METHODS

A METHOD OF DETERMINATION OF THE OXYGEN DEMAND OF CARDIAC MUSCLE BY MEANS OF THE KREPS OXIMETER

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It can now be accepted as proved that the rate of the coronary blood flow is determined by the oxygen demand of the heart [3]. The relationship between the rate of the coronary blood flow and the oxygen demand of the heart has even been expressed mathematically [5]. Accordingly, a reasonably complete picture of the coronary circulation may be obtained if simultaneously with the study of the rate of the coronary blood flow, the oxygen demand of the heart is determined.

Usually in the study of the coronary circulation, in order to measure the oxygen demand of the cardiac muscle the oxygen content of samples of arterial and venous blood is measured, the blood being drawn simultaneously from the artery and the coronary sinus. The oxygen content of the blood samples is estimated by Van Slyke's method. This method is sufficiently accurate but it is very laborious. Neither does it allow continuous measurement of the oxygen content of the blood in the coronary sinus.

In the present paper is described a photoelectric method of determination of the oxygen demand of the heart muscle of the cat, based on the measurement of the content of oxyhemoglobin in the venous blood flowing from the coronary sinus.

The photoelectric method of continuous estimation of the oxygen content in unopened vessels was first described in 1935 by Kramer [4]. Later Drabkin and Schmidt [2] suggested determining the content of oxyhemoglobin in the arterial blood flowing through a receiver by means of a spectrophotometer. Several other papers [6, 7, 8] were devoted to the development of spectrophotometric methods of rapid determination of the oxygen content in blood samples obtained by catheterization of the various chambers of the heart.

For the continuous measurement of the oxygen content of the blood flowing from the coronary sinus we used the oximeter devised by E. M. Kreps. The Kreps apparatus was designed for determining the oxyhemoglobin content of the arterial blood. The detector of the apparatus is applied to the pinna of the ear, in which, after warming, the blood is almost completely arterial. So that the oxyhemometer could be used to determine the oxyhemoglobin in the blood flowing from the coronary sinus, a receiver made of organic glass and having flat sides was inserted into the detector of the apparatus. The lumen of the receiver was 1 mm deep. The receiver was joined on one side to a polyethelene catheter along which blood was brought from the coronary sinus, and on the other side, by means of a rubber tube, to the jugular vein (Fig. 1).

The Kreps oxyhemometer was designed to determine oxyhemoglobin between limits of 100 and 60%, but the oxyhemoglobin content of the blood flowing from the coronary sinus of the heart may reach 20%. In view of this, the scale of the apparatus was extended to the required limits, and recalibrated. For this purpose, by means of parallel determinations of the oxyhemoglobin content using the Kreps oximeter and the OKO-01 reflecting oximeter (the readings of the reflecting oximeter were first checked against those obtained by Van Slyke's method), a calibration curve was drawn up for the new scale of the Kreps oximeter.

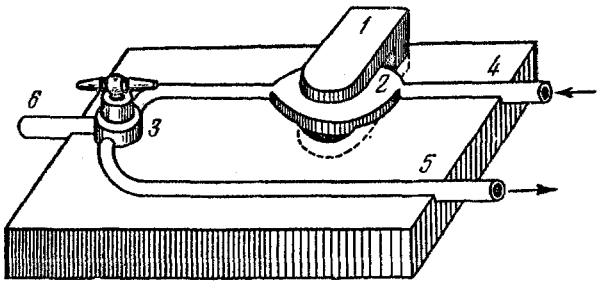

Fig. 1. Diagram of the apparatus for measuring the oxyhemoglobin content of the blood flowing from the coronary sinus.
1) Oximeter detector; 2) receiver; 3) cock; 4) tube bringing blood from the coronary sinus; 5) tube returning blood to the jugular vein; 6) tube leading to the apparatus for measuring the rate of the coronary blood flow.

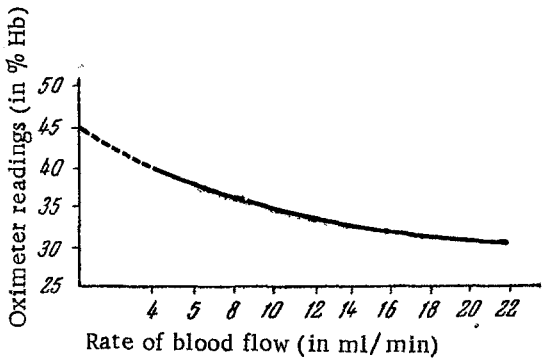

Fig. 2. The effect of the rate of blood flow on the readings of the oximeter.

