International Journal of Medical and Pharmaceutical Research

Online ISSN-2958-3683 | Print ISSN-2958-3675
Frequency: Bi-Monthly
Available online on: https://ijmpr.in/

Original Article

Correlation of Red Blood Cell Parameters with Glycated Hemoglobin (HbA1c) in Gestational Diabetes Mellitus

Dr. Mayank Kumar[1], Dr. Shatakshee Tewari[2], Dr. Diksha Ambedkar[3], Dr. Virendra Verma[4], Dr. Manish Kumar Misra[5], Dr. Paras Kharbanda[6], MsAnanya Pandey[7]

[1]Associate Professor, Department of Pathology, Rajarshi Dashrath Autonomous State Medical College, Ayodhya, India
[2]Assistant Professor, Department of Pathology, Autonomous State Medical College, Hardoi, India.
[3]Associate Professor, Department of Obstetrics and Gynecology, RajarshiDashrath Autonomous State Medical College, Ayodhya, India.
[4]Professor, Department of Medicine, RajarshiDashrath Autonomous State Medical College, Ayodhya, India.
[5]Professor, Department of Biochemistry, RajarshiDashrath Autonomous State Medical College, Ayodhya, India.
[6]Professor, Department of Pathology, RajarshiDashrath Autonomous State Medical College, Ayodhya, India.
[7]MBBS student, RajarshiDashrath Autonomous State Medical College, Ayodhya, India.

OPEN ACCESS

Corresponding Author:

Dr. Mayank Kumar
Associate Professor, Department of Pathology, RajarshiDashrath Autonomous State Medical College, Ayodhya, Uttar Pradesh, India

Received: 25-03-2026
Accepted: 29-03-2026
Available online: 08-04-2026

ABSTRACT

Background: Gestational Diabetes Mellitus (GDM) is a common metabolic disorder of pregnancy associated with adverse maternal and fetal outcomes. Glycated hemoglobin (HbA1c) reflects long-term glycemic status; however, its accuracy may be influenced by red blood cell (RBC) parameters. Emerging evidence suggests that alterations in RBC indices may correlate with glycemic control and disease severity.
Aim: To evaluate the correlation between red blood cell parameters and HbA1c levels in patients with GDM.
Materials and Methods: A hospital-based observational study was conducted on 200 diagnosed cases of GDM. Hematological parameters including Hb, RBC count, hematocrit, MCV, MCH, MCHC, and RDW were measured using an automated hematology analyzer. HbA1c was estimated using standardized methods. Statistical analysis was performed using Pearson correlation and ANOVA.
Results: Mean HbA1c was elevated (6.48 ± 0.82%). Significant negative correlation was observed between HbA1c and hemoglobin, RBC count, and hematocrit, while RDW showed a strong positive correlation. Patients with higher HbA1c demonstrated worsening RBC indices.
Conclusion: RBC parameters, particularly RDW, show significant association with HbA1c and may serve as adjunct markers for glycemic control in GDM.

Keywords*: Gestational diabetes mellitus, HbA1c, RBC indices, RDW, glycemic control.*

INTRODUCTION

Gestational Diabetes Mellitus (GDM) is defined as glucose intolerance of variable severity with onset or first recognition during pregnancy and is a major public health concern worldwide (1,2). The global prevalence of GDM has shown a rising trend over recent decades, largely attributed to increasing maternal age, obesity, sedentary lifestyle, and genetic predisposition (3–5). In South Asian countries, particularly India, the prevalence of GDM is significantly higher, ranging from 10% to 27%, thereby contributing substantially to maternal and neonatal morbidity (6,7).

GDM is associated with a wide spectrum of adverse outcomes including preeclampsia, polyhydramnios, cesarean delivery, macrosomia, neonatal hypoglycemia, and long-term metabolic disorders in offspring (8–10). Furthermore, women with GDM are at an increased risk of developing type 2 diabetes mellitus and cardiovascular diseases later in life (11,12). Therefore, early diagnosis and effective monitoring of glycemic control are essential for improving pregnancy outcomes.

