Original Article

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Pathology Section

Analysis of Red Blood Cell Parameters and Serum Iron Profile in Patients with Chronic Kidney Disease: A Retrospective Cross-sectional Study

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ABSTRACT

Introduction: Chronic Kidney Disease (CKD) is a progressive loss of kidney function that frequently leads to anaemia, primarily due to erythropoietin deficiency. Anaemia in CKD exacerbates cardiovascular risk, reduces quality of life, and accelerates disease progression, particularly in advanced stages. Regular monitoring of Red Blood Cell (RBC) parameters is essential for accurate anaemia classification and management.

Aim: To analyse RBC parameters and the serum iron profiles in patients at different stages of CKD and to determine their associations with renal function markers.

Materials and Methods: The present retrospective cross-sectional study was conducted at Yenepoya Medical College and Hospital, Mangalore, Karnataka, India. Data from 113 CKD patients aged ≥18 years, collected between May 2024 and May 2025, were analysed. Parameters assessed included RBC count, haemoglobin, haematocrit, Mean Corpuscular Volume (MCV), Mean Corpuscular Haemoglobin (MCH), Mean Corpuscular Haemoglobin Concentration (MCHC), serum iron profile (serum iron, Total Iron-Binding Capacity [TIBC], and serum ferritin), peripheral smear findings, blood urea, and serum creatinine. The relationships between RBC parameters, iron profile parameters, serum creatinine, and blood urea were analysed using Pearson's correlation coefficient. A p-value <0.05 was considered statistically significant. Statistical analysis was performed using Statistical Package for Social Sciences (SPSS) software version 27.

Results: Among the 113 patients, 79 (69.91%) were male, and 84 (74.34%) were in stage 5 CKD. Moderate anaemia was the most common severity, observed in 79 patients (69.91%). The severity of anaemia increased with advancing CKD stage. The mean haemoglobin level was 8.21 g/dL. Serum creatinine showed moderate, statistically significant negative correlations with RBC count, haemoglobin, and packed cell volume (r=-0.31 to -0.33, p<0.001). Blood urea also demonstrated moderate negative correlations with these parameters (r=-0.24 to -0.28, p <0.01). Serum iron exhibited a weak positive correlation with serum creatinine (r=0.26, p=0.006). Normocytic normochromic anaemia (91%) was the predominant peripheral smear pattern.

Conclusion: Anaemia is a common and progressive complication of CKD, with severity increasing as renal function declines. Monitoring RBC parameters and iron profiles is essential for accurate anaemia classification, optimising treatment strategies, and preventing unnecessary iron supplementation, particularly in advanced stages of CKD.

Keywords: Anaemia, Chronic renal failure, Haemoglobin, Iron profile

INTRODUCTION

Chronic Kidney Disease (CKD) has emerged as a major global health concern, affecting approximately 8-10% of adults and contributing to over 1.2 million deaths worldwide each year [1,2]. It is characterised by a persistent decline in renal function, defined by a Glomerular Filtration Rate (GFR) below 60 mL/min/1.73 m^2 or evidence of kidney damage for more than three months [3-5]. CKD is associated with significant morbidity, reduced quality of life, and an increased risk of cardiovascular disease [3,4]. Haematological abnormalities, particularly anaemia, are among the most common complications of CKD and contribute substantially to morbidity and mortality. Erythropoietin deficiency is the primary cause of anaemia in CKD, although several additional factors may contribute [5,6]. These include haemolysis, reduced red cell survival, iron deficiency, vitamin B12 and folate deficiencies, blood loss, aluminium toxicity, osteitis fibrosa cystica, anaemia of chronic disease, and resistance to erythropoietin therapy [7].

