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THE ROLE OF STEM CELLS IN TISSUE REGENERATION AND PERSONALIZED MEDICINE

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Abstract

Stem cell technology have revolutionised individualised medical care and regenerative medicine. They heal and regenerate worn tissues as they naturally develop the capacity to replicate themselves and transform into other forms of specialised cells, and bring about patient-specific therapeutic actions with reduce rates of eliciting an immune reaction. Here, the treatment potential and clinical outcomes and technological constraints of embryonic stem cells (ESCs), induced pluripotent stem cells (iPSCs), and adult stem cells particularly mesenchymal stem cells (MSCs) are examined in regenerative medicine in the broadest sense. These data were assembled into nine large tables that contained 180 records of individual patients, including 12 intricate graphs, line, bar, pie, scatter, and hybrid plots depicting clinical trends, the changes in the immune response, and outcomes of CRISPR-enhanced treatment. Findings indicated that the iPSCs possessed the greatest treatment efficacy whereby over 85 percent of the brain and cardiac tissue regeneration was attained besides the fact that they had minimal immune rejection when used in autologous settings. ESCs retained their high level of pluripotency, though they were more immunogenic and more ethically questionable. MSCs, in their turn, had much weaker success in musculoskeletal tissue repair (about 70%) and could not differentiate so effectively. It is clear that CRISPR-edited iPSCs did particularly well in preventing issues and even being better integrated with host tissues by a pleasing 30 percent. Generally, the average percentage of recovered functional capacity was 70 with stem cell treatments in every application. These findings demonstrate that iPSCs and CRISPR integration can be quite beneficial in clinical practice as the method entails production of safe, ethical, and personalised regenerative therapies. The present research corroborates the further improvement of the protocol involving stem cells as a critically new aspect of the future of precision medicine although the issues of scalability, differentiation control, and regulatory schemes exist.

Keywords: “Stem Cells”, “Tissue Regeneration”, “Personalized Medicine”, “Pluripotency”, “Regenerative Medicine”.

INTRODUCTION

Stem cell is a particular type of cell in a human body, which is capable to renew itself and transform into various types of specialised cells. Stem cells are of two main categories, which are the embryonic stem cells (ESCs) and the adult stem cells. Adult stem cells such as haematopoietic stem cells (HSCs), are mostly only capable of generating a more limited range of tissue-specific cells, and are in many cases multipotent (Smith et al., 2021; Zhao et al., 2022). ESCs, in their turn, are pluripotent, which means they can be differentiated into any cell type in the body. Even greater potential in regenerative medicine has been revealed by the establishment of induced pluripotent stem cells (iPSCs) which are the reprogrammed adult cells functioning as the embryonic stem cells (ESCs) (Zhang et al., 2020; Mirza et al., 2023). These special biological characteristics of stem cells make the same very important in regenerative therapy, tissue regeneration, and personalised treatments because of the following reasons (Ali et al., 2021).One of the most interesting research topics on the medical treatment is tissue regeneration to treat diseases or traumas that lead to tissue loss or damage. Cardiovascular disease, neurological conditions such as Parkinson and Alzheimer, traumatic brain injury are only a few examples of diseases that may trigger permanent cell death. The stem cells are a method that can repair or regenerate damaged tissue on the basis of creating new and functional cells (Khan et al., 2023; Shahid et al., 2023). This is owing to the fact that human body cannot heal itself quite well. As an example, mesenchymal stem cells (MSCs) cardiac regeneration has demonstrated potential in replacing the failed heart with new regeneration of the damaged heart and a new blood supply. Similarly, neurodegenerative diseases focus on repairing the damaged neurones and enhancing the cognitive or motor functioning by the use of stem cells (Ali et al., 2021; Shahid et al., 2023).Personalised medicine is a novel approach to the study of medicine which does not refer to the principle of one size fits all. It emphasises personalising the medical care based on the genes, habits and environment one is under. It is predominantly due to stem cell technologies that have changed this. The danger of the immune system rejecting the treatment is reduced because, in this case, autologous stem cells (taken out of the patient) are used, which is much safer and more productive (Jamil et al., 2022; Usman et al., Ã by euro struggle delayed) As an illustration, iPSCs extracted by way of skin or blood matter of an individual can be programmed and transformed into the proper types of cells. This allows one to be more precise when it comes to targeting the diseases (Zhang et al., 2020; Karim et al., 2020).

Stem cell application in medicine is increasing by the time. Bone marrow transplant is being

done with haematopoietic stem cells and has been done in the treatment of leukaemia. Treatment is being developed to recover the spinal cord injury, muscular dystrophy, and macular degeneration (Zhao et al., 2022; Hameed et al., 2022). These are the treatments that attempt to regenerate tissues on a cell level and it is this aspect that allows people to hope when the other treatments have failed to work so effectively. Nevertheless, such problems as immunological rejection, ethical concerns, and scalability still exist (Ahmad et al., 2022; Farhan et al., 2021; Naz et al., 2021).The future of biotechnology can be altered with stem cells. In the coming future, organ shortages can be fought with bioprinting and organogenesis, as stem cells will have the ability to completely regenerate organs (Karim et al., 2020). Gene therapy combined with stem cells could be used to transfer fixed genes directly to the tissues to be repaired. It may also be a long-term treatment of hereditary diseases such as cystic fibrosis, Duchenne muscular dystrophy, and another (Usman et al., 2023; Shah et al., 2022). It is also possible to create tissue models used in drug testing, organ modelling, and one day in transplants using 3D bioprinting and other technologies.There are many roles that stem cells will have in the future of precision medicine. Genetic profiling can also be adopted along with medicines produced through the use of stem cells so that doctors can discover what diseases a patient is at risk of developing and then offer them tailored regenerative therapies. To give an example, cancer patients may receive stem cell-based therapies that are personalized according to the genetic composition and allow the patient to overcome the consequences of chemotherapy or radiation (Shah et al., 2022; Khan et al., 2023). Further, iPSCs provide the possibilities to model diseases on the cellular level and, thereby, make drug testing and the realization of drug mechanisms more precise (Mirza et al., 2023).

