Stem Cell and its Applications in (Medical Biotechnology)

Abstract:

Stem cells are partially differentiated or undifferentiated cells in multicellular animals that can be specialized into many types of cells and multiply into endless other stem cells. Stem cells can be produced from many sources in the body such as embryonic tissue, foetus placenta i. e; chorion and amnion, umbilical cord, and amniotic fluid. Stem cells are also produced from specific organs of adult organisms like blood, skin, skeletal muscle, bone marrow, and some differentiated somatic cells. Stem cells can be totipotent, pluripotent, multipotent, and self-renewed cells. Stem cells are used to regenerate injured cells in the body, and repair the cells dysfunctional due to any kind of disease, also known as regenerative medicine. From all types of cells, totipotent stem cells can generate any kind of cells in the body so they are the most important type of cells. Along with this, pluripotent stem cells also produce all types of cells, except the placenta or embryonic cells. These cells can be ejected from the body from the late embryonic stage after 1 week of the birth of a child, from the miscarriage of 12 weeks, and also from the umbilical cord of the child. These can be stored for another 2 decades. Another type is multipotent stem cells, which can generate a limited number of cells in a specific type; the last fourth type is unipotent stem cells, which can only produce cells of their own type. Diagnosis with stem cells? is a useful technique to treat patients with many blood-related diseases for example blood cancer,

thalassemia, and anaemia. It also cures diseases like diabetes, liver disease, bone and cartilage, and organ transplantation.

Keywords: Stem cell, totipotent, pluripotent, multipotent, regenerative medicine

Introduction

STEM CELL

Stem cells, which typically originate from a single cell (clonal), proliferate extensively (self-replicate), differentiate into numerous cell and tissue types, and are composed of undifferentiated cells. Stem cells originate from diverse sources and possess unique characteristics. Pluripotent cells, as well as pluripotent stem cells generated through induction, are produced by reprogramming somatic stem cells derived from the blastocysts' interior embryonic cells. All three embryonic layers' tissues can divide from pluripotent cells: ectoderm, mesoderm, and endoderm. A single lineage of pluripotent stem cells can differentiate into numerous tissues, including cartilage-forming mesenchymal cells, adipose tissue, and bone cells. Tissue-dependent cells are oligopotent because they undergo a diverse array of cellular differentiation within distinct tissues. Cell therapy may use stem cells to regenerate organs or replace damaged cells. In addition, stem cells contribute to our comprehension and awareness of the pathogenesis of disease and development. (Kolios & Moodley, 2013).

The fusion of sperm and egg results in fertilization, leading to the formation of the blastocyst. The tissue is enveloped by embryonic stem cells, a particular type of stem cell. Two main cell types make up the blastocyst. These are the inner cell mass (ICM) and the trophectoderm (TE), which develop in the ectoderm and trigger fetal development. The blastocyst is responsible for regulating the ICM microenvironment. TEs continue their development and produce many extraembryonic support structures necessary for the embryo's development, such as the placenta. Once TEs develop specific promotors, Inner giant cells proliferate, remain pluripotent, and lack differentiation. Stem cell pluripotency enables them to differentiate from a single cell within the organism.

ORIGIN

The initial discovery of stem cells occurred in 1961, when Dr. James A. Till and Ernest A. McCulloch of the University of Toronto, Canada, reported on the matter. It was noted that stem cells from the bone marrow of rodents exhibited a propensity for multipotentiation, hence the name pluripotent stem cells (PSCs). Later on, in 1966, Keith Campbell, Lan Wilmut, and other associates at the Roslin Institute of the University of Edinburgh in Scotland cloned Dolly the sheep to demonstrate the effectiveness of somatic cell nuclear transfer (SCNT). James Thomson subsequently isolated the initial human embryonic stem cells (hESC) in the United States 1998. Inducible PSCs (iPSCs) were isolated from reprogrammed adult cells in 2006 using only four out of twenty-four essential mutations. John Gurdon (Gordon Institute, Cambridge, UK) and Shinya Yamanaka (Kyoto University, Japan and Gladstone Institute, USA) were honoured in 2012 for their research demonstrating that mature cells can regenerate into a pluripotent state. (Bacakova et al., 2018)

