ROLE OF INTEROCEPTORS IN THE REGULATION OF OXYGEN SATURATION OF ARTERIAL BLOOD

COMMUNICATION III. EFFECTS OF DENERVATION OF THE CAROTID SINUS REGION ON OXYGEN SATURATION OF ARTERIAL BLOOD AND ON PULMONARY VENTILATION

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(Received December 15, 1956. Presented by V. N. Chernigovskii, Active Member Acad. Med. Sci. USSR)

Our earlier observations [1], based on chronic experiments on animals, established a relationship between the degree and the dynamics of saturation of arterial blood with oxygen, under hypoxic conditions, and the function of the sinocarotid receptor zones. These findings permitted us to draw the conclusion that the dominating role is played in this process by the respiratory disturbances appearing after denervation of the carotid sinuses.

The object of the present research was to investigate the dynamics of saturation of arterial blood with oxygen, and to follow pulmonary ventilation changes after denervation of the carotid sinuses. As controls we used observations of oxygen saturation of blood after denervation of the spleen and after division of the femoral nerves.

EXPERIMENTAL METHODS

The experiments were performed on cats and rabbits, both during aseptic operations, to prepare the animals for long term experiments, and conditons of short term experimentation. In all, we performed 33 experiments on 29 cats and 4 rabbits. In addition, we followed the course of oxygenation of blood in 3 control animals which had not been operated on, but were merely immobilized on the bench for the same length of time as were the experimental animals. We measured pulmonary ventilation in 11 short-term experiments before and 10-25 minutes after bilateral denervation of the carotid sinus regions.

Oxygen saturation of arterial blood was measured by the method described in Part I of this series [1]. The volume of expired air was measured by collecting it in a thin rubber bag for 3 minutes (through water valves with a resistance to inspiration and expiration of 5-7 mm of water), by replacement of water in a connecting graduated vessel. We calculated the volume of air respired per minute.

The experiments on cats were conducted under Evipan narcosis. The evipan was given by intramuscular injection (0.1 per kg body weight). Local anesthesia with 2% procaine was used in experiments with rabbits.

EXPERIMENTAL RESULTS

a) Denervation of Carotid Sinus Regions

Denervation of the carotid sinus regions was followed in all cases by a fall in the mean level of saturation of the blood with oxygen. The effect of unilateral division of a sinus nerve was relatively small. Bilateral division of the carotid sinus nerves was followed by a marked fall in the degree of saturation of arterial blood with oxygen; it remained at the same low level during the whole of the period of observation. Administration of pure oxygen for 20-30 minutes after the operation raised saturation to 99-100%, but when it was replaced by air saturation, fell to the low level previously observed. Pulmonary ventilation diminished after denervation in all of 9 cats and 2 rabbits examined. Whereas in cats, saturation of arterial blood with oxygen fell from a mean value of 96.5% to 89-90% 5-10 minutes after denervation, in rabbits, the fall was from 95% to 86.5%. Pulmonary ventilation, which in cats amounted to 750 cc before denervation, fell after 20 minutes to 530 cc. Similar changes were found in rabbits.

We observed various transient fluctuations in oxygen saturation during preparation of the animals for operation and during the operation itself. These changes appeared in conjunction with various operative manipulations (skin incisions, exposure of nerves and vessels, pulling up of vessels preparatory to ligation, etc.), and also with violent movements of the animals. These were particularly evident in rabbits, which were not operated under general anesthesia.

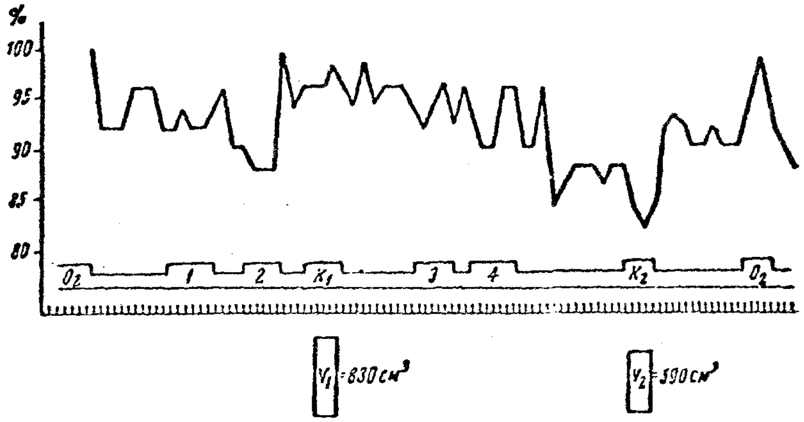

Fig. 1. Oxygen saturation of arterial blood, and pulmonary ventilation after denervation of the carotid sinuses (short-term experiment of May 25, 1956). Ordinates: percentage saturation; abscissae: time in minutes, and experimental conditions. Explanation of markings (from left to right): O_2 – setting of the instrument for 100% saturation when breathing pure oxygen; 1) skin incision and preparation of the neurovascular bundle; 2) preparation of the bifurcations of the left and right common carotid arteries; K_1 – measurement of pulmonary ventilation (breathing through inlet and outlet valves); 3) denervation of the right carotid sinus; 4) denervation of the left carotid sinus; K_2 – measurement of pulmonary ventilation; O_2 – breathing pure oxygen after denervation.

