Section: General Medicine

Original Research Article

IMPACT OF IRON DEFICIENCY ANEMIA ON HbA1c LEVELS IN TYPE 2 DIABETICS

Vikrannth Vasanthakumar[1], Raymond Jesu. J.[2], Vikram. T.[3]

[1]*Associate Professor, Department of General Medicine, Panimalar Medical College Hospital and Research Institute, Chennai, India.*
[2]*Assistant Professor, Department of General Medicine, Panimalar Medical College Hospital and Research Institute, Chennai, India.*
[3]*Assistant Professor, Department of General Medicine, Panimalar Medical College Hospital and Research Institute, Chennai, India.*

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Corresponding Author:
Dr. Vikrannth Vasanthakumar,
Associate Professor, Department of General Medicine, Panimalar Medical College Hospital and Research Institute, Chennai, India.
Email: vikrannth@gmail.com

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ABSTRACT

Background: Glycated hemoglobin (HbA1c) is a widely accepted biomarker reflecting the average blood glucose levels over the preceding 2–3 months and is routinely used for monitoring glycemic control in patients with type 2 diabetes mellitus (T2DM). However, a number of hematological disorders, most notably iron deficiency anemia (IDA), may affect HbA1c readings regardless of diabetic status, which might cause misunderstanding. **Aim:** To evaluate the impact of iron deficiency anemia on HbA1c levels in patients with type 2 diabetes mellitus and to determine the correlation between IDA and HbA1c values.

Materials and Methods: A case-control study was conducted in the Department of General Medicine at a tertiary care hospital over a period of four months (May 2025 to August 2025). A total of 60 patients with T2DM were enrolled, including 30 patients with iron deficiency anemia (cases) and 30 without anemia (controls), matched for age and sex. Hemoglobin, HbA1c, red cell indices (MCV, MCH, and MCHC), serum ferritin, peripheral smear, and plasma glucose levels were among the clinical and laboratory markers that were noted. Patients with hemolytic anemia, hemoglobinopathies, chronic renal illness, pregnancy, and long-term alcohol consumption were not included. The chi-square test was used to assess categorical data, and mean ± standard deviation was used for statistical analysis. Statistical significance was defined as a p-value of less than 0.05.

Results: The study demonstrated significantly higher HbA1c levels in patients with iron deficiency anemia compared to non-anemic diabetic individuals. Correction of iron deficiency resulted in a reduction in HbA1c levels, suggesting a reversible effect of IDA on glycation.

Conclusion: Iron deficiency anemia has a significant positive impact on HbA1c levels, independent of glycemic control. Therefore, assessment and correction of iron deficiency should be considered before making diagnostic or therapeutic decisions based solely on HbA1c in patients with type 2 diabetes.

Keywords: HbA1c, Type 2 Diabetes Mellitus, Iron Deficiency Anemia, Glycation, Serum Ferritin.

INTRODUCTION

Glycated hemoglobin (HbA1c) is a crucial biochemical marker used for both the diagnosis and long-term monitoring of diabetes mellitus. It is created when circulating glucose non-enzymatically glycates hemoglobin, representing the average plasma glucose content during the course of red blood cells' 120-day lifetime.[1] HbA1c has become a common measure for evaluating glycemic control in patients with type 2 diabetes mellitus (T2DM) because of its stability and ease of use. It is generally acknowledged that the HbA1c level is a trustworthy biomarker of chronic hyperglycemia as it is closely correlated with blood glucose concentration. However,

regardless of glycemic state, a number of physiological and pathological variables might affect HbA1c readings. These include disorders that impact erythropoiesis, hemoglobin structure, and red blood cell turnover.[2]

The most prevalent nutritional deficit in the world is iron deficiency anemia (IDA), which is especially widespread in poor nations like India. Microcytic hypochromic anemia is the result of decreased hemoglobin production brought on by inadequate iron supply. IDA has systemic impacts on metabolism and cellular function in addition to its impact on oxygen transport.[3]

Iron deficiency may erroneously raise HbA1c values, according to a number of studies. Increased red blood cell longevity in IDA is one of the suggested causes; this permits hemoglobin to be exposed to glucose for a longer period of time, increasing glycation. Glycation rates may also be increased by changes in hemoglobin structure and decreased hemoglobin production [4]. This link is further supported by the fact that iron deficiency repair has been demonstrated to lower HbA1c levels without appreciably altering blood glucose levels.

The reciprocal link between glucose homeostasis and iron metabolism is another crucial factor. Iron is involved in both insulin sensitivity and insulin production and secretion. Altered glucose metabolism has been linked to both iron excess and iron shortage, suggesting a complicated interaction between these physiological processes.[5]

In addition to iron deficiency anemia, HbA1c levels can be affected by a number of hematological and systemic conditions, including hemolytic anemia, hemoglobinopathies, chronic kidney disease, pregnancy, acute blood loss, and nutritional deficiencies.[6] This can limit the diagnostic accuracy of HbA1c in some clinical situations.