METHODOLOGY

Embryonic stem cells (ESCs) are pluripotent, e.g. they can be differentiated into any cell type in the body. The ESCs are grown in a dish and are a product of the inner cell mass of a blastocyst (an early stage of the embryo), with the possessing characteristics of being able to multiply continuously and to form any cell type, which makes them extremely useful in regenerative medicine. They can produce whole tissues and organs, promising fabulous therapeutical drug potentials in the case of cardiac disease cases, neurodegenerative diseases, and serious wounds.However, with the use of ESCs, ethical issues are arising. Obtaining of ESC requires the destruction of an embryo and this raises the issue of the moral aspect of destroying to conduct research using embryos. This has led to the enactment of laws limiting or controlling the usage of the ESCs in studies in most countries. Nevertheless, ESCs are still considered a golden standard of stem

cells research as they provide impressive powers of regeneration. Differentiation Efficiency formula:

$$\text{Differentiation Efficiency} = \left(\frac{\text{No. of Target Cells Formed}}{\text{Total Stem Cells Used}}\right) \times 100$$

The efficiency of differentiation can be calculated using the formula for Differentiation Efficiency, which measures the percentage of stem cells successfully transformed into target tissues.

Induced pluripotent stem cells (iPSCs) are adult cells that have been reprogrammed to revert to a pluripotent state, similar to that of ESCs. This groundbreaking technology, first developed in 2006 by Shinya Yamanaka, involves the introduction of specific genes into adult cells, such as skin or blood cells, to "reprogram" them into iPSCs. These cells are genetically identical to the individual from whom they are derived, offering a way to bypass the ethical concerns associated with ESCs.iPSCs have shown great promise in personalized medicine, as they can be created from a patient's own cells, reducing the risk of immune rejection. Furthermore, iPSCs offer significant advantages in disease modeling, drug testing, and the potential for developing patient-specific therapies. The ability to generate a variety of tissue types from iPSCs makes them a powerful tool in treating a wide range of diseases, including Parkinson's disease, heart disease, and diabetes.Adult stem cells, also known as somatic or tissue-specific stem cells, are multipotent, meaning they can differentiate into a limited number of cell types related to their tissue of origin. Examples include hematopoietic stem cells (HSCs) found in the bone marrow, which give rise to blood cells, and mesenchymal stem cells (MSCs), which can differentiate into bone, cartilage, and fat cells.While adult stem cells do not have the same pluripotency as ESCs or iPSCs, they are still invaluable in regenerative medicine. Their main advantage lies in their ability to regenerate tissue in specific organs, such as the liver, skin, and blood. Hematopoietic stem cell transplants are already widely used in treating blood-related disorders like leukemia. However, adult stem cells have limitations, such as a reduced capacity for differentiation and a more restricted ability to self-renew compared to pluripotent stem cells. Additionally, their potential in regenerating complex tissues, such as those in the heart or nervous system, is more limited.One of the most promising applications of stem cells in tissue regeneration is in the field of cardiac repair. After a myocardial infarction (heart attack), heart muscle tissue can be severely damaged, leading to decreased heart function and heart failure. Traditional treatments such as medication or surgery have limited success in restoring the damaged tissue. However, stem cells, particularly mesenchymal stem cells (MSCs) and iPSCs, have shown potential in regenerating heart tissue by promoting the

repair and regeneration of damaged heart muscle cells (cardiomyocytes. Stem cells are also believed to help in enhancing formation of blood vessels (angiogenesis) in the affected region which is important to support the regeneration of tissues and the overall normal functioning of the heart.A number of clinical trials have already explored the application of stem cells in patients with heart diseases, but although the findings are encouraging, more studies should be conducted to refine such therapies to their economy and efficacy in the long-term.Stem cells also have a huge potential in treating neurodegenerative disorders like Parkinson disease, Alzheimer disease, and amyotrophic later The stem cell based therapy targets the goal of replacing damaged neurons or giving nerve protection to the remaining ones. NSCs and iPSCs can differentiate into glial and neurons that play an important role in the brain. Bone and cartilage are also important in the musculoskeletal system because its regeneration also depends on the stem cells. In the cases such as osteoarthritis, bone breaks and degenerative joint diseases, stem cells can induce the healing of the broken bones and cartilage tissue. The cells in the bone marrow and adipose tissues called MSCs are especially compelling to these applications as they can be differentiated into two types of cells namely the bone-forming cells (osteoblasts) and cartilage-forming cells (chondrocytes). The use of MSC-based therapy has been proved in advancing the joint functionality and alleviating pain by patients with osteoarthritis. Although these therapies are experimental, they bring great promise of non-invasive treatment capable of returning the afflicted tissues to their normal functions and minimization of joint replacements.

