Ultrasonic monitoring of ice ball formation in biological tissues under low-temperature exposure

1st - 5th June 2026

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Low temperatures down to –195 °C are used in cryosurgery for the complete destruction of pathological tissue while maximally preserving adjacent healthy tissue. To obtain the required results of cryogenic exposure, it is necessary to control the volume of the freezing zone, consider the cooling rate, final tissue temperature, exposure time, and rate of thawing. In clinical settings, the primary method of intraoperative monitoring of the freezing zone size and shape dynamics of the freezing zone is ultrasound examination (US). US provides insight into the outer edges of the freezing zone with a typical ultrasound imaging resolution of about 1 mm in real time.

However, there are errors that can lead to an incorrect assessment of the dynamics of the freezing zone size and, consequently, to incomplete destruction of pathological tissue. These errors may be due to violation of methodological principles of positioning the ultrasonic sensor and inconsistency of technical characteristics of the ultrasonic equipment (sensor frequency, actual dimensions and inappropriate software).

A technology has been developed to use the US for exploring the ice ball during low-temperature exposure, which is capable of constructing the 3D- volumetric models of an ice ball under low-temperature exposure for the analysis of its boundaries and the freezing-thawing front movement.

Fig. 1. Cryoinstrument with an 8 mm applicator mounted on a tripod

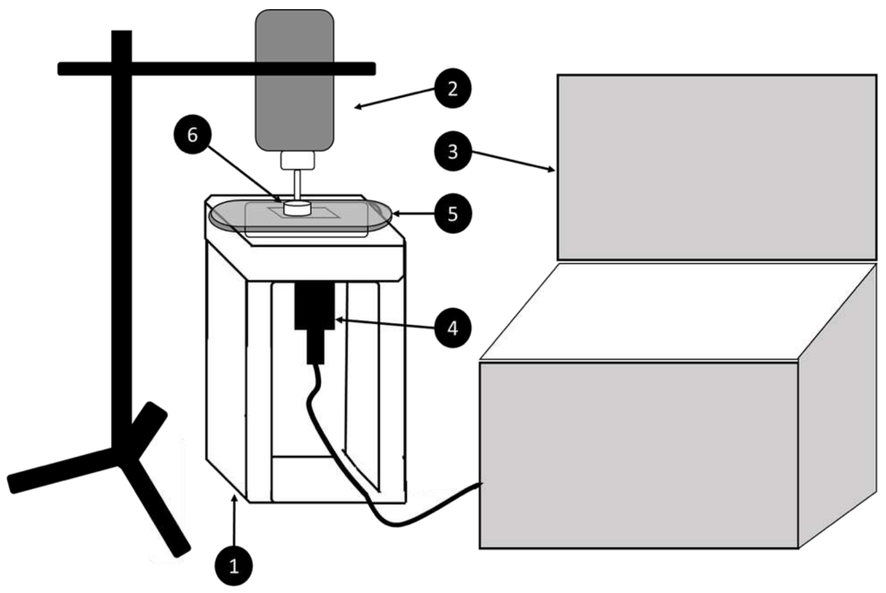

Fig. 2. Block diagram of the experimental setup: positioning device (1), cryoinstrument (2), ultrasonic echotomoscope (3), linear sensor (4), latex container filled with ultrasound gel (5), object of study (6) in the freezing zone

The technology consists of a special laboratory facility for ultrasonic research and an appropriate methodology for monitoring in vitro / in vivo cryogenic exposure on this complex.

The laboratory facility for ultrasonic research of the development of ice balls in biological tissues during low-temperature exposure includes a positioning device, a cryoinstrument mounted on a tripod, an ultrasonic echotomoscope with a linear sensor, the scanning surface of which is flush with the outer surface of the device, on top of which is a latex container filled with ultrasound gel, on which the object of study is placed. The placement of the linear sensor in the positioning device allows for reducing the number of errors and artifacts due to its rigid fixation, which prevents violations of the methodological principles of positioning the ultrasound sensor. Such fixation of the linear sensor enables controlling the volume of the freezing zone, as well as the state of cryogenic influence objects regardless of the operator's experience and skills, which allows for obtaining reliable data from experimental studies.

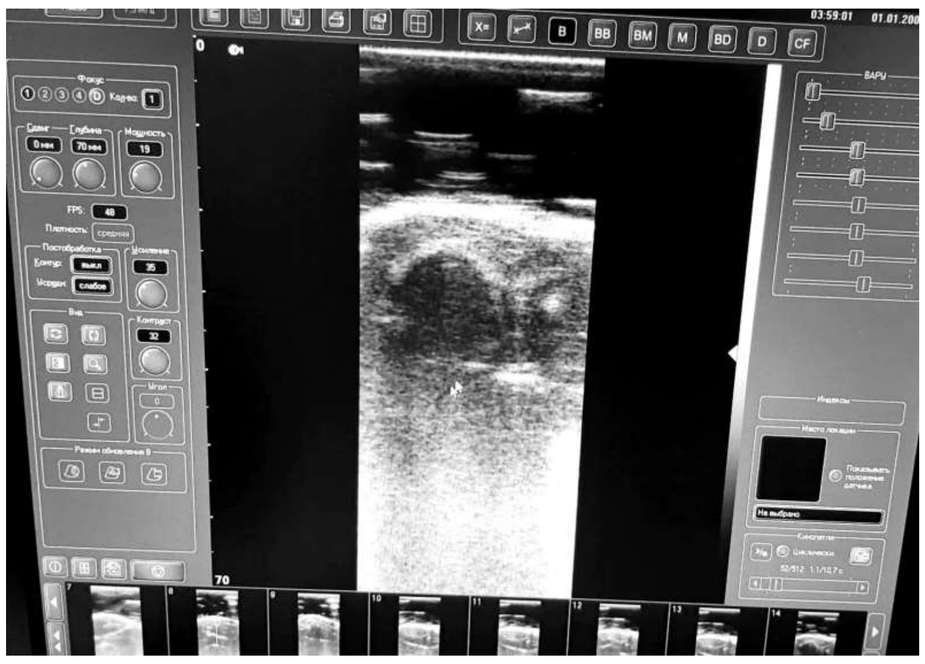

Fig. 3. The process of ultrasonic monitoring cryogenic exposure in vivo

The methodology contains requirements for equipment and facilities as well as a step-by-step description of testing and preparing equipment, measuring using all components of the set-up, quantitative analysis of the results obtained, etc.

Further research involves the use of various cryoinstruments and freeze-thawing modes, varying the composition and temperature of the model system, simulating the presence of blood vessels in the zone of cryoimpact, etc.

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