

SYSTEMIC INFLAMMATORY CHANGES AND ELECTROLYTE DYSHOMEOSTASIS IN AN IRAQI ESRD COHORT: A COMPARATIVE STUDY

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ABSTRACT

Background: End-stage renal disease ESRD was associated with severe hematologic and biochemical derangements due to decreased renal function, accumulation of uremic toxins, defective erythropoiesis, and abnormal electrolyte metabolism. This study assessed key hematological parameters, renal biochemical markers, and serum electrolytes in maintenance hemodialysis patients and compared them with those of healthy controls.

Methods: There were 90 subjects in total in this hospital-based comparative cross-sectional study which 56 patients with ESRD were on maintenance hemodialysis, and 34 were healthy controls. Venous blood samples were tested for hemoglobin, platelet count, white blood cells (WBC) count, serum urea, creatinine, sodium and potassium. The data were presented as the mean $\pm$ standard deviation. Between-group comparisons were conducted with Welch's independent-samples t-test and correlations among laboratory measures within the ESRD group were assessed with Pearson correlation and simple linear regression. Two-sided P values <0.05 were regarded as statistically significant.

Results: ESRD patients had markedly lower hemoglobin (9.30 ± 1.40 vs 13.50 ± 1.10 g/dL) and platelet count (184.0 ± 52.0 vs $254.0 \pm 46.0 \times 10^3/\mu\text{L}$), whereas WBC count was higher (7.80 ± 1.70 vs $6.40 \pm 1.20 \times 10^3/\mu\text{L}$). Serum urea (160.0 ± 42.0 vs 29.2 ± 6.0 mg/dL), creatinine (9.30 ± 2.00 vs 0.88 ± 0.15 mg/dL), and potassium (5.35 ± 0.75 vs 4.15 ± 0.35 mmol/L) were significantly increased, while sodium was modestly lower (136.2 ± 4.1 vs 139.0 ± 2.8 mmol/L). Creatinine correlated inversely with hemoglobin ($r = -0.428$, $P = 0.001$).

Conclusion: They also had a consistent pattern of anemia, reduced platelet counts, elevated WBC counts, marked azotemia, and disturbed sodium and potassium metabolism in patients with ESRD on HD. These changes emphasize the need for integrated hematologic and biochemical surveillance in the management of dialysis.

Keywords: End-Stage Renal Disease; Hemodialysis; Hemoglobin; Creatinine; Urea; Sodium; Potassium; Hematological Parameters.

1 INTRODUCTION

Chronic kidney disease (CKD) was a progressive disorder characterized by persistent functional or structural abnormalities of the kidney with implications for health. The global burden remains high, and progression to kidney failure is associated with substantial cardiovascular, hematological, metabolic, and quality-of-life burden [1–3]. End-stage renal disease (ESRD) or kidney failure that requires renal replacement therapy, represents the most severe stage of CKD, and is usually treated with maintenance hemodialysis in case transplantation is not promptly available [2,4].

Among the most clinically relevant complications of advanced chronic kidney disease (CKD) and dialysis is anemia. Erythropoietin deficiency-mediated anemia is central to the pathogenesis, though other factors such as iron restriction, inflammation, reduced red-cell survival, recurrent blood loss, and the uremic milieu can further compromise erythropoiesis [5,6]. The current KDIGO recommendations for a 'structured' assessment of anemia and iron status reflect that seriousness and aetiology of anemia varies widely among individuals who have dialysis [5]. Disorders of blood cells may also affect platelets and leukocytes; uremia may alter platelet number and function, and leukocyte abnormalities may occur in association with inflammatory states or superimposed systemic stress [6,7]. The kidney is also instrumental in the biochemical and electrolyte environments within the body. Urea and creatinine, as well as other nitrogenous waste products, build up, and sodium and potassium balance become increasingly influenced by dietary intake, medication, and dialysis prescription, as the ability to excrete diminishes [2,8,9]. This is very important for potassium since its marked elevation can cause potentially fatal disturbances in cardiac conduction. Sodium disturbances are also clinically significant as they are indicative of perturbations in water and sodium physiology and have the potential to be linked with poor prognosis in dialysis subject [8].

