RECOVERY OF CONDITIONED REFLEXES IN DOGS AFTER INDUCTION OF HYPOTHERMIA BY MEANS OF HEAD PACKS*

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Translated from Byulleten' Eksperimental'noi Biologii i Meditsiny, Vol. 50, No. 12,
pp. 34-38, December, 1960
Original article submitted October 26, 1959

The induction of hypothermia in animals by means of application of packs to the head causes an intensive fall in the temperatures of all divisions of the brain, and especially of the cerebral cortex. The body temperature under these conditions falls much more slowly [5, 6, 11]. In cats, when the temperature of the cerebral cortex falls to 14.7-18.7°, the rectal temperature is 28.8-32.2° [5], and in dogs, when the temperature of the cerebral cortex reaches 17-22°, the rectal temperature varies between 26 and 30° [6].

It has been shown that a low brain temperature increases the resistance of the central nervous system to anoxia [2, 4, 8, 9]. This enables the time of exclusion of the heart from the circulation during "dry field" operations to be extended. Meanwhile, when the animal is subjected to hypothermia by means of head packs, the body temperature does not fall to such low temperatures as lead to the development of ventricular fibrillation [5, 6]. Isolated cases of the clinical application of this method have been described [12].

The present investigation is concerned with the study of the restoration of the functions of the cerebral cortex after induction of hypothermia by means of head packs.

METHOD

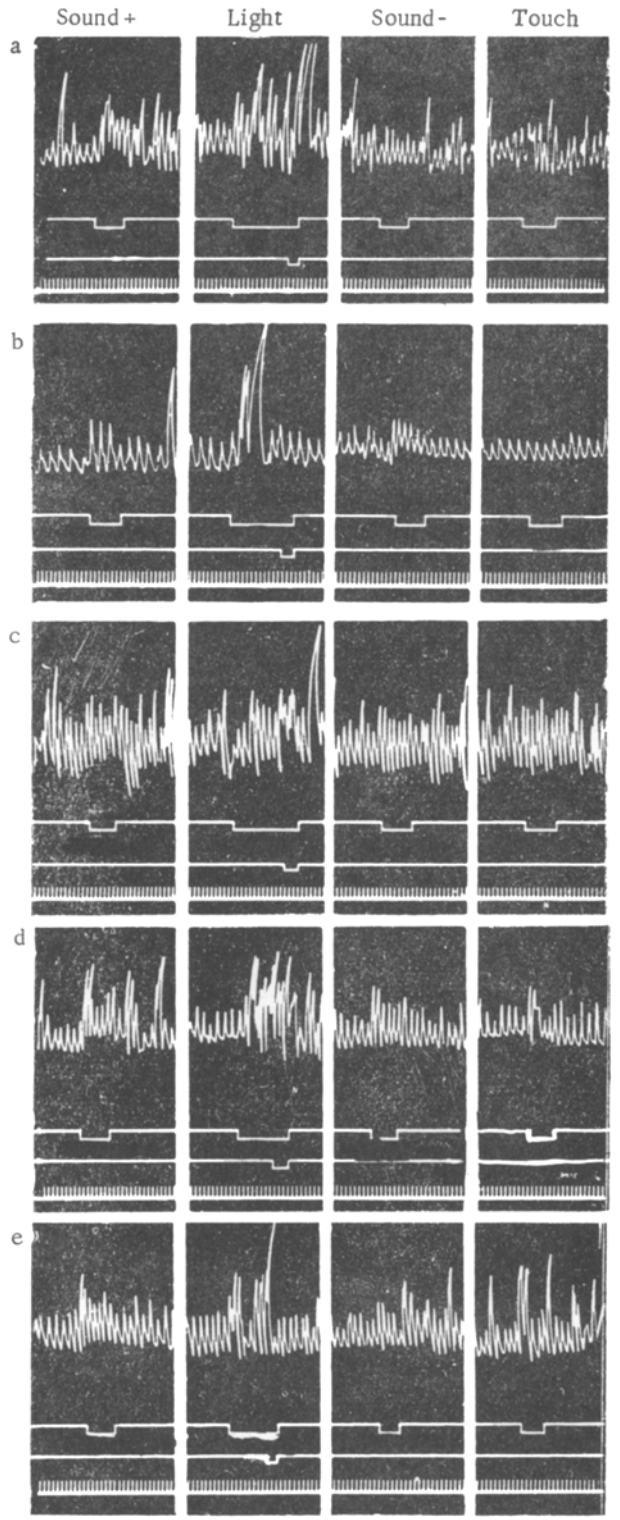
The investigation was carried out on two dogs. The dog Valetka had firmly established secretory food reflexes to a metronome, a light and a touch stimulus, and also one differential reaction. In the dog Sil'va protective conditioned respiratory reflexes had been established to reinforcement with ammonia. In order to secure the first action of cold on the brain, as a preliminary measure the temporal muscles had been removed from both dogs one year previously. Hypothermia was induced under morphine-ether-oxygen anesthesia. The animals' head was covered with a special double-layered cellular pack, through which cold water (3-5°) passed. When the rectal temperature was 30° the anesthesia was discontinued. When the rectal temperature reached 28° the induction of hypothermia was discontinued and warming of the trunk commenced by means of the passage of warm water (45°) through a cellular pack covering the animals' body. At a body temperature of 33° the warming was discontinued, the dogs were removed from the experimental table and further observations on the recovery of the conditioned reflexes were carried out in a conditioned reflex chamber.

