Mechanism of Development of Human Freezing Under the Action of Naturally Low Temperatures

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Abstract. The study of the effects of naturally low temperatures on the human and animal body is of interest to clinicians who provide medical care to persons who have hypothermia. At present, deaths from general cooling in naturally low temperatures (below -40°C) have not been studied in the world. The possibility of returning to life after freezing has not only not been studied, but is not even expected, although there is very valuable scientific evidence on the return to life of individual organs after deep hypothermia, including the brain. Thermometry was performed for twelve people exposed to a low temperature of -40°C and below. Original thermocouples were manufactured and applied for measurement. In order to study the state of the brain during freezing and the cooling development mechanism, experiments were carried out. The experiments were performed on clinically healthy 6 pigs obtained from the Khatassky pig complex at the age of 3-4 months, weighing from 15 to 20 kg. Data on temperature changes in various organs was collected. Comparative analyzes of changes in the EEG and ECG, depending on changes in body temperature was carried out.
1. Introduction

The effect of low temperatures on the human and animal organism has been studied for 150 years [4]. Surely, the number of deaths from hypothermia over the past 50 years has dropped significantly. However, when studying this issue, it turned out that in spite of everything, death from hypothermia of the body is not a rare case. The problem of the effect of cold on the human body has a long history. The high reversibility of cold death, as well as the extreme resistance of organs to cooling during experiments, is one of the reasons why it is necessary to study the effect of low temperatures on the body. This is of interest, both for theory and for practice, for example, the use of hypothermia during surgery. The pathomorphology of the effect of cold on the human body is also of interest to clinicians who provide medical care to people who have undergone hypothermia [4, 5, 2]. At present, deaths from general cooling in naturally low temperatures (below -40°C) have not been studied in the world. The possibility of returning to life after freezing has not only not been studied, but is not even expected, although there is very valuable scientific evidence on the return to life of individual organs after deep freezing (including the brain). Louis Re proved that the heart of a chicken embryo can restore regular heart beat after being cooled to the temperature of liquid nitrogen, then warmed to +38°C.

In order to study changes in body temperature, we performed thermometry of 12 persons who died from the effects of naturally low temperature -40°C and below. Thermometry was carried out immediately after the delivery of corpses to the premises of the forensic medical examination department. Exposure to cold was within 18 to 26 hours.

For this study, the following measuring instruments were used:

- Intramuscular temperature was taken with a needle thermocouple chromel-alumel type K. The temperature range is from -40 to +200°C.
- Colon temperature was taken with a rectal thermocouple chromel-alumel type K.
- Surface temperature was taken with an external chromel-alumel type K thermocouple.
- Esophageal temperature was taken with DS1922L-F5 loggers.
- A companion device for switching with thermocouples HH506RA manufactured by Theseus. The HH506RA dual-channel temperature meter has the following advantages:
  - Temperature measurement through two independent channels.
  - Accuracy of 0.1 degrees.
  - Saving data to the internal memory.
  - Three-section display with backlight.
  - Moisture and dustproof housing.

The device is supplied with software and a communication cable to computer. Thermocouples are connected to the HH506RA using mini thermocouple connectors that comply with ASTM E1684. The device is certified in the register of measuring instruments, certificate No. 31188. The expanded measurement uncertainty does not exceed the values specified in the technical specifications. The accuracy of this device allows verification with uncertainty normalized in the MI 3091-07 methodology.

During measurements it was established:

- surface temperature of the skin in all parts of the limbs and face is +4°C ±2 upon delivery to room temperature
- temperature in the foot area at a depth of 2 cm is -38 to -40 °C ±2
- temperature in the region of the middle third of the lower leg -30 to -32 °C ±2 at a depth of 5 cm
- In the gluteal area at a depth of 10-12 cm +7°C ±3
- Inside the liver at a depth of 5 cm +10°C ±2
- In the area of the lungs +10°C ±1
- In the region of the heart +10°C ±0.5
- In the face at a depth of 1.5 cm-32°C ±2
- Intracranial temperature at a depth of 10 cm +6°C ±2

Historically, there was an idea of the human body as a homogeneous mass, regulating the heat balance like a physical thermostat: limiting heat transfer and increasing heat production. I.P. Pavlov [3] in his article on the innervation of the pancreas as early as 1888 expressed the idea: "A warm-blooded animal can be imagined as consisting of two halves: warm-blooded and cold-blooded. We must expect
that other living conditions of these halves will also differ from each other." To date, it can be considered proven that the thermal scheme of the human body consists of a "core" (homoiothermic core), which includes the brain, internal organs of the chest and abdominal cavities and the "shell" (poikiloithermic superficial layer), consisting of skin, subcutaneous tissue and superficial and deep muscles.