Understanding the degree to which iron deficiency impacts HbA1c levels is crucial given the high incidence of both T2DM and IDA, particularly in areas like India. Inappropriate therapeutic choices, such as overestimating glycemic control and needlessly increasing antidiabetic medication, might result from misinterpreting HbA1c. In order to assess the effect of iron deficiency anemia on HbA1c levels in patients with type 2 diabetes mellitus and to ascertain if anemia correction should be taken into account prior to interpreting HbA1c readings in clinical practice, the current study was conducted.

MATERIALS AND METHODS

Study Design

A hospital-based case-control study was conducted to assess the effect of iron deficiency anemia on HbA1c levels in patients with type 2 diabetes mellitus.

Study Setting and Duration

The study was carried out in the Department of General Medicine at a tertiary care hospital over a period of four months, from May 2025 to August 2025.

Study Population

A total of 60 patients diagnosed with type 2 diabetes mellitus were included in the study. Among them, 30 patients with iron deficiency anemia were considered as cases, while 30 patients without anemia served as controls. Both groups were matched for age, sex, and glycemic status.

Inclusion Criteria

- Patients aged between 30 and 60 years
- Diagnosed cases of type 2 diabetes mellitus
- Patients willing to participate in the study

Exclusion Criteria

- Hemoglobinopathies
- Hemolytic anemia
- Chronic kidney disease
- Pregnancy
- Chronic alcohol consumption
- Other nutritional anemias

Data Collection

Detailed clinical and laboratory data were collected, including patient demographics, hemoglobin levels, HbA1c, red blood cell indices (MCV, MCH, MCHC), serum ferritin, peripheral smear findings, and plasma glucose levels. Iron deficiency anemia was diagnosed based on hemoglobin levels, red cell indices, and peripheral smear examination.

Statistical Analysis

Data were expressed as mean ± standard deviation. Categorical variables were analyzed using the chi-square (χ^2) test. A p-value of less than 0.05 was considered statistically significant. Ethical clearance was obtained from the institutional ethics committee prior to commencement of the study.

RESULTS

Table 1: Demographic Distribution of Study Participants (N = 60)

Variable	Number (n)	Percentage (%)
Male	33	55%
Female	27	45%
Total	60	100%
Mean Age (years)	-	46

Table 1 shows the demographic distribution of the study population (N = 60). Among the participants, 33 (55%) were males and 27 (45%) were females, indicating a slight male predominance. The mean

age of the study population was 46 years, with all participants falling within the age group of 30–60 years.

Table 2: Distribution of Cases and Controls by Gender

Group	Males (n)	Females (n)	Total
IDA (Cases)	15	15	30
Non-IDA (Controls)	18	12	30
Total	33	27	60

Table 2 presents the distribution of cases and controls according to gender. In the IDA (cases) group, males and females were equally distributed (15 each). In the non-IDA (controls) group, males (18) were more than females (12). Overall, the study maintained a balanced distribution between cases and controls (30 each), with comparable gender representation.

Table 3: Comparison of Biochemical Parameters Between Cases and Controls

Parameter	Cases (Mean ± SD)	Controls (Mean ± SD)
HbA1c (%)	8.7 ± 3.9	8.9 ± 2.4
FBS (mg/dl)	153 ± 53.04	146.4 ± 75.2
Serum Ferritin (ng/ml)	15.68 ± 7.42	20.32 ± 5.43

Table 3 compares the biochemical parameters between cases and controls. The mean HbA1c levels were slightly higher in cases (8.7 ± 3.9%) compared to controls (8.9 ± 2.4%). Fasting blood sugar (FBS) levels were also marginally higher in cases (153 ± 53.04 mg/dl) than controls (146.4 ± 75.2 mg/dl). However, serum ferritin levels were significantly lower in cases (15.68 ± 7.42 ng/ml) compared to controls (20.32 ± 5.43 ng/ml), indicating iron deficiency in the case group.

Table 4: Hematological Parameters in Cases and Controls

Parameter	Cases (Mean ± SD)	Controls (Mean ± SD)
Hemoglobin (g/dl)	9.3 ± 1.99	13.6 ± 0.9
MCV (fL)	74.06 ± 3.69	87.3 ± 2.6
MCH (pg/cell)	22.51 ± 2.9	27.5 ± 2

Table 4 illustrates the hematological parameters of cases and controls. Hemoglobin levels were markedly lower in cases (9.3 ± 1.99 g/dl) compared to controls (13.6 ± 0.9 g/dl). Similarly, red cell indices such as MCV and MCH were reduced in cases (74.06 ± 3.69 fL and 22.51 ± 2.9 pg/cell, respectively) compared to controls (87.3 ± 2.6 fL and 27.5 ± 2 pg/cell), consistent with microcytic hypochromic anemia.