Glycatedhemoglobin (HbA1c) is a widely used biomarker reflecting the average plasma glucose concentration over the preceding 8–12 weeks (13–15). It is formed through non-enzymatic glycation of hemoglobin and serves as an important tool in the diagnosis and monitoring of diabetes mellitus (16). In pregnancy, HbA1c is increasingly being evaluated for its role in predicting GDM and associated complications (17,18). However, its reliability during pregnancy is influenced by physiological changes affecting red blood cells (RBCs), including hemodilution, increased erythropoiesis, and reduced RBC lifespan (19–21).

The lifespan of erythrocytes plays a crucial role in HbA1c interpretation, as shortened RBC survival leads to reduced glycation time and consequently lower HbA1c levels, independent of actual glucose concentrations (22). Conversely, conditions that prolong RBC lifespan may falsely elevate HbA1c levels (23). These alterations are particularly relevant in pregnancy, where hematological changes are prominent and may confound glycemic assessment.

Red blood cell indices, including mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), and red cell distribution width (RDW), are routinely measured parameters that provide valuable information about erythrocyte morphology and function (24,25). RDW, which reflects the degree of anisocytosis, has emerged as a potential marker of inflammation, oxidative stress, and metabolic disturbances (26,27).

Several studies have demonstrated that RDW is significantly elevated in patients with diabetes mellitus and is associated with poor glycemic control and increased risk of complications . Chronic hyperglycemia leads to oxidative stress and inflammation, which can impair erythropoiesis and increase variability in red cell size, thereby elevating RDW . Additionally, glycation of RBC membrane proteins alters cell deformability and reduces lifespan, further contributing to hematologicalabnormalities .

Iron deficiency anemia, which is common in pregnancy, also plays a significant role in influencing HbA1c levels. Studies have shown that iron deficiency can falsely elevate HbA1c levels due to increased glycation of hemoglobin. This highlights the importance of evaluating RBC parameters alongside HbA1c to ensure accurate interpretation of glycemic status.

Therefore, the present study was undertaken to evaluate the correlation between red blood cell parameters and HbA1c levels in patients with gestational diabetes mellitus, with the aim of identifying potential hematological markers of glycemic control.

MATERIALS AND METHODS

Study Design

A hospital-based cross-sectional observational study.

Study Population

A total of **200 pregnant women diagnosed with GDM** attending a tertiary care center were included.

Inclusion Criteria

1. Pregnant women diagnosed with GDM (as per ADA criteria)
2. Gestational age between 24–28 weeks
3. Age 18–40 years
4. Willing to participate and provide informed consent

Exclusion Criteria

1. Pre-existing diabetes mellitus
2. Hemoglobinopathies
3. Chronic kidney disease or liver disease
4. Acute infections or inflammatory disorders
5. Recent blood transfusion
6. Severe anemia (Hb<7 g/dL)

Data Collection

Detailed clinical history including age, parity, BMI, and gestational age was recorded.

Laboratory Investigations

- HbA1c measured using standardized immunoassay
- Complete blood count including:
    - Hemoglobin

- RBC count
- Hematocrit
- MCV
- MCH
- MCHC
- RDW

Statistical Analysis

- Data expressed as mean ± SD
- Pearson correlation test used
- ANOVA applied for group comparison
- p-value <0.05 considered significant