Still, regional data are relevant since demographics of patients, mode of dialysis access, nutritional habits, availability of treatment and comorbidity profiles might vary within each country. Anemia, azotemia and deranged electrolyte levels have been uniformly reported in cases from Iraq and other dialysis centres [11–13]. The current study was established with the goal to estimate a number of the haematological parameters, renal biochemical parameters and serum electrolytes in patients with ESRD on maintenance hemodialysis (HD) and healthy individuals at Tikrit Teaching Hospital, Iraq and to analyse the relationship between markers of renal dysfunction, selected haematological indices.

2 MATERIALS AND METHODS

2.1 Study Design and Setting

A comparative cross-sectional study was conducted in the Nephrology Unit of Tikrit Teaching Hospital, Tikrit/ Iraq from June 2025 to July 2026. The study was conducted on 90 adults: 56 patient with final-stage renal disease (ESRD) on maintenance hemodialysis, & 34 healthy control subjects with no known renal disease. Hematological parameters, renal biochemical parameters and serum electrolytes were analyzed and compared between the two groups, and a number of correlations between renal biochemical and hematological parameters were also investigated in the ESRD group.

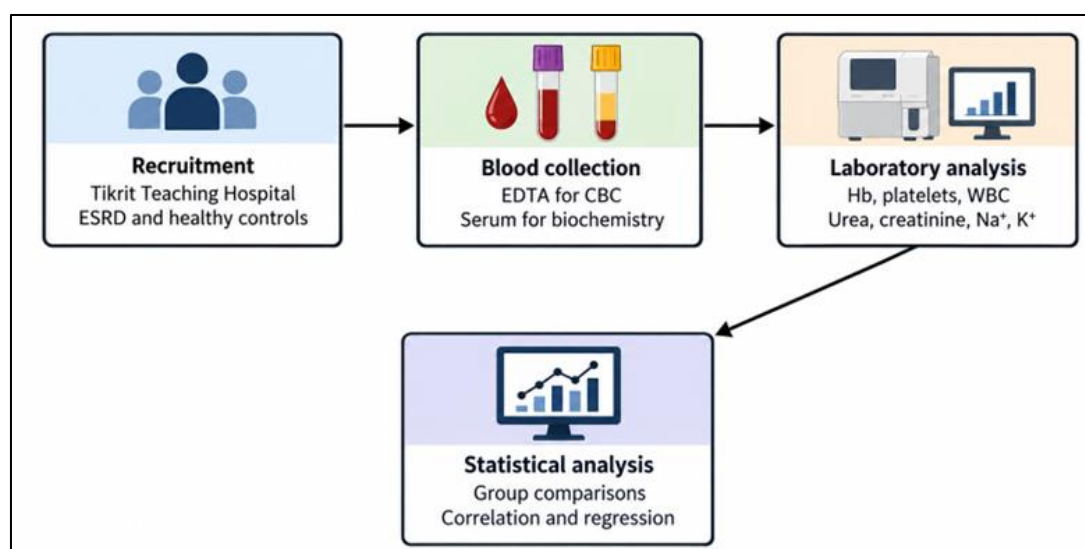


Figure 1: Schematic overview of the study design and analytical workflow.

2.2 Ethical Framework

The study protocol conformed to the ethical principles of the Declaration of Helsinki. Approval from the ethics committee of Tikrit Teaching Hospital (no. TTH00964 dated 16/3/2025) was obtained. Prior to sample collection, informed consent in writing was obtained from all subjects.

2.3 Participant Recruitment and Eligibility

The ESRDudi group was composed of adult patients with ESRD who presented for maintenance hemodialysis at the Nephrology Unit in Tikrit Teaching Hospital from June 2025 to July 2026. Patients eligible for inclusion were clinically diagnosed with ESRD, and were undergoing regular, maintenance hemodialysis. The control group was formed by healthy individuals matched for age and gender with no history of renal disease and no current symptoms. "Participants who had an acute infection, active cancer, or a primary hematological disease were excluded because these conditions may have a major impact on the hematologic and biochemical parameters assessed in this investigation. The final analysis included 56 ESRD patients and 34 healthy controls."

