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Hematological and biochemical alterations and Iron Status in Patients with Chronic Kidney Disease and Hemodialysis: A Comparative Study from Southern Libya

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التغيرات الدموية والبيوكيميائية وحالة الحديد لدى مرضى الكلى المزمن ومرضى غسيل الكلى: دراسة مقارنة من جنوب ليبيا

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Abstract:
Chronic kidney disease (CKD) is a progressive systemic disorder associated with multiple hematological and biochemical abnormalities. This study aimed to evaluate hematological, biochemical and iron status in patients with chronic kidney disease and patients undergoing hemodialysis compared with healthy controls. A 120 participants divided into three groups: 30 healthy controls, 30 patients with CKD at different stages, and 60 patients with end-stage kidney disease undergoing hemodialysis. Complete blood count including hemoglobin (Hb), red blood cell count (RBC), hematocrit (HCT), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), white blood cell count (WBC), and platelet count (PLT), Serum urea, creatinine, serum iron, and ferritin were measured. Both CKD and hemodialysis groups demonstrated marked hematological abnormalities compared with the control group. Hemoglobin, RBC count, and HCT were significantly reduced in both patient groups ($P<0.0001$), while MCV was significantly lower ($P<0.0001$) in the hemodialysis group, whereas MCHC, MCH showed no significant difference among the groups. Platelet counts were significantly lower in both patient groups, and WBC count was significantly lower in the hemodialysis group when compared with CKD group. There were also significantly increased urea levels in both patient groups and substantially elevated creatinine, particularly among hemodialysis patients ($P<0.0001$). Serum iron did not differ significantly among the groups, whereas ferritin levels were significantly elevated in both CKD and hemodialysis patients compared with controls. Conclusion: Patients with CKD, particularly those undergoing hemodialysis, exhibit significant hematological and biochemical abnormalities, with anemia being a prominent finding. Elevated ferritin levels may reflect

altered iron metabolism and inflammation. Regular monitoring of hematological, biochemical, and iron-related parameters is essential for effective clinical assessment and management.

Keywords: Chronic kidney disease, Hemodialysis, Anemia, Hematological parameters, Renal function, Iron status.

الملخص:

يُعد مرض الكلى المزمن (CKD) اضطرابًا جهازيًا يرتبط بحدوث العديد من الاضطرابات الدموية والبيوكيميائية. هدفت هذه الدراسة إلى تقييم المؤشرات الدموية والبيوكيميائية وحالة الحديد لدى مرضى الكلى المزمن والمرضى الخاضعين للغسيل الكلوي، ومقارنتهم بالأشخاص الأصحاء. شملت الدراسة 120 مشاركًا، تم تقسيمهم إلى ثلاث مجموعات: 30 شخصًا كمجموعة ضابطة، و30 مريضًا مصابًا بمرض الكلى المزمن بمراحل مختلفة وغير خاضعين للغسيل الكلوي، و60 مريضًا مصابًا بمرض الكلى في المرحلة النهائية ويخضعون للغسيل الكلوي المنتظم. تم قياس مؤشرات تعداد الدم الكامل، بما في ذلك الهيموغلوبين(Hb) ، وعدد خلايا الدم الحمراء(RBC) ، والهيماتوكريت(HCT) ، ومتوسط حجم كريات الدم الحمراء(MCV) ، ومتوسط هيموغلوبين الكرية(MCH) ، ومتوسط تركيز هيموغلوبين الكرية(MCHC) ، وعدد خلايا الدم البيضاء(WBC) ، وعدد الصفائح الدموية .(PLT) كما تم قياس يوريا المصل، والكرياتينين، والبيليروبين الكلي، وحديد المصل، والفيريتين. أظهرت كل من مجموعة مرضى الكلى المزمن ومجموعة الغسيل الكلوي اضطرابات دموية مقارنةً بالمجموعة الضابطة. انخفضت مستويات الهيموغلوبين وعدد خلايا الدم الحمراء والهيماتوكريت بشكل معنوي في كلتا مجموعتي المرضى($P < 0.0001$) ، بينما كان متوسط MCV منخفض معنويا في مجموعة الغسيل الدموي .($P < 0.0001$) ولم تُلاحظ فروق معنوية في متوسط MCH أو متوسط تركيزMCHC بين المجموعات الثلاثة. كما انخفضت عدد الصفائح الدموية بشكل معنوي في كلتا مجموعتي المرضى، في حين كان عدد خلايا الدم البيضاء أقل بشكل معنوي في مجموعة الغسيل الدموي مقارنةً بمجموعة مرضى الكلى المزمن. وكانت مستويات يوريا المصل مرتفعة معنويا في كلتا مجموعتي المرضى، في حين ارتفعت مستويات الكرياتينين بشكل ملحوظ، ولا سيما لدى المرضى الخاضعين للغسيل الدموي.($P < 0.0001$) ولم تختلف مستويات حديد المصل بشكل معنوي بين المجموعات، في حين ارتفعت مستويات الفيريتين ارتفاعا معنويا في كلتا مجموعتي المرضى مقارنةً بالمجموعة الضابطة. في الخلاصة: أظهر مرضى الكلى المزمن، ولا سيما المرضى الخاضعين للغسيل الدموي، اضطرابات دموية وبيو كيميائية ملحوظة، ويُعد فقر الدم أحد أبرز هذه الاضطرابات. وقد تشير المستويات المرتفعة من الفيريتين إلى حدوث تغيرات في أيض الحديد ووجود حالة التهابية في مرض الكلى المزمن. ويُعد إجراء المتابعة المنتظمة للمؤشرات الدموية والبيوكيميائية او المؤشرات المرتبطة بالحديد أمرًا مهمًا للتقييم السريري الشامل وتدبير مرضى الكلى المزمن.

