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DIABETES MELLITUS: PATHOPHYSIOLOGY, DIAGNOSIS AND EMERGING THERAPEUTIC STRATEGIES

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ABSTRACT

Diabetes mellitus ranks as one of the most common diseases found in people worldwide, and the numbers of those who suffer from it have been rapidly rising in recent years. In essence, diabetes is characterized by improper regulation of blood sugar, resulting from insufficient production of insulin by the pancreas and/or lack of sensitivity of the body's cells to insulin. As a consequence, increased blood sugar levels gradually lead to damage of blood vessels and nerves and predispose patients to various complications, ranging from cardiovascular problems to issues with the function of kidneys, eyesight, and feet. The current literature review is aimed at providing a general overview of diabetes, focusing on such aspects as causes and types of this disease, its diagnosis and treatment, as well as reasons behind the need to prevent diabetes and potential ways of treating it. Considering the fact that there are more than half a billion people suffering from this condition, it is essential to be aware of all the relevant information.

KEYWORDS: Diabetes mellitus, type 1 diabetes, type 2 diabetes, insulin resistance, hyperglycemia, HbA1c.

1. INTRODUCTION

For thousands of years, diabetes has been a reality for mankind. In ancient times, between 1550 BC and the 6th century, the disease had already been identified by the Egyptians in papyrus writings as a strange disease with the symptoms of extreme thirst and excessive urination, which we know today to be classic symptoms of diabetes. It is safe to say that for most of the time before the breakthrough in 1921 by Frederick Banting et al., being diagnosed with diabetes meant almost certain death, especially those with severe diabetes. The discovery of insulin, which led to the treatment of diabetes, was revolutionary. However, even with insulin and the subsequent advancements made since then, the condition of diabetes continues to pose a significant threat. The International Diabetes Federation reports that, in 2021,

there were about 537 million adults affected by diabetes, and this figure is estimated to increase to 783 million in 2045.[1]

In addition to the human cost associated with this condition, there is a huge economic toll, as diabetes utilizes a great deal of healthcare spending around the globe.What makes diabetes particularly insidious is that it does its damage quietly. Many people live with elevated blood sugar for years without feeling unwell, during which time the disease steadily erodes the health of blood vessels and nerves. By the time complications become apparent, significant and often irreversible damage may already be done. Early detection and consistent management are therefore not just advisable — they are essential. This review aims to bring together the current understanding of diabetes in a clear and accessible way, covering what the disease is, how it works, how it is diagnosed, and what can be done about it.

2. Classification of Diabetes Mellitus

Diabetes is not a single disease but rather a family of related metabolic disorders, all sharing the common feature of elevated blood glucose but differing considerably in their underlying causes, typical age of onset, and management needs.

Fig. 1: Classification of Diabetes Mellitus.

2.1 Type 1 Diabetes Mellitus (T1DM)

Type 1 diabetes mellitus is a disease where the body's immune system turns against its own insulin-secreting pancreatic beta cells found in the islets of Langerhans. In type 1 diabetes, the outcome is the total depletion of insulin in the body. Insulin depletion implies that there will be excessive amounts of glucose circulating in the bloodstream while the body's cells will suffer from a lack of fuel supply, a scenario that can quickly turn fatal. The onset of type 1 diabetes is usually during childhood and adolescence but it may occur at any age. Patients suffering from this type of diabetes have

to take insulin throughout their lifetime because of its absolute lack in their bodies. Both genetic predisposition and environmental factors such as viral infections seem to be responsible for the onset of type 1 diabetes.[3]

2.2 Type 2 Diabetes Mellitus (T2DM)

Diabetes mellitus type 2 is far and away the most common type, comprising an estimated 90 to 95% of all cases of diabetes. While the basic problem in type 1 diabetes is lack of insulin, that in type 2 diabetes involves an insensitivity of the body to insulin's effects, termed "insulin resistance." Initially, the body responds by producing excess amounts of insulin, allowing blood glucose levels to remain near normal despite the growing resistance to the hormone's effects. Over time, the pancreatic beta cells become unable to maintain this higher rate of production and result in increasing hyperglycemia.[4]

Genetics play a significant role in the development of type 2 diabetes; hence, its prevalence within certain families. The disorder was once thought to affect primarily adults and elderly individuals. Type 2 diabetes has middle age and beyond, type 2 diabetes is now increasingly diagnosed in younger adults and even adolescents, a troubling trend closely tied to rising rates of obesity worldwide.