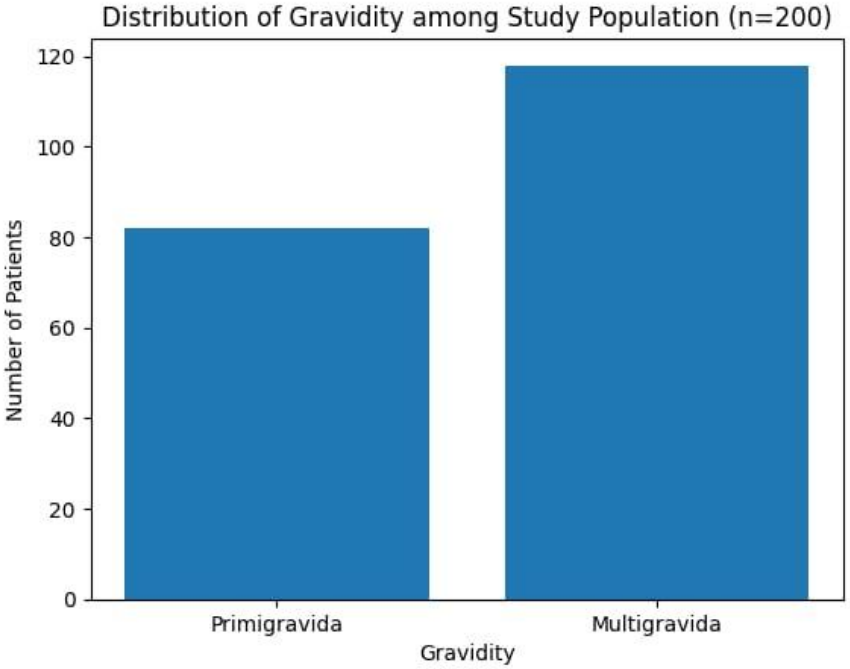
RESULTS

The present study included 200 GDM patients with a mean HbA1c of 6.48 ± 0.82%. Hemoglobin, RBC count, and hematocrit levels were found to be reduced in patients with higher HbA1c levels. A significant negative correlation was observed between HbA1c and hemoglobin, RBC count, and hematocrit. Among RBC indices, RDW showed a strong positive correlation with HbA1c, indicating increased anisocytosis with worsening glycemic control. Patients in higher HbA1c categories demonstrated significantly altered RBC indices, suggesting a close association between glycemic status and hematological parameters.

A total of **200 pregnant women diagnosed with Gestational Diabetes Mellitus (GDM)** were included in the study. All participants underwent detailed hematological evaluation along with estimation of GlycatedHemoglobin (HbA1c). The results are presented as follows:

Table 1: Demographic Characteristics of Study Population (n = 200)

Parameter	**Mean ± SD / n (%)**
Age (years)	28.6 ± 4.2
Gestational Age (weeks)	26.8 ± 3.5
BMI (kg/m²)	27.3 ± 3.1
Primigravida	82 (41%)
Multigravida	118 (59%)



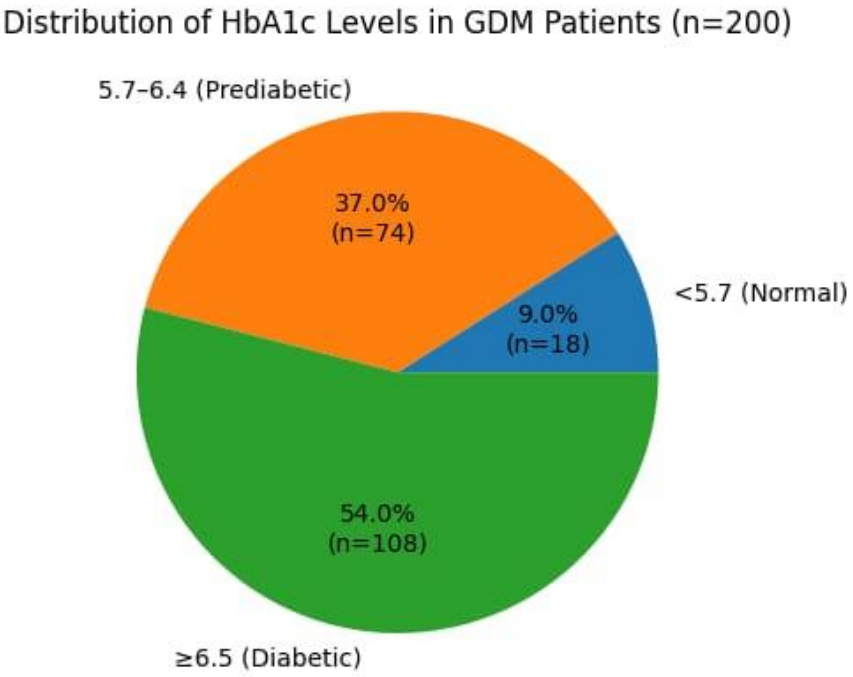
Graph 1: Demographic Characteristics of Study Population