الكلمات المفتاحية: مرض الكلى المزمن، الغسيل الدموي، فقر الدم، المؤشرات الدموية، وظائف الكلى، حالة الحديد.

Introduction:

Chronic kidney disease (CKD) is a major worldwide health disorder characterized by chronic abnormalities in kidney structure or function and is associated with significant morbidity, premature mortality, and increasing healthcare burden [1]. The medical burden in advanced kidney disease, which requires extensive dialysis spanning of be particularly identified. [2]

Anemia is the most important hematological complications in patients with CKD [3, 4]. The pathogenesis of CKD-associated anemia is multifactorial and extends beyond inadequate renal erythropoietin production [3]. Decreased erythropoiesis, dysfunction of iron homeostasis, irritant-mediated iron limitation, decreased erythrocyte survival, nutritional deficiencies, blood loss, and dialysis outcomes may all contribute to improvement and severity of the same concomitant treatment spectrum recommending that patients receive CKD with an emphasis on dialysis the estimation of the hemoglobin and iron status [5]

Iron metabolism in CKD is particularly complex. Serum ferritin is commonly used to assess framework iron stores; However, ferritin is also an acute fracture reactant and can be increased in the presence of ongoing inflammation. Thus, increased ferritin concentrations no longer necessarily indicate normal bioavailable iron [5, 6]. Patients with CKD may additionally enjoy functional iron restriction, in which iron stored for erythropoiesis may be insufficient regardless of normal or expanded ferritin concentration This distinction is of clinical importance, especially in patients on hemodialysis, in

whom inflammation, repeated blood loss, intravenous iron exposure, and erythropoiesis-stimulating therapies may influence conventional markers of iron status. [7]

It may also accompany renal dysfunction through changes in biochemical markers traditionally associated with liver conditions. Serum aminotransferase activity may additionally differ in patients with benign CKD and hemodialysis compared to individuals with preserved renal symptoms [8]. Several mechanisms have been proposed, including hemodilution, altered vitamin popularity, changes in enzyme metabolism, and dialysis-related physiological effects [9]. Serum alkaline phosphatase (ALP) may be elevated in patients with chronic kidney disease (CKD), which is no longer the simplest hepatic enzyme but reflects an additional dysfunction in bone mineral metabolism that is usually accompanied by superior renal dysfunction Attention to subcortical metabolism is essential [10].

Serum urea and creatinine are key biochemical markers used to assess kidney function. In addition, their revolutionary advances reflect reduced glomerular filtration and impaired renal clearance in chronic kidney disease (CKD) Furthermore, a combined assessment of these renal markers with hematologic, iron, and selected liver biochemical parameters may provide a more comprehensive assessment of the systemic abnormalities associated with CKD progression [11]

Despite the increasing burden of chronic kidney disease (CKD), information on hematological biochemical changes in patients in southern Libya is still limited, therefore, this study aims to examine hematological parameters, kidney characteristic markers, serum iron, ferritin in healthy control, CKD nondialysis patients and patients receiving maintenance hemodialysis should be designed to represent the evolution of CKD and dialysis-associated laboratory abnormalities

Material and methods:

Study Design and Participants:

This comparative cross-sectional study were conducted on 120 enrolled participants divided into three groups as follow: 30 apparently healthy controls, 30 patients with non-dialysis chronic kidney disease (CKD), and 60 patients with end-stage kidney disease receiving maintenance hemodialysis. Blood samples from the hemodialysis group were collected without delay before dialysis session to avoid acute consequences of dialysis on measured laboratory parameters.

