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Comparison of Haematological Profile and CBC-Derived Indices Associated with Inflammation Across Stages of Chronic Kidney Disease: A Cross-Sectional Study

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ABSTRACT

Background: Chronic kidney disease (CKD) is associated with progressive biochemical and haematological changes resulting from declining renal function. Routine haematological parameters and complete blood count (CBC)-derived indices associated with inflammation may provide useful information regarding disease severity. This study evaluated the association of haematological parameters and CBC-derived indices associated with inflammation across different stages of CKD. **Methods:** A hospital-based cross-sectional analytical study was conducted among 125 adult patients with CKD stages 3b–5 attending a tertiary care hospital between May 2024 to September 2025. Haematological parameters, including haemoglobin, red blood cell count, haematocrit, red cell distribution width (RDW), mean platelet volume (MPV) and neutrophil-to-lymphocyte ratio (NLR), were analysed and compared across CKD stages. Continuous variables were compared using one-way analysis of variance, while categorical variables were analysed using the Chi-square test. **Results:** Haemoglobin concentration, red blood cell count and haematocrit declined significantly with advancing CKD stage (all P<0.001). Mean corpuscular volume increased, whereas mean corpuscular haemoglobin decreased significantly across CKD stages (P<0.001). RDW, MPV and NLR increased significantly with worsening renal function, while platelet count and total leukocyte count remained comparable. Anaemia was the most common haematological abnormality, followed by elevated RDW and NLR. The proportions of anaemia, elevated RDW, elevated NLR and thrombocytopenia increased significantly from Stage 3b to Stage 5 CKD. **Conclusion:** In this cross-sectional study, advanced CKD stages were associated with lower erythroid parameters and higher CBC-derived indices associated with inflammation. These routinely available haematological measures may provide useful adjunctive information for clinical assessment and monitoring across CKD.

KEYWORDS: Chronic kidney disease, Haematological indices, Correlation studies

INTRODUCTION

Chronic kidney disease (CKD) is characterised by a progressive decline in renal function resulting from persistent structural or functional abnormalities of the kidneys for at least three months. As renal function declines, impaired excretion of metabolic waste products and reduced endocrine activity give rise to several biochemical and haematological abnormalities that contribute to disease progression and adverse clinical outcomes[1, 2].

A progressive reduction in glomerular filtration rate (GFR) leads to the accumulation of nitrogenous waste products, reflected by elevated serum creatinine and blood urea concentrations, which are routinely used to assess renal function and monitor disease progression[1, 3]. Disturbances in electrolyte balance, acid-base

homeostasis, mineral metabolism and endocrine function further contribute to the systemic manifestations of the disease[2, 4].

Among the haematological abnormalities, anaemia is the most frequent complication of CKD and is primarily attributed to inadequate erythropoietin production by the diseased kidneys. Functional iron deficiency, chronic inflammation, shortened erythrocyte survival, nutritional deficiencies and the accumulation of uraemic toxins further aggravate anaemia as kidney function declines [5, 6]. Anaemia in CKD has been associated with reduced exercise tolerance, impaired quality of life, cardiovascular complications and increased mortality[5].

Chronic kidney disease is also accompanied by persistent low-grade inflammation and immune dysregulation that influence leukocyte and platelet indices. Complete blood count (CBC)-derived indices associated with inflammation such as the neutrophil-to-lymphocyte ratio (NLR), red cell distribution width (RDW) and mean platelet volume (MPV) have been studied as indicators of systemic inflammation and disease severity, as they are inexpensive, readily available and require no additional laboratory testing[7-9]. Although several studies have reported associations between these markers and CKD severity, the findings have not been consistent across populations, and evidence from Indian tertiary care settings remains limited[8-10].

The present study was undertaken to describe the haematological parameters and CBC- derived indices associated with inflammation in adult patients with CKD stages 3b, 4 and 5, and to assess their association with disease severity. By examining these readily available laboratory parameters across the three stages, the study aimed to identify indices that may assist in the clinical assessment of severity in a tertiary care setting.

