EFFECT OF HYPERCAPNIA ON THE BLOOD SUPPLY TO THE HEART IN CHRONIC EXPERIMENTAL CONDITIONS

I. N. Kiryushina

Laboratory of the Physiology and Pathology of Respiration and the Circulation (Head, Corresponding Member AMN SSSR Professor M. E. Marshak), Institute of Normal and Pathological Physiology (Director – Active Member AMN SSSR Professor V. V. Parin) of the AMN SSSR, Moscow
(Presented by Active Member AMN SSSR V. V. Parin)
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In a previous investigation [1] on dogs in acute experimental conditions, under anesthesia, and with natural respiration, it was found that the changes in the volume velocity of the coronary blood flow during inhalation of a gaseous mixture containing an increased concentration of CO_2 (7-30%) are biphasic in character.

At the beginning of inhalation of this mixture the coronary blood flow was diminished (1st phase), but as inhalation continued this gave way to a gradual increase (2nd phase). When the synchronized tracings of the arterial pressure and coronary blood flow on the photokymogram were compared, it was concluded that the coronary vessels were constricted in the 1st phase and dilated in the 2nd phase. It was postulated that the tone of the coronary vessels was dependent on the interaction between the central (vasoconstrictor) and peripheral (vasodilator) influences of CO_2, as a result of which the tone of these vessels was increased in the 1st phase (when the action of the CO_2 was predominantly central) and decreased in the 2nd phase (when the local action of CO_2 was predominant).

To rule out any possible effect on the anesthetic on the results obtained in the acute experiments, in the present investigation the effect of varying degrees of hypercapnia on the blood supply to the heart was studied in chronic experiments on unanesthetized dogs. Taking into consideration the fact that anesthesia modifies the functional state of the nervous centers, we assume that absence of anesthesia would be reflected mainly on the character of the 1st phase (constriction) if this was, in fact, due to the central influence of CO_2.

EXPERIMENTAL METHODS

Observations were made on 4 adult dogs in the course of 33 experiments. The dynamics of the changes in the volume velocity of the blood flow was recorded by a thermoelectric method. In 3 dogs the thermoelectrode was implanted on the circumflex branch of the left coronary artery, and in one dog on the right. The course of the operation, conducted in sterile conditions, was as described previously [2]. The pneumogram was recorded synchronously with the blood flow on a photokymograph. The arterial pressure was traced by Vartapetov's method [1] in the carotid artery, exteriorized in a skin flap. The ECG was recorded in three standard leads on an eight-channel ink-writing electrocardiograph of the "Galileo" type throughout the period of inhalation of the mixture and for some time thereafter, the intervals between taking photographs ranging from 15 to 60 sec. Amplification 1 mV = 1 cm.

EXPERIMENTAL RESULTS

Inhalation of gas mixtures containing 3-5% CO_2 caused no appreciable changes in the coronary blood flow, and a slight increase was observed in only one experiment (5% CO_2). With an increase in the CO_2 concentration (7% or more), obvious changes began to be observed in the coronary blood flow, which, in contrast to the changes in the experiments on the anesthetized dogs, were not always biphasic in character (Fig. 1). In many cases the 1st phase (constriction) was absent. Even in the same dog inhaling a gaseous mixture with the same CO_2 concentration, in the course of the same experiment a biphasic change in the blood flow was recorded in some tests and a monophasic change (an increase only) in others. Another important difference was the partial disappearance of the 1st phase, which was diminished in amplitude and duration. No relationship could be observed between the degree