On each dog 35 investigations of the conditioned reflexes were made after one induction of hypothermia.

RESULTS

The body temperature of the dogs reached 33° 1.5 hr after discontinuing hypothermia and starting to warm the animals. At this stage the dogs placed their head crown uppermost and carried out energetic movements of the head, and shivered. Stimulation by means of a weak rustling or tapping noise, or application of the conditioned stimuli caused intensification of the motor reactions. General behavioral reflexes to a summons by name or to the sight of the experimenter, and also the defensive reaction to threatening with a stick were absent in both dogs. The secretory food reflexes and protective conditioned respiratory reflexes, established experimentally in the animals, failed to appear.

*Given at a scientific meeting of the Kuban Medical Institute on May 14, 1959.



Recovery of protective respiratory conditioned reflexes in the dog Sil'va after hypothermia, induced by means of head packs, to a body temperature of 28°. a) Before hypothermia; b) on the 2nd day; c) on the 3rd day; d)on the 6th day; e) on the 7th day after hypothermia. Significance of the curves (from above down): respiration; marker of conditioned stimulus; marked of unconditioned stimulus; time marker (3 sec).

When the body temperature reached 34° the dogs tried to stand up but fell. Analysis of proprioceptive stimuli was disturbed. The unnatural position artificially assumed by the limb when flexed at the ankle joint was not corrected by the dog while the paw was involved in the general motor reaction. The natural and artificial conditioned reflexes were absent under these conditions (see table).

From 2.5-3 hr after discontinuation of the hypothermia, when the body temperature was 35°, the dogs were able to stand on their feet and to move about the laboratory. Nevertheless, their staggering and clumsiness of movement during walking were evidence of the incomplete recovery of coordination of movement. The shivering ceased. At this temperature the dogs first began to show general behavioral reflexes to a summons by name and to the sight of the experimenter.

An increase in the body temperature to 36° (4 hr after discontinuation of hypothermia) was not accompanied by any appreciable normalization of the conditioned reflex activity of the animals. Their behavior corresponded to that at a body temperature of 35°. Natural food conditioned reflexes to the sight and smell of meat-biscuit powder were absent in both dogs, and they did not take food. The protective conditioned respiratory reflexes were also not apparent.

On the second day after hypothermia, the dogs' body temperature was back at its initial level. The animals' behavior was not fully restored, and the dogs were lethargic and moved about little. The appearance of protective conditioned respiratory reflexes to the bell and light was observed in Sil'va (see figure, a and b). It can be seen from the figure that the conditioned reaction to the light was greater than the control magnitude of the reflex before hypothermia, whereas the conditioned reaction to the bell was greatly weakened. The protective conditioned respiratory reflex to a weak stimulus (touch) was absent. Differentiation was slightly disinhibited. The natural and artificial food conditioned reflexes were absent in Valetka (see Table). Under these circumstances, however, the recovery of the motor component of the food conditioned reaction was observed—in response to the conditioned stimulus the dog turned its head towards the feeding bowl but did not take food.

Recovery of the secretory food conditioned reflexes began on the third day after hypothermia. This was shown by the appearance of conditioned salivation in response to the metronome and light, and also of the natural conditioned reflex to meat-biscuit powder. The touch stimulus did not produce

Recovery of Conditioned Reflexes in the Dog Valetka after Induction of Hypothermia by Means of Head Packs to a Body Temperature of 28°

Date of experiment	11/XI	12/XI	13/XI	14/XI	15/XI	16/XI	17/XI	18/XI	19/XI	20/XI
	1958									
Body temperature	37,2°	34°	37°	37°	37,3°	37°	37	37,2	37,2°	37
Metronome + 240	5	0	0	3	4	6	3	6	6	5
Light	4	0	0	1	4	1	1	1	4	4
Metronome − 60	0	0	0	0	2	1	1	0	0	0
Touch stimulus	3	0	0	0	2	1	1	2	2	3
Total	12	0	0	4	12	9	6	9	12	12

Note. The magnitude of the conditioned reflexes is given in drops of saliva during the action of the stimulus for 30 seconds. Hypothermia was induced on Nov. 12.

a salivatory conditioned reaction, and differentiation was not disinhibited (see table). It may be seen from the table that the total volume of saliva secreted in response to the conditioned stimuli throughout the whole experiment was one-third the initial value (4 drops instead of 12 of saliva). In Sil'va, on the third day after hypothermia, marked weakness of excitation was observed. This was shown by the low magnitude of the protective conditioned respiratory reflexes to the bell and light and by the complete absence of reaction to the touch stimulus (see figure, a and d). The dogs' behavior was normal.

