INTERNATIONAL JOURNAL OF PHARMACEUTICAL SCIENCES
[ISSN: 0975-4725; CODEN(USA): IJPS00]
Journal Homepage: https://www.ijpsjournal.com

OPEN ACCESS

Case Study Article

HBA1C Study in Diabetic Patients

Sakshi Manekar*, Shubham Tikait, Dr. Swati Deshmukh

Shraddha Institute of Pharmacy, Kondala Zambre Washim, Maharashtra India- 444505.

ARTICLE INFO

Published: 16 May 2025
Keywords:
HbA1c; Glycated hemoglobin; Type 2 diabetes mellitus; Type 1 diabetes mellitus; Glycaemic control; Blood glucose levels; Diabetic complications; Insulin resistance; Hypoglycemia
DOI:
10.5281/zenodo.15437842

ABSTRACT

This study evaluates the role of Hemoglobin A1c (HbA1c) as a glycemic control marker in a diverse cohort of 60 diabetic patients. The sample includes individuals with multiple risk profiles and complications, specifically: obese patients, pregnant women, cardiac patients, and individuals with comorbidities such as retinopathy, nephropathy, neuropathy, and glaucoma. Data were collected through clinical assessments, patient histories, and laboratory investigations. The primary objective was to correlate HbA1c levels with the severity and presence of these complications to assess its reliability as a predictive biomarker. Preliminary analysis shows elevated HbA1c levels were significantly associated with microvascular complications like retinopathy, nephropathy, and neuropathy, as well as with the presence of comorbid conditions. The study underscores the utility of HbA1c not only for routine monitoring but also for risk stratification in diabetic patients with complex clinical backgrounds. Tailored glycemic targets may be necessary for special populations, such as pregnant women and those with cardiac disease or glaucoma.

INTRODUCTION

Haemoglobin A1c (HbA1c) is a form of haemoglobin, the protein in red blood cells that carries oxygen, that is chemically attached to glucose (a type of sugar). It reflects the average level of blood sugar (glucose) over the past 23 months, since red blood cells live for about 120 days. HbA1c levels are expressed as a percentage, representing the proportion of haemoglobin molecules in the blood that have glucose attached to them. [38,40]

***Corresponding Author:** Sakshi Manekar
Address: *Shraddha Institute of Pharmacy, Kondala Zambre Washim, Maharashtra India- 444505.*
Email ✉: manekarsakshi@gmail.com
Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

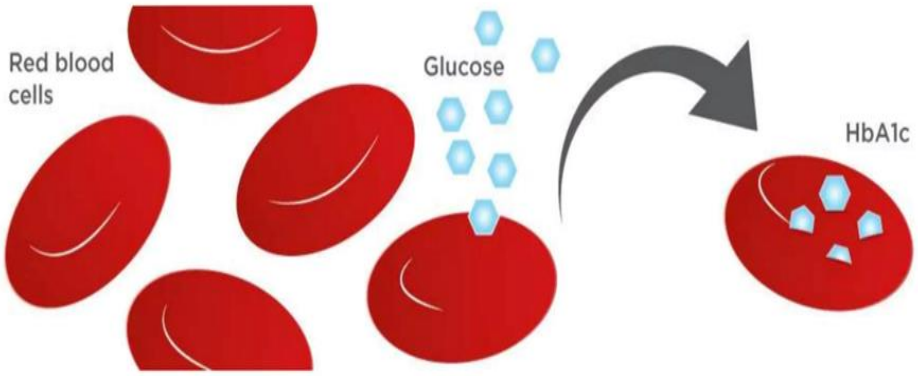

Figure.1. Haemoglobin

HbA1c as a biomarker

A biomarker is a biological substance that can be measured to indicate the presence or severity of a disease or the effect of a treatment. Haemoglobin A1c (HbA1c) is considered a biomarker for long-term blood glucose control, reflecting the average blood sugar levels over a period of approximately 23 months. As a biomarker, HbA1c is an important indicator of how well glucose is being managed in the body and it provides insight into both diabetes management and the risk of complications associated with chronic high blood glucose. [38,41]

Role of HbA1c in Diabetes Management

1. Reflects Long Term Blood Sugar Control
2. Diagnosis and Monitoring
3. Setting Treatment Goals
4. Risk Assessment for Complications
5. Evaluating Treatment Effectiveness
6. A Guide for Adjusting Lifestyle and Medications. [39]

Pathophysiology of diabetes

Diabetes mellitus is a group of metabolic disorders characterized by chronic high blood glucose (hyperglycemia). This occurs due to either insufficient insulin production or insulin resistance ora combination of both. Insulin is a hormone produced by the pancreas that helps cells absorb glucose from the bloodstream for energy or storage. [51,53,54]

How Type 1 and Type 2 diabetes affect blood glucose levels and HbA1c

Type 1 Diabetes (T1D)

Blood Glucose Levels in Type 1 diabetes, there is an absolute deficiency of insulin due to the autoimmune destruction of beta cells in the pancreas. Without insulin, glucose cannot enter cells, leading to persistent high blood glucose levels (hyperglycaemia). HbA1c Since insulin is not available to regulate blood sugar over time, HbA1c levels tend to Be higher in individuals with Type 1 diabetes if not properly managed. Over time, chronically elevated blood glucose levels result in an increase in the percentage of glucose bound hemoglobin, leading to higher HbA1c readings. Good insulin management can help bring HbA1c levels back within the target range.

Type 2 Diabetes (T2D)

Blood Glucose Levels in Type 2 diabetes, insulin resistance (where cells do not respond Properly to insulin) is the primary issue. The body tries to compensate by producing more Insulin, but eventually, beta cells in the pancreas fail to keep up. As a result, glucose cannot Enter the cells efficiently, leading to elevated blood glucose levels.

