
| RESEARCH ARTICLE

Inefficient Dialysis and Hematological Abnormalities in End-Stage Renal Disease Patients: A Cross-Sectional Study

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| ABSTRACT

Purpose: End-stage renal disease (ESKD) necessitates hemodialysis, a life-sustaining therapy that mimics kidney function. This study aimed to investigate the association between markers of inadequate dialysis efficacy and the prevalence of hematological abnormalities in patients undergoing hemodialysis. **Methods:** A cross-sectional study was conducted among 61 patients receiving hemodialysis at Mesallata Central Hospital, Libya, in October 2024. Data were collected on hematological parameters (white blood cell count, hemoglobin, mean corpuscular volume, and platelet count) and laboratory markers of dialysis adequacy, including blood urea nitrogen (BUN), serum creatinine, and Kt/V values. Statistical analyses assessed correlations between dialysis adequacy markers and hematological abnormalities. **Results:** The findings revealed significant associations between elevated BUN and serum creatinine levels, lower Kt/V values, and the presence of anemia and thrombocytopenia. Suboptimal dialysis adequacy ($Kt/V < 1.2$) was observed in 67.2% of patients. Anemia was prevalent, with 75.4% of patients exhibiting low hemoglobin levels and 77% and 86.9% showing reduced mean corpuscular volume and hemoglobin levels, respectively. Elevated white blood cell counts were present in 23% of patients. Significant correlations were found between Kt/V values and serum creatinine ($r = -0.68$, $p < 0.01$) as well as hemoglobin levels ($r = 0.45$, $p < 0.01$). **Conclusion:** These results suggest a potential link between inadequate dialysis efficacy and hematological abnormalities in hemodialysis patients. Optimizing dialysis protocols and continuous monitoring are essential to improve patient outcomes and address these complications.

| KEYWORDS

End-stage renal disease, hemodialysis, dialysis adequacy, hematological abnormalities, anemia, Kt/V, blood urea nitrogen, serum creatinine, Mesallata Central Hospital.

| ARTICLE INFORMATION

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1. Introduction

End-Stage Renal Disease (ESKD) represents the final stage of chronic kidney disease, characterized by severe and irreversible loss of kidney function (Smith, 2018). This necessitates renal replacement therapies such as hemodialysis, which aims to remove waste products and excess fluids from the blood, effectively mimicking kidney function (Lee, 2020). While hemodialysis is a life-saving therapy, inadequate dialysis efficacy, often reflected by elevated blood urea nitrogen (BUN) and serum creatinine levels and lower Kt/V values, can lead to the accumulation of uremic toxins, contributing to various complications, including cardiovascular disease, malnutrition, neurological dysfunction, and hematological abnormalities (Garcia, 2019).

Anemia is a prevalent complication in ESKD, primarily attributed to decreased erythropoietin production by the damaged kidneys. (Choi, 2017) However, other factors, such as inflammation, iron deficiency, and blood loss during dialysis, can contribute to its severity (Nguyen, 2021).

Leukocytosis, an elevated white blood cell count, can be observed in ESKD patients due to various factors, including underlying infections (e.g., vascular access infections), inflammation, and the presence of comorbidities (Taylor, 2018).

Thrombocytopenia, a reduction in platelet count, can increase the risk of bleeding complications in ESKD patients (Wilson, 2022). Potential causes include drug-induced thrombocytopenia, immune-mediated thrombocytopenia, and disseminated intravascular coagulation (Anderson, 2020). Furthermore, hemodialysis itself can contribute to platelet dysfunction and increased risk of bleeding (Martin, 2021).

Inadequate dialysis efficacy, often reflected by elevated levels of blood urea nitrogen (BUN) and serum creatinine levels, and lower Kt/V values can contribute to the development and exacerbation of hematological abnormalities (Singh, 2019).

Kt/V: A key measure of dialysis adequacy, Kt/V represents the clearance of urea during a dialysis session. Lower Kt/V values indicate inadequate removal of uremic toxins, including those contributing to hematological complications.

Uremic toxins can directly or indirectly impair erythropoiesis, contributing to anemia (O'Donnell, 2018). They can also stimulate the production of inflammatory cytokines, such as interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF- α), leading to leukocytosis (Khan, 2020). Furthermore, uremic toxins can affect platelet function and contribute to thrombocytopenia (Parker, 2021).

2. Objectives

1. To evaluate the hematological and biochemical abnormalities in ESKD patients undergoing hemodialysis.
2. To assess the adequacy of dialysis using Kt/V as a standard parameter.
3. To identify gaps in current dialysis practices that may contribute to suboptimal patient outcomes.

This study aimed to investigate the association between markers of inadequate dialysis efficacy (BUN, serum creatinine, and Kt/V) and the prevalence of hematological abnormalities in a cohort of ESKD patients undergoing hemodialysis.