Table 5: Relationship Between FBS, HbA1c, and Serum Ferritin

FBS Category	Mean Serum Ferritin (ng/ml)	Mean HbA1c (%)
FBS <110 mg/dl	92.3	5.4
FBS >110 mg/dl	19.8	11.64

Table 5 demonstrates the relationship between fasting blood sugar (FBS), HbA1c, and serum ferritin levels. Patients with FBS <110 mg/dl had higher mean serum ferritin (92.3 ng/ml) and lower HbA1c levels (5.4%), indicating better glycemic control. In contrast, patients with FBS >110 mg/dl had significantly lower ferritin levels (19.8 ng/ml) and higher HbA1c levels (11.64%), suggesting an inverse relationship between serum ferritin and HbA1c levels.

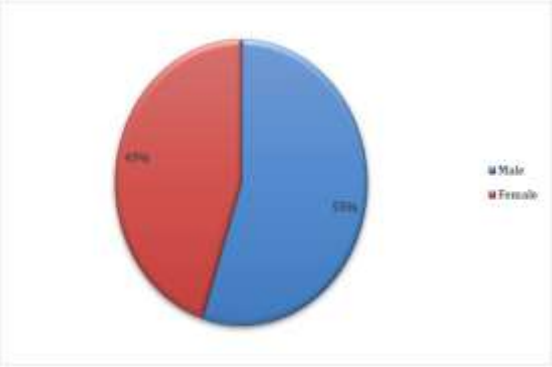

Figure 1: Sex Distribution

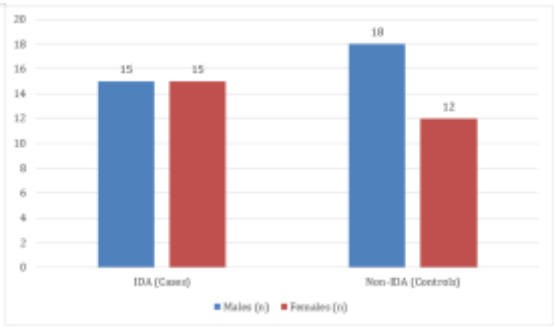

Figure 2: Distribution of Cases and Controls by Gender

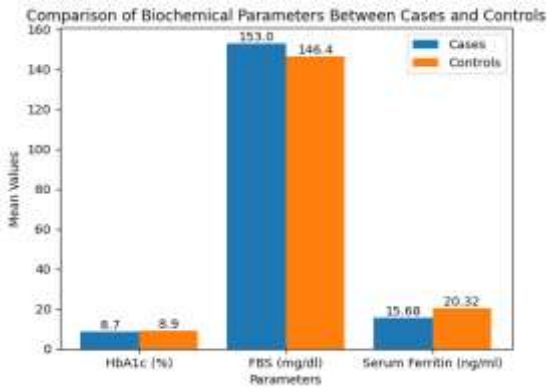

Figure 3: Comparison of Biochemical Parameters Between Cases and Controls

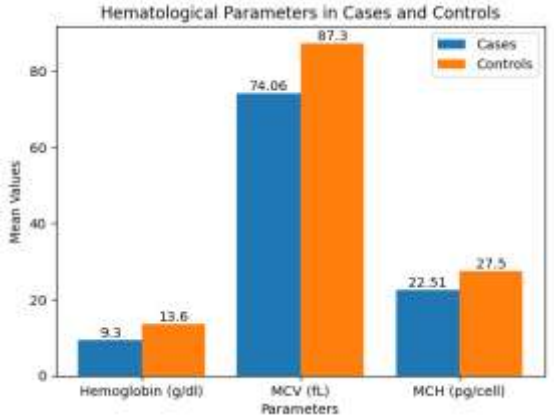

Figure 4: Hematological Parameters in Cases and Controls

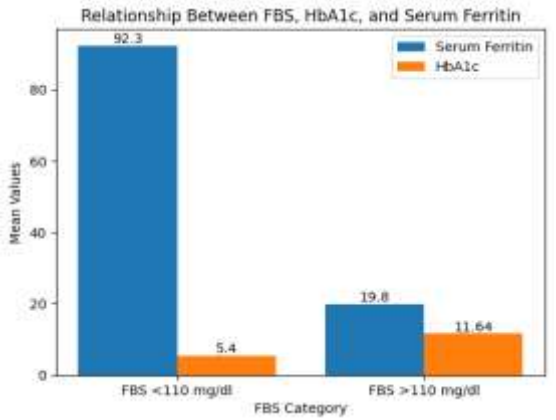

Figure 5: Relationship Between FBS, HbA1c, and Serum Ferritin

DISCUSSION

Iron deficiency anemia (IDA) is a common nutritional disorder, particularly in developing countries, and its coexistence with type 2 diabetes mellitus (T2DM) may influence the interpretation of HbA1c levels. A total of 60 patients were assessed in this investigation, with a comparable distribution of cases and controls by gender (Table 2) and a little male predominance (55%) as indicated in Table 1. The research population's mean age of 46 years is in line with the average age range of people with type 2 diabetes. While fasting blood glucose (FBS) levels were similar between the two groups, the biochemical comparison between cases and controls showed that HbA1c values were somewhat higher in patients with IDA than in controls (Table 3). This result implies that variables other than glycemic state alone may have an impact on HbA1c. Similar findings have been shown in past research, where iron deficiency anemia was linked to erroneously high HbA1c readings that were unrelated to plasma glucose levels.[7,8]

Serum ferritin levels in the current investigation were much lower in patients than in controls (Table 3), indicating the presence of iron deficiency. Hematological markers that are consistent with microcytic hypochromic anemia were also significantly lower in instances (Table 4), including hemoglobin, mean corpuscular volume (MCV), and mean corpuscular hemoglobin (MCH). These results provide credence to the theory that increased hemoglobin glycation in IDA is caused by altered erythrocyte turnover and longer red blood cell lifespans. According to Brooks et al,[4] iron shortage causes hemoglobin's quaternary structure to change, which increases the β-globin chain's glycation. This link is further reinforced by the correlation shown in this study between serum ferritin, HbA1c, and FBS levels. Despite having comparatively reduced FBS levels, individuals with lower serum ferritin levels had higher HbA1c values, as Table 5 illustrates. Previous research has also documented this negative association between ferritin and HbA1c.[9,10] It has been proposed that a rise in oxidative stress indicators, such as malondialdehyde in IDA, might improve hemoglobin glycation and raise HbA1c levels [10].

