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The Effect of Heparin On blood Components in Hemodialysis Patients in Dialysis Center in Tarhouna City, Libya

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تأثير الهيبارين على مكونات الدم لدى مرضى غسيل الكلى في مركز غسيل الكلى بمدينة ترهونة، ليبيا

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Abstract:
This study aimed to evaluate the impact of unfractionated heparin (UFH) administration during hemodialysis on hematological parameters in patients with chronic kidney disease (CKD). A total of 50 patients undergoing regular hemodialysis in Tarhouna City, Libya, were included and divided based on the dialysis machine used (Nipro vs. Fresenius). Blood samples were collected immediately before and after dialysis sessions to measure changes in complete blood count (CBC) values, specifically red blood cell (RBC) indices, white blood cells (WBC), and platelets (PLT). The results demonstrated statistically significant reductions in RBC count, hemoglobin (HGB), and hematocrit (HCT) levels after the dialysis session ($p < 0.05$), suggesting a potential contribution of heparin and mechanical factors to red cell loss. Conversely, no statistically significant changes were observed in WBC or PLT counts. Notably, bleeding complications were recorded exclusively in patients using the Fresenius machine (16% incidence) and were statistically linked to the use of high-flux filters (60High and 80High) (p=0.019). These findings underscore the importance of developing individualized heparin protocols and considering dialysis machine and filter characteristics to minimize hematological complications and enhance patient safety.

Key words: Hemodialysis, Heparin, Blood Components, Unfractionated Heparin (UFH), Red Blood Cells, Bleeding Risk.

الملخص
هدف هذا البحث إلى تقييم تأثير استخدام الهيبارين غير المجزأ (UFH) أثناء جلسات الغسيل الكلوي على معايير الدم لدى مرضى الفشل الكلوي المزمن .شملت الدراسة 50 مريضًا يخضعون لغسيل كلوي منتظم في مدينة ترهونة، ليبيا، وتم تقسيمهم بناءً على نوع جهاز الغسيل المستخدم (نيبرو مقابل فريزنيوس) . جُمعت عينات الدم مباشرة قبل وبعد الجلسة لقياس التغيرات في قيم تعداد الدم الكامل(CBC) ، وتحديداً مؤشرات كريات الدم الحمراء(RBC) ، وكريات الدم البيضاء(WBC) ، والصفائح الدموية .(PLT)

أظهرت النتائج انخفاضات ذات دلالة إحصائية في عدد كريات الدم الحمراء، والهيموغلوبين(HGB) ، والهيماتوكريت (HCT) بعد الجلسة($p < 0.05$) ، مما يشير إلى دور محتمل للهيبارين والعوامل الميكانيكية في فقدان الخلايا الحمراء .في المقابل، لم تُلاحظ تغيرات ذات دلالة إحصائية في أعداد كريات الدم البيضاء أو الصفائح الدموية. ومن الجدير بالذكر أن حالات النزيف سُجلت حصريًا لدى المرضى الذين استخدموا جهاز فريزنيوس (بنسبة 16%)، وارتبطت إحصائيًا باستخدام مرشحات عالية التدفق (60High , 80High) (p=0.019). تؤكد هذه النتائج على أهمية تطوير بروتوكولات فردية لاستخدام الهيبارين ومراعاة خصائص جهاز الغسيل والمرشح لتقليل المضاعفات الدموية وتعزيز سلامة المرضى.

الكلمات المفتاحية :غسيل الكلى، الهيبارين، مكونات الدم، الهيبارين غير المجزأ، كريات الدم الحمراء، خطر النزيف.

Introduction

The kidneys are vital organs responsible for maintaining the body's internal balance by regulating fluid and electrolyte levels, eliminating metabolic waste products, and producing essential hormones such as erythropoietin, which stimulates red blood cell production. In cases of chronic kidney disease (CKD), progressive loss of renal function can lead to end-stage renal disease (ESRD), necessitating renal replacement therapies such as hemodialysis.

Heparin is a widely used anticoagulant during hemodialysis sessions, essential for preventing thrombus formation within the extracorporeal blood circuit. Its administration ensures smooth blood flow and prevents clotting that could compromise the efficiency of dialysis. However, accumulating evidence suggests that heparin may exert significant effects on various hematological parameters, particularly on red blood cells, white blood cells, and platelets (Smith & Johnson, 2020; Chen et al., 2021).

Several clinical studies have demonstrated a notable reduction in hemoglobin and hematocrit levels following heparin use in hemodialysis patients. Additionally, a decrease in platelet count, potentially due to platelet activation, aggregation, or immune-mediated destruction, has been reported, indicating the risk of heparin-induced thrombocytopenia (Chen et al., 2021). Changes in leukocyte counts have also been observed, albeit less consistently.