Complications of Untreated Diabetes

The complications associated with poorly controlled diabetes are devastating. These include

- cardiovascular diseases (heart attacks, strokes)
- Kidney damage (leading to kidney failure and dialysis)
- Nerve damage (neuropathy, often leading to amputations)
- Vision problems (diabetic retinopathy, potentially leading to blindness)
- Poor wound healing and higher risk of infections

Literature Review

Relationship between HbA1c and Diabetic Complications

Numerous studies have highlighted the strong association between HbA1c levels and the risk of diabetes related complications, such as retinopathy, nephropathy, neuropathy and cardiovascular diseases. The Diabetes Control and Complications Trial (DCCT) and the UKPDS study have shown that a reduction in HbA1c levels is linked to a lower risk of microvascular complications in type 1 and type 2 diabetes, respectively (DCCT Research Group, 1993; UKPDS, 1998). Furthermore, the Action to Control Cardiovascular Risk in Diabetes (ACCORD) study found a higher risk of mortality in individuals who lowered their HbA1c levels too aggressively, suggesting that the relationship between HbA1c and macrovascular events is more complex (ACCORD Study Group, 2010). Sherwani SI, Khan HA, Ekhzaimy A, Masood A, Sakharkar MK. Significance of HbA1c test In diagnosis and prognosis of diabetic patients. Biomarker Insights . 2016,11)95 104. This review highlights the role of HbA1c in Diagnosis and prognosis of diabetes patients. Diabetes Control and Complications Trial Research Group. The effect of intensive treatment of diabetes on the development and progression of long term complications in Insulin dependent diabetes mellitus. N Engl J Med. 1993;329(14)977986. HbA1C Variability Among Type 2 Diabetic Patients A Retrospective Cohort Study . This study is done by the authors D. Akselrod, M. Friger, A. Biderman in year 2021 .This study investigated the variability of HbA1c levels in type 2 diabetic patients and its association with demographic and clinical factors. The findings suggest that understanding HbA1c variability can aid in better management of diabetes. Clinical Study on Association of Diabetic Retinopathy Severity with HbA1c Level .This study is done by this authors Pankaj Kumar Sharma, Kavita Kumar, Aditi Dubey, Nitin Kushwaha, Pooja Maravi in year 2024 A significant correlation was found between higher HbA1c levels and increased severity of diabetic retinopathy. Patients with poorer glycemic control exhibited more severe grades of retinopathy, highlighting the importance of maintaining optimal blood sugar levels to prevent ocular complications. HbA1c is a Risk Factor for Cardiovascular Disease in Association with Oxidative Stress in patients with Type 2 Diabetes Mellitus. This study is done by this authors Siva Prasad Palem in year 2017. The study identified a positive association between elevated HbA1c levels and oxidative stress markers in type 2 diabetic patients. This suggests that higher HbA1c levels may contribute toan increased risk of cardiovascular events through mechanisms involving oxidative stress. The Role of Hemoglobin A1c as a Predictor of Major Adverse Cardiovascular Events in patients with Type 2 Diabetes Mellitus After Percutaneous Coronary Intervention A-Case Cohort Study.This study was conducted by this authors Babak Bagheri et.al in year 2024-25. This study evaluated the predictive value of HbA1c levels for major adverse

cardiovascular events (MACE) in type 2 diabetic patients post percutaneous coronary intervention. The findings suggest that HbA1c can serve as a significant predictor for MACE in this patient population. HbA1c Marker for Long Term Glycemic Control. Authors: Puri A, Kohli J, Chrunjoo VJ .This review highlights the clinical importance of HbA1c (glycated hemoglobin) as a biomarker for long-term glycemic control in diabetic patients. HbA1c reflects the average blood glucose levels over the previous 23 months, making it a valuable tool for monitoring .The effectiveness of diabetes management strategies. Effect of early glycemic control on HbA1c tracking and development of vascular complications after 5 years of childhood onset type 1 diabetes: systematic review and Meta analysis. Authors: Paes VM, Barrett JK, Taylor Robinson DC, et al.

HBA1C As A Diagnostic And Monitoring Tool

Diagnostic potentials of HbA1c

HbA1c is used to diagnose diabetes and prediabetes because it reflects the average blood glucose levels over a prolonged period, rather than a snapshot of a single moment in time. Normal HbA1c: Below 5.7%. Indicates normal blood glucose levels and no diabetes. Prediabetes Between: 5.7% and 6.4%. Suggests that blood sugar levels are higher than normal but not high enough to be classified. As diabetes. It's a warning sign of potential future diabetes if lifestyle changes aren't made. Diabetes 6.4% or higher. A result of 6.4% or more on two separate occasions typically confirms the diagnosis of diabetes.

Monitoring potentials of HbA1c

Once diabetes is diagnosed, HbA1c becomes an essential tool for monitoring how well a Person's blood sugar is being controlled over time. Goal for most people with diabetes: An HbA1c target of below 7% is generally Recommended, although individual goals may vary depending on factors such as age, Comorbid conditions and risk of complications. Higher HbA1c: If HbA1c levels are consistently higher than the target, it suggests that blood. Glucose is not well controlled and changes in medication, diet orexercise may be necessary. Lower HbA1c: If HbA1c is too low, this could indicate the risk of hypoglycemia (low blood

Sugar), so adjustments to treatment might be needed.

6. Study Of Hba1c in Diabetic Paints

patients	Gender	Age	Weight (kg)	Height(ft/in)	HbA1c (%)	Remarks
Pt.1	Female	29	50	5.3	6.0	Pre diabetic
Pt.2	Male	35	65	5.5	6.7	Diabetic
Pt.3	Male	42	68	5	6.8	Diabetic
Pt.4	Female	19	43	5	7.7	Diabetic
Pt.5	Female	23	42	5.1	5.8	Pre diabetic
Pt.6	Female	60	58	6.2	9.8	Diabetic
Pt.7	Male	54	60	5.8	10.4	Diabetic
Pt.8	Male	35	58	4.9	6.9	Diabetic
Pt.9	Male	59	55	5.1	8.3	Diabetic
Pt.10	Male	10	22	4.5	8.2	Diabetic
Pt.11	Male	12	28	4.8	7.0	Diabetic
Pt.12	Male	28	45	5.2	9.3	Diabetic
Pt.13	Female	55	70	6	11.7	Diabetic
Pt.14	Female	27	43	5.3	5.9	Pre diabetic
Pt.15	Female	35	54	5.8	8.8	Diabetic

