Stem cell research: transforming medicine

Stem cell research has been of interest to the medical community, other healthcare professions, and the general publics since 1945 (1). Stem cell-based therapies are a reality today, and recent use of stem cells validates the wisdom of recovering and cryo-preserving stem cells today for autologous transplants later in life. Autologous transplants appear to be the best method of stem cell transfer to use in the emerging fields of regenerative and personalized medicine, due to their anti-rejection capabilities.

Stem cells are noted for their ability to self-renew and differentiate into a variety of cell types. Some stem cells, described as totipotent cells, have tremendous capacity to self-renew and differentiate (2). Embryonic stem cells (ESCs) have pluripotent capacity, able to form tissues of all three germ layers but unable to form an entire live being (2). Cell characteristics in stem cell biology are the following: totipotent – able to produce an entire being, such as blastomeres; pluripotent – able to produce all tissues and self-renew indefinitely, such as ESCs; and multipotent – able to produce many cell types and self-renew over the lifetime of the being and over many subsequent generations if transplanted, such as hematopoietic stem cells; and progenitor – able to produce restricted number of cell types and with limited to no capacity of self-renewal, such as neural stem cells (2).

Flap prefabrication has been used in plastic surgery, bridging the role between conventional reconstructive surgery and tissue engineering (3). According to the researchers, a further step would be to incorporate cultured cells and stem cells for new tissue generation and specialized function. Liver specific differentiation of embryonic, foetal or adult stem cells is currently under investigation. Different types of foetal liver (stem) cells during development were identified in one study, and their beneficial growth potential and bipotential differentiation capability were shown (4). Other bone marrow derived liver stem cells might be mesenchymal stem cells.

Singapore researchers have developed an unlimited number of pure insulin-producing cells from mouse ESCs (5). There are companies in the United States that plans to start embryonic stem cell studies in humans with spinal cord injuries, if the Food and Drug Administration gives their approval. However, ethical and legal issues must be addressed before using human foetal cells. Along with important beneficial opportunities, many ethical challenges arise, which are largely based on concerns for safety, efficacy, resource allocation and methods of harvesting stem cells (2). Discussing the moral and legal status of the human embryo is critical to the debate on stem cell ethics. Religious perspectives and political events leading to regulation of stem cell research must be addressed. Use of adult stem cells is clinically established, an example being transplantation of hematopoietic stem cells. Sources of adult stem cells include the umbilical cord, amniotic fluid, bone marrow, adipose tissue, brain and teeth (6). Adult stem cells are not subject to the ethical controversy that is associated with ESCs, and they can be autologous and isolated from the patient being treated, whereas ESCs cannot be used in this manner.

Surgeons in Spain recently performed the world's first tissue-engineered whole organ transplant using a windpipe made with the patient's own stem cells. This novel technology of using 'self' cells allows tissue transplants without the need for anti-rejection drugs (7). Scientists from Bristol, England, helped grow the cells for the transplant for the Columbian woman to save one of her lungs after it was damaged by tuberculosis. To create the new airway, the trachea was taken from an individual who had recently died. The donor trachea was thoroughly cleansed and disinfected, leaving a tissue scaffold made of the fibrous protein collagen. The structure was used as a frame to repopulate with cells from the transplant recipient, which could then be used in an operation to repair the damaged left bronchus. Two types of cell were taken from the transplant recipient: cells lining her windpipe, and adult stem cells from the bone marrow. The newly coated donor windpipe was ready to be transplanted into the donor/recipient after 4 days of growth in the lab in a rotating bioreactor. Four days after transplantation the hybrid windpipe was almost indistinguishable from adjacent normal airways, according to the surgeons, and after a month, a biopsy of the site proved that the transplant had developed its own blood supply. After 4 months the transplant showed no signs of rejection.

Another exciting discovery that bypasses the legal and ethical concerns is to use teeth as a source of stem cells. Researchers at the National Institutes of Health have discovered that stem cells in teeth have self-renewal capability (8). Stem cells must be derived from living tissue and must be preserved, usually by cryopreservation (9). The cells are rapidly cooled to subzero temperatures as low as −196°C, stopping any cellular or biochemical activity. This technique is necessary to prevent ice from forming around or inside the cells and to prevent dehydration, which would cause cell damage and death (9). Extracted permanent and deciduous teeth, including exfoliating teeth, can be preserved for future use with cryopreservation techniques. Research has demonstrated that stem cells derived from the dental pulp of extracted third molars maintain the capability to differentiate into numerous cell types, subsequent to thawing after cryopreservation using liquid nitrogen (10). Stem cells derived from the periodontal ligament are capable of living following cryopreservation (11). After 2 years of cryopreservation, stem cells have been able to differentiate and to proliferate, and it has been concluded that dental stem cells can undergo long-term cryopreservation (12). Companies are currently engaged in the collection and cryopreservation of deciduous teeth for patients' potential use in later life (StemSave, New York, NY, USA; BioEden, Inc., Austin, TX, USA).

These developments are very exciting and progress on advancements in regenerative medical therapies and applications will advance at a rapid rate with more to come in the very near future. There is a recent report of the successful establishment of human adult germline stem cells derived from spermatogonial cells of adult human testis (13). As well, researchers at the Yerkes National Primate Research Center, Emory University, have discovered dental pulp stem cells can stimulate growth and generation of several types of neural cells (14). Research in this area will no doubt proliferate in the future.

Resources

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BioEden – http://www.bioeden.com/ (accessed 24 November 2008).

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