These hematological alterations can be influenced by multiple factors, including the type of heparin used—whether unfractionated heparin (UFH) or low molecular weight heparin (LMWH)—as well as the dose and duration of administration. The KDIGO 2021 guidelines emphasize the importance of individualized anticoagulation strategies to minimize complications in dialysis patients (KDIGO, 2021). Therefore, monitoring blood components before and after dialysis sessions is essential to evaluate the safety and hematological impact of heparin, particularly in patients with pre-existing anemia or bleeding risk.

Research Problem

Chronic kidney disease (CKD) often progresses to end-stage renal disease (ESRD), requiring regular hemodialysis as a life-sustaining therapy. During hemodialysis, anticoagulation is critical to prevent clot formation in the extracorporeal circuit, with heparin—particularly unfractionated heparin (UFH) and low molecular weight heparin (LMWH)—being the most commonly used anticoagulants. While heparin administration is essential for maintaining vascular access and ensuring dialysis efficacy, emerging clinical evidence suggests that it may adversely affect various hematological parameters.

Numerous studies have reported reductions in hemoglobin, hematocrit, and platelet counts among patients undergoing heparinized dialysis. These changes may result from direct effects of heparin on blood components or from immune-mediated mechanisms such as heparin-induced thrombocytopenia (HIT). Alterations in leukocyte counts have also been observed, although less consistently. These hematological disturbances raise significant clinical

concerns, particularly in dialysis patients who are already predisposed to anemia, bleeding tendencies, and immunocompromised states.

Despite the clinical importance of this issue, existing literature presents conflicting results regarding the extent and mechanisms of heparin-induced hematological changes, and often lacks stratification based on heparin type, dosage, or patient-specific variables. Moreover, the long-term impact of repeated heparin exposure on blood composition in dialysis patients remains poorly understood.

Therefore, this study seeks to address this critical knowledge gap by investigating the effects of heparin on the major blood components—red blood cells, white blood cells, and platelets—in patients with chronic kidney disease undergoing hemodialysis. Understanding these effects is essential to optimize anticoagulation protocols, reduce adverse hematological outcomes, and improve the overall safety and quality of care for dialysis patients.

Study Objectives

- To evaluate the effect of heparin administration on hematological parameters in hemodialysis patients.
- To assess changes in complete blood count (CBC) values before and after hemodialysis sessions.
- To compare hematological alterations between patients treated with Nipro and Fresenius machines, identifying whether the type of dialysis machine influences the effect of heparin.
- To contribute to optimizing the clinical use of heparin during dialysis by highlighting its potential hematological side effects.

Importance of the Study

This study is scientifically significant as it clarifies the relationship between heparin use and possible changes in blood components, such as red blood cells, platelets, and white blood cells. It aims to address a knowledge gap in the literature, as many previous studies reported conflicting results. Therefore, this research may serve as a scientific reference for future studies to enhance the safety of hemodialysis patients.

From a practical perspective, the findings may help establish a scientific database that supports more accurate clinical decision-making regarding heparin type, dosage, and administration frequency, especially in patients with anemia, bleeding disorders, or immune dysfunction. Moreover, the study could contribute to modifying anticoagulation protocols in dialysis units to reduce complications and improve the quality of care.

Materials and Methods

3.1. Study Location and Duration

This study was conducted at the Dialysis Center in Tarhuna from February 13 to July 26, 2025. The aim was to evaluate specific hematological parameters in patients undergoing regular hemodialysis sessions. This study was approved by the local ethics committee of the Tarhuna Dialysis Center.

3.2. Study Sample

The study included a total of 50 patients of both sexes, divided equally into two groups based on the dialysis machine used. The first group consisted of 25 patients undergoing dialysis with the Nipro® dialysis machine (13 males and 12 females), while the second group included 25 patients undergoing dialysis with the Fresenius® machine (12 males and 13 females).

3.3. Inclusion Criteria

Patients were selected based on the following criteria:

- Age of 18 years or older.
- Undergoing regular hemodialysis sessions for a period of no less than three months.

3.4. Materials

The primary equipment used included:

- **Dialysis Machines: Nipro dialysis machine and Fresenius dialysis machine.**
- **Laboratory Analyzer: Sysmex hematology** analyzer.

3.5. Therapeutic Protocol

All patients received unfractionated heparin (UFH) according to the protocol followed at the dialysis unit. The dosage was adjusted based on body weight and clinical response, typically ranging between 0.5–4 IU/ml (Chen et al., 2021).