2.3 Gestational Diabetes Mellitus (GDM)

Gestational diabetes is a condition that arises during pregnancy among females who were never diabetic before conception. This condition arises from the fact that pregnancy results in hormonal changes, which lead to the development of insulin resistance. In certain cases, the pancreas fails to generate sufficient amounts of insulin. Although gestational diabetes subsides after childbirth, this disease has several adverse effects on both the mother and the baby before giving birth. However, the most important fact regarding gestational diabetes is that females suffering from gestational diabetes are at a high risk of contracting type 2 diabetes in the future.[5]

2.4 Other Specific Types

Beyond the three main categories, several rarer forms of diabetes exist. Maturity-Onset Diabetes of the Young (MODY) refers to a group of single-gene disorders that impair beta cell function; these conditions are sometimes misdiagnosed as type 1 or type 2 diabetes. Secondary diabetes can also arise as a consequence of other conditions such as chronic pancreatitis, Cushing's syndrome, or the use of certain medications like corticosteroids. Each of these forms requires a tailored diagnostic and management approach.[6]

Table 1: Comparative Overview of Diabetes Mellitus Types.

Feature	Type 1 DM	Type 2 DM	Gestational DM
Cause	Autoimmune beta cell destruction	Insulin resistance + beta cell exhaustion	Hormonal insulin resistance
Onset	Childhood / adolescence	Adult (increasingly younger)	During pregnancy
Insulin Production	Absent / negligible	Reduced over time	Relatively reduced
Prevalence	~5-10% of DM cases	~90-95% of DM cases	~7% of pregnancies
Primary Treatment	Insulin therapy (lifelong)	Lifestyle + oral agents + insulin	Diet, exercise, insulin if needed
Genetic Risk	HLA-DR3/DR4 variants	Polygenic + lifestyle	Prior GDM, family history

3. Pathophysiology

Understanding how diabetes develops at a cellular and molecular level is crucial not only for appreciating why symptoms occur but also for designing effective treatments. The central thread running through all forms of diabetes is inadequate insulin action whether that means insufficient insulin production, impaired insulin signaling, or both.[7]

3.1 Normal Glucose Regulation

In ideal conditions, the level of blood sugar is kept under control due to the perfect coordination between the pancreas, liver, muscles, and adipose tissues. Once someone consumes food, sugar taken up in the process moves into the blood, causing insulin secretion by the beta-cells of the pancreas. This insulin works like a key that unlocks receptors on the cell surfaces and makes the process of glucose intake possible for energy usage or storage. The liver, constantly monitoring the level of sugar in the blood, starts switching from the secretion of glucose to the formation of glycogen. Once the sugar levels drop between meals, glucagon is secreted from alpha-cells of the pancreas, causing the opposite action of the liver.[8,9]

3.2 Mechanisms in Type 1 Diabetes

For type 1 diabetes, however, all of this fails because the beta cells that produce insulin have been destroyed by the autoimmune response. It is important to remember that this autoimmune attack occurs over a period of several months or even years and only results in the development of high blood glucose levels when too many beta cells have been destroyed. Once this stage is reached, most of the beta cells will be gone by the time symptoms occur.[10,12]

Without insulin, the cells cannot absorb glucose from the blood and effectively starve, while at the same time the level of blood glucose rises to dangerous levels. With no insulin, the message to stop is not received by the liver, which creates acidic substances called ketones.This response activates T-lymphocytes (CD4+ and CD8+) that wrongly attack and destroy the insulin-producing β-cells of the pancreas. To make up for this, the body increases fat breakdown, creating ketone bodies as an alternative energy source.

