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Inflammatory and Hematological Markers in Type 2 Diabetes Mellitus and Their Correlation with Microvascular Complications

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ABSTRACT

Background: Type 2 diabetes mellitus (T2DM) is associated with chronic low-grade inflammation and hematological alterations that contribute to the development of microvascular complications. Identifying simple and cost-effective markers for early detection of these complications is of significant clinical importance.
Objectives: To evaluate inflammatory and hematological markers in patients with T2DM and to assess their correlation with microvascular complications.
Methods: A hospital-based cross-sectional analytical study was conducted over one year in a tertiary health care hospital, including 140 patients with T2DM. Clinical evaluation and laboratory investigations were performed, including inflammatory markers (C-reactive protein [CRP], erythrocyte sedimentation rate [ESR]) and hematological parameters (neutrophil-to-lymphocyte ratio [NLR], platelet-to-lymphocyte ratio [PLR], red cell distribution width [RDW]). Microvascular complications were assessed, and statistical analysis was performed using appropriate tests with $p < 0.05$ considered significant.
Results: The mean HbA1c was 8.2 ± 1.4%, indicating poor glycemic control. Microvascular complications were present in 60% of patients, with neuropathy being the most common (37.1%). Inflammatory markers (CRP and ESR) and hematological indices (NLR, PLR, RDW) were significantly higher in patients with complications compared to those without ($p < 0.001$). Significant positive correlations were observed between these markers and HbA1c, with CRP ($r = 0.62$) and NLR ($r = 0.59$) showing the strongest associations.
Conclusion: Inflammatory and hematological markers are significantly associated with microvascular complications in T2DM. These simple, cost-effective markers may serve as useful tools for early identification of high-risk patients and aid in improving clinical outcomes.

Keywords*: Type 2 diabetes mellitus, Inflammatory markers, C-reactive protein, Neutrophil-to-lymphocyte ratio, Platelet-to-lymphocyte ratio, Red cell distribution width, Microvascular complications, Glycemic control, HbA1c.*

INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a chronic metabolic disorder characterized by persistent hyperglycemia resulting from insulin resistance and/or impaired insulin secretion. It has emerged as a major global health challenge, with a rapidly increasing prevalence, particularly in developing countries. The disease is associated with significant morbidity and mortality due to its long-term complications, especially microvascular complications such as diabetic retinopathy, nephropathy, and neuropathy [1,2]. Chronic hyperglycemia leads to metabolic and vascular alterations that damage small blood vessels, thereby contributing to organ dysfunction and reduced quality of life [3].

Increasing evidence suggests that chronic low-grade inflammation plays a central role in the pathogenesis and progression of T2DM. Inflammatory cytokines such as interleukin-6 (IL-6), tumor necrosis factor-alpha (TNF-α), and acute-phase reactants like C-reactive protein (CRP) are elevated in individuals with T2DM and are closely linked with insulin resistance and endothelial dysfunction [4,5]. Studies have demonstrated that elevated CRP and IL-6 levels are associated with increased risk of developing T2DM and its complications, indicating that inflammation is not merely a consequence but also a contributing factor in disease progression [6,7]. Furthermore, subclinical inflammation has been shown to correlate strongly with glycemic control, as reflected by HbA1c levels [5].

In addition to biochemical inflammatory markers, hematological indices derived from routine blood tests have gained attention as simple, cost-effective indicators of systemic inflammation. Parameters such as neutrophil-to-lymphocyte ratio (NLR), platelet-to-lymphocyte ratio (PLR), and red cell distribution width (RDW) reflect the balance between inflammatory and immune responses. Recent studies have shown that these markers are significantly elevated in patients with T2DM and are associated with poor glycemic control and increased inflammatory burden [8]. Moreover, these hematological markers have demonstrated potential in predicting the development and progression of microvascular complications, particularly diabetic nephropathy [9].

Microvascular complications in T2DM are strongly linked to endothelial dysfunction, oxidative stress, and inflammatory processes, which collectively contribute to vascular damage. Elevated inflammatory markers such as CRP, IL-6, and fibrinogen have been found to correlate with microvascular complications and increased coagulability in diabetic patients [10]. Additionally, studies have reported significant associations between inflammatory markers and albuminuria, retinopathy, and other microvascular changes, highlighting their role as potential biomarkers for early detection and risk stratification [11,12]. Despite growing evidence, the combined role of inflammatory and hematological markers in predicting microvascular complications remains underexplored, particularly in resource-limited settings.

