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A Review on Stem Cell and its Medical Applications

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Abstract—* Stem cells are undifferentiated cells capable of self-replication and differentiation into various specialized cell types, offering significant potential in medicine. These cells, classified as embryonic or adult stem cells, vary in their abilities, from totipotent (forming all cell types) to multipotent (producing specialized categories). Stem cells have numerous medical applications, including treating diabetes, HIV, multiple sclerosis, and promoting wound healing. They are central to regenerative medicine, anti-aging treatments, and organ engineering. Additionally, stem cells help in understanding genetic diseases and testing new drugs, reducing the reliance on animal models. However, challenges like immune rejection, difficulty in large-scale differentiation, and the risk of uncontrolled cell growth remain. Stem cells can be harvested from sources such as bone marrow, peripheral blood, and umbilical cords, with emerging technologies like CRISPR and induced pluripotent stem cells (iPSCs) enhancing their therapeutic potential. Despite the challenges, ongoing research continues to advance their application in treating chronic diseases, genetic disorders, and injuries.

***Indexed Terms-* Stem cells, Cell differentiation, Undifferentiated cells, Medical Application, Stem cell therapy**

I. INTRODUCTION

For the first time in 1981, researchers successfully isolated stem cells from mouse embryos. More accurate investigations on the biology of mouse stem cells resulted in the development of methods for separating stem cells from human embryos in 1998 (1). Stem cells are undifferentiated cells with the ability to proliferate, regenerate, differentiate, and produce tissue. Stem cells are classified into two types: embryonic and adult stem cells. Embryonic stem cells are formed from zygote cells that are fertilised in vitro and typically form a 4-5-day embryo in the shape of a hollow ball known as a blastocyst. Blastocyst is made up of three parts: the trophoblast layer that surrounds the blastocyst, a hollow chamber within the blastocyst, and an inner cell mass that develops into an embryo. Non-differentiated cells, other than embryonic stem cells, can be identified in differentiated cells of some tissues after birth. These cells are known as adult or non-embryonic stem cells, although a more appropriate term is "somatic stem cells" because they also exist in children and the umbilical cord. They are classified into two types: haematopoietic stem cells, which differentiate into blood cells, and mesenchymal stem cells, which are less differentiated. Adult stem cells have a significant advantage over embryonic stem cells in that they can be obtained without the requirement for destruction of embryo. (1) (2) (3)

Potential Uses of Stem Cells:

Scientists believe that stem cells, because of their potential to differentiate into many types of cells, can be used to treat and understand diseases. Stem cells is used for:

- Creating new cells in a lab to repair damaged organs or tissues.
- Identifying and repairing malfunctioning organ parts.
- Understanding the causes of genetic abnormalities in cells.
- Investigating the causes of diseases and how specific cells become cancerous
- Testing novel medications for safety and efficacy. (4)

Types Of Stem Cells:

Class	Cell Type	Mature Cell Lineages
Totipotent	Embryonic stem cells (e.g., Zygotes)	Differentiate into any cell types
Pluripotent	Embryonic stem cells, iPSCs	Differentiate into cells from any of the three germ layers
Multipotent	Adult stem cells (e.g., Mesenchymal, hematopoietic)	Differentiate into a limited range of cell types
Oligopotent	Adult stem cells (e.g., lymphoid, myeloid)	Differentiate into a limited number of cell types
Unipotent	Adult Stem cells (e.g., satellite, epidermal	Differentiate into a single cell type

Medical Application of Stem Cell

1. Treatment of diabetes:

In clinical trials, a variety of stem cell types were employed to treat diabetes. Diabetes mellitus can be caused by lifestyle decisions and genetic inheritance (type 2 diabetes), autoimmune conditions (type 1 diabetes), or even hormonal changes during pregnancy (gestational diabetes). Insulin injections are commonly used to treat diabetes; however, they are expensive and only temporary. Stem cells can remedy this problem by directly repairing pancreatic cells. Furthermore, diabetes related ailments, such as non-healing wounds, are being treated with stem cells.

2. Human stem cell (HSC) transplantation:

Healthy HSCs can be transplanted into patients with bone marrow and blood abnormalities. Replace defective bone marrow cells in diseases such leukaemia, lymphoma, and tumours. Cells can be transferred in three ways: autologous (from the patient), allogeneic (from someone else), or syngeneic (from identical twins). Bone marrow transplants are a well-established medical practice. [5]

3. Stem Cell Treatment for HIV

HIV infection has been thought to negatively impact the haematopoietic stem's ability to produce immune cells. The most recent data document reduces the malfunctioning of HIV cells and demonstrates that the immune system is A fresh generation of T-cells. HIV has an indirect effect on stem cell function due to their strong resistance to the virus. Although haematopoietic stem cells have surface receptors for HIV, they are not infected and can be used to treat AIDS. [6]

4. HSC Therapy (HSCT)

Clinical research has shown that HSCT can treat multiple sclerosis (MS). Multiple sclerosis is an autoimmune illness that affects the central nervous system. Multiple sclerosis is traditionally treated with disease-modifying therapy (DMT). DMT affects the immune system via modifying it, altering immune cell trafficking, or lowering its population. However, it requires long-term administration and may cause major side effects. Clinical trials of HSCT have shown superior results than DMT.