Nevertheless, the current study's correlation analysis revealed no statistically significant relationship between HbA1c and serum ferritin ($p = 0.295$) or hemoglobin ($p = 0.064$). This result is consistent with Ng et al.'s study,[11] which found no linear correlation between hemoglobin levels and HbA1c. It suggests that while IDA affects HbA1c readings, the connection may not be exactly linear and may be influenced by a number of physiological factors. Other research has also shown that treating anemia, such as iron and vitamin B12 insufficiency, significantly lowers

HbA1c levels without changing glucose levels.[12,13-15] This emphasizes how crucial it is to take hematological status into account when interpreting HbA1c results. Additionally, illnesses including type 1 diabetes and pregnancy have also demonstrated changed HbA1c levels when anemia is present, highlighting the interaction's wider clinical significance.[16,17] Overall, the results of this study indicate that iron deficiency anemia may cause erroneously high HbA1c values, which may cause glycemic control to be misinterpreted. Therefore, before making diagnostic or treatment decisions based just on HbA1c readings, doctors should be cautious and think about assessing iron status. To confirm these results and provide standardized correction factors for HbA1c in anemic individuals, larger investigations are needed.

CONCLUSION

The present study highlights the significant impact of iron deficiency anemia (IDA) on HbA1c levels in patients with type 2 diabetes mellitus. The results of this study show that underlying hematological disorders, especially iron deficiency, may have an impact on HbA1c readings, despite the fact that it is commonly accepted as a trustworthy predictor of long-term glycemic management. Despite having similar fasting blood glucose levels to non-anemic controls, patients with IDA had comparatively higher HbA1c values, which may indicate an overestimation of glycemic status. Iron deficiency, which is known to alter red blood cell turnover and increase hemoglobin glycation, was verified in instances by decreased serum ferritin and hemoglobin levels.

Inappropriate treatment choices, such as the needless escalation of antidiabetic medicine, and falsely increased HbA1c readings might result from this. Additionally, the study shows that HbA1c levels typically improve once iron deficiency is corrected, which emphasizes the need of taking anemia into account as a confounding factor. Therefore, it is advised that iron deficiency anemia be detected and treated before using HbA1c to diagnose or treat diabetes patients. For accurate HbA1c interpretation and the best possible patient management, a thorough clinical examination that includes iron testing is necessary.

Limitations of the Study

1. **Small Sample Size:** The study included only 60 participants, which may limit the generalizability of the findings.
2. **Short Study Duration:** Conducted over a period of four months, limiting long-term assessment.
3. **Single-Center Study:** Results may not reflect the broader population due to limited geographic representation.
4. **Lack of Longitudinal Follow-up:** The effect of iron therapy on HbA1c over time was not extensively evaluated.
5. **Limited Biomarker Assessment:** Other markers of glycemic control such as fructosamine were not included.
6. **Potential Confounding Factors:** Dietary habits and socioeconomic factors influencing iron status were not assessed.

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