INDUCTION OF HYPOTHERMIA BY DIRECT COOLING OF THE BRAIN THROUGH ITS EXTERNAL COVERINGS

N. V. Klykov

From the Chair of Normal Physiology (Director: Prof. P. M. Starkov), Kuban Medical Institute
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The changes observed in the organism as a result of its general cooling are in the first place due to progressive inhibition of the central nervous system. The result of this inhibition is to produce step-wise abolition of its functions, beginning with the cerebral cortex. Conditioned reflex activity is abolished in dogs when the body temperature falls to 28-30° [4]. Changes take place in the electrical activity of the cerebral cortex, which becomes weaker as the temperature falls, finally ceasing altogether [10, 12, 3].

Disturbance of function of the between-brain and the mid-brain takes place much later [10], while the functions of the medulla oblongata and the spinal cord persist to lower temperatures, and are the last to be abolished [1, 4].

Procurement of profound inhibition of the central nervous system by means of generalized lowering of body temperature is now widely applied clinically, in particular in connection with heart surgery [12, 8, and others]. The induction of generalized hypothermia, especially in its more extreme forms, is by no means a safe or a simple undertaking, either in the human or in animals. One of its most dangerous complications in surgical practice is the development of ventricular fibrillation, in particular when the heart has been excluded from the circulation. The frequency of incidence of fibrillation is in direct proportion to the degree of cooling of the organism [8, 9, 16]. This fibrillation greatly limits the possibilities of applying hypothermia. It is of importance to find ways and means of preventing its onset.

The useful effect of hypothermia under conditions of exclusion of the action of the heart is that it protects the central nervous system, and in particular the cerebral cortex, from the harmful effect of the resulting anoxia, since the tolerance of the brain to oxygen lack is much higher in the hypothermic state [6, 2]. It follows from this that the most important aspect of hypothermia is the lowering of the temperature of the brain, and in particular of its higher levels. This points to the possibility of inducing hypothermia by cooling the head alone, leaving the rest of the body at a relatively high temperature; since this includes the heart, it may fully prevent its fibrillation. The cooling of the brain through the cranium is quite feasible, since of all tissues bone is the best conductor of heat. It should in this connexion be mentioned that Nikitinov [7] proposed the application of cold to the head for the treatment of certain brain conditions, as far back as 1885.

Attempts at clinical applications of cold to the head have been described in the literature. Thus Fay and Smith [13], who treated cancerous disease by hypothermia, applied ice-packs not only to various parts of the body of the patient, but also to the head. Fay [14], in the treatment of headaches of varied etiology, used a special helmet placed on the head, with a stream of cold water running through it.

The present paper describes a study of the induction of hypothermia by cooling the brain alone, through its external coverings, and of the temperature profiles achieved at different levels.
EXPERIMENTAL METHODS

In all, we performed 17 experiments on cats. Cooling was effected by means of a small cooling blanket, in which the head of the animal was wrapped. The hair had first been thoroughly removed from the head. Water at 3-5°C was circulated through the blanket. Temperature readings were recorded simultaneously from two or three levels of the brain, using a copper-constantan thermocouple, the insulated function of which was enclosed in a hollow needle with a closed end. At the same time rectal temperature was measured by means of a mercury thermometer inserted to a depth of 8 cm.

In some of the experiments we did not insert the thermocouple needles, in order to avoid injury to the brain, but judged the brain temperature from that of the blood returning from the brain in the jugular vein. For this purpose we inserted a very thin and smooth thermocouple into the vein, against the direction of the current of blood. Control experiments showed that the temperature of the blood was very close to that of the brain.

Arterial pressure was recorded from the carotid artery by means of a mercury manometer, and respiration by means of a Marey capsule, connected through a four-way tube to the trachea. Ether anesthesia was applied.

Restoration of brain temperature was achieved by warming the whole body with an electric heater until the rectal temperature reached 33-34°C, with a short period of heating of the head at the beginning of the recovery period.

EXPERIMENTAL RESULTS

Different temperatures were recorded from different levels of the brain (upper, middle, deep) during the cooling process. As is evident from the Figure, the temperature fell fastest in the outer layer, and more slowly in the middle one (subcortical region). The temperatures of the basilar regions of the brain differed considerably from the two preceding regions. The temperature of the rest of the body fell to some extent, but remained high, relative to the brain. At the end of the period of cooling, the brain temperatures (means of 10 determinations) were: upper layer (cortex) about 18°C, middle layer (subcortical) 21.2°C, while the rectal temperature was 29°C. The temperature of the base of the brain (mean of 4 experiments) was 24.7°C.

TABLE 1

Changes in Arterial Pressure, Heart Rate, and Respiratory Rate During External Cooling of the Brain (temperatures relate to the mid-brain). Means of 9 Experiments

<table>
<thead>
<tr>
<th>Brain temperature Function</th>
<th>Cooling phase (°C)</th>
<th>Rewarming phase (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>37°</td>
<td>35°</td>
</tr>
<tr>
<td>Arterial pressure, mm Hg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>137</td>
<td>140</td>
<td>114</td>
</tr>
<tr>
<td>Heart rate, beats per minute</td>
<td>176</td>
<td>172</td>
</tr>
<tr>
<td>Respirations per minute</td>
<td>27</td>
<td>24</td>
</tr>
</tbody>
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