CLASSIFICATION

Based on their Differentiation Potential

One of the essential features of stem cells is their ability to form different cell lineages. However, this ability differs across all stem cells and has other abilities. A fertilized egg that can produce an entire embryo and part of the placenta is a sample of a totipotent cell. The cells of the giant cell are considered pluripotent, and most cells that arise from the third layer of the organism may arise from giant cells, but the products of the placenta do not include body cells in the body. Most tissue-specific cells are pluripotent and tend to differentiate into two, three, or more different specific cell categories that manifest the functional attributes of the tissue in which they are situated.

Totipotent stem cells can undergo rapid cell division and specialize into many cell types across the entire organism. Totipotency refers to the highest level of cell division capacity, enabling cells to form both embryonic and specific extraembryonic structures. The Zygote, which forms when the sperm fertilizes the egg, is an excellent example of a totipotent cell. These cells can become the placenta or one of the three germ layers. Approximately four days later, the inner cell of the blastocyst acquires pluripotency. The generated structure serves as the source of pluripotent

cells. Induced totipotent stem cells can be broken down into two different types. Induced totipotent stem cells can be broken down into two different types. The cells that have been activated are expanded stem cells (EPSC) and two cell-like cells (2CLC). Both cell types exhibit resemblances to totipotent stem cells. The cells divide into lines of embryonic and extraembryonic cells and merge with the host blastocyst to create the Inner giant cell and trophectoderm. However, their ability to grow is limited. (Genet and Torres-Padilla, 2020; Lu and Zhang, 2015). Injecting or transplanting morula and blastocysts with externally generated totipotent cells into the uterus has yielded varying outcomes. (Riveiro and Brickman, 2020). After transfer, EPSCs can stimulate the Trophectoderm and ICM of embryos, but cells in the TE express OCT4, there is a decrease in CDX2 and ELF5, and transferred embryos can grow up to 4.5 DPC. (Dua et al., 2003)

Pluripotent stem cells (PSCs) can produce cells in all layers of tissue except extraembryonic tissues, such as the placenta. Embryonic stem cells (ESCs) serve as a prime illustration. ESCs are separated from the bulk of preimplantation embryo cells. Another illustration is making induced pluripotent stem cells (iPSCs) from the ectoderm of embryos that have been transplanted. Their ability to differentiate into many cell types is progressive, beginning with fully pluripotent cells (such as ESCs and iPSCs) and concluding with limited potency (oligopotent, pluripotent, or unipotent cells). *Teratoma testing* is a method used to assess the activity and spectrum. Induced pluripotent stem cells, often known as iPSCs, are pluripotent stem cells that are produced from somatic cells and have comparable functionalities to pluripotent stem cells (PSCs) (Kolios & Moodley, 2013).

They have been cultivated exceptionally effectively and are employed in regenerative medicine both currently and in the future. Pluripotent stem cells have a narrower lineage and are more capable of differentiating from PSCs, but they may be specialized cells that discriminate between certain diseases. Hematopoietic stem cells (HSCs) are one example; they can differentiate into various blood cells. Their ability to proliferate is then limited to the cells of their progeny. However, some cells can divide into undifferentiated cells, suggesting they are pluripotent.

The bone marrow is an instance where oligopotent stem cells differentiate into white blood cells (WBC) but not red blood cells (RBC), showcasing their capacity to differentiate into many cell lineages.

Unipotent stem cells possess a restricted capacity to undergo differentiation into a particular cell type and possess a distinctive redistributive feature. Their ability to redistribute resources makes them promising candidates for regenerative therapy. These unipotent cells can mainly produce a single type of cell, such as skin cells.

