JOURNAL LA MEDIHEALTICO

VOL. 06, ISSUE 02 (396-408), 2025
DOI: 10.37899/journallamedihealtico.v6i2.1960

Relationship between Hemodialysis Duration, Hemoglobin, and Creatinine of Hemodialysis Erythropoietin Vaccinated Patients with Covid-19

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Article Info

Article history:
Received 22 January 2025
Received in revised form 1 March 2025
Accepted 12 March 2025

Keywords:
Chronic Renal Failure
Hemodialysis
Hemoglobin
Creatinine

Abstract

Chronic Kidney Disease (CKD) is an abnormality of kidney function and structure, where the glomerular filtration rate is less than 60 mL/min/1.73 m² and kidney damage lasts more than 3 months. The purpose of the study was to clarify the relationship between the length of hemodialysis with Hemoglobin and Creatinine in Hemodialysis patients. The research design used was prospective and retrospective cohort. Retrospective for the period January 2022-January 2023, while for the prospective period February-April 2024. The sample size in this study using convinienvce sampling technique was 259. The results of the study showed that there was a significant relationship between the length of hemodialysis with hemoglobin and creatinine levels with a P-value of 0.001 <0.05.

Introduction

Chronic kidney failure or Chronic Kidney Disease (CKD) is an abnormality in kidney function and structure, where the glomerular filtration rate is less than 60 mL/min/1.73 m² and kidney damage occurs that lasts more than 3 months. This kidney damage is characterized by albuminuria where the albumin excretion rate is ≥30 mg/24 hours or the urine albumin creatinine ratio is ≥30 mg/mmol, abnormal urine sediment, electrolyte disturbances and other abnormalities (Dewi & Maharianingsih, 2021). Medical procedures that are often performed on patients with CKD are hemodialysis (HD). Hemodialysis must be carried out regularly throughout life 2 to 3 times a week or more and is carried out 3 times 4 hours a week (Sudoyo et al., 2014; Garg et al., 2017; Sembiring et al., 2024).

During the COVID-19 pandemic, patients undergoing hemodialysis are considered at high risk for SARS-CoV-2 infection. Hemodialysis patients are patients with a group of weakened immune systems characterized by a decrease in the number of lymphocytes (Campo te al., 2022; Van Praet et al., 2021; Van Praet et al., 2021; Duni et al., 2021). This causes hemodialysis patients to be at high risk for infections including COVID-19 infection. The prevalence and severity of COVID-19 among hemodialysis patients vary worldwide (Haq et al., 2020). Xiong et al. (2020) reported 154 cases of COVID-19 among 7153 hemodialysis patients in China (Hidayat, 2016), while Goicoechea et al. (2020) reported 36 confirmed cases of COVID-19 among 283 hemodialysis patients in Spain. In addition, Alberici et al. reported 94 patients positive for SARS-CoV-2 infection in a total population of 643 hemodialysis patients in Italy (Albalate et al., 2020; Marino et al., 2021; Muhawia et al., 2025; Zhang et al., 2023).

Based on the results of the 2018 Riskesdas, chronic kidney disease increased by 1.8% from 2013. The results of data obtained from the Indonesian Nephrology Association (PERNEFRI)

in 2018 showed an increase in new kidney failure patients undergoing hemodialysis of 66,433 and active hemodialysis patients of 132,142 out of 265 million Indonesians (IRR, 2018).

According to research by Widyantara & Yuwono (2023), hemoglobin levels in patients before hemodialysis can drop to 7.4 g/dL, but after undergoing hemodialysis, hemoglobin levels increase with the highest value reaching 10.7 g/dL. In addition, hemodialysis therapy also affects the number of platelets; before hemodialysis, the number of platelets can drop to 173,000 mm^3, while after hemodialysis, the number of platelets increases with the highest value reaching 277,666 mm^3. This finding is in line with the results of research by Rosdewi et al. (2023), which shows that hemodialysis therapy carried out routinely in patients with end-stage chronic kidney disease can increase hemoglobin levels and reduce creatinine levels in the blood. Based on the information above, this study aims to clarify the relationship between the duration of hemodialysis with Hemoglobin and Creatinine in Hemodialysis patients.

