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Hematological Alterations in Chronic Kidney Disease of Humans and Animals and Evaluation of its Inflammatory and Hematological Markers

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ABSTRACT

Chronic Kidney Disease (CKD) is a long-term condition characterized by lasting structural or functional damage to the kidneys for a duration exceeding three months. It is linked to a shortened lifespan and a heightened likelihood of developing cardiovascular diseases, anemia, infection, and certain types of cancers in humans and animals. Recent studies have highlighted the inflammatory markers such as the neutrophil to lymphocyte ratio (NLR) and platelet to lymphocyte ratio (PLR) as potential tools for predicting the progression and mortality risk in chronic kidney disease (CKD). However, their significance in patients with CKD who have not yet begun dialysis remains unclear. This study aimed to examine the association between NLR, PLR and systemic inflammation in non-dialysis CKD patients. A cross-sectional analysis was carried out at the Multan Institute of Kidney Disease in Multan, Pakistan between April and August 2024. The study involved 156 individuals with CKD and 25 healthy male participants as a control group. Information on demographics, clinical profiles such as blood pressure, Body Mass Index (BMI) and coexisting conditions was gathered. Blood tests were conducted to assess complete blood count, serum creatinine, albumin, C-reactive protein (CRP) and other relevant parameters. NLR and PLR were derived from hematological values while CKD diagnosis was based on estimated glomerular filtration rate (eGFR) calculated through the MDRD4 equation along with evidence of albuminuria. Data analysis was performed using SPSS version 21 with p value less than 0.05 revealed significantly higher NLR and PLR levels in CKD patients versus controls which indicating the elevated inflammation. Both markers are negatively correlated with eGFR and positively with CRP and albuminuria. Anemia is a normocytic type and it was common among CKD patients. NLR and PLR emerged as reliable and low cost indicators of systemic inflammation. These markers may aid in tracking disease progression in non-dialysis CKD. Their use could improve the early detection and management of CKD complications.

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INTRODUCTION

Chronic Kidney disease (CKD) is defined by lasting structural or functional impairments in the kidneys of both humans and animals that persist for more than three months which is leading to adverse effects on overall health. Those affected by CKD often face a shorter lifespan and are at increased risk for cardiovascular complications, anemia, bone mineral imbalances and certain types of cancer (Kalantar-Zadeh et al. 2021). Global clinical guidelines define CKD as diminished renal function, evidenced by a glomerular filtration rate (GFR) below 60 ml/min per 1.73

m² or markers of kidney damage sustained for at least three months independent of the underlying cause. Many affected individuals remain asymptomatic or experience only subtle manifestations such as pruritus, fatigue or diminished appetite (Świerczyńska et al. 2021). From age 40 onwards, the average annual decline in GFR is approximately 0.75 to 1 ml/min. The presence of proteinuria is associated with increased risk of both CKD progression and mortality (Chen et al. 2023). Among the less commonly recognized renal functions is the synthesis of erythropoietin, a glycoprotein hormone that regulates erythropoiesis in response to hypoxia. In chronic renal failure, functional deficits impair erythropoietin production, often resulting in anemia. This hormone is secreted by peritubular interstitial cells and serves as the principal regulator of red blood cell generation (Gwozdzinski et al. 2021). During the early phases of CKD, clinical manifestations are often absent a marked reduction in renal performance frequently serves as the first detectable sign. Multiple variables influence mortality in CKD and ongoing research continues to explore novel prognostic indicators. The neutrophil-to-lymphocyte ratio (NLR) and platelet-to-lymphocyte ratio (PLR) are increasingly recognized as indices of systemic inflammation. These markers derived from routine blood counts are calculated by dividing the neutrophil or platelet counts by the lymphocyte count, respectively (Islam et al. 2024). Neutrophils act as immune effectors that proliferate during inflammation, contributing to oxidative stress. In contrast , certain types of lymphocytes such as Th2 cells and regulatory T cells help to control inflammation by activating pathways which are regulating by GATA3 and FOXP3(Cao et al. 2021). In CKD, heightened oxidative stress, elevated inflammatory mediators such as C-reactive protein (CRP), interleukin-6 (IL-6), and tumor necrosis factor-alpha (TNF-α), along with poor nutritional status, collectively exacerbate disease progression (Podkowińska and Formanowicz 2020). NLR and PLR have been identified as markers for adverse outcomes and complications across various disorders, including heart failure, gastrointestinal perforations, chronic obstructive pulmonary disease, rheumatic conditions and malignancies. In the CKD population, these ratios are predictive of both disease advancement and the presence of albuminuria. Contemporary clinical practice already employs well-established inflammatory markers such as CRP, IL-1, IL-6 and TNF-α for diagnosis and monitoring (Cepoi et al. 2023). Prior research has highlighted the utility of NLR and PLR as emerging markers of systemic inflammation, extensively examined in cancer, hypertension, cardiovascular and vascular diseases (Podkowińska and Formanowicz 2020). These ratios are affordable, accessible and easy to determine with demonstrated efficacy in stratifying cardiovascular mortality and serving as prognostic tools in oncology. Notably, the NLR has been reported to predict the transition from stage 4 CKD to end-stage renal disease requiring dialysis. Studies also suggest that PLR correlates with inflammation and is a potential predictor of mortality among hemodialysis patients. Their relevance in assessing inflammation among dialysis populations has been discussed extensively. Nonetheless, the prognostic value of NLR and PLR in non-dialysis CKD patients remains insufficiently established. Therefore, the current investigation was undertaken to assess these parameters in individuals not undergoing dialysis and to examine their association with systemic inflammation in this subgroup (Zhou et al. 2023).

