CHANGES IN THE REFLEX VARIATIONS OF ARTERIAL PRESSURE AND RESPIRATION DURING INDUCTION OF HYPOTHERMIA BY VARIOUS METHODS

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Overcooling of the body of a warm-blooded animal leads to a gradual exclusion of the functions of the central nervous system, beginning with the cerebral cortex. The functions of the vitally important bulbar centers are preserved until deep hypothermia is produced, and are then excluded in order of sequence [3 10].

We showed in a previous paper [4] that the reflex excitation of the vasomotor centers indecerebrated and decapitated cats, when subjected to cooling in the usual way by means of cold packs, is preserved even at a body temperature of 20°.

There is sufficient information in the literature [8, 9, 11] on the changes in the reflex variations of the arterial pressure and respiration during the devopment of hypothermia by external cooling, whereas in the case of other methods of cooling, and in particular of extracorporeal cooling of the blood and direct cooling of the head, this question has received insufficient study.

We have previously shown [5] that the method of extracorporeal cooling of the blood is comparatively suitable for induction of hypothermia. This method causes hardly any shivering and requires lighter anesthesia than does external cooling. The latter feature is evidently associated with the absence of the direct action of cold on the receptors of the skin, for the perception of cold by the interoceptors is considerably more weakly expressed.

During cooling of the brain by means of cooling the blood in the carotid artery or through the external coverings of the head a more profound fall in the temperature of the brain by comparison with the rectal temperature is observed, which is of great importance in heart surgery, since the comparatively high body temperature protects the heart against the development of ventricular fibrillation due to cold [5, 6].

The object of the present research was to make a comparative study of the changes in the reflex variations in respiration and arterial pressure during induction of hypothermia by the methods mentioned above.

EXPERIMENTAL METHOD

Twenty-four experiments were carried out on cats. General hypothermia of the animals (10 experiments) was induced by cooling the venous blood.

Previously heparinized blood was taken from the superior vena cava through a catheter inserted through the jugular vein, and by means of a special pump it was forced through the coiled cooling tube and injected into the femoral vein.

In 9 experiments the brain was cooled directly, for which purpose blood taken from the common carotid artery was cooled in the coiled tube and reinjected into the cranial end of the same artery.

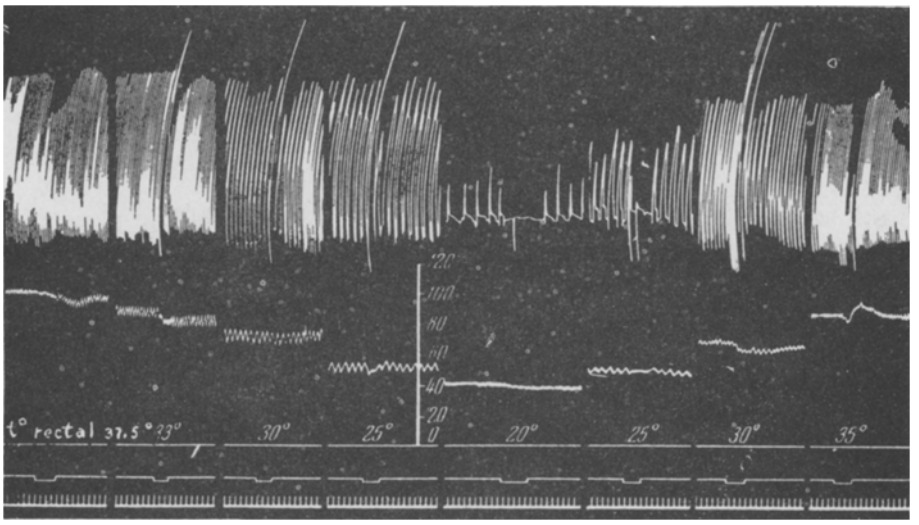

Fig. 1. Reflex reactions of the arterial pressure and respiration in response to stimulation of the central cut end of the vagus nerve by an induction current during extracorporeal cooling of the blood and subsequent warming of the animal. Significance of the curves (from above down): respiration, arterial pressure, zero line, stimulus marker (distance between induction coils 20 cm); time marker (5 seconds)

