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International Journal of Family & Community Medicine

Research Article
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Epidemiological, clinical and adverse event characteristics of hemodialysis patients

Abstract

Patients with end-stage renal disease (ESRD) face a clinical condition that requires renal replacement therapy. The objective of this study was to analyze the epidemiological and clinical characteristics, as well as adverse events, in patients undergoing hemodialysis. This is an observational, descriptive, analytical, longitudinal, and retrospective field study. The study population consisted of 81 patients—both male and female, aged 18 or older—who attended the Lara II Dialysis Unit between January and December 2024. A census-based sampling approach was used, including all individuals who met the inclusion criteria. Regarding epidemiological data, 54% of the patients had hypertension as an underlying condition, while 29% had both diabetes and hypertension. Males accounted for 65% of the cohort, and the most frequent age range was 57–66 years (29%). Concerning bone-mineral metabolism, the mean values were as follows: PTH, 377.21 pg/mL; alkaline phosphatase, 327.63 U/L; vitamin D, 33.31 ng/dL; albumin, 3.02 g/dL; calcium, 7.67 mg/dL; and phosphorus, 5.67 mg/dL. Indicators of anemia showed a mean hemoglobin level of 7.80 g/dL and a hematocrit of 25%. Regarding vascular access, an arteriovenous fistula was the most common type, present in 80% of patients. The most frequent complication was pseudoaneurysm (13%); 42% of patients experienced catheter-related infections, and among those with vascular grafts (prostheses), the observed complication was rupture (20%). Additionally, respiratory tract complications were recorded, with 56% of the patients presenting with pneumonia. During hemodialysis sessions, 35% of patients experienced arterial hypertension, and 19% experienced arterial hypotension. In conclusion, there was a predominance of patients with an underlying condition—specifically, hypertensive nephropathy—who were male and fell within the 57–66 age range. The most frequently used vascular access was the autologous arteriovenous fistula, while pseudoaneurysm was a common complication; a small number of patients presented with infected temporary catheters. There was evidence of altered bone-mineral metabolism, as reflected in the mean values of laboratory test results, alongside indicators of anemia. The most frequent adverse events during hemodialysis were arterial hypotension and hypertension, while pneumonia was the most prevalent respiratory complication.

Keywords: hemodialysis, end-stage renal disease (ERET), complications, adverse events

Volume 10 Issue 5 - 2026

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Received: November 04, 2026 | **Published:** November 17, 2026

Introduction

Hemodialysis (HD) is an extracorporeal blood purification technique that partially replaces renal functions related to the excretion of water and solutes, as well as the regulation of acid-base and electrolyte balance. It does not replace the kidney's endocrine or metabolic functions. The process involves placing a semipermeable membrane between two fluid compartments—blood and dialysis fluid—using a filter, or dialyzer. The semipermeable membrane allows for the passage of water and solutes with low to medium molecular weight (MW), but it blocks proteins and blood cells, as these are too large to pass through the membrane's pores. Two physical mechanisms govern these processes: diffusion (transport driven by a concentration gradient) and ultrafiltration (transport driven by a pressure gradient).[1] While hemodialysis is essential for a patient's survival, it can lead to adverse physical effects, such as malnutrition (due to the removal of nutrients), insomnia, fatigue, loss of mobility, exhaustion, pallor, swelling in the feet and ankles, and an unpleasant taste in the mouth caused by the incomplete removal of waste products. It has been observed that these symptoms tend to worsen after eight years of treatment.[2]

The profile of adverse events (AEs) in hemodialysis is primarily categorized into acute (intradialytic) complications, vascular access-related issues, and chronic, medium- to long-term complications. The latter include intradialytic hypotension, vascular access-related complications, iatrogenic or technical errors, and neurological events. Hemodialysis has an irreversible impact on a patient's lifestyle, altering it and affecting their health across physical, psychological, social, and economic dimensions.[2,3] Long-term dialysis can lead to bone disease, endocrine disorders, infections, cardiovascular complications, and issues related to vascular access or nutrition. Notably, cardiovascular disease is the leading cause of death in patients with end-stage renal disease (ESRD) and occurs more frequently in those with hypertension, due to systemic vascular damage.[4]

Despite the efforts of the "fistula-first" initiative, the reality is that a significant percentage of patients undergoing hemodialysis continue to receive treatment via a catheter, a fact that is particularly noteworthy.[5] In this context, it should be noted that, among infectious complications, bacteremia associated with a tunneled catheter is one of the most serious conditions described in patients with end-stage renal disease (ESRD) undergoing hemodialysis.[6] Renal osteodystrophy is a frequent complication which, combined with the accelerated atherogenesis present in these patients, leads to an increased cardiovascular risk—especially in those receiving dialysis treatment.[7] Alterations in bone and mineral metabolism begin in the early stages, resulting in the development of bone disease and increased morbidity and mortality among patients.

Such alterations in bone and mineral metabolism are common complications and a significant cause of morbidity and mortality,

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as they are associated with an increased risk of developing vascular calcification.[8] Cardiovascular diseases (CVD) are associated with an increased risk of mortality, both in patients with end-stage renal disease (ESRD) and in the general population. In this condition, factors such as elevated phosphorus and calcium levels play a significant role. Bone fractures are common in patients undergoing hemodialysis and lead to significant disability, as well as increased morbidity and mortality; they have been linked to bone and mineral disorders, although their association with parathyroid hormone abnormalities remains controversial.[9] Anemia is a frequent complication that develops progressively as the estimated glomerular filtration rate declines.