5. Anti-aging effects.

The ageing process involves biological factors such as DNA damage, telomere shortening, loss of proteostasis, mitochondrial malfunction, and stem cell fatigue. Adipose-derived stem cells stimulate mitophagy, boost mitochondrial synthesis, reduce reactive oxygen species, and finally alter cell metabolism to mimic youthful cells. Pathways for nucleotide metabolism and mitochondrial function are also enriched.

6. Wound healing

Stem cells enhance wound healing, regulate immunological responses, and secrete antimicrobial substances. Using autologous stem cells removes the risk of immune rejection.

7. Treatment for burn wounds

Stem cells outperform traditional approaches for curing burn burns. Direct injection of stem cells, tissue-engineered grafts, and exosome therapy have shown encouraging outcomes for burn wound healing.

8. Development towards artificial organ engineering

When stem cells are cultivated in a 3D environment under permissive growth conditions, they multiply and differentiate into their original structures. These formations, known as "organoids," mimic organs and serve as a habitat for stem cells. Organoids exhibit unique characteristics such as size, shape, and cell composition, which cannot be replicated with existing technology. These organoids are utilised for numerous studies. [5]

How Do Physicians Harvest Stem Cells?
Stem cell harvesting is the technique of extracting stem cells from the body for transplant. Stem cells can be sourced from bone marrow, peripheral blood, or the umbilical cord.

Bone marrow: These cells are extracted under general anaesthesia, typically from the hip or pelvic bone. Technicians then separate the stem cells from the bone marrow for storage or donation.

Peripheral stem cells: Following several injections, a person's bone marrow releases stem cells into the bloodstream. The blood is then withdrawn from the body, the stem cells are separated using a machine, and the blood is returned to the body by doctors.

Umbilical cord blood: Stem cells can be extracted from the umbilical cord after delivery without harming the new-born. Some individuals donate cord blood, while others choose to store it. [7].

Future Prospects
Currently, there are various issues with stem cells. The first and most crucial is a thorough grasp of how stem cells function in animal models. This step can't be avoided. Fear of the unknown is the most difficult obstacle to achieving widespread, global acceptance of the technique.

The effectiveness of stem cell-directed differentiation must be increased in order to make stem cells more reliable and trustworthy for a typical patient. Another problem is the procedure's scope. Future stem cell therapies may provide a considerable challenge. Transplanting new, completely functional organs created by stem cell therapy would necessitate the production of millions of working, biologically accurate collaborating cells. Bringing such complex methods into common use in regenerative medicine will necessitate interdisciplinary and international collaboration.

Another obstacle is to accurately identify and isolate stem cells from the patient's tissues. Immunological rejection is a significant barrier to effective stem cell transplantation. With certain types of stem cells and techniques, the immune system may recognise transplanted cells as alien substances, causing an immunological reaction that results in transplant or cell rejection. [8]

- Gene Editing via Stem cells

Combining stem cell technologies with gene editing methods such as CRISPR-Cas9 opens up new possibilities for treatment.

Hereditary illnesses and genetic defects can be fixed. Gene-edited stem cells could treat genetic illnesses and reduce the risk of harmful mutations passing down to future generations.

- Stem cells (autoimmune diseases)

AIDS-related immunological weaknesses can be addressed using stem cells. They regulate the immunological system encourages tissue regeneration, perhaps curing autoimmune diseases. Future research will focus on developing safe and effective stem cell therapies for disorders such type 1 diabetes, rheumatoid arthritis, and multiple sclerosis.

- Regenerative medicine

In regenerative medicine, damaged or diseased tissues and organs can be restored or replaced by healthy stem cell-derived cells. This could transform the treatment of ailments like heart disease, Parkinson's disease, spinal cord injuries, and others.

- Personalised medicine.

With the introduction of iPSCs, it is now possible to generate stem cells from a patient's cells, resulting in an endless supply of personalised cells for therapeutic use. IPSCs can be genetically matched to the patient, dramatically lowering the risk of immune rejection and enabling personalised therapy for a variety of medical problems.

- Tissue Engineering

Organoids can be used to test drugs, simulate diseases, and provide personalised medicine, allowing for more precise and efficient therapies.

- Artificial Organs and Body Parts

In the not-too-distant future, we may see the production of fully functional artificial organs and body parts from stem cells. This could help to reduce the organ scarcity for transplants and provide tailored solutions for people in need. (5)

What Are the Risks Associated with Stem Cell Therapy?

During an allogeneic stem cell transplant, the donor cells may initiate an immune reaction against the host. They treat host cells as alien invaders in the donor's body. This can cause diarrhoea, dermatitis, eye pain, and, if severe, death.

The host may also reject the transplant, causing disease and, if the transplant fails, death.

Infection is never good. While antibiotics are normally used to treat bacterial infections that may occur at the site of the incision, there is no guarantee that infection will not develop. Similarly, a patient can die during anaesthesia regardless of the procedure, especially if they are elderly or in bad health.

One of the most serious risks of stem cell transplantation is uncontrolled cell proliferation. Uncontrolled cells are the definition of cancer, which is a major worry. Scientists must perform additional research to determine what will considerably reduce or eliminate these risks (9)

CONCLUSION

Stem cell research has the potential to greatly improve human health. However, there is some dispute over the development, use, and destruction of human embryos. Scientists may be able to address these concerns by creating a new method of transforming adult stem cells into pluripotent stem cells, which can differentiate into any cell type. This would eliminate the requirement for embryonic stem cells in research. These findings highlight the enormous improvements made in stem cell research. Despite these breakthroughs, much more work needs to be done before scientists can develop successful stem cell medicines.

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