

The Role of HbA1c and Oral Glucose Tolerance Test in the Diagnosis and Differentiation of Prediabetes: Article Review

Khalil MA¹[ID](#), Mutashar SA¹, Hussain WMH²[ID](#)

¹Department of Chemistry and Biochemistry, College of Medicine, Ibsina University for Medical and Pharmaceutical Science, Baghdad, Iraq

²Department of Physiology, College of Medicine, Ibsina University for Medical and Pharmaceutical Science, Baghdad, Iraq

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Abstract

Background: Prediabetes is a condition resulted when the level of glucose is between the normal and hyperglycaemic limits, and it is very important to follow up because it may be developed to diabetes mellitus. It is critical to identify its 2 main phenotypes early and accurately: impaired fasting glucose (IFG) or impaired glucose tolerance (IGT), to prevent us from progressing to type 2 diabetes and its complications. This review is intended to clarify the separate roles of glycated haemoglobin (HbA1c) and the oral glucose tolerance test (OGTT) in diagnosing and discriminating these prediabetic states.

Main body: IFG and IGT result from different pathophysiological processes: IFG is primarily due to hepatic insulin resistance (IR) and also impaired early-phase insulin secretion, while IGT shows prominent peripheral (mainly muscle) IR with defects in both early and late (over the post-prandial period) insulin secretion. The OGTT still provides the gold standard for IGT diagnosis by assessing postprandial glucose excursions. Measurement of HbA1c provides a simple assessment of long-term glycaemia, indicating average glucose level within the previous 2–3 months and is recommended (5.7–6.4%) by the American Diabetes Association for prediabetes screening. However, its diagnostic utility is limited by several confounding factors (such as anaemias, haemoglobinopathies and ethnic variations) that contribute to misclassification. FPG, OGTT and HbA1c identify distinct prediabetic phenotypes with different risk profiles for progression to diabetes and cardiovascular disease. However, it can be diagnosed by making more than one test at the same time, and this is very important to increase the sensitivity of the diagnosis. Both the HbA1c and the oral glucose tolerance test can provide these features. The clinical examination by the physician is important to classify the prediabetes, either IGT or IFG.

Keywords: Prediabetes, Impaired fasting glucose, Impaired Glucose Tolerance, HbA1c, Oral Glucose Tolerance Test, Insulin resistance

Background

The worldwide prevalence of diabetes affects human health in the world, especially who have a lower income, and these attributed to excessive stress among these people. Prediabetes is a critical state of glucose concentration when it becomes above the normal limit, but without any typical criteria or signs, symptoms, or laboratory findings of diabetes. Prediabetes can be classified into two important types, which are

impaired fasting glucose and the second type called impaired glucose tolerance, and both types can develop into type 2 diabetes in future if it is not considered (1, 2, 3). Prevention of prediabetes by a healthy lifestyle and dietary regimen is very important, and it can be considered as a first step in reducing the probability of developing type 2 diabetes. Metformin can be used in the sometime (4, 5, 6). But the best way to diagnose them is hotly

Correspondence

Mohammed Abd Al-Hussain Khalil
Department of Chemistry and Biochemistry, College of Medicine,
Ibsina University for Medical and Pharmaceutical Science,
Baghdad,
Iraq.
mohammed.abdalhussain@ibnsina.edu.iq

debated. The oral glucose tolerance test (OGTT) has been the gold standard for diagnosing IGT, but it is time-consuming, cumbersome, and poorly reproducible. Glycated haemoglobin (HbA1c), which reflects average glycaemia over the previous 2–3 months, provides a more practical option than blood glucose, but it also has drawbacks; a major limitation is that HbA1c can be influenced by factors such as anaemia, haemoglobinopathies and ethnic differences (7, 8, 9). This review aims to summarise current evidence regarding these controversial roles of HbA1c and OGTT in the diagnosis/differentiation of prediabetic states. We searched PubMed, Scopus, and Google Scholar for all articles published up to 2025, focusing on studies on IFG, IGT pathophysiology, diagnosis, and the clinical impact of using HbA1c or OGTT.

Main Text

Epidemiology and Diagnostic Criteria of Prediabetes

The prevalence of prediabetes is a moving target, greatly affected by diagnostic criteria, ethnicity and lifestyle factors. Global estimates suggest that about one in three adults may have prediabetes, and the number is expected to increase. Blood glucose levels reflect the

underlying physiology, but NHANES and other large cohort study data offer an insight into how these physiological changes translate to the risk of developing IFG, as they have shown substantial increases in prevalence that vary widely across many different populations (10, 11). Primarily centred on the Global South, one recent analysis reported that due to rapid urbanisation and changing eating habits, there is a rising incidence of prediabetes (12). Similar high prevalence of IGT, particularly with advancing age, is often higher in women than IFG, which is more male predominant (13, 14). Table 1 summarises the diagnostic criteria for prediabetes according to the American Diabetes Association (ADA) and World Health Organisation (WHO). These thresholds identify individuals at high risk, but they are not interchangeable: Each identifies different segments of the population. Individuals can present with isolated IFG, isolated IGT or both states as they have different underlying pathophysiology and clinical implications (15, 16, 17). Importantly, discordance between tests is common: an individual may qualify for prediabetes with one test but not with another, reflecting the different physiological domains captured by each test.