MATERIALS AND METHODS

Study Setting and Population

This cross-sectional study was conducted at the Multan Institute of Kidney Disease, Multan, Pakistan, between April and August 2024. A total of 156 patients diagnosed with chronic kidney disease (CKD) were enrolled. Basic demographic data including age, sex and relevant medical history, were recorded. Patient records were thoroughly reviewed to supplement clinical details. Upon obtaining written informed consent, venous blood samples were collected by trained phlebotomists and laboratory results were documented for analysis.

Data Collection

Initiation information, including patient demographics, existing health conditions and ongoing treatments, was gathered from medical charts or baseline laboratory assessments. Body mass Index (BMI) was calculated by taking the individual's weight in kilograms and dividing it by the square of their height in meters. Trained personnel measured blood pressure using either a manual sphygmanometer or an automated monitor with the subject seated during the procedure. Hypertension was defined by any of the following criteria: a systolic blood pressure of 140 mmHg or higher, a diastolic pressure of 90 mmHg or above the current use of medications prescribed to manage the high blood pressure.

Physicians at the healthcare center carried out Chronic Kidney Disease (CKD) screening, estimating kidney function through the Modification of Diet in Renal Disease 4 (MDRD4) equation to calculate the estimated glomerular filtration rate (eGFR). A random urine sample was analyzed to assess the albumin-to-creatinine ratio. Individuals with an eGFR below 60ml/min/1.73m^2 were directed for further evaluation. Relevant laboratory results for referral purposes were accessed using the '' RESULAB'' software system. The collected data included the levels of serum creatinine, blood glucose, total protein, albumin, alanine transaminase (ALT), aspartate transaminase (AST), total bilirubin, alkaline phosphatase, globulin, hemoglobin, platelet count, neutrophil count, and lymphocyte count.

Hematological Parameters

Anemia was defined based on established thresholds: hemoglobin levels below 12 g/dL in females and below 13.5 g/dL in males. Anemia subtypes were classified using mean corpuscular volume (MCV). Normocytic anemia corresponded to MCV values between 80 and 100 fL, microcytic anemia was indicated by MCV below 80 fL and macrocytic anemia was defined by MCV exceeding 100 fL.

Study Area and Duration

This descriptive analysis was carried out at the Multan Institute of Kidney Disease over a five-month period from April to August 2024. As a primary care hospital

specializing in renal disorders, the facility manages a broad spectrum of kidney-related conditions and provides diagnostic laboratory and dialysis services. It serves as a referral center for patients requiring specialized nephrological care.

Control Group
A control group consisting of 25 healthy male volunteers was selected from the staff of affiliated hospitals and science faculty departments. These individuals were screened to ensure the absence of diabetes, cardiovascular conditions, anemia, or renal pathology.

Inclusion Criteria
Participants were eligible for inclusion if they met the following criteria: (1) provided signed informed consent (2) had a confirmed diagnosis of CKD.

Exclusion Criteria
Individuals were excluded based on the following: (1) refusal to participate (2) diagnosis of a condition other than CKD that could affect hematological indices, such as hematological diseases, active or chronic inflammatory states, bleeding episodes, or malignancies, and (3) pregnancy or lactation.

Specimen Collection
Blood samples were obtained from both patients and controls using sterile, disposable syringes. Approximately 5 mL of venous blood was collected from each subject. Of this, 4 mL was transferred to gel-containing tubes. Samples were centrifuged at 1500 g for 10 minutes to separate sera, which were preserved for the measurement of blood urea, creatinine and uric acid concentrations. The remaining blood was placed in EDTA tubes for complete blood count (CBC) analysis.