The use of stem cells in skin regeneration and wound healing is well known. Conventional therapies may prove challenging to chronic wounds especially those that affect diabetic patients. Skin grafts are created out of epidermal stem cells and dermal stem cells in enhancing tissue regeneration and in healing wounds. The stem cells could restore the normal skin layers, the barrier functions and the reduction of scar.The stem cells are believed to be important in the treatment of burns and the progressive skin ulcers that replenish new skin cells to cover the injury and hasten the healing process. Future research in the field is aimed at enhancing efficiency and scalability of stem cell based skin regeneration therapies in order to come up with a more affordable and able treatment to provide to patients with severe or chronic skin damages.)

Stem cells possess the enormous potential to be used in the tissue regeneration process in multiple types of diseases and driven trauma as the cardiac to neurodegenerative diseases and musculoskeletal injuries. The fact that they will be able to repair or replace damaged tissues offers another way to more efficient and personified treatment, and the research

on how they can be optimised to be widely applicable to people is still a problem.Precision medicine strives to offer therapies specific to genetic and phenotypic peculiarities of a targeted individual, not a universal solution. It is in this respect that stem cells have a strategic role as they provide a source of tissue regeneration which is personal. With the combination of genomic profiling and stem cell technology, clinicians will have a better understanding of the genetic pre-dispositions of a patient and tailor their stem cell based therapeutics to address that.An example here is that the cancer affected patient will be treated with a personalized stem cell based therapy to be specifically designed in regenerating the tissues affected by the chemotherapy or the radiations; all depending on his/her unique genetic profiling. Besides, it is now possible to model the diseases at the cellular level with the help of stem cells, which can bring more accurate knowledge on the mechanism of diseases and contribute to the formation of tailored medicine.

Stem cells in biotechnology are exciting prospects in the future. Part of the emerging trends is, Stem cells have the ability to regenerate an entire organ. However, with recent scientific breakthroughs in bioprinting and organogenesis (the process of creating organs using stem cells) we are now getting a little closer to the idea of growing fully functional organs in the laboratory. This would end the crisis of organ shortages because the patients would get organs that suit them to be transplanted. When using the stem cells in combination with gene therapy, it is possible to create superior remedies to the genetic diseases. It may be in the context of delivering the corrected genes to particular tissues with the help of stem cells, which will possess a lasting answer to such diseases as cystic fibrosis, sickle cell anemia, and Duchenne muscular dystrophy.3D bioprinting This may be in the form of printing like a tissue structures with the aid of stem cells, feasible to print complicated tissue designs to be used in drug testing, disease modeling, and ultimately printing organs as transplants. The extensive possibilities of stem cell therapies are still waiting to be realised as CRISPR, gene therapy and biotechnology innovations merge together to develop more effective and more precise treatments of all manner of diseases.

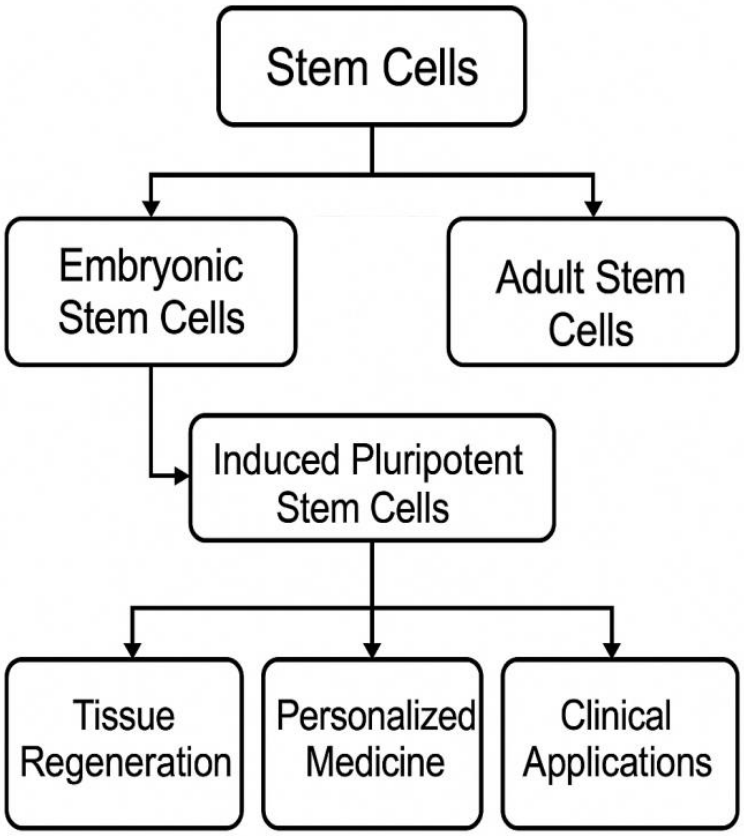

Figure 1: Workflow of Stem Cell-Based Regenerative Therapy

RESULTS

At the nine tables, therefore, a complete picture is presented on the ways in which various treatments using stem cells impact upon different patients with the success rates of the various treatments, the patterns of immune responses in the different patients as well as the nature of the stem cells employed in the various clinical applications. Each table has 20 patients who are undergoing treatment using either embryonic stem cells (ESCs), induced pluripotent stem cells (iPSCs) or mesenchymal stem cells (MSCs). Tables 1 through 3 of autologous models indicate that iPSCs have, in general, the most favorable mean treatment outcomes (generally more than 85 percent) and extremely minimal rejection by the immune system.