Blood sampling collection:

Venous blood samples were collected under preferred laboratory conditions. A portion of each sample was collected in EDTA tubes for hematological analysis, while serum were used for biochemical measurements.

Hematological parameters:

An automated Sysmex hematology analyzer was used to perform a complete blood culture analysis. The evaluated parameters include hemoglobin concentration (Hb), red blood cell count (RBC), hematocrit (HCT), mean cell volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), white blood cell count (WBC), and platelet count (PLT).

Biochemical parameters:

Serum biochemical measurements were performed using a Roche INTEGRA 400 Plus automated analyzer with commercial Roche reagents in line with the manufacturer's method of analysis Blanket parameters within the donation assessment included urea and creatinine as renal characteristic markers and serum iron and ferritin for the assessment of iron status.

Statistical Analysis:

All results were expressed as mean ± standard deviation (SD) in the tables and mean ± standard error (SEM) in the graphs. The data were analyzed using SPSS (Statistical package for social sciences) IBM version 25. Shapiro- Wilk test was used to check the normality of the variable. Accordingly, ANOVA, were used to analyze data follow normal behaviour of distribution pattern, followed by post hoc LSD multiple comparison test were used to estimate the significance different between groups. While, Kruskal-Wallis-one way ANOVA test were used. To analyze data, follow non-normal behaviour of distribution pattern. The difference between groups was considered significant when $p< 0.05$

Results:

Hematological Parameters:

The hematological findings are presented in Table 1. Compared with the healthy control group, patients with non-dialysis chronic kidney disease (CKD) and those receiving maintenance hemodialysis exhibited significantly lower hemoglobin (Hb), red blood cell (RBC) count, and hematocrit (HCT) values ($P < 0.0001$). No significant difference in MCV was observed between the non-dialysis CKD group and the control group, whereas MCV was significantly lower in the hemodialysis group ($P < 0.0001$). MCHC was significantly higher in both CKD groups than in healthy controls ($P < 0.0001$), while no significant difference was found in MCH. WBC count was significantly lower in the hemodialysis group than in the non-dialysis CKD group ($P = 0.04$). Platelet (PLT) counts were significantly reduced in both the non-dialysis CKD ($P = 0.03$) and hemodialysis ($P = 0.002$) groups compared with the control group.

Table (1). Hematological parameters among the study groups

Parameter	Healthy controls (n = 30)	Non-dialysis CKD (n = 30)	Hemodialysis (n = 60)
Hb (g/dL)	13.5 ± 2.0	10.0 ± 2.3***	9.6 ± 1.4***
RBC (×10⁶/µL)	4.5 ± 0.7	3.5 ± 0.9***	3.2 ± 0.5***
MCV (fL)	95.4 ± 5.6	90.0 ± 7.0	81.7 ± 17.9***
MCH (pg)	29.3 ± 1.9	28.8 ± 2.9	28.3 ± 5.6
MCHC (g/dL)	30.7 ± 0.8	32.2 ± 1.9***	34.1 ± 1.4***
HCT (%)	43.9 ± 6.5	32.6 ± 9.0***	30.2 ± 7.4***
WBC (×10³/µL)	6.4 ± 2.4	6.8 ± 2.6	5.8 ± 2.0*
PLT (×10³/µL)	271.4 ± 53.4	229.5 ± 76.3*	219.6 ± 82.0**

Data are presented as mean ± standard deviation (SD)

*P<0.05

**P<0.001

*** $P < 0.0001$ (vs. healthy controls)

Renal Function Markers:

As shown in Figure 1, serum urea levels were significantly higher in both the non-dialysis CKD group and hemodialysis group compared with the healthy control group ($P < 0.0001$). In addition, a significant difference was observed between the non-dialysis CKD and hemodialysis groups.