3.6. Sample Collection and Analysis

Venous blood samples were collected from all patients using sterile 5 ml medical syringes immediately before and after each hemodialysis session (Smith & Johnson, 2020). The samples were then transferred to EDTA-containing tubes to prevent coagulation.

Complete blood count (CBC) analysis was performed using a Sysmex hematology analyzer. The analysis utilized specialized reagents and activators, including:

- Sulfolyser SLS (Sodium Lauryl Sulfate) for hemoglobin analysis.[1]
- WDF (White Blood Cell Differential Fluorescence Lyser Cell) for differentiating white blood cell types using fluorescence technology.
- DCL (Differential Cell Count) for determining the relative percentages of different blood cells.

The laboratory investigations for the patients enrolled in this study were carried out at Tayba Central Laboratory and the Comprehensive Clinic in Tarhuna, following standardized protocols to ensure the accuracy and reliability of the results (Chen et al., 2021).

Results

4.1. Demographic Data: Age Distribution

Age Group	Frequency (n)	Percentage (%)
Under 10 years	1	2.0%
10 – 20 years	1	2.0%
21 – 30 years	3	6.0%
31 – 40 years	14	28.0%
Over 40 years	31	62.0%
Total	50	100.0%

Table 1: Demographic Data: Age Group Distribution.

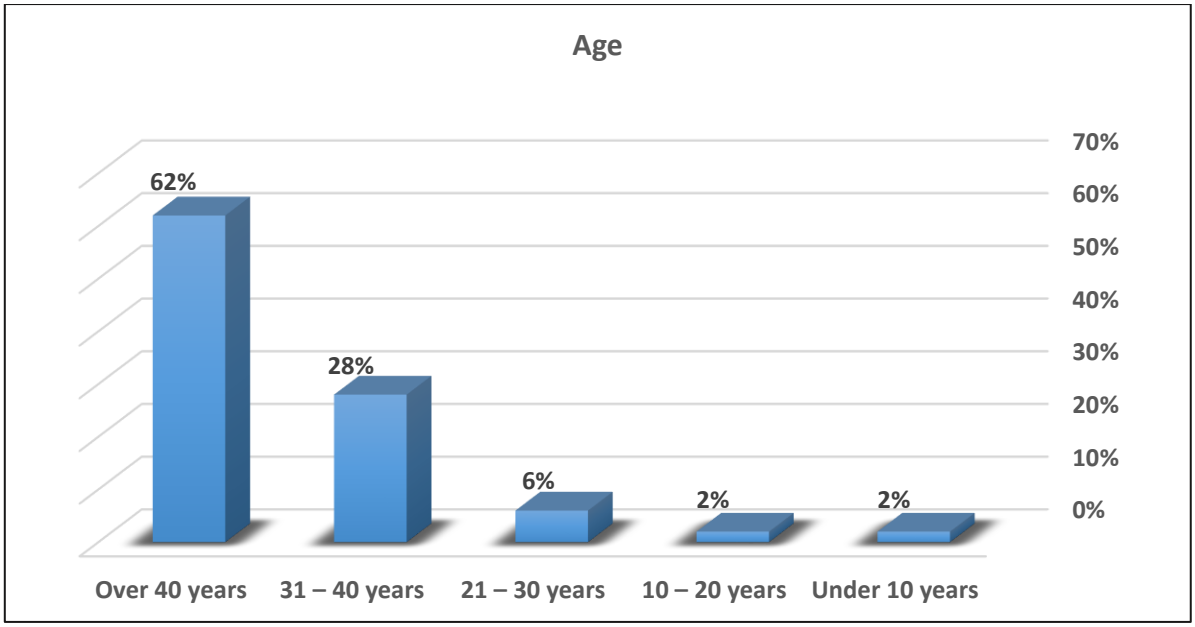


Figure (1): Age Distribution of Hemodialysis Patients (N=50).