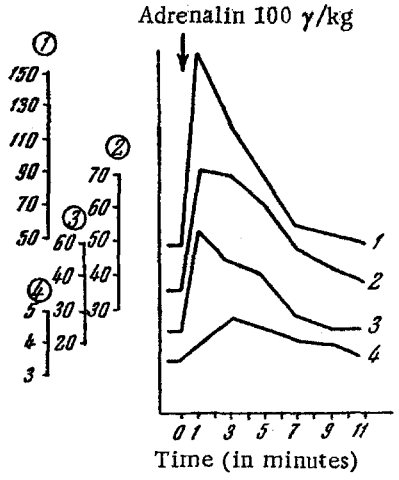

Fig. 3. The effect of adrenalin on the coronary circulation.
1) Arterial pressure in mm of mercury; 2) rate of blood flow from the coronary sinus in ml / min/ 100 g weight of the heart; 3) oxyhemoglobin content in the blood of the coronary sinus in %; 4) oxygen demand of the heart from the blood drained by the coronary sinus, in ml/ min/ 100 g weight of the heart.

In view of the fact that during the determination of the degree of saturation of the hemoglobin with oxygen in the blood flowing through the receiver the rate of flow may alter, we investigated the relationship between the rate of flow of blood and the readings of the oximeter.

By means of a perfusion pump, which allowed the rate of the blood flow to be varied, the results shown in Fig. 2 were obtained. As may be seen from the Figure, with an increase in the rate of blood flow, the readings of the apparatus tended to show a lower percentage content of oxyhemoglobin. However, in view of the fact that the rate of blood flow from the coronary sinus of the heart of the cat is 4-8 ml/ min, and the maximum increase in the rate of the blood flow does not usually exceed 50-100%, the error due to changes in the rate of blood flow is insignificant: an increase of up to 50% in the rate of blood flow will give an error not exceeding 2% of oxyhemoglobin, and an increase of up to 100% – not more than 3-4%. In order to obtain more accurate values of the oxygen saturation of the hemoglobin, the blood flow can be arrested for each determination of the oxyhemoglobin.

It has to be borne in mind that by means of the Kreps apparatus only relative values of the oxyhemoglobin can be obtained, i.e. the scale of the oximeter must be calibrated by testing blood with a known percentage content of oxyhemoglobin, and only then can readings be taken under the desired conditions. For this reason, at the beginning of each experiment the oxyhemoglobin content of the blood entering the receiver inserted into the detector of the Kreps oximeter was determined by means of a reflecting oximeter, after which the pointer of the apparatus was moved to the figure obtained. If no reflecting oximeter is available, a sample of arterial blood is oxygenated in the air for 15-20 minutes (in an open vessel, with agitation), which usually ensures complete saturation of the blood with oxygen. The sample of blood is then introduced into the receiver and the pointer of the oximeter is moved to 100% of oxyhemoglobin.

By the use of this method the percentage content of oxyhemoglobin in the outflowing venous blood was determined. In order to calculate the oxygen demand of the heart muscle, the following formula was applied:

$$A = \frac{1{,}34\ (C_1 - C_2)\ VH}{100},$$

where A is the quantity of oxygen in ml/min; C_1 is the oxyhemoglobin content in the arterial blood in per cent (determined by the reflecting oximeter; under the conditions of our experiments, with artificial respiration, it was constant within the limits of possible error of the apparatus of ±5%); C_2 is the oxyhemoglobin content in per cent in the blood flowing from the coronary sinus; V is the rate of flow of blood from the coronary sinus in min/min (this value was determined in parallel with the measurement of the oxyhemoglobin content by the method described in the paper by N. V. Kaverina [1]); H is the quantity of hemoglobin in 1 ml of blood, in g. The hemoglobin content was determined by means of a photoelectric erythrohemometer.

Figure 3 shows the results of an experiment on a cat, obtained by means of the method just described. In view of the fact that the coronary sinus drains mainly the blood entering the left ventricle, the oxygen demand of the heart muscle as a whole cannot be determined. However, from the absorption of oxygen from the blood drained by the coronary sinus, a sufficiently complete picture can be obtained of the oxygen balance of the heart.

In our opinion the method suggested may be used for the study of the oxygen demand of other organs as well as the heart.

SUMMARY

The author proposes a method of determining oxygen intake by the heart in anesthetized cats. Determination of oxygen intake by cardiac muscle is based upon continuous determination of oxyhemoglobin content in the blood flowing from the coronary sinus. Modified Krep's oximeter is employed for this purpose.

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