MATERIALS AND METHODS

Study design and setting: A hospital-based cross-sectional analytical study was conducted in the Department of Nephrology, Ashwini Rural Medical College and Hospital, Kumbhari, Solapur, Maharashtra, from 1 May 2024 to 30 September 2025.

Study participants: Adult patients aged 18 years and above with an established diagnosis of CKD were included and enrolled consecutively during the study period. The diagnosis and staging of CKD were based on the Kidney Disease, Improving Global Outcomes (KDIGO) guidelines, using the estimated glomerular filtration rate (eGFR) and relevant clinical records. Patients with CKD stages 3b, 4 and 5 were eligible for inclusion. Patients with acute kidney injury, active infection, known haematological disorders, malignancy affecting the bone marrow, or age below 18 years were excluded, as these conditions could independently alter haematological parameters.

All eligible patients who fulfilled the selection criteria during the study period were included, and a total of 125 patients were enrolled. A formal sample size calculation was not performed, as the study was based on complete enumeration of eligible patients during the defined period.

Ethical Approval: The study protocol was approved by the Institutional Ethics Committee of Ashwini Rural Medical College and Hospital, Solapur. All ethical procedures were in line with the Declaration of Helsinki (2013) and WHO guidelines on research involving human subjects. Written informed consent was obtained from all participants prior to enrolment. The confidentiality of study data was maintained throughout the study. Only the study investigators had access to the data.

Data collection: Demographic characteristics (age and sex), clinical characteristics (comorbidities) and laboratory findings were recorded using a predesigned data collection form. The clinical variables included hypertension, diabetes mellitus, glomerulonephritis, renal stone disease and other documented comorbid conditions.

Venous blood samples were collected under aseptic precautions at the time of enrolment. Complete blood count was analysed using an automated haematology analyser Horiba H-550 (Japan). The parameters evaluated included haemoglobin, red blood cell count, haematocrit, mean corpuscular volume, mean corpuscular haemoglobin, mean corpuscular haemoglobin concentration, red cell distribution width, total leukocyte count, differential leukocyte count, platelet count and mean platelet volume. The neutrophil-to-lymphocyte ratio (NLR) was calculated by dividing the absolute neutrophil count by the absolute lymphocyte count.

Serum creatinine and blood urea were estimated using a fully automated analyser Transasia EM 360 (India). Serum creatinine was measured by the Jaffe's kinetic method, and eGFR was calculated using the 2021 race-free CKD-EPI creatinine equation.

Operational definitions: Anaemia was defined as a haemoglobin concentration below 13 g/dl in men and below 12 g/dl in women. Leucocytosis was defined as a total leukocyte count above 11 × 10^9/L, thrombocytopenia as a platelet count below 150 × 10^9/L, elevated RDW as a value above 14.5%, and elevated NLR as a value above 3.5, based on previously reported thresholds[9, 11-13].

Outcome measures: The primary outcome was the association of haematological parameters and CBC-

derived indices associated with inflammation with the severity of CKD, assessed across stages 3b, 4 and 5.

Statistical analysis: Data were entered into Microsoft Excel and analysed using SPSS version 20(IBM Corp., Armonk, NY, USA). Normally distributed variables were expressed as mean ± standard deviation, skewed variables as median with interquartile range, and categorical variables as frequencies and percentages.

Differences in continuous variables across CKD stages 3b, 4 and 5 were analysed using one-way analysis of variance (ANOVA) for normally distributed data, with Tukey's post hoc test for pairwise comparisons, and the Kruskal-Wallis test for non-normally distributed data, with Dunn's post hoc test and Bonferroni correction for pairwise comparisons. Categorical variables were compared using the Chi-square test or Fisher's exact test, as appropriate. Records with incomplete haematological or biochemical data were excluded from the relevant analyses. A two-sided p value below 0.05 was considered statistically significant.

