HEAT DEFICIT DURING BRAIN COOLING

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The dynamics of changes in the brain temperature, the thermal insulating properties and thermal conductivity of the tissues and the heat loss were investigated in dogs during craniocerebral cooling by means of a water-jet apparatus. Despite the increase in thermal insulation of the tissues and the decrease in their thermal conductivity, the heat deficit arising at the beginning of cooling persisted throughout the period of hypothermia.

Artificial hypothermia of a warm-blooded animal is accompanied by changes in its heat balance. The heat deficit [10, 12] in this case is positive because the heat lost exceeds the heat formed. Characteristically, during craniocerebral cooling [3], heat is transmitted principally through the head [8], and the temperature gradient between the brain and internal organs in sharply altered [2, 6].

This paper describes the results of an investigation of the dynamics of heat loss, the index of heat circulation, and the temperature of dogs cooled in a craniocerebral hypothermia apparatus of new design [4, 5].

EXPERIMENTAL METHOD

The experiments were carried out on adult dogs, anesthetized with ether and cooled through the head in a "Kholod-2F" water-jet hypothermia apparatus (water temperature 2-5°, pressure 1 atm). The brain temperature (in the motor area) at depths of 7, 20, and 30 mm and the body temperature (rectal) were measured by Chromel drop thermocouples on a PP-59 potentiometer. The heat loss and skin temperature were recorded by copper-Constantan thermocouples through a PP-63 potentiometer.

EXPERIMENTAL RESULTS

Table 1 shows that cooling the animal's head lowered the body temperature. However, the greatest changes in temperature occurred in the skin of the head and the upper layers of the brain. The temperature gradient reflecting the temperature drop from the internal organs to the body surface increased sharply at the beginning of cooling, and continued to rise as the hypothermia deepened. This increase in the gradient, both for the skin and for the deep layers of the brain, virtually ceased at the level 31-30°, i.e., on reaching the maximum for these conditions of operation of the hypothermia apparatus.

The heat loss was directly related to the temperature changes. It increased appreciably (Fig. 1) at the beginning of cooling and remained high throughout the period of hypothermia. The flow of heat through the head in the interval from 35 to 34° increased by 2.2-2.4 times compared with initially. Consequently, at the initial moment of hypothermia a large heat deficit developed, and this persisted until the end of cooling. The decrease in heat loss at a temperature of 33° probably reflects compensatory reactions to cold. These were expressed, in particular, by a decrease in thermal conductivity and an increase in the thermal insulating properties of the tissues (Fig. 2). With the development of hypothermia the degree of change in the thermal conducting and thermal insulating properties of the skin of the head were equalized and the heat loss slightly reduced. At these temperatures this decrease in heat loss was due to depression of

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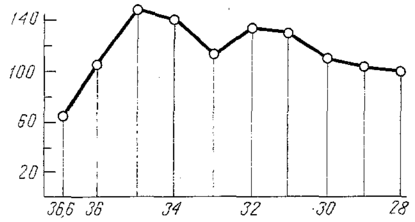

Fig. 1. Dynamics of heat loss through the skin of the head during hypothermia. Abscissa, body temperature (in degrees C); ordinate, heat loss (in kcal/$m^2 \cdot$ h).

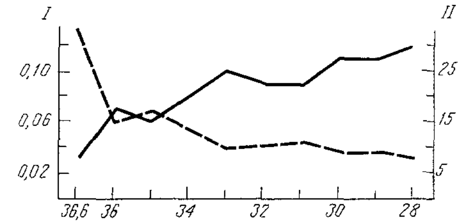

Fig. 2. Effect of hypothermia on thermal insulation and thermal conduction of skin of dog's head. Abscissa, body temperature (in degrees C); ordinate: I) thermal insulation (in $m^2 \cdot h \cdot$ deg/kcal), II) thermal conduction (in kcal/$m^2 \cdot h \cdot$ deg). Continuous line shows thermal insulation, broken line thermal conduction.

metabolism [9], and to a decrease in the intensity of the blood supply to the internal organs and, in particular, to the brain [7].

The index of heat circulation [1, 10, 11], the ratio between the physical temperature gradient and the physiological gradient, and which defines the degree of changes in the thermal insulating properties and the thermal conduction of the tissues, varied to a different extent in different parts of the body. This index for the brain and the skin of the head decreased as the temperature fell, indicating increased thermal conductivity of the tissues (Table 2).

Characteristically at a depth of 30 mm, toward the end of cooling the index was reduced by 6 times compared with the initial period, whereas at a depth of 20 mm the decrease was only 4.8 times and in the upper layer of the cerebral cortex and skin of the head the decreases were only 3.4 and 3.3 times. Differences in the degree of the change in thermal conductivity in the thermal insulating properties of the deep tissues and skin of the head were evidently due to differences in the decrease in their blood supply and in their ability to withstand the action of cold.

Analysis of these results shows that the craniocerebral method of producing hypothermia is an effective means of lowering the temperature artificially. The temperature gradient between the internal organs and brain rises considerably, and this is a positive factor in the practical utilization of hypothermia.

The increase in the thermal insulating properties of the tissues and the decrease in thermal conductivity during the development of cerebral hypothermia leads to a uniform and physiological change in the thermal state of the body. The heat deficit arising in the initial period is maintained until the end of cooling, increasing the resistance of the nerve cells.

TABLE 1. Changes in Temperature and Temperature Gradient of Dogs during Brain Cooling

	Body temperature									
	36,6°	36°	35°	34°	33°	32°	31°	30°	29°	28°
Skin of head....	34,4	28,5	25,5	22,2	21,2	19,2	18,1	17,5	16,6	15,4
Gradient......	2,2	7,5	9,5	11,8	11,8	12,8	12,9	12,5	12,4	12,6
Brain										
at depth of 7 mm.......	35,6	28,9	26,9	22,3	21,8	20,8	19,2	18,0	17,2	15,9
gradient	1,0	7,1	9,1	11,7	11,2	11,2	11,8	12,0	11,8	12,1
at depth of 20 mm......	36,1	34,6	33,1	31,4	30,2	29,1	27,4	26,6	25,3	24,6
gradient	0,5	1,4	1,9	3,6	2,8	2,9	3,6	3,4	3,7	3,4
at depth of 30 mm......	36,5	35,7	34,5	33,2	32,0	31,1	29,8	28,6	27,6	27,1
gradient	0,1	0,3	0,5	0,8	1,0	0,9	1,2	1,4	1,4	0,9

TABLE 2. Heat Circulation Index (in Conventional Units) in Brain Tissues and Skin of the Head during Hypothermia

	Body temperature									
	36,6°	36°	35°	34°	33°	32°	31°	30°	29°	28°
Brain:										
at depth of 30 mm......	144,00	85,00	47,00	22,25	19,20	19,11	13,41	11,07	10,43	14,89
at depth of 20 mm......	28,80	18,93	12,39	5,61	6,86	5,93	4,47	4,56	3,95	3,97
at depth of 7 mm......	14,40	3,73	2,74	1,73	1,71	1,54	1,36	1,29	1,24	1,11
Skin of head	6,55	3,53	2,47	1,71	1,63	1,34	1,25	1,24	1,18	1,06

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