Cryobiology: Cryopreserving Organs for Transplant

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Cryopreservation is a method through which organs, tissues, or cells are preserved while outside the human body. It is achieved by cooling living matter to temperatures, usually below -196°C, so that reactions such as decay and cell degeneration cannot occur. Organs and living matter are then stored with the goal of reviving them for future operation, such as organ transplants and the storage of sperm and eggs in environments such as space ships. In their frozen state, the organs can theoretically be preserved for decades without aging or decay.

The process of cryopreservation begins with the preparation of the organs, which are soaked in a chemical called a cryoprotectant, such as Glycerol or DMSO. Cryoprotectants, or CPAs, coat the organs, lower the freezing point of water in their cells, and prevent the formation of ice crystals, which could puncture cell membranes. However, these cryoprotective agents must be able to “penetrate the cytoplasm of cells and should have low toxicity” (Anurag N Jaiswal & Anjali Vagga, 2022). Cryoprotectants are essential in preventing cryoinjury, or “the damage of cells associated with the phase changes of water in both extra- and intracellular environments at low temperatures” (Tae Hoon Jang et al., 2017). CPAs can be categorized into two types, cell membrane-permeating cryoprotectants and non membrane-permeating cryoprotectants (Tae Hoon Jang et al., 2017).

Then, the organs are cooled slowly in machines called Controlled-Rate Freezers to temperatures as low as -196°C, eventually becoming vitrified, a state in which an organ is frozen but does not contain ice. When vitrified, all of the organ’s cells are locked in place. The cooling rate is essential in preventing cryoinjury, for “cryoinjury mechanisms involving osmotic rupture caused by intracellular ice formation” have been highly suggested (Tae Hoon Jang et al., 2017).

The processes of osmotic rupture, which is when a cell ruptures due to a pressure difference, and intracellular ice formation are dependent on the cooling rate. After the organ is fully cooled and vitrified, the organ is placed in Cryochambers or Cryo Baths filled with liquid nitrogen and is kept at -196°C, which stops cellular activity and degeneration.

The challenge of cryopreservation arrives in the rewarming process. Organs must be rewarmed uniformly, which can only be achieved slowly. Currently, scientists are developing "single mode microwave resonance technolog[ies]," to warm organs quickly and uniformly, since uneven warming during the process of reviving organs may cause intracellular ice recrystallization, killing cells (John G Baust, Dayong Gao, & John M Baust, 2009).

Cryopreservation comes with the potential of organ preservation, but the process itself entails many difficulties. For example, current cryoprotectants can be toxic at warm temperatures and need to be used in high concentrations. Additionally, it is hard to vitrify complex organs without ice forming. Currently, the technology or process of cryopreservation must be done in a lab, making the technology inaccessible to the general public. However, major innovations have been made in the field of cryopreservation, including the findings of a recent experiment where scientists "gave transplants of kidneys preserved with a new cryoprotectant to rats that regained regular organ function within weeks" (Michael Irving, 2023). This technology has a promising future ahead, showing potential to benefit all aspects of organ or organic matter processing.

References

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