measuring bridge, amplifier, output signal regulator, tuning system, calibration system, indication system, power supply system, and recorder. The temperature transducer is connected into one arm of the measuring bridge of the proposed system. The catheter with temperature transducer is introduced into the coronary sinus under x-ray control using the TUR DE-16 x-ray

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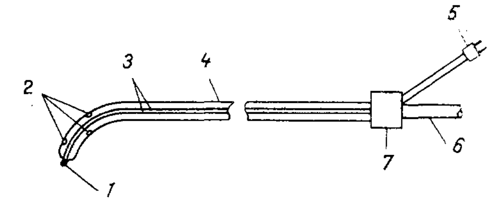

Fig. 1. Catheter for coronary sinus. Explanation in text.

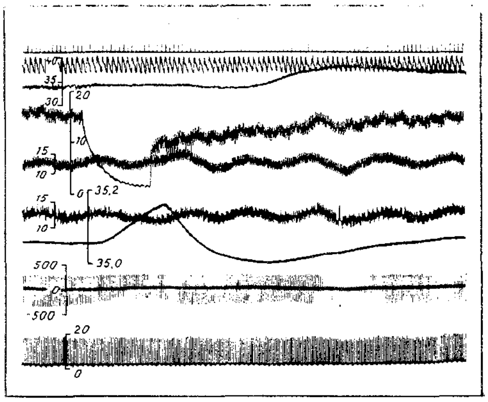

Fig. 2. Reactions of cardio- and hemodynamics to stopping and restarting perfusion of the coronary artery. From top to bottom: time marker (1 sec); respiration; oxygen saturation of blood flowing from the heart (in %); perfusion pressure of coronary and femoral arteries and arterial blood pressure (in kPa); temperature of blood in coronary sinus (in °C); maximal velocity of contraction and relaxation of left ventricle (in kPa/sec); pressure in left ventricle (in kPa).

apparatus. After introduction of the catheter, the measuring bridge is adjusted and the amplitude of the signal applied to the input of the recorder is calibrated. Since blood flows into the coronary sinus not only from the perfusion zone, but also from unperfused segments of the myocardium of the left and right ventricles, in order to calculate changes of temperature in the course of reactions of the heart, the ratio between the volumes of venous blood from the heart in the coronary sinus from perfused and nonperfused zones is determined by calculating the coefficient after injection of a nondiffusing indicator into the coronary perfusion blood flow [1]. In the course of the experiments, by periodic measurements of parameters of the gas composition and acid—base balance in blood samples on the "Corning-166" instrument, the fact that the catheter remains in the coronary sinus is additionally verified.

EXPERIMENTAL RESULTS

The use of a miniature temperature transducer with low heat capacity and low power of scatter due to the small current in the circuit of the measuring bridge greatly reduced errors arising during recording temperature in the presence of marked changes in cardiac output and in velocity of the coronary blood flow. The use of a preamplifier with high amplification factor yielded an output signal which was adequate for the detection of very small changes in the blood from the coronary sinus for recording. As Fig. 2 shows, temporary cessation of perfusion of the circumflex branch of the left coronary artery was accompanied by reduction of the outflow of heat and a considerable increase in temperature of blood flowing from the heart, in the absence of any significant changes in most of the cardiohemodynamic parameters. Meanwhile simultaneous recording of the blood temperature in the coronary sinus in the course of physiological reactions of the circulation, when marked changes were present in the cardio- and hemodynamics, biochemical parameters, acid—base balance, and gas composition in samples of blood flowing from the heart, enabled correlation between changes in cardiac function, in metabolic processes in the myocardium, and in respiration to be analyzed.

Correlation between changes in the function, metabolism, and heat production of the heart was analyzed in experiments with intracoronary injection of catecholamines and acetylcholine, and also in experiments with a model of acute myocardial ischemia. Potentiation of cardiac function in adrenergic reactions as a rule was accompanied by an increase in heat production by the heart, and a decrease in contractility of the heart when a cholinergic component was introduced into adrenergic reactions or in response to intracoronary injection of acetylcholine, reduced the myocardial oxygen consumption and its heat production. Quantitative relations between myocardial function and heat production require consideration to be paid to changes in the coronary blood flow, cardiac output, respiration, and so on. Additional information may also be obtained by recording the temperature of blood flowing from the heart as well as measuring the arterial blood temperature and the animal's body temperature and determining the myocardial consumption of oxygen, fatty acids, glucose, and lactic and pyruvic acids, and the carbon dioxide excretion. Investigations showed that the time course of myocardial heat production is largely dependent on the direction of changes in cardiac output and associated changes in the level of myocardial metabolism.

The continuous method of recording heat production by the myocardium can be used in conjunction with other methods to study myocardial metabolism in circulatory reactions and under the influence of physiologically active substances and of other factors on myocardial function and metabolism, which cannot be done by traditional biochemical methods of determination of substrate concentrations in blood flowing from the heart. There are thus good prospects for the use of the method of studying heat production of the heart in connection with analysis of the dynamics of myocardial metabolism.

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