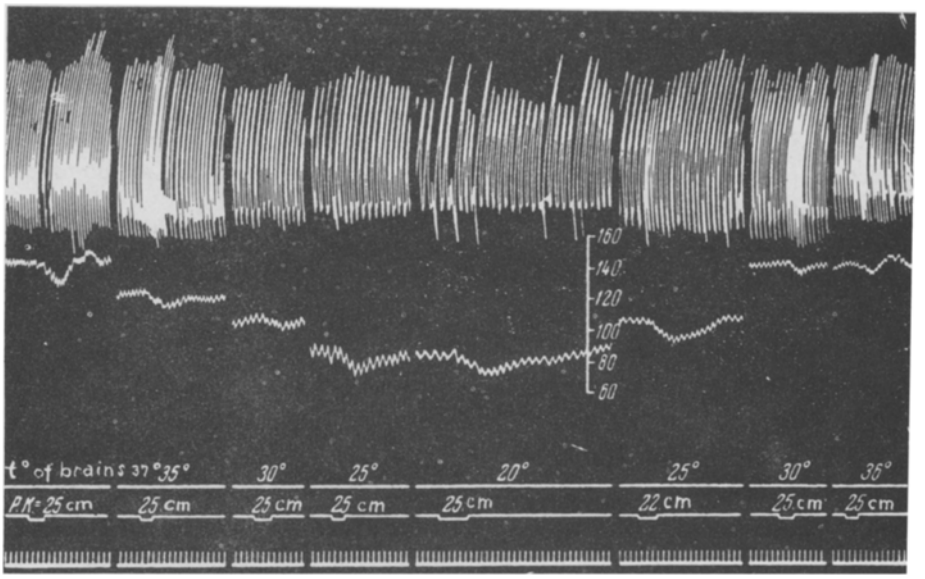

Fig. 2. Reflex reactions of the arterial pressure and respiration in response to stimulation of the central cut end of the sciatic nerve with an induction current during cooling of the brain by means of cooling the blood in the carotid artery and during the subsequent restoration of its temperature. (Experiments on February 4, 1956 on a cat weighing 2.5 kg.) Significance of the curves (from above down): respiration, arterial pressure, zero line, stimulation marker time marker (5 seconds).

In 5 experiments the head was cooled directly through its outer coverings, for which purpose we used a cold blanket in which the animal's head was wrapped. As a preliminary measure the hair was throughly shaved from the head.

TABLE 1

Changes in the Threshold of the Reflex Variations in the Arterial Pressure during Hypothermia Induced by Cooling of the Venous Blood (mean of 10 experiments)

Rectal temperature	37°	Cooling				Warming			
		34°	30°	25°	22°	25°	30°	34°	37°
Threshold (in cm on the scale of the induction coil)	29.3	31	26.7	22.4	18.1	22.9	27.4	29.1	27.0

TABLE 2

Cooling of the Brain by Means of Cooling the Arterial Blood (mean of 9 experiments)

Temperature in the middle layers of the brain	36°	34°	30°	25°	20°
Threshold (in cm of the scale of the induction coil)	30.2	26.6	26.6	24.5	20.7

TABLE 3

Cooling of the Head through Its Outer Coverings (mean of 5 experiments)

Temperature in the middle layers of the brain	Cooling				Warming		
	36°	30°	25°	21°	25°	30°	33°
Threshold (in cm of the scale of the induction coil)	27	26.8	25	23.4	23.6	24.7	27.2

The arterial pressure was recorded by a mercury manometer in the common carotid artery, and respiration by means of a Marey's capsule connected to the trachea through a four-way tube.

In all the experiments the body temperature was measured rectally be means of a mercury thermometer at a depth of about 8 cm. In the experiments with a direct cooling of the brain the temperature was measured with a copper-constantan thermocouple introduced through a narrow hole in the skull into the middle layers of the brain.

Restoration of the body temperature and of the functions of the cooled animals was brought about by warming the blood as well as by external heating with an electric blanket applied to the animal's body. The induction of hypothermia was accompanied by the use of ether anesthesia.