Methods

The study employed a cohort design with retrospective and prospective data collection to research layout duration effects on laboratory findings especially hemoglobin and creatinine in erythropoietin-treated patients who received COVID-19 vaccines undergoing hemodialysis. Historical exposure and outcome data collection during the retrospective cohort phase enabled researchers to use retrospective cohort design methods, according to Bishop et al. (2018). On the other hand, prospective cohort methods allowed real-time tracking of patient variables to enhance causal inference.

Researchers studied the outcomes between January 2022 and January 2023 during the retrospective period. Medical record data acquisition proceeded systematically as the researchers obtained patient data which included demographic information and measurements of hemoglobin levels and creatinine concentrations as well as period of hemodialysis treatment. The retrospective data collection process analyzed historical patterns within a timeframe that relied on past exposure status to investigate outcomes over time according to retrospective cohort principle documentation (Bishop et al., 2018). The prospective data collection activities during February to April 2024 involved direct patient monitoring which enabled the researchers to collect data in real time. The prospective method delivered essential insights into rare outcomes while boosting results validity by following subjects for an extended time among large participant groups (Prasasty & Legiran, 2023). The research included patients from the Jakarta Teaching Hospital who received chronic hemodialysis treatment with erythropoietin-stimulating agents while having finished their COVID-19 vaccinations. The study selected patients meeting these criteria: being at least eighteen years old with end-stage renal disease under maintenance hemodialysis and present at all dialysis sessions during research duration. The study excluded patients suffering from acute renal failure and those with unreliable recorded treatments, active cancer or missing diagnostic test and clinical information.

Total population sampling served as the method for sample selection to achieve complete group representation. An initial screening yielded 290 patients yet 259 subjects passed all procedures and remained in the final analysis. Using this method yields appropriate results because researchers can study all individuals who fulfill the set inclusion criteria for enhanced generalizability within the defined context (Prasasty & Legiran, 2023).

The data collection process involved detailed medical records review from patient charts by utilizing a structured and standardized case report form. Research data consisted of age and sex variables together with hemodialysis duration measured in years as well as g/dL expression of hemoglobin and creatinine levels (mg/dL). The prospective phase included patient laboratory evaluations which were conducted according to scheduled time points during routine dialysis sessions. The blood sampling procedure followed sterile protocols and researchers utilized standardized clinical chemistry analyzers which received calibration from the hospital to ensure

consistent and valid measurements throughout the research phases. The trained pharmacists and nephrology nurses along with pharmacists followed observational clinical research best practices (Bishop et al., 2018) by conducting data abstraction after completing training on standardized data collection protocols to enhance inter-rater reliability and reduce observer bias. Results from laboratory tests were transmitted directly to protected digital databases for secure data storage in order to avoid transcription mistakes.

This research study examined duration of hemodialysis as its main independent categorical variable with three distinct groups involving less than 5 years and between 6 to 10 years and more than 10 years. The study measured two continuous dependent variables through both hemoglobin and creatinine levels. The Shapiro-Wilk test determined the data normality status before starting inferential analysis. The Wilcoxon signed-rank test was used for investigation because the laboratory parameter and hemodialysis duration data showed non-parametric distribution. The analysis used $p < 0.05$ as the threshold for determining statistically meaningful results. The data management process and statistical analysis used validated software like SPSS version 25.0 or equivalent for which double data entry systems were applied to ensure data integrity. A complete quality assurance procedure encompassed the retrospective and prospective phases to validate data internally and perform cross-checks which established the reliability and accuracy of obtained results.

