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Clinical Assessment of Anemia Patterns and Iron Status Among End-Stage Renal Disease Patients: A Cross-Sectional Study at the Tripoli Kidney Services Center

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ABSTRACT

Background: Anemia is a well-known complication of chronic kidney disease (CKD), especially in patients on maintenance hemodialysis. It is characterized by erythropoietin deficiency and disturbed iron homeostasis and is linked to high cardiovascular risk. According to that the present study aimed to assess the biochemical profile of iron status (Serum Iron, Ferritin, TIBC, TSAT) and its clinical manifestations among ESRD patients in Tripoli, Libya.

Methods: A cross-sectional analysis was performed on 50 randomly selected patients at the Tripoli Kidney Services Center (May–September 2024). Hematologic data were also cross-checked with clinical symptomatic surveys. Statistical analysis was performed by IBM SPSS v26.

Results: Of the cohort, 34% were male and 66% were female. The mean Hemoglobin (Hb) level was 9.56 ± 1.77 g/dl, significantly lower than international targets. Analysis of Iron profile showed a mean Serum Iron of 50 µg/dl and TSAT of 21%. This is indicative of functional iron deficiency. The clinical picture was severe with 84% profound fatigue and 74% neurological disturbances (headache/vertigo). Despite 96% of patients receiving intravenous iron sucrose, anemia remained poorly controlled.

Conclusion: There is a gap between clinical management and hematological targets in the studied center. Increased monitoring of TSAT and Ferritin and individualized iron replacement protocols is urgently needed to improve the quality of life of patients.

KEYWORDS: Chronic Kidney Disease, Iron Homeostasis, Hemodialysis, Functional Iron Deficiency, Tripoli.

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INTRODUCTION

Chronic kidney disease (CKD) and its progression toward end-stage renal disease (ESRD) present a profound global epidemiological challenge, imposing immense socio-economic and clinical burdens on modern healthcare systems due to its association with high morbidity and mortality rates (KDIGO, 2024). As renal function progressively declines, patients experience a multitude of systemic complications that severely compromise their physiological well-being and overall quality of life. Among these secondary manifestations, anemia stands out as one of the most pervasive and clinically significant complications, demonstrating a direct, proportional relationship with the worsening of the glomerular filtration rate (GFR) (Badura et al., 2024). The primary pathophysiological mechanism underlying this hematological decline involves the structural deterioration of renal peritubular fibroblasts, which drastically diminishes the kidneys' capacity to synthesize and secrete erythropoietin (EPO), the essential hormone driving bone marrow erythropoiesis. This hormone deficiency is further aggravated by a shortened lifespan of circulating red blood cells, caused by the hostile, oxidative, and toxic environment characteristic of uremic systemic accumulation (Kazmi et al., 2025). Beyond EPO deficiency, profound metabolic disruptions in iron homeostasis play a critical and co-dependent role in accelerating the severity of anemia, making the precise management of iron status a primary focal point in nephrology (Andappa, 2025).

The clinical presentation of altered iron metabolism in renal failure patients typically diverges into two complex pathophysiological states. The first is absolute iron deficiency, which is commonly driven by depleted systemic iron stores resulting from impaired gastrointestinal absorption, frequent diagnostic blood sampling, and chronic occult blood loss during extracorporeal dialysis circuits. The second, more complex state is functional iron deficiency, where body iron reserves are quantitatively abundant within tissue stores but remain structurally sequestered and unavailable for active erythropoiesis (Portolés et al., 2021). This functional blockade is largely mediated by the chronic, low-grade systemic inflammatory response inherent to renal failure, which triggers the overproduction of the hepatic acute-phase hormone, hepcidin. Elevated hepcidin levels bind to and degrade the iron exporter ferroportion, effectively trapping iron within reticuloendothelial macrophages and splenic stores, thereby starving developing erythroid progenitors of the iron required for heme synthesis (Gaweda, 2017). Consequently, evaluating standalone iron markers can be clinically misleading; thus, a comprehensive panel of biomarkers—including hemoglobin (Hb) concentration, serum iron, serum ferritin (reflecting storage status), and transferrin saturation (TSAT, indicating real-time iron availability for transport)—is fundamentally essential to accurately diagnose and manage the patient's actual hematological status (Wong et al., 2020).