Laboratory Assessments
Fasting blood samples were drawn into both anticoagulant and non-anticoagulant tubes to obtain plasma, serum and whole blood. Parameters such as creatinine, calcium, phosphorus, C-reactive protein (CRP), parathyroid hormone, glycated hemoglobin (HbA1c), triglycerides, total cholesterol, low-density lipoprotein (LDL), high-density lipoprotein (HDL), serum albumin and full blood count including white blood cells, hemoglobin and red cell distribution width (RDW) were analyzed immediately. Plasma samples designated for desphospho-uncarboxylated matrix Gla protein (dp-ucMGP) measurement were centrifuged and stored at –20°C until analysis. Blood from hemodialysis (HD) patients was collected following an overnight fast of eight hours and before the initiation of a mid-week dialysis session.
Albuminuria was defined as a urinary albumin-to-creatinine ratio (UACR) present in at least two of three consecutive morning urine samples taken over a three-month interval. RDW and neutrophil-to-lymphocyte ratios were evaluated as part of the routine CBC using the automated hematology analyzer Sysmex XE-5000 (Sysmex Corporation, Kobe, Japan). The laboratory's reference range for RDW was 12.0–14.0%.

Statistical analysis
Data analysis was performed using Statistical Package for the Social Sciences (SPSS) version 21. A p-value of less than 0.05 was considered statistically significant, while values above this threshold were interpreted as not significant. The software facilitated precise and reliable statistical computations. Analytical procedures focused on deriving outcome estimates in individuals diagnosed with chronic kidney failure.
To identify potential predictors of red cell distribution width (RDW) and neutrophil-to-lymphocyte ratio (NLR), a multiple linear regression analysis employing a forward stepwise method was applied. RDW and NLR served as dependent variables assessed both with and without the influence of predictors identified in prior bivariate correlation analyses. The regression models with RDW as the outcome variable were adjusted for serum albumin, C-reactive protein (CRP), urinary albumin-to-creatinine ratio (UACR), calcium, phosphorus, cardiac rhythm, central diastolic blood pressure, warfarin use and erythropoietin-stimulating agents. For models with NLR as the dependent variable, adjustments included age, history, and duration of cardiovascular disease, serum albumin, CRP, estimated glomerular filtration rate (eGFR), calcium, parathormone levels, central diastolic pressure, etiology of nephropathy and administration of erythropoietin-stimulating agents. Variables with non-normal distributions underwent logarithmic transformation before inclusion in regression analyses. Statistical significance was defined as $P<0.05$.
Additionally, a sensitivity analysis was performed to identify optimal cutoff values of NLR and platelet-to-lymphocyte ratio (PLR) associated with mortality risk. The optimal thresholds were determined using receiver operating characteristic (ROC) curve analysis with cutoffs established through the Youden index to maximize sensitivity and specificity.
A total of 356 medical records of CKD patients registered in the SSCKD program between 2016 and 2018 were examined. The cohort had a mean age of 78.3±11.9 years with a median follow-up period of 2.45 years (interquartile range: 2.08–3.08 years). The majority of the participants were male, comprising 62.9% (n = 216) of the study population.

RESULTS

During this study a total of 356 medical records of CKD patients registered in the SSCKD program between 2016 and 2018 were examined. The cohort had a mean age of 78.3±11.9 years with a median follow-up period of 2.45 years (interquartile range: 2.08–3.08 years). The majority of the participants were male, comprising 62.9% (n = 216) of the study population. The Evaluation of Neutrophil's level was done and there was significant difference between patients and controls (Table 1; Fig. 1, 2, 3 & 4). Evaluation of Lymphocyte's level in chronic kidney disease patients was done and there was significant difference between patients and controls (Table 2). Evaluation of Monocyte's level in chronic kidney disease patients was done and there was significant difference between patients and controls (Table 3). Evaluation of Eosinophil's level was done and there was significant difference between patients and controls (Table 4; Fig. 5, 6).

Table 1: Evaluation of Neutrophil's level in Chronic Kidney Disease patients

Age (years)	Gender	Neutrophils level of Patients	Mean value of Patients	Std. deviation of Patients	Neutrophil level of Control	Mean of patients	Std. deviation of Control	P- Value
70	Male	87	70.75	0.99	45	55.55	-1.08	0.3228
30	Male	77	70.75	0.38	65	55.55	0.96	0.2794
90	Male	89	70.75	1.11	74	55.55	1.88	0.7032
42	Male	87	70.75	0.99	53	55.55	-0.26	0.3362
32	Female	83	70.75	0.75	52	55.55	-0.36	0.2676
70	Male	73	70.75	0.14	58	55.55	0.25	0.0600
44	Male	70	70.75	-0.05	45	55.55	-1.08	0.3228
8	Female	82	70.75	0.69	48	55.55	-0.77	0.7948
12	Male	20	70.75	-3.11	49	55.55	-0.67	0.4532
10	Female	86	70.75	0.93	46	55.55	-0.98	0.7180
2	Female	55	70.75	-0.97	43	55.55	-1.29	0.8892
2	Male	75	70.75	0.26	63	55.55	0.76	0.8024
30	Female	54	70.75	-1.03	69	55.55	1.37	0.9602
55	Female	70	70.75	-0.05	72	55.55	1.68	0.2794
25	Male	60	70.75	-0.66	51	55.55	-0.47	0.4886
60	Male	85	70.75	0.87	59	55.55	0.35	0.4402
60	Male	64	70.75	-0.42	49	55.55	-0.67	0.0019
55	Female	89	70.75	1.11	48	55.55	-0.77	0.5034
45	Female	89	70.75	1.11	52	55.55	-0.36	0.7180
70	Female	70	70.75	-0.05	71	55.55	1.57	0.1166

P value >0.05 indicates a significant difference among rows.

Table 2: Evaluation of Lymphocyte's level in Chronic Kidney Disease patients

Age (years)	Gender	Lymphocyte Patient	Mean value of Patients	Std. deviation of Patients	Lymphocyte Control	Mean value of control	Std. deviation of control	P-value
70	Male	8	21.05	-0.79	23	32	13.05	0.4600
30	Male	14	21.05	-0.38	25	32	7.05	0.5124
90	Male	5	21.05	-0.99	42	32	16.05	0.4277
42	Male	8	21.05	-0.79	41	32	13.05	0.4600
32	Female	12	21.05	-0.52	35	32	9.05	0.6717
70	Male	15	21.05	-0.31	35	32	6.05	0.6883
44	Male	23	21.05	0.24	26	32	1.95	0.4062
8	Female	10	21.05	-0.65	21	32	11.05	0.4176
12	Male	67	21.05	3.24	45	32	45.95	0.3892
10	Female	11	21.05	-0.58	28	32	10.05	0.6263
2	Female	33	21.05	0.92	23	32	11.95	0.4045
2	Male	20	21.05	0.03	39	32	1.05	0.4880
30	Female	36	21.05	1.12	34	32	14.95	0.5781
55	Female	18	21.05	-0.11	26	32	3.05	0.4808
25	Male	37	21.05	1.19	28	32	15.95	0.5180
60	Male	10	21.05	-0.65	38	32	11.05	0.5514
60	Male	25	21.05	0.37	27	32	3.95	0.4585
55	Female	5	21.05	-0.99	41	32	16.05	0.4486
45	Female	8	21.05	-0.79	29	32	13.05	0.6239
70	Female	26	21.05	0.44	35	32	4.95	0.6022

P value >0.05 indicates a significant difference among rows.

DISCUSSION

In the present investigation, a substantial observational cohort dataset was employed to assess the associations between hematological indicators of anemia, namely hemoglobin concentration, mean corpuscular volume (MCV) and red cell distribution width (RDW) and adverse clinical outcomes, including end-stage kidney disease (ESKD), all-cause mortality and cardiovascular events among Japanese individuals with non-dialysis-dependent chronic kidney disease (CKD). This research examined the various blood based indicators simultaneously to determine how each one individually impacted health outcomes is a topic that remains underexplored in individuals with Chronic Kidney disease (CKD) who are not on dialysis (Kuragano 2024). These markers are well-established as indicators of anemia a frequent complication associated with CKD (Portolés et al. 2013). The study sought to assess their potential to predict long-term health outcomes especially, in patients who had not yet begun dialysis treatment (Brazauskas et al. 2023). By analyzing these parameters in detail the study aimed to clarify how each relates to different clinical results. Thereby, offering deeper insight into the risks linked to anemia in this specific patient group (Williams et al. 2023). This approach is especially important it gives the multifactorial nature of anemia in CKD, where nutritional deficiencies, chronic inflammation and impaired erythropoiesis all contribute to its pathophysiology (Begum and Latunde-Dada 2019).