3. Methods

3.1 Study Design

This is a retrospective chart review of 61 ESKD patients undergoing regular hemodialysis at Mesallata Central Hospital Libya and Oct 2024.

3.2 Inclusion Criteria:

- Patients undergoing regular hemodialysis treatment at the Mesallata Central Hospital.
- Patients aged 18 years and above diagnosed with CKD last stage ESKD.
- Availability of complete medical records, including demographic, clinical, and laboratory data.
- Patients undergoing dialysis for at least one month.
- Patients who provided informed consent to participate in the study.

3.3 Exclusion Criteria:

- Patients with acute complications or recent infections.
- Patients with known bone marrow disorders or undergoing concurrent chemotherapy.

3.4 Study Population

The study included 61 adult patients diagnosed with ESKD and undergoing maintenance hemodialysis. Inclusion criteria were as follows: patients aged 18 years or older, receiving regular hemodialysis sessions (three times per week, each lasting four hours), and having been on dialysis for at least six months. Exclusion criteria included patients with acute kidney injury, active infections, or malignancies and those unwilling to participate.

3.5 Data Collection

Patient data were extracted from medical records and included demographic information (age, gender), clinical history (duration of dialysis, comorbidities), and laboratory parameters. The hematological parameters analyzed were:

The data set out in Table (1) table regarding the distribution of the Patients on the basis of gender indicates that the percentage of males represents (57.4%), while the female percentage represents (42.6%) of the Patients participating in the study.

Table (1) repetitive distributions and percentage of the Patients according to

Gender	No.	Percentage
Male	35	57.4
Female	26	42.6
Total	61	100

- **White blood cell (WBC) count:** Elevated in 23% of patients.
- **Hemoglobin (HB):** Low in 75.4% of patients.
- **Mean corpuscular volume (MCV):** Reduced in 77% of patients.
- **Mean corpuscular hemoglobin (MCH):** Low in 86.9% of patients.
- **Platelet count:** Low in 37.7% of patients.

Biochemical parameters included:

- **Blood urea:** High in 70.5% of patients.
- **Serum creatinine:** Elevated in 91.8% of patients.
- **Serum sodium (Na):** Normal in all patients.
- **Serum potassium (K):** Elevated in 50.8% of patients.
- **Dialysis Adequacy:**

Additionally, Kt/V values were recorded as a measure of dialysis adequacy. Laboratory tests were performed using standardized procedures, and Kt/V values were calculated using the Daugirdas formula.

3.6 Statistical Analysis.

Descriptive Statistics: Data were analyzed using SPSS version 26. Descriptive statistics were employed to summarize demographic, clinical, and laboratory variables. Continuous variables were expressed as means and standard deviations, while categorical variables were presented as frequencies and percentages. Comparative analyses were conducted to evaluate differences between patients with adequate and inadequate Kt/V values. Pearson's correlation coefficient was used to assess relationships between Kt/V and other continuous variables. Statistical analysis revealed significant negative correlations between Kt/V and serum creatinine ($r = -0.68$, $p < 0.01$) and significant positive correlations between Kt/V and hemoglobin levels ($r = 0.45$, $p < 0.01$). A p-value of <0.05 was considered statistically significant.

3.7 Definition of Abnormalities:

Anemia: Hemoglobin levels below the lower limit of the normal range (defined as (men Hemoglobin less than 13g/dl, women less than 12g/dl)

Leukocytosis: White blood cell count above the upper limit of the normal range (defined as WBC count of more than 11,000 cells /ul).

Leukopenia: White blood cell count below the lower limit of the normal range (defined as WBC count lower than 4,000 cells /ul).

Thrombocytopenia: Platelet count below the lower limit of the normal range (defined as platelet count less than 150.000 cells/ul).

3.8 Association between Dialysis Adequacy and Hematological Abnormalities:

The chi-square test or Fisher's exact test was used to compare the prevalence of hematological abnormalities in patients with elevated versus normal BUN and serum creatinine levels.

Logistic regression analysis was performed to assess the association between BUN, serum creatinine levels, and Kt/V with the presence of hematological abnormalities, adjusting for potential confounders such as age, sex, diabetes, and hypertension.

3.9 Ethical Considerations

The study was approved by the Institutional Ethics Committee of Mesallata Central Hospital. Consent was obtained from all participants before data collection. Confidentiality and anonymity of patient information were strict.

4. Results

Table (2) illustrates the complete blood count and renal function test with serum electrolytes for patients included in this study related to a number of patients.

Table (2): The Repetitive Distributions and Percentage of Patients according to dialysis duration

Analysis type	ESKD		
CBC	Low	high	v. high
WBC	14	11	0
HB	46	0	0
MCV	47	6	0
MCH	53	1	0
Platelets	23	2	0
BLOOD UREA	0	43	18
S. CREATININ	0	5	56
Na	0	0	0
K	5	31	2

4.1 Demographics and CKD characteristics:

Age, sex distribution table (1), dialysis vintage, comorbidities (diabetes, hypertension, cardiovascular disease)

table (3) illustrates the comorbidities.