Table 1: Diagnostic Criteria for Prediabetes and Diabetes

Test	Normal	Prediabetes	Diabetes
Fasting blood glucose (FPG)	less than 100 mg/dL	100 – 125 mg/dL (5.6–6.9 mmol/L) (IFG)	≥ 126 mg/dL (7.0 mmol/L)
2-hour post-prandial glucose (2h PG) during 75g OGTT	less than 140 mg/dL	140 – 199 mg/dL (7.8–11.0 mmol/L) (IGT)	≥ 200 mg/dL (11.1 mmol/L)
Glycated haemoglobin	less than 5.7%	5.7–6.4%	≥ 6.5%

Adapted from the ADA Standards of Medical Care in Diabetes (2025)

Pathophysiological Distinction Between IFG and IGT

A key difference between IFG and IGT is the location and type of underlying metabolic defect. These differences between the two types of prediabetes have a direct and important effect on the development of prediabetes to diabetes, and on the treatment that will be used (18, 19).

The IFG resulted from the abnormal glucose concentration at the prediabetic level as a response to the abnormal glucose homeostasis, which is characterised by the following features: Hepatic Insulin Resistance (IR)

Insulin resistance at the level of the liver results in the overproduction of glucose due to the diminishing of the inhibitory insulin signals for the endogenous hepatic production of glucose in the fasting state (20). At the molecular level, this is

manifested by decreased insulin receptor substrate (IRS)-2 signalling and increased expression of gluconeogenic enzymes.

Defective Early-Phase Insulin Secretion

Impairment of the first phase insulin response, either produced endogenously or orally, which is characterised by the elevation of the glucose concentration about 2.3–none μ U/ml above the normal baseline during the first 10 minutes. This defect plays a role in the early postprandial rise of glucose, while secretion late after feeding is relatively preserved (21, 22).

Impaired Glucose Tolerance (IGT), by contrast, is mainly a defect in postprandial glucose disposal. Its defining characteristics are:

Peripheral (Muscle) Insulin Resistance

The main defect is in skeletal muscle, which does not adequately take up glucose after a meal in the presence of insulin. The main cause of this resistance may result from the slow translocation of the glucose transporter, which is GLUT4, and disturbing the insulin signals (23).

When the beta cell loses its function or becomes inert, these resulted in a reduction in insulin secretion and an inability to compensate for the required amount of insulin in insulin resistance, causing the glucose to elevate after meals (24, 25). Some people have both forms of prediabetes, which making more prone to metabolic abnormalities than those who have one form of prediabetes and increases the risk of developing type 2 diabetes (26). However, more than one test should be required to diagnose the normality of glucose homeostasis in both the fasting and postprandial states. Clinically, these findings may be helpful in the development of the preventive strategies against prediabetics, such as lowering the endogenous glucose production in the case of IFG and a healthy lifestyle, such as sports and dietary regimen in the case of IGT

HbA1c: Mechanism, Utility, and Limitations

Mechanism and Historical Context

The glycated haemoglobin is a compound resulted from the glycation of the terminal valine amino acid of the haemoglobin beta chain, the main features of these irreversible enzymatic reaction it is the rate of glycation are directly correlated to the level of the glucose in the blood stream and its based on the age and amount of the RBC, HbA1c considered as an indicator on the level of the glucose for the last 90-120 days, so it can be used for the long term monitoring of the prediabetics or diabetes (27, 28, 29).

Utility in Prediabetes Diagnosis

The glycated haemoglobin is considered one of the most important tests included in the criteria that will be available for the diagnosis of glucose abnormality, such as prediabetics or diabetic state, at normal values between 5.7 and 6.4 in prediabetics. Its benefits are substantial: it does not require fasting, has greater pre-analytical stability than plasma glucose and correlates closely with long-term glycaemia and the risk of microvascular complications (30). Accumulating evidence from cohort studies based in the Global South indicates that both visceral and HbA1c status (in non-diabetic range) may predict cardiovascular risk, especially alongside inflammatory markers such as C-reactive protein (CRP) and markers of endothelial dysfunction (31, 32). In addition, in resource-constrained settings where the OGTT may be logistically challenging, HbA1c provides a feasible

alternative for screening of large populations (12).

Critical Limitations

Although HbA1c is a useful test, its limitations are multiple and can result in both over- and under-diagnosis. In clinical practice, these factors that are independent of glycaemia need to be considered (33):

Conditions Affecting Red Cell Survival

Any condition that changes erythrocyte turnover will also affect HbA1c. Reduced turnover (e.g., haemolytic anaemia, recent blood transfusion) artificially lowers HbA1c. Reduced turnover (e.g. iron, vitamin B12 deficiency) artefactually raises it.