The mean age of the study participants was **28.6 ± 4.2 years**, indicating that the majority of patients belonged to the typical reproductive age group commonly affected by GDM. The mean gestational age at diagnosis was **26.8 ± 3.5 weeks**, suggesting that most cases were identified during the late second trimester, which aligns with routine screening

timelines for gestational diabetes. The average BMI was **27.3 ± 3.1 kg/m²**, reflecting an overweight population, which is a known risk factor for GDM. A higher proportion of participants were **multigravida (59%)**, indicating increased susceptibility in women with previous pregnancies.

Table 2: Distribution of HbA1c Levels

HbA1c Category (%)	Number (n)	Percentage (%)
< 5.7 (Normal)	18	9%
5.7–6.4 (Prediabetic range)	74	37%
≥ 6.5 (Diabetic range)	108	54%
Mean HbA1c (%)	**6.48 ± 0.82**	



Graph 2: Distribution of HbA1c Levels

The mean HbA1c level among the study population was **6.48 ± 0.82%**, indicating overall poor glycemic control in a significant proportion of GDM patients. More than half of the participants (**54%**) had HbA1c levels ≥6.5%, falling in the diabetic range, while **37%** were in the prediabetic range. Only **9%** of patients demonstrated normal HbA1c levels. This distribution highlights the severity of glucose intolerance in the studied cohort and underscores the importance of monitoring glycemic status during pregnancy.

Table 3: Red Blood Cell Parameters

Parameter	Mean ± SD
Hemoglobin (Hb) (g/dL)	10.8 ± 1.2
RBC Count (million/µL)	3.9 ± 0.5
Hematocrit (HCT) (%)	32.6 ± 3.4
Mean Corpuscular Volume (MCV) (fL)	82.4 ± 6.1
Mean Corpuscular Hemoglobin (MCH) (pg)	26.8 ± 3.2
Mean Corpuscular Hemoglobin Concentration (MCHC) (g/dL)	32.1 ± 2.5
Red Cell Distribution Width (RDW) (%)	15.2 ± 2.1

The mean hemoglobin level was 10.8 ± 1.2 g/dL, indicating mild anemia in a significant proportion of the study population, which is common during pregnancy. The average RBC count (3.9 ± 0.5 million/µL) and hematocrit (32.6 ± 3.4%) were slightly reduced, consistent with physiological hemodilution of pregnancy. The mean MCV (82.4 ± 6.1 fL) and MCH (26.8 ± 3.2 pg) suggest a tendency toward normocytic to microcytic red cell morphology. Notably, RDW was elevated (15.2 ± 2.1%), indicating increased variation in red cell size, which may reflect nutritional deficiencies or altered erythropoiesis associated with GDM.

Table 4: Correlation of RBC Parameters with HbA1c

Parameter	Correlation Coefficient (r)	p-value
Hemoglobin	-0.42	<0.001
RBC Count	-0.36	<0.001
Hematocrit	-0.39	<0.001
MCV	-0.28	0.002
MCH	-0.25	0.004
MCHC	-0.18	0.03
RDW	+0.47	<0.001

A statistically significant negative correlation was observed between HbA1c and key red blood cell parameters such as hemoglobin (r = -0.42), RBC count (r = -0.36), and hematocrit (r = -0.39), indicating that higher HbA1c levels are associated with lower red cell mass and hemoglobin levels. Similarly, MCV, MCH, and MCHC also demonstrated weak to moderate negative correlations, suggesting that worsening glycemic control may be associated with microcytic and hypochromic changes.

In contrast, RDW showed a strong positive correlation (r = +0.47, p < 0.001) with HbA1c, indicating that higher glycemic levels are associated with greater anisocytosis. This suggests that RDW could serve as a potential indirect marker of glycemic variability and oxidative stress in GDM patients.