Given that unmanaged iron deficiency anemia exponentially increases the risk of severe secondary complications, such as left ventricular hypertrophy and adverse cardiovascular events, regular and meticulous monitoring of these biochemical variables constitutes the cornerstone of effective therapeutic intervention (Tahara and Dutta, 2024). Accordingly, the present study was undertaken to evaluate the biological profiles and establish the statistical correlations between iron levels and various hematological indicators among patients receiving specialized medical care at the Kidney Services Center in Tripoli, Libya. By analyzing these specific biochemical parameters within a localized cohort, this investigation aims to provide a reliable clinical baseline that can assist healthcare professionals in optimizing iron-replacement protocols, enhancing the precision of anemia management strategies, and ultimately improving patient survival rates and therapeutic outcomes.

Chronic Kidney Disease (CKD) and the Pathophysiology of Anemia

Anemia is a profound and almost inevitable complication of chronic kidney disease (CKD), particularly among patients undergoing maintenance hemodialysis. The primary etiology involves a deficiency in erythropoietin (EPO) production by the failing kidneys, compounded by shortened red blood cell survival and chronic inflammation.

The clinical and biological mechanisms driving iron metabolism disruption in CKD are heavily dictated by the upregulation of hepcidin—a master iron-regulatory hormone. (Santos-Silva et al., 2019), in

an authoritative study published via Elsevier / ScienceDirect (Vitamins and Hormones), demonstrated that the progressive deterioration of renal function triggers an elevation of serum hepcidin driven by both reduced renal clearance and chronic systemic uremic inflammation. This upregulation acts as a key pathogenetic factor that impairs duodenal iron absorption and immobilizes iron within macrophage stores. This mechanism precipitates a state of "functional iron deficiency," where patients possess sufficient total body iron stores but remain incapable of mobilizing them for effective bone marrow erythropoiesis.

To address these pathophysiological deficits, optimization of iron delivery remains critical. (Macdougall et al., 2019), in a landmark clinical trial published in The New England Journal of Medicine, investigated iron management strategies in patients undergoing maintenance hemodialysis (the PIVOTAL trial). The researchers demonstrated that a proactive, high-dose intravenous iron regimen significantly optimizes hemoglobin levels and safely reduces the required doses of erythropoiesis-stimulating agents (ESAs). Furthermore, the study emphasized that stabilizing core hematological indicators is critical to reducing cardiovascular morbidity and minimizing hospitalization rates within dialysis clinics.

Evaluation of Iron Markers and Hematological Indicators managing anemia in clinical kidney service centers heavily relies on differentiating between absolute and functional iron deficiency through precise biochemical assays. Historically, Serum Ferritin and Transferrin Saturation (TSAT) have stood as the standard diagnostic indicators. However, their interpretation is frequently confounded by underlying clinical conditions.

(Gaweda, 2017), in a clinical study published in Hemodialysis International, critically evaluated the clinical utility and limitations of standard biomarkers used to assess iron status in CKD patients undergoing hemodialysis. The investigation focused on primary laboratory indicators, specifically serum ferritin and TSAT. The findings demonstrated that while these conventional markers are fundamental in clinical practice, their interpretation is frequently complicated by chronic systemic inflammation, which can falsely elevate serum ferritin levels as an acute-phase reactant. The author emphasized the clinical necessity of moving towards a multi-parametric diagnostic approach integrating advanced red blood cell indices alongside traditional markers to accurately differentiate between absolute and functional iron deficiency, thereby optimizing intravenous iron administration protocols.

