



Review Article

Adipose-Derived Stem Cells for Regenerating Insulin-Producing Cells: An Innovative Therapeutic Strategy for Diabetes

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ABSTRACT

Diabetes mellitus is a major global health concern, affecting millions of people. Existing treatments, including as insulin injections and oral medicines, assist manage symptoms but do not replace destroyed insulin-producing β cells. In recent years, regenerative medicine has developed as a fresh method to treating the underlying causes of diabetes. Among the many types of stem cells. Adipose-derived stem cells (ADSCs) are distinguished by their ease of extraction, quantity, and capacity to differentiate into insulin-secreting cells. This page covers how ADSCs can replenish β -cells, their basic mechanisms, available preclinical and clinical data, and future difficulties and directions. Notably, certain clinical instances from China demonstrated substantial improvements, including total independence from diabetic treatment. These findings provide hope for a long-term treatment to diabetes using cellular therapy.

INTRODUCTION


Diabetes mellitus (DM) is a complex and chronic metabolic condition caused by elevated blood sugar levels. This disorder is caused by either the loss of insulin-producing β -cells or the body's inability to adequately use insulin. The two most popular forms are:

Type 1 Diabetes Mellitus (T1DM) is a chronic autoimmune condition defined by the loss of insulin-producing beta cells in the pancreas,

resulting in absolute insulin shortage and chronic hyperglycaemia. It usually appears in childhood or adolescence, but it can occur at any age. The disease is caused by a combination of genetic susceptibility and environmental triggers that stimulate immune responses against pancreatic islet cells. Current treatment involves lifelong exogenous insulin administration, which, while necessary, does not restore beta-cell activity or prevent long-term problems. This has sparked increased interest in regenerative therapies such

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adipose-derived stem cells (ADSCs), which have the ability to replace beta-cell bulk and modify immunological responses. Type 2 Diabetes Mellitus (T2DM) is a metabolic condition that is most typically found in adults, but is increasingly being identified in younger people due to lifestyle factors. It results from a combination of insulin resistance and a steady therapy to maintain sufficient blood sugar control. T2DM's progressive nature and related loss of β -cell function has prompted interest in regenerative techniques, such as adipose-derived stem cells (ADSCs), to restore insulin-producing capacity and lessen insulin reliance.

Limitations Of Current Treatment

Despite substantial breakthroughs in diabetes care, current treatments are mostly concerned with symptom control rather than disease reversal. Exogenous insulin therapy is the primary treatment for Type 1 and advanced Type 2 diabetes. However, it just regulates blood glucose and does not address the loss or malfunction of pancreatic β -cells. Furthermore, insulin therapy necessitates lifelong adherence, frequent blood glucose monitoring, and exact dose adjustments, which can be difficult and prone to human error, potentially leading to hypoglycemia episodes. Oral hypoglycemic medications for Type 2 diabetes may improve insulin sensitivity or secretion, but their efficacy decreases over time as β -cell activity declines. Furthermore, long-term usage of certain antidiabetic medicines has been linked to side effects such as weight gain, gastrointestinal issues, and cardiovascular risks. Importantly, these therapies do not provide a curative answer. They simply manage the metabolic imbalance, not restoring endogenous insulin production or slowing disease progression. As a result, many patients have decreased quality of life, ongoing problems, and a growing need on combination

medicines over time. Given these limits, there is an increasing demand for novel disease-modifying treatments, such as stem cell-based regenerative therapies, which attempt to restore the body's natural ability to manufacture insulin, perhaps leading to long-term remission or even cure.

Introduction To Regenerative Medicine And Stem Cell Therapy

Regenerative medicine is a growing area that focuses on repairing, replacing, or regenerating damaged tissues and organs using the body's own healing mechanisms. This novel strategy tries to restore normal function by either encouraging cell regeneration or introducing fresh, functional cells into damaged areas. Among the many ways investigated, stem cell therapy has received significant attention for its potential to revolutionize the treatment of chronic diseases such as diabetes mellitus. Stem cells are pluripotent cells that can self-renew and differentiate into specialized cell types, including muscle cells, brain cells, and insulin-producing pancreatic β -cells. Their adaptability makes them excellent candidates for cellular treatments, tissue engineering, and disease models. Stem cell therapy for diabetes aims to restore damaged or defective β -cells in the pancreas, restoring the body's natural ability to create and regulate insulin. Recent developments in stem cell research have resulted in the discovery of a variety of stem cell sources, including embryonic stem cells (ESCs), induced pluripotent stem cells (iPSCs), and adult-derived stem cells such as mesenchymal stem cells. Adipose-derived stem cells (ADSCs) stand out as a particularly promising source due to their abundance, ease of collection, and high differentiation potential. As regenerative medicine advances, stem cell-based therapies are being investigated not only as supportive treatments, but also as potential cures for



previously incurable illnesses such as Type 1 and advanced Type 2 diabetes. This paradigm change from symptomatic therapy to tissue regeneration represents a fundamental development in current medical science.