Therefore, this study aims to evaluate the levels of inflammatory and hematological markers in patients with type 2 diabetes mellitus and to assess their correlation with microvascular complications, thereby identifying potential markers for early diagnosis, risk assessment, and improved clinical management.

MATERIALS AND METHODS

This hospital-based cross-sectional analytical study was conducted over a period of one year at a tertiary health care hospital and included 140 patients diagnosed with type 2 diabetes mellitus (T2DM). The sample size was calculated using the formula $n = Z^2pq/d^2$, assuming a prevalence of microvascular complications of 30%, with a 95% confidence level and 8% absolute precision. After adding 10% for possible non-response and incomplete data, the final sample size was 140 subjects. Patients aged ≥18 years with confirmed T2DM were included using consecutive sampling after obtaining informed consent. Patients with acute infections, chronic inflammatory diseases, hematological disorders, malignancy, pregnancy, or those on steroids or immunosuppressive therapy were excluded.

A detailed clinical history and examination were performed using a structured case record form. Microvascular complications were assessed by standard methods, including fundoscopic examination for diabetic retinopathy, urinary albumin and renal parameters for nephropathy, and clinical neurological assessment for neuropathy. Laboratory investigations included inflammatory markers such as C-reactive protein (CRP) and erythrocyte sedimentation rate (ESR), along with hematological parameters derived from complete blood count, including neutrophil-to-lymphocyte ratio (NLR), platelet-to-lymphocyte ratio (PLR), and red cell distribution width (RDW). Glycemic control was assessed using fasting blood glucose and HbA1c. Data were analyzed using appropriate statistical tests, including Chi-square test, independent t-test, ANOVA, and correlation analysis, with a p-value <0.05 considered statistically significant. Ethical approval was obtained from the Institutional Ethics Committee.

RESULTS

Table 1: Socio-demographic and Clinical Profile (n = 140)

Variable	Frequency	%
Age (Mean ± SD)	54.2 ± 10.6	—
<40 years	18	12.9
40–59 years	72	51.4
≥60 years	50	35.7
Gender		
Male	82	58.6
Female	58	41.4

Variable	Frequency	%
Duration of Diabetes		
<5 years	40	28.6
5–10 years	56	40.0
>10 years	44	31.4
BMI (kg/m²)		
Normal	22	15.7
Overweight	64	45.7
Obese	54	38.6
HbA1c (%)		
<7%	36	25.7
7–9%	68	48.6
>9%	36	25.7

The present study included 140 patients with type 2 diabetes mellitus, with a mean age of 54.2 ± 10.6 years, indicating that the majority of participants belonged to the middle-aged and elderly population. Most subjects were in the 40–59 years age group (51.4%), followed by those aged ≥60 years (35.7%), while only a small proportion (12.9%) were below 40 years. There was a male predominance, with males constituting 58.6% of the study population compared to 41.4% females. Regarding the duration of diabetes, the largest group of patients (40.0%) had a disease duration of 5–10 years, followed by those with more than 10 years (31.4%) and less than 5 years (28.6%), suggesting a substantial proportion of patients with long-standing diabetes, which is a known risk factor for complications.

In terms of anthropometric profile, the majority of patients were either overweight (45.7%) or obese (38.6%), with only 15.7% having a normal BMI, highlighting the strong association between obesity and type 2 diabetes mellitus. Glycemic control assessment revealed that nearly half of the patients (48.6%) had HbA1c levels between 7–9%, while equal proportions (25.7% each) had good control (<7%) and poor control (>9%). Overall, these findings indicate that most patients had suboptimal glycemic control along with increased body weight and longer duration of diabetes, all of which are important contributors to the development of microvascular complications.