When these ketones build up too much, they cause metabolic acidosis, which can develop into a serious and life-threatening condition called diabetic ketoacidosis (DKA).[12]

Clinically, Type 1 diabetes is characterized by the classic symptoms of polyuria (frequent urination), polydipsia (excessive thirst), and polyphagia (increased hunger), along with weight loss, fatigue, and blurred vision. Due to the lack of insulin, the body begins to break down fats for energy, leading to the production of ketone bodies, which can accumulate and cause a serious condition known as Diabetic ketoacidosis (DKA). If not treated promptly, DKA can be life-threatening.

Management of Type 1 diabetes requires lifelong insulin therapy, as the body is unable to produce insulin on its own. Patients must regularly monitor their blood glucose levels, follow a balanced diet, and maintain physical activity to achieve good glycemic control. Early diagnosis and proper management are essential to prevent acute complications like DKA as well as long-term complications affecting the eyes, kidneys, nerves, and cardiovascular system.

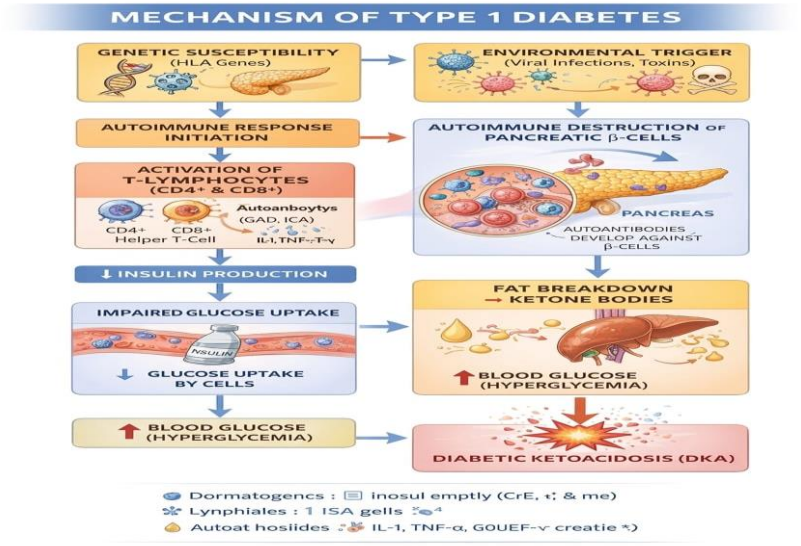

Fig. 2: Mechanisms in Type 1 Diabete

3.3 Mechanisms in Type 2 Diabetes

The development of type 2 diabetes, on the other hand, is a much slower and more intricate process. First, there is insulin resistance, which refers to a condition whereby normal levels of insulin do not elicit an adequate biological response. The development of insulin resistance is highly favored by having excessive body fat, especially fat that surrounds internal organs and produces inflammation and fatty acids that disrupt insulin action in the liver and muscles.[14]

The early stages of type 2 diabetes are characterized by overproduction of insulin by the pancreas in an attempt to keep blood glucose levels under control. This can continue for many years before eventually they can no longer produce enough insulin to overcome the underlying resistance. At this point, blood glucose rises above normal, first appearing as prediabetes and progressing to overt type 2 diabetes if nothing intervenes. Interestingly, elevated glucose itself is toxic to beta cells a phenomenon called glucotoxicity creating a vicious cycle that accelerates beta cell decline once the disease is established.[18]