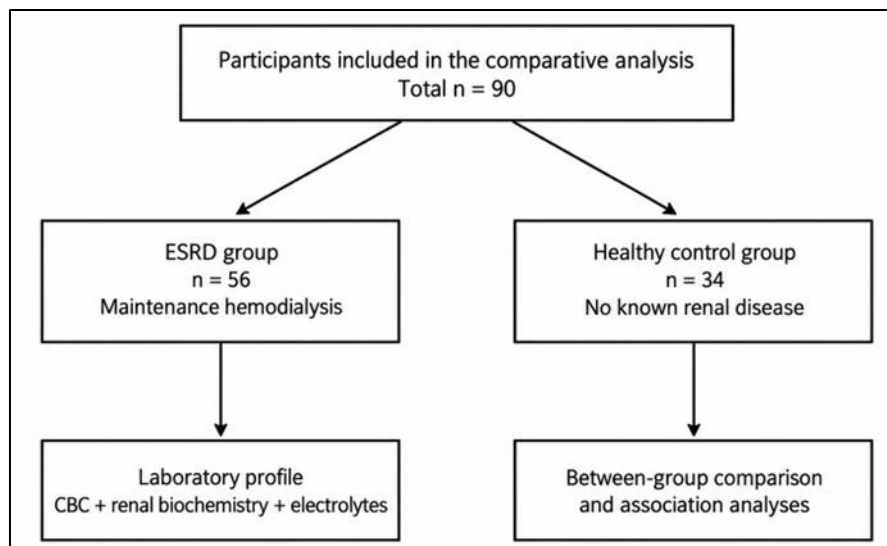


Figure 2: Cohort structure and analytical grouping of the study participants.

2.3 Blood Specimen Collection and Laboratory Processing

Five (5 mL) venous blood samples were collected by aseptic venipuncture. Two (2 mL) of the samples were added to K3EDTA tubes for complete blood count determination and the remaining 3 mL were added to serum-separator tubes and allowed to clot at room temperature for nearly 15 minutes. The serum was isolated by centrifugation at 5000 rpm for 10 minutes. The automated hematology analyzer determined the hemoglobin concentration, total WBC count, and platelet count. Common automated biochemistry techniques were used to determine serum urea, creatinine, sodium, and potassium. The pre-analytical blood collection and processing were performed according to standard clinical laboratory practices and current pre-analytical quality recommendations [14].

2.4 Statistical Analysis

Statistical analysis was performed using SPSS version 26.0 and GraphPad Prism version 9.0. Continuous variables were summarized as mean $\pm$ standard deviation (SD), and categorical variables were summarized as number and percentage. Distributional assumptions were assessed using Shapiro–Wilk testing together with visual inspection. Owing to unequal group sizes and variance patterns, between-group comparisons for continuous variables were performed with Welch's independent-samples t-test. Categorical sex distribution was compared with the chi-square test with Yates continuity correction. Effect sizes for continuous between-group contrasts were expressed as Cohen's d with 95% confidence intervals reported for mean differences. Within the ESRD group, Pearson correlation was used to evaluate associations between selected biochemical and hematological variables. Simple linear regression was used to quantify the association between serum creatinine and hemoglobin. All tests were two-sided, and $P < 0.05$ was considered statistically significant.

3 RESULTS

3.1 Participant Characteristics

The case-control analytical study consisted of 90 subjects (56 ESRD and 34 healthy controls). The mean age of the ESRD group was 53.4 ± 11.8 and the control group was 51.0 ± 10.6 years, with no significant difference ($P = 0.322$). The ESRD group included 31 men (55.4%) and 25 women (44.6%), while the control group included 18 men (52.9%) and 16 women (47.1%). Sex distribution was comparable between groups ($P = 0.996$).

Table 1: Baseline characteristics of the ESRD and healthy control groups.

Characteristic	ESRD patients (n = 56)	Healthy controls (n = 34)	P value
Age (years), mean $\pm$ SD	53.4 ± 11.8	51.0 ± 10.6	0.322
Male, n (%)	31 (55.4)	18 (52.9)	0.996
Female, n (%)	25 (44.6)	16 (47.1)	—
Dialysis duration (months), median (IQR)	27.3 (18.3–37.2)	Not applicable	—

3.2 Hematological Profile

ESRD patients demonstrated a marked reduction in hemoglobin concentration (9.30 ± 1.40 g/dL) compared with healthy controls (13.50 ± 1.10 g/dL; $P < 0.001$). Platelet count was also lower in the ESRD group ($184.0 \pm 52.0 \times 10^3/\mu\text{L}$) than in controls ($254.0 \pm 46.0 \times 10^3/\mu\text{L}$; $P < 0.001$). In contrast, WBC count was higher in ESRD patients ($7.80 \pm 1.70 \times 10^3/\mu\text{L}$) than in healthy controls ($6.40 \pm 1.20 \times 10^3/\mu\text{L}$; $P < 0.001$). The corresponding Cohen's d values were -3.24 for hemoglobin, -1.40 for platelet count, and 0.91 for WBC count, with the largest absolute standardized difference observed for hemoglobin.