This diagnostic complexity was further addressed at an international scale by (Macdougall et al., 2016) in a global consensus report from the Kidney Disease: Improving Global Outcomes (KDIGO) Controversies Conference published in Kidney International. The global expert panel synthesized contemporary clinical evidence, highlighting that while traditional markers like serum ferritin and TSAT remain fundamental for baseline screening, their thresholds frequently fluctuate due to systemic inflammation and uremic toxicity. The authors recommended an optimized, patient-centric approach to intravenous iron administration to safely maintain target hemoglobin levels. Furthermore, the conference conclusions emphasized the necessity of monitoring full blood indicators and red blood cell indices to effectively avoid the risks of clinical iron overload in maintenance dialysis settings.

Providing a contemporary directive for the multi-disciplinary care setting, (Hain et al., 2023), in a narrative clinical review published in Kidney Medicine, evaluated modern diagnostic strategies and management paradigms for iron-deficiency anemia (IDA) in CKD. The investigation focused on providing actionable clinical insights regarding the interpretation of baseline blood indicators for kidney care teams. The authors reaffirmed the clinical challenges of relying solely on traditional biomarkers, demonstrating that threshold fluctuations necessitate a continuous, longitudinal auditing of full hematological and iron profiles rather than an over-reliance on isolated cross-sectional values. The study concluded that implementing structured, multi-parametric laboratory screening is crucial to accurately differentiate absolute iron depletion from inflammation-induced functional iron deficiency, thereby optimizing personalized iron replacement therapies and enhancing patient outcomes.

Regional and Local Contextual Studies

Investigating hematological profiles within specific regional demographics is essential due to variations in healthcare infrastructure, clinical protocols, and regional nutritional profiles. In the local clinical

context, (Azab and Alshoukry, 2023), in a localized cross-sectional study published in the Global Journal of Cardiovascular Diseases, investigated the prevalence of anemia and evaluated specific variations in core hematological parameters among a cohort of CKD patients undergoing maintenance hemodialysis in the Tripoli region, Libya. The clinical investigation analyzed comprehensive complete blood count (CBC) matrices to screen vital red blood cell indices. The findings demonstrated an exceptionally high prevalence of severe anemia within the clinical sample, characterized by marked reductions in hemoglobin (Hb), packed cell volume (PCV/Hematocrit), and red blood cell count (RBC). The authors concluded that the progressive decline in these baseline blood indicators is closely associated with impaired renal erythropoietin secretion and compromised iron homeostasis, emphasizing the urgent clinical need for regular, structured laboratory auditing of hematological profiles in regional dialysis centers to optimize therapeutic management.

Complementing these findings across different stages of the disease, (Jaher et al., 2022), in a localized cross-sectional study published in The Scientific Journal of Diseases, investigated the prevalence of anemia and evaluated specific variations in baseline hematological parameters among a cohort of CKD patients undergoing conservative treatment in Benghazi city, Libya. The clinical investigation analyzed comprehensive laboratory profiles to track red blood cell indices and hemoglobin levels across pre-dialysis stages. The findings demonstrated a high prevalence of anemia within the studied clinical sample, showing that the progressive deterioration of renal function directly correlates with a significant decline in hemoglobin (Hb) and altered iron status markers. The authors concluded that early, systematic auditing of hematological and iron profiles is a crucial clinical strategy in regional clinics to delay disease progression, optimize conservative therapeutic interventions, and improve the quality of life for CKD patients before advancing to end-stage renal failure. While these international and regional studies underscore the physiological complexities of iron deficiency in CKD, there remains a critical shortage of up-to-date baseline data addressing the specific hematological trends within metropolitan municipal centers in Libya. The current study aims to address this gap by evaluating the iron status and blood indicators specifically at the Kidney Services Center in Tripoli City.

Importance of the Study:

This study is important as anemia is considered as one of the most common complications among the patients with renal failure especially chronic renal failure. Therefore, early diagnosis and accurate identification of the type of anemia are essential for selecting the most appropriate treatment and reducing the risk of complications or medications side effects. In addition, iron deficiency is recognized as a major contributing factor to anemia among renal failure patients, making regular monitoring and proper management necessary. Furthermore, effective treatment of anemia may help improve patients' overall health condition and slow the progression of kidney dysfunction.