Haemoglobinopathies

Variant haemoglobins (e.g., HbS, HbC, HbE) may cause interference in some assay methodologies, producing inaccurate results. Most of these conditions differ substantially in prevalence by ethnicity, particularly problematic when dealing with heterogeneous populations (34). In those circumstances, other markers such as fructosamine or glycated albumin can be assessed. Other Factors: Chronic kidney disease (due to carbamylated haemoglobin interference), specific medications (e.g. salicylates, high-dose vitamin C/E), and ethnicity (individuals of African, Mediterranean, or Southeast Asian descent may have greater HbA1c per given glycaemia) all mangle the interpretation of HbA1c.

Assay variability

Proposal for standardisation (NGSP, IFCC) has improved comparability, but inter-assay variability persists, especially in low-resource settings, where quality control may be less stringent.

Diagnostic Value of HbA1c vs. OGTT

However, the question of which is better (HbA1c or OGTT) for diagnosing prediabetes is not an issue of superiority but complementary utility. They answer different physiological questions.

The OGTT remains the sensitive test for diagnosing IGT. And by evoking the glucose regulatory apparatus with a diagnostic 75g glucose load, it exposes postprandial hyperglycaemia that would be otherwise undetected by fasting glucose or HbA1c measurement. You Read: They are the only tests that can separate both IFG, IGT and combination states (35). However, it is time-consuming, necessitating fasting and a 2-hour blood draw and has low day-to-day reproducibility. These logistical barriers contribute to inadequate utilisation of the OGTT in many primary care settings.

HbA1c is an easily measured, temporally integrated marker of chronic risk. One HbA1c value gives an instant picture of average glucose exposure. Although it is less sensitive than an OGTT for detecting IGT, extensive evidence supports an HbA1c in the prediabetic range as a strong independent predictor of future diabetes and cardiovascular disease (36, 37). Due to its convenience, it is a suitable screening tool in primary care settings and is increasingly being used in population-based screening programs. The glycated haemoglobin and OGTT should both be used at the same time because both test in sometime can give different results. In some individuals, the level of the HbA1c is normal, but the result of the tolerance test is at the prediabetic level, and such an inconsistency in the results between both tests should be considered because it may reflect a different metabolic abnormality (38). However, both tests should be used for the diagnosis of prediabetics, especially in those whom has diabetic family history, obesity and gestational diabetes or prediabetes

Clinical Implications and Future Directions

The clinical management of the prediabetics, especially IGT required reduction in the endogenous production of glucose by different strategies, such as following the healthy programs through sports or by metformine can give good results and effectiveness on the glucose homeostasis and reduce the risk fir the developing of the prediabetics to the diabetes. This last approach is especially effective for exercise programs that improve muscle glucose uptake in patients with IGT. Severe lifestyle modification is very strongly warranted when both are present.

Novel technologies in CGM (Continuous glucose monitoring) may enhance our understanding of glycaemic variability and optimise risk prediction further. Although not routinely used to diagnose prediabetes, CGM can detect those with excessive glucose excursions who would be missed on laboratory tests (39, 40). Similar strategies using inexpensive point-of-care HbA1c and targeted OGTT in high-risk groups form a pragmatic strategy in the Global South, where access to advanced technology is limited (12, 31).

Conclusion

Prediabetes is a condition resulting from abnormal glucose homeostasis, making the glucose level in the bloodstream between the diabetic and normal limits. There is a difficulty in separating the types of prediabetics, either IFG or IGT, because each one results as a response

to either hepatic insulin resistance or peripheral resistance at the level of the muscle.

Because of the difficulty in diagnosing the type of prediabetes, more than one test should be performed. The tolerance test is critical for IGT because it can provide a clear idea of the glucose tolerance, while the HbA1c can give a typical idea of the quantification and long-term monitoring of the glucose over a period. There are many different factors that can affect the accuracy of the HbA1c, which makes it more prone to misdiagnosis, so different complementary tests or strategies should be required to increase the accuracy and effectivity additionally to the prevention of prediabetics and their consequences.

List of Abbreviations

AGE: Advanced glycation end product
CGM: Continuous glucose monitoring
CRP: C-reactive protein
FPG: Fasting plasma glucose
HbA1c: Glycated haemoglobin
IFG: Impaired fasting glucose
IGT: Impaired glucose tolerance
NHANES: National Health and Nutrition Examination Survey
NGSP: National Glycohemoglobin Standardisation Program
OGTT: Oral glucose tolerance test
T2DM: Type 2 diabetes mellitus

Declarations

Ethics approval and consent to participate

Not applicable. This is a review paper and does not encompass new data collection from human or animal subjects

Consent for publication

All authors gave consent for publication of the work under the Creative Commons Attribution-Non-Commercial 4.0 license.

Availability of data and materials

This article lacks associated data sharing as no datasets were produced or analysed in the current study.

Competing interests

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Authors' contributions

KMA: Conceptualisation, literature search, writing the first draft, writing, reviewing, and editing.

MSA: Searching for literature, writing the first draft, writing, reviewing, and editing.

HWMH: Conceptualisation, writing-review and editing, supervision.

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