Significance Of the Recent Chinese Therapy

Recent advances in stem cell therapy have prompted global interest in their potential for diabetes treatment, particularly after promising early clinical results. Among these, a notable case series from China has lent support to the therapeutic potential of adipose-derived stem cells (ADSCs) in diabetes treatment. Although small in scale, this trial found positive outcomes in Type 2 diabetic patients, with ADSC transplantation related with improved glycemic control and reduced medication dependency. In one documented example, a patient attained normoglycemia after only a few months of treatment and was able to maintain stable blood glucose levels without pharmacological intervention for an extended period of time. ADSCs can positively impact β -cell regeneration and glucose metabolism, making them a viable alternative to traditional insulin therapy. This clinical observation is significant in the broader context of regenerative medicine because it demonstrates the feasibility of employing autologous, readily available adipose tissue as a cell source for therapeutic intervention. ADSCs' ability to develop into insulin-producing cells, together with their low immunogenicity, supports their use as a feasible option for cellular treatment in diabetes management. While the research is preliminary and from a limited patient population, this paper adds to the growing body of evidence supporting stem cell-based therapies. It emphasizes the significance of bigger, controlled clinical studies to test efficacy, evaluate long-term

results, and fine-tune techniques for wider implementation.

Adipose Dervied Stem Cells

Adipose-derived stem cells (ADSCs) are a specific type of mesenchymal stem cell (MSC) produced from adipose tissue. They have sparked widespread interest in regenerative medicine due to their abundance, simplicity of collecting, and strong regeneration potential. Compared to other stem cell sources such as bone marrow or embryonic tissues, ADSCs have significant practical benefits. The harvesting procedure, which is often conducted with liposuction, is minimally invasive, causes little discomfort, and produces a large amount of viable stem cells. ADSCs are multipotent and can differentiate into several cell types, such as adipocytes, osteoblasts, chondrocytes, and insulin-producing pancreatic β -like cells. This differentiation capability is crucial for diabetes therapy, as β -cell malfunction is a key factor in the development of Type 1 and severe Type 2 diabetes. ADSCs can replicate normal β -cell activity by expressing pancreatic markers and secreting insulin in response to glucose under specific laboratory circumstances. In addition to their differentiation potential, ADSCs have immunomodulatory and anti-inflammatory capabilities, predominantly through the release of bioactive compounds such cytokines and growth factors. These paracrine actions can improve the milieu of injured tissues, increase cell survival, and reduce chronic inflammation—all of which are especially useful in controlling diabetic complications. Another significant advantage of ADSCs is their low immunogenicity, which enables autologous transplantation with a lower risk of immunological rejection. This makes them ideal for clinical application because they can be produced from the patient's own body, removing ethical and compatibility concerns. Together,

these qualities make ADSCs a potent and useful tool for regenerative therapy in diabetes mellitus. Their ability to repair injured cells while also modifying the local tissue environment provides a twofold advantage, perhaps restoring insulin production and improving long-term glycemic control. Ongoing research seeks to enhance techniques for ADSC development, transport, and integration into host tissues in order to fully realize.

Mechanism Of Regeneration

The therapeutic promise of adipose-derived stem cells (ADSCs) in diabetes stems from their ability to be separated, guided through precise cellular modifications, and re-implanted to assist restore insulin production. This regenerative process is divided into multiple phases, beginning with cell extraction and ending with functional integration into the host's glucose regulating system.

- 1. Isolating ADSCs:** ADSCs are commonly collected using liposuction, a less invasive approach for removing subcutaneous fat conducted under local anesthetic. The collected adipose tissue is enzymatically broken down—usually with collagenase—to produce the stromal vascular fraction (SVF), which contains ADSCs. These stem cells are then isolated, cultivated, and expanded in a laboratory to produce adequate numbers for therapeutic use.
- 2. Promoting Differentiation into Insulin-Secreting Cells:** Following isolation, ADSCs are cultured in controlled settings designed to mimic the pancreatic niche. Researchers can induce insulin-producing β -like cells in ADSCs by exposing them to particular growth factors and signaling molecules, including activin A, exendin-4, and nicotinamide. During this step, cells start expressing

pancreatic genes and proteins such Pdx1, MafA, and Nkx6.1, which are essential for β -cell identity and function. As cells mature, they produce insulin, C-peptide, and glucose transporters, replicating the activity of natural β -cells.

- 3. Transplantation and Functional Integration:** Once developed, insulin-producing cells are transplanted into suitable organs such as the pancreas, liver (via the portal vein), or subcutaneous tissue. The goal is for the transplanted cells to integrate into the body and properly respond to blood glucose levels. Some delivery methods may use encapsulating technologies to protect cells from immunological rejection, whilst others may employ biocompatible scaffolds or hydrogels to promote cellular survival and attachment at the target region.
- 4. Restoration of Glucose Regulation:** Following transplantation, these cells are intended to monitor blood glucose levels and produce insulin as needed, restoring normal glucose balance. Experimental investigations in animal models and early human trials have shown that ADSC-derived insulin-producing cells can effectively lower blood sugar levels, enhance insulin sensitivity, and, in some circumstances, eliminate the need for exogenous insulin therapy. ADSCs' paracrine activity, which releases signaling molecules to modify immune response, boost angiogenesis, and reduce inflammation, helps preserve β -cell function and improve metabolic health.