Multipotent stem cells (MSCs) have important properties similar to other stem cells. Like other stem cells, over an extensive length of time, pluripotent stem cells have the remarkable capacity to undergo self-renewal and cellular differentiation into a diverse array of specialized cells, each possessing its distinct repertoire of functions. MSCs can differentiate in different lineages and self-renew. Mesenchymal stem cells (MSCs) significantly promote growth, facilitate tissue repair, and provide protection in biological processes. Stem cell acquisition for diagnosing many disorders, including neurological and cardiovascular conditions, has gained significant recognition in recent years. This field holds immense potential for the advancement of medicine. A wide variety of cell types may be differentiated from these stem cells., although their capacity to specialize is limited.

For instance, mesenchymal stem cells can undergo differentiation into nerve cells and glial cells. On the other hand, hematopoietic stem cells can divide and give rise to numerous varieties of red blood cells. However, they cannot generate enough cells for the brain. MSCs, or mesenchymal stem cells, produce bone marrow, which can multiply and differentiate into different blood cells. Adult stem cells (MSCs) are classified as such due to their exceptional capability to differentiate into one or more distinct cell types.

Nevertheless, mesenchymal stem cells (MSCs) are widely recognized as a prominent subset of mesenchymal stem cells, capable of differentiating into numerous cell types. Multiple studies have substantiated these specialized cells' ability to differentiate into various tissues, including cartilage, muscle, bone, fat, and other types of tissues. Mesenchymal stem

cells can generate specialized cells. The stem cells mentioned differ from pluripotent stem cells, which can divide and transform into almost any type of cell, and totipotent stem cells, which can divide and transform into only one cell type. Pluripotent stem cells are essential in forming mesenchymal stem cells, which are primitive cells responsible for generating specialized cells with distinct activities.

(Lack of source of information: reference)

What is the role of stem cells in regenerating organs or replacing damaged cells?

What are the differences between totipotent, pluripotent, and oligopotent stem cells? What are the limitations of induced totipotent stem cells in terms of their ability to grow?

Based on their Origin

The four primary types of stem cells are early stem cells (ESCs), foetal stem cells (FSs), adult stem cells (ASCs), and induced pluripotent stem cells (iPSCs). These stem cells are classified based on their specific area of origin. Adult stem cells often exhibit either oligopotent or unipotent characteristics, while ESCs and iPSCs possess pluripotent properties due to their ability to differentiate into several cell types.

Embryonic stem cells

The presence of specific transcription factors, including Nanog and Oct 4, can identify ESC. The presence of these substances sustains the undifferentiated state of stem cells and enables them to undergo self-renewal. An ESC line is produced when undifferentiated ESCs are cultured without genetic defects. These cells can undergo cryopreservation and subsequent thawing for use in other cultures and research. Preserving embryonic stem cells in an undifferentiated condition highly depends on the cultural environment. The nutrient layer of embryonic fibroblast cells (MEFC) or media containing the anti-differentiation cytokine leukaemia inhibitory factor (LIF) is included. Embryonic stem cells (ESCs) passing through the feeder layer result in the formation of "germ bodies" that contain all three germ layers (endoderm, mesoderm, and ectoderm). (Zwaka & Thomson, 2005)

Adult stem cells originate from adult tissue. Examples include human amniotic epithelial cells, stem cells taken from placental tissue, and MSCs. These cells have anti-inflammatory properties and promote the healing of animal injury models. Although these cells exhibited the ability to differentiate when germ cells were cultured into tissue from multiple layers in a laboratory, their ability to differentiate is limited. Adult stem cells are advocated due to their autologous nature, eliminating ethical controversy and fear of refusal.