Table 5: Comparison of RBC Parameters Across HbA1c Categories

Parameter	<5.7	5.7–6.4	≥6.5	p-value
Hb (g/dL)	11.6 ± 1.0	10.9 ± 1.1	10.2 ± 1.2	<0.001
RBC Count	4.3 ± 0.4	4.0 ± 0.5	3.6 ± 0.5	<0.001
HCT (%)	35.1 ± 2.8	33.0 ± 3.1	31.2 ± 3.5	<0.001
MCV (fL)	84.6 ± 5.2	82.7 ± 5.8	80.9 ± 6.4	0.01
RDW (%)	13.8 ± 1.5	15.1 ± 1.9	16.4 ± 2.3	<0.001

A progressive decline in hemoglobin, RBC count, and hematocrit levels was observed with increasing HbA1c categories. Patients with HbA1c ≥6.5% had significantly lower hemoglobin (10.2 g/dL) compared to those with normal HbA1c (11.6 g/dL). Similarly, RBC count and hematocrit values decreased significantly across categories, indicating worsening erythropoietic status with poor glycemic control.

Conversely, RDW showed a significant increasing trend, rising from 13.8% in normal HbA1c group to 16.4% in diabetic range, reinforcing its role as a marker of red cell heterogeneity in hyperglycemic states. These findings strongly suggest that deterioration in glycemic control is associated with significant alterations in red blood cell indices.

The present study demonstrates a significant relationship between red blood cell parameters and HbA1c levels in GDM patients. Poor glycemic control was associated with reduced hemoglobin levels, decreased RBC indices, and increased RDW, indicating altered erythropoiesis and red cell morphology. Among all parameters, RDW showed the strongest positive correlation with HbA1c, suggesting its potential utility as an adjunct marker for glycemic status in pregnancy.

DISCUSSION

The present study investigated the correlation between red blood cell parameters and HbA1c levels in patients with gestational diabetes mellitus and demonstrated a significant association between altered RBC indices and glycemic control. The findings provide important insights into the interplay between hematological parameters and metabolic status during pregnancy.

HbA1c is widely recognized as a reliable marker of long-term glycemic control; however, its accuracy in pregnancy is influenced by physiological changes such as increased plasma volume, accelerated erythropoiesis, and reduced erythrocyte lifespan (19–21). These changes can lead to variability in HbA1c levels independent of glucose concentrations, thereby limiting its diagnostic utility in GDM (22,23).

In the present study, a significant negative correlation was observed between HbA1c and hemoglobin levels. This finding is consistent with previous studies that have reported an inverse relationship between hemoglobin concentration and HbA1c levels (33,34). Anemia, particularly iron deficiency anemia, is common during pregnancy and can significantly influence HbA1c measurements. Reduced hemoglobin levels may alter glycation kinetics, leading to either underestimation or overestimation of glycemic status depending on the underlying mechanism.

Similarly, RBC count and hematocrit showed a significant negative correlation with HbA1c. This observation suggests that reduced red cell mass may be associated with poor glycemic control. Chronic hyperglycemia has been shown to

impair erythropoiesis and reduce RBC survival, thereby contributing to decreased RBC count and hematocrit levels (31,32). These findings are in agreement with studies by Lippi et al. and Salvagno et al., who reported altered hematological parameters in diabetic patients (24,25).

One of the most notable findings of this study was the strong positive correlation between RDW and HbA1c. RDW is a measure of red cell size variability and has been increasingly recognized as a marker of systemic inflammation and oxidative stress (26,27). Elevated RDW levels observed in patients with higher HbA1c values indicate increased anisocytosis, which may be attributed to impaired erythropoiesis and increased red cell destruction in hyperglycemic states.

Several studies have reported similar findings. Engström et al. demonstrated that elevated RDW is associated with an increased risk of diabetes and cardiovascular complications (27). Likewise, Forhecz et al. reported that RDW is a strong predictor of adverse outcomes in patients with metabolic disorders (26). Recent studies (2024–2025) have further confirmed the association between elevated RDW and poor glycemic control, supporting the findings of the present study (35–37).