Pt.16	Female	75	68	5.5	7.2	Diabetic
Pt.17	Female	68	45	6.2	10.0	Diabetic
Pt.18	Male	5	15	3.5	6.8	Diabetic
Pt.19	Male	15	29	4.8	6.8	Diabetic
Pt.20	Female	4	17	2.8	12.0	Diabetic
Pt.21	Male	64	75	5.2	6.0	Pre diabetic
Pt.22	Male	59	66	5.8	13.4	Diabetic
Pt.23	Female	25	60	5.5	10.2	Diabetic
Pt.24	Male	22	40	6.2	10.4	Diabetic
Pt.25	Female	28	55	6.6	9.5	Diabetic
Pt.26	Male	35	70	5.8	13.5	Diabetic
Pt.27	Male	50	62	6.2	6.4	Diabetic
Pt.28	Male	69	82	6.6	12.9	Diabetic
Pt.29	Male	11	25	4.5	6.9	Diabetic
Pt.30	Female	9	20	5	10.1	Diabetic
Pt.31	Female	53	59	6.2	10.1	Diabetic
Pt.32	Female	75	50	5.8	11.4	Diabetic
Pt.33	Female	38	65	5.2	7.9	Diabetic
Pt.34	Male	22	50	5.1	6.4	Diabetic
Pt.35	Female	23	45	5	5.8	Pre diabetic
Pt.36	Male	39	59	5	15.0	Diabetic
Pt.37	Female	63	52	6	6.8	Diabetic
Pt.38	Male	60	72	5.2	8.4	Diabetic
Pt.39	Female	44	60	4.8	7.3	Diabetic
Pt.40	Female	40	69	4	7.9	Diabetic
Pt.41	Male	45	85	5.10	6.2	Pre diabetic
Pt.42	Female	52	74	5.3	7.8	Diabetic
Pt.43	Male	36	90	5.10	12.5	Diabetic
Pt.44	Female	60	68	5.2	8.9	Diabetic
Pt.45	Male	29	95	6.0	6.5	Pre diabetic
Pt.46	Female	41	70	5.5	12.8	Diabetic
Pt.47	Male	55	100	5.8	9.2	Diabetic
Pt.48	Female	48	77	5.3	7.1	Diabetic
Pt.49	Male	34	88	5.7	6.0	Pre diabetic
Pt.50	Female	39	64	5.1	11.3	Diabetic
Pt.51	Male	45	85	5.1	6.2	Pre diabetic
Pt.52	Female	52	74	5.4	7.8	Diabetic
Pt.53	Male	29	95	6.0	6.5	Pre diabetic
Pt.54	Male	55	100	5.9	9.2	Diabetic
Pt.55	Female	48	77	5.3	7.1	Diabetic
Pt.56	Male	62	92	5.8	6.3	Pre diabetic
Pt.57	Female	60	68	5.2	8.9	Diabetic
Pt.58	Male	39	89	5.1	6.4	Pre diabetic
Pt.59	Female	50	80	5.5	7.5	Diabetic
Pt.60	Male	47	94	5.1	6.1	Pre diabetic

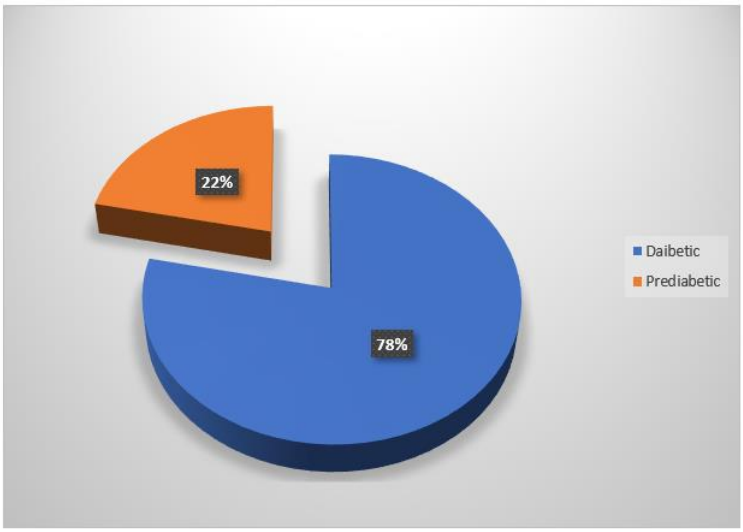

Fig .2. Graphical Representation of Total Diabetic Patients

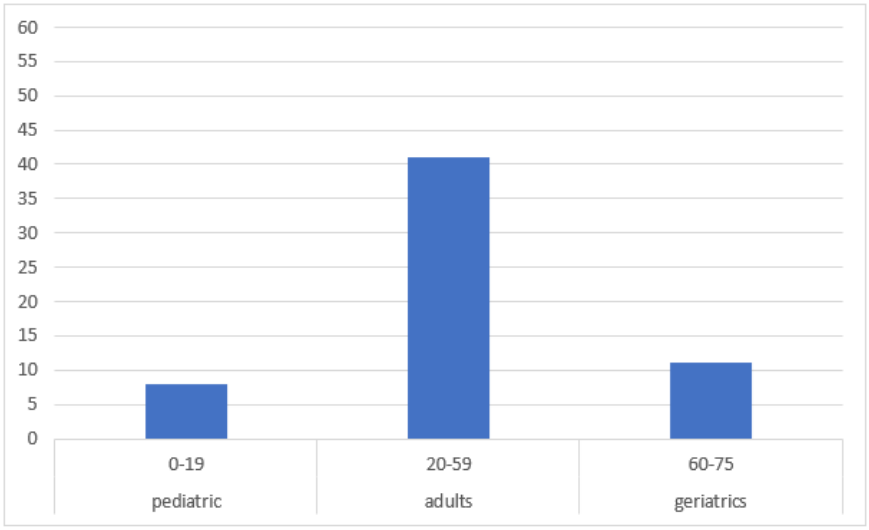

Fig .3. Graphical Representation of Diabetic Patients Based on Age Group

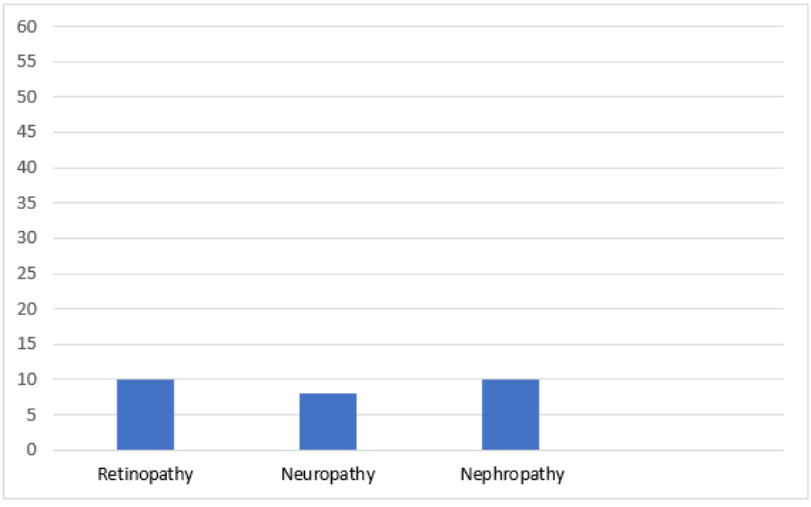

Fig.4. Graphical representation of diabetic patients based on microvascular complications