Preclinical And Clinical Evidence

The regeneration potential of adipose-derived stem cells (ADSCs) in diabetes treatment has been extensively studied in both preclinical models and early-stage clinical trials. These investigations



have yielded promising findings regarding the differentiation potential, safety, and glucose-regulating actions of ADSC-derived insulin-producing cells. Preclinical studies in diabetic animal models show that transplanted ADSCs can develop into pancreatic β -like cells, produce insulin, and improve glycemic control. Rodent models treated with ADSC-derived insulin-producing cells demonstrated considerable blood glucose reductions, as well as enhanced glucose tolerance and insulin sensitivity. Furthermore, histological examination of these animal models frequently indicates partial regeneration of pancreatic islets and decreased inflammatory markers, implying both direct and indirect treatment effects. Building on this preclinical success, early clinical data have begun to appear. One of the most widely discussed examples is a clinical case series from China, in which a small number of Type 2 diabetes patients received autologous ADSC therapy. After one remarkable example, a patient obtained complete diabetic remission after 75 days while maintaining normal glucose levels without insulin or oral hypoglycemics. Another patient was drug-free for more than three years, demonstrating the potential long-term benefits of this method. These early human investigations similarly found that ADSC treatment was well tolerated, with no significant side effects or immunological problems. The use of autologous cells is critical in reducing rejection risk, hence enhancing the safety profile of ADSC-based therapies. Despite these promising results, many restrictions must be recognized. Most current studies use small sample sizes, lack randomized controls, and have brief follow-up periods. These considerations limit our ability to draw clear conclusions about the long-term efficacy, safety, and scalability of ADSC treatment in varied diabetic groups.

Challenges

Despite the promising potential of adipose-derived stem cells (ADSCs) in diabetes treatment, numerous significant difficulties must be overcome before this therapy may go from experimental research to conventional clinical practice. These constraints concern safety, long-term efficacy, manufacturing processes, affordability, and regulatory monitoring. Safety and Immune Concerns Although ADSCs are usually thought to be harmless, especially when produced from the patient's own tissue, questions concerning long-term implications persist. Risks such as abnormal cell differentiation, uncontrolled proliferation, and tumorigenicity have not yet been completely eliminated. While autologous transplantation decreases immunogenicity, genetic alteration or prolonged culture may result in immune reactivity or unexpected consequences. Durability of Therapeutic Effect The long-term survival and stability of insulin-producing cells generated from ADSCs is a major concern. Some studies reveal a steady drop in β -cell-like activity after transplantation. The functional durability of these cells—particularly their ability to sense glucose and release insulin consistently—is critical to the success of this restorative method. Standards and Technical Barriers. The procedure of isolating, expanding, and distinguishing ADSCs is technically challenging and frequently varies between laboratories. The lack of defined processes, cultural diversity, and quality control problems can all have an impact on outcome consistency and predictability. Furthermore, making ADSCs in accordance with Good Manufacturing Practice (GMP) standards is challenging and currently limited to specialist facilities. Economic and logistical constraints The high expense of stem cell therapies, particularly ADSC-based techniques, restricts their availability and scalability. The costs of cell processing and transplantation are high, making widespread usage in clinical settings problematic, particularly in



resource-constrained nations. As a result, cost-cutting tactics and scalable production techniques are critical to enabling wider clinical application.

Future Perspective

Adipose-derived stem cell (ADSC) therapy is emerging as a possible diabetes treatment option. Large-scale clinical trials are required to establish its safety and long-term advantages. The use of a patient's own fat tissue allows for more tailored therapy, which may improve treatment outcomes. Future developments could integrate ADSCs with technologies like as CRISPR gene editing, 3D bioprinting, and tissue scaffolds to improve cell survival and insulin secretion. If proven effective, ADSC therapy could transform diabetes care from symptom control to functional cure, providing long-term glucose regulation.

CONCLUSION

ADSCs can replenish insulin-producing β -cells and restore glycemic balance, making them a promising therapy option for diabetes. Their accessibility, ease of separation, and high differentiation potential make them an appealing alternative to traditional stem cell sources. ADSC-based therapies aim to repair lost or defective pancreatic β -cells, unlike current diabetic medications that just target symptoms. Preclinical and early clinical data demonstrate their potential for lowering insulin dependency and improving metabolic outcomes. However, problems persist, including as safety issues, regulatory constraints, and the necessity for consistent differentiation techniques. Despite these challenges, current research and developing biomedical technology could soon propel ADSCs to the forefront of regenerative diabetic care, potentially altering the paradigm from lifetime disease control to functional recovery and long-term remission.

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