An example of the changes in oxygen saturation during a short term experiment with a cat is given in Fig. 1. The figure shows the fluctuations in oxygenation of the blood during the period of preparation for denervation, and at the moment of denervation (skin incision, preparation of the common, internal, and external carotid arteries, and division of the sinus nerves).

Changes in pulmonary ventilation are shown below the time axis. It is apparent that even a slight resistance to collection of expired air after denervation led to a considerable fall in oxygen saturation of the blood. The mean fall in oxygen saturation following denervation of this animal was from 96 to 90%, and in pulmonary ventilation from 830 to 590 cc. Still greater changes were found for rabbits.

It is thus evident that denervation of the carotid sinus regions uniformly leads to development of a hypoxemic state of the animals, and to a fall in pulmonary ventilation.

b) Denervation of the Spleen, and Division of the Femoral Nerves

Measurement of oxygen saturation of the blood during denervation of the spleen, performed for the purposes of a long term experiment, also revealed certain changes. These appeared both during division of the splenic nerves and during irritation of the peritoneum. The fluctuations in oxygen saturation were, however, only transient ones, and in general oxygen saturation of the blood had reverted to the preoperation levels with 15 minutes of division of the nerves.

Division of the femoral nerves had only an insignificant effect on oxygen saturation, which remained at a practically constant level.

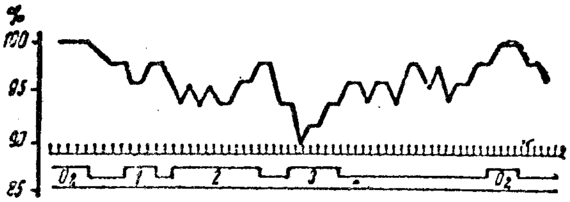

Fig. 2. Oxygen saturation of arterial blood following denervation of the spleen.
Ordinate – percentage saturation; abscissae – time in minutes, and experimental conditions. Explanation of markings (from left to right): O_2 – setting of instrument for 100% saturation when breathing pure oxygen; 1) skin incision; 2) opening of the abdominal cavity and exteriorization of the spleen; 3) division of the splenic nerves; O_2 – breathing of pure oxygen after denervation.

Figure 2 illustrates the changes in oxygen saturation of arterial blood during the operation of denervation of the spleen. A certain fall in saturation is evident at the moment of division of the splenic nerves and during insertion of stitches into the peritoneum. After the operation saturation rose to the initial level, amounting to 96-98%, and rose further to 100% during oxygen breathing. No appreciable changes in saturation followed division of the femoral nerves, except for a transient fall at the moment of division of the nerves (Fig. 3). Saturation of arterial blood is here practically the same as seen in the control experiments on the animals tied to the operating table, but not operated on. It follows that neither denervation of the spleen nor division of the femoral nerves cause any appreciable persistent changes in oxygen saturation of arterial blood.

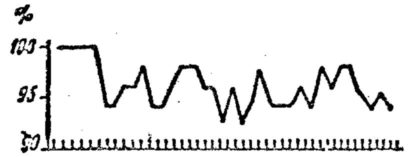

Fig. 3. Oxygen saturation of arterial blood after division of the femoral nerves.
Ordinate – percentage saturation; abscissa – time. The fluctuations seen half-way through the experiment appeared at the moment of division of the nerves.

DISCUSSION OF RESULTS

Denervation of the carotid sinus regions caused a pronounced fall in pulmonary ventilation and led to a marked hypoxemic state of the experimental animals. Division of other nerves (splenic, femoral), and also infliction of other powerful stimuli, such as laparotomy, for example, caused disturbances of oxygen saturation of only very short duration.

It is known that respiration is one of the most labile functions of the organism, and is readily affected by different factors acting on the organism. It was to be expected that operations involving stimulation of sensory nerves or of the peritoneum would cause transient changes in respiration, and would affect the degree of saturation of arterial blood. Exclusion of such massive receptor fields as are the carotid sinuses, which participate constantly in the regulation of respiration, caused persistent respiratory disturbances, manifested in lowering of pulmonary ventilation. This effect was probably the cause of the lowering of oxygen saturation of arterial blood.

Our results point to a connection between oxygen saturation of blood and changes in pulmonary ventilation, and are evidence that the regulation of the degree of oxygen saturation of arterial blood is effected by means of reflex action on the respiratory function.

SUMMARY

Denervation of sinocarotid zones causes a stable decrease in the saturation of the arterial blood by oxygen and a decrease of the volume of lung ventilation in cats and rabbits. Only short decrease of saturation was noted during denervation of the spleen and removal of the femoral nerves. This was due to the section of the nerves and irritation of the peritoneum. An important role is played by the reflex component in regulation of the saturation of the arterial blood by oxygen.

LITERATURE CITED

[1] N. N. Beller, Biull. Eksptl. Biol. i Med. 43, No. 6, 12-18 (1957). *

[2] N. N. Beller, Biull. Eksptl. Biol. i Med. 45, No. 2, 42-45 (1958). *

* Original Russian pagination. See C. B. Translation.