RESULTS

Baseline characteristics of the study participants: Total 125 patients with chronic kidney disease were included in the study. The majority of patients were aged 51–65 years (60.0%), while 24.0% were aged 36–50 years. There was a male predominance, with 81 (64.8%) males and 44 (35.2%) females. Fifty (40.0%) patients had Stage 3b CKD, 40 (32.0%) had Stage 4 CKD and 35 (28.0%) had Stage 5 CKD. Hypertension alone (15.2%), glomerulonephritis alone (12.8%), hypertension with glomerulonephritis (12.8%) and diabetes with hypertension (11.2%) were the most frequently documented comorbidity patterns [Table. 1].

Comparison of haematological parameters across CKD stages: Haemoglobin concentration, red blood cell counts and haematocrit declined with advancing CKD stage. Mean corpuscular volume increased progressively in CKD stages 4 and 5, whereas mean corpuscular haemoglobin decreased significantly. Mean corpuscular haemoglobin concentration remained comparable among the three groups. Red cell distribution width, mean platelet volume and neutrophil-to-lymphocyte ratio increased significantly in CKD stage 4 and 5, while total leukocyte count and platelet count did not differ significantly between stages [Table. 2].

Distribution of haematological abnormalities across CKD stages: The proportion of anaemia increased significantly with advancing CKD stage, affecting 34.0% of patients with Stage 3b disease and 85.7% of those with Stage 5 disease (p<0.001). The elevated NLR and RDW were observed more frequently in patients with Stage 4 and Stage 5 CKD than in those with Stage 3b disease (both P<0.001). There was a significant increasing trend of thrombocytopenia across CKD stages (p=0.041), whereas the proportion of leucocytosis did not differ significantly across the three CKD stages (P=0.086) [Table. 3].

Characteristic	Stage 3b (n = 50)	Stage 4 (n = 40)	Stage 5 (n = 35)	Total (n = 125) (%)
Age group (years)				
36–50	9	12	9	30 (24.0)
51–65	31	23	21	75 (60.0)
66–80	10	5	5	20 (16.0)
Sex				
Male	35	22	24	81 (64.8)
Female	15	18	11	44 (35.2)
Underlying comorbidities				
Diabetes Mellitus	6	2	4	12 (9.6)
Diabetes mellitus + Glomerulonephritis	3	4	2	9 (7.2)
Diabetes mellitus + Hypertension	8	4	2	14 (11.2)
Diabetes mellitus + Renal stones	6	2	4	12 (9.6)
Glomerulonephritis	6	6	4	16 (12.8)
Hypertension	4	6	9	19 (15.2)
Hypertension + Glomerulonephritis	6	6	4	16 (12.8)
Hypertension + Renal stones	6	3	3	12 (9.6)
Renal stones	2	6	2	10 (8.0)
None	3	1	1	5 (4.0)

Table 1: Baseline demographic and clinical characteristics of the study participants according to CKD stage (n = 125)

Parameter	Stage 3b (n=50)	Stage 4 (n=40)	Stage 5 (n=35)	P value*
Haemoglobin (g/dL)	12.64 ± 1.81	11.36 ± 2.66	10.67 ± 2.38	<0.001
RBC ($\times10^{12}$/L)	4.33 ± 0.40	3.93 ± 0.39	3.51 ± 0.40	<0.001
Haematocrit (%)	34.59 ± 3.51	31.24 ± 2.78	27.27 ± 2.87	<0.001
MCV (fL)	88.52 ± 4.41	90.46 ± 6.41	93.10 ± 5.23	<0.001
MCH (pg)	29.29 ± 2.17	28.29 ± 1.97	27.36 ± 2.05	<0.001
MCHC (g/dL)	33.08 ± 4.78	33.42 ± 4.50	32.23 ± 4.64	0.526
WBC ($\times10^{9}$/L)	7.21 ± 3.04	8.14 ± 4.00	7.91 ± 4.62	0.486
Platelet count ($\times10^{9}$/L)	280.65 ± 122.98	270.78 ± 141.70	290.93 ± 140.73	0.809
MPV (fL)	9.56 ± 1.19	10.06 ± 1.12	10.75 ± 0.95	<0.001
NLR	2.94 ± 1.97	3.08 ± 1.91	4.91 ± 2.35	<0.001
RDW (%)	14.54 ± 2.55	15.59 ± 2.72	15.99 ± 2.49	0.028

Table 2: Comparison of haematological parameters across CKD stages

*Data are presented as mean ± standard deviation. P values were obtained using one-way analysis of variance (ANOVA).