Objectives of the Study:

The present study was undertaken to determine the hemoglobin status, iron profile (serum iron, total iron binding capacity, ferritin), total iron saturation and treatment of renal failure patients receiving hemodialysis at Tripoli kidney services center. To assess the incidence and severity of patient's anemia and explore association between the iron indices and hemoglobin levels and finally to emphasize the importance of regular laboratory tests and awareness about the anemia of chronic kidney disease.

METHODOLOGY

Study Design and Location

This is a cross-sectional observational study carried out from May to September 2024 at Tripoli Kidney Services Center. The facility is the main referral center for hemodialysis in Souq Al-Jumaa municipality, Tripoli, providing dialysis treatment to a large proportion of end-stage renal disease (ESRD) patients living in the area.

Participants and Sampling

A total of 50 patients, including 17 men and 33 women, were selected using a random sampling method. The patients' ages ranged from 20 to 86 years, with a mean age of 49 years. Each participant met the inclusion criteria, which were as follows: (1) having end-stage renal disease (ESRD), (2) receiving hemodialysis for at least six months, and (3) giving informed consent to participate in the study. The exclusion criteria included having acute

renal failure, undergoing peritoneal dialysis, and having blood cancer.

Data Collection

The biochemical parameters such as hemoglobin (Hb), serum iron, total iron-binding capacity (TIBC), serum ferritin, and transferrin saturation (TSAT%) were extracted from the patients' paper-based medical records and routine laboratory investigations available in the hospital's database. The required data were obtained by the researcher through a self-administered structured questionnaire to record the patients' sociodemographic characteristics and clinical features of IDA, including the presence or absence of fatigue, weakness, pallor, chest pain, palpitations, dyspnea on exertion, headache, dizziness, and cold hands. In addition, the patients were asked to provide information on their age, gender, disease duration, and the coexistence of hypertension and diabetes mellitus. The TSAT% for each patient was calculated by dividing the serum iron by TIBC and multiplying the result by 100.

Statistical Analysis

All collected data were coded, entered, and analyzed using IBM SPSS Statistics (Version 26) software. The descriptive statistical analysis included measures such as the mean, standard deviation, frequency, and percentages. The analysis results were presented in tabulated forms, including the baseline clinical, demographic, and laboratory characteristics of the study participants. The values of the continuous variables were presented as the mean ± standard deviation, whereas the categorical variables were expressed as frequencies and percentages.

RESULTS:

The demographic and clinical characteristics of the study population are summarized in the following tables.

Table 1: Demographic and Clinical Profile of the Study Population (N=50)

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	17	34%
	Female	33	66%
Comorbidities	Hypertension	32	64%
	HTN + Diabetes	18	36%
Disease Duration	2–5 years	30	60%
	6–8 years	14	28%
	≥ 9 years	6	12%

The sample size of the study was 50 individuals. There were more female participants than male ones, which accounts for 33% and 17%, respectively. As for the accompanying diseases, 32 participants suffered from hypertension, which constitutes 64%, and 18 patients had diabetes mellitus and hypertension, which is 36%. Concerning the number of years since disease onset, 30 patients or 60% had it for 2-5 years, 14 or 28% – 6-8 years, and 6 or 12% – for 9 years and more.

Table 2: Biochemical Iron Profile and Hematological Indicators

Parameter	Mean ± SD	Normal Range*	Status
Hemoglobin (Hb)	9.56 ± 1.77 g/dl	11.5–16.5 g/dl	Below Target
Serum Iron	50 ± 25 µg/dl	60–170 µg/dl	Low
TSAT	21% ± 12	25%–35%	Low
TIBC	280 ± 90 µg/dl	240–450 µg/dl	Normal
Serum Ferritin	56 ± 37 ng/ml	10–250 ng/ml	Normal (Low for CKD)
**Normal ranges reflect standard laboratory values; CKD-specific targets may vary.*			

The main biochemical and hematological indices of patients are presented in Table 2. The mean hemoglobin concentration was 9.56±1.77 g/dL, which is below the reference range (11.5-16.5 g/dL), which indicates that there is a substantial number of cases of anemia in the study population. The mean serum iron amount was 50±25 µg/dL that is also below the reference range (60-170 µg/dL).