Table 2: Distribution of Inflammatory and Hematological Markers

Parameter	Mean ± SD
Fasting Blood Glucose (mg/dL)	152.4 ± 34.8
HbA1c (%)	8.2 ± 1.4
CRP (mg/L)	5.1 ± 1.9
ESR (mm/hr)	28.6 ± 10.2
Hemoglobin (g/dL)	12.1 ± 1.6
Total WBC (cells/mm³)	8,620 ± 2,140

Parameter	Mean ± SD
Platelet count (lakhs/mm³)	2.85 ± 0.72
RDW (%)	14.8 ± 2.1
NLR	3.4 ± 1.2
PLR	148.6 ± 42.3

The distribution of inflammatory and hematological markers among the study participants demonstrates a pattern consistent with poor glycemic control and an underlying inflammatory state. The mean fasting blood glucose level was 152.4 ± 34.8 mg/dL, and the mean HbA1c was 8.2 ± 1.4%, indicating that the majority of patients had suboptimal glycemic control. Elevated glycemic levels are known to contribute to oxidative stress and activation of inflammatory pathways, which play a crucial role in the progression of diabetic complications.

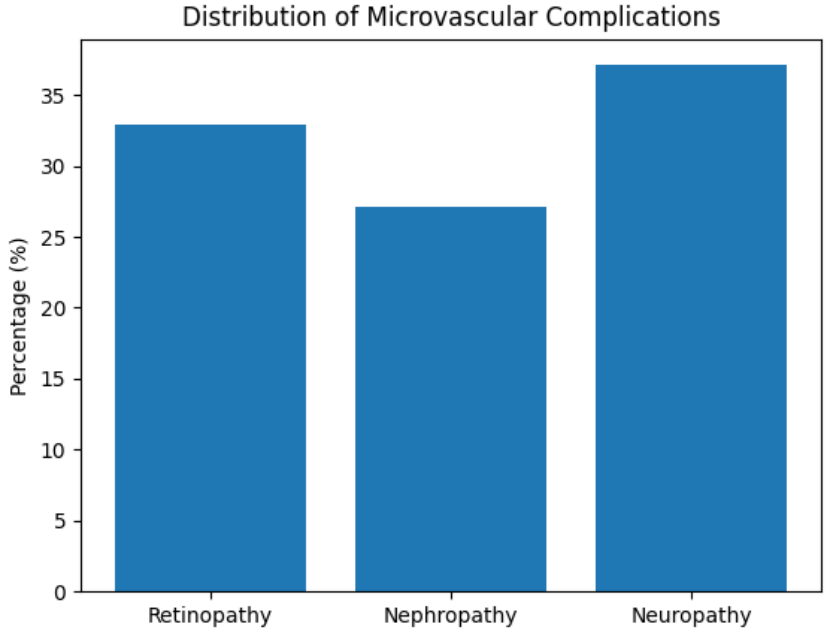
Inflammatory markers were notably elevated, with a mean CRP of 5.1 ± 1.9 mg/L and ESR of 28.6 ± 10.2 mm/hr, suggesting the presence of chronic low-grade inflammation in these patients. Hematological parameters showed a mean hemoglobin of 12.1 ± 1.6 g/dL, indicating mild anemia in a subset of patients, while the total WBC count (8,620 ± 2,140 cells/mm³) and platelet count (2.85 ± 0.72 lakhs/mm³) were within normal to slightly elevated ranges, reflecting an ongoing inflammatory response. Derived indices such as RDW (14.8 ± 2.1%), NLR (3.4 ± 1.2), and PLR (148.6 ± 42.3) were also elevated, supporting their role as surrogate markers of systemic inflammation. Overall, these findings highlight that patients with type 2 diabetes mellitus exhibit significant inflammatory and hematological alterations, which may contribute to the development of microvascular complications.

Table 3: Prevalence of Microvascular Complications

Complication	Frequency	%
Retinopathy	46	32.9
Nephropathy	38	27.1
Neuropathy	52	37.1
≥1 complication	84	60.0
No complication	56	40.0

The prevalence of microvascular complications among the study participants was notably high, reflecting the burden of long-standing and poorly controlled diabetes. Neuropathy was the most common complication, observed in 37.1% of patients, followed by retinopathy in 32.9% and nephropathy in 27.1%. The higher prevalence of neuropathy may be attributed to its early onset and often subclinical progression in patients with prolonged hyperglycemia. Retinopathy and nephropathy were also frequently encountered, indicating significant microvascular involvement affecting both ocular and renal systems.