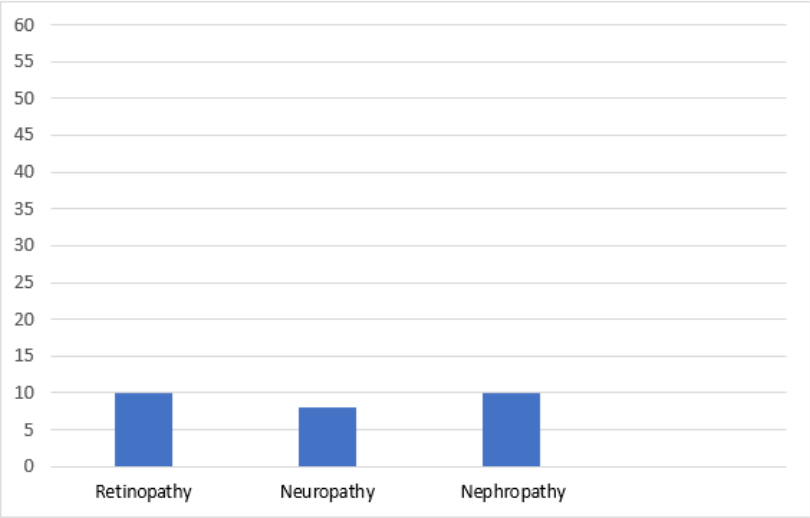

Fig.5. Graphical Representation of Diabetic Patients Including Heart Patients, Patient with Glaucoma, Obesity

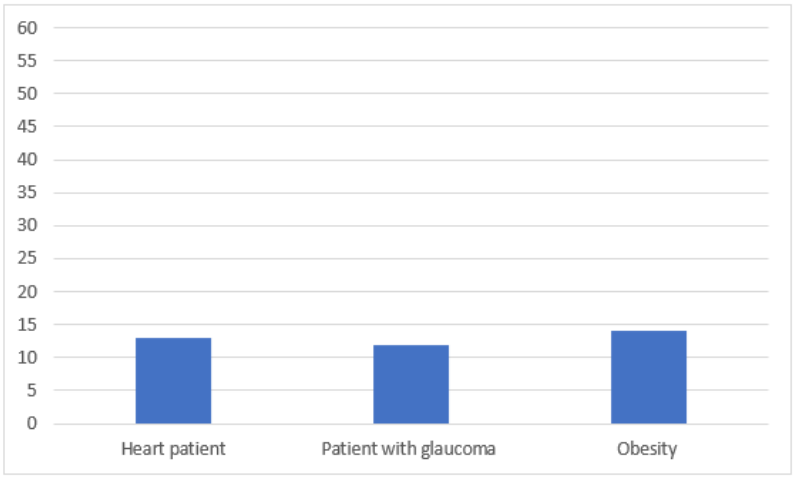

Fig.6. Graphical Representation of Diabetic Patients Including Pregnant Women and Thyroid Patients