TSAT was 21%±12%, which is lower than the desired threshold of 25%-35%, while TIBC was within the normal range (280±90 µg/dL; normal range: 240-450 µg/dL). The mean serum ferritin was 56±37 ng/mL, which is normal (normal range: 10-250 ng/mL), but insufficient for CKD patients.

Table 3: Prevalence of Clinical Anemia Symptoms

Symptom	Frequency (n)	Percentage (%)
Severe Fatigue	42	84%
Neurological (Headache/Dizziness)	37	74%
Cardiovascular (Palpitations/Chest Pain)	29	58%
General Weakness	34	68%

The prevalence of clinical symptoms related to anemia is demonstrated in the table below. Thus, among the 50 study participants, 42 patients (84%) complained of severe fatigue, while 37 patients (74%) reported experiencing headaches and dizziness. In addition, 34 participants (68%) indicated the presence of a general sense of weakness, and 29 patients (58%) suffered from palpitations and chest pain. The symptoms of fatigue and tiredness were the most frequent ones among anemic patients.

DISCUSSION

This study examined the demographic profile, laboratory findings, and clinical manifestations associated with anemia among 50 patients with chronic kidney disease (CKD) at Tripoli Kidney Services Center. The findings revealed several important features concerning the patients' health status and the factors that may contribute to the severity of anemia.

According to the demographic findings (Table 1), women constituted the larger proportion of the participants, representing 66% of the total sample. The higher proportion of females may reflect the greater occurrence of anemia among women with CKD, as previously reported in the literature (Locatelli et al., 2017). Hypertension was identified as the predominant accompanying condition, being present in 64% of the participants, whereas the remaining 36% had a combination of hypertension and diabetes mellitus. The frequent occurrence of these two conditions is consistent with their well-established association with CKD development and progression (KDIGO, 2026).

With respect to the duration of kidney disease, most participants (60%) had been diagnosed for between 2 and 5 years, while 12% had a disease duration exceeding 9 years. A longer duration of CKD may increase exposure to disease-related complications and persistent disturbances in erythropoiesis, potentially contributing to anemia that is more difficult to correct (Weiner et al., 2005).

The laboratory findings (Table 2) provided evidence of abnormalities in the hematological and iron profiles of the studied patients. The mean hemoglobin concentration was 9.56 g/dl, demonstrating that anemia was relatively pronounced within the study population. This value was lower than the hemoglobin level of 11 g/dl referred to in the KDIGO recommendations (KDIGO, 2026). The average serum iron concentration was also relatively low at 50 mcg/dl, whereas the mean TIBC remained within the normal laboratory range. The mean TSAT was 21%, and the average ferritin concentration was 56 ng/ml. Although the mean TSAT was slightly above the threshold commonly used to indicate iron deficiency, the relatively low ferritin concentration raises concern about reduced iron stores in at least a proportion of the patients.

Assessment of iron status in CKD is complicated by the inflammatory environment commonly associated with chronic renal disease. Ferritin does not exclusively reflect stored iron because it can increase as part of the inflammatory response and therefore may not accurately represent the amount of iron available for erythropoiesis (Ganz & Nemeth, 2015). Consequently, a ferritin value that falls within a conventional laboratory reference interval does not necessarily exclude iron depletion in a patient with CKD. The combination of low serum iron, reduced hemoglobin, and the observed ferritin concentration therefore suggest that iron availability may have been inadequate in some of the participants. This finding supports the importance of evaluating several iron-related parameters together when determining the need for iron replacement. Appropriate iron administration in CKD patients may improve iron availability and has also been associated with favorable cardiovascular outcomes in selected patient populations (Macdougall et al., 2016).

The clinical findings (Table 3) further demonstrated that anemia imposed a considerable symptom burden on the participants. Fatigue was the most frequently reported complaint, occurring in 84% of the patients.