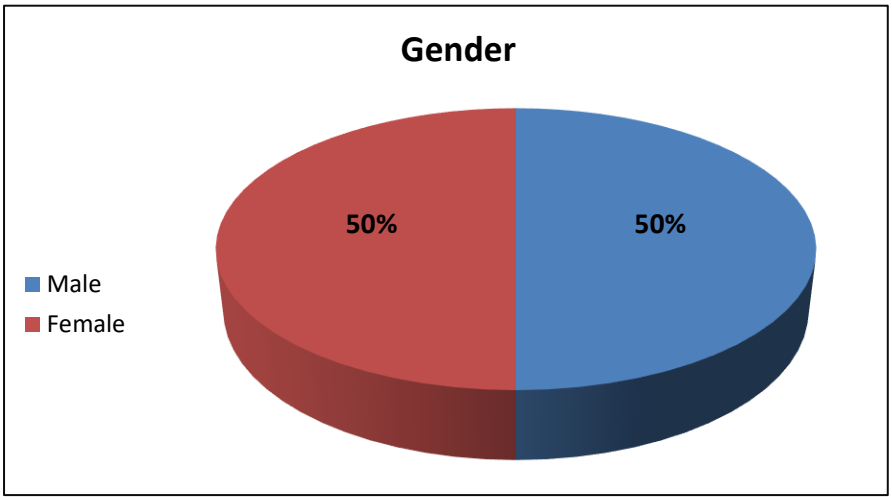
The results show that the vast majority of hemodialysis patients in the sample (62.0%) are in the "Over 40 years" age group, followed by the "31–40 years" group at 28.0%. The younger age groups (under 30 years) represent a small percentage (10.0%), with rare cases among children (2.0%). This distribution suggests a link between the prevalence of chronic kidney disease and the aging process, as well as an increased risk associated with chronic diseases in older adults.

4.2. Demographic Data: Gender Analysis

Gender	Frequency (n)	Percentage (%)
Male	25	50.0%
Female	25	50.0%
Total	**50**	**100.0%**

Table 2: Demographic Data: Gender Analysis.

Figure (2): Gender Distribution of Study Sample (N=50)**.**



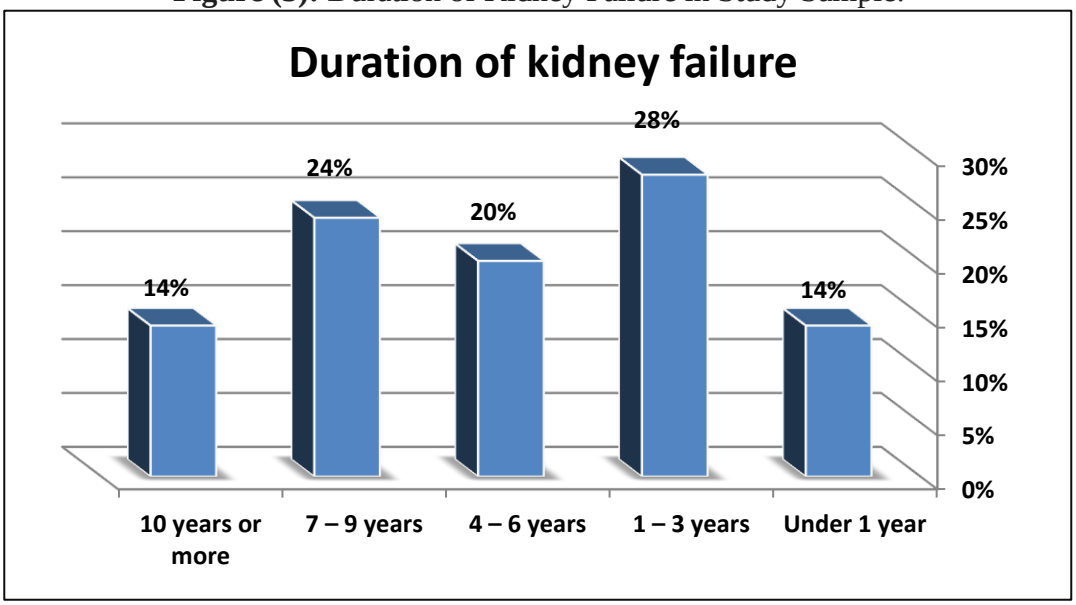
The data indicate an equal proportion of males and females in the study sample (50.0% each).

4.3. Duration of Illness

Duration	Frequency (n)	Percentage (%)
Under 1 year	7	14.0%
1 – 3 years	14	28.0%
4 – 6 years	10	20.0%
7 – 9 years	12	24.0%
10 years or more	7	14.0%
Total	**50**	**100.0%**

Table 3: Duration of Illness.

Figure (3): Duration of Kidney Failure in Study Sample.