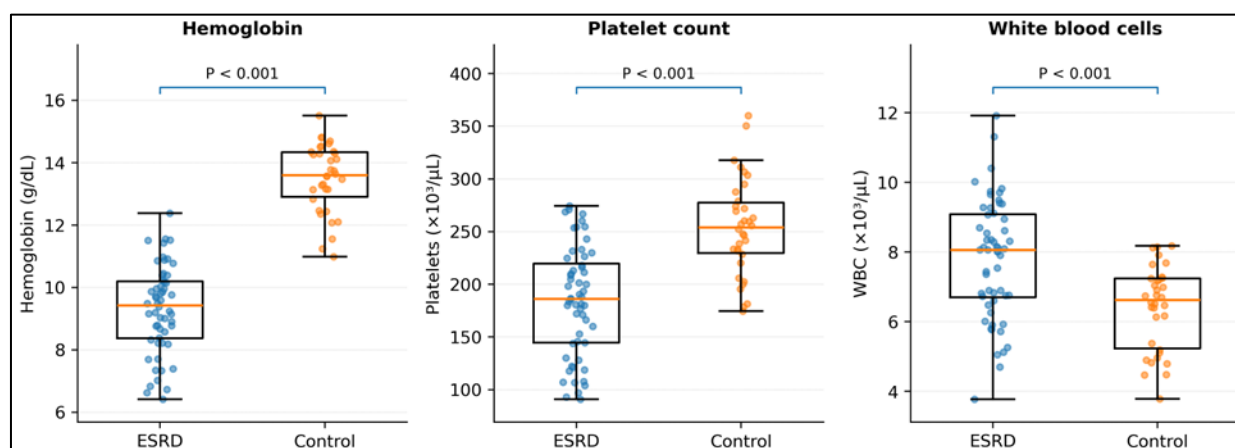


Figure 3: Distribution of hematological parameters in ESRD patients and healthy controls.

Table 2: Comparison of hematological parameters between ESRD patients and healthy controls.

Parameter	ESRD (n = 56)	Control (n = 34)	Mean difference	95% CI	P value	Cohen's d
Hemoglobin (g/dL)	9.30 ± 1.40	13.50 ± 1.10	-4.20	-4.73 to -3.67	<0.001	-3.24
Platelets ($\times 10^3/\mu\text{L}$)	184.0 ± 52.0	254.0 ± 46.0	-70.0	-90.9 to -49.1	<0.001	-1.40
WBC ($\times 10^3/\mu\text{L}$)	7.80 ± 1.70	6.40 ± 1.20	1.40	0.79 to 2.01	<0.001	0.91

There is a relatively severe negative hemoglobin difference, which is in keeping with an overt anemia in the dialysis group. The drop in platelets was pronounced but, on average, still within the range typically seen in maintenance

hemodialysis populations. High WBC count is a leukocyte between-group shift, which is a non-specific indicator, and this finding is considered to represent an acute inflammatory or physiological activation, not evidence of chronic inflammation.

3.3 Renal Biochemical Markers

Serum urea and creatinine were markedly elevated in ESRD patients. The mean urea level in ESRD patients was 160.0 ± 42.0 mg/dL, which was much higher than the 29.2 ± 6.0 mg/dL found in healthy controls ($P < 0.001$). The mean creatinine level in ESRD patients was 9.30 ± 2.00 mg/dL, compared with 0.88 ± 0.15 mg/dL in healthy controls ($P < 0.001$). These are among the largest biochemical differences seen in the study.