Reflex variations in the arterial pressure and respiration were produced by stimulation of the central cut ends of the sciatic and the right vagus nerves with an induction current from a movable induction coil. A voltage of 4v was applied to the primary coil.

EXPERIMENTAL RESULTS

The threshold of the reflex variations in arterial pressure in response to stimulation of the sciatic nerve when various methods of induction of hypothermia were used increased with the fall in temperature (Tables 1-2). At the same time there was a decrease in the magnitude of the reflex variations of arterial pressure. This was evidence of a fall in the reflex excitation and of the development of inhibition in the bulbar centers. The excita-

tion of the vasomotor and respiratory centers was preserved, however, even when the temperature of the body or brain was 20° (Figs. 1, 2).

Stimulation of the central cut end of the vagus nerve during the development of hypothermia led to inhibition of respiration, which was a reflection of the decrease in lability and development of inhibition in the respiratory center. In Fig. 1, for instance, it may be seen that the fall in the body temperature led to a transient holding of the breath at the moment of stimulation. The holding of the breath was preceded by deepening of inspiration and expiration. With the fall in the temperature of the body the changes in respiration were increased, and at the end of the period of hypothermia they were particularly pronounced.

At the time of warming of the animal the threshold of reflex reactions of the arterial pressure and respiration in response to stimulation of the sciatic nerve, and also the character of their reflex effects in response to stimulation of the vagus nerve were restored, which indicated the restoration of the normal excitation of the bulbar centers. During warming of the body to a temperature of over 35°, the excitation sometimes fell slightly once again. This was associated with the unfavorable influence of further active warming of the animals [1, 3, 7].

The findings described thus showed that when hypothermia was produced in different ways, the character of the changes observed in the reflex excitation of the bulbar centers was identical and consisted of a lowering of the excitation. This was maintained until a deep stage of hypothermia was produced.

The lowering of reflex excitation reflected the development of inhibition in these centers. The latter was shown by the fall in their faradic excitation, by the falling off in the magnitude of the reactions of the arterial pressure and by the tendency of the respiration to become weaker and to stop during stimulation of the vagus nerve. Under these circumstances phasic states in the activity of the respiratory center were often observed: inhibition directly after excitation.

The reflex excitation of the respiratory center was, however, preserved until lethal stages of hypothermia. This finding is in agreement with those of P. M. Starkov [9, 11] and also of I. G. Varman [2], who observed a reflex reaction of respiration to the extent of its cessation in lethal stages of general hypothermia in cats and dogs induced by means of external cooling.

The almost equal magnitude of the change in the threshold of reflex excitation of the vasomotor center both during general hypothermia with extracorporeal cooling of the blood and during direct cooling of the brain with cold blood showed the importance of the temperature factor for the state of excitation of this particular center. So far as the slightly more pronounced variation in the arterial pressure at a low temperature during direct cooling of the brain is concerned, by comparison with general cooling of the animal, this may have depended on the higher general level of the arterial pressure.

This high level was due to the presence of a higher temperature in the remaining of the body [5] and to the preservation of high excitation of the spinal vasomotor centers, which are of definite importance in the regulation of the circulation of the blood during hypothermia, and retain their excitation to a body temperature of 20° in decapitated cats [4].

Correct warming of the cooled animal and increasing the temperature of the brain had a favorable influence on the restoration of the reflex excitation of the respiratory and vasomotor centers.

SUMMARY

Experiments were performed on 24 cats. The authors studied variations of the arterial blood pressure and respiration obtained by extracorporeal cooling of the blood pumped from the superior vena cava into the femoral vein and by direct overcooling of the head through the skin surface or by cooling the blood in the carotid artery.

Hypothermia induced by any method would cause a gradual increase of the threshold of faradic excitability of the vasomotor center, decrease in the fluctuation range of the arterial blood pressure, and also intensify the inhibition of the respiratory center in stimulating the vagus nerve. This points to the reduction of the reflex excitability and development of the parabiotic inhibition in these centers However, their excitability was still preserved at the body and brain temperature of about 20°C. Warming of an overcooled body restored the excitability of the centers.

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