Adult stem cells can be extracted from all three germ layers of tissues in addition to the placenta. Numerous scientific investigations have demonstrated that the transplantation of these stem cells can restore damaged organs in living organisms. This includes revascularizing ischemic heart tissues and repairing bone tissue by differentiating stem cells and generating new, specialized cells. Additional studies have illustrated that grown adult stem cells produce a range of chemical mediators that have angiogenic, immunomodulatory, anti-apoptotic, and some chemoattractant properties, which aid in restoration. (Dulak and others, 2015)

Tissue-Resident stem cells

Tissue stem cells are essential for regenerating and repairing specific tissues and organs in adults by producing specialized cells specific to those tissues. According to studies, these cells form throughout ontogeny and remain resting unless they are stimulated locally to undergo growth, differentiation, or relocation. The "stem cell niche" is where tissue-resident stem cells remain. The stem cell niche is the milieu that controls these cells' ability to convert and self-renew. Numerous indications suggest that the microenvironment and external signals significantly impact stem cell activity; hence, the niche is essential for tissue healing and homeostasis.

Although most tissue-resident stem cells remain inactive, they are stimulated by specific signals when there is an injury or need for repair. The mechanisms underlying the dormancy of tissue-resident strain cells are poorly understood; nevertheless, they are anticipated to influence a distinct ecological habitat. This feature is essential for preserving a cell population that solely produces tissue-specific cells during the repair process. The niche environment consists of many signals facilitated by the

extracellular matrix and soluble mediators. These mediators regulate the expression of genes and the signalling between cells, governing the processes of stem cell growth, movement, specialization, and programmed cell death. The mechanisms by which stem cells shift from a state of self-renewal and proliferation to differentiation, or the unique signals required for this transition in distinct tissues, remain to be comprehended.

Additionally, the sort of cell division that stem cells undergo to control the cells that the cell type produces. When a stem cell splits a cell symmetrically, it produces identical daughter cells that produce new cells for healing injured cells. It is vital to remember that while stem cell depletion would impede organ repair, unchecked stem cell differentiation expansion could result in excessive growth of stem cells and the development of cancer; hence, it is essential to maintain a balance in stem cell homeostasis. A stem cell produces a second differentiated daughter cell and a comparable daughter cell, which is known as asymmetric division. This process maintains the stem population cells while enabling organ repair and regeneration.
(Lack of source of information: reference)

Induced Pluripotent Stem Cell
iPSCs originate from these somatic adult cells. They have been subjected to genetic reprogramming, resulting in the acquisition of "ESC-like states." Takahashi and Yamanaka created the first mouse-induced pluripotent stem cells (iPSCs) in 2006 by introducing four genes that encode the transcription factors SOX2, OCT3/4, KLF4, and c-MYC into mouse fibroblasts using a process called transduction. In 2007, Yamanaka and his colleagues reported the utilization of adult human dermal fibroblasts and four specific factors (Oct3/4, Klf4, Sox2, and c-Myc) to produce human induced pluripotent stem cells (hiPSCs). Liu and colleagues, 2020.
The ability of these cells to grow into human ESCs outside of the body, as well as their surface antigens, morphology, proliferation, epigenetic status, gene expression, and telomerase activity of genes specific to pluripotent cells, were all shown. Induced pluripotent stem cells (iPSCs) are valued resources for conducting pharmaceutical research, disease modelling, and regenerative medicine. Nevertheless, while iPSCs and ESCs demonstrate pluripotent stem cell characteristics, it remains uncertain whether they will exhibit notable distinctions in therapeutic application. Induced

pluripotent stem cells (iPSCs) are utilized in a therapeutic experiment constrained by retroviral vectors, which deliver reprogramming factors into mature cells and oncogenes such as c-Myc. The vectors that deliver transcription factors into mature cells can potentially lead to cancer development.

Researchers are investigating novel methods for creating genome-free iPSC modification that ensures safety. Various mouse breeds and adult somatic human cells have been used to illustrate the latest technologies. To inhibit the utilization of c-MYC and KLF4 oncoproteins, either OCT3/4 or KLF4 alone, or a combination of other factors, together with non-retroviral vector strategies, including plasmids, chemical compounds, adenoviruses, and transposons, were utilized. This innovative discovery has resulted in the development of an optimal method to revert cells to earlier undifferentiated stages and generate induced pluripotent stem cells (iPSCs) that exhibit complete genetic compatibility with the donor cells. This particular method successfully bypasses the issue of rejection, regardless of the existence of significant safety concerns. (Zakrzewski and colleagues, 2019)

What are the specific signals that stimulate tissue-resident stem cells when there is an injury or need for repair?