Anaemia in CKD is typically normocytic and normochromic; however, it may also be hypoproliferative due to reduced bone marrow response to erythropoietin or microcytic hypochromic secondary to iron deficiency. Macrocytic anaemia may result from vitamin B12 or folate deficiency, dialysis-related changes, or bone marrow suppression [5,6]. Haemodilution in CKD patients further lowers haematocrit levels. Reticulocyte counts are often inappropriately low relative to the degree of anaemia, reflecting impaired erythropoiesis. Peripheral blood smears are generally normal, although acanthocytes and burr cells may occasionally be observed, along with reduced polychromasia [5]. The prevalence and severity of anaemia increase with disease progression, affecting up to 43% of patients, particularly those with a GFR below 30 mL/min/1.73 m^2 [8]. A significant proportion of patients in advanced stages require transfusion support due to persistently low haematocrit levels [4]. Monitoring RBC indices in CKD is crucial for early detection and classification of anaemia, guiding appropriate management and avoiding unnecessary iron supplementation. Therefore, the present study aimed to evaluate RBC parameters and serum iron profiles across different stages of CKD and to determine their associations with renal function markers.

Study objectives

1. To analyse RBC parameters, iron profile, and peripheral smear findings in CKD patients
2. To assess serum creatinine and blood urea levels in CKD patients

3. To determine associations between RBC parameters, iron profile, peripheral smear findings, and renal function markers.

MATERIALS AND METHODS

The present retrospective cross-sectional study was conducted at Yenepoya Medical College Hospital, a tertiary care centre in Mangalore, Karnataka, India. Ethical clearance was obtained from Yenepoya Ethics Committee 1 (YEC1/2024/187), and a waiver of informed consent was approved. Patient data collected between May 2024 and May 2025 were analysed.

Inclusion criteria: CKD patients aged ≥18 years; Availability of complete RBC parameters, peripheral smear findings, iron profile, and renal function test results.

Exclusion criteria: Patients with pre-existing anaemia; Patients with bleeding disorders; Pregnant individuals; Patients with chronic inflammatory diseases; Patients with haematological malignancies.

Study Procedure

Data on RBC parameters (RBC count, haemoglobin, haematocrit, MCV, MCH, MCHC), peripheral smear findings, iron profile (serum iron, serum ferritin, TIBC), and renal function tests (serum creatinine and blood urea) were retrieved from computerized medical records of 113 CKD patients.

Staging of CKD: Participants were classified into five stages of CKD based on their estimated GFR. Stages 1 and 2 were considered mild, with GFR values above 60 mL/min/1.73 m^2. Stages 3, 4, and 5 were defined by GFR values below 60, 30, and 15 mL/min/1.73 m^2, respectively. GFR was estimated using the Modification of Diet in Renal Disease (MDRD) equation [9].

Estimated GFR (mL/min/1.73 m^2)=175×standardised serum creatinine$^{-1.154}$×age$^{-0.203}$

Multiply by 0.742 for women [9].

Severity of Anaemia (based on Haemoglobin levels) [10]

Mild anaemia: 10-12 g/dL

Moderate anaemia: 7-9 g/dL

Severe anaemia: <7 g/dL

Adult Males

- Mild anaemia: 11.0-12.9 g/dL
- Moderate anaemia: 8.0-10.9 g/dL
- Severe anaemia: <8.0 g/dL

Adult Females (non-pregnant)

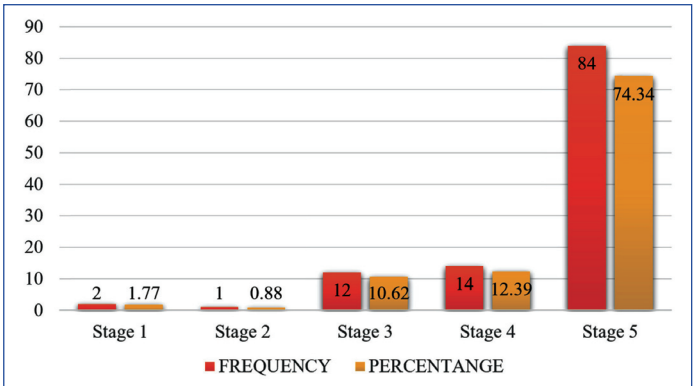
- Mild anaemia: 11.0-11.9 g/dL
- Moderate anaemia: 8.0-10.9 g/dL
- Severe anaemia: <8.0 g/dL

STATISTICAL ANALYSIS

Continuous variables were summarised using mean and Standard Deviation (SD), while categorical variables were expressed as frequencies and percentages. RBC parameters and serum iron levels were estimated along with their corresponding 95% confidence intervals. The relationships among RBC parameters, iron profile parameters, serum creatinine, and blood urea were analysed using Pearson's correlation coefficient. A p-value <0.05 was considered statistically significant. Statistical analysis was performed using SPSS software version 27.