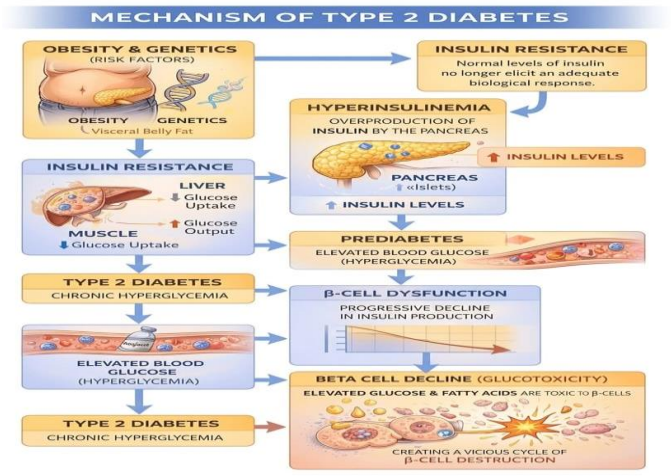

Fig. 3: Mechanisms in Type 2 Diabetes.

4. Clinical Features and Diagnosis

4.1 Symptoms

These traditional signs of diabetes mellitus – polydipsia, polyuria, weight loss, tiredness, and poor eyesight – develop due to persistent hyperglycemia. Once blood glucose rises beyond the renal capacity to absorb it, it gets secreted into the urine, causing a lot of urine production and thirst due to osmosis. In addition, cells suffering from glucose deficiency despite having plenty of glucose in the blood suffer from energy deficit, resulting in exhaustion and weight loss due to fat and muscle breakdown in type 1 diabetes. Patients with type 2 diabetes, on the other hand, exhibit mild or nonexistent symptoms initially, often failing to diagnose the disease for years.[17]

Fig. 4: Symptoms of Diabetes.

4.2 Diagnostic Criteria

1. Diagnosis of diabetes depends upon proving high levels of blood glucose concentration by any one of the recognized procedures. The American Diabetes Association/World Health Organization has defined four criteria for diagnosing diabetes, where any one of the tests that give clear results is sufficient to confirm the disease [17,18]. The criteria include:
2. FPG (fasting plasma glucose): Concentration equal to or greater than 126 mg/dL (7.0 mmol/L) after fasting for at least 8 hours.
3. 2-Hour OGTT (glucose tolerance test): Glucose concentration equal to or above 200 mg/dL (11.1 mmol/L), after loading glucose (75g).
4. HbA1c (Glycated Hemoglobin): Value greater than or equal to 6.5% (48 mmol/mol), showing the average blood glucose level in the last 2 to 3 months.
5. Random plasma glucose: Value greater than or equal to 200 mg/dL (11.1 mmol/L), in presence of characteristic hyperglycemia symptoms.

Prediabetes the intermediate state between normal glucose metabolism and overt diabetes is defined by fasting glucose between 100 and 125 mg/dL, 2-hour OGTT glucose between 140 and 199 mg/dL, or HbA1c between 5.7% and 6.4%. Prediabetes is a crucial window of opportunity; with appropriate lifestyle modification, progression to type 2 diabetes can often be delayed or even prevented entirely.[20]

Table 2: Diagnostic Thresholds for Prediabetes and Diabetes.

Test	Normal	Prediabetes	Diabetes
Fasting Plasma Glucose	< 100 mg/dL	100–125 mg/dL	≥ 126 mg/dL
2-hr OGTT Glucose	< 140 mg/dL	140–199 mg/dL	≥ 200 mg/dL
HbA1c	< 5.7%	5.7–6.4%	≥ 6.5%
Random Plasma Glucose	—	—	≥ 200 mg/dL (with symptoms)

5. Complications

Among the many reasons why one should not neglect diabetes, its negative effects on one's physical body are one of the major ones. Chronic hyperglycaemia leads to vascular and nerve damage via a variety of different mechanisms such as increased production of advanced glycation end-products, oxidative stress, and inflammation activation. The development of diabetic complications is often traditionally classified according to the type of vessels affected: microvascular and macrovascular complications.[20,21]