On the fourth day after hypothermia, protective conditioned respiratory reflexes appeared in response to all stimuli, but were weaker than in the control tests. A similar picture was observed on the fifth day. Full normalization of the protective conditioned respiratory reflexes took place on the sixth day (see figure a, d, and e).

On the fourth day after hypothermia the strength of excitation in Valetka had perceptibly increased. Internal inhibition at this stage was severely weakened. In the experiment on November 15, 1958, for instance, shown in the table, the magnitude of the positive conditioned reflexes, characterizing the level of excitation, was almost the same as initially, whereas differentiation was disinhibited (2 drops).

On the fifth or sixth day after hypothermia the weakness of inhibition was less pronounced. Differentiation was disinhibited (1 drop of saliva). The magnitude of the conditioned reflex to the metronome reached its initial level (6 drops of saliva) on the fifth day after hypothermia. Meanwhile the limit of functional capacity of the cortical cells was severely reduced, and rapid exhaustion of the conditioned reaction developed. The first stimulus in the stereotype (metronome) evoked a much stronger effect (3-6 drops of saliva) than the later stimuli (1 drop of saliva).

On the seventh day after hypothermia internal inhibition was restored. Differentiation was complete, and a positive stimulus following it (touch stimulus) evoked a response a characteristic magnitude. The limit of functional capacity of the cortical cells was increased, although not to its initial level. This was confirmed by tests of the conditioned reflex to light (1 drop of saliva instead of 4) after a strong stimulus (the metronome).

Complete restoration of the secretory food conditioned reflexes took place on the eighth day after hypothermia (see table).

Investigation of the conditioned reflexes, like observation of the general behavior of the dogs during the following week and one or two months after hypothermia showed no abnormality in the conditioned reflex activity of the animals.

It must be pointed out that in Sil'va, on the day of induction of hypothermia, absence of the unconditioned protective respiratory reflex to ammonia was observed, and in Valetka the food reflex to meat-biscuit powder was absent. Complete recovery of the unconditioned protective respiratory reflex took place on the second day after hypothermia, and of the unconditioned salivatory reflex on the third day.

These facts show that the induction of hypothermia in dogs by means of head packs cuases a marked weakness of the fundamental nervous processes in the cerebral cortex. Excitation is disturbed to a lesser degree than internal inhibition. We discovered a similar pattern in 1957 after general hypothermia of the same dogs to a rectal temperature of 24° [1]. In this case, however, the recovery of the conditioned reflexes took place two or three times quicker than after induction of hypothermia by means of head packs. The explanation of this fact is that, by the latter method of cooling, the temperature of the cerebral cortex of the dogs falls much more rapidly than the rectal temperature, and the difference between then amounts to 8-10° [6, 11]. It may therefore be considered that after the induction of hypothermia in dogs by means of head packs to a rectal temperature of 28°, the temperature of the cerebral cortex fell to 18-20°, whereas after general hypothermia it fell to 24-26°. A direct relationship between the depth of hypothermia and the speed of recovery of the conditioned reflex activity has been established by O. A. Karpovich [3, 8]. In ther experiments on dogs subjected to general hypothermia to a body temperature of 25°, recovery of a motor conditioned reflex took place at 32°.

After cooling of the same animal to a body temperature of 28°, recovery of the motor conditioned reflex took place at a body temperature of 29°.

In conclusion it must be pointed out that the use of morphine-ether-oxygen anesthesia alone, without hypothermia, does not cause prolonged disturbances of the conditioned reflex activity. Under such circumstances the conditioned reflexes are restored during the first two days.

Meanwhile it has been found that the action potential of the brain (as shown by the electroencephalogram) during hypothermia disappear more rapidly the deeper the initial level of anesthesia [7, 10]. This demonstrates that anesthesia deepens the action of hypothermia, and may thereby lead to greater disturbance of the function of the cerebral cortex.

SUMMARY

Following the restoration of the body temperature in dogs, overcooled by head packs to the rectal temperature of 28°C, the secretory food and defensive respiratory conditioned reflexes are also completely restored. The process of restoration of the cerebral cortical function is 2-3 times slower than after external overcooling of the whole body. The restoration of defensive respiratory reflexes begins on the day after overcooling and is completed on the sixth day. The restoration of secretory food conditioned reflexes begins only on the third day after hypothermis and is completed on the 8th day.

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