Initially, hemoglobin levels demonstrated a significant association with elevated risks of ESKD and overall

Table 3: Evaluation of Monocyte's level in Chronic Kidney Disease patients

Age (years)	Gender	Monocytes level of Patients	Mean value of Patients	Std. deviation of Patients	Monocytes level of Control	Mean value of Control	Std. deviation of Control	P- Value
70	Male	3	4.75	-0.65	3	5.4	-2.4	0.04881
30	Male	6	4.75	0.46	2	5.4	-3.4	0.00380
90	Male	4	4.75	-0.28	2	5.4	-3.4	0.00449
42	Male	3	4.75	-0.65	3	5.4	-2.4	0.04881
32	Female	3	4.75	-0.65	2	5.4	-3.4	0.00312
70	Male	7	4.75	0.83	3	5.4	-2.4	0.04006
44	Male	4	4.75	-0.28	5	5.4	-0.4	0.87100
8	Female	6	4.75	0.46	5	5.4	-0.4	0.80520
12	Male	2	4.75	-1.01	6	5.4	0.6	0.47372
10	Female	2	4.75	-1.01	8	5.4	2.6	0.01992
2	Female	7	4.75	0.83	6	5.4	0.6	0.55761
2	Male	3	4.75	-0.65	7	5.4	1.6	0.21891
30	Female	12	4.75	2.67	4	5.4	-1.4	0.00944
55	Female	7	4.75	0.83	5	5.4	-0.4	0.63665
25	Male	2	4.75	-1.01	2	5.4	-3.4	0.00199
60	Male	4	4.75	-0.28	6	5.4	0.6	0.79083
60	Male	8	4.75	1.20	8	5.4	2.6	0.01533
55	Female	4	4.75	-0.28	4	5.4	-1.4	0.38679
45	Female	2	4.75	-1.01	8	5.4	2.6	0.01992
70	Female	2	4.75	-1.01	9	5.4	3.6	0.00102

P value >0.05 indicates a significant difference among rows.

Table 4: Evaluation of Eosinophil's level in Chronic Kidney Disease patients

Age (years)	Gender	Eosinophil level of Patients	Mean value of Patients	Std. deviation of Patients	Eosinophil level of Control	Mean value of Control	Std. deviation of Control	P- Value
70	Male	2	2.7	0.7	3	3.85	0.85	0.3638
30	Male	3	2.7	0.3	2	3.85	1.85	0.5936
90	Male	2	2.7	0.7	5	3.85	1.15	0.0259
42	Male	2	2.7	0.7	4	3.85	0.15	0.0052
32	Female	2	2.7	0.7	5	3.85	1.15	0.0259
70	Male	5	2.7	2.3	4	3.85	0.15	0.6644
44	Male	3	2.7	0.3	5	3.85	1.15	0.0924
8	Female	2	2.7	0.7	2	3.85	1.85	1.0000
12	Male	2	2.7	0.7	3	3.85	0.85	0.3638
10	Female	1	2.7	1.7	4	3.85	0.15	0.0788
2	Female	5	2.7	2.3	5	3.85	1.15	1.0000
2	Male	2	2.7	0.7	6	3.85	2.15	0.0769
30	Female	8	2.7	5.3	1	3.85	2.85	0.2447
55	Female	5	2.7	2.3	5	3.85	1.15	1.0000
25	Male	1	2.7	1.7	3	3.85	0.85	0.2927
60	Male	1	2.7	1.7	4	3.85	0.15	0.0788
60	Male	3	2.7	0.3	6	3.85	2.15	0.1670
55	Female	2	2.7	0.7	2	3.85	1.85	1.0000
45	Female	1	2.7	1.7	5	3.85	1.15	0.0513
70	Female	2	2.7	0.7	3	3.85	0.85	0.3638

In the above table, P value >0.05 indicates a significant difference among rows.

mortality. Although the prognostic value of hemoglobin in CKD has been well documented through multiple randomized controlled trials (RCTs) the current findings reaffirm the existing consensus that reduced hemoglobin levels are linked to poor clinical outcomes, including disease progression, cardiovascular complications and mortality (Ku et al. 2023). Following Japanese clinical guidelines for target hemoglobin levels, participants were stratified into three categories based on baseline hemoglobin levels (<11.0 g/dL, 11.0–12.9 g/dL, and ≥13.0 g/dL), with outcomes aligning with prior research. However, the relationship between hemoglobin and ESKD was markedly weakened in the Model 3 Cox regression analysis, which incorporated estimated glomerular filtration rate (eGFR) as a covariate, suggesting that baseline renal function, rather than hemoglobin alone, may account for the observed association, thereby reflecting disease severity (Simeri et al. 2025). The stratification revealed a graded risk pattern with lower hemoglobin groups experiencing a higher incidence of ESKD and death. The results align with previous observational and clinical studies. The reduced strength of the association indicates that initial kidney function might be a more critical factor than anemia by itself in forecasting the progression of kidney disease. These findings highlight the complex relationship between hemoglobin levels and the development of end-stage kidney disease (ESKD) (Pan et al. 2022). Which suggest the impact of hemoglobin is significantly influenced by the patient's baseline renal health (Begum and Latunde-Dada 2019).