5.1 Microvascular Complications

Diabetic retinopathy is an eye condition involving the damage to the small blood vessels in the retina, and it remains the main cause of blindness among adults who are still in their prime years. Early signs consist of microaneurysms and small hemorrhages, while advanced cases may result in proliferative retinopathy with abnormal vessel development. Diabetic nephropathy, which involves damage to the small filtering unit structures of the kidney called glomeruli, is a major cause of end-stage renal disease. Microalbuminuria represents the earliest sign, where there will be traces of protein found in the urine, and in some patients, diabetic nephropathy will eventually progress to kidney failure requiring treatment through dialysis or transplantation. On the other hand, diabetic neuropathy, which affects the nerves, remains the most common of all complications. It often involves symptoms such as numbness, tingling sensation, and pain that usually present in both feet and hands in a stock-and-glove distribution.[22]

5.2 Macrovascular Complications

People with diabetes face a substantially elevated risk of cardiovascular disease. Atherosclerosis the buildup of plaques in artery walls tends to develop earlier, progress faster, and affect more vessels in people with diabetes than in the general population.[23] The complications associated with diabetes include myocardial infarction, stroke, and peripheral arterial disease. In peripheral arterial disease, where there is neuropathy, the feet become susceptible to ulcers because of the lack of adequate blood supply and sensitivity to feel pain. Amputation may be the last resort for these complications. Indeed, diabetes is the number one cause of non-traumatic amputations of the legs globally.[23]

6. Management and Treatment

Managing diabetes is a lifelong endeavor that requires coordinating multiple interventions: lifestyle changes, medications, regular monitoring, and preventive care for complications. The overarching goal is to keep blood glucose as close to the normal range as safely possible, while also managing other risk factors like blood pressure and cholesterol that compound cardiovascular risk.[28]

6.1 Lifestyle Modification

In case of both types of diabetes, especially for those patients who are prone to develop type 2 diabetes, it is crucial to modify their lifestyle habits. In particular, one should pay attention to following a proper healthy diet, which includes eating plenty of vegetables, unprocessed cereals, proteins, as well as good fats. Moreover, patients should avoid eating

any foods high in refined carbohydrates and sugars, as well as drinking sodas and similar beverages. Furthermore, it is crucial to be physically active on a regular basis. To be more specific, patients need to practice aerobic exercise at moderate intensity, which equals 150 minutes a week, and perform strength exercises. In addition, losing some excess weight, if one has a problem with it, will result in improvement in glucose control.[28]

6.2 Pharmacological Treatment

If lifestyle interventions do not help to meet glycemic goals, then drugs should be considered. Pharmacotherapy of diabetes treatment has greatly changed in the last two decades, and today there are many more choices than before.

Metformin is usually prescribed as the first line agent in case of type 2 diabetes according to various guidelines. This drug reduces the amount of glucose produced by the liver and increases insulin sensitivity in the periphery. Metformin is effective, relatively inexpensive, neither causes weight gain nor loss, and has a proven good safety profile. Sulfonylurea drugs cause insulin release from beta cells, and their use has a history of several decades; however, sulfonylureas have a high risk of hypoglycemia and some weight gain.More recent drug classes have transformed diabetes management.

SGLT2 inhibitors (such as empagliflozin and dapagliflozin) work by causing the kidneys to excrete excess glucose in the urine; beyond glucose control, These medications have shown impressive cardiovascular and renal protective effects.

GLP-1 receptor agonists, including semaglutide and liraglutide, are drugs that imitate a hormone produced in the gastrointestinal tract, which regulates insulin release, glucagon release inhibition, slows digestion, and decreases hunger; apart from lowering blood glucose, these agents lead to considerable weight loss and a reduction in heart disease risk factors.[27]

DPP-4 inhibitors such as sitagliptin are more conservative medications for glucose management that do not affect body mass index. Insulin continues to be essential for type 1 and late-stage type 2 diabetes patients, with contemporary formulations providing better flexibility and physiologic administration compared to previous ones. In type 2 diabetes mellitus, the pharmacotherapy regimen involves the use of oral hypoglycemics in conjunction with a change in lifestyle. The drug that is often recommended is Metformin, which reduces liver glucose synthesis and increases insulin sensitivity. However, in case the required results are not obtained, other drugs are introduced, including sulfonylureas like Glibenclamide.

