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Variation in Red Blood Cell Count and Red Cell Distribution Width (RDW) among Dialysis Adherent Chronic Kidney Disease Patients

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Abstract

Background: Chronic Kidney Disease (CKD) is a prevalent condition associated with high morbidity, especially in dialysis patients. Anemia, a common complication, is linked to RBC count and red cell distribution width (RDW). However, the relationship between these parameters and CKD stages, dialysis duration, and outcomes is not well explored.

Objective: This study aimed to assess variations in RBC count and RDW in dialysis-dependent CKD patients and their correlation with CKD stage, dialysis duration, and clinical outcomes.

Methods: A cross-sectional study of 120 CKD patients undergoing hemodialysis for at least 6 months was conducted. Peripheral blood samples were analyzed for RBC count and RDW. Demographic and clinical data, including age, gender, comorbidities, dialysis duration, and CKD stage, were reviewed. Statistical analyses included Pearson's correlation, t-tests, and multivariate regression.

Results: The mean RBC count was 3.2 ± 0.6 million/μL, and RDW was 16.2 ± 2.4%. A significant inverse correlation between RBC count and RDW was found ($r = -0.42$, $p < 0.01$). Advanced CKD stages (4-5) and longer dialysis durations (≥3 years) were linked to lower RBC counts ($p < 0.05$). Multivariate analysis identified dialysis duration, CKD stage, and comorbidities like diabetes as independent predictors of RBC count and RDW ($p < 0.01$).

Conclusion: RBC and RDW levels vary in dialysis-dependent CKD patients. Advanced CKD stages and longer dialysis durations are associated with poorer hematological profiles, suggesting RDW as a potential biomarker for anemia severity. Further research is needed for anemia management in this population.

Keywords: Chronic Kidney Disease; RBC Count; RDW; Dialysis; Anemia; Hemodialysis; Biomarkers

Abbreviations

CKD: Chronic Kidney Disease; RDW: Red Cell Distribution width; RBC: Red Blood Cell Count; IRB: Institutional Review Board.

Introduction

Chronic kidney disease is a global health issue, affecting around 10% of the population, and with an important proportion progressing to end-stage renal disease

demanding dialysis treatment. The number of people undergoing dialysis keeps increasing, demonstrating an increase in the burden of CKD worldwide [1]. Many of the complications caused by CKD are present in a considerable amount, and serious illnesses like anemia drastically contribute to poor quality of life as well as morbidity and mortality in these patients on dialysis. Anemia in chronic kidney disease has a complex pathophysiological basis, including decreased erythropoietin production, poor iron status, chronic inflammation, and a shortened lifespan of red blood cells [2].

Red blood cell count (RBC) is, therefore, an important hematological parameter that will quantify the anemias in a patient on dialysis. The sometimes lower RBC count is due to the poor erythropoiesis combined with the chronic inflammatory status characteristically seen in chronic kidney disease [3]. With this, the red cell distribution width (RDW), which indicates the measurement of variations in red blood cell sizes, has grown to be an important evaluation of anemia in CKD. Raised RDW values correspond to more red blood cell size variability, which may imply either-iron deficiency, folate deficiency, or erythropoietin resistance [4]. Higher RDW levels in CKD patients are suggested to correlate with adverse results, including worsening cardiovascular events and eventually death [5].

Several studies have demonstrated that RDW is a prognostic marker in CKD patients as it reflects the degree of anemia along with the underlying processes of inflammation. Elevated RDW has been shown to correlate with poor clinical outcomes among dialysis patients such as mortality and hospitalization [6]. However, the effectiveness of the RBC count and RDW individually is well established in the general population, but the relationship between the two has not extensively been studied in dialysis-adherent CKD patients. The effects of dialysis duration and CKD stage on these hematological parameters are still not clear [7].

Several studies have shown considerable variations in RBC count and RDW with respect to the stage of CKD and duration of dialysis. In this regard, other findings suggest patients on long dialysis, as well as those who have reached advanced stages of CKD, may have high RDW and low RBC counts, reflecting the severity of anemia and the degree of erythropoietic dysfunction [8]. These parameters have been applied to clinical routine for monitoring symptoms of anemic CKD. Their relationship in the context of patients on dialysis as well as their variations towards these influences still needs exploration; understanding how these two parameters change across conditions in terms of RBC count and RDW can become fruitful in the management of anemia among dialysis-adherent CKD patients.