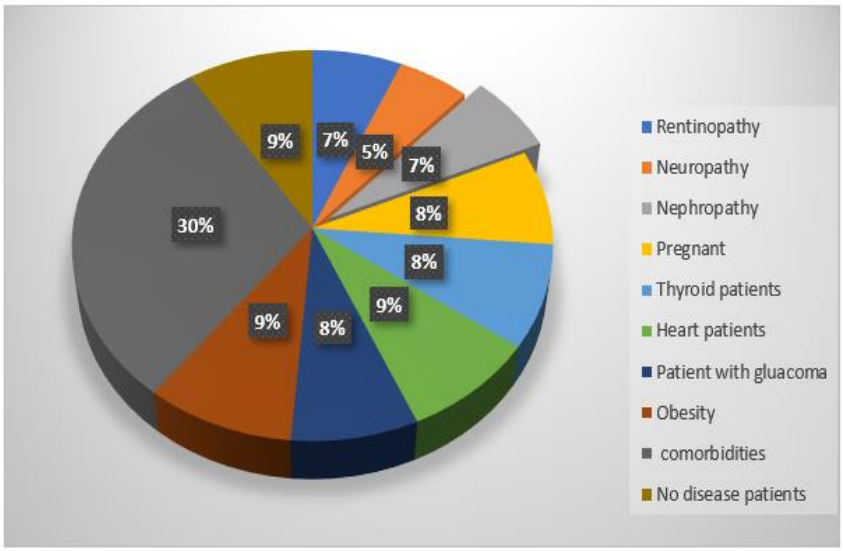

Fig.7. Compilation of total diabetic patients in the form of pie chart

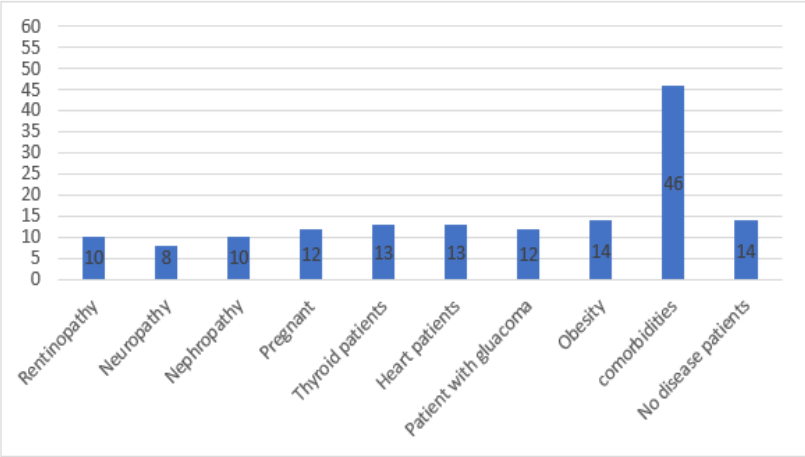

Fig.8.Graphical representation of compilation of total diabetic patients

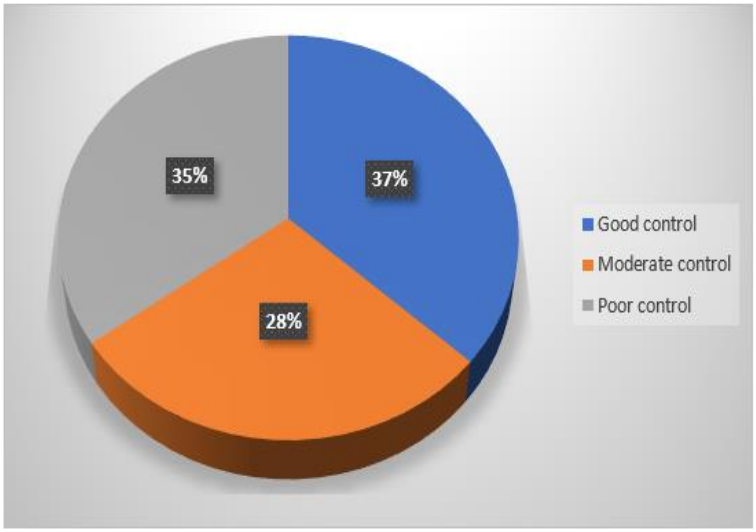

Fig.9. Graphical representation of diabetic patients based on glycaemic control

Factors Influencing Hba1c Levels

1. Blood Glucose Control

Diet: High carbohydrate or sugary foods can raise blood glucose, leading to higher HbA1c levels.

Exercise: Regular physical activity helps lower blood glucose and improve HbA1c.

Medications: Diabetes medications, including insulin and oral drugs, directly impact blood

sugar control and HbA1c levels.

2. Diabetes Type

Type 1 Diabetes: Insulin dependent and the ability to control HbA1c may vary based on insulin management.

Type 2 Diabetes: Involves insulin resistance, where lifestyle changes and medication may be more significant in managing HbA1c.

3. Health Conditions

Chronic Kidney Disease: Can impact HbA1c accuracy as the kidneys play a role in clearing haemoglobin.

Anemia: Low red blood cell turnover can lead to false readings (lower or higher HbA1c levels).

Liver Disease: Liver conditions can alter glucose metabolism, affecting HbA1c levels.

4. Age

Older Adults: As people age, their red blood cells may have a longer lifespan, which could lead to artificially high HbA1c readings.

5. Hemoglobin Variants

Certain hemoglobin variants (like sickle cell anemia) can cause HbA1c to be misleading

because the standard test may not be accurate for people with these variants.

6. Pregnancy

During pregnancy, especially in the case of gestational diabetes, HbA1c may not be an ideal indicator of blood glucose control. More frequent blood glucose testing may be necessary.

7. Blood Disorders

Conditions like iron deficiency anemia or thalassemia can affect HbA1c measurements.

8. Lifestyle and Stress

Stress can temporarily increase blood glucose levels due to the release of stress hormones, which may influence HbA1c over time.

Sleep and mental health: Poor sleep and high stress can also negatively affect blood glucose

regulation.

9. Medications and Supplements

Certain drugs, like steroids, can raise blood glucose levels and HbA1c. Some supplements might have an impact on glucose metabolism.

10. Other Factors

Smoking: Chronic smoking can affect blood sugar regulation and HbA1c.

Infections or Illness: Acute or chronic infections can elevate blood sugar levels, thus affecting HbA1c levels.[43]

Variability And Accuracy of Hba1c Measurements

1. High Performance Liquid Chromatography (HPLC)

HPLC is one of the most widely used methods for HbA1c measurement. It separates haemoglobin variants based on their electrical charge and size. HbA1c is separated from other haemoglobin fractions (e.g., HbA0) and quantified by the peak area or peak height corresponding to HbA1c in the chromatogram.

2. Immunoassays (e.g., Immunoturbidimetric, Immunoenzymatically)

Immunoassays are based on the principle of antigen antibody interactions. Antibodies specific to glycated hemoglobin bind to HbA1c in the blood sample and the concentration of the antibody bound HbA1c is measured by either turbidimetry (cloudiness of the sample) or

enzyme linked detection (color change or fluorescence).

1.Biological Factors

A .Hemoglobin Variants and Genetic Disorders
B. Anemia and Red Blood Cell Disorders
C. Renal Dysfunction
D.Age

E.Pregnancy

2.Analytical Factors

A.Hemoglobin Concentration
B.Interference from Other Hemoglobin Forms
C. Laboratory Methodology and Assay Variability

3.Preanalytical Factors

A.Sample Handling and Storage

B. Blood Sample Type

4. Physiological Factors

A. Stress and Illness

B. Short-term Glucose Fluctuations

Limitations Of HBA1C

1. Does Not Reflect Short Term Glucose Fluctuations

HbA1c measures the average blood glucose level over the past 2-3 months. It does not capture daily variations, postprandial spikes or hypoglycemic episodes that might be critical for assessing overall glucose control. A person could have frequent glucose spikes after meals or episodes of hypoglycemia, which can be damaging to organs, but these fluctuations will not be reflected in the HbA1c result.

2. Inaccurate in Certain Populations

Ethnic variations in HbA1c levels and the presence of certain hemoglobinopathies can lead to inaccurate readings. For example, African American, Hispanic andAsian populations may have naturally higher HbA1c levels even without elevated blood glucose.

3. Affected by Anemia and Red Blood Cell Lifespan

Anemia, chronic kidney disease and conditions that alter red blood cell lifespan (e.g., renal failure, hemolysis) can affect HbA1c levels, making it unreliable in these cases. Shortened red blood cell lifespan in conditions like anemia or kidney disease can lead to falsely low HbA1c values. Conversely, prolonged red blood cell lifespan can result in falsely high HbA1c levels, potentially masking the true glucose control.

4. Not Accurate in Patients with Renal Dysfunction

In patients with chronic kidney disease (CKD) or end stage renal disease (ESRD), the clearance of glucosebound hemoglobin is impaired, potentially leading to falsely elevated or falsely low HbA1c levels. Renal dysfunction can alter the rate at which glucose binds to hemoglobin, affecting the accuracy of HbA1c as a marker of glycemic control. These patients may have HbA1c levels that do not match their actual blood glucose levels, leading to potential mismanagement of their diabetes treatment.

5. Variability Between Different Laboratories and Test Methods

HbA1c is measured using various techniques, including high performance liquid chromatography (HPLC), immunoassays and capillary electrophoresis, which may result in variability in results across different laboratories.

6. Limited Sensitivity for Early Detection of Diabetes

HbA1c has limited sensitivity in identifying early stages of diabetes and prediabetes, particularly in individuals with impaired glucose tolerance or those with mild glucose abnormalities. Some individuals with early insulin resistance or mild hyperglycemia may have normal HbA1c levels, missing the opportunity for early intervention to

prevent the progression to diabetes. HbA1c may fail to identify patients at risk who have normal or near normal HbA1c but exhibit elevated fasting plasma glucose or postprandial glucose levels.