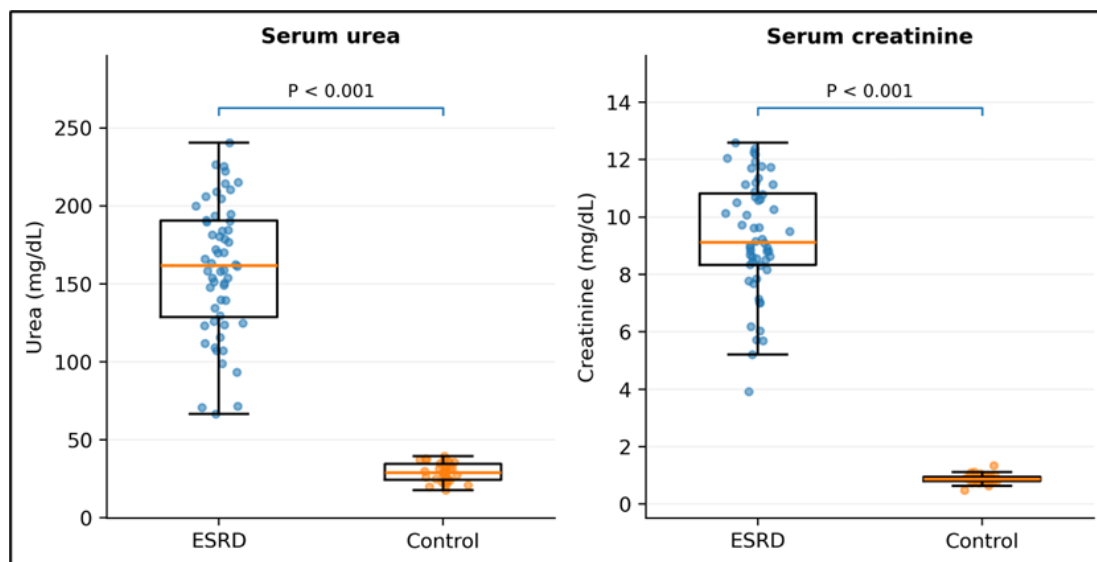


Figure 4: Distribution of serum urea and creatinine in ESRD patients and healthy controls.

3.4 Electrolyte Profile

ESRD patients had slightly lower serum sodium (136.2 ± 4.1 mmol/L) than controls (139.0 ± 2.8 mmol/L; $P < 0.001$). Serum potassium was significantly elevated in the ESRD group (5.35 ± 0.75 mmol/L) vs controls (4.15 ± 0.35 mmol/L; $P < 0.001$). This difference in potassium was clinically relevant and represented a large standardized effect size.