Reduced hemoglobin can compromise oxygen delivery to tissues and may consequently contribute to persistent tiredness and reduced physical capacity in individuals with CKD (Johansen et al., 2010). Neurological complaints, particularly headache and dizziness, were reported by 74% of the participants. Such manifestations may occur when tissue oxygenation is inadequate and may further affect the daily functioning and well-being of patients (Murray et al., 2016). Generalized weakness was reported by 68%, while cardiovascular complaints, including palpitations and chest pain, were present in 58% of the study population. The presence of these manifestations is clinically important because anemia in CKD may increase cardiovascular stress and has been associated with an increased risk of heart failure and ischemic heart disease (McCullough et al., 2004).

The overall findings indicate that anemia in CKD should be approached as a condition requiring continuous clinical and laboratory follow-up rather than being evaluated solely on the basis of hemoglobin concentration. Periodic assessment of hemoglobin together with serum iron, ferritin, TIBC, and TSAT can assist in recognizing abnormalities in iron availability and determining whether therapeutic intervention is required. In patients demonstrating evidence of iron depletion, iron replacement should be considered according to the patient's clinical characteristics and applicable treatment recommendations. Intravenous iron may be particularly useful in selected patients when oral replacement is insufficient or poorly tolerated, although treatment decisions should be individualized (Fishbane & Spinowitz, 2018).

The considerable frequency of fatigue, weakness, and neurological complaints also emphasizes the need for a broader approach to anemia management. Improving hematological parameters alone may not address all aspects of the patient's functional impairment. Management should therefore include appropriate attention to associated medical conditions, particularly hypertension and diabetes, as adequate control of these disorders may contribute to slowing further renal deterioration (Locatelli et al., 2017). In addition, supportive measures aimed at maintaining physical activity and improving functional capacity may be beneficial for patients experiencing persistent fatigue and weakness.

Several limitations need to be taken into account when considering the findings of this investigation. The study included only 50 participants, and this relatively limited sample size may restrict the applicability of the results to larger CKD populations. In addition, the cross-sectional methodology provides information about the patients at a particular point in time but cannot establish whether abnormalities in iron status directly caused the observed clinical manifestations. Another limitation was the absence of inflammatory biomarkers, including C-reactive protein and hepcidin. Measurement of these markers could have provided additional information regarding the contribution of inflammation to impaired iron utilization and could have assisted in distinguishing absolute iron deficiency from functional iron deficiency. Furthermore, information concerning erythropoietin concentrations, the use of erythropoiesis-stimulating agents, and previous iron treatment was not available. These factors may have affected both hemoglobin levels and the measured iron parameters. Finally, the clinical symptoms were obtained through patient reporting rather than standardized validated assessment scales, which may have introduced subjective or reporting-related bias.

Overall, the findings demonstrate that CKD-related anemia in the studied population was accompanied by reduced hemoglobin levels, alterations in iron-related parameters, and a substantial burden of clinical symptoms. The results reinforce the importance of regular hematological and iron-status evaluation in CKD patients, together with appropriate assessment of associated comorbidities and symptoms. Future research involving larger patient populations and prospective follow-up, combined with inflammatory markers, treatment history, erythropoietin-related data, and validated symptom assessment tools, would provide a clearer understanding of the mechanisms and clinical consequences of anemia in patients with CKD.

CONCLUSION

The findings of this study indicate that anemia is a common and clinically important condition among patients with chronic kidney disease, with many patients experiencing moderate to severe anemia, iron deficiency, and considerable fatigue and neurological manifestations. Hypertension and diabetes mellitus were also frequently observed as associated comorbid conditions. These findings emphasize the importance of continuous assessment of hemoglobin and iron status, together with appropriate management of anemia, to help reduce symptoms and enhance patients' overall quality of

life.

Although this study was limited by its relatively small number of participants and cross-sectional design, it provides useful information regarding the occurrence and contributing factors of anemia among patients with CKD. The results may support better clinical assessment and management strategies for affected patients. Further research involving larger populations and more comprehensive study designs is recommended to validate these findings and provide stronger evidence for the effective management of anemia in patients with chronic kidney disease.

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