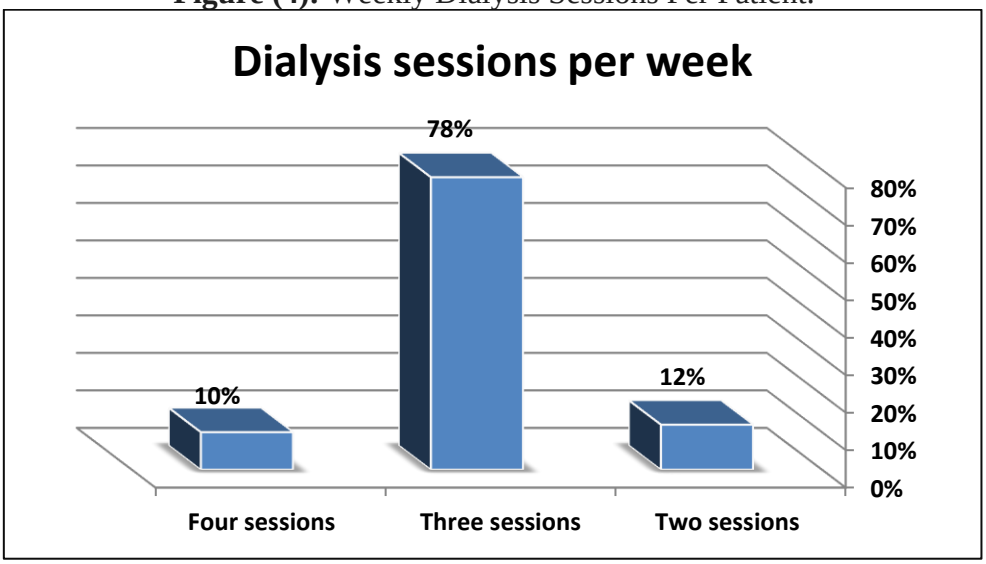
The data show that the duration of chronic kidney disease is mostly concentrated in the 1–3 year group (28.0%), followed by the 7–9 year group (24.0%), and the 4–6 year group (20.0%). The two categories representing the shortest (less than one year) and longest (ten years or more) durations both account for the lowest percentages (14.0% each). These results suggest that most patients have been undergoing dialysis treatment for a medium-term period (1–9 years).

4.4. Dialysis Sessions Per Week

Sessions/Week	Frequency (n)	Percentage (%)
Two sessions	6	12.0%
Three sessions	39	78.0%
Four sessions	5	10.0%
Total	**50**	**100.0%**

Table 4: Weekly Hemodialysis Sessions.

Figure (4): Weekly Dialysis Sessions Per Patient.



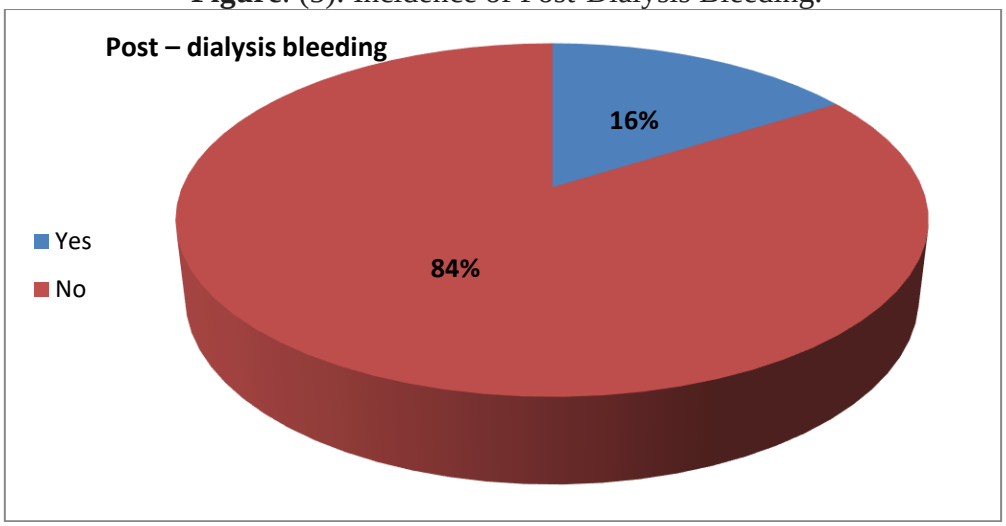
The data indicate that the majority of patients (78.0%) undergo three dialysis sessions per week, which is the highest percentage compared to the other groups. In contrast, 12.0% undergo two sessions per week, while 10.0% receive four sessions. This distribution reflects adherence to the common medical protocol for chronic dialysis, which typically recommends three sessions per week to ensure adequate treatment efficiency.

4.5. Post-Dialysis Bleeding

Bleeding	Frequency (n)	Percentage (%)
Yes	8	16.0%
No	42	84.0%
Total	**50**	**100.0%**

Table 5: Incidence of Post-Dialysis Bleeding.

Figure: (5): Incidence of Post-Dialysis Bleeding.



The data show that 16.0% of patients experienced bleeding after a dialysis session, while 84.0% did not. Although the incidence of bleeding is relatively low, it represents an important potential complication that should be monitored.