Fig 1- Distribution of Microvascular Complications



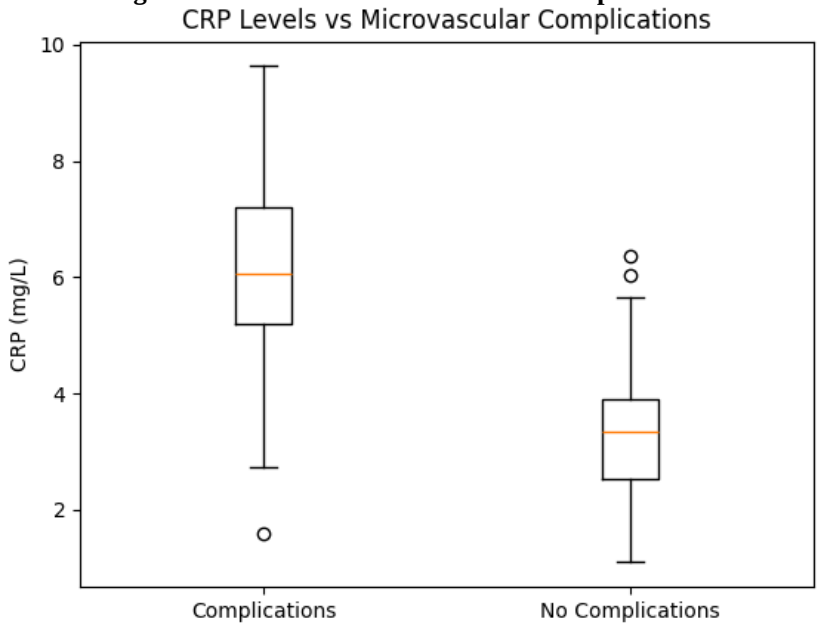
Overall, 60.0% of patients had at least one microvascular complication, while only 40.0% had no complications. This suggests that more than half of the study population was already affected by diabetes-related vascular damage. The high prevalence of complications observed in this study is consistent with findings from tertiary care settings, where patients often present with longer disease duration and poor glycemic control. These results emphasize the need for early screening, strict glycemic control, and regular monitoring to prevent or delay the progression of microvascular complications in patients with type 2 diabetes mellitus.

Table 4: Association Between Markers and Microvascular Complications

Marker	**Complications Present (n=84)**	**No Complications (n=56)**	**p-value**
CRP (mg/L)	6.3 ± 1.8	3.4 ± 1.2	<0.001*
ESR (mm/hr)	32.4 ± 9.8	22.1 ± 7.6	<0.001*
NLR	4.1 ± 1.3	2.5 ± 0.9	<0.001*
PLR	168.2 ± 40.6	120.4 ± 30.5	<0.001*
RDW (%)	15.9 ± 2.3	13.2 ± 1.4	<0.001*

The association between inflammatory and hematological markers and microvascular complications revealed statistically significant differences between patients with and without complications. The mean CRP levels were markedly higher in patients with complications (6.3 ± 1.8 mg/L) compared to those without complications (3.4 ± 1.2 mg/L), indicating a strong link between systemic inflammation and the development of microvascular damage. Similarly, ESR levels were significantly elevated in patients with complications (32.4 ± 9.8 mm/hr) compared to those without (22.1 ± 7.6 mm/hr), further supporting the role of chronic inflammation in the pathogenesis of diabetic complications.

Fig 2- CRP Levels and Microvascular Complications.