RESULTS

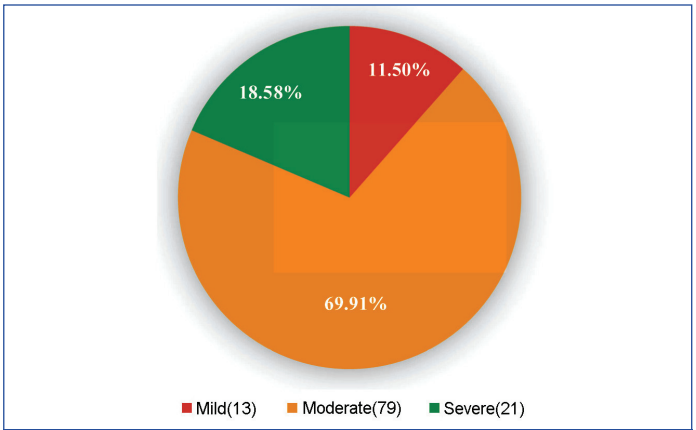
A total of 113 CKD patients were included in the present study. The age of participants ranged from 18 to 93 years, with a mean age of 50±16 years. Most patients belonged to the 34-53-year age group (n=47). Among the study population, 79 patients (69.91%) were male and 34 (30.08%) were female.



[Table/Fig-1]: Bar graph showing the frequency and percentage distribution of patients across CKD stages

Of the 113 patients, the largest proportion, 74.34% (n=84), were in stage 5 CKD, followed by 12.39% (n=14) in stage 4, indicating that most patients presented at advanced stages of the disease [Table/Fig-1]. Moderate anaemia was observed in the majority of cases (n=79) [Table/Fig-2].

The mean serum creatinine level was 6.76 mg/dL and the mean blood urea level was 95.03 mg/dL, reflecting significantly impaired renal function [Table/Fig-3].



[Table/Fig-2]: Pie diagram showing the percentage of severity of anaemia among CKD patients.

Parameters	Mean	95% Confidence Interval		SD
		Lower	Upper	
RBC (Male: 4.5-5.5 Female: 3.8- 4.8 million cells/mm^3)	2.91	2.78	3.04	0.7
Haemoglobin (Male: 13-17 Female: 12-15 gm/dL)	8.21	7.9	8.53	1.69
PCV (Male: 40-50 Female: 36-46%)	26.42	25.41	27.43	5.4
MCV (80-100 fL)	90.53	89.21	91.84	7.05
MCH (27-31 pg)	28.48	28.03	28.93	2.41
MCHC (32-36gm/dL)	31.51	31.19	31.82	1.69
Serum Iron (Male: 49-181 Female: 37-170 µg/dL)	72.28	63.04	81.53	49.6
Serum Ferritin (Male: 261-462 Female:265-497 µg/L)	602.25	420.22	784.28	976.6
TIBC (Total Iron Binding Capacity) (Male: 18-464 Female:11-264 µg/dL)	236.84	220.72	252.96	86.49
Serum Creatinine (0.52-1.05 mg/dL)	6.76	5.87	7.65	4.77
Blood urea(15-36 mg/dL)	95.03	83.54	106.51	61.63

[Table/Fig-3]: Descriptive statistics of RBC parameters, serum iron profile parameters and renal function test parameters

Participants demonstrated anaemia, with mean haemoglobin, RBC count, and packed cell volume (PCV) below normal reference ranges, while MCV, MCH, and MCHC remained within normal limits. This pattern indicated predominantly normocytic normochromic anaemia. Peripheral smear findings supported this observation, with normocytic normochromic anaemia being the most prevalent pattern. The corresponding mean serum creatinine and blood urea levels were 6.7 mg/dL and 94.37 mg/dL, respectively.