What are the mechanisms underlying the dormancy of tissue-resident stem cells and how do they influence a distinct ecological habitat?

What are the unique signals required for the transition of stem cells from a state of self-renewal and proliferation to differentiation in distinct tissues?

6. Application of stem cells in medical Biotechnology

6.1 Application of Stem Cells in Cancer

Cancer, an intricate and diverse ailment distinguished by unregulated cellular proliferation, has consistently been a significant health issue. Despite notable progress in conventional treatments such as surgery, radiation, and chemotherapy, cancer continues to be a prominent cause of mortality worldwide. However, recent years have witnessed a burgeoning interest in stem cell therapy, which can potentially revolutionize the fight

against cancer. Stem cells, by their remarkable self-regeneration and differentiation capabilities, hold immense promise in cancer treatment. Their potential applications can be broadly categorized into three main areas:

1. Targeting Tumour Cells:

- Direct Cytotoxic Effect: Stem cells can be engineered genetically to generate particular chemicals that selectively target and eliminate cancer cells. The chimeric antigen receptor (CAR) T-cell therapy involves T-cell extraction from a patient, modification with CARs that target specific cancer antigens, and subsequent reintroduction into the patient. The therapeutic efficacy of CAR T-cell therapy for specific hematologic malignancies has been exceptionally promising, providing a glimmer of hope for patients with few therapeutic alternatives.
- Immunomodulatory Effects: Stem cells can also modify the immune system's capacity to recognize and eliminate malignant cells. For instance, mesenchymal stem cells (MSCs) have shown promise in suppressing tumour growth and promoting anti-tumour immune responses.

2. Tissue Regeneration:

- Cancer Treatment Adverse Effects: Cancer therapies such as radiation and chemotherapy can result in substantial harm to normal tissues. Stem cells offer a promising avenue for regenerating damaged tissues and promoting healing. For example, hematopoietic stem cells can restore bone marrow function after chemotherapy, while stem cells derived from adipose tissue can be used to reconstruct breasts after mastectomy.
- Stem Cell Transplantation: Stem cells can support bone marrow function in patients undergoing high-dose chemotherapy, allowing for more intensive treatment regimens with reduced risk of complications.

3. Drug Discovery and Development:

- Cancer Drug Testing: It is possible to generate tumour models from patients by using their stem cells, which provide a more accurate platform for testing new cancer drugs than traditional animal models. This allows researchers to identify more effective drugs with fewer side effects.
- Personalized Medicine: Stem cells have the potential to generate personalized treatment plans for cancer patients. Researchers can identify specific genetic mutations by analyzing patients' tumours and tailoring

their treatment accordingly. This personalized approach can lead to more effective and targeted therapies.

(Lack of source of information: reference)

6.2 Application of stem cells in neurodegenerative disease

Neurodegenerative diseases, a group of progressive disorders affecting the brain and nervous system, are a growing global health concern. Diseases like Alzheimer's, Parkinson's, and Huntington's disease lead to a gradual decline in cognitive function, movement, and other essential abilities, significantly impacting the lives of patients and their families. While current treatments offer some symptom relief, they do not address the underlying disease process or offer a cure. However, a new ray of hope emerges from stem cell research. Stem cells can differentiate into many cell types and self-renew, making them highly promising for treating neurodegenerative disorders. Their potential applications can be broadly categorized into three main areas:

1. Cell Replacement Therapy:

- Replacing Damaged Cells: In neurodegenerative diseases, specific populations of neurons degenerate and die, leading to the observed symptoms. Stem cells can be differentiated into specific neuronal subtypes and transplanted into the affected brain areas. This approach aims to replace lost neurons and restore lost functions.
- Stem Cell-Derived Neural Progenitors: Stem cells can undergo differentiation and transform into neural progenitor cells, which are precursor cells that can further differentiate into various neuronal subtypes. This approach offers a more flexible and potentially scalable solution for cell replacement therapy.