As for the point of view of I.P. Pavlov that "other living conditions of these halves will also differ from each other", according to I.S. Kandor (1968) this can be attributed primarily to the nature of the reactions of the "core" and "shell" to thermal stimuli. The "core" reacts according to the "counteraction" method: to cooling - by an increase in blood circulation and heat production, to heating - by a decrease. The "shell" reacts according to the "plastic adaptation" method: to cooling - by narrowing of blood vessels and reducing blood flow, that is, even more cooling, to heating - by increasing blood flow, that is, even more heating. The "core" of the body has a relatively constant and high temperature, in contrast to the "shell", the physical constants of the tissues of which are relatively small in thermal conductivity, the main role is played by the transfer of heat from the core to the periphery by blood flow. Earlier, Claude Bernard in special experiments showed that only a dead body is cooled or heated like a physical body - in layers, from the surface inward. As for a living organism, external warming or cooling changes the temperature of its tissues through, mainly, cooling or heating of the blood and its distribution in the body.

A similar point of view was shared by N. Miropolsky. He wrote in his dissertation published in 1880, as cited by N.K. Witte, 1956: “From the foregoing it follows: firstly, the distribution of heat in the animal organism is accomplished mainly through blood circulation; secondly, blood circulation is directly related to the warm flow in the peripheral parts of the body. Hence, the mechanism that controls blood circulation must at the same time regulate both heat loss and the distribution of heat throughout the body.”

Our study confirms the above statements, which suggests the possibility of the brain in a state of anabiosis. Thus, the temperature in the "shell" is negative, and in the core region is positive, which is a very characteristic feature of the protection of the "core" from the damaging effects of the cold. The brain is in a state of hypothermia and is not damaged.

In order to determine the state of the brain during freezing, the cooling development mechanism, the experiments were carried out. The experiments were performed on clinically healthy 6 pigs obtained from the Khatassky pig complex at the age of 3-4 months, weighing from 15 to 20 kg. In order to limit the mobility and fixation of animals, neuroplegia was performed at the beginning of the experiment (neuroleptic – xylazine (“Xyla®”) 0.2% 0.5 ml and droperidol 0.5 ml.). Next, we performed simulation of the state of intoxication with enteric ethyl alcohol 40% at a dose of 5-6 ml/kg. Animals were immobilized and placed outside at an ambient temperature of 40°C to 43°C. The experimental work was carried out in accordance with the ethical standards governing animal experiments, in accordance with the European Convention for the Protection of Vertebrate Animals used for experiments or other scientific purposes No. 123 issued on March 18, 1986, Strasbourg, and by Order of the Ministry of Health of Russia issued 01.04. 2016 No. 199n “On the Approval of the Rules of Good Laboratory Practice”. Permission of the bioethical commission was acquired.

To study the bioelectric activity of the brain, the Neiron-Spektr-1 computer complex was used, which was made on the basis of Neiron-Spektr-4P and is designed to record EEG, long-latent evoked potentials (EP) of the brain in any unscreened room. The recording electrodes were connected to a biopotential amplifier, then connected to a computer and recorded on the hard drive. EEG was recorded during the experiment until the signals stopped and the isoelectric amplitude appeared. The ECG was performed using the Poli-Spektr 8/V device.

At the same time, thermometry was performed: the environment, the surface temperature of the body, limbs. Thermometry of the lower leg at a depth of 1 cm, at a depth of 2.5-3 cm, in the thigh at a depth of 3 cm. Thermometry in the liver, abdomen, in the lungs, mediastinum, in the brain (between the hemispheres).

The obtained data on temperature changes were matched with the data of electroencephalography and electrocardiography. As the body temperature decreases, the EEG indicators naturally change - the
oscillation frequency, and their amplitude gradually decrease and, finally, at a body temperature of about +18...+20°C, the EEG becomes almost isoelectric (flat). At a temperature of +20...+21°C, the ECG sharply slows down and cardiac arrest occurs. In this case, the temperature inside the esophagus was +18...+20°C, the temperature inside the brain between the hemispheres was +14...+15°C. A gradual decrease in brain temperature occurred due to the temperature of the circulating blood, until the heart stopped. Also, a decrease in brain temperature occurred due to the influence of external temperature directly through the bones of the skull. Later, after 4-6 hours of the cold exposure, the following data were obtained: temperature inside the esophagus was +17...+18°C, rectal temperature was +16...+17°C, intracerebral temperature was +11...+12°C. One can see a decrease in brain temperature due to the direct action of cold through the skull. At the same time, according to ECG indications, there was a gradual slowdown in atrioventricular conduction and corresponding bradycardia with subsequent arrhythmia and cardiac arrest. The appearance of the isoelectric line occurred immediately after cardiac arrest.

2. Conclusion
Thus, a decrease in brain temperature to +10°C indicates that the brain is in a state of anabiosis. The possibility of resuscitating the brain is possible. The next stage of experiments on the resuscitation of the brain is determined.

3. References
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