RBC parameters, including haemoglobin, RBC count, and PCV, exhibited moderate negative correlations with both serum creatinine and blood urea, all of which were statistically significant ($p<0.05$), indicating a decline in haematological parameters with worsening renal function. Other indices such as MCV, MCH, and MCHC showed no significant associations with serum creatinine or blood urea.

Serum iron demonstrated a weak but statistically significant positive correlation with serum creatinine ($r=0.26$, $p=0.006$), whereas its correlation with blood urea was not significant. Serum ferritin and TIBC showed no significant associations with either renal function parameter, although TIBC exhibited a weak negative correlation [Table/Fig-4].

RBC Parameters	Serum creatinine		Blood urea	
	Correlation (Pearson's correlation coefficient)	p-value	Correlation (Pearson's correlation coefficient)	p-value
RBC	-0.31	<0.001	-0.24	0.01
Haemoglobin	-0.33	<0.001	-0.27	0.004
PCV	-0.32	<0.001	-0.28	0.002
MCV	0.11	0.244	0.03	0.724
MCH	0.06	0.505	0.02	0.806
MCHC	-0.07	0.479	-0.03	0.742
Serum Iron	0.26	0.006	0.17	0.07
Serum Ferritin	0.04	0.68	0.03	0.749
TIBC	-0.18	0.06	-0.14	0.151

[Table/Fig-4]: Correlation between RBC parameters, Iron profile parameters with Serum Creatinine and Blood Urea

DISCUSSION

Chronic Kidney Disease (CKD) is a progressive renal disorder that causes long-term damage to renal parenchyma and may progress to End-Stage Renal Disease (ESRD) if not appropriately managed [11]. Anaemia is a common complication of advanced CKD and is a major contributor to morbidity and mortality in affected patients [5,6,12]. The frequency and severity of anaemia increase as CKD progresses, leading to reduced physical capacity, increased susceptibility to infections, cognitive impairment, and fatigue [13]. The present study evaluated RBC parameters, serum iron profile, peripheral smear findings, and their associations with serum creatinine and blood urea levels in CKD patients across different disease stages. Among the 113 patients analysed, 69.91% were male and 30.08% were female, with the majority (74.34%) in stage 5 CKD.

Study population and demographics: A male predominance (69.91%) was observed, consistent with findings reported by Anwar Habib et al., [14], who noted 75% males and 25% females, and by George SV et al., [15], who reported a similar distribution. This may be attributed to a higher prevalence of CKD risk factors among men.

RBC parameters and anaemia severity: Mean haemoglobin (8.21 g/dL), RBC count (2.91 million/mm^3), and PCV (26.42%) were all below normal reference values, confirming the presence of anaemia. Moderate anaemia was the most prevalent form (69.91%), followed by severe (18.58%) and mild (11.50%) anaemia, in agreement with previous studies. These findings are consistent with reports by Suresh M et al., [16], Shittu AO et al., [17], and Shastry I and Belurkar S [18]. Alghythan AK and Alsaeed AH [19] also observed significantly lower haematological parameters in CKD patients compared to healthy controls [Table/Fig-5].

Mean values	Suresh M et al., 2012 [16]	Shittu AO et al., 2013 [17]	Shastry I and Belurkar S 2019 [18]	Alghythan AK and Alsaeed AH 2012 [19]	Present study
RBC count (million cells/mm^3)	3.06±0.65	2.82±1	3.29 ± 0.79	4.13±0.54	2.91 ± 0.70
Hb(g/dL)	8.83±1.78	7.6±2.6	9.31 ± 0.52	11.7±1.29	8.21 ± 1.69
PCV (%)	27.13±4.41	24.41±8.4	28.48 ± 7.8	35.14±3.86	26.42 ± 5.40

[Table/Fig-5]: Comparison of mean RBC count, Haemoglobin and Haematocrit with similar studies [16-19].

Anaemia severity in CKD: Moderate anaemia was most common (69.91%), followed by severe (18.58%) and mild (11.50%), which aligns with observations by Khadayate R et al., [20] and Chakravarti A et al., [21], who similarly reported higher prevalence of moderate and severe anaemia in advanced CKD stages. Erken E et al., [22] reported variability in anaemia severity influenced by co-morbidities and nutritional status.

Peripheral smear findings: Normocytic normochromic anaemia (91%) was the predominant pattern, reflecting reduced erythropoietin production. Similar findings were reported by Chakravarti A et al., [21] (77.19%) and Arun S et al., [23] (59%). However, Talwar VK et al., [24] observed a higher prevalence of microcytic anaemia (67%), particularly in under-resourced settings, as also noted in the study by Shittu AO et al., [17].

Serum iron profile: The mean serum iron level was 72.28 µg/dL, mean ferritin was 602.25 ng/mL, and mean TIBC was 236.84 µg/dL, indicating altered iron metabolism likely related to chronic inflammation. These findings are consistent with those of Shastry I and Belurkar S [18] (serum iron 61 µg/dL, TIBC 216 µg/dL, ferritin 540 ng/mL) and Talwar VK et al., [24] (serum iron 55.1 µg/dL, ferritin 30.4 ng/mL).

Serum ferritin may not always accurately reflect true iron availability, as it functions as an acute-phase reactant. Naeem M et al., [25] also reported normal ferritin levels despite the presence of anaemia, suggesting the possibility of underdiagnosed iron deficiency. The mean serum creatinine and blood urea levels were 6.76 mg/dL and 95.03 mg/dL, respectively, indicating significantly impaired renal function. These results align with findings by Amin N et al., [26], who reported elevated creatinine and urea levels in haemodialysis patients, and by Khasawnah N et al., [27], who documented mean serum creatinine of 9.35±3.21 mg/dL and blood urea nitrogen of 69.52 ± 30.89 mg/dL.

Correlation of RBC parameters with renal markers: RBC count, haemoglobin, and packed cell volume demonstrated moderate negative correlations with serum creatinine and blood urea, indicating worsening anaemia with declining renal function. Similar associations were reported by Rahman MA et al., [28] ($r=-0.739$, $p<0.001$), George C et al., [29] ($p<0.005$), Suresh M et al., [16] ($p<0.005$), and Singh S et al., [30] ($p<0.001$), supporting the use of RBC indices as indicators of CKD progression.

Correlation of iron profile with renal markers: A weak positive correlation was observed between serum iron and serum creatinine ($r=0.26$, $p=0.006$), consistent with the findings of Asaduzzaman M et al., [31], who emphasised the importance of monitoring iron status in CKD patients. Wong MM et al., [32] also highlighted inadequate iron monitoring in many cases.

Jairam A et al., [33] reported that approximately 60% of patients with ESRD had sufficient iron stores, largely due to prior parenteral iron therapy before hospital admission. Iron deficiency was mainly seen in patients who had not received intravenous iron. Their study further noted that frequent iron supplementation and repeated blood transfusions in CKD patients often resulted in iron overload. Moreover, they cautioned that reliance solely on serum ferritin for assessing iron status can be misleading, as ferritin levels increase during inflammatory states, which are common in CKD.

Limitation(s)

The present study has several limitations. Being retrospective, it relied on existing medical records, which may have resulted in incomplete or missing data for certain variables. As it was conducted at a single tertiary care centre, the findings may not be generalisable to other healthcare settings within the Dakshina Kannada region or beyond. Additionally, the study population predominantly comprised Stage 5 CKD patients, with limited representation from earlier stages, restricting comparative analysis across disease stages. The absence of longitudinal follow-up also prevented evaluation of changes in anaemia status or renal function over time or in response to treatment.

CONCLUSION(S)

The present study demonstrated significant haematological alterations associated with CKD progression. Most patients (74%) presented in Stage 5 CKD, indicating late diagnosis. Anaemia was highly prevalent, predominantly normocytic normochromic, and most commonly of moderate severity. Haemoglobin, RBC count, and packed cell volume exhibited significant negative correlations with serum creatinine and blood urea, reflecting worsening anaemia with declining renal function. Although serum iron showed a weak positive correlation with creatinine, serum ferritin and TIBC demonstrated no significant associations, suggesting altered iron metabolism related to inflammation or impaired iron utilisation. These findings underscore the importance of routine monitoring of haematological parameters and iron profiles in CKD management, particularly in advanced stages.

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