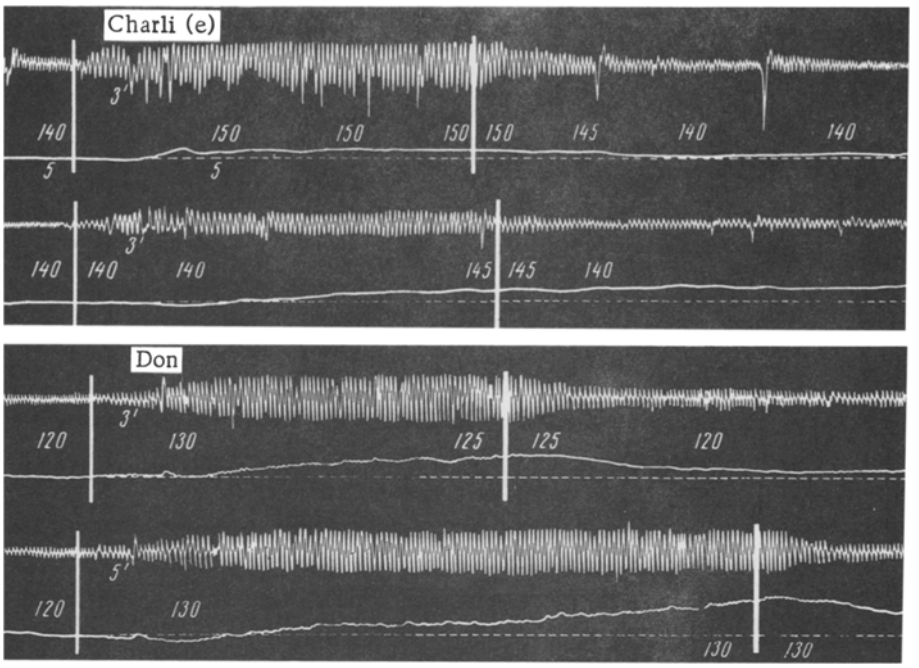

Fig. 1. Changes in volume velocity of blood flow in coronary artery during inhalation of a gaseous mixture with the same CO_2 concentration (10%) in different tests in the course of one experiment. Significance of curves (from top to bottom): pneumogram, coronary blood flow. Numbers indicate height of arterial pressure (in mm). Vertical lines denote beginning and end of period of inhalation of gaseous mixture.

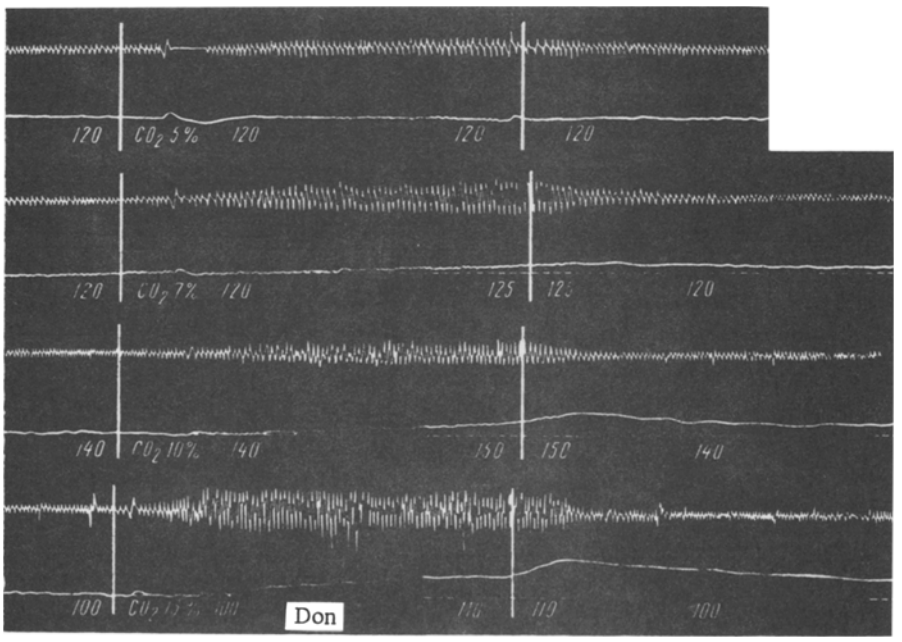

Fig. 2. Changes in coronary blood flow during inhalation of gaseous mixtures with different concentrations of CO_2 in the course of one period of exposure (3 min). Legend as in Fig. 1.

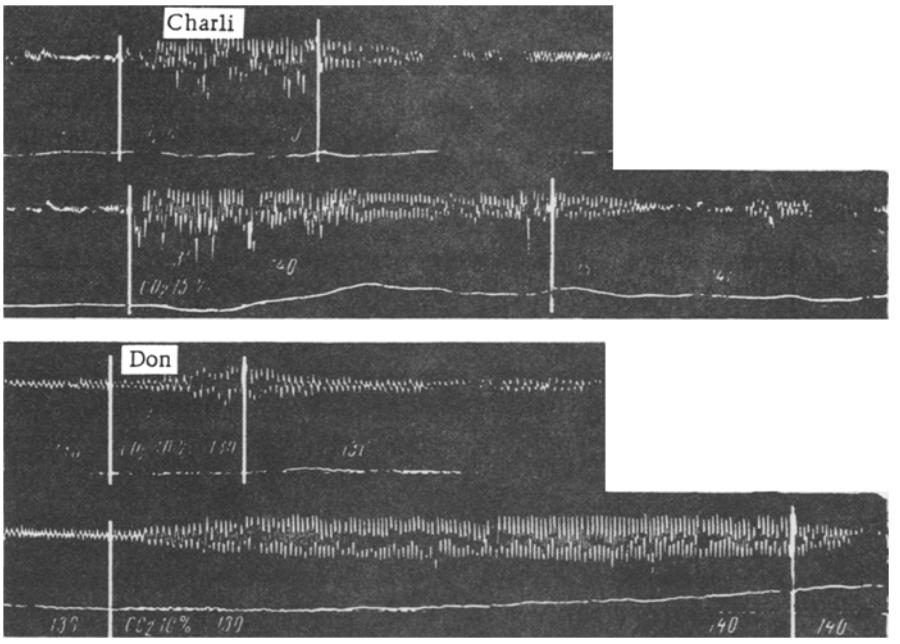

Fig. 3. Changes in the coronary blood flow during inhalation of a gaseous mixture containing the same CO_2 concentration for different periods. Legend as in Fig. 1.

of constriction and the CO_2 concentration in the mixture. Hence, the characteristic feature of the chronic experiments was the inconstancy of the constriction, which was shorter in duration and less marked in degree.