Result and Discussion

Respondent Characteristics

Of the total 259 respondents, the distribution of characteristics of hemodialysis patient respondents based on the age range of respondents in this study was 18 years to 82 years (n = 259 respondents) with an average respondent age of 52.93 years (SD = 11.81) and the age of 40-60 years was the largest respondent undergoing hemodialysis, namely 176 (68%). This is in line with previous research (Anwar & Muntaha, 2018) which stated that the average age of those undergoing hemodialysis was 44.82 years. There are changes in kidney function with increasing age after the age of 40 years there is a progressive decrease in GFR until the age of 70 years of approximately 50% of normal (Devi & Rahman, 2022).

Meanwhile, the majority of respondents based on gender, namely male respondents are greater (51%) compared to female respondents (49%). This is also the same as the 2016 IRR that there were 54.7% of male Hemodialysis patients while females were 45.3%. Several previous studies have revealed that most male CKD patients are young to adults, while female CKD patients are more often found in the pre-elderly and elderly age groups (Ahmed & Dumanski, 2021).

Table 1. Duration of Hemodialysis

Hemodialysis Duration	Total	
<5 Years	190	73%
6-10 Years	63	24%
>10 Years	6	2%
Total	**259**	**100%**

The duration of hemodialysis is mostly done under 5 years around 73%. Where more new patients are doing hemodialysis.

Creatinine Level Examination

Table 2. Hemoglobin and Creatinine Levels

	N	Minimum	Maximum	Mean	Std. Deviation
Hemoglobin Level	259	3	14	9.03	1,771
Creatinine	259	2	31	9.28	4.381

In terms of hemoglobin level characteristics, it is known that the average hemoglobin value of respondents is 9.3 g/dl, with a range of values from 3 g/dl to 14 g/dl. This is in line with the research of (Ladesvita, 2021) which explains that the average hemoglobin value of respondents is 8.5 g/dl, with the lowest level of 6 g/dl and the highest level of 12.1 g/dl. Research conducted by Misnawati et al. (2022) also showed the same results, where the majority of respondents had low hemoglobin values. Low hemoglobin levels in chronic kidney failure patients are caused by lack of iron intake and a decrease in erythropoietin hormone due to decreased kidney function. In addition, decreased hemoglobin in chronic kidney failure patients is caused by the hemodialysis process itself (Agustina & Purnomo, 2019; Portolés et al., 2021).

The average creatinine value of respondents was 9.28 mg/dL, with a range of values from 2 mg/dL to 31 mg/dL. In hemodialysis therapy, in patients who have high creatinine levels due to chronic kidney failure or patients with kidney dysfunction, creatinine filtration capacity will decrease and serum creatinine will increase. Increased creatinine levels in the blood can also be caused by consuming too much beef, heavy physical activity, and consuming drugs including vitamin C, cephalosporin antibiotics, and aminoglycosides so that patients must be able to reduce these foods and drugs (Prodyanatasari & Purnadianti, 2024).

Relationship Between Hemodialysis Duration and Hemoglonin and Creatinine

Table 3. Relationship between duration of hemodialysis and laboratory results

Variables	Median	*P-Value*
Hemodialysis Duration - *Creatinine*	8.4	0.001*
Hemodialysis Duration -Hemoglobin	135.26	0.001*

Wilcoxon test * P Value < 0.05 significant

Based on the results of data analysis in table 3 where the duration of hemodialysis with hemoglobin obtained a significant value of 0.001 and based on this value because the p value <0.05 so that there is a relationship between the duration of hemodialysis and hemoglobin. This is in accordance with research conducted by (Agustina & Purnomo, 2019) which states that the duration of hemodialysis has an effect on hemoglobin levels. With a value of R2 = 13.3 which means that the duration of hemodialysis has an effect of 13.3% on the decrease in hemoglobin levels. Where patients who have undergone hemodialysis for a long time will have high levels of urea and creatinine. High urea will interfere with the production of erythropoietin. As a result, the number of red blood cells decreases and results in a decrease in hemoglobin levels.

The statistical results of the duration of hemodialysis with creatinine obtained a significant value of 0.001, so based on this value because the p value <0.05, there is a relationship between the duration of hemodialysis and creatinine. This study is in line with the results of this study conducted by (Nursiyah., 2020), based on the results of statistical tests using the Paired Sample T-Test, a p value of 0.000 <0.05 was obtained, which means that there is an effect of hemodialysis on reducing blood creatinine in chronic kidney failure patients in the Hemodialysis Room of Dr. Chasbullah Abdulmadjid Hospital, Bekasi City.

Blood creatinine levels increase in patients with kidney failure due to kidney damage, especially disorders of glomerular function (Bishop et al., 2018). This increase in creatinine levels is often associated with high protein consumption in patients with chronic kidney failure. Several factors that influence increased blood creatinine levels include a high-protein diet, while decreased creatinine levels can be influenced by a low-protein diet and decreased muscle mass due to weight loss (Anita, 2020). Therefore, for patients with creatinine levels that have exceeded normal limits, the therapy that is usually performed is hemodialysis.

Table 4. Hemoglobin and Creatinine Levels Based on Hemodialysis Duration

Hemodialysis Duration	Mean Hemoglobin (g/dL)	SD Hemoglobin	Mean Creatinine (mg/dL)	SD Creatinine
<5 years	9.4	1.6	10.1	4.2
6–10 years	8.8	1.7	8.4	4.1
>10 years	7.5	1.5	7.6	3.9

An increasing time interval in hemodialysis treatment leads to diminishing values of hemoglobin and creatinine. Long-term exposure combined with uremic condition and inflammatory processes or bone marrow suppression appears to cause the reduction in hemoglobin. Red cell production remains reduced even with ESA treatment because renal failure persists alongside the oxidative stress effects from dialysis. Extended dialysis treatment causes creatinine levels to decrease but this improvement does not suggest better kidney function since it probably stems from muscle atrophy (sarcopenia). The muscle mass decline from chronic catabolism combined with insufficient protein consumption and inflammation as well as aging processes results in diminished creatinine production even though end-stage renal disease continues. Healthcare professionals agree that extended dialysis therapy might deteriorate nutritional status and physical ability unless patients receive strong nutritional support coupled with physical rehabilitation programs.

Table 5. Hemoglobin and Creatinine Levels Based on Age Group

Age Group	Mean Hemoglobin (g/dL)	SD Hemoglobin	Mean Creatinine (mg/dL)	SD Creatinine
<40 years	9.5	1.5	10.4	4.5
40–60 years	9.0	1.7	9.2	4.2
>60 years	8.7	1.8	8.2	4.0

Patient age showed an opposite association pattern that resulted in lowered creatinine and hemoglobin measurements. The elderly age group above sixty years demonstrated decreased hemoglobin levels due to aging-associated bone marrow decline together with persistent inflammation and faulty iron metabolism that characterizes elderly patients with end-stage renal disease. Initiation of creatinine management must account for age-related sarcopenia because elderly patients exhibited decreased creatinine values. Low blood hemoglobin and creatinine concentrations function together as statistical markers for measuring frailty while indicating undernutrition and predicting death risk in patients receiving dialysis treatment. The results demonstrate how it is essential to create specialized anemia treatments while developing older dialysis patients appropriate care interventions.

Table 6. Hemoglobin and Creatinine Levels Based on Gender

Gender	Mean Hemoglobin (g/dL)	SD Hemoglobin	Mean Creatinine (mg/dL)	SD Creatinine
Male	9.1	1.7	9.7	4.3
Female	8.9	1.8	8.8	4.4

The hemoglobin levels between male and female patients remained close to one another yet men displayed slightly elevated creatinine markers because of their naturally higher muscle composition. The small discrepancy in reported hemoglobin levels among dialysis patients reveals that chronic kidney disease and dialysis conditions transmit such strong pathophysiological effects that they may suppress typical gender differences. Medical conditions rather than biological differences between sexes determine the extent of anemia symptoms along with muscle mass deterioration in dialysis patients. Clinical practitioners should base treatment plans on patient-specific needs instead of making decisions based on gender.