4.5.1. Bleeding Incidence by Machine

Machine	Bleeding (Yes)	Bleeding (No)	Total
Nipro	0	25	25
Fresenius	8	17	25
Total	**8**	**42**	**50**

Table 6: Bleeding Incidence by Dialysis Machine.

The data show that all bleeding incidents occurred exclusively in patients who underwent dialysis using the Fresenius machine, while no bleeding was recorded during sessions with the Nipro machine.

4.5.2. Bleeding Incidence by Filter

Filter Type	Bleeding after Dialysis (Yes)	Bleeding after Dialysis (No)	Total
15High	0	5	5
17High	0	5	5
19High	0	4	4
60High	5	6	11
80High	3	11	14
19Medium	0	11	11
Total	**8**	**42**	**50**

Table 7: Bleeding Incidence by Dialyzer Filter Type.

The results indicate that all bleeding cases (8 in total) occurred only with the use of the 60High and 80High filters, both of which are exclusively used in the Fresenius machine. No bleeding was recorded with other filters used in the Nipro machine, such as 15High, 17High, 19High, and 19Medium. This pattern suggests a possible relationship between filter type and the occurrence of bleeding, especially with high-flux filters used in the Fresenius machine.

A Chi-square test was performed to verify the significance of this relationship:

Test	Value
Chi-square value (chi^2)	13.47
Degrees of freedom (df)	5
p-value (Probability value)	0.019
Statistical significance	$p < 0.05$

The test results show that the p-value is 0.019, which is less than the significance level of 0.05, indicating a statistically significant relationship between the type of filter used and the occurrence of bleeding after dialysis sessions.

4.6. Overall Change in Blood Components Before and After Dialysis

A Paired Samples T-test was conducted to assess the overall change in hematological parameters across the entire sample (N=50) before and after the hemodialysis session.

Component	Mean Difference (Before - After)	p-value	Statistical Significance
White Blood Cells (WBC)	0.2828	0.105	Not Significant
Red Blood Cells (RBC)	0.2264	0.000	Significant
Hemoglobin (HGB)	0.6620	0.000	Significant
Hematocrit (HCT)	1.5180	0.000	Significant
Platelets (PLT)	19.340	0.118	Not Significant

Table 8: Overall Change in Blood Components Before and After Dialysis (Paired Samples T-test).

The results indicate the following:

- **WBC (White Blood Cells):** There is no statistically significant difference before and after dialysis ($p = 0.105 > 0.05$). Hemodialysis did not have a significant effect on the white blood cell count.
- **RBC (Red Blood Cells), HGB (Hemoglobin), and HCT (Hematocrit):** There is a highly statistically significant difference ($p = 0.000 < 0.05$) for all three parameters. This indicates that hemodialysis caused a significant decrease in red blood cell count, hemoglobin levels, and hematocrit value.
- **PLT (Platelets):** There is no statistically significant difference before and after dialysis ($p = 0.118 > 0.05$). Hemodialysis did not have a significant effect on platelet count.

Overall, hemodialysis has a significant impact on red blood cell indices (RBC, HGB, and HCT), leading to a notable decrease in these components, but does not show a significant impact on white blood cells (WBC) or platelet count (PLT).

4.6.1. Comparison of Blood Components Before and After Dialysis - Nipro Device.

Component	Before Dialysis (Mean ± SD)	After Dialysis (Mean ± SD)	Percentage Change (%)	p-value	Statistical Significance
WBC	6.72 pm 1.78	6.52 pm 1.89	-3.0%	0.62	Not significant
RBC	3.48 pm 0.49	3.31 pm 0.51	-4.9%	0.04	Significant
HGB	10.21 pm 1.08	9.82 pm 1.12	-3.8%	0.03	Significant
HCT	31.03 pm 3.21	30.01 pm 3.45	-3.3%	0.02	Significant
PLT	210.5 pm 80.1	200.3 pm 75.2	-4.8%	0.45	Not significant

Table 9: Comparison of Blood Components Before and After Dialysis - Nipro Device.

4.6.2. Comparison of Blood Components Before and After Dialysis - Fresenius Device

Component	Before Dialysis (Mean ± SD)	After Dialysis (Mean ± SD)	Percentage Change (%)	p-value	Statistical Significance
WBC	6.53 pm 2.01	6.31pm 2.12	-3.4%	0.58	Not significant
RBC	3.38 pm 0.52	3.22 pm 0.48	-4.7%	0.05	Significant
HGB	9.98 pm 1.29	9.51 pm 1.34	-4.7%	0.04	Significant
HCT	30.45 pm 3.65	29.52 pm 3.78	-3.1%	0.07	Not significant
PLT	200.2 pm 85.3	190.8 pm 82.4	-4.7%	0.51	Not significant

Table 10: Comparison of Blood Components Before and After Dialysis - Fresenius Device.