Table 3: Key Pharmacological Agents in Diabetes Management.

Drug Class	Mechanism	Key Benefits	Main Risks
Metformin	Reduces hepatic glucose output	Proven, inexpensive, weight neutral	GI side effects, rare lactic acidosis
Sulfonylureas	Stimulates insulin secretion	Effective, low cost	Hypoglycemia, weight gain
SGLT2 Inhibitors	Urinary glucose excretion	CV & kidney protection	UTI, DKA (rare)
GLP-1 Receptor Agonists	Mimics incretin hormone	Weight loss, CV benefit	Nausea, pancreatitis (rare)
DPP-4 Inhibitors	Enhances incretin action	Weight neutral, low hypoglycemia	Modest efficacy
Insulin	Direct glucose regulation	Universal applicability	Hypoglycemia, weight gain

6.3 Monitoring and Targets

Continuous monitoring of blood glucose plays a key role in the management of diabetes mellitus. Conventional self-testing through finger pricks is still common practice; however, newer technology such as CGM (Continuous Glucose Monitoring), involving a sensor that detects glucose concentration by being embedded just under the skin and providing data on the go, is more readily available today and has significantly improved diabetes treatment in type 1 diabetes mellitus.[28]

Hemoglobin A1c (HbA1c) measurements are usually performed once in three to six months. In general, the optimal level of HbA1c in the blood for adult patients is less than 7.0%.[29] However, an individualized approach should be taken depending on the patient's clinical condition, risk factors, and personal preference.

7. Prevention and Public Health Considerations

Although there is no current method of preventing type 1 diabetes, things are markedly different when it comes to preventing type 2 diabetes and gestational diabetes, which have been proven via clinical studies to be highly preventable. The results of the groundbreaking Diabetes Prevention Program (DPP) study showed that intense lifestyle modifications such as losing 7% of one's body mass and engaging in at least 150 minutes of exercise per week were able to decrease the chances of developing type 2 diabetes by 58%, far outpacing the performance of metformin.

On the other hand, implementing an effective diabetes prevention program on a wider scale will require not only treating individuals but tackling the root causes of obesity and physical inactivity within society itself, such as the availability of healthy food choices, accessible areas to engage in physical activities, and appropriate health education. Moreover, healthcare systems should be more diligent in determining those who have already contracted diabetes.

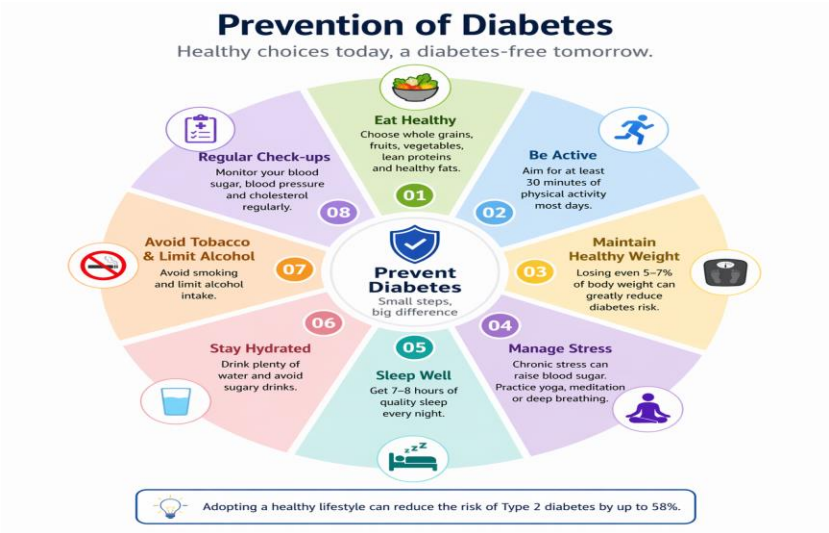

Fig. 5: Prevention of Diabetes.