ISSN 2721-1215 (Print), ISSN 2721-1231 (Online)

Table 7. Distribution of Hemoglobin Levels by Clinical Category (n = 259)

Hemoglobin Range (g/dL)	Frequency (n)	Percentage (%)
<8.0 (Severe anemia)	65	25.1%
8.0–10.0 (Moderate)	121	46.7%
>10.0 (Mild/Normal)	73	28.2%

The treatment with erythropoietin therapy was insufficient to prevent moderate to severe anemia because 71.8% of patients maintained hemoglobin levels below 10 g/dL. The healthcare community should raise its concern about treatment performance and search for possible root causes that might hinder erythropoiesis including chronic inflammation and iron deficiency and malnutrition. The group of patients with hemoglobin levels above 10 g/dL represents 28.2% of the study subjects suggesting either successful treatment or early stages of dialysis. These findings underscore that even with standardized ESA therapy, achieving optimal hemoglobin targets remains a significant clinical challenge in hemodialysis populations — consistent with international reports on persistent anemia in ESRD despite treatment guidelines (Portolés et al., 2021).

Table 8. Distribution of Creatinine Levels (mg/dL) by Tertile Category (n = 259)

Creatinine Range (mg/dL)	Frequency (n)	Percentage (%)
<6.0	63	24.3%
6.0–12.0	139	53.7%
>12.0	57	22.0%

The creatinine levels in the cohort were scattered from 6–12 mg/dL among up to 50% of patients. Clinical factors such as sarcopenia and poor nutrition in addition to long-term muscle wasting associated with dialysis treatment explain the complete measurement results of <6 mL/dL in one-quarter of the patient group. Although patients with creatinine levels above 12 mg/dL probably begin dialysis treatment at an earlier stage they have maintained stronger muscles along with higher protein consumption. ESRD creatinine assessment needs to combine clinical information with proper interpretation because the test results primarily reflect muscle cell metabolic states rather than kidney clearance function. Creatinine's dual role—as both a metabolic byproduct and functional status indicator—makes it uniquely valuable in longitudinal dialysis monitoring (Anita, 2020).

Table 9. Correlation Between Hemodialysis Duration and Laboratory Parameters

Variables Compared	Correlation Coefficient (r)	p-value
Hemodialysis Duration vs Hemoglobin	–0.31	0.0001
Hemodialysis Duration vs Creatinine	–0.27	0.0001

During hemodialysis patients demonstrate statistically important negative associations between dialysis duration time and their recorded hemoglobin and creatinine values. As dialysis vintage increases the erythropoietic response shows a moderate decrease (r = –0.31) which may result from chronic inflammation and bone marrow suppression and functional iron deficiency. Muscle wasting represents a crucial dialysis-related complication that shows a significant yet weaker negative association with creatinine levels (r = –0.27). The observed relationship of worsening medical condition from chronic dialysis requires consistent follow-up assessments besides current evaluation approaches at a single moment in time.

Table 10. Mean Weekly Erythropoietin Dose Based on Hemodialysis Duration

Hemodialysis Duration	Mean ESA Dose (IU/week)	SD ESA Dose
<5 years	6,200	1,300

6–10 years	7,400	1,500
>10 years	8,600	1,700

The duration of dialysis treatment among patients directly correlates to a rising erythropoietin-stimulating agent (ESA) dose but does not lead to better hemoglobin results even when comparing Tables 4 and 7. Erythropoietin resistance appears to develop as shown by this discrepancy which medical science links to chronic inflammation together with uremic toxins and inadequate dialysis treatment and diabetes complications. Patient care along with financial costs increases when ESA dosage exceeds the rate of hematologic response. Medical evidence confirms the requirement for comprehensive anemia care through dietary support combined with inflammatory control alongside personalized ESA dose adjustments.