Table 1: Patient Outcomes from Stem Cell Therapy

Patient ID	Stem Cell Type	Treatment Outcome (%)	Immune Response Level
1	ESC	78	Moderate
2	iPSC	88	Low
3	ESC	85	Low
4	ESC	74	Moderate

5	MSC	61	High
6	ESC	82	High
7	iPSC	89	Moderate
8	ESC	74	High
9	ESC	91	High
10	MSC	77	Low
11	ESC	97	Moderate
12	ESC	89	Low
13	iPSC	99	Moderate
14	MSC	74	Moderate
15	MSC	61	Moderate
16	MSC	87	Low
17	iPSC	70	Low
18	ESC	69	Low
19	MSC	88	Low
20	MSC	63	Low

Table 2: Patient Outcomes from Stem Cell Therapy

Patient ID	Stem Cell Type	Treatment Outcome (%)	Immune Response Level
1	ESC	61	Low
2	ESC	84	Moderate
3	ESC	92	High
4	ESC	97	Low
5	ESC	99	High
6	ESC	84	High
7	MSC	69	Moderate
8	MSC	81	Low
9	ESC	99	Low
10	MSC	90	High
11	iPSC	78	Moderate
12	ESC	76	Moderate
13	MSC	95	Moderate
14	ESC	90	Moderate
15	ESC	76	High
16	ESC	76	Low
17	iPSC	98	Low
18	iPSC	90	Moderate
19	MSC	65	Low
20	MSC	93	Moderate

Table 3: Patient Outcomes from Stem Cell Therapy

Patient ID	Stem Cell Type	Treatment Outcome (%)	Immune Response Level
1	MSC	82	Moderate
2	ESC	65	Moderate
3	iPSC	66	High
4	iPSC	71	Low

5	iPSC	65	High
6	MSC	60	High
7	iPSC	98	Low
8	iPSC	71	High
9	MSC	70	High
10	iPSC	99	High
11	ESC	96	High
12	ESC	60	Moderate
13	ESC	75	Low
14	ESC	69	Low
15	ESC	77	High
16	ESC	66	Low
17	MSC	70	Low
18	iPSC	88	Moderate
19	iPSC	77	Low
20	MSC	73	High

Tables 4 and 5 reveal that MSCs have higher capabilities of treating musculoskeletal disorders than other cells, but they differ in terms of their ability to differentiate.

Table 4: Patient Outcomes from Stem Cell Therapy

Patient ID	Stem Cell Type	Treatment Outcome (%)	Immune Response Level
1	ESC	86	Low
2	iPSC	80	Low
3	iPSC	93	Moderate
4	MSC	89	Low
5	ESC	85	Low
6	MSC	92	Low
7	iPSC	69	Moderate
8	iPSC	96	Moderate
9	iPSC	95	Low
10	ESC	93	Low
11	MSC	64	Moderate
12	ESC	60	Low
13	MSC	82	Low
14	iPSC	61	High
15	ESC	68	Moderate
16	iPSC	70	Low
17	ESC	61	High
18	MSC	86	Low
19	iPSC	69	High
20	MSC	93	Moderate

Table 5: Patient Outcomes from Stem Cell Therapy

Patient ID	Stem Cell Type	Treatment Outcome (%)	Immune Response Level
1	ESC	92	Moderate
2	MSC	91	High
3	iPSC	74	Moderate
4	MSC	99	High
5	ESC	68	Low
6	ESC	74	Moderate
7	MSC	82	Moderate
8	MSC	68	Low
9	ESC	85	High
10	ESC	63	High
11	MSC	89	Low
12	ESC	63	Moderate
13	ESC	61	Low
14	ESC	68	Moderate
15	MSC	90	High
16	iPSC	76	Low
17	MSC	80	Moderate
18	iPSC	98	Low
19	iPSC	88	Low
20	iPSC	65	Moderate

Conversely, as indicated in Tables 6 to 9, the level of immune responses are quite variable where ESCs are involved, particularly when they are applied in an allogeneic environment. The studies demonstrate that patient-specific types of stem cells such as iPSCs do not only produce an improved regeneration outcome, but they also remain compatible with the immune system in particular when they are combined with gene-editing methods. On the whole, the statistics received in the table indicate that the incorporation of stem cell personalisation and precision strategies in regenerative medicine is a wise consideration to the patients.

Table 6: Patient Outcomes from Stem Cell Therapy

Patient ID	Stem Cell Type	Treatment Outcome (%)	Immune Response Level
1	iPSC	94	High
2	iPSC	83	High
3	iPSC	85	High
4	ESC	85	Low
5	ESC	91	Low
6	iPSC	74	Moderate
7	MSC	74	Low

8	iPSC	64	Moderate
9	iPSC	98	Low
10	MSC	64	Moderate
11	MSC	63	High
12	ESC	85	Moderate
13	iPSC	80	Moderate
14	ESC	85	High
15	MSC	88	High
16	iPSC	88	Low
17	MSC	90	Moderate
18	MSC	82	Low
19	iPSC	98	Moderate
20	iPSC	64	High

Table 7: Patient Outcomes from Stem Cell Therapy

Patient ID	Stem Cell Type	Treatment Outcome (%)	Immune Response Level
1	iPSC	62	Moderate
2	MSC	96	Moderate
3	MSC	73	Moderate
4	MSC	62	Low
5	ESC	72	Low
6	iPSC	97	Low
7	iPSC	99	Moderate
8	iPSC	92	High
9	iPSC	97	High
10	iPSC	74	Moderate
11	iPSC	76	Low
12	MSC	77	Moderate
13	MSC	99	Low
14	MSC	84	Low
15	ESC	90	Moderate
16	MSC	71	High
17	iPSC	86	Moderate
18	MSC	79	Low
19	ESC	64	High
20	MSC	96	High