7. Not a Reliable Marker of Glycemic Variability

HbA1c is not a reliable indicator of glycemic variability (the fluctuations in blood glucose throughout the day) or acute glucose changes, such as postprandial glucose spikes. People with variable glucose levels may have an HbA1c that appears normal or within target, but their actual glycemic control is suboptimal, potentially putting them at risk for complications. HbA1c does not reflect glucose excursions that occur after meals or in response to stress or illness, which are important for understanding longterm risks in diabetes.

8. Less Effective for Monitoring Some Treatments

HbA1c may not be the best tool for monitoring certain treatments, particularly those that have nonglycemic effects. For example, SGLT2 inhibitors or GLP1 receptor agonists lower blood glucose via mechanisms that may not immediately affect HbA1c. Medications that increase glucose excretion in the urine (like SGLT2 inhibitors) or improve insulin sensitivity (like GLP1 receptor agonists) may result in significant improvements in blood glucose without a corresponding immediate reduction in HbA1c. This creates a discrepancy where patients on these therapies may experience improved glucose control without a change in their HbA1c, leading to possible confusion or mismanagement.

9. Not Representative of All Diabetes Complications

While HbA1c is a strong indicator of longterm glycemic control, it does not capture the full scope of diabetesrelated complications, such as neuropathy, retinopathy ormicrovascular damage, which may occur even with "normal" HbA1c levels. Diabetic complications can progress even when HbA1c is within target range, particularly in people who experience blood glucose variability or acute hyperglycemia that is not captured by HbA1c. In some cases, intensive glucose control may not prevent complications andother factors, like blood pressure and lipid control, may play a more important role.

10. Potential to Underestimate Risk in Certain Individuals

HbA1c may underestimate the actual risk of complications in certain individuals, particularly those with poor metabolic health or conditions like insulin resistance, where glucose is not utilized effectively by tissues, leading to higher blood glucose despite "normal" HbA1c. Patients with obesity, metabolic syndrome or insulin resistance may have normal HbA1c despite having elevated fasting glucose or postprandial glucose, which could still increase the risk of complications over time. HbA1c alone may fail to identify those at risk for longterm damage in these populations.[49]

RESULTS

The study was conducted on a sample of diabetic patients, comprising both Type 1 and Type 2 diabetes mellitus (T1DM and T2DM).A total of 60 patients were included, which includes the pediatrics, adults and geriatrics . This data includes the age range between 4 to 75 . It includes the 22 % of pre diabetic patients and 78 % of diabetic patients.

HbA1c levels were measured and categorized as follows

- <7.0% (Good control) 37% of patients
- 7.08.9% (Moderate control) 28% of patients

- ≥9.0% (Poor control) 35% of patients

Patients with HbA1c ≥9% were more likely to report complications such as diabetic retinopathy (7%), neuropathy (5%) and nephropathy (7%), compared to those with HbA1c <7%, who showed much lower prevalence rates. Additional findings revealed that age, obesity and medication adherence significantly influenced HbA1c levels. Patients with a high body weight had significantly higher HbA1c values. Nonadherence to prescribed medications or irregular follow ups was observed in 35% of the poor control group. It includes the pregnant woman who are recommended to check the HbA1c level firstly by the physicians. The women's which are having low HbA1c levels are suggested to change some lifestyle factors for the better glycaemic control. Overall, the total 60 patients some are having microvascular complications, some are pregnant women, some are Patients with glaucoma, obesity, thyroid patients, heart patients. Most of the patients are with comorbidities. All these patients' data is shown in Fig .7 in the graphical form. Patients who practiced regular physical activity and dietary control had lower HbA1c levels on average.

DISCUSSION

The findings of this study reaffirm the importance of HbA1c as a reliable biomarker for monitoring glycemic control in diabetic patients. The results align with previous research showing that maintaining HbA1c below 7% is associated with a lower risk of microvascular and macrovascular complications. One of the key observations was the direct relationship between poor glycemic control (HbA1c ≥9%) and the development of long term complications. This finding emphasizes the necessity of early and aggressive interventions, especially in patients with longstanding diabetes or those who are overweight or obese. The data also suggest that lifestyle factors—such as physical inactivity and poor diet—play a significant role in glycemic control, indicating a need for more robust lifestyle counseling in clinical settings. Interestingly, even though a significant proportion of patients were on antidiabetic medications, poor adherence to therapy was commonly reported, particularly among patients with high HbA1c levels. This underscores the importance of patient education, regular counselling and individualized treatment plans that consider socioeconomic and behavioural factors. This study supports current clinical guidelines that recommend regular HbA1c testing (every 3 to 6 months) as part of routine diabetes management. The patients who had regular followups and consistent monitoring demonstrated better control over time, highlighting the effectiveness of continuous care models. This study sheds light on the multifactorial nature of diabetes management. It demonstrates that while pharmacological treatment is essential, it must be supported by behavioral, dietary and psychosocial interventions to maintain optimal HbA1c levels and minimize the risk of complications.

This HbA1c range testing on regular basis helps to achieve the following:

1. Improved Glycemic Control.
2. Reduction in Diabetic Complications.
3. Impact on Cardiovascular Risk.
4. Effectiveness of Different Treatment Modalities.
5. Patient Adherence and HbA1c Control.
6. Socio Demographic Factors Affecting HbA1c.

Summary

The study focused on evaluating HbA1c (glycated hemoglobin) as a marker for longterm blood glucose control in patients with diabetes mellitus. HbA1c provides an average of blood glucose levels over the past 2 to 3 months and is used to

monitor the effectiveness of diabetes treatment. Higher HbA1c levels were significantly associated with poor glycemic control and increased risk of complications such as retinopathy, nephropathy and cardiovascular disease. Most patients with HbA1c levels below 7% had better clinical outcomes and fewer diabetes related complications. Factors contributing to elevated HbA1c included longer duration of diabetes, poor medication adherence, unhealthy diet and lack of physical activity. Interventions like patient education, lifestyle modification and regular monitoring helped in reducing HbA1c levels. The study reinforces the importance of routine HbA1c testing as part of diabetes management and highlights the need for individualized care plans to maintain optimal glycemic control.

