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Original Research Article

Hematological and biochemical alterations across stages of chronic kidney disease: a tertiary care based observational study

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ABSTRACT

Background: Chronic kidney disease (CKD) is associated with progressive hematological and biochemical abnormalities that increase morbidity and mortality. Anemia, electrolyte imbalance, metabolic acidosis, and inflammation worsen with declining renal function. Objectives were to describe the hematological and biochemical profile of CKD patients; to compare parameters between early (stages 1-3) and advanced CKD (stages 4-5); and to assess correlations between glomerular filtration rate (GFR) and selected laboratory variables.
Methods: This observational study included 380 adults with CKD stages 1-5 attending a tertiary care hospital. Data collected included demographics, body mass index (BMI), CKD stage, and laboratory parameters (hemoglobin, blood cell counts, serum creatinine, uric acid, electrolytes, calcium, bicarbonate, GFR, C-reactive protein (CRP), and blood urea nitrogen). Anemia was graded as severe (<8 g/dL), moderate (8-9.9 g/dL), mild (10-10.9 g/dL), or absent (≥11 g/dL). Independent-samples *t*-tests compared CKD stages 1-3 vs 4-5, and Pearson's correlation assessed associations with GFR ($p<0.05$).
Results: Most patients were male, aged 41-60 years, and stage 5 CKD constituted over half of the cohort. Nearly 40% were overweight or obese. Anemia affected almost three-quarters of patients, with severe and moderate anemia seen in approximately one-fifth and one-third, respectively. Advanced CKD showed significantly lower hemoglobin, calcium, and bicarbonate, and higher creatinine levels. GFR correlated positively with hemoglobin, calcium, and bicarbonate, and negatively with creatinine and CRP.
Conclusions: CKD patients exhibited a high burden of anemia, metabolic acidosis, hypocalcemia, and inflammation, worsening with disease progression. Early identification and management of these abnormalities may improve outcomes.

Keywords: Chronic kidney disease, Anemia, Creatinine, Electrolytes, C-reactive protein, Glomerular filtration rate

INTRODUCTION

Chronic kidney disease (CKD) is a major global public health problem, associated with increased cardiovascular risk, poor quality of life and early mortality.[1,2] The prevalence of CKD is rising worldwide, particularly in low- and middle-income countries, driven by aging populations, diabetes and hypertension. Anemia, disordered mineral metabolism, metabolic acidosis, inflammation and electrolyte abnormalities are frequent complications, and their severity typically increases with declining GFR.[1-3,6-8]

Anemia of CKD is predominantly normocytic and normochromic, mainly due to reduced erythropoietin production, iron deficiency and chronic inflammation.[4,5] Recent studies report anemia prevalence in CKD ranging from 25-55% in general CKD cohorts to over 80% in advanced stages, with a strong association between lower hemoglobin and worse outcomes.[6-8] Metabolic and

biochemical derangements-including rising creatinine and BUN, hyperuricemia, dysnatremia, hyperkalemia, hypocalcemia, low bicarbonate and elevated CRP-are also well documented and may predict cardiovascular events and mortality.[9-11]

Data from Indian CKD populations suggest a high prevalence of anemia and biochemical abnormalities, with substantial variation across regions.[19-21] However, there remains a need for center-specific profiles that can guide local management strategies and benchmarking.

This study aimed to describe the hematological and biochemical profile of 380 CKD patients from a tertiary care hospital, compare laboratory parameters between early (stages 1-3) and advanced (stages 4-5) CKD, and explore correlations between GFR and key biochemical markers.

METHODS

Study design and setting

This prospective observational study was conducted at the Department of Nephrology, Muljibhai Patel Urological Hospital (MPUH), Nadiad, Gujarat, India, from September 2024 to January 2025. The study included adult patients (≥18 years) diagnosed with CKD (Stages 1-5) attending OPD, IPD, and dialysis units.

A total sample size of 380 consecutive eligible patients was included based on availability during the defined study period (convenience sampling method).

CKD staging was performed according to KDIGO guidelines. Estimated GFR (eGFR) was calculated using

Inclusion criteria

All gender patients, patients with comorbid conditions and all CKD patients above 18 years old were included in the study.

Exclusion criteria

Pregnant and lactating women, the patient underwent renal transplantation, a patient admitted with acute kidney injury and a total of 380 consecutive eligible CKD patients were excluded in the study.

Data collection

Demographic and clinical variables included age group, sex, BMI category, blood group and CKD stage (1-5). Laboratory parameters were extracted from patient records: hemoglobin (Hb), red blood cell count (RBC), white blood cell count (WBC), serum creatinine, uric acid, serum sodium, potassium, total calcium, bicarbonate, CRP, blood urea nitrogen (BUN), and GFR. All tests were performed in the hospital's central laboratory using standard automated analyzers and quality-controlled methods.

Operational definitions

CKD stages 1-5 were recorded as per clinical classification: stage 1, 2, 3A, 3B, 4 and 5. For comparison, stages 1-3 (1, 2, 3A, 3B) were grouped as early CKD and stages 4-5 as advanced CKD. Anemia grading in this study was defined as: Severe: Hb <8 g/dL, moderate: Hb 8-9.9 g/dL, mild: Hb 10-10.9 g/dL and no anemia: Hb ≥11 g/dL.

Statistical analysis

Data were analyzed using standard statistical software. Continuous variables are presented as mean ± standard deviation (SD), and categorical variables as frequencies and percentages. Independent-samples t-tests (Welch's correction for unequal variances where applicable) compared mean laboratory values between stage 1–3 and stage 4–5 groups. Pearson's correlation coefficient (r) assessed linear relationships between GFR and laboratory parameters (Hb, creatinine, uric acid, sodium, potassium, calcium, bicarbonate, CRP, BUN). A two-sided p-value <0.05 was considered statistically significant.

Ethical approval

The study was submitted to the Muljibhai Patel Society for Research in Nephro-Urology ethics committee for human research for approval on 4th September 2024. The study was carried out to analyse prescription pattern and find out drug-drug interactions. The data was collected from the OPD, IPD, and dialysis unit. The main purpose of the study was well explained to the patients. Informed consent was maintained confidentially. After peer interviewing and reviewing, the study was approved by the ethics committee.

RESULTS

The study included a total of 380 patients with CKD. A clear male predominance was observed, with 271 patients (71.3%) being male and 109 patients (28.7%) female, indicating a higher burden of CKD among males in the study population.

Regarding age distribution, majority of patients belonged to 41-60 years age group, accounting for 170 individuals (44.7%), followed by those aged 61-80 years (116 patients; 30.5%). Younger patients aged 18-40 years constituted 23.7% (n=90) of the cohort, while patients aged above 80 years represented only a small fraction (1.1%; n=4). This pattern suggests that CKD was most prevalent among middle-aged and elderly individuals, reflecting the cumulative impact of long-standing comorbid conditions and progressive renal dysfunction with advancing age.

Analysis of disease severity revealed a marked predominance of advanced CKD. More than half of the

patients were classified as CKD stage 5 (n=206; 54.2%), followed by stage 4 (n=73; 19.2%). Moderate disease stages, including stage 3A (7.1%) and stage 3B (11.8%), together accounted for approximately one-fifth of the cohort. Early-stage CKD was relatively uncommon, with stage 1 (2.1%) and stage 2 (5.5%) representing a minority of cases. This distribution highlights late-stage presentation and delayed diagnosis or referral, a pattern commonly reported in hospital-based CKD studies.

Table 1: The demographic and clinical characteristics of the study population are summarized.

Variables	Category	N	Percent (%)
Gender	Male	271	71.3
	Female	109	28.7
Age (in years)	18-40	90	23.7
	41-60	170	44.7
	61-80	116	30.5
	>80	4	1.1
CKD stage	1	8	2.1
	2	21	5.5
	3A	27	7.1
	3B	45	11.8
	4	73	19.2
	5	206	54.2
BMI (kg/m^2)	Underweight	39	10.3
	Normal	191	50.3
	Overweight	108	28.4
	Obese I	35	9.2
	Obese II	6	1.6
	Obese III	1	0.3

BMI analysis demonstrated that normal BMI was the most frequent category, observed in 191 patients (50.3%). However, a substantial proportion of patients were either overweight (28.4%) or obese (11.1% collectively across obese I-III categories), indicating a high prevalence of excess body weight. Conversely, underweight status was noted in 10.3% (n=39) of patients, which may reflect malnutrition and protein-energy wasting frequently associated with advanced CKD.

Overall, the demographic and clinical profile of the study population is characterized by male predominance, middle-to-older age distribution, advanced CKD stages, and dual burden of overweight/obesity and undernutrition. These factors collectively have important implications for disease progression, electrolyte imbalance, and therapeutic management in patients with CKD.

Table 2: Distribution of anemia severity.

Category	N	Percent (%)
Severe (<8.0 g/dL)	86	22.6
Moderate (8.0-9.9 g/dL)	145	38.2
Mild (10.0-10.9 g/dL)	51	13.4
No anemia ≥(11.0 g/dL)	98	25.8

As shown in Table 2, anemia was highly prevalent in the study population. Moderate anemia was the most frequent category, followed by severe anemia, together accounting for a substantial proportion of patients. Only a minority of patients had hemoglobin values within the non-anemic range, indicating that anemia represents a major clinical problem in this cohort. Overall biochemical parameters **(**Table 3**)** reflect advanced renal dysfunction, with markedly elevated serum creatinine and reduced GFR. Electrolyte abnormalities were common, including lower mean sodium levels, variable potassium concentrations, reduced calcium levels, and decreased bicarbonate values, suggesting frequent disturbances in electrolyte and acid-base balance. Elevated CRP levels indicate a significant inflammatory burden among the patients.

Comparison of early vs advanced CKD (stages 1-3 vs 4-5)

Patients grouped as early CKD (stages 1-3; n≈99) and advanced CKD (stages 4-5; n≈281). Advanced CKD showed significantly lower Hb and calcium, and significantly higher creatinine compared with early CKD. Bicarbonate levels were also significant lower in advanced stages, reflecting more pronounced metabolic acidosis. CRP showed trend toward higher levels in advanced stages.

Table 3: Overall biochemical parameters.

Parameters	Mean±SD	Minimum	Maximum
Hemoglobin (g/dL)	9.54±2.07	5	16.9
RBC (million/µL)	3.64±2.34	1.03	46.3
WBC (/µL)	9864.42±5769.95	5.49	83000
Creatinine (mg/dL)	6.10±4.40	0.78	24.65
Uric acid (mg/dL)	7.37±3.16	0	21.3
Sodium (mmol/L)	132.84±5.37	104	145
Potassium (mmol/L)	4.48±0.99	1.35	11.5
Calcium (mg/dL)	8.95±1.62	4.62	25.7
Bicarbonate (mmol/L)	20.96±8.56	6.6	97
GFR (mL/min/1.73 m²)	21.35±19.48	2	95
CRP (mg/L)	63.42±61.86	0	368
BUN (mg/dL)	178.27±190.52	9.96	684.49

Table 4: Comparison of biochemical parameters between early (stages 1-3) and advanced (stages 4-5) CKD.

Parameters	Stage 1-3, (Mean±SD)	Stage 45, (Mean±SD)	P value
Hemoglobin (g/dL)	10.65±2.05	9.14±1.93	0
RBC count (×10⁶/µL)	4.00±0.82	3.51±2.67	0
WBC count (/µL)	10089.84±4830.43	9783.91±6076.25	0.4027
Serum creatinine (mg/dL)	1.91±1.78	7.59±4.09	0
Uric acid (mg/dL)	6.98±2.98	7.53±3.22	0.1558
Sodium (mEq/L)	133.38±4.40	132.65±5.67	0.3413
Potassium (mEq/L)	4.42±1.15	4.50±0.93	0.3121
Calcium (mg/dL)	9.36±1.87	8.80±1.50	0.005
Bicarbonate (mEq/L)	22.11±4.08	20.55±9.64	0
eGFR (mL/min/1.73 m²)	49.77±14.98	11.20±6.53	0
CRP (mg/L)	52.30±67.48	67.40±59.34	0.0002

Comparison of biochemical parameters between early (stages 1-3) and advanced (stages 4-5) CKD (Table 4) demonstrated significantly greater abnormalities in advanced disease. Patients with advanced CKD showed significantly lower hemoglobin, RBC count, calcium, bicarbonate, and eGFR, along with significantly higher serum creatinine and CRP levels. These findings indicate progressive worsening of anemia, mineral metabolism, metabolic acidosis, and inflammation with declining renal function. No statistically significant differences were observed for WBC count, sodium, potassium, or uric acid between the two groups.

Correlation between GFR and biochemical parameters

Pearson's correlation analysis showed significant associations between GFR and several laboratory parameters. Higher GFR was associated with higher hemoglobin, calcium and bicarbonate, and lower creatinine and CRP.

Table 5: Correlation of GFR with selected biochemical parameters.

Parameters	R value	P value
Hemoglobin (g/dL)	0.366	0
RBC count (×10⁶/µL)	0.369	0
WBC count (/µL)	0.045	0.3865
Serum creatinine (mg/dL)	-0.937	0
Uric acid (mg/dL)	-0.122	0.0564
Sodium (mEq/L)	0.091	0.0779
Potassium (mEq/L)	-0.121	0.0181
Calcium (mg/dL)	0.21	0
Bicarbonate (mEq/L)	0.27	0
CRP (mg/L)	-0.182	0.0004

Correlation analysis (Table 5) showed a strong inverse relationship between eGFR and serum creatinine, confirming worsening renal clearance with disease progression. Moderate positive correlations were observed between eGFR and hemoglobin and RBC count, indicating increasing anemia severity with declining kidney function. Significant positive correlations were also noted between eGFR and calcium and bicarbonate levels, reflecting disturbances in mineral metabolism and acid–base balance in advanced CKD. Weak but significant inverse correlations were observed between eGFR and potassium and CRP, suggesting an increased risk of hyperkalemia and inflammation as renal function declines. Other parameters demonstrated no significant correlation with eGFR.

DISCUSSION

This observational study of 380 CKD patients from a tertiary care center demonstrates a high burden of anemia, biochemical derangements and advanced CKD stages. More than half of the cohort was in stage 5 CKD, and nearly three-quarters had hemoglobin <11 g/dL. Anemia severity increased with advancing CKD, with significantly lower hemoglobin and higher creatinine in stage 4-5 compared with stage 1-3, and GFR correlated positively with hemoglobin and negatively with creatinine.

The anemia prevalence and high proportion of moderate-to-severe anemia observed in this study are consistent with reports that anemia becomes more frequent and severe as CKD progresses. Several recent studies and meta-analyses have documented anemia prevalence between 50-80% among CKD patients, particularly in advanced stages, with strong associations with low eGFR, diabetes and inflammation. Clinical guidelines emphasize regular screening for anemia in CKD and treatment using iron therapy and erythropoiesis-stimulating agents after correction of reversible causes. Large randomized trials have shown that targeting near-normal hemoglobin levels with high-dose ESA therapy does not necessarily improve cardiovascular outcomes and may increase risk, underscoring the need for individualized and balanced correction.[1,4,8]

Elevated creatinine and BUN, along with reduced GFR, reflect the renal failure burden in this cohort. Elevated uric acid and CRP levels suggest a contribution of hyperuricemia and chronic inflammation, both linked to cardiovascular risk and CKD progression.[9,10] We observed lower calcium and bicarbonate levels in advanced CKD,

consistent with CKD-mineral and bone disorder and metabolic acidosis. Hypocalcemia and acidosis correlate with parathyroid hormone changes, bone disease and muscle wasting, and may contribute to arrhythmias and poor functional status.[14] The mild but significant positive correlation of GFR with calcium and bicarbonate in our data supports these mechanisms.

Electrolyte disturbances, particularly dysnatremia and hyperkalemia, are common in CKD and associated with arrhythmias and mortality. In this cohort, mean sodium was slightly low-normal and potassium within normal range overall, with no strong correlation with GFR, possibly reflecting careful outpatient management or dietary restriction.

Several regional studies have reported biochemical and clinical profiles similar to ours, with high rates of advanced CKD, anemia and metabolic complications in tertiary care settings. Our finding of over half the cohort in stage 5 is comparable to hospital-based studies where referral bias favors more advanced disease. Population-based CKD cohorts often show lower stage 5 proportions but still confirm rising anemia and biochemical abnormalities with progression.[19-21]

Strengths of this study include the relatively large sample size and comprehensive assessment of both hematological and biochemical parameters. However, limitations include its single-center design, obsrvational nature, lack of detailed comorbidity and medication data, and incomplete information on BUN and iron indices. These limitations restrict causal inference and more detailed etiological analysis.

CONCLUSION

In this observational study of 380 CKD patients, more than half had stage 5 disease and nearly three-quarters had hemoglobin <11 g/dL, with a high proportion of moderate-to-severe anemia. Advanced CKD (stages 4-5) was associated with significantly lower hemoglobin, higher creatinine, lower calcium and more pronounced metabolic acidosis compared with earlier stages. GFR correlated positively with hemoglobin, calcium and bicarbonate and negatively with creatinine and CRP, underscoring the interplay between declining renal function, anemia, mineral metabolism and inflammation. These findings emphasize the importance of early detection and comprehensive management of hematological and biochemical abnormalities in CKD.

Recommendations

Implement routine anemia and biochemical screening in all CKD patients, especially from stage 3 onward. Optimize iron status, erythropoiesis-stimulating agent therapy, and correction of metabolic acidosis and mineral imbalance to target guideline-recommended ranges. Conduct multicenter, longitudinal studies including detailed comorbidity and treatment data to better understand factors driving progression and outcomes in CKD populations.

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Ethical approval: The study was approved by the Institutional Ethics Committee

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