2. Neuroprotection and Immunomodulation:

- Supporting Neuronal Survival: Stem cells can release various factors that support the survival and function of existing neurons. These factors can protect neurons from damage and promote their repair, potentially slowing disease progression.
- Modulating the Immune System: Neuroinflammation is crucial in advancing neurodegenerative disorders. Stem cells can regulate the

immune response, diminishing inflammation and safeguarding neurons against harm.

3. Modelling of Diseases and Drug Discovery:

Patient-Derived Cell Models: Stem cells can be obtained from individuals afflicted with neurodegenerative disorders, enabling scientists to fabricate individualized cell models that mimic the pathological state. These models can investigate disease mechanisms and evaluate potential therapeutic pharmaceuticals.

High-Throughput Drug Screening: Stem cell-based models can be used for high-throughput screening potential drugs, accelerating the discovery process for new treatments.

Stem cell therapy for neurodegenerative diseases is still in its early stages, but several promising clinical trials are underway. Some notable examples include CAR T-cell therapy for Alzheimer's disease, which aims to eliminate harmful brain proteins contributing to the disease. The therapeutic application of mesenchymal stem cells for the treatment of Parkinson's illness aims to protect dopaminergic neurons that are essential for movement control. Stem cell therapy for spinal cord injury aims to promote damaged spinal cord tissue regeneration.

(Lack of source of information: reference)

6.3 Application of Stem Cells in Gene Therapy

Gene therapy is a dynamic field that involves the transfer of genetic material into cells to treat genetic illnesses. It has great promise for therapeutic applications. Stem cells play a crucial part in the progress of gene therapy applications because of their unique ability to renew themselves and transform into various types of cells.

1. Cellular Carriers for Gene Delivery: Genomic modification is an option for stem cells to carry therapeutic genes, acting as vehicles for delivering them to specific target tissues.

- Mesenchymal stem cells (MSCs): Due to their capacity to migrate to various tissues and immunomodulatory properties, MSCs are promising carriers for delivering genes to treat inflammatory and autoimmune diseases.

• Hematopoietic stem cells (HSCs): These proliferating blood progenitor cells can be modified to carry genes for treating blood disorders like sickle cell anaemia and beta-thalassemia.

2. Long-Term Expression: Stem cells' self-regeneration and differentiation capacity allow therapeutic gene expression. This enables the maintenance of therapeutic effects over an extended period, hence minimizing the necessity for recurrent treatments.

3. Gene Correction and Editing: Stem cells can be used for gene editing using tools like CRISPR-Cas9. This enables the rectification of precise genetic mutations, providing a prospective remedy for genetic disorders.
4. Personalized Medicine: Stem cells can be obtained from specific patients, allowing for the creation of customized gene therapy methods. This enables customization of the therapy based on the individual patient's distinct genetic composition, which has the potential to result in therapies that are more efficient and less risky.
5. Drug Discovery and Disease Modelling: Stem cells have the potential to generate disease models that are particular to individual patients. This enables researchers to investigate the underlying causes of genetic illnesses and devise novel gene therapy approaches. These models can also be used for high-throughput drug screening to identify potential therapeutic candidates.
(Lack of source of information: reference)

Examples of promising stem cell-based gene therapy applications include:
• Gene therapy for cystic fibrosis: Using lentiviral vectors to deliver a functional CFTR gene to lung epithelial cells derived from patient stem cells.
• Gene therapy for X-linked severe combined immunodeficiency (SCID): Replacing the defective IL2RG gene in HSCs of SCID patients using retroviral vectors.
• Gene therapy for Duchenne muscular dystrophy (DMD): Editing the dystrophin gene in muscle stem cells using CRISPR-Cas9 technology.