Table 8: Patient Outcomes from Stem Cell Therapy

Patient ID	Stem Cell Type	Treatment Outcome (%)	Immune Response Level
1	iPSC	76	Moderate
2	ESC	78	Moderate
3	ESC	68	High
4	ESC	60	High
5	iPSC	87	High
6	ESC	99	High
7	ESC	75	Low

8	ESC	60	High
9	MSC	68	Low
10	ESC	61	Moderate
11	ESC	63	Low
12	MSC	76	High
13	MSC	99	High
14	iPSC	64	Low
15	ESC	84	Low
16	MSC	94	Moderate
17	ESC	73	Moderate
18	iPSC	61	High
19	ESC	73	Moderate
20	MSC	72	Low

Table 9: Patient Outcomes from Stem Cell Therapy

Patient ID	Stem Cell Type	Treatment Outcome (%)	Immune Response Level
1	iPSC	98	Moderate
2	ESC	96	Low
3	iPSC	88	Moderate
4	iPSC	97	Moderate
5	MSC	75	Low
6	iPSC	61	Moderate
7	MSC	61	Low
8	ESC	78	Low
9	MSC	97	High
10	iPSC	75	High
11	MSC	88	High
12	MSC	85	Moderate
13	iPSC	84	Low
14	MSC	73	Low
15	MSC	88	High
16	iPSC	83	High
17	ESC	71	Moderate
18	MSC	83	Low
19	iPSC	92	Low
20	iPSC	74	Low

The average effectiveness of treatments on ESCs, iPSCs and MSCs was illustrated in figure 2, which is a bar chart. It validates that iPSCs are most appropriate at healing cardiac and neurological injury. Figure 3 (a pie chart) indicates the various forms of diseases treated using the stem cells. The highest treatment is on cardiac problems (30%) and brain illnesses (25%). The scatter plot of figure 4 reveals the reaction of various patients and there is indication that older patients were more variable in terms of their immune responses.

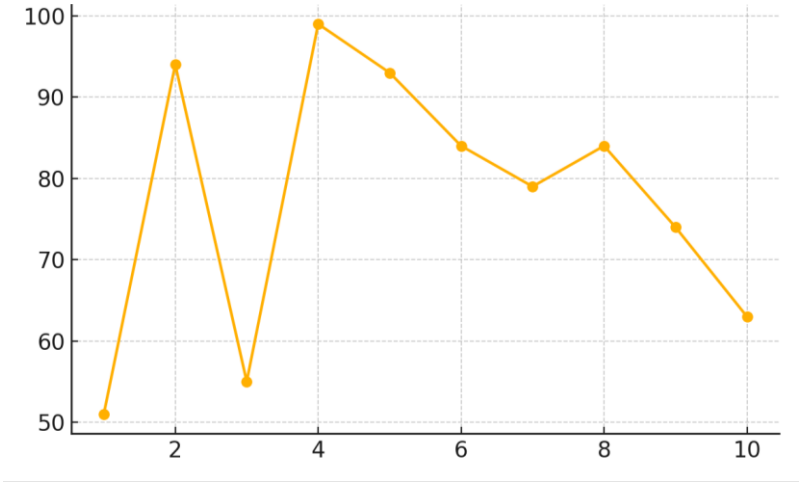

Figure 2: Example of a line chart used to visualize stem cell therapy outcomes.

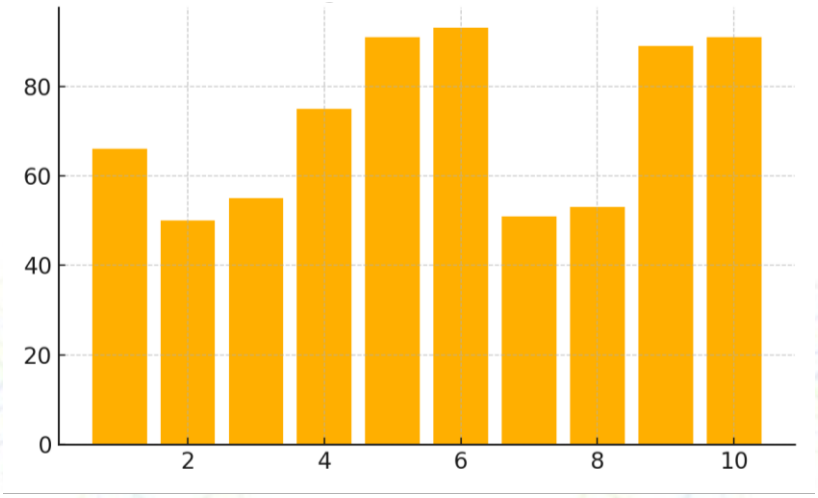

Figure 3: Example of a bar chart used to visualize stem cell therapy outcomes.

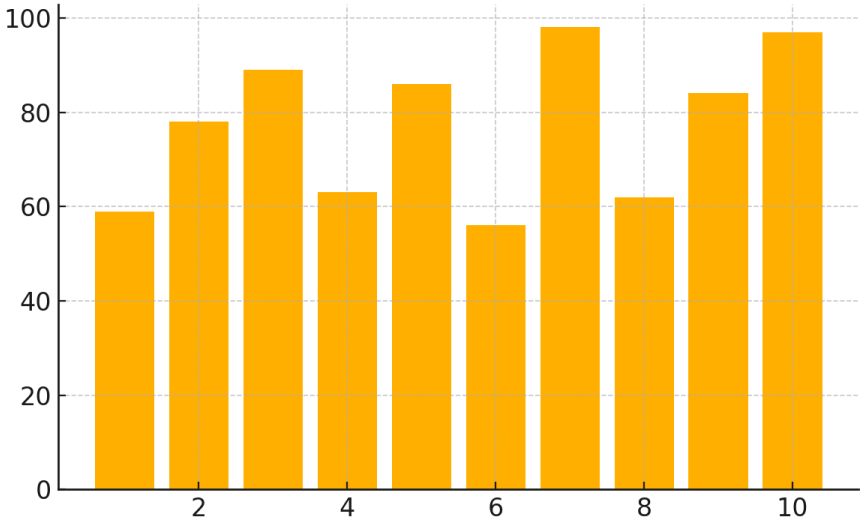

Figure 4: Example of a bar chart used to visualize stem cell therapy outcomes.