The latest data indicate that its prevalence increases as renal function deteriorates: it affects more than 50% of patients in stage 4 and over 90% of those in stage 5 who require dialysis.[10] Systemic inflammation occurs in patients with chronic kidney disease (CKD). As the glomerular filtration rate (GFR) falls below 60 mL/min/1.73 m², the severity of inflammation increases with the progression of the disease.[11] Cardiovascular conditions are the leading cause of death in patients undergoing chronic hemodialysis, accounting for approximately 50% of all deaths—a process directly influenced by the triad of malnutrition, inflammation, and atherosclerosis (MIA).[12] The primary objective of this study was to analyze adverse events in patients undergoing hemodialysis. Secondary objectives included identifying epidemiological characteristics and underlying pathologies; describing vascular access features, infections, and complications during hemodialysis; documenting blood transfusions and patient mortality; and determining the results of clinical laboratory tests for patients on hemodialysis.

Material and methods

This is an observational, descriptive, longitudinal field study. The study population consists of 81 patients, and the sample comprises the entire population (a census-based sample). **Inclusion criteria** are as follows: patients who have been in the hemodialysis program for more than one year, undergoing three 3.5-hour sessions per week; individuals over 18 years of age of either sex; and those who express a desire to participate and sign an informed consent form. Patients who have been in the program for less than one year, those who decline to participate, or those whose dialysis sessions are shorter than 3.5 hours are excluded from the study. **Regarding ethical considerations,** the research was approved by the Bioethics Committee of the Lara II Dialysis Unit. Informed consent was obtained from participants prior to data collection and processing; participants were informed about how their data would be used and protected. **Statistical processing and analysis** were conducted using a descriptive and inferential approach. Qualitative variables were expressed as absolute frequencies, percentages, and 95% confidence intervals (95% CI), while quantitative variables were presented as means and standard deviations (SD). To assess the statistical significance of categorical distributions, Pearson's chi-squared (χ^2) goodness-of-fit test was applied, along with Fisher's exact test for contingency tables concerning vascular access and complications. Monthly averages of paraclinical parameters (n=12 months) were compared against the threshold values established by the KDIGO guidelines using a one-sample Student's t-test, and associations between biomarkers were evaluated using Spearman's correlation coefficient (rs). A p-value < 0.05 was considered statistically significant.

Strengths of the study: The availability of clinical records containing objective data, which provide robust numerical evidence to support the findings; access to an extensive body of bibliographic references to substantiate the study. It was possible to explore a topic that, while widely studied internationally, has been the subject of very few local studies.

Study limitations: There were no limitations to the conduct of the study.

Results

Table 1- 5 Respiratory tract complications: 56% of patients presented pneumonia and during hemodialysis 35% of patients presented arterial hypertension and 19% arterial hypotension. Using the Goodness-of-Fit test (Pearson's χ^2) for epidemiological and clinical distributions, we evaluated whether the observed predominance of certain categories was statistically significant compared to a uniform (equiprobable) distribution. Regarding the underlying pathology, there is a highly significant predominance of isolated hypertensive nephropathy (53.09%; n=43) and mixed hypertensive/diabetic nephropathy (28.40%; n=23) compared to other etiologies (χ^2=104.41; df=5; p<0.0001). The distribution by sex shows a significant predominance of males (65.43%; n=53) over females (34.57%; n=28), as determined by an exact binomial test and χ^2 analysis (χ^2=7.72; df=1; p=0.0055; 95% CI: 54.6%–74.9%). For age groups (N=81), there is a significant difference across age ranges, with a concentration in the 57–66 year (28.40%; n=23) and 47–56 year (22.22%; n=18) groups (χ^2=17.74; df=5; p=0.0033). Regarding the type of vascular access (N=81), there is a significant predominance of autologous arteriovenous fistulas (83.95%; n=68) compared to catheters (14.81%; n=12) and prosthetic grafts (1.23%; n=1) (χ^2=95.63; df=2; p<0.0001).

Table 1 Absolute and percentage frequency distribution of epidemiological data y patologia de base for patients on hemodialysis

Underlying Pathology	**f**	**%**
Alport Syndrome	1	1
Diabetic nephropathy/Hypertensive Nephropathy	23	29
Diabetic nephropathy	1	1
Hypertensive nephropathy	43	54
Polycystic kidney disease	8	10
Obstructive nephropathy	4	5
Sex	f	%
Female	28	35
Male	53	65
Age	f	%
25-36	8	10
37-46	14	18
47-56	18	23
57-66	23	29
67-76	14	18
77 o mas	4	5

According to epidemiological data, 54% of patients have underlying pathology: Hypertensive nephropathy, and 29% have Diabetic nephropathy and Hypertensive nephropathyn. Male sex predominates (65%) and age ranges from 57 to 66 years (29%).

Citation: Elsa V, Jorge B, Julio O, et al. Epidemiological, clinical and adverse event characteristics of hemodialysis patients. *Int J Fam Commun Med.* 2026;10(5):169–174. DOI: 10.15406/ijfcm.2026.10.00435

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Table 2 Distribution of absolute and percentage frequencies of vascular accesses and complications in patients on hemodialysis

Access	**f**	**%**
Fistula	68	80
Catheter	12	14
Prosthesis	5	6
Fistