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Anaemia in Chronic kidney Disease: Insights into Prevalence, Morphology, and Biochemical Alterations

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Abstract

Introduction: Anaemia is a common and clinically significant complication of chronic kidney disease (CKD), contributing substantially to morbidity, reduced quality of life, and increased cardiovascular risk.
Aims and Objectives: The present study investigates the prevalence, clinical characteristics, and biochemical correlations of anaemia in patients with CKD compared with individuals with anaemia without CKD and healthy controls.
Methods: The research was conducted as an observational cross-sectional study at the Nephrology Department of Amrita Hospital, Faridabad, India. A total of 150 participants were included and categorized into three groups: anaemia without CKD (n=50), anaemia with CKD (n=50), and healthy controls (n=50). Demographic details and laboratory parameters including haemoglobin (Hb), haematocrit (HCT), white blood cell count (WBC), platelet count, urea, creatinine, blood urea nitrogen (BUN), and glomerular filtration rate (GFR) were evaluated.
Results: The findings demonstrated significantly reduced haemoglobin and haematocrit levels in both anaemic groups compared with healthy controls. CKD patients exhibited markedly elevated urea, creatinine, and BUN levels, reflecting impaired renal function. Normocytic normochromic anaemia was the predominant morphological pattern among CKD patients. The study highlights the multifactorial pathogenesis of anaemia in CKD, including erythropoietin deficiency, iron dysregulation, inflammation, and shortened red blood cell lifespan.
Conclusion: Early diagnosis, appropriate monitoring of haematological indices, and targeted therapeutic strategies are essential to improve clinical outcomes and reduce complications associated with CKD-related anaemia.

1.INTRODUCTION

One Anaemia is a global health concern affecting millions of individuals across different age groups and socioeconomic backgrounds. It is characterized by a reduction in the number of circulating red blood cells (RBCs) or a decrease in haemoglobin concentration below normal physiological levels. Haemoglobin plays a vital role in oxygen transport from the lungs to tissues; therefore, any reduction in haemoglobin levels results in impaired oxygen delivery and various systemic manifestations (Bonomini 1996, Eckardt 1994, Eckardt 2005).

The causes of anaemia are diverse and include nutritional deficiencies, chronic diseases, genetic disorders, infections, and blood loss. Among these causes, nutritional deficiencies particularly iron, vitamin B12, and folate deficiencies are the most common worldwide. However, anaemia associated with chronic diseases represents a major clinical challenge because it often arises from complex and multifactorial mechanisms (Eckardt 1991, Ganz 2012).

One of the most clinically significant forms of anaemia occurs in patients with chronic kidney disease (CKD). CKD is a progressive condition characterized by the gradual loss of kidney function over time. The kidneys perform essential physiological roles, including filtration of metabolic waste products, electrolyte balance, regulation of blood pressure, and production of hormones necessary for red blood cell formation. When kidney function deteriorates, these physiological processes become disrupted (Haase 2013, Helkmann 2011).

Among the complications of CKD, anaemia is particularly important because it contributes significantly to patient morbidity and mortality. CKD-associated anaemia is defined by reduced haemoglobin levels, typically below 13 g/dL in men and below 12 g/dL in women. The prevalence of anaemia increases with the progression of renal dysfunction and becomes more prominent in advanced stages of CKD (KDOQI 2006, KDIGO 2012).

The underlying mechanism of anaemia in CKD is primarily related to insufficient production of erythropoietin (EPO), a hormone responsible for stimulating red blood cell production in the bone marrow. EPO is produced mainly by the peritubular interstitial

cells of the kidneys. In healthy individuals, hypoxia triggers increased EPO production, which promotes erythropoiesis and restores oxygen-carrying capacity. However, in CKD patients, damaged kidneys are unable to produce adequate amounts of EPO, resulting in decreased RBC production (Koury 2015).

The severity of anaemia generally correlates with the degree of kidney dysfunction. Studies have shown that anaemia begins to manifest when the glomerular filtration rate (GFR) declines significantly, often below 30 mL/min. In certain patient groups, such as those with diabetic nephropathy, anaemia may develop even earlier (KDIGO 2012).

Clinically, anaemia in CKD is typically normocytic and normochromic, meaning that red blood cells are normal in size and haemoglobin content but reduced in number. However, variations in red blood cell morphology may occur depending on additional factors such as iron deficiency or nutritional deficiencies (KDIGO 2012).

The consequences of anaemia extend far beyond haematological abnormalities. Patients often experience symptoms such as fatigue, weakness, dyspnea, reduced physical capacity, and cognitive impairment. Moreover, anaemia significantly increases cardiovascular risk by forcing the heart to work harder to deliver adequate oxygen to tissues. This increased workload can lead to complications such as left ventricular hypertrophy, heart failure, and increased mortality (Locatelli 2004).

Epidemiological data reveal considerable regional variation in the prevalence of anaemia among CKD patients. For example, studies have reported prevalence rates of approximately 14% in the United States, 39% in India, 51% in China, and even higher percentages in some African populations. These variations highlight the importance of population-specific research and tailored clinical management strategies (Macdougall 2004, Macdougall 2014).

Given the significant clinical burden of CKD-associated anaemia, it is essential to improve our understanding of its prevalence, pathophysiology, and clinical implications. The present study aims to evaluate the prevalence and severity of anaemia among CKD patients and to compare clinical and biochemical parameters between CKD-associated anaemia and anaemia without kidney disease.

2. STUDY DESIGN AND METHODOLOGY

2.1 Study Design

The present study was designed as an observational cross-sectional study conducted over a one-year period (August 1, 2024 – July 30, 2025). Patients were collected from Department of Nephrology, Amrita Hospital, Faridabad, Delhi, India. The study was approved by departmental research committee, Brainware University. Informed consent was given to each patient.

2.2 Study Population

A total of 150 participants were included in the study and divided into three groups:

1. Group 1: Anaemia without CKD (50 individuals)

2. Group 2: Anaemia with CKD (50 individuals)

3. Group 3: Healthy control subjects (50 individuals)

2.3 Inclusion Criteria

Participants were selected based on the following criteria:

• Adults aged above 18 years.

• Patients diagnosed with CKD according to KDIGO 2012 guidelines.

• Individuals willing to provide written informed consent.

• Healthy individuals with haemoglobin levels between 12–15 g/dL and no history of kidney disease or autoimmune disorders.

2.4 Exclusion Criteria

Participants were excluded if they:

• Had autoimmune disorders.

• Receiving iron supplementation.

• Had other known causes of anaemia unrelated to CKD.

2.5 Data Collection

Information collected included:

• Demographic characteristics (age, gender)

• Medical history

• Laboratory parameters including:

- Haemoglobin (Hb)
- Haematocrit (HCT)
- White Blood Cell Count (WBC)
- Platelet Count
- Blood Urea Nitrogen (BUN)
- Serum Creatinine
- Urea
- Glomerular Filtration Rate (GFR)

2.6 Classification of Anaemia

Anaemia was categorized into three severity levels (Nangaku 2006):

• Mild: Hb 10–12 g/dL

• Moderate: Hb 7–9.9 g/dL

• Severe: Hb <7 g/dL

Morphological classification was based on red cell indices:

• Microcytic hypochromic anaemia

• Normocytic normochromic anaemia

• Macrocytic anaemia

3. RESULT

The demographic and biochemical characteristics of study participants revealed significant differences between CKD patients and control subjects. All demographic data was given in table no 1.

Table 1. Demographic and biochemical data of all study participants

Parameter	Control (n=50)	Anemia without CKD (n=50)	Anemia with CKD (n=50)
Age (years)	30±5	39±10	58±13
Sex	Male =28 Female = 22	Male =23 Female= 27	Male = 34 Female= 16
Hb(gm/dl)	11±0.87	8.4±0.93	8.2±0.86
HCT (%)	24.5±1	24±1.5	27.4±2.7
WBC	11327±2954	9460±2065	12987±8700
Platelet	183±68	214±75	202±86
Urea(mg/dl)	30±7	33+5	105±56
Creatinine(mg/dl)	0.93±0.31	0.60±0.89	3.9±1.4
BUN (mg/dl)	14.5±3.5	21±6	48.8±26.2
GFR	-	-	19±10.6

3.1.Male female distribution in anaemia with CKD:

Among the 50 participants of anaemia with CKD, 34 (67 %) and 16 (33%) were male and female, respectively. The distribution of the patient's gender is shown in (Figure 1).

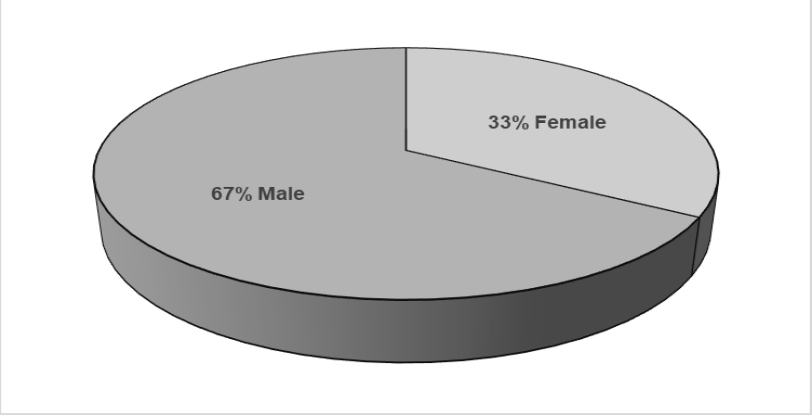

Figure 1: Gender distribution among anaemia with CKD patients

3.2. Age distribution in anaemia with CKD:

The mean age was 55.3±17 SD. The age groups were divided into intervals to estimate the age of the majority of participants. Five age groups were done, and a high percentage was for participants aged between 60 and 80 years, which accounted for 24 (40%). The age-wise distribution is shown in (Table 2).

Table 2: Age distribution among anaemia with CKD patients

Age (years)	N	%
18-29	3	6
30-44	10	20
45-59	10	20
60-80	24	48
> 80	3	6
Total	60	100

3.3.Severity of CKD among anaemic patients

In accordance with studies in the literature, anaemia is characterized as haemoglobin levels below 13 g/dl for men and below 12 g/dl for women (Nangaku 2006). According to the aforementioned standards, haemoglobin served as an indicator of anaemia in our investigation. Considering additional data, the CKD stage was determined using the creatinine level. Based on their GFR assessment, participants were divided into five phases. Compared to higher stages, participants in this study were absent from stages 1 and 2. This may be due to the fact that most CKD cases in their early stages go undiagnosed, and patients are already in more advanced stages when they receive the necessary diagnosis and assessment. The majority of patients may not receive the necessary evaluation because there aren't any high-alert symptoms in the early stages (depicted in Table 3).

Table 3: Distribution of study population according to CKD stage

CKD stage	N	%
Stage 1	Not found	
Stage 2	Not found	
Stage 3	2	4
Stage 4	13	26
Stage 5	35	70
Total	50	100

3.4.Male female distribution in anaemia without CKD:

Among the 50 participants of anaemia without CKD, 23 (47 %) and 27 (53%) were male and female, respectively. The distribution of the patient's gender is shown in (Figure 2).

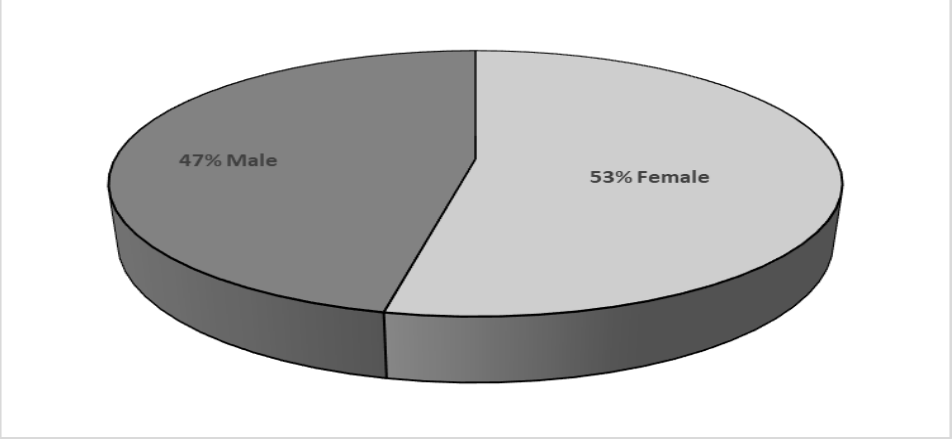

Figure 2: Gender distribution among anaemia without CKD patients

3.5. Comparative analysis of haematological parameters among anaemia with vs without CKD patients

Table 4: Evaluation of Anemia with CKD vs. Anemia without CKD Patients

Category	Parameter	Anaemia with CKD (n=50)	Anemia without CKD(n=50)	p value	Normal range
Anemia Severity	Mild	4	3		
	Moderate	38	43		
	Severe	8	4		
Morphological patterns	Normocytic Normochromic	30	26		
	Microcytic Hypochromic	2	16		
	Macrocytic	18	8		
Laboratory measure	Hemoglobin (Hb) (g/dL)	8.2±1.5	8.3±0.79	0.58	12-16g/dL
	Mean Corpuscular Volume (MCV) (fL)	96.04±8.8	87.5±12.5	<0.0001	80-100 fL
	Mean Corpuscular Hemoglobin Conc. (MCHC) (g/dL)	32.6±1.6	32.08±2.4	0.16	32-36 g/dL

This study demonstrated a significant reduction in haematocrit (HCT%) in both CKD patient groups compared to healthy controls ($p < 0.0001$ for both anaemia with CKD and anaemia without CKD). However, no significant difference was observed between the anaemia with CKD and anaemia without CKD groups ($p = 0.4$). (figure-3)

The data showed a significant decrease in haemoglobin (Hb, g/dL) levels in both CKD patient groups compared to healthy controls ($p < 0.0001$ for both anaemia with CKD and anaemia without CKD). However, no significant difference was observed between the anaemia with CKD and anaemia without CKD groups ($p = 0.7$). (figure-4)

Both the anaemia with CKD and anaemia without CKD groups showed a significant decrease in White Blood Cells (WBC)compared to the healthy control group ($p = 0.2$ for both Anemia without CKD and Anemia with CKD). However, there was no significant variation in WBC count between the two patient groups ($p = 0.5$). (figure-5)

Data showed that in Platelet level there was no change in both Anemia with CKD and Anemia without CKD patients groups compare to the healthy control group. ($p=0.6$ for Anemia without CKD and $p=0.8$ for Anemia with CKD). Also, no change between were found between Anemia with CKD and Anemia without CKD patients ($p=0.9$). (figure-6)

The anaemia with CKD group showed a significant increase in urea (mg/dL) levels compared to both the healthy control group and the anaemia without CKD group ($p < 0.0001$ for both comparisons). However, no significant difference was observed between the healthy control group and the anaemia without CKD group. (figure-7)

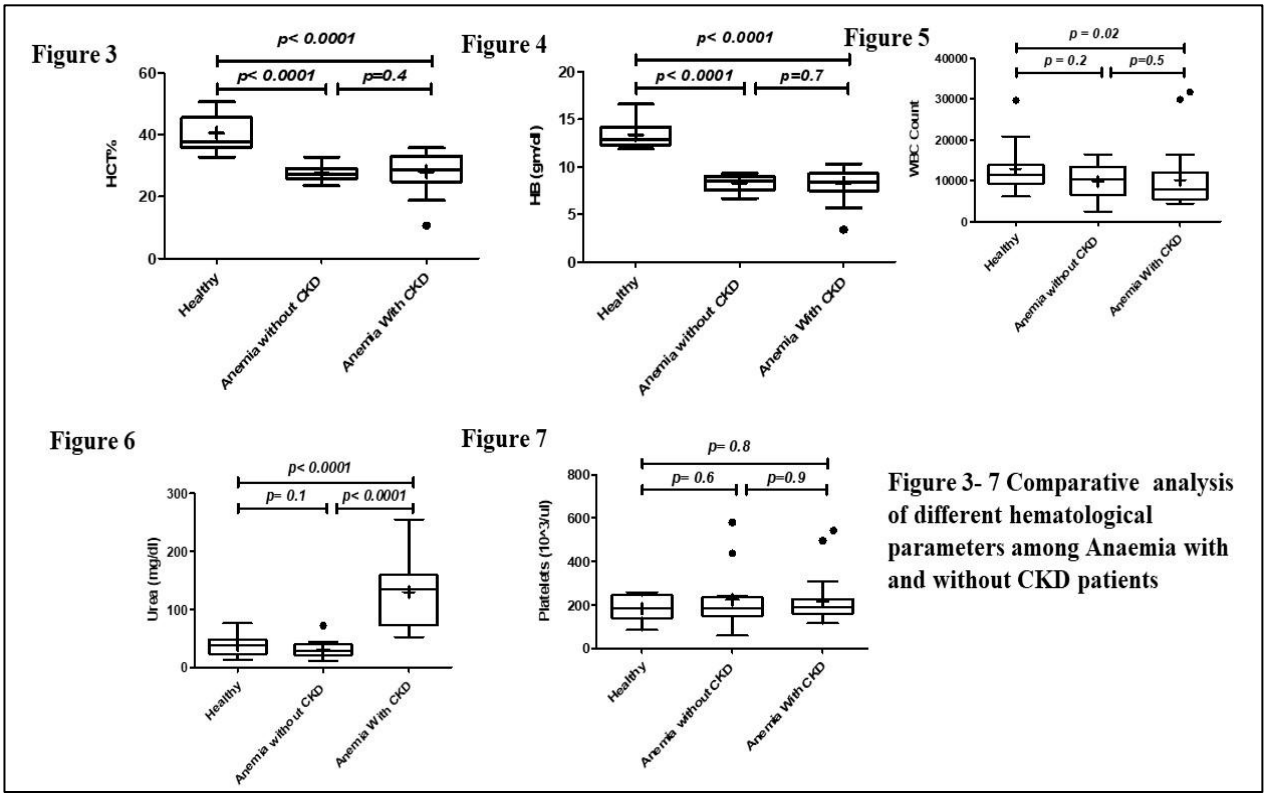

Figure 3- 7 Comparative analysis of different hematological parameters among Anaemia with and without CKD patients

4. DISCUSSION

The results of the present study highlight a strong and clinically significant association between chronic kidney disease (CKD) and anaemia. Anaemia is widely recognized as one of the most common complications of CKD and tends to worsen as renal function progressively declines (Stauffer 2014). In patients with CKD, the kidneys gradually lose their ability to perform several physiological functions, including the production of erythropoietin (EPO), a hormone that plays a crucial role in stimulating red blood cell (RBC) production in the bone marrow. As kidney damage progresses, the synthesis of erythropoietin decreases, resulting in inadequate stimulation of erythroid progenitor cells and reduced RBC formation. Consequently, haemoglobin levels fall, leading to the development of anaemia.

The decrease in haemoglobin levels observed among CKD patients in this study is therefore consistent with findings reported in earlier research, which have consistently identified impaired erythropoietin production as a major contributor to anaemia in CKD (Thomas 2008).

Another important observation from the present study is the predominance of normocytic normochromic anaemia among CKD patients. In this morphological pattern, red blood cells are normal in size (normocytic) and contain a normal concentration of haemoglobin (normochromic), but their overall number is reduced (Weiss 2005). This pattern strongly supports the concept that CKD-related anaemia arises primarily due to decreased RBC production rather than abnormalities in haemoglobin synthesis or defects in red blood cell maturation. In contrast, other types of anaemia, such as iron deficiency anaemia or vitamin B12 deficiency anaemia, typically present with microcytic hypochromic or macrocytic RBC patterns. Therefore, the

identification of normocytic normochromic anaemia in CKD patients serves as an important diagnostic clue indicating that the underlying pathology is associated with impaired erythropoiesis rather than nutritional deficiencies alone (Wish 2006).

The findings of this study also reveal that none of the participants were identified in the early stages of CKD. Most patients were diagnosed when the disease had already progressed to more advanced stages. This observation suggests that CKD often remains asymptomatic during its initial phases and may go undetected for long periods. In the early stages, patients frequently experience minimal or non-specific symptoms, which may not prompt them to seek medical attention. As a result, diagnosis is often delayed until significant kidney damage has occurred and complications such as anaemia, electrolyte imbalance, or hypertension become evident. This delay in diagnosis highlights an important challenge in the clinical management of CKD (Fishbane 2017).

Early detection of CKD is therefore essential to prevent or minimize complications associated with the disease. Regular screening of high-risk populations—such as individuals with diabetes mellitus, hypertension, cardiovascular disease, or a family history of kidney disorders—can facilitate earlier identification of declining kidney function. Early diagnosis allows healthcare providers to initiate appropriate therapeutic interventions, slow disease progression, and reduce the risk of complications including anaemia, cardiovascular disease, and reduced quality of life (Babitt 2012, Levin 2013).

Furthermore, the results of the study emphasize the importance of evaluating renal function markers when assessing anaemia in clinical practice. Laboratory parameters such as serum creatinine, blood urea nitrogen (BUN), and glomerular filtration rate (GFR) provide essential information regarding the functional status of the kidneys. Elevated serum creatinine and BUN levels typically indicate impaired renal filtration, while a reduced GFR reflects decreased kidney function. By correlating these renal markers with haemoglobin levels and other haematological parameters, clinicians can better determine whether anaemia is related to kidney dysfunction or other underlying causes.

In addition, assessing renal function markers helps clinicians determine the severity and stage of CKD, which is critical for guiding treatment decisions. For instance, patients with advanced CKD and significant erythropoietin deficiency may benefit from erythropoiesis-stimulating agents (ESAs) or iron supplementation as part of their treatment strategy. Monitoring these biochemical indicators also allows physicians to evaluate disease progression and adjust therapeutic approaches accordingly.

Overall, the findings of this study reinforce the well-established relationship between chronic kidney disease and anaemia. They highlight the importance of early screening, accurate diagnosis, and comprehensive evaluation of both haematological and renal parameters. Such an integrated clinical approach is essential for improving patient outcomes, preventing disease progression, and reducing the overall burden of CKD-associated complications.

5. CONCLUSION

Anaemia is a common and significant complication of chronic kidney disease that contributes to reduced quality of life and increased cardiovascular risk. The present study demonstrates that anaemia is highly prevalent among CKD patients and is closely associated with impaired renal function. The results emphasize the importance of early screening, accurate diagnosis, and appropriate treatment strategies for managing anaemia in CKD patients. Monitoring haematological parameters alongside renal function markers can help clinicians identify anaemia early and implement targeted therapeutic interventions.

Future research should focus on exploring novel therapeutic approaches and improving public health strategies to reduce the burden of CKD-related anaemia.

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Conflict of Interest
All authors declared that they have no conflict of interest in this study

Declaration for using Artificial Intelligence
The authors declare that artificial intelligence (AI) tools were used solely to assist in language refinement, grammar correction, and improvement of the manuscript. The AI tools did not contribute to the study design, data collection, data analysis, interpretation of results, or generation of original scientific content.

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