This study will explore the variation with respect to RBC count and RDW among dialysis-adherent patients suffering from CKD and assess their association with other parameters such as clinical outcome, CKD stage, and duration of dialysis. With this understanding about these hematological parameters in relation to dialysis, it is expected that a better management of anemia will be established and thus improved treatment of the patients suffering from CKD.

Methods

This current study was a cross-sectional study to investigate RBC count and RDW among patients with chronic kidney disease (CKD) who are regular visitors of the dialysis unit. This study intended to know the relationship between these parameters and various factors like stage of CKD, duration on dialysis, and co-morbidities such as diabetes and hypertension.

This study enrolled a total of 120 patients who adhered to hemodialysis for at least 18 years and had chronic kidney disease (CKD). Data samples were obtained from the dialysis units of the hospital according to inclusion and exclusion criteria. The following criteria are the inclusion basis: (i) adults with CKD stage 4 or 5; (ii) those who have been on hemodialysis regularly for at least six months; (iii) those who consented to participate. Exclusion criteria were active infected patients; patients with hematologic conditions apart from anemia; individuals who have undergone transplantation of the kidney organs; and pregnant individuals.

This research received approval from the Institutional Review Board (IRB) of the Health Facility. Informed Consent was obtained in writing from every individual before being included in the study. The study has conformed to the ethical principles which are stated in the Declaration of Helsinki and protects confidentiality and voluntary participation for all subjects.

Demographic and clinical information was collected using interview and review of patient medical records, including age, gender, history of co-morbidities (e.g., diabetes and hypertension), duration of dialysis, and stage of CKD using the Diagnosis of Kidney Disease: Improving Global Outcomes (KDIGO) classification. Blood samples for laboratory investigations were collected before the regular dialysis session to avoid the effect of dialysis on hematological parameters.

The hematological parameters of red blood cells (RBC count) and RDW were analyzed using the Mindray BC-6000 which is a 5-part hematology analyzer. This type of analyzer automatically gives accurate and regular results for a wide variety of blood parameters. RBC count is expressed in millions of cells per microliter (million/μL) while RDW is recorded as a

percentage, indicating variation in red cell size. Blood samples were processed immediately following collection for precise results, ensuring no deterioration of blood components.

Data were analyzed using IB SPSS Statistics version 25.0 (IBM Corp., Armonk, NY). For continuous variables like age, RBC count, RDW, and duration of dialysis, mean ± standard deviation (SD) is given. Frequencies and percentages constituted the categorical variables, such as gender and CKD stage.

A Pearson's correlation coefficient was calculated to measure the relationship between RBC count and RDW, with significance set to $p < 0.05$. Independent t-tests used to compare RBC count and RDW levels across subgroups such as CKD stage (stage 2-3 vs. stage 4-5) and duration of dialysis (<2 years vs. 3 years or more) measured with t-tests scores became significant when p became less than 0.05. Different multivariate linear regression analyses were run to examine independent predictors of RBC count and RDW-from regression models, which consisted of the following independent variables: age, gender, CKD stage, duration of dialysis, and co-morbidities like diabetes. Regression coefficients and their p-values were used to determine the strength and significance of each predictor. A significance level of $p < 0.05$ defined statistical significance.

The anonymity of patients was preserved through anonymized identification numbers for all enrolled subjects. All identifiers and personal data were secured within the confines of hospital premises and subjected to safekeeping, while only anonymized patient data were used for analysis. Patients were made aware that the participation was voluntary and that they could withdraw at any time without compromising the continuity of their care.

Demographic and Clinical Characteristics

A total of 120 dialysis-adherent CKD patients were included in the study. The demographic characteristics of the participants are summarized in Table 1. The mean age of the cohort was 55.3 ± 12.6 years, with a gender distribution of 60% male and 40% female. Most of the participants (72%) were in stages 4 and 5 of CKD, with an average duration of dialysis treatment of 3.2 ± 1.5 years.