8. Emerging Research and Future Directions

The diabetes research field is really exciting now. There are areas that show a lot of promise for improving the lives of people with diabetes in the coming years. Closed-loop insulin delivery systems, also known as the "pancreas" are being developed. These systems use glucose monitors and automated insulin pumps to adjust insulin delivery in real time based on glucose readings. Diabetes patients are already seeing improvements in glucose control and quality of life

especially those with type 1 diabetes. These systems are getting better and better In type 1 diabetes research scientists are looking into therapies that can slow down or stop the autoimmune destruction of beta cells. Teplizumab, a -CD3 monoclonal antibody got FDA approval in 2022 for delaying the onset of clinical type 1 diabetes in high-risk individuals [29]. This is the disease-modifying therapy approved for this use. Another area of research is cell replacement through pancreatic islet transplantation, which could potentially offer a functional cure for some patients.

* GLP-1 receptor agonists are getting a lot of attention. New and more potent molecules are being developed, including triple agonists that target multiple hormonal pathways at the same time. These new agents seem to offer greater weight loss and metabolic improvements than current GLP-1 drugs for diabetes [30]. The diabetes research landscape is rapidly evolving. Several areas hold promise for improving the lives of people with diabetes in the coming years.

The development of closed-loop insulin delivery systems also known as the " pancreas " is underway. These systems pair glucose monitors with automated insulin pumps. They adjust insulin delivery in time based on glucose readings. People with diabetes are already seeing improvements in glucose control. Quality of life improvements are also being seen, in type 1 diabetes. These systems are becoming increasingly sophisticated.

In type 1 diabetes researchers are actively investigating therapies. The goal is to slow or halt the destruction of beta cells. Teplizumab, a -CD3 monoclonal antibody received FDA approval. The approval was for delaying the onset of type 1 diabetes. High-risk individuals are the target for this treatment. This is the disease-modifying therapy approved. It targets type 1diabetes. Beta cell replacement through transplantation of islets is another area. This includes transplanting islets from stem cell-derived sources. It could potentially offer a cure. Some patients may benefit from this treatment.

The interest, in GLP-1 receptor agonists is growing rapidly. New and more potent molecules are being developed.

These include triple agonists. They target hormonal pathways simultaneously. These new agents appear to offer weight loss. They also offer metabolic improvements. Current GLP-1 drugs are being compared to these agents. Diabetes patients may benefit from these advancements. People are starting to use a way to treat diabetes. This way is called precision medicine. It uses a lot of information about the patient like their genes and what is going on with their body to figure out the treatment for them.

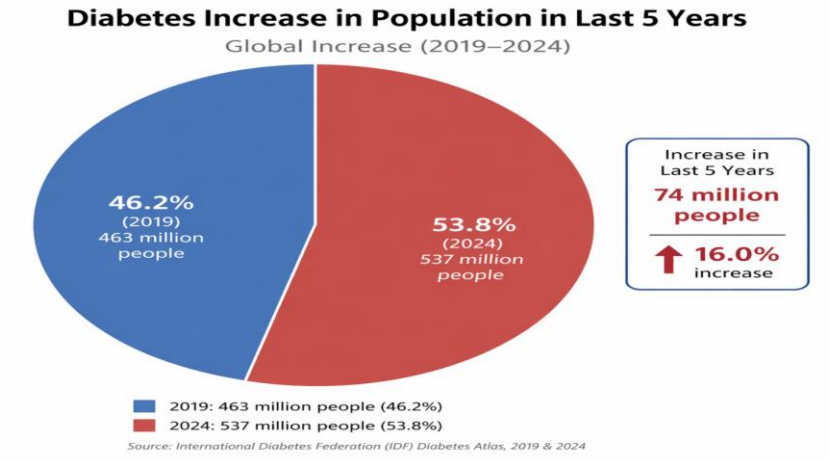

Fig. 6: Global Increase.

