VASCULAR REACTIONS OF THE NEONATAL BRAIN

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Changes in the blood volume in vessels of the cerebral hemispheres and diencephalon were studied photoplethysmographically. A response to an increase or decrease in the O_2 concentration in the inspired air was found to be present in newborn rats. On the other hand, they did not respond to changes in the CO_2 concentration. The authors attribute this to low carbonic anhydrase activity in the tissues of the cerebral hemispheres and diencephalon. By the age of 20 days the response to CO_2 was still less marked than in adult animals.

KEY WORDS: cerebral blood flow; plethysmography; postnatal ontogeny.

The regulation of the cerebral circulation has so far been investigated almost entirely in the adult. The object of the present investigation was to study the responses of the brain vessels of newborn animals to an increased and reduced oxygen concentration, and to a change in the carbon dioxide concentration in the inspired air.

EXPERIMENTAL METHOD

Experiments were carried out on albino rats kept in a gas chamber using a technique of photoplethysmography. A beam of light with wavelength 780-830 nm was passed tranversely through the parietal region of the head. Changes in blood volume were assessed from changes in the optical density of the tissues of the head, and were expressed as a percentage of the total optical density of blood in the region examined.

This last parameter was determined beforehand for the animals of each age group by comparing data before and after rinsing the blood from the vessels with physiological saline.

EXPERIMENTAL RESULTS AND DISCUSSION

The effect of oxygen on the blood volume of the brain was studied in ten unanesthetized animals during the first day of life. To produce a hyperoxic medium the chamber, with a volume of 12.5 liters, was ventilated with oxygen at the rate of ten liters/min. By the end of the second minute, when the calculated oxygen concentration in the chamber was 80%, the blood volume in the brain was reduced by $9.4 \pm 0.64\%$.* The chamber was then opened and the animals allowed to breathe the ordinary air of the room. Under these conditions the blood volume of the brain after 1-1.5 min had returned to or a little above its initial level.

An hypoxic atmosphere was created by ventilating the chamber with nitrogen at the rate of 10 liters/min. Experiments were carried out on ten intact unanesthetized rats during the first day after birth. The results obtained were consistent: by the end of the second minute from the beginning of ventilation of the chamber, when the calculated concentration of oxygen in it was reduced to 5%, the blood volume of the brain had increased by $13.1 \pm 0.52\%$. Changes in the rhythm and depth of respiration had not yet begun to occur. The blood volume of the brain returned to its initial level 50-60 sec after the beginning of breathing in the ordinary air of the room.

*The values of $\bar{X} \pm tS_{\bar{X}}$ are given, in which $\bar{X}$ is the arithmetical mean, $S_{\bar{X}}$ the mean error of $\bar{X}$, and t the standard deviation; the values of t are taken from tables of Student's t-distribution (P. F. Rokitskii, 1967, Table III) for a level of significance of 0.01.

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The effect of hypercapnia was studied on 18 rats during the first day of life, 13 rats aged 20 days, and 19 rats aged 30 days. The hypercapnic atmosphere was created by introducing separate portions of CO_2 from a gas cylinder into the chamber.

These experiments showed that in rats aged one month anesthetized with ether, kept in a chamber with an atmosphere containing 4% CO_2, and in the absence of any marked changes in respiration, the blood volume of the brain increased in the course of 2 min by 4.3 ± 0.18% (a longer exposure did not significantly affect the results). A stay in a medium containing 16-20% CO_2 led to an increase of 8.6 ± 0.17% in the blood volume of the brain.

In animals aged 20 days anesthetized with ether the response to CO_2 was significantly less marked: in an atmosphere containing 4% CO_2, the blood volume of the brain was increased by 1.9 ± 0.09%, and in an atmosphere of 20% CO_2 it was increased by 4.5 ± 0.23%.

In the animals during the first day of life (unanesthetized) kept in an atmosphere containing 4% CO_2, no response of the brain vessels could be observed even after 5-8 min. An extremely small increase, less than 0.9%, in the cerebral blood volume was found in only one young rat toward the end of the third minute. During inhalation of a mixture containing 20% CO_2, a tendency for the brain vessels to dilate was found in five animals. However, the intensity of the response remained low (1.1 ± 0.16%). The remaining 13 animals reacted to none of the concentrations used.

Dilation of the brain vessels and an increase in the cerebral blood flow regularly observed in adult animals under conditions of hypercapnia are suppressed by acetazolamide, a carbonic anhydrase inhibitor [4]. In a special series of experiments on rats aged one month, in which the animals were given an intramuscular injection of the sodium salt of acetazolamide in a dose of 50 mg/100 g body weight, this fact was tested and confirmed.

In newborn animals blind at birth, as in man, carbonic anhydrase activity in the diencephalon and cerebral hemispheres is close to zero [2, 5]. This can account for the areactivity of the vessels in these parts of the neonatal rat brain located within the zone of photometric examination, even to high CO_2 concentrations.

Adequacy of the cerebral blood flow to the level of metabolism of the nerve tissue in adult animals is ensured primarily by the response of the vessels to endogenous CO_2. The response to a change in the oxygen concentration now becomes a second line of defence, for in healthy individuals hypoxia does not arise even under severe loading [1]. In newborn animals, on the other hand, the cerebral blood flow is increased initially only in response to a fall in the oxygen partial pressure in the brain tissue. This qualitative difference in regulation of the cerebral hemodynamics must be taken into account when the pathogenesis of "disorders of the cerebral circulation" in newborn and prematurely born infants is discussed.

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