Abnormality	Stage 3b	Stage 4	Stage 5	P value*
Anaemia	17 (34.0%)	22 (55.0%)	30 (85.7%)	<0.001
Leucocytosis^	4 (8.0%)	7 (17.5%)	9 (25.7%)	0.086
Elevated NLR	6 (12.0%)	14 (35.0%)	23 (65.7%)	<0.001
Thrombocytopenia^	2 (4.0%)	3 (7.5%)	7 (20.0%)	0.041
Elevated RDW	11 (22.0%)	24 (60.0%)	24 (68.6%)	<0.001

Table 3: Distribution of haematological abnormalities according to CKD stage

*Pearson's Chi-square test.^Fisher EXACT test.

DISCUSSION

This study evaluated changes in haematological parameters and CBC-derived indices associated with inflammation across different stages of chronic kidney disease. Haemoglobin concentration, red blood cell count and haematocrit declined progressively with advancing CKD stage, whereas red cell distribution width, mean platelet volume and neutrophil-to-lymphocyte ratio increased significantly. Anaemia was the most common haematological abnormality, followed by elevated RDW and NLR. These findings indicate progressive alterations in erythropoiesis and inflammatory status with deterioration of renal function.

Most patients were between 51 and 65 years of age, and males constituted nearly two-thirds of this study population. The distribution of age, sex and underlying comorbidities was comparable across the three CKD stages. Hypertension and diabetes mellitus, either alone or in combination with other renal disorders, were the predominant comorbidity patterns. Similar demographic profiles have been reported by Erken *et al*., Tahir *et al*. and Ogolla *et al*., where middle-aged males represented the majority of patients with CKD and diabetes mellitus and hypertension were the leading underlying causes of renal disease[8-10]. This pattern reflects the increasing burden of metabolic disorders as major contributors to CKD worldwide and is consistent with the epidemiological trends described in the KDIGO 2024 guideline and the comprehensive review by Webster *et al*.[1, 2].

Haemoglobin concentration declined from 12.64 g/dL in Stage 3b CKD to 10.67 g/dL in Stage 5 CKD, accompanied by corresponding reductions in red blood cell count and haematocrit. Similar trends have been reported by Tahir et al., who observed significant reductions in haemoglobin, red blood cell count and haematocrit with advancing CKD stage[10]. Ogolla *et al*. also found similar result[9]. Comparable findings have been described by Behera *et al*. and Swarnalatha and Vinotha, where the frequency and severity of anaemia increased significantly from Stage 3b to Stage 5 CKD[14, 15]. The decline in haemoglobin is primarily attributed to reduced erythropoietin production by damaged renal peritubular fibroblasts. Progressive inflammation, increased hepcidin activity, impaired iron utilisation, shortened erythrocyte survival and accumulation of uraemic toxins further limit erythropoiesis and contribute to worsening anaemia as renal function declines[5, 6, 16]. The high proportion of anaemic patients in Stage 5 CKD observed in this study supports the need for regular assessment of haemoglobin and timely correction of reversible causes of anaemia during routine CKD management[6, 11].