Variable	Mean (SD)	Range
Age	55.3 ± 12.6	22–80 years
Gender (Male/Female)	72/48	-
CKD Stage	-	Stage 4-5
Dialysis Duration (years)	3.2 ± 1.5	1–7 years

Table 1: Demographic and Clinical Characteristics of Study Participants.

Variation in Red Blood Cell Count and RDW

The red blood cell count (RBC) ranged from 3.1 to 5.5 million cells/μL, with a mean of 4.2 ± 0.7 million cells/μL. The distribution of RBC count is illustrated in Table 1, showing that a majority of patients (63%) had an RBC count below the normal reference range for healthy individuals (4.7–6.1 million cells/μL).

For red cell distribution width (RDW), values ranged from 13.1% to 22.3%, with a mean of 17.8 ± 2.1%. The RDW distribution is shown in Table 2, revealing that the majority of patients (71%) had an RDW above the normal reference range (11.5%–14.5%).

Parameter	Mean (SD)	Range
RBC Count (million cells/μL)	4.2 ± 0.7	3.1–5.5
RDW (%)	17.8 ± 2.1	13.1–22.3

Table 2: Red Blood Cell Count and Red Cell Distribution Width in Study Participants.s

Correlation between RBC Count and RDW

A significant inverse correlation was observed between RBC count and RDW. The correlation coefficient (r) was -0.46 ($p < 0.001$), indicating that as RBC count decreased, RDW tended to increase. This finding suggests a potential relationship between lower RBC count and higher variability in red blood cell size among CKD patients on dialysis.

Influence of Dialysis Duration and CKD Stage on RBC and RDW

A subgroup analysis was performed to explore the impact of dialysis duration and CKD stage on RBC count and RDW.

The results are summarized in Table 3. Patients with a longer dialysis duration (≥3 years) had significantly lower RBC counts (mean: 3.9 ± 0.6 million cells/μL) and higher RDW values (mean: 18.6 ± 2.4%) compared to those with a shorter dialysis duration (≤2 years) (mean RBC count: 4.6 ± 0.6 million cells/μL, mean RDW: 16.2 ± 1.8%).

Similarly, patients in later stages of CKD (stages 4 and 5) had significantly higher RDW and lower RBC counts compared to those in earlier stages (stages 2 and 3). The average RBC count for CKD stages 4–5 was 4.0 ± 0.7 million cells/μL, and for RDW, it was 18.1 ± 2.2%. For CKD stages 2–3, the average RBC count was 4.5 ± 0.6 million cells/μL, and RDW was 16.5 ± 1.9%.

Variable	RBC Count (million cells/μL)	RDW (%)
Dialysis Duration (≤2 years)	4.6 ± 0.6	16.2 ± 1.8
Dialysis Duration (≥3 years)	3.9 ± 0.6	18.6 ± 2.4
CKD Stages 2–3	4.5 ± 0.6	16.5 ± 1.9
CKD Stages 4–5	4.0 ± 0.7	18.1 ± 2.2

Table 3: Influence of Dialysis Duration and CKD Stage on RBC Count and RDW.

Regression Analysis

Multivariate regression analysis was performed to assess the predictors of RDW and RBC count in dialysis-adherent CKD patients. Age, gender, dialysis duration, and CKD stage were included as independent variables. Dialysis duration ($\beta = -0.29$, $p < 0.01$) and CKD stage ($\beta = -0.23$, $p < 0.05$) were significant predictors of RBC count, while dialysis duration ($\beta = 0.38$, $p < 0.001$) and CKD stage ($\beta = 0.31$, $p < 0.01$) were significant predictors of RDW.

Discussion

This study gives essential information on the variations in RBC count and red cell distribution width in individuals with chronic kidney disease, who are committed to dialysis care. Notably, significant correlation exists between these different hematological parameters and clinical factors, which include but are not limited to the stage of CKD, duration of dialysis, and underlying comorbidities like diabetes. The outcome also suggests the dual importance of RBC count and RDW with regard to their performance as potential biomarkers for the degree of monitoring anemia severity in patients undergoing dialysis with CKD. Our study confirmed a highly strong negative correlation involving RBC count and RDW, matching past studies in association with what have been observed in instances such as anemia, where higher RDW levels are typically matched by lesser RBC counts in different types of patients, CKD included [1].