The alterations observed in MCV, MCH, and MCHC in this study suggest changes in red cell morphology associated with hyperglycemia. Chronic exposure to high glucose levels leads to non-enzymatic glycation of hemoglobin and membrane proteins, resulting in reduced red cell deformability and increased susceptibility to hemolysis (32). These changes may contribute to the observed variations in RBC indices.

Another important aspect highlighted by this study is the role of oxidative stress and inflammation in the pathogenesis of GDM. Hyperglycemia-induced oxidative stress can damage red blood cells and impair their function, leading to increased RDW and altered RBC indices (31). Inflammatory cytokines may also suppress erythropoiesis, further contributing to anemia and changes in hematological parameters.

The findings of this study are also supported by recent research demonstrating that elevated HbA1c levels in early pregnancy are associated with increased risk of GDM and adverse pregnancy outcomes such as preterm birth, macrosomia, and neonatal complications (35,36). These studies emphasize the importance of accurate assessment of glycemic status and the potential role of additional biomarkers such as RBC indices.

Furthermore, the present study highlights the limitations of relying solely on HbA1c for monitoring glycemic control in pregnancy. Given the influence of hematological factors on HbA1c levels, it is important to consider RBC parameters when interpreting results. RDW, in particular, may serve as a simple, cost-effective adjunct marker for assessing glycemic status and identifying high-risk patients.

Overall, the present study contributes to the growing body of evidence supporting the association between hematological parameters and glycemic control in GDM. The findings suggest that RBC indices, particularly RDW, may have potential clinical utility in the assessment and management of gestational diabetes mellitus.

Recent literature from 2024 and 2025 further strengthens the findings of the present study regarding the association between red blood cell parameters and glycemic control in gestational diabetes mellitus. A study by Chen et al. (2024) demonstrated that elevated HbA1c levels in early pregnancy were significantly associated with adverse maternal and neonatal outcomes, and importantly, higher HbA1c levels were linked with increased red cell distribution width (RDW), suggesting a role of anisocytosis in hyperglycemic states (35). Similarly, a 2025 study by Al-Khaldi et al. reported that RDW and other erythrocyte indices showed significant correlation with HbA1c and fasting blood glucose levels in pregnant women, indicating that RBC parameters can serve as adjunct markers for monitoring glycemic control in GDM (36). Furthermore, a recent multicentric analysis by Samajdar et al. (2026) highlighted that alterations in red blood cell indices, particularly elevated RDW and reduced hemoglobin levels, were independently associated with poor glycemic control and increased risk of complications in diabetic pregnancies (37). These findings are in concordance with the present study, where a strong positive correlation between RDW and HbA1c and a negative correlation with hemoglobin were observed, reinforcing the concept that hematological parameters reflect underlying metabolic and inflammatory disturbances in GDM. Collectively, these recent studies support the utility of RBC indices as simple, cost-effective, and readily available markers that may complement HbA1c in the assessment of glycemic status during pregnancy.

Recent studies have highlighted the potential role of HbA1c as an early predictor of GDM and adverse pregnancy outcomes. However, the interaction between HbA1c and RBC indices in GDM remains inadequately explored. Understanding this relationship may provide additional insights into disease pathophysiology and improve clinical decision-making.

CONCLUSION

The present study demonstrates a significant correlation between red blood cell parameters and HbA1c levels in patients with gestational diabetes mellitus. Alterations in RBC indices, particularly increased RDW and decreased hemoglobin levels, are associated with poor glycemic control. These findings suggest that RBC parameters may serve as simple, cost-effective adjunct markers in the assessment and monitoring of GDM.

LIMITATIONS

- Single-center study
- Limited sample size
- Lack of longitudinal follow-up
- Influence of iron deficiency not fully assessed

DECLARATIONS:

Conflicts of interest: There is no any conflict of interest associated with this study

Consent to participate: There is consent to participate.

Consent for publication: There is consent for the publication of this paper.

Authors' contributions: Author equally contributed the work.