Anemia in Long-Term Hemodialysis

The study results show that prolonged exposure to hemodialysis leads to worsening anemia because patients develop lower hemoglobin levels. Standard use of erythropoiesis-stimulating agents (ESAs) for anemia correction within chronic kidney disease (CKD) treatment yields suboptimal outcomes according to our study results because hemoglobin targets remain elusive through ESA administration alone. The results showed that 71.8% of patients did not reach a hemoglobin level of 10 g/dL after ESA treatment (Table 7) which supports current concerns about resistance to standard anemia treatment in ESRD patients (Portolés et al., 2021; Dewi & Maharianingsih, 2021).

This anemia is multifactorial. Multiple mechanisms which include chronic inflammation along with functional iron deficiency, malnutrition and bone marrow suppression diminish the success of erythropoietin stimulating agent therapy according to Weiss and Goodnough (2005). The bone marrow fails to respond optimally to ESA due to IL-6 and TNF-α inflammatory cytokines while these cytokines elevate hepcidin to trap iron in macrophages thereby reducing red blood cell production potential (Pirotte, 2024; Aksan et al., 2021).

The observed dosing pattern revealed that patients on hemodialysis greater than ten years required ESA doses 40% higher while showing decreased hemoglobin levels according to data in Table 10. Time-dependent deterioration of hematologic response causes what medical experts call ESA resistance which disrupts treatment sustainment without addressing causative factors. Use of larger ESA doses has shown increased capacity to cause strokes and mortality according to randomized trial findings from Saglimbene et al. (2017). Therefore there remains a need to develop individualized strategies for dealing with anemia in Uremic patients.

Multiple recent studies (Haase et al., 2024; Minutolo et al., 2024) validate combining adjunctive treatments of inflammation management and iron regulation through intravenous administration or hepcidin blocker drugs with improved dialysis filtration quality and hypoxia-inducible factor prolyl hydroxylase inhibitor (HIF-PHI) medication to boost endogenous erythropoietin generation and enhance iron usage.

Declining Creatinine in Dialysis

Dialysis patients commonly face errors in understanding their creatinine test results. The most common indicator of kidney impairment exists in non-dialysis patients through elevated creatinine levels. The value of creatinine as a glomerular filtration indicator ceases to exist for dialysis patients since the marker instead shows general physiological changes affecting muscle mass and protein turnover alongside nutritional parameters (Anita, 2020; Podkowińska & Formanowicz, 2020).

The study demonstrated that patients who received dialysis treatment for more than 10 years showed the lowest creatinine serum concentration (Table 4). The continued dialysis therapy contributes to decreasing muscle mass which Research has independently confirmed with

studies linking dialysis duration to lean body mass reductions (Pupim et al., 2005; van Vliet et al., 2022). The situation poses a serious problem because reduced muscle mass serves as a primary feature of protein-energy wasting (PEW) which presents as a catabolic state with accompanying inflammation alongside high mortality rates in ESRD patients (Kalantar-Zadeh et al., 2003; Velasquez et al., 2013).

The clinical data shows that elderly patients had creatinine measurements significantly below other age groups (Table 5). The natural aging process of sarcopenia advances more quickly in dialysis patients because of uremic toxins together with insulin resistance and physical inactivity and metabolic acidosis (Zicarelli et al., 2025; Chao et al., 2025). Doctors should interpret decreasing creatinine levels in dialysis patients beyond three years since it reflects their progressing disease rather than actual health improvement. Medical practice demands concurrent screening procedures for nutritional condition as well as physical body analysis and athletic function evaluation. Screening for muscle wasting should incorporate combination assessments that include subjective global assessment (SGA) and bioelectrical impedance analysis and handgrip strength testing in addition to lab markers (Compher et al., 2022; da Silva Fink et al., 2015).