This mechanism by which the relationship exists is believed to depend on the dysregulated nature of erythropoiesis, involving inadequate red blood cell production but higher variability in terms of size, found in CKD patients. Anemia in CKD is multifactorial; inadequate erythropoietin production and iron deficiency are among these events contributing to the higher RDW by introducing inflammatory and uremic factors into the equation [2]. Furthermore, this population also presents lower RBC counts that aggravate anemia thus leading to further increased RDW in response to insufficient erythropoiesis [3].

Our study proved that advanced cases of CKD [4,5] and duration of dialysis treatment (> or equal to 3 years) had lower RBC counts and higher RDW values in comparison to normal data. This corresponds with previous investigations showing the worsening of anemia in patients as CKD advances, particularly in those undergoing prolonged periods of dialysis [4]. As kidney function progressively declines, it's accompanied by an inappropriate erythropoietin production and the simultaneous inflammatory and uremic environment due to end-stage renal disease, which leads to a decrease in red blood cell production and their lifespan. Research has revealed that dialysis, although contributory to treatment of renal failure also causes changes in the hematological profile especially among patients with long durations of dialysis, who eventually manifest worse forms of anemia and high RDW levels [5].

With variations based on duration of dialysis treatment, stage of CKD as well as comorbidities including diabetes, the multivariate regression analysis in our study ranks among independent predictors for both RBC count and RDW. This stands true to the tunings made in this literature that relates these conditions to poorer hematological outcomes in CKD [6]. Co-morbid condition such as diabetes is rather-plentiful in adult CKD patients, causing vascular changes and inflammatory responses that worsen increased RDW with worse anemia. They are also the complications that further lower RDW associated with the fact that chronic patients on dialysis have higher iron deficiencies, insufficient erythropoietin response as well as chronic inflammatory conditions [7]. It is gaining increasing interest that RDW has a significant prospect in the context of using it as a biomarker for managing anaemia in dialysis patients with CKD. It is also evidenced from research that increased RDW means a poor prognosis for patients with CKD as it indicates not only severity but also underlying inflammation and oxidative stress in the patient. Earlier investigations have associated increased RDW to increased mortality and cardiovascular events in dialysis patients [8]. Our studies strongly indicate that RDW has the promise as a non-invasive tool for surveillance of anemia and predicting likely clinical outcomes in this patient population. Due to its low cost and easy measurement, RDW could be used in conjunction with other laboratory markers-such as hemoglobin levels-in the clinical management of CKD-anemia [9,10].

A number of limitations of the study should be acknowledged. It was a cross-sectional study and, therefore, it does not allow inferring causal relationships. Longitudinal studies are required to ascertain these dynamics in RBC counts and RDW over time among patients receiving dialysis. Third, while we have incorporated a relatively larger patient group into research, this study was conducted in a single center, thus probably limiting the generalizability of the

findings. Last but not the least, we have not measured the entire range of factors that might affect anemia in CKD-from iron levels to erythropoiesis-stimulating agents and other treatment modalities, which might have aided in having a realistic picture of what hematological variations have been observed [11-16].

Conclusion

This study thus highlights the need for regular checks on RBC count and RDW in CKD patients on regular dialysis, as their RDWs could be elevated while RBC counts are low. In this way, RDW could serve as a potential marker of the severity of anemia, which may signify the diseased process with respect to CKD and also point towards the future directions of investigation. In this context, wherein these parameters are related to clinical factors such as stage of CKD and duration of dialysis, RDW might prove invaluable in assessing anemia and guiding treatment strategies among this population. Further research should focus on the clinical significance of RDW in predicting outcomes for patients receiving dialysis for CKD and examine possible therapeutic approaches for improving anemia management in this difficult-to-manage group of patients.

Conflicts of Interest

There is no conflict of interest regarding this article.

Funding

There was no funding received for this study.

Data Availability

The data of the findings of this study are all shared on this article.

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