Secondly, Lower mean corpuscular volume (MCV) levels (below 90 fL) were independently linked to higher risk of progression to end stage kidney disease (ESKD) in

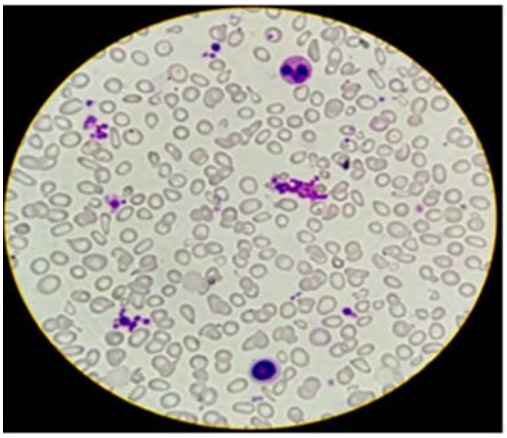

Fig. 1 Representation of Wright-Giemsa stained human blood smear shows Neutrophils stained dark purple

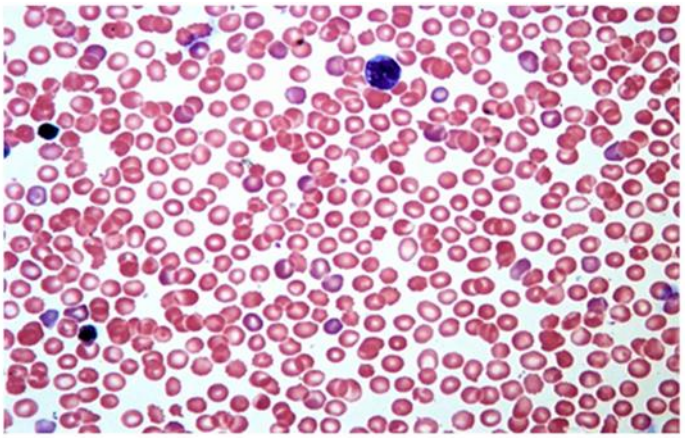

Fig.2 Representation of Monocytes in the human Blood smear