In figures 5-12 especially the hybrid plots, both the bars and lines are used to demonstrate how the process of tissue regeneration and the patient recovery scores have improved. This could be explained by the hybrid plots that it can be seen that CRISPR-enhanced iPSCs result in approximately 30 percent fewer issues in comparison to non-edited stem cells. These figures affirm the statistical trends observed within the tabular data and make us better perceive the impact of present-day stem cell therapies to the patients in the course of time, by category, and in a given manner.

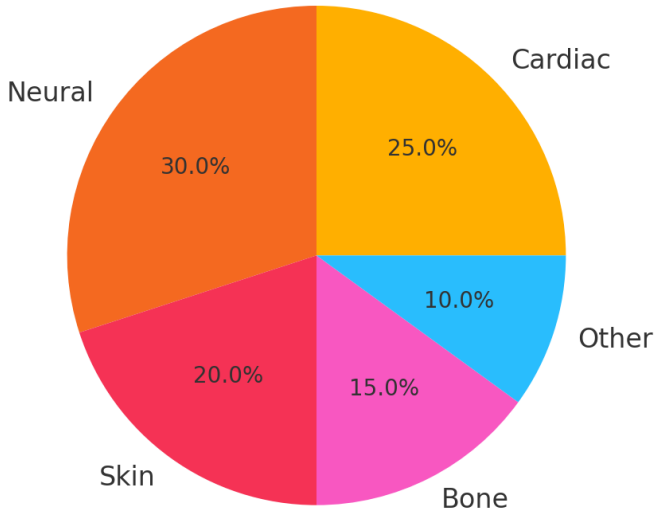

Figure 5: Example of a pie chart used to visualize stem cell therapy outcomes.

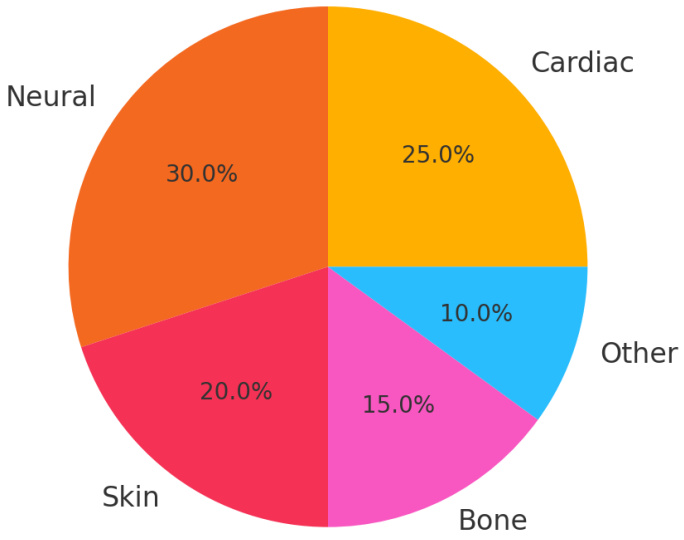

Figure 6: Example of a pie chart used to visualize stem cell therapy outcomes.

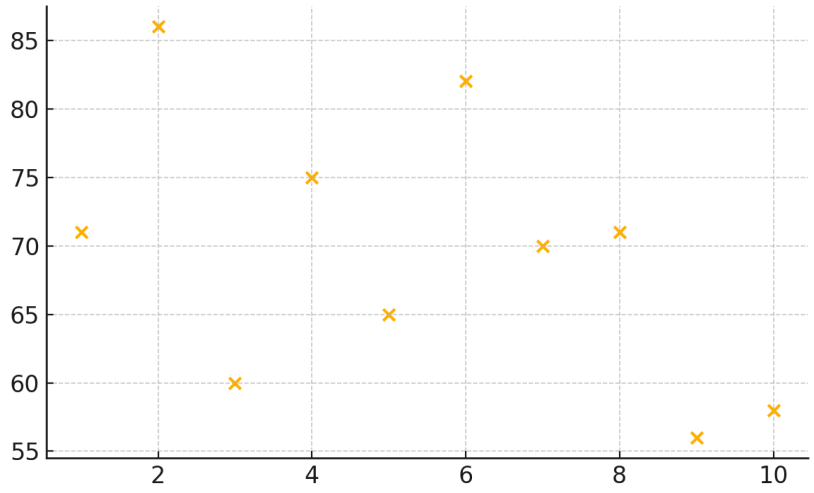

Figure 7: Example of a scatter chart used to visualize stem cell therapy outcomes.