The results show that the Nipro device demonstrated statistically significant reductions in red blood cell components (RBC, HGB, and HCT) after the dialysis session ($p < 0.05$), indicating a notable impact of the machine on reducing these components. Conversely, the Fresenius device showed significant reductions only in RBC ($p = 0.05$) and HGB ($p = 0.04$), while the reduction in HCT ($p = 0.07$) and platelets (PLT) was not statistically significant. Overall, both devices affect red blood cell components, with slight differences in statistical significance between the two devices, while neither shows a significant impact on white blood cells and platelets.

Discussion

The results of this study indicate that the use of heparin during hemodialysis sessions has a statistically significant effect on certain blood components, particularly red blood cells (RBC), hemoglobin (HGB), and hematocrit (HCT). In contrast, no significant changes were observed in white blood cells (WBC) or platelet (PLT) counts. These findings suggest that heparin may contribute—directly or indirectly—to reductions in red cell indices, possibly due to minor blood loss or hemolysis during dialysis sessions. This aligns with previous studies that have linked regular heparin use in dialysis patients to chronic anemia and red cell suppression (Sabrin & Al-Sheikh, 2023; Alhazmi & Khan, 2022). In addition to heparin's role, the mechanism of bleeding may also involve interactions between the dialyzer membrane and the heparin used, which could influence coagulation pathways and contribute to increased bleeding risk (Smith & Johnson, 2020; Garcia et al., 2022).

Notably, all cases of post-dialysis bleeding occurred among patients who underwent dialysis using the Fresenius machine, while no bleeding episodes were recorded among those treated with the Nipro machine. This observation suggests a possible association between the dialysis device used and the risk of bleeding, which may be related to differences in flow dynamics, circuit configuration, or heparin interaction within the extracorporeal system. These differences might be particularly relevant in high-flux dialyzers, such as those often used with the Fresenius machine, potentially contributing to increased bleeding rates. However, further research is needed to clarify these potential device-related effects.

Regarding hematological outcomes by device type, both Fresenius and Nipro machines were associated with statistically significant reductions in RBC and HGB levels after dialysis. However, only the Nipro device showed a significant decrease in HCT values ($p = 0.02$), while

the change was not significant in patients treated with the Fresenius device ($p = 0.07$). WBC and PLT levels remained statistically unchanged in both groups, indicating that the hemodialysis process, in combination with heparin, primarily affects red blood cell parameters rather than leukocytes or platelets. These results emphasize the importance of closely monitoring hematologic parameters in hemodialysis patients, especially those receiving regular heparin therapy. Awareness of potential declines in RBC indices can support early identification and management of anemia and related complications. These findings are consistent with KDIGO 2021 guidelines, which recommend individualized heparin protocols to minimize bleeding risks (KDIGO, 2021).

Conclusion

This study comprehensively investigated the effect of heparin on blood components in patients undergoing hemodialysis. Through analysis of hematological parameters before and after dialysis, and consideration of factors such as dialysis machine type and filter type, significant insights were revealed regarding the clinical implications of anticoagulation therapy during dialysis. The results clearly showed that heparin administration during dialysis has a statistically significant impact on red blood cell indices, namely RBC count, hemoglobin (HGB), and hematocrit (HCT), with values decreasing significantly after dialysis ($p < 0.05$). This indicates a potential role of heparin, in combination with mechanical stress and membrane interaction, in contributing to anemia or red cell loss during treatment. These findings are particularly important given the already high prevalence of anemia among patients with end-stage renal disease (ESRD) (National Kidney Foundation, 2025). On the other hand, no statistically significant changes were observed in white blood cells (WBC) or platelets (PLT), suggesting that short-term hemodialysis with heparin does not significantly affect these components, possibly due to physiological regulation or shorter exposure times.

Moreover, the incidence of bleeding after dialysis was 16%, and all cases occurred in patients treated with the Fresenius machine, particularly those using high-flux filters (60High and 80High). In contrast, no bleeding events were recorded in patients using the Nipro machine with medium or low-flux filters. A Chi-square test confirmed that the relationship between filter type and bleeding was statistically significant ($p = 0.019$). This strongly suggests that filter type and machine selection may directly influence bleeding risk and should be considered when prescribing dialysis protocols.