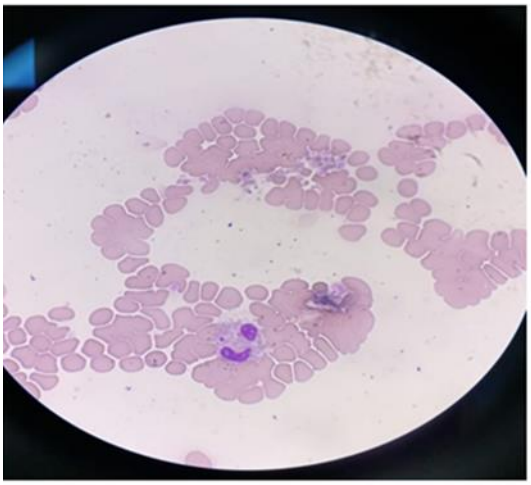

Fig. 3 Representation of Lymphocytes in Human Blood smear

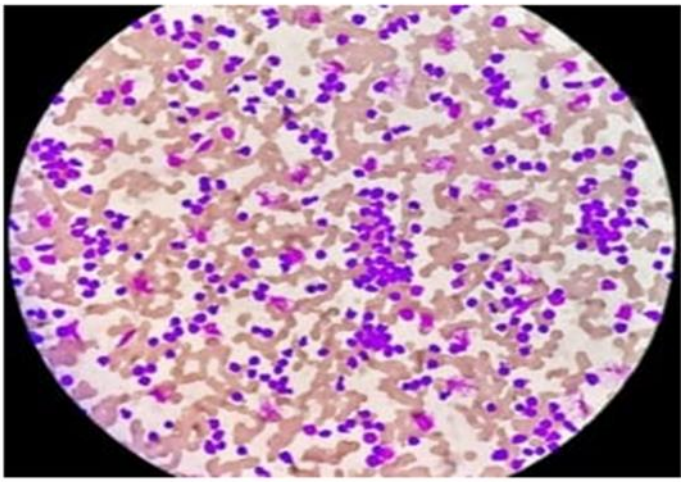

Fig. 4 Representation of Neutrophils in Human Blood smear

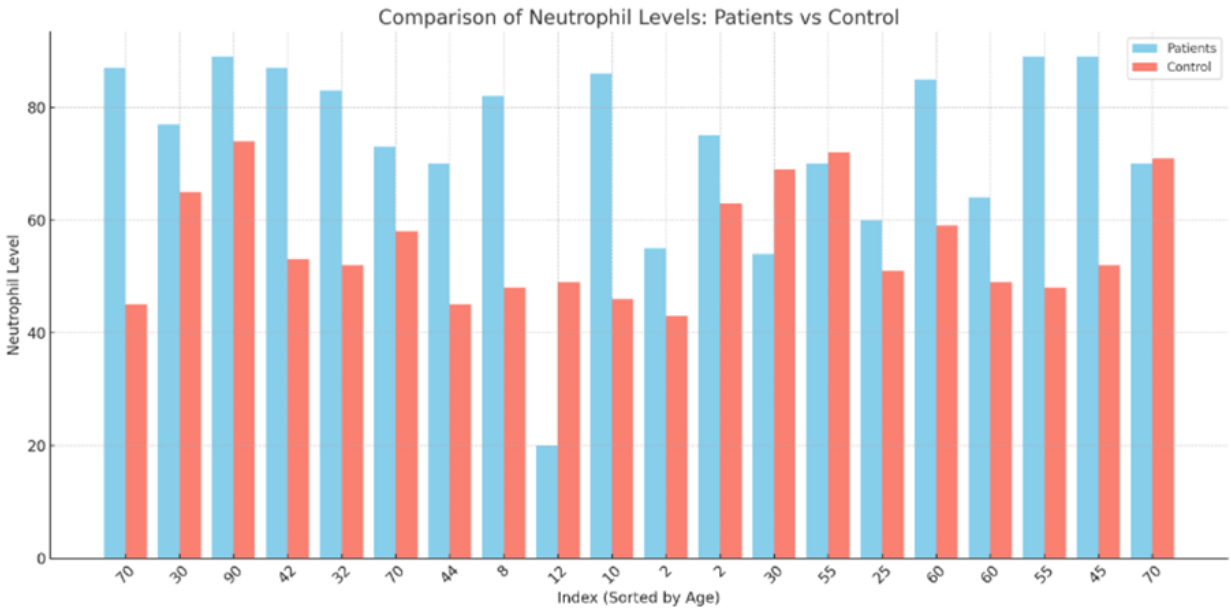

Fig. 5: Comparison of the Neutrophilic level between patients and controls.

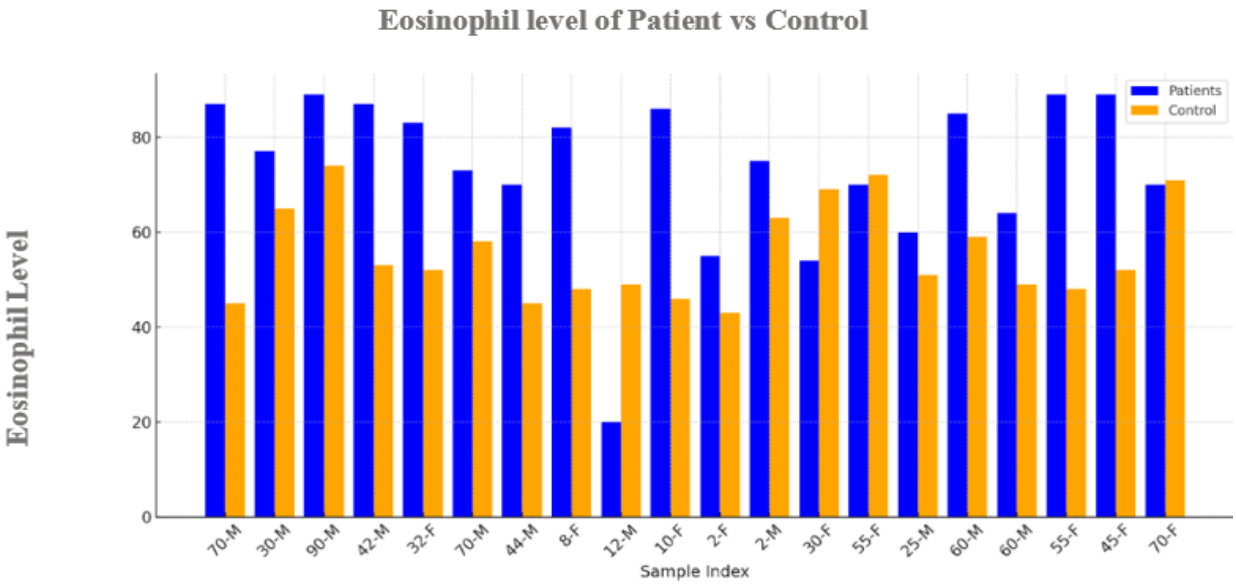

Fig. 6: Comparison between the Eosinophilic levels of patients and controls.