The 2nd phase (dilatation) was always well marked and was observed 1-2 min after the beginning of inhalation of the mixture (Fig. 2). If the period of inhalation was shorter, only the 1st phase was observed or, in the absence of this phase, the blood flow was unchanged (Fig. 3). As also in the acute experiments, the increase in the blood flow was greater the higher the CO_2 concentration in the mixture. In contrast, however, to the acute experiments the increase in blood flow usually began at the 30th-60th second of exposure, and after the animal had resumbed breathing the air of the room the coronary blood flow returned much more slowly to its initial level.

The arterial pressure usually remained unchanged during inhalation of a mixture containing 5% of CO_2, and often 7%, but when the concentration of CO_2 was increased further (to 10-15%) the pressure rose by 5-10 mm 1-2 min after the beginning of inhalation of the mixture, and it was maintained at this level until the end of the period of inhalation. The arterial pressure returned to its initial level 1-2 min after cessation of inhalation of the gaseous mixture.

As also in the acute experiments, it was concluded from a comparison of the changes in the arterial pressure and blood flow that a decrease in the blood flow was usually associated with a constriction, and an increase with dilatation, of the coronary vessels.

Respiration was deepened and quickened corresponding to an increase in the CO_2 concentration in the inspired mixture. However, the changes in respiration began sooner and were more marked, especially as regards depth, than in the anesthetized animals.

The changes in the pulse rate and in the ECG were basically similar in character to those described in the earlier acute experiments. A varied degree of bradycardia was observed, giving way to tachycardia 30-40 sec after discontinuing the inhalation of a mixture containing 10-15% CO_2, and the amplitude of the positive T waves was increased, especially in leads 2 and 3. Where the T waves were initially negative, their amplitude decreased, and sometimes they disappeared or became positive. The degree of these changes increased with an increase in the concentration of CO_2 in the inspired mixture.

Hence, the investigations of the changes in the coronary blood flow during hypercapnia, determined in chronic experimental conditions, largely confirmed the results previously obtained in acute experiments. The principal

effect of the absence of anesthesia was seen on the character of the 1st phase, associated with constriction of the coronary vessels. As mentioned above, the 1st phase is evidently the result of the central action of CO_2. This is indicated by the speed with which it develops (within 20-30 sec after the beginning of inhalation). The inconstancy, the lesser degree, and the shorter duration of the constriction of the coronary vessels in the unanesthetized dogs indicate that the central action of CO_2 is weaker in these conditions. The animal in the waking state evidently possesses greater powers of compensation enabling it to overcome the vasoconstrictor influences of the CO_2 on the coronary vessels. This is perfectly logical from the biological point of view, for constriction of the vessels of the heart, and, consequently, worsening of the nutrition of the myocardium, would lead to weakening of the work of the heart, and might ultimately be a dnager to the animal as a whole.

It is impossible on the basis of these experimental results to reach any firm conclusions regarding the mechanism of the changes observed in the tone of the coronary vessels, and of the frequent omission of the 1st phase in the unanesthetized dogs. It can only be postulated that one of the causes is acceleration of the process of saturation of the myocardium with carbon dioxide as a result of the stronger reaction of respiration to the increased concentration of CO_2 in the gaseous mixture in the unanesthetized animal. It would be expected that the local action of CO_2 is exhibited earlier; it causes dilatation of the coronary vessels, and thus reverses the preceding constriction. In fact, our experiments deomonstrated displacement of the 2nd phase (vasodilatation) towards the beginning of exposure to the gaseous mixture from the time of its development in the experiments on anesthetized animals.

SUMMARY

Experiments were staged on dogs in chronic conditions without anesthesia. The changes in the volume velocity of the coronary circulation were recorded by the thermoelectric method. Respiration, blood pressure and ECG were registered simultaneously. Hypercapnia of different degrees was provoked by inhalation of gas mixtures with 3, 5, 7, 10 and 15% CO_2 for 1-10 min.

The changes in the coronary circulation in response to hypercapnia were either biphasic (reduction at the beginning of the action, replaced by its gradual increase, as in dogs under anesthesia), or – monophasic (increase only). During the first phase there was constriction of the coronary vessels, and during the second – dilatation. Characteristic of dogs without anesthesia were inconstancy, a lesser degree and a shorter duration of constriction (during, the first phase). Evidently while awake the animals possessed greater compensatory powers for overcoming the vasoconstrictor effects of CO_2 on the coronary vessels than did dogs under anesthesia.

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