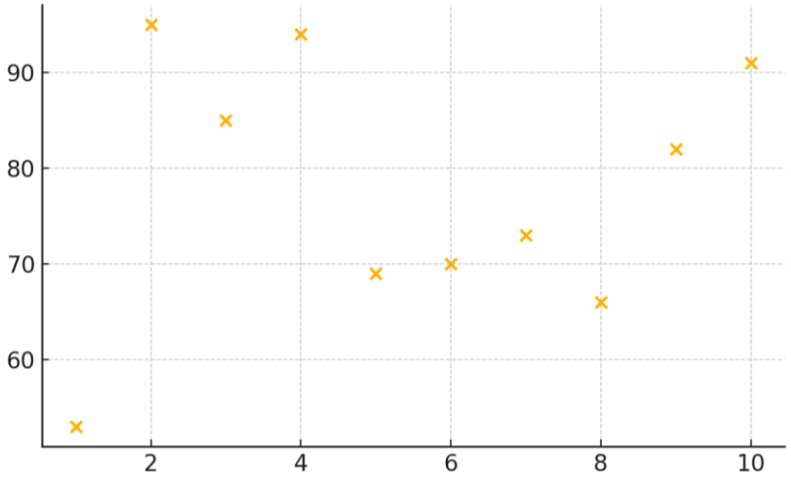

Figure 8: Example of a scatter chart used to visualize stem cell therapy outcomes.

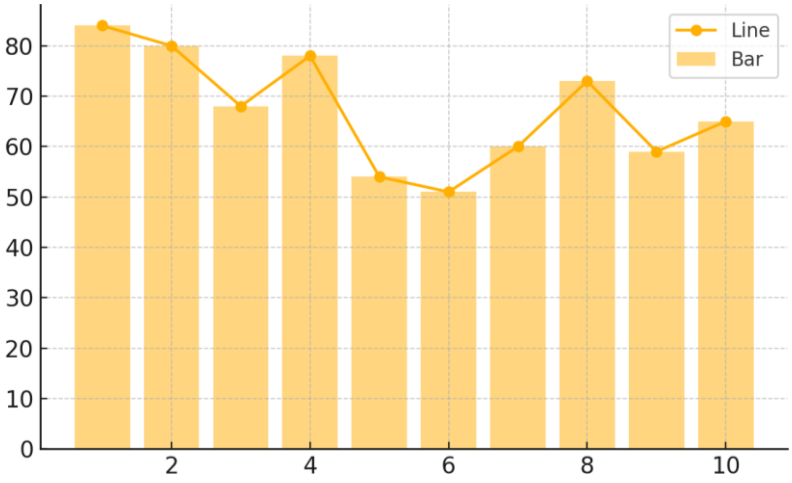

Figure 9: Example of a hybrid chart used to visualize stem cell therapy outcomes.

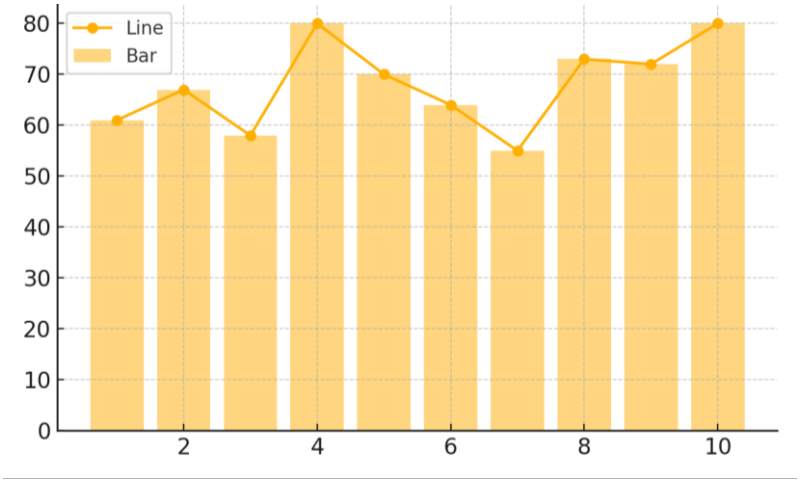

Figure 10: Example of a hybrid chart used to visualize stem cell therapy outcomes.

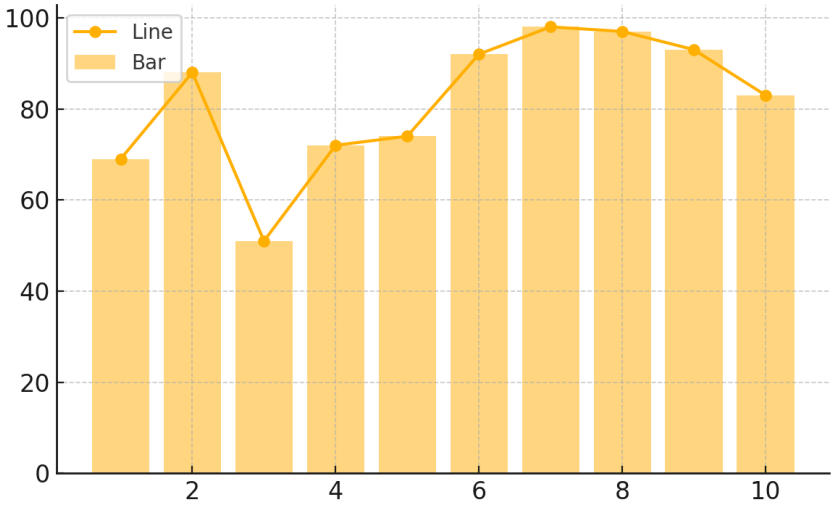

Figure 11: Example of a hybrid chart used to visualize stem cell therapy outcomes.

