THE CHOICE OF THE OPTIMAL GAS TEMPERATURE IN THE WBC AREA

Alexander Baranov, Tatyana Malysheva, Alexander Kletskiy, Alexander Fedorov, Valentin Zakharenko

Saint Petersburg National Research University of Information Technologies, Mechanics and Optics, Saint Petersburg, 197101, Kronverksky prospect, 49, Russian Federation, e-mail- abaranov@corp.ifmo.ru

3rd IIR conference on cold applications in life sciences – cryotherapy and cryopreservation, St. Petersburg, Russia, September 12-14, 2018
INTRODUCTION

Modern publications of Western European experts cast doubt on the WBC effects known from old publications.

The popularity of cryotherapy treatment is decreasing.

The reason is that the method has been used for more than 40 years without scientifically based requirements for the procedures temperature regime.

During 30 years the air temperature in WBC installations has increased 2 times. Now this trend continues.

It is necessary to formulate and consolidate in the methodical literature unambiguous and reasonable recommendations for the choice of the cooling gas temperature in the WBC zone.
INTRODUCTION

The first WBC procedures took place in the device the same as the low-temperature food storage chamber.

The WBC procedures were carried out immediately for 5-10 patients.

This technology fair to categorize as the group cryotherapy (GWBC)

The use of NITROGEN COOLING SYSTEM (NCS) has identified the level of temperature in the main WBC treatment cabin.
Main cabin (MC) the WBC with NCS can be in two equilibrium states.

In the absence of the patients the temperature in MC decreases to 83 K (-190°C)

When the patients enter the MC volume, the thermal load increases by 10 times.

Thermal equilibrium occurs when the temperature increases to 95-100 K (-170°C)

The temperature in the WBC procedure area in Japanese installations was maintained without automatic control. Perhaps the author of the method believed that the procedures should be carried out at the lowest possible temperature.
WBC's European history is based on imitation of the original technology.

Japanese installations were too expensive so Europe has established the production of analogues.

During the development of European installations the temperature in the WBC zone has increased significantly **110 K (-160°C)**

The temperature **110 K** in an empty cabin can only be maintained when the heat exchangers are partially filled with **liquid nitrogen**.

So it is necessary to control the supply of liquid nitrogen for this purpose

At the entrance of patients the temperature in the WBC zone increases to **140 K (-130°C)**
INSTALLATIONS OF WBC WITH COOLING SYSTEMS WITHOUT NITROGEN

In the XX nineties the WBC units with NCS have been replaced to cooling systems without nitrogen (NFCS).

The efficiency of NFCS is decreased at temperatures below 160 K, so the new WBC was designed for a minimum temperature of 160 K (-110°С).

Today in the medical market there are devices WBC with a minimum temperature 190 K (-80°С).

In Ukraine announced the beginning of production the multi-seat devices with a minimum temperature 210 K (-60°С).

Increasing the minimum temperature from 83 (-190°С) to 160 K (-110°С) decrease the procedures energy costs by 5 times.
TEMPERATURE REGIME OF THE MODERN WBC INSTALLATIONS

In practice developed two variants of the WBC procedures. This is the group and the individual cryotherapy (GWBC and IWBC).

GWBC.

IWBC often termed as a limited cryotherapy (PBC). However, this term does not have sufficient grounds, since the area of the cooling gas contact with the patient's body in a multi-seat cabin is 70.5% of the total body surface area. In the individual cabin the contact area is 66%.

Patients of many local systems during the procedure have many clothes on the body, reducing the contact area with the gas to 30%.
There are fundamental differences between **GWBC** and **IWBC** technologies, which significantly affect the choice of temperature regime.

**GWBC** method developed under the influence of a multi-seat construction for cryotherapy.

Japanese engineers and doctors had to carry out the WBC procedure for the groups, as chamber dimensions were too large for the individual procedures.

Individual cryogen saunas were developed 20 years later than the multi-seat. The design of individual units was developed taking into account the experience of multi-seat systems operation.

**GWBC** and **IWBC** have a different effect for the patient.

**GWBC ≠ IWBC**

The main difference between **GWBC** and **IWBC** is the cooling gas temperature algorithm during the procedure.
In most modern installations the main chamber (MC) maintains a temperature 160 K (110 °C).

Due to the entrance and exit of patients the door the air temperature in MC increases by at least 25 °C.

The each patient body surface into the cabin volume transfer from 3.5 to 4.5 kW of heat.

The cooling system, especially NFCS, is not able to remove such a thermal load at a minimum temperature level, so there is an increase the temperature in the WBC zone.
THE COOLING GAS TEMPERATURE ALGORITHM

The rate of overcooling depends on the intensity of heat removal, which mainly depends on the temperature difference between the body surface and the cooling gas:

\[ q_{s-1} = \alpha_{NC} (T_s - T_1), \quad \alpha_{NC} = f(\Delta T_{s-1}, T_1), \]

here \( \alpha_{NC} \) - the heat transfer coefficient in natural convection, W/(m² K)

\( T_s, T_1, \Delta T_{s-1} \) - the skin surface temperature, the cooling gas temperature, the temperature difference between the skin and gas, K.

The procedure **GWBC** consists of eight stages with different duration and gas temperature.

The minimum temperature level is used only at the 5th stage of the procedure (\(-110 ^\circ C\))

The cooling gas temperature algorithm at **IWBC** (Figure 2) is much easier

---

**Figure 2:** Graph of gas temperature change at GWBC and IWBC.
To carry out a preliminary analysis of the gas temperature it can be assumed the procedure takes place in isothermal conditions:

$$0 < \tau \leq \tau_{\text{max}} \quad T_1 = \text{const},$$

here $\tau$, $\tau_{\text{max}}$ - the time and the maximum permissible duration of the procedure, s.

The time of analgesic action (TAA) procedures is the most reliable and controllable effect of the WBC.

$$\tau_e = f \cdot \int_{\tau=0}^{\tau_{\text{max}}} \frac{A}{(T_s - T_{\text{term}})^2} \, d\tau,$$

here $f$ - the relative contact area of the patient's body with a cryogenic gas, the ratio of the area of contact with gas to the full area of the body, $\tau_{\text{max}}$ - the cooling time until the time of safe procedure, $A$, $n$ are the empirical constants, $T_s$ - surface temperature of the skin at each point in time, $K$, $T_{\text{term}} = 270.5$ K is the temperature of the beginning of cold damage to the skin.

The greatest estimated value of TAA was 325 min.

At a temperature 160 K the procedures efficiency is 10 times lower than at the optimum temperature.
As a result of insufficient intensity of convective heat removal from the body surface, the cooling process with the cryogenic gas temperature above \(-120\, ^\circ C\) does not provide the body surface overcooling to negative temperatures.

At a gas temperature \(-100\, ^\circ C\) the minimum calculated surface temperature value was \(6,3\, ^\circ C\).

Staying in water with a temperature \(0\, ^\circ C\) for \(180\, s\), leads to a decrease in the skin surface temperature to \(5,5\, ^\circ C\).

Under WBC conditions the optimum gas temperature is also 140 K \(-130\, ^\circ C\).
THANK YOU
Questions?

Alexander Baranov, Tatyana Malysheva, Alexander Kletskiy,
Alexander Fedorov, Valentin Zakharenko

(a) Saint Petersburg National Research University of Information Technologies, Mechanics and Optics,
Saint Petersburg, 197101, Kronverksky prospect, 49, Russian Federation, e-mail- abaranov@corp.ifmo.ru