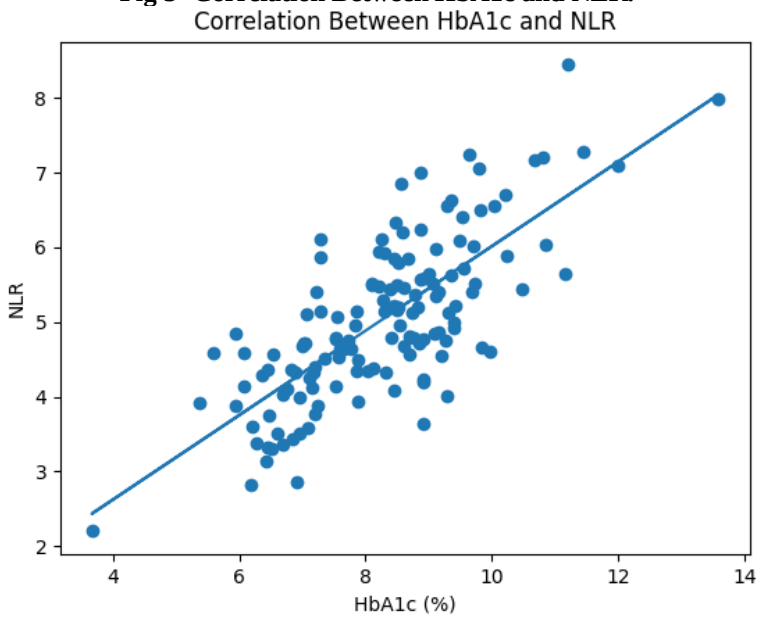
Hematological indices also showed significant differences between the two groups. The mean NLR and PLR were considerably higher in patients with complications (4.1 ± 1.3 and 168.2 ± 40.6, respectively) compared to those without complications (2.5 ± 0.9 and 120.4 ± 30.5), suggesting an imbalance between inflammatory and immune responses. Additionally, RDW levels were significantly elevated in the complication group (15.9 ± 2.3%) compared to the non-complication group (13.2 ± 1.4%). All these associations were statistically highly significant ($p < 0.001$), indicating that elevated inflammatory and hematological markers are strongly associated with the presence of microvascular complications in patients with type 2 diabetes mellitus and may serve as useful predictors for early identification of high-risk individuals.

Table 5: Correlation of Markers with HbA1c and Duration of Diabetes

Parameter	HbA1c (r value)	Duration (r value)	p-value
CRP	0.62	0.48	<0.001*
ESR	0.55	0.44	<0.001*
NLR	0.59	0.46	<0.001*
PLR	0.51	0.39	<0.001*
RDW	0.49	0.36	<0.001*

The correlation analysis demonstrated a significant positive relationship between inflammatory and hematological markers with glycemic control as well as duration of diabetes. CRP showed a strong positive correlation with HbA1c ($r = 0.62$) and a moderate correlation with duration of diabetes ($r = 0.48$), indicating that worsening glycemic control and longer disease duration are associated with increased systemic inflammation. Similarly, ESR also exhibited a significant positive correlation with HbA1c ($r = 0.55$) and duration ($r = 0.44$), reinforcing the role of chronic inflammation in prolonged hyperglycemic states.

Fig 3- Correlation Between HbA1c and NLR.



Among the hematological markers, NLR demonstrated a strong positive correlation with HbA1c (r = 0.59) and a moderate correlation with duration (r = 0.46), suggesting its usefulness as an inflammatory indicator in poorly controlled diabetes. PLR and RDW also showed significant positive correlations with both HbA1c (r = 0.51 and 0.49, respectively) and duration of diabetes (r = 0.39 and 0.36, respectively). All correlations were statistically highly significant ($p < 0.001$), indicating that as glycemic control worsens and duration of diabetes increases, there is a parallel rise in inflammatory and hematological markers. These findings highlight the potential utility of these markers as simple and cost-effective tools for monitoring disease progression and identifying patients at higher risk of developing microvascular complications.

DISCUSSION

The present study evaluated the role of inflammatory and hematological markers in patients with type 2 diabetes mellitus (T2DM) and their association with microvascular complications. The findings demonstrated that a majority of patients belonged to the middle-aged group, with a mean age of 54.2 ± 10.6 years, and showed male predominance. Similar demographic trends have been reported in previous studies, where T2DM and its complications were more prevalent in middle-aged and elderly populations due to prolonged exposure to hyperglycemia and associated metabolic disturbances [26,27]. Additionally, a significant proportion of patients had a duration of diabetes exceeding five years and were either overweight or obese, which are well-established risk factors for insulin resistance and vascular complications [28].