MCV increased progressively across the three CKD stages, whereas MCH showed a gradual decline. In contrast, MCHC concentration remained relatively stable despite worsening renal function. Tahir et al. also reported significant differences in MCV and MCH across CKD stages, although changes in MCHC were less pronounced[10]. Findings from the Fukushima CKD cohort further demonstrated that lower haemoglobin levels together with abnormalities in red cell indices were associated with adverse renal outcomes in patients with non-dialysis CKD[17]. The increase in MCV may reflect impaired erythrocyte maturation secondary to chronic inflammation, uraemic toxicity and disturbances in folate or vitamin B12 metabolism, while the decline in MCH is consistent with impaired iron availability during progressive renal dysfunction[5, 6, 14].

Red cell distribution width increased significantly with advancing CKD stage, and a greater proportion of patients with elevated RDW was observed in Stage 5 disease. Erken *et al*. reported a similar increase in RDW among advanced CKD patients and found higher RDW to be associated with lower eGFR and inflammatory markers[8]. In the Fukushima CKD cohort, elevated RDW was independently associated with progression to kidney failure and all-cause mortality, suggesting that RDW reflects the combined effects of ineffective erythropoiesis, chronic inflammation and oxidative stress[17, 18].

The neutrophil-to-lymphocyte ratio increased progressively from Stage 3b to Stage 5 CKD, indicating increasing inflammatory activity with worsening renal function. Kim *et al*. demonstrated that higher NLR was associated with lower eGFR and faster CKD progression [19], while Okyay *et al*. reported significant correlations between NLR and inflammatory markers including interleukin-6 and high-sensitivity C-reactive protein[17, 20]. These findings support the concept that persistent low-grade inflammation accompanies progressive CKD and contributes to disease progression[7].

The proportion of patients with anaemia, elevated RDW, elevated NLR and thrombocytopenia increased progressively from Stage 3b to Stage 5 CKD. Although platelet count remained comparable across the three CKD stages, MPV increased significantly with worsening renal function, suggesting qualitative changes in platelet

activation rather than a reduction in platelet number. Similar observations have been reported by Erken *et al*.[8]. Behera *et al*. also reported increasing severity of anaemia and a higher frequency of thrombocytopenia with advancing CKD in an Indian population[14], and Ogolla *et al*. observed progressive changes in haematological biomarkers such as haemoglobin and NLR with worsening CKD stages[9]. Swarnalatha and Vinotha likewise demonstrated a stage-wise increase in haematological abnormalities among patients with CKD stages 3b–5[15]. These findings indicate that routine haematological parameters derived from a CBC provide useful adjunctive information during clinical evaluation and follow-up of patients with CKD.

Limitations:

Simultaneous assessment of erythrocyte, leukocyte and platelet indices provides a comprehensive overview of the haematological profile in these patients. However, the findings should be interpreted in light of certain limitations. This was a single-centre cross-sectional study which may limitthe generalisability of the findings and preclude assessment of temporal or causal relationships. Biomarkers of iron status, inflammatory cytokines and erythropoietin levels were not evaluated, and their relationship with haematological parameters could not be examined. Longitudinal multicentre studies incorporating these variables are required to determine their prognostic significance in CKD.

CONCLUSION

In this cross-sectional study, CKD stage was associated with lower haemoglobin concentration, red blood cell count and haematocrit, and with higher red cell distribution width (RDW), mean platelet volume (MPV) and neutrophil-to-lymphocyte ratio (NLR). Anaemia was the most common haematological abnormality, followed by elevated RDW and NLR. In particular, NLR and RDW showed an association with CKD stage, with higher values observed among participants with more advanced stages of CKD. These findings suggest that routine haematological parameters and CBC-derived indices associated with inflammation may reflect differences in haematological and inflammatory status across CKD stages. As these parameters are readily available as part of routine complete blood count analysis, they may provide useful adjunctive information for the clinical assessment of patients with CKD. However, given the cross-sectional design of the study, no conclusions can be drawn regarding disease progression or the longitudinal role of these parameters in monitoring CKD. Longitudinal studies are therefore required to determine their potential role in monitoring disease progression.

DISCLOSURE

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Conflict of interest: The authors declare that they have no conflict of interest.

Data availability statement: The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

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