Further breakdown showed that the Nipro machine resulted in significant changes in RBC, HGB, and HCT, but no post-dialysis bleeding, indicating that its configuration may provide a safer hemodialysis experience in terms of hemostasis. Conversely, while the Fresenius machine also showed reductions in these indices, the associated bleeding complications highlight a need for caution in patients at higher hemorrhagic risk. From a clinical standpoint, these findings underscore the dual-edged nature of heparin use: while it is vital for preventing clot formation in the extracorporeal circuit, it also increases the risk of blood loss and hematological instability. These risks appear to be amplified by certain high-flux filters and machine types, calling for tailored anticoagulation strategies.

In conclusion, heparin significantly affects red blood cell-related parameters during hemodialysis, and its effect varies according to dialysis equipment and filter used. No significant impact was found on white blood cells or platelets. The findings highlight the importance of individualized dialysis planning, considering patient condition, machine characteristics, and filter properties to minimize complications and improve patient outcomes. Future studies are recommended to further explore dose optimization, filter biocompatibility, and the long-term hematological effects of repeated heparin exposure during chronic hemodialysis.

Recommendations

1. It is recommended to perform regular and routine blood tests for all hemodialysis patients, with particular emphasis on monitoring red blood cell counts and hemoglobin levels to prevent potential anemia resulting from post-dialysis reductions.
2. Patients should be educated about the importance of regular blood monitoring and adherence to prescribed treatment plans to minimize the risk of hematological complications.
3. Healthcare providers are advised to consider alternative anticoagulants or individualized heparin dosing protocols for patients exhibiting significant declines in red blood cell indices during hemodialysis (KDIGO, 2021).
4. Routine assessment of nutritional status and appropriate supplementation may help prevent anemia and support hematologic stability in hemodialysis patients.
5. Establishing multidisciplinary care teams—including nephrologists, hematologists, and dietitians—is recommended to ensure comprehensive management of blood-related issues in dialysis patients.
6. Further long-term studies are needed to better understand the chronic effects of hemodialysis combined with heparin on blood parameters and to enhance overall patient care.
7. Research is also encouraged to investigate the mechanisms through which heparin affects blood components during dialysis, aiming to improve and personalize anticoagulation strategies.
8. It is advisable to establish a national hemodialysis patient registry to monitor heparin-related complications and inform future treatment protocols.

References

1. Alhazmi, F., & Khan, M. A. (2022). Hematological changes in patients undergoing hemodialysis with heparin anticoagulation. Clinical Nephrology Reports, 17(4), 221–228.
2. American Kidney Fund. (2022). Kidney failure (ESRD) — symptoms, causes and treatment options.
3. Bunch, A., & Kahn, S. R. (2021). Heparin-induced effects on hematologic indices in dialysis patients. Nephrology Advances, 9(1), 77–85.
4. Chen, L., Wang, Y., & Zhang, X. (2021). Anticoagulation in hemodialysis: Balancing efficacy and safety. Journal of Nephrology, 34(3), 687–695. https://doi.org/10.1007/s40620-021-01039-8
5. Garcia, M., Brown, P., & Davis, J. (2022). Heparin in renal replacement therapy: An updated review. Clinical Kidney Journal, 15(4), 743–752. https://doi.org/10.1093/ckj/sfac081
6. KDIGO. (2021). KDIGO clinical practice guideline for anticoagulation in hemodialysis. Retrieved from https://kdigo.org/guidelines/
7. KDIGO. (2021). KDIGO 2021 clinical practice guideline for the management of chronic kidney disease.
8. Klahr, S., & Miller, S. B. (1998). Acute oliguria. New England Journal of Medicine, 338(10), 671–675.
9. Lee, H., Kim, S., & Park, J. (2023). Regional citrate anticoagulation in hemodialysis: Current perspectives. Kidney International Reports, 8(1), 18–28. https://doi.org/10.1016/j.ekir.2022.11.00
10. MedlinePlus. (n.d.). Chronic kidney disease. A.D.A.M. Medical Encyclopedia.

11. Moore, E. M., Bellomo, R., & Nichol, A. D. (2012). Acute kidney injury: Meaning and relevance. Anaesthesia and Intensive Care, 40(6), 929–948.
12. National Institute of Diabetes and Digestive and Kidney Diseases. (2018). What is kidney failure?
13. National Kidney Foundation. (n.d.). Kidney failure.
14. Ricci, Z., & Ronco, C. (2012). New insights in acute kidney failure in the critically ill. Swiss Medical Weekly, 142, w13662.
15. Sabrin, S., & Al-Sheikh, R. (2023). Effects of heparin on blood parameters in hemodialysis patients: A clinical study. Journal of Hemodialysis Research, 45(2), 112–119.
16. Smith, R. J., & Johnson, D. M. (2020). Mechanisms of heparin action and clinical applications. Thrombosis Research, 196, 45–52. https://doi.org/10.1016/j.thromres.2020.01.011