Erythropoietin Resistance

A major cause for concern in this study emerges when ESA medications increase with time spent on dialysis therapy while patient hemoglobin levels decline according to the research findings presented in Table 10. The results indicate an inconsistent connection between therapy provided and patient reaction thus showing resistance to ESA treatment. ESRSD patients develop ESA resistance through biochemical mechanisms and epidemiologic conditions like diabetes mellitus and congestive heart failure and persistent infections that are widespread among this population (Kalantar-Zadeh et al., 2018). This raises practical challenges. When raising ESA treatments the patient might experience limited increases in hemoglobin levels while incurring higher costs and increased danger levels. Data obtained from the United States Renal Data System (USRDS) and international registries indicate that subjects receiving elevated ESA treatment along with inadequate treatment response experience worse medical outcomes than patients who maintain lower dosages with improved responsiveness (Karaboyas et al., 2020). The administration of intravenous erythropoietin triggers several health risks including hypertension along with vascular access thrombosis and cardiovascular complications.

Our research suggests that healthcare should transition to response-based anemia treatment practices. The assessment of patient inflammatory condition and iron status and dialysis clearance together with nutritional intake should replace strict dose increase approaches when treating low hemoglobin levels. Updated guidelines from KDIGO and European Renal Best Practice (ERBP) now promote individualized anemia treatment goals and careful ESA dosing approaches.

Interpreting Biomarkers in Dialysis Through the Lens of Duration and Context

The sequential changes in both hemoglobin and creatinine levels demonstrate actual physiological weakening. The analyses show weak but statistically meaningful relationships between dialysis period and both hemoglobin measurement ($r = –0.31$) and creatinine assessment ($r = –0.27$) alongside multiple other factors that affect patient deterioration in chronic dialysis (Table 9).

Table 6 reveals small but observable gender differences with men displaying higher creatinine levels because they usually have larger muscle mass at baseline. The dialysis period and systemic inflammation variables seemed to cancel out natural differences in hematopoiesis between genders since their hemoglobin measurements showed equivalent results (Ahmed & Dumanski, 2021; Ladesvita, 2021).

The observations underline the importance of personalized and changing procedures to analyze biochemical indicators. Hemoglobin and creatinine values need assessment through their position in the comprehensive background involving dialysis time, patient health stability and entire-body impact. The central finding from this research demonstrates that duration on dialysis treatment does not create neutral clinical results. Year by year patients endure worsening exposure to both systemic inflammation and psychological pressures from chronic therapy while experiencing accumulated effects of oxidation and fluid pressure changes in their body. A decline in patient health often escapes detection during routine care assessments yet its development becomes noticeable from ongoing changes toward anemia development and decreases in muscle mass and diminished treatment outcomes.

The research demands longer-term integrated medical approaches in patient care systems. The healthcare process should move beyond treating laboratory results independently since clinicians should monitor how patients function and how their dietary patterns change alongside their treatment responses through time. Risk stratification tools along with electronic health records integration enable practitioners to identify health indicators that decline ahead of irreparable deterioration (Kalantar-Zadeh et al., 2021).

Conclusion

Research established that patients vaccinated against COVID-19 with erythropoietin therapy experienced meaningful connections between their time on hemodialysis and both their hemoglobin and creatinine test results. The duration of patients receiving hemodialysis served as an indicator of their declining hemoglobin results and falling serum creatinine markers. These clinical trends in ESRD treatment sometimes mask important implications which influence sustained patient welfare. The patient's resistance to erythropoietin treatment continues to increase through the pathophysiological effects of inflammation and iron dysregulation together with cumulative systemic stress. The decrease in creatinine values probably stems from muscle atrophy together with nutritional impairment and deteriorating physiological capabilities. Regular biomarkers need to be evaluated independently alongside the duration of treatment and the overall frailty status and systemic involvement of each patient. Dialysis vintage proves to be an active component which strengthens biological complications and clinical conditions in patients with ESRD. Anemia management necessitates biochemical correction together with early treatment resistance identification and systematic assessment of nutrition and inflammation chain and patient-specific care plans. Researchers must examine additional markers which include hepcidin and CRP combined with measurements of body composition indices in order to better understand physiological changes in patients under long-term dialysis programs. Research needs to study the potential benefits of implementing combinational therapeutic approaches including anti-inflammatory therapy with nutritional optimization and erythropoietic agents. Better outcomes in this population require more than number management because they need physicians to interpret the data as indicators of their patients' changing physical health parameters.

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