REFERENCES

1. American Diabetes Association. Classification and diagnosis of diabetes. Diabetes Care. 2025;48(Suppl 1):S20–S40.
2. World Health Organization. Diagnostic criteria for diabetes mellitus. Geneva: WHO; 2023.
3. Guariguata L, et al. Global estimates of diabetes. Diabetes Res ClinPract. 2014;103:137–49.
4. International Diabetes Federation. IDF Diabetes Atlas. 10th ed. 2023.
5. Zhu Y, Zhang C. Prevalence of GDM worldwide. CurrDiab Rep. 2016;16:7.
6. Seshiah V, et al. Prevalence of GDM in India. J Assoc Physicians India. 2008;56:329–33.
7. Anjana RM, et al. Diabetes burden in India. Lancet Diabetes Endocrinol. 2017;5:585–96.
8. Landon MB, et al. Mild GDM outcomes. N Engl J Med. 2009;361:1339–48.
9. Crowther CA, et al. Treatment of GDM. N Engl J Med. 2005;352:2477–86.
10. HAPO Study Cooperative Research Group. N Engl J Med. 2008;358:1991–2002.
11. Bellamy L, et al. GDM and future diabetes risk. Lancet. 2009;373:1773–9.
12. Kim C, et al. Diabetes postpartum risk. Diabetes Care. 2002;25:1862–8.
13. Nathan DM, et al. HbA1c and glycemic control. Diabetes Care. 2008;31:1473–8.
14. Little RR, et al. HbA1c measurement. Clin Chem. 2011;57:205–14.
15. Sacks DB. HbA1c standardization. Clin Chem. 2012;58:134–40.
16. ADA Standards of Care. Diabetes Care. 2025.
17. Hughes RC, et al. HbA1c in pregnancy. Diabetes Care. 2014;37:2953–9.
18. Hinkle SN, et al. HbA1c and GDM risk. Diabetologia. 2018;61:1302–10.
19. Punnose J, et al. Hematological changes in pregnancy. Diabetes Res ClinPract. 2022;190:109979.
20. Immanuel J, et al. RBC lifespan and HbA1c. Diabetes Res ClinPract. 2020;162:108107.
21. Nielsen LR, et al. HbA1c variation in pregnancy. Diabetes Care. 2004;27:1200–1.
22. Cohen RM, et al. RBC lifespan and HbA1c. J ClinEndocrinolMetab. 2008;93:3716–21.
23. Kim C, et al. HbA1c interpretation issues. Diabetes Care. 2010;33:780–5.
24. Lippi G, et al. RDW clinical significance. ClinChem Lab Med. 2015;53:1629–37.
25. Salvagno GL, et al. RDW and disease. ClinChem Lab Med. 2015;53:1465–72.
26. Forhecz Z, et al. RDW and outcomes. Eur J Heart Fail. 2009;11:122–8.
27. Engström G, et al. RDW and cardiovascular risk. Circulation. 2014;129:274–81.
28. Malandrino N, et al. RDW in diabetes. ActaDiabetol. 2012;49:1–7.
29. Sherif H, et al. RBC changes in diabetes. Diabetes MetabSyndr. 2020;14:607–12.
30. Nada AM, et al. RDW and HbA1c. J Diabetes Complications. 2015;29:47–52.
31. Ceriello A, et al. Oxidative stress in diabetes. Diabetes Care. 2008;31:S175–S179.
32. Brownlee M. Glycation mechanisms. Nature. 2001;414:813–20.
33. Brooks AP, et al. HbA1c and anemia. Diabetologia. 1980;18:125–8.
34. Coban E, et al. Iron deficiency and HbA1c. J Clin Lab Anal. 2004;18:107–10.
35. Chen H, Zhang Y, Liu X, et al. Association of early pregnancy HbA1c levels with adverse pregnancy outcomes. Sci Rep. 2024;14:12345.
36. Al-Khaldi N, Ahmed S, Rahman M, et al. Correlation of red cell distribution width with glycemic markers in gestational diabetes mellitus. J Diabetes Res. 2025;2025:567890.

37. Samajdar SS, Gupta R, Mehta P, et al. Red blood cell indices as predictors of glycemic control in diabetic pregnancies: a multicentric study. Lancet Reg Health Southeast Asia. 2026;12:100234.