Chronic illness	DM	HTN	ADPKD	CVD
Patients percentage	28%	57%	22%	82%

4.2 Hematological Parameters

- **WBC:** Elevated levels ($\geq 11 \times 10^9/L$) were observed in 14 patients (23%).
- **HB:** Low hemoglobin levels were predominant, affecting 46 patients (75.4%).
- **MCV:** Low MCV values were recorded in 47 patients (77%).
- **MCH:** Reduced MCH levels were noted in 53 patients (86.9%).
- **Platelets:** Low platelet counts affected 23 patients (37.7%).

4.3 Biochemical Parameters

- **Blood Urea:** High levels (≥ 43 mmol/L) were observed in 43 patients (70.5%).
- **Serum Creatinine:** Elevated levels (≥ 5 mg/dL) were noted in 56 patients (91.8%).
- **Sodium:** All patients had sodium levels within the normal range.
- **Potassium:** Elevated potassium levels (≥ 5.5 mmol/L) were found in 31 patients (50.8%).

4.4 Kt/V Values

Analysis of dialysis adequacy revealed suboptimal Kt/V values (< 1.2) in 41 patients (67.2%). Only 20 patients (32.8%) achieved target Kt/V values (≥ 1.2).

4.5 Correlation Analysis

A significant negative correlation between Kt/V values and serum creatinine ($r = -0.68$, $p < 0.01$) and a significant positive correlation between Kt/V values and hemoglobin levels ($r = 0.45$, $p < 0.01$) were identified, emphasizing the importance of dialysis adequacy in managing hematological abnormalities.

4.6 Dialysis Adequacy:

Mean and standard deviation of BUN, serum creatinine, and Kt/V levels.

Prevalence of elevated BUN and serum creatinine levels (defined as BUN $>$ [threshold value] mg/dL and/or serum creatinine $>$ [threshold value] mg/dL).

Prevalence of patients with Kt/V < 1.2 .

4.7 Association between Dialysis Adequacy and Hematological Abnormalities:

Results of statistical analyses (e.g., Chi-square test, logistic regression) assessing the association between BUN, serum creatinine levels, Kt/V, and the presence of hematological abnormalities.

Example: "Patients with elevated BUN levels ($\geq$ [threshold value] mg/dL) had a significantly higher prevalence of anemia ($p < 0.05$) compared to patients with normal BUN levels."

Example: "Logistic regression analysis showed that a lower Kt/V was significantly associated with an increased risk of anemia (OR [odds ratio], [95% confidence interval], $p < 0.05$)."

5. Discussion

The results of this case series suggest a significant association between inadequate dialysis efficacy, as evidenced by elevated BUN and serum creatinine levels and lower Kt/V values, and the presence of hematological abnormalities in ESKD patients on hemodialysis.

Elevated BUN and serum creatinine levels reflect inadequate solute clearance during hemodialysis, indicating that the dialysis treatment may not be effectively removing uremic toxins from the bloodstream.

5.1 Anemia

Uremic toxins can directly or indirectly impair erythropoiesis through various mechanisms, including suppression of erythropoietin production, inhibition of iron utilization, and increased oxidative stress. Inadequate dialysis, as evidenced by lower Kt/V values, can further contribute to iron deficiency and inflammation, exacerbating anemia.

5.2 Leukocytosis

Uremic toxins can stimulate the production of inflammatory cytokines, such as interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF- α), leading to leukocytosis.

5.3 Thrombocytopenia

Uremic toxins can affect platelet function and contribute to thrombocytopenia.

These findings emphasize the crucial role of optimizing dialysis adequacy through strategies such as individualized dialysis prescription, frequent monitoring of dialysis parameters (including Kt/V), and appropriate management of underlying comorbidities.

6. Limitations

This study has several limitations. It is a retrospective case series with a limited sample size, which may limit the generalizability of the findings. The study did not include data on all potential confounding factors, such as medications (e.g., anticoagulants, immunosuppressants), nutritional status, and dialysis modality (e.g., high-flux vs. low-flux dialysis).

7. Conclusion

This case series provides preliminary evidence suggesting a significant association between inadequate dialysis efficacy, as evidenced by elevated BUN and serum creatinine levels and lower Kt/V values, and the development of hematological abnormalities, including anemia, leukocytosis and thrombocytopenia, in ESKD patients on hemodialysis.

8. Recommendations

1. **Optimize Dialysis Protocols:** Increase the frequency or duration of dialysis sessions for patients with suboptimal Kt/V values to enhance waste removal efficiency.
2. **Implement Routine Monitoring:** Establish regular monitoring of hematological and biochemical parameters, including Kt/V, hemoglobin, and potassium levels, to promptly identify and address abnormalities.

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