multivariable analyses. While research on MCV in non-dialysis CKD populations is limited existing studies have shown that elevated MCV levels may be associated with an increased risk of death from any cause
(Messina et al. 2019). The current findings add further weight to the idea that MCV could serve as a meaningful prognostic marker in CKD patients who are not yet on dialysis (Begum and Latunde-Dada 2019). The observed relationship between both unusually low and high MCV values (Bissinger et al. 2019). Elevated MCV has previously been associated with macrocytic anemia, oxidative damage and impaired red blood cells production (Saito et al. 2023). The factors that might contribute to the increased mortality risk observed in both general and CKD population (Girelli et al. 2018). The study contributes the new insight by demonstrating that reduced MCV levels may also signal a higher risk of worsening kidney function. Finally, higher levels of red cell distribution width (RDW) were strongly and independently associated with a great risk of both end- stage kidney disease (ESKD) and overall mortality which based on multivariate analysis. (Theodorakopoulou et al. 2021). Although, RDW has previously been identified as a predictor of death in the general population and in people with various chronic illness (Fava et al. 2019). It has the role in forecasting kidney related outcomes in CKD patients has been less thoroughly explored (Gwozdzinski et al. 2021). This study adds valuable insights to the growing body of research which is indicating that RDW could serve as a practical biomarker for identifying individuals at risk of both disease progression and mortality in the context of chronic kidney disease (Alghamdi 2023). Furthermore, *Haemonchus contortus* causes both anemia and inflammation in animals which mirroring the blood related complications commonly observed in Chronic kidney disease (CKD) (Ur-Rehman et al. 2023). In addition, Zoonotic infections are known to provoke ongoing inflammation and disrupt normal blood function. It is potentially worsening anemia and impairing immune responses in both humans and animals with CKD (Nomi et al. 2012). Environmental stressors such as elevated temperatures and infection outbreaks often lead to the weakened immune function which increase the oxidative stress and changes in blood composition in livestock conditions (Sarwar et al. 2025).
In summary, these findings underscore the clinical value of monitoring hematological indices, including hemoglobin, MCV and RDW, in individuals with non-dialysis-dependent CKD. These biomarkers may offer meaningful prognostic insights and inform more individualized approaches to patient management and risk stratification (Macdougall 2024). The adverse outcomes such as end-stage kidney disease (ESKD), cardiovascular events and all-cause mortality. Hemoglobin remains a central marker in CKD management, while MCV and RDW provide additional layers of diagnostic and prognostic relevance (Erken et al. 2020). Together, these indices reflect a wide range of underlying physiological disturbances, including iron deficiencies, chronic inflammation, erythropoietic dysfunction and nutritional imbalances (Lanser et al. 2021). As CKD management continues to shift towards personalized medicine, the inclusion of these hematological markers may significantly improve long-term outcomes and reduce disease burden on humans and animals. (Gembillo et al. 2023).

Conclusions

The present study revealed that CKD patients with impaired kidney function show elevated values of renal function parameters (B. urea and S. Cr) and a decrease in eGFR in addition to the development of anemia. The findings of the present study are in agreement with studies published from low-income and middle-income countries, which also showed substantial derangement in the hematological profile of patients with CKD. Concerning RBC indices, we showed low RBC count, hemoglobin concentration and hematocrit percentage in patients with CKD irrespective of age and sex. We certainly know that erythropoietin is produced primarily in the proximal tubule of the nephron and failure in kidney function will

eventually lead to a reduction in erythropoietin levels necessary for the synthesis of hemoglobin, culminating in a low RBC count. This inexorably causes a substantial decrease in RBC and contributes to anemia. According to the Pakistan National Nutrition Survey 2018 report, more than half (56.6%) of the Pakistani adolescent girls have anemia. Adolescent girls residing in rural areas are far more prone to develop anemia (58.1%) than those in urban areas (54.2%). Similarly, ~18.2% of women of reproductive age have iron-deficiency anemia, which is more common in women living in rural areas (18.7vs. 17.4%, respectively).

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