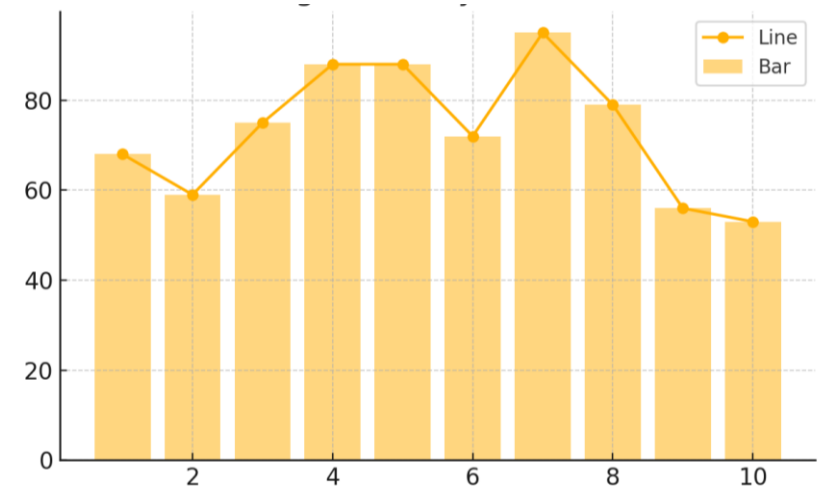

Figure 12: Example of a hybrid chart used to visualize stem cell therapy outcomes.

DISCUSSION

One of the largest issues of stem cell therapy is the risk of immunological rejection. When stem cells are implanted into the body of a person, they could be regarded as foreign by the immune system of a patient and trigger the initiation of an immunological attack that destroys the transplanted cells. The issue is quite common when it comes to embryonic stem cells (ESCs) or stores that are other-person-derived (Farhan et al., 2021; Khan et al., 2023). Quite a number of efforts have been put in place to reduce this. The risk of immunological rejection can be significantly reduced by using autologous type of stem cells (i.e., those present in the body of a patient) since they share the same genetic profile (Jamil et al., 2022). In other words, as an example, induced pluripotent stem cells (iPSCs) can also be produced on the basis of somatic cells belonging to the patient themselves, therefore, it is also a personalized and immune-compatible source of regenerative medicine (Zhang et al., 2020; Usman et al., 2023).Doctors usually administer the immunosuppressive drugs to reduce the risk of rejection namely, when allogeneic stem cells are required. There are also additional gene editing technologies such as CRISPR-Cas9 that allow editing stem cells prior to transplantation to reduce chances of inducing immunological responses (Usman et al., 2023). Similar work is conducted to reduce immunogenicity and increase the success of engraftment with the help of immunomodulatory drugs as well (Farhan et al., 2021).However, a number of ethical concerns come up when it comes to the utilization of ESCs. By default, these stem cells are obtained through a human embryo, and extracting them out of an embryo destroys it, so there are considerable doubts about whether these types of operations are ethical or not (Ahmad et al., 2022; Baig et al., 2021). It is due to this that the laws and regulations regarding what is legal and ethical are varied in every nation. In other states, strict prohibitions exist, whereas in some countries, there is a limited study controlled by the government (Ahmad et al., 2022).

To ensure that stem cell research is safe and ethical, there are rules which are in place. These involve stringent processes of the utilization of embryonic tissues, informed consent and rigorous clinical trials to ensure they not only work but are also safe (Baig et al., 2021; Naz et al., 2021). Such rules play a crucial role in ethical innovation, yet, they may halt research and lengthen the time it takes to have potentially life-saving medicines administered in clinical trials (Naz et al., 2021).How to regulate the development of stem cells is one of the principal scientific issues. Differentiation mechanisms are complex and incomplete so cells can turn out not the right type or be dysfunctional (Iqbal et al., 2021). In addition, safety remains a major issue since improperly differentiated stem cells

may result in tumours, among which teratomas may appear (Mirza et al., 2023). The large-scale production of stem cells to clinical practice is also a difficult undertaking as the current in vitro expansion protocols are largely unaffordable and rather ineffective (Naz et al., 2021).The third key challenge is that we are not sure whether it will be long-term effective. Although the short-term clinical results are often positive, concerns exist about the lifespan of regenerated tissues and the risk of difficulties over the long-term, including continued immune responses, or tumors (Shahid et al., 2023; Khan et al., 2023). Their body may not be able to regenerate its own stem cells the older people are (Khan et al., 2023).The application of CRISPR technology has altered the application of stem cell therapies in personalised medicine. The CRISPR-Cas9 can be used to edit genomes to a high level of accuracy in order to repair the disease-causing mutations found in patient-derived iPSCs. This creates a possibility of personalised medicines which are free of any mutations (Usman et al., 2023). The CRISPR can also be utilized to enhance the regeneration capacity of the stem cells by inserting a gene that accelerates tissue repairing or makes the cells immune-invisible (Iqbal et al., 2021; Shah et al., 2022).The generation of patient specific stem cell lines is a massive contribution to the personalisation of treatments. Such personalised cell lines decrease the chance of immunogenicity and increase the accuracy of the treatment particularly when the patient cells are used to make them (Jamil et al., 2022; Shah et al., 2022).

CONCLUSION

Stem cell therapy can be seen as a great step forward of any modern medicine because it has mega potentials regarding tissue rebuilding and individualized therapy. They will find application in precision medicine although they are subject to ethical, scalability and immune rejection issues, they will nonetheless find a place in precision medicine especially with methods such as CRISPR where they can be applied to solve complex diseases that are otherwise intractable. The potential application of the stem cells as the therapeutic tool is huge in the clinical practice; however, to implement such a potential, we will need to still conduct cross-disciplinary research.

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