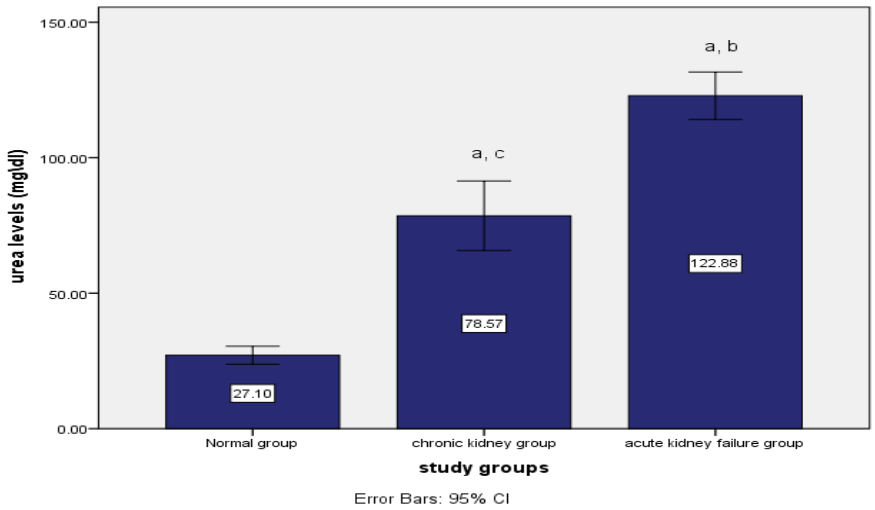

Figure (1): Serum urea levels (mg/dL) in the study groups. Data are presented as mean ± standard error (SE).

a) Significant difference compared with the healthy control group ($P < 0.05$).
b) Significant difference compared with the non-dialysis CKD group ($P < 0.05$).
c) Significant difference compared with the maintenance hemodialysis group ($P < 0.05$).

The results presented in Figure 2. demonstrated a highly significant increase in serum creatinine levels in the hemodialysis patient group compared with both the chronic kidney disease (CKD) group and the healthy control group (P = 0.0001).

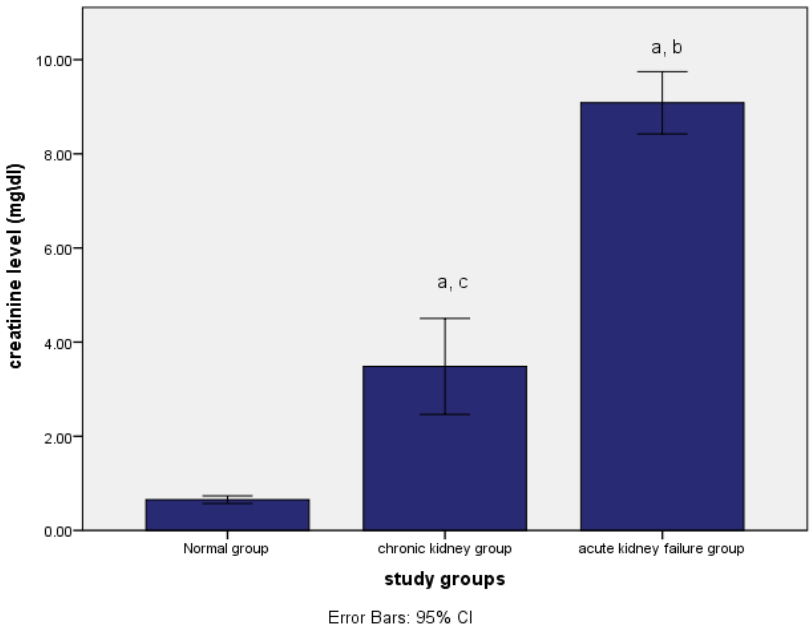

Figure (2): Serum Creatinine levels (mg/dL) in the study groups. Data are presented as mean ± standard error (SE).

a. significant difference compared with the healthy control group (P < 0.05).
b. Significant difference compared with the non-dialysis CKD group (P < 0.05).
c. Significant difference compared with the maintenance hemodialysis group (P < 0.05).

Serum Iron and Ferritin:

Iron Levels: As shown in Figure 3. Serum iron levels were higher in the hemodialysis patient group compared with both the chronic kidney disease (CKD) group and the healthy control group. However, no statistically significant differences were observed among the study groups.