CONCLUSION

Diabetes mellitus is a serious disease that has affected human health for thousands of years and continues to do so today on a large scale. To truly understand diabetes mellitus, you need to consider everything from its causes to the problems it can cause, as well as how it is diagnosed and treated. Doctors, researchers, policymakers, and patients with diabetes all need to grasp this disease. In the past hundred years, we have made significant progress with diabetes mellitus. We discovered insulin, developed machines that can check glucose levels continuously, and created medicines that can help protect the heart and kidneys. Despite these advancements, the rising number of people with diabetes means we must keep working to find new solutions.

The real effort should be put into prevention of acquiring type 2 diabetes mellitus through identification of factors causing it, early identification of at-risk patients, and effective treatment in case of diagnosis of diabetes mellitus.

Currently, scientists are actively searching for innovative treatment strategies for patients with diabetes mellitus. Their efforts are concentrated on slowing the course of type 1 diabetes mellitus, developing more natural approaches to regulation of blood sugar and personalized treatment strategies for patients with diabetes mellitus.

Only the joint efforts of hospitals, scientists and members of society will allow achieving considerable success with diabetes mellitus. However, significant results that were achieved by today give us all reasons to hope for further improvement in the treatment of diabetes mellitus. This complication occurs predominantly among individuals with Type 1 diabetes or undiagnosed T1D. The condition develops due to insufficient production of insulin. If there is no sufficient amount of insulin, the body starts using fat deposits to produce energy. Fat breakdown results in the release of ketone bodies, which turn the blood acidic, making patients breathe heavily, vomit and lose consciousness. DKA requires immediate medical treatment.Hypoglycemia happens when your blood sugar level drops below the range that’s healthy for you. Severe hypoglycemia is very low blood sugar. It mainly affects people with diabetes who use insulin.

Signs include blurred or double vision, clumsiness, disorientation and seizures. It requires treatment.

- Around 9.5 million people worldwide are living with Type 1 diabetes
- About 1.8–2 million are children/adolescents
- New cases per year: ~5 lakh (513,000)
- Prevalence has been rising more rapidly in low- and middle-income countries than in high-income countries.
- More than half of people living with diabetes did not take medication for their diabetes in 2026. Diabetes treatment coverage was lowest in low- and middle-income countries.
- Diabetes causes blindness, kidney failure, heart attacks, stroke and lower limb amputation.[22,23]
- In 2025, diabetes and kidney disease due to diabetes caused over 2 million deaths.[1] In addition, around 11% of cardiovascular deaths were caused by high blood glucose.
- A healthy diet, regular physical activity, maintaining a normal body weight and avoiding tobacco use are ways to prevent or delay the onset of type 2 diabetes.[5,19]
- Diabetes can be treated and its consequences avoided or delayed with diet, physical activity, medication and regular screening and treatment for complications.
- Tobacco use are ways to prevent or delay the onset of type 2 diabetes.
- Diabetes can be treated and its consequences avoided or delayed with diet, physical activity, medication and regular screening and treatment for complications.

Diabetes is a chronic disease that occurs either when the pancreas does not produce enough insulin or when the body cannot effectively use the insulin it produces. Insulin is a hormone that regulates blood glucose. Hyperglycaemia, also called raised blood glucose or raised blood sugar, is a common effect of uncontrolled diabetes and over time leads to serious damage to many of the body's systems, especially the nerves and blood vessels.

Diabetes continues to rise as a major global health problem, with approximately 589 million adults living with the disease worldwide as of 2025–2026, representing about 11% of the global adult population. A significant proportion of individuals remain undiagnosed, especially in low- and middle-income countries where nearly 80% of cases occur.

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