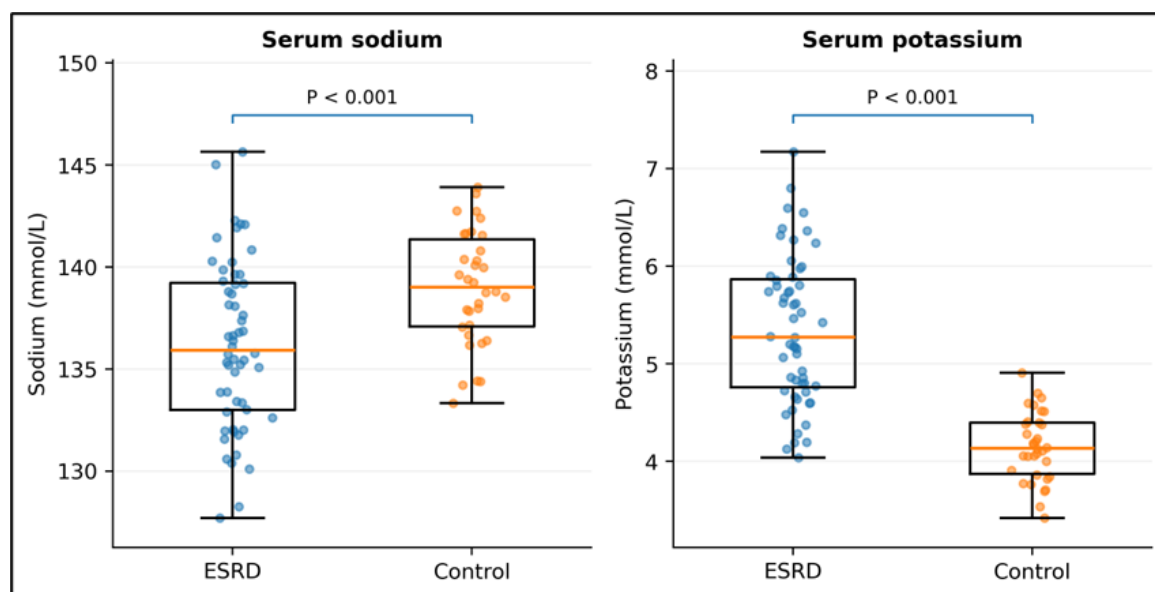


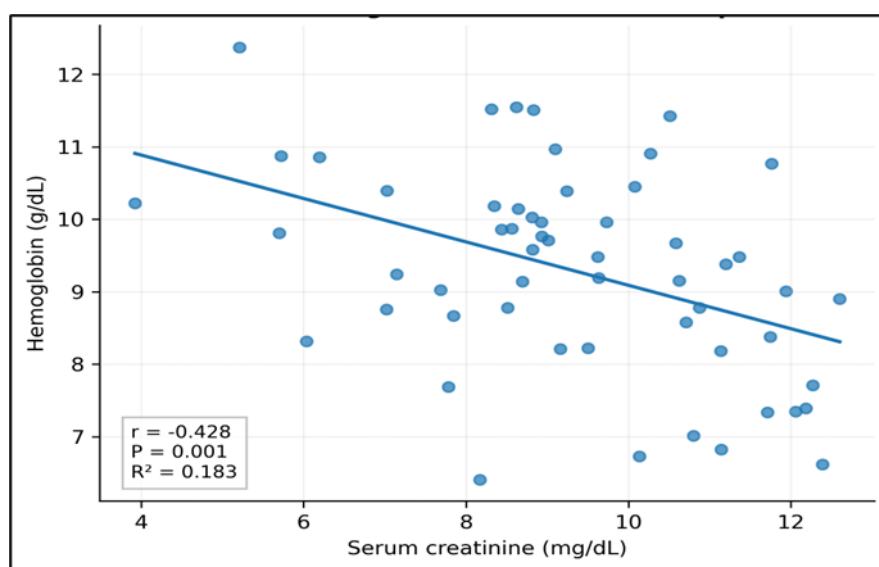
Figure 5: Distribution of serum sodium and potassium in ESRD patients and healthy controls.

Table 3: Comparison of renal biochemical and electrolyte parameters between ESRD patients and healthy controls.

Parameter	ESRD (n = 56)	Control (n = 34)	Mean difference	95% CI	P value	Cohen's d
Urea (mg/dL)	160.0 ± 42.0	29.2 ± 6.0	130.8	119.4 to 142.2	<0.001	3.92
Creatinine (mg/dL)	9.30 ± 2.00	0.88 ± 0.15	8.42	7.88 to 8.96	<0.001	5.32
Sodium (mmol/L)	136.2 ± 4.1	139.0 ± 2.8	-2.8	-4.2 to -1.4	<0.001	-0.76
Potassium (mmol/L)	5.35 ± 0.75	4.15 ± 0.35	1.20	0.97 to 1.43	<0.001	1.90

3.5 Correlation and Regression Analyses

In the ESRD patients, serum creatinine was moderately the inverse of hemoglobin ($r = -0.428$, $P = 0.001$), suggesting that higher creatinine levels were related to lower hemoglobin levels. Urea correlated positively with WBC ($r = 0.388$, $P = 0.003$), and creatinine exhibited a mild inverse correlation with platelet count ($r = -0.332$, $P = 0.013$). In simple linear regression, creatinine accounted for 18.3% of the variance in hemoglobin ($R^2 = 0.183$). The estimated slope was -0.300 g/dL per 1 mg/dL increase in creatinine (95% CI -0.472 to -0.127; $P = 0.001$).

**Figure 6: Relationship between serum creatinine and hemoglobin in ESRD patients.****Table 4: Selected associations between biochemical and hematological variables in the ESRD group.**

Association	Pearson r	P value	Interpretation
Creatinine vs hemoglobin	-0.428	0.001	Moderate inverse association
Urea vs WBC	0.388	0.003	Moderate positive association
Creatinine vs platelets	-0.332	0.013	Weak-to-moderate inverse association

4 DISCUSSION

This comparison reveals that patients with end-stage renal disease (ESRD) on maintenance hemodialysis exhibit a uniform hematological and biochemical profile. Compared with healthy individuals, the dialysis group showed significantly decreased hemoglobin and platelet counts, increased WBC count, massive elevations of urea and

creatinine, decreased mean sodium, and increased potassium. This is biologically plausible with advanced renal failure of excretory and endocrine function and generally consistent with published dialysis cohorts [5,6,11–13].