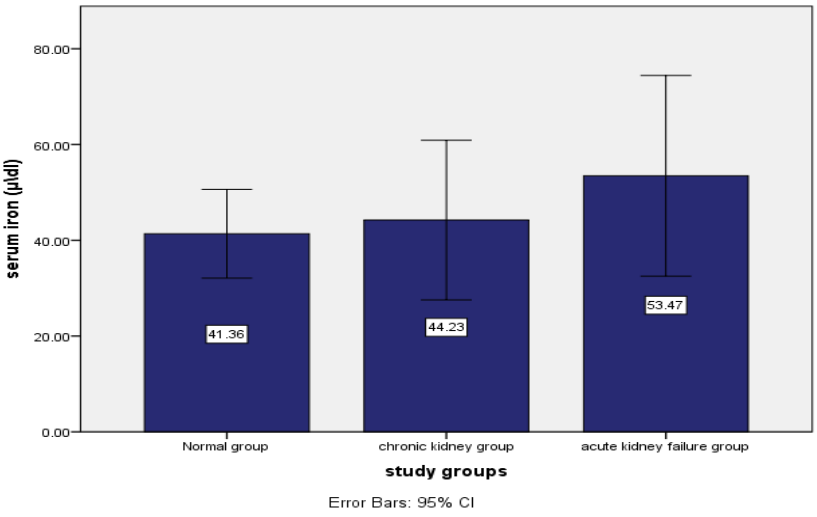

Figure (3): Serum iron levels (µ\dl) in the study groups. Data are presented as mean ± standard error (SE).

Serum ferritin levels: In contrast, serum ferritin was significantly elevated in patients with non-dialysis CKD compared with healthy controls (P=0.01). Ferritin was also significantly higher in the hemodialysis

group than in controls (P=0.04). A significant difference was additionally observed between the two patient groups, with lower ferritin levels in the hemodialysis group than in the non-dialysis CKD group (P=0.04).

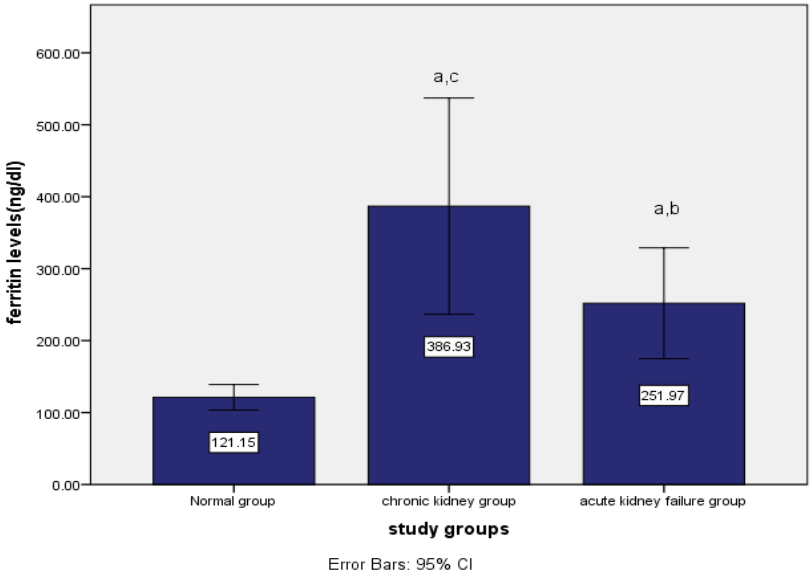

Figure (4): Serum ferritin levels (ng\dl) in the study groups. Data are presented as mean ± standard error (SE).

Discussion:

Hematological Alterations and Anemia:

The current study showed that individuals with chronic kidney disease (CKD) had significantly lower hemoglobin (Hb), red blood cell (RBC) counts, and hematocrit (HCT), with the greatest reductions observed in the hemodialysis group. These findings indicate that anemia becomes progressively more severe as kidney function deteriorates and reaches its greatest magnitude in patients with end-stage kidney disease undergoing maintenance hemodialysis. . This pattern is in line with the established link between the rising incidence and severity of CKD-associated anemia and deteriorating renal function [5].

As kidney function deteriorates, the kidneys' peritubular fibroblasts are unable to produce enough erythropoietin, which reduces erythropoiesis and consequently lowers Hb concentration, RBC count, and HCT. Further aggravating anemia in patients with severe chronic kidney disease (CKD) are chronic inflammation, higher hepcidin levels, functional iron deficiency, decreased erythrocyte lifespan, dietary inadequacies, and hemodialysis-related blood losses [12]. The current results are also in line with earlier research showing that hematological abnormalities worsen as chronic kidney disease (CKD) advances and are linked with adverse clinical outcomes, such as decreased exercise tolerance, cardiovascular complications, increased hospitalization, and lower quality of life. Consequently, early identification and proper treatment of anemia continue to be crucial aspects of CKD therapy [3].