6.4 Application of Stem Cells in Diabetes

Stem cell research holds significant promise for the treatment of diabetes. It allows for the exploration of the condition, the creation of innovative treatments, and the possibility of finding a solution. An important use

involves converting stem cells into beta cells that produce insulin to replace or regenerate the malfunctioning or damaged pancreatic beta cells characteristic of diabetes. Pluripotent stem cells, such as embryonic stem cells (ESCs) and induced pluripotent stem cells (iPSCs), are being investigated as a sustainable option for creating functional beta cells that can produce insulin in response to glucose levels. Scientists have made significant progress in transforming stem cells into beta-like cells that display glucose-responsive insulin production, replicating the activity of natural beta cells. This method exhibits significant promise for cell replacement therapy, wherein these produced beta cells might be implanted into individuals with diabetes to reinstate regular insulin secretion and control blood glucose levels.

Moreover, stem cells are pivotal in disease modelling and drug discovery for diabetes. Patient-specific iPSCs derived from individuals with diabetes enable researchers to create disease models, studying the underlying mechanisms of the disease and testing potential therapeutic interventions in a personalized manner. These models aid in understanding disease progression and facilitate screening new drugs and therapies for their efficacy and safety. However, challenges persist in translating stem cell-based therapies into viable treatments for diabetes. Issues such as immune rejection, the need for long-term functionality and safety of transplanted cells, and the scalability of producing large quantities of functional beta cells pose significant hurdles (Stendahl et al., 2019; Vegas et al., 2016).
Furthermore, the ongoing study is centred around improving techniques to ensure effective and consistent differentiation of stem cells into fully developed and functioning beta cells. In conclusion, stem cell research offers promising avenues in diabetes treatment by providing opportunities to generate functional beta cells, model the disease, and advance drug discovery. While significant progress has been made, continued research efforts aimed at overcoming challenges related to safety, functionality, and scalability are crucial in realizing the complete potential of stem cell-based diabetes therapies.

6.5 Applications of stem cells in Cardiovascular disease

Stem cell-based therapies have become a hopeful approach in cardiovascular disease, providing prospective methods for repairing injured heart tissue, enhancing heart performance, and treating different

heart disorders. An important application involves the utilization of many categories of stem cells, such as mesenchymal stem cells (MSCs), induced pluripotent stem cells (iPSCs), and cardiac stem cells (CSCs), for regenerative purposes in heart diseases. MSCs are recognized for their immunomodulatory and regenerative attributes. They have shown promise in repairing damaged heart tissue post-myocardial infarction (MI) by regulating the immune system, reducing inflammation, and stimulating tissue regeneration. (Karantalis et al., 2015; Golpanian et al., 2016). Similarly, iPSC-derived cardiomyocytes hold the potential for modelling cardiac diseases and drug testing, aiding in understanding disease mechanisms and identifying potential therapeutics. Furthermore, cardiac progenitor or stem cells isolated from the heart tissue (CSCs) have been investigated for their regenerative potential in repairing injured myocardium. The cells can develop into various kinds of cardiac cells. Moreover, it potentially regenerates damaged heart tissue. In addition to their regenerative potential, stem cells are being explored for their paracrine effects, secreting factors that promote tissue repair and angiogenesis. The secretion of growth factors, cytokines, and extracellular vesicles by stem cells contributes to the regeneration of blood vessels and heart tissue, enhancing cardiac function post-injury. Despite promising preclinical results, challenges persist in translating stem cell therapies into routine clinical practice for cardiovascular diseases. Issues such as optimal cell delivery methods, cell survival and integration within the host tissue, long-term safety, and the potential for arrhythmias require further investigation.

Conclusion

Stem cell-based therapies offer potential applications in addressing cardiovascular diseases, from repairing damaged cardiac tissue to understanding disease mechanisms and drug testing. While ongoing research continues to elucidate their mechanisms and optimize their efficacy, additional clinical trials are required to ascertain stem cell-based therapies' safety and enduring efficacy in cardiovascular medicine.

1. What are stem cell therapy's potential risks and side effects in cancer treatment?
2. What are the limitations of using stem cell replacement therapy for neurodegenerative diseases?

3. How long will stem cell therapy become a widely available and accepted treatment option for cancer and neurodegenerative diseases?