The average hemoglobin value in the ESRD group was 9.30 g/dL, which was markedly lower than that of control. Renal anemia is multi-factorial, but insufficient erythropoietin production is the key pathogenic mechanism, with iron restriction, inflammation, recurrent blood loss and shortened red-cell survival playing variable roles in individual patients [5,6]. Hemoglobin levels of approximately 9–10 g/dL have been reported in modern hemodialysis cohorts, although this level is affected by use of erythropoiesis-stimulating agents, iron status, comorbidity, dialysis adequacy, and local treatment practice [12,13,15–17]. The opposite creatinine–hemoglobin relationship illustrates that a higher serum creatinine was related with a lower hemoglobin among these patients. Given that serum creatinine in hemodialysis patients is additionally affected by muscle mass, residual kidney function (RKF), nutrition and the timing of dialysis, this cross-sectional association should not be considered as indicative of a direct causal pathway or a single marker of disease severity.

The platelet number in ESRD was lower compared to controls. Uremia is already known to impact primary hemostasis and platelet dysfunction may arise despite absence of severe thrombocytopenia. The mean ($\pm$ standard deviation) platelet count of $184.0 \times 10^3/\mu\text{L}$ lies within values documented in maintenance hemodialysis study populations [13]. The increased WBC count detected in the ESRD group may be a manifestation of inflammatory activation, repeated vascular-access exposure, comorbidity, or an unspecific illness-related stress response. In the absence of C-reactive protein and cytokine levels, WBC must not be used as a single evidence of chronic systemic inflammation [7].

Urea and creatinine displayed the most significant differences between the groups, with mean values of 160.0 mg/dL and 9.30 mg/dL for the ESRD group. Similar biochemical changes are reported in hemodialysis populations, however, absolute values vary with respect to dialysis schedule, residual renal function, nutritional status and adequacy of dialysis [11,12,18–21]. Thus these markers allow a clear biochemical separation of the ESRD and healthy groups, but should also be considered in light of possible dialysis-session timing and dialysis-adequacy measurements when available. Electrolytes results were consistent mild hyponatremia and hyperkalemia in the ESRD group. The mean sodium in the ESRD group was 136.2 mmol/L and the mean potassium was 5.35 mmol/L. Published hemodialysis cohorts commonly report sodium in the mid-to-high 130 mmol/L range and potassium around 4.8–5.4 mmol/L, with variation by sampling conditions.

Retention of potassium is clinically relevant in ESRD because serum potassium becomes more reliant on dietary intake, cellular shifts, medications, residual kidney function, and dialysis timing and adequacy, as renal excretion is severely compromised [8].

The present analysis reports effect sizes and confidence intervals rather than exclusively P values. This is relevant as explains the clinical size of the differences differences for hemoglobin, urea, creatinine and potassium are quite large while the sodium contrast is smaller albeit statistically significant. The inclusion of both effect magnitude and statistical uncertainty makes the results more interpretable and more suitable for comparison with future regional studies.

Limitations and Future Directions

Several caveats should be mentioned. The cross-sectional design precludes temporal or causal associations, and the single center might limit the extrapolation of the results to other dialysis units. Several key factors that influenced anaemia and the inflammatory state, such as ferritin, transferrin saturation, C-reactive protein, erythropoietin or erythropoiesis-stimulating agent exposure, and measures of dialysis adequacy (e.g., Kt/V) were not among the present laboratory panel. Sampling time (relative to dialysis) was not captured as a formal analytical variable in the present report; this has particular bearing for the interpretation of sodium, potassium, urea and creatinine. Moreover, WBC count is nonspecific, and in the context of no direct inflammatory biomarkers it should not be used as a standalone marker to infer systemic inflammation. Future multicenter studies should incorporate longitudinal sampling, standardized pre-dialysis or post-dialysis sampling, dialysis adequacy, residual kidney function, iron indices, inflammatory markers, medication exposure, and clinically meaningful outcomes.

5 CONCLUSION

Maintenance hemodialysis (HD) patients with ESRD have significant hematological and biochemical derangements compared to healthy individuals. The principal differences were the lower hemoglobin and platelets, higher WBC count, striking increases in the urea and creatinine, slightly lower sodium, and higher potassium. In the dialysis group, serum creatinine correlated inversely with hemoglobin, but this does not imply causality. Integrated blood count, renal biochemical markers, and electrolyte surveillance remains pertinent to detecting clinically meaningful disturbances and facilitating personalised dialysis care.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

Disclosure of conflict of interest

The authors declare no conflicts of interest.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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