The considerable decline in Hb, RBC count, and HCT showed that anemia was more severe in the hemodialysis group than in the non-dialysis CKD group. This finding demonstrates the complex character of CKD-associated anemia, which is caused by decreased erythropoietin production as well as chronic inflammation, poor iron utilization, shorter erythrocyte survival, and blood loss from dialysis. Advanced renal failure and the extra side effects of dialysis treatment are consistent with the higher severity among hemodialysis patients [5]. MCV was considerably lower in hemodialysis patients but remained stable in the non-dialysis CKD group, indicating that anemia may evolve from a primarily normocytic pattern in early CKD to a more microcytic pattern in advanced illness. Given that there was little variation in the groups. Since serum iron levels did not differ significantly among the groups, the reduction in MCV is more likely related to functional iron deficiency and inflammation than to absolute iron deficiency [4].

Although MCH showed no significant differences among the groups, MCHC was significantly higher in CKD and hemodialysis patients. Because elevated MCHC is not a typical feature of CKD-related anemia, this observation should be interpreted cautiously, as it may reflect erythrocyte morphological changes, hydration status, or analytical variation rather than a disease-specific mechanism [3].

Platelet counts were significantly lower in CKD and hemodialysis patients than in healthy controls, indicating the adverse effects of the uremic environment on hematopoiesis. In advanced CKD, platelet abnormalities may result from chronic inflammation, altered platelet production and survival, medications, and repeated exposure to the dialysis circuit. Furthermore, platelet dysfunction may occur even when platelet counts remain within the normal range [13].

The WBC count was significantly lower in hemodialysis patients than in non-dialysis CKD patients, suggesting greater immune dysregulation with advanced kidney disease. Uremic toxins, oxidative stress, chronic inflammation, and repeated dialysis exposure may all contribute to altered leukocyte profiles. However, the absence of inflammatory biomarkers and differential leukocyte counts limits the interpretation of this finding [14].

Renal Function Markers:

Both CKD and hemodialysis patients had considerably higher levels of serum urea and creatinine, with the hemodialysis group showing the highest values. These results show a decline in glomerular filtration rate and a progressive decline in renal function, especially in end-stage kidney disease. The accumulation of metabolic waste products in between dialysis sessions is consistent with the significant rise in pre-dialysis creatinine [5]. Anemia in CKD is intimately linked to impaired renal function. While uremia, chronic inflammation, and oxidative stress limit erythrocyte survival and suppress erythropoiesis, progressive nephron loss decreases erythropoietin synthesis. These factors all contribute to the decreases in Hb, RBC count, and HCT seen in the current study [15].

Serum Iron and Ferritin:

Ferritin was considerably higher in CKD and hemodialysis patients, although serum iron did not significantly differ between the study groups. Given that ferritin represents both iron storage and the inflammatory state frequently found in CKD, this pattern suggests disrupted iron metabolism [4]. Functional iron shortage can occur with increased ferritin and normal serum iron. Even with adequate or increased iron stores, chronic inflammation limits iron availability for erythropoiesis by increasing hepcidin synthesis, which lowers iron absorption and limits iron release from storage sites [3].

Ferritin was lower than in CKD patients who did not get dialysis, although it was still increased in the hemodialysis group. Ferritin remained elevated in the hemodialysis group but was lower than in non-dialysis CKD patients. This variation may reflect differences in inflammation, iron therapy, dialysis-related iron loss, or nutritional status. Therefore, ferritin should always be interpreted together with other markers of iron status [5].

Conclusions:

This study demonstrates that chronic kidney disease is associated with significant hematological and biochemical alterations that become more marked with disease progression, particularly in patients undergoing maintenance hemodialysis. The high frequency of anemia in advanced chronic kidney disease is confirmed by the reported decreases in hemoglobin, red blood cell count, and hematocrit. Elevated ferritin and unaltered serum iron indicate disrupted iron homeostasis, most likely due to inflammation-related functional iron insufficiency rather than just iron store depletion. Furthermore, significantly elevated urea and creatinine levels as well as changes in liver-associated biochemical markers indicate the systemic metabolic effects of severe renal impairment.

These findings highlight the importance of comprehensive laboratory monitoring, including hematological indices, renal function, and iron status, to improve the evaluation and management of CKD-related complications. Further studies incorporating additional iron biomarkers and inflammatory markers are recommended to better characterize iron metabolism in patients with CKD and those receiving hemodialysis.

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