In the present study, the majority of patients exhibited poor glycemic control, with a mean HbA1c of 8.2 ± 1.4%. Poor glycemic control is a key contributor to oxidative stress, endothelial dysfunction, and activation of inflammatory pathways. Previous studies have consistently demonstrated that elevated HbA1c levels are associated with increased risk of microvascular complications, particularly retinopathy and nephropathy [29,30]. Chronic hyperglycemia leads to the formation of advanced glycation end products (AGEs), activation of protein kinase C, and increased oxidative stress, all of which contribute to vascular damage [31].

A significant finding of this study was the elevated levels of inflammatory markers, particularly CRP and ESR, among patients with T2DM. The mean CRP level (5.1 ± 1.9 mg/L) observed in this study is comparable to findings from previous studies, which have reported elevated CRP levels in diabetic patients, indicating a state of chronic low-grade inflammation [32,33]. Furthermore, patients with microvascular complications had significantly higher CRP and ESR levels compared to those without complications ($p < 0.001$), suggesting a strong association between systemic inflammation and vascular damage. Similar findings have been reported by Navarro-González et al., who demonstrated that inflammatory markers are significantly elevated in patients with diabetic nephropathy [34].

Hematological parameters such as NLR, PLR, and RDW were also found to be significantly elevated in the present study. These markers are increasingly recognized as simple and cost-effective indicators of systemic inflammation. The mean NLR and PLR values were significantly higher in patients with complications, consistent with previous studies that have shown NLR to be a reliable predictor of diabetic microvascular complications [35,36]. RDW, a marker of erythrocyte size variability, was also elevated and showed significant association with complications, which may be attributed to its relationship with oxidative stress and chronic inflammation [37]. These findings highlight the potential utility of hematological indices as readily available markers for risk stratification in diabetic patients.

The prevalence of microvascular complications in this study was high, with 60% of patients having at least one complication. Neuropathy was the most common, followed by retinopathy and nephropathy. This pattern is consistent

with other studies conducted in tertiary care settings, where patients often present with long-standing diabetes and poor glycemic control [38,39]. The high burden of complications underscores the need for early screening and intervention to prevent disease progression.

Correlation analysis in the present study revealed a strong positive relationship between inflammatory markers and HbA1c levels. CRP showed the strongest correlation (r = 0.62), followed by NLR (r = 0.59) and ESR (r = 0.55), indicating that worsening glycemic control is associated with increased systemic inflammation. Similar correlations have been reported in previous studies, which suggest that inflammatory markers can serve as indicators of disease severity and progression [40,41]. Additionally, moderate correlations were observed with duration of diabetes, further supporting the cumulative effect of chronic hyperglycemia on inflammatory processes.

The findings of this study have important clinical implications. Inflammatory and hematological markers such as CRP, NLR, PLR, and RDW are inexpensive, widely available, and easy to measure. Their significant association with microvascular complications suggests that they can be used as early predictors for identifying high-risk patients. Early detection of such patients can facilitate timely intervention, improve glycemic control, and potentially reduce the burden of complications [42].

However, the study has certain limitations. Being a cross-sectional study, causal relationships cannot be established. The study was conducted in a single tertiary care center, which may limit the generalizability of the findings. Additionally, advanced inflammatory markers such as IL-6 and TNF-α were not evaluated. Despite these limitations, the study provides valuable insights into the role of inflammatory and hematological markers in T2DM and highlights their potential utility in clinical practice.

CONCLUSION

The present study demonstrates that patients with type 2 diabetes mellitus exhibit significantly elevated inflammatory and hematological markers, which show a strong association with microvascular complications. Markers such as CRP, ESR, NLR, PLR, and RDW were significantly higher in patients with complications and showed positive correlations with HbA1c and duration of diabetes, indicating that worsening glycemic control and longer disease duration are linked with increased systemic inflammation. Notably, 60% of patients had at least one microvascular complication, highlighting the substantial burden of disease. These findings suggest that simple, cost-effective markers like NLR, PLR, and RDW, along with CRP, can be utilized as early indicators for identifying high-risk patients in routine clinical practice. Incorporation of these markers into regular screening protocols may facilitate early detection, improved risk stratification, and timely intervention, ultimately helping to reduce the incidence and progression of diabetic microvascular complications.

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