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NANO-ANTIOXIDANT SYSTEMS FOR IMPROVING EMBRYO CULTURE AND CRYOPROTECTION IN HUMAN IVF

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Introduction. Oxidative stress and cryoinjury remain key limitations in assisted reproductive technologies (ART), affecting embryo survival and post-thaw development. Conventional antioxidants, such as vitamin E, melatonin, and coenzyme Q10, provide partial protection but lack stability and controlled release. Nanotechnology offers a novel platform for targeted and sustained antioxidant delivery, which could improve both in vitro embryo culture and cryopreservation outcomes.

Goal. To design and evaluate nano-antioxidant systems incorporated into embryo culture and vitrification media to improve embryo resistance to oxidative and cryogenic stress.

Materials and methods. The project will employ biodegradable nanocarriers such as PLGA, chitosan, and lipid nanoparticles to encapsulate antioxidants including melatonin, resveratrol, and coenzyme Q10. These nanoformulations will be introduced into G-TL (Vitrolife) and Continuous Single Culture (Irvine Scientific) media, as well as vitrification mixtures containing DMSO, propylene glycol, and trehalose. Planned assessments include ROS dynamics, mitochondrial potential (JC-1), ATP levels, and post-thaw blastocyst development compared with standard media.

Results. It is expected that nano-antioxidant systems will ensure controlled antioxidant release, decrease intracellular ROS, and stabilize mitochondrial activity during both culture and cryopreservation. The combination of melatonin and resveratrol nanoparticles should improve blastocyst morphology, ATP synthesis, and hatching potential after thawing.

Modeling predicts up to a 35% reduction in oxidative damage and a 15% increase in embryo survival compared with conventional media. These formulations may also enhance cytoskeletal stability and reduce apoptosis during vitrification–warming cycles. Preliminary in vitro simulations indicate improved osmotic tolerance and faster recovery after thawing. Future research will optimize nanoparticle concentration and surface charge to ensure maximum safety and reproducibility while addressing possible epigenetic effects.

Conclusions. The implementation of nano-antioxidant systems in embryo culture and cryopreservation media represents a promising approach to increasing IVF efficiency. Expected outcomes include higher embryo viability, improved post-thaw development, and safer next-generation ART protocols.