CONCLUSION

The research on HbA1c levels in diabetic patients highlights its critical role as a gold standard for assessing longterm glycemic control. HbA1c, which reflects the average blood glucose concentration over the previous two to three months, serves not only as a diagnostic tool but also as a reliable indicator of the effectiveness of diabetes management strategies. The study confirms that maintaining HbA1c levels below 7% is strongly associated with a reduced risk of diabetes related complications, including neuropathy, nephropathy, retinopathy and cardiovascular diseases. Patients with tighter glycemic control had fewer hospitalizations and showed improved quality of life. In contrast, elevated HbA1c levels were frequently linked to poor lifestyle habits, inadequate adherence to medication and longer disease duration. In conclusion, HbA1c remains an essential biomarker in diabetes care, offering valuable insight into disease progression and treatment efficacy. Ongoing efforts should aim to increase awareness, improve access to care and encourage proactive diabetes self management to achieve better glycemic outcomes and reduce the burden of complications. Further research should continue to explore targeted strategies to optimize HbA1c control across diverse patient populations.

REFERENCES

1. DCCT Research Group. The Diabetes Control and Complications Trial (DCCT) design and methodology. Diabetes Care. 1993;16(4) 447464.
2. The Action to Control Cardiovascular Risk in Diabetes Study Group. Effects of intensive glucose lowering in type 2 diabetes. N Engl J Med. 2008;358(24)25452559.
3. Diabetes Control and Complications Trial Research Group. The effect of intensive treatment of diabetes on the development and progression of longterm complications in insulin dependent Diabetes mellitus. N Engl J Med. 1993;329(14)977986.
4. American Diabetes Association. Classification and diagnosis of diabetes Standards of medical care in diabetes2019. Diabetes Care. 2019 Jan;42 S13S28.
5. Sherwani SI, Khan HA, Ekhzaimy A, Masood A, Sakharkar MK. Significance of HbA1c test in diagnosis and prognosis of diabetic patients. Biomarker Insights . 2016(11)95 104.
6. Lind M, Odeen A, Fahlén M, Eliasson B. A systematic review of HbA1c variables used in the study of diabetic complications. Diabetes &Metabolic Syndrome Clinical Research Review. 2008;2(4)282293.
7. Weykamp C. HbA1c A review of analytical and clinical aspects. Clinical Chemistry. 2013;33393400.
8. Kselrod D, Friger M, Biderman A. HbA1C variability among type 2 diabetic patients a retrospective cohort study. Diabetes Metab Syndr. 2021;15(6)102270.

9. Sharma PK, Kumar K, Dubey A, Kushwaha N, Maravi P. Clinical study on association of diabetic retinopathy severity with HbA1c level. Int J Clin Exp Ophthalmology. 2024;10(1)2530.
10. Palem SP. HbA1c is a risk factor for cardiovascular disease in association with oxidative stress in patients with type 2 diabetes mellitus. Int J Res Med Sci. 2017;5(12)517581.
11. Bagheri B, Jalalian R, Mousavi FS, Azizi S, Alipour A, Mousavi F, et al. The role of hemoglobin A1c as a predictor of major adverse cardiovascular events in patients with type 2 diabetes mellitus after percutaneous coronary intervention a case cohort study. BMC Cardiovasc Disord. 2024;24(1)35.
12. Singh J, Aggarwal M. To study the prognostic significance of glycosylated hemoglobin (HbA1c) levels in type 2 diabetic patients and nondiabetic patients. Int J Res Rev. 2019;6(11)4517.
13. Eqbal S, Mishra A, Halim D, Aftab A. HbA1C levels and its correlation in diabetic retinopathy. J Med Sci Clin Res. 2020;8(9)1439.
14. Danesh H, Maleknejad A, Emami MA, Keykha M, Bahmani A. Evaluation and comparison of HbA1C level in diabetic patients with and without foot ulcer a case control study. Iran J Emerg Med. 2024;11(1)1722.
15. Chen Z, Shao L, Jiang M, Ba X, Ma B, Zhou T. Interpretation of HbA1c lies at the intersection of analytical methodology, clinical biochemistry and hematology (Review). Exp Ther Med. 2022;24707.
16. Campbell L, Pepper T, Shipman K. HbA1c a review of nonglycaemic variables. J Clin Pathol. 2019;72(1)1219.
17. Gupta S, Chauhan N, Jain U. Laboratory diagnosis of HbA1c a review. J Nanomed Res. 2017;5(4).
18. Fayyaz B, Rehman HJ, Minn H. Interpretation of hemoglobin A1C in primary care setting. J Community Hosp Intern Med Perspect. 2019;9(1)1821.
19. O'Sullivan CJ, Hynes N, Mahendran B and rews EJ, Avalos G, Tawfik S, et al. Haemoglobin A1c (HbA1C) in nondiabetic and diabetic vascular patients Is HbA1C an independent risk factor and predictor of adverse outcome? Eur J Vasc Endovasc Surg. 2006;32(2)188197.
20. Ryder REJ. 1993The Diabetes Control and Complications Trial (DCCT). Br J Diabetes. 2022;22S23S25. Doi10.15277/bjd.2022.357.
21. Kaiafa G, Veneti S, Polychronopoulos G, Pilalas D, Daios S, Kanellos I, et al. Is HbA1c an ideal Biomarker of well controlled diabetes? Postgrad Med J. 2021;97(1149)380383.
22. Wang A, Yang K, Wang T, Zhang N, Tang H, Feng X. Effects of sodiumglucose cotransporter 2 Inhibitors on risk of venous thromboembolism in patients with type 2 diabetes A systematic review and metaanalysis. Diabetes Metab Res Rev. 2019;35(7)e3174.
23. Zou CY, Liu XK, Sang YQ, Wang B, Liang J. Effects of SGLT2 inhibitors on cardiovascular outcomes and mortality in type 2 diabetes A metaanalysis. Medicine (Baltimore). 2019;98(49)8245.
24. Klonoff DC. Hemoglobinopathies and hemoglobin A1c in diabetes mellitus. J Diabetes Sci
25. American Diabetes Association. Classification and diagnosis of diabetes Standards of medical care in diabetes—2019. Diabetes Care. 2019;42 1S13S28. Doi10.2337/dc19S002.

26. Karalliedde J, Gnudi L. Diabetes mellitus, a complex and heterogeneous disease and the role of insulin resistance as a determinant of diabetic kidney disease. Nephrol Dial Transplant.
27. Herman WH, Cohen RM. Racial and ethnic differences in the relationship between HbA1c and blood glucose Implications for the diagnosis of diabetes. J Clin Endocrinol Metab.
28. 2012;97(4)10671072.
29. The DCCT Research Group. Diabetes Control and Complications Trial (DCCT) results of feasibility study. Diabetes Care. 1987;10(1)119.
30. Herman WH. Are there clinical implications of racial differences in HbA1c? A difference, to be a difference, must make a difference. Diabetes Care. 2016;39(8)14621467.
31. Selvin E, Steffes MW, Ballantyne CM, Hoogeveen RC, Coresh J, Brancati FL. Racial differences in glycemic markers a crosssectional analysis of communitybased data. Ann Intern Med. 2011;154(5)303309.
32. Santiago JV. Lessons from the Diabetes Control and Complications Trial. Diabetes. 1993 Nov;42(11)15491554.
33. O'Sullivan CJ, Hynes N, Mahendran B and rews EJ, Avalos G, Tawfik S, Lowery A, Sultan S. Haemoglobin A1c (HbA1C) in nondiabetic and diabetic vascular patients. Is HbA1C an Independent risk factor and predictor of adverse outcome? Eur J Vasc Endovasc Surg. 2006;32(2)188197.
34. Ahmad J, Rafat D. HbA1c and iron deficiency A review. Diabetes Metab Syndr. 2013;7(2)118122.
35. Sahoo Subhasmita, Mishra Chandrakanta. Correlation of HbA1c with severity of coronary artery disease in nondiabetic ACS patients A crosssectional study in a tertiary care hospital, Odisha. ABCSI2023306. Indian Heart J. 2023;75 S1S27.
36. Kassaian SE, Goodarzynejad H, Boroumand MA, Salarifar M, Masoudkabir F, MohajeriTehrani MR, Pourhoseini H, Sadeghian S, Ramezanpour N, Alidoosti M, Hakki E, Saadat S, Nematipour E. Glycosylated hemoglobin (HbA1c) levels and clinical outcomes in diabetic patients Nematipourcoronary artery stenting. Cardiovasc Diabetol. 2012;1182.
37. Su JB, Zhao LH, Zhang XL, Cai HL, Huang HY, Xu F, Chen T, Wang XQ. HbA1c variability and diabetic peripheral neuropathy in type 2 diabetic patients. Cardiovasc Diabetol. 2018;1747.
38. Rawal G, Yadav S, Kumar R, Singh A. Glycosylated hemoglobin (HbA1C) A brief overview for clinicians. Indian J Immunol Respir Med. 2016;1(2)336.
39. Eyth E, Naik R. Hemoglobin A1C. In: StatPearls [Internet]. Treasure Island (FL): StatPearls
40. Publishing; 2023 Mar 13.
41. Matoori S. Diabetes and its complications. ACS Pharmacol Transl Sci. 2022 Jul 12;5(8):513515.
42. Puri A, Kohli J, Chrunjoo VJ. HbA1c Marker for Long Term Glycemic Control. Asian J Med Res. 2020;9(1):BC01BC03. ISSN (Online): 23473398; ISSN (Print): 22777253.
43. American Diabetes Association. Glycemic targets: Standards of medical care in diabetes—2020. Diabetes Care. 2020;43(Suppl 1):S66S76.
44. World Health Organization. Use of glycated hemoglobin (HbA1c) in the diagnosis of diabetes mellitus. Geneva: World Health Organization; 2011.
45. Miyamoto H, et al. Influences of anemia, kidney disease, thyroid dysfunction andliver disease on the ratio of glycated albumin to

hemoglobin A1c. J Diabetes Sci Technol. 2018;12(5):10821083.

46. American Diabetes Association. Glycemic targets: standards of care in diabetes—2023. Diabetes Care. 2023;46:S97S110.
47. Garofolo M, Gualdani E, Giannarelli R, Aragona M, Campi F, Lucchesi D, Daniele G, Miccoli R, Francesconi P, Del Prato S, Penno G. Microvascular complications burden (nephropathy, retinopathy and peripheral polyneuropathy) affects risk of major vascular events and all cause mortality in type 1 diabetes: a 10year followup study. Cardiovasc Diabetol. 2019;18:159.
48. Colberg SR, Sigal RJ, Yardley JE, et al. Physical activity/exercise and diabetes: a position statement of the American Diabetes Association. Diabetes Care. 2016 Jan;39(11):20652079.
49. Shai I, Schwarzfuchs D, Henkin Y, et al. Weight loss with a lowcarbohydrate, Mediterranean Orlowfat diet. N Engl J Med. 2008 Aug 14;359(7):22941
50. Li J, Huang J, Zheng L, Li X. Application of artificial intelligence in diabetes education and management: present status and promising prospect. Front Public Health. 2020 May 29;8:173
51. Selvin E, Steffes MW, Zhu H, et al. Hemoglobin A1c and the risk of kidney disease and cardiovascular disease in diabetes: a metaanalysis of prospective studies. Diabetes Care. 2010 Dec;33(12):27462752.
52. Little RR, Roberts WL. A review of variant hemoglobins interfering with hemoglobin A1c measurement. J Diabetes Sci Technol. 2011 Jul;5(4):10131020.
53. Defronzo RA. Pathogenesis of type 2 diabetes mellitus. Med Clin North Am. 2004;88(4):787835.
54. Muoio DM, Newgard CB. Mechanisms of disease: molecular and metabolic mechanisms of insulin resistance and βcell failure in type 2 diabetes. Nat Rev Mol Cell Biol. 2008;9(3):193205.
55. Stumvoll M, Goldstein BJ, van Haeften TW. Type 2 diabetes: principles of pathogenesis and therapy. Lancet. 2005;365(9467):133346.
56. Kahn SE. The relative contributions of insulin resistance and betacell dysfunction to the pathophysiology of Type 2 diabetes. Diabetologia. 2003;46(1):319.
57. American Diabetes Association. 2. Classification and diagnosis of diabetes: Standards of Medical Care in Diabetes—2024. Diabetes Care. 2024;47(Suppl 1):S17S29.
58. Paes VM, Barrett JK, TaylorRobinson DC, et al. Effect of early glycemic control on HbA₁c tracking and development of vascular complications after 5 years of childhood onset type 1 Diabetes: systematic review and metaanalysis. Pediatr Diabetes. 2019;20(5):494509.

HOW TO CITE: Sakshi Manekar*, Shubham Tikait, Dr. Swati Deshmukh, HBA1C Study in Diabetic Patients, Int. J. of Pharm. Sci., 2025, Vol 3, Issue 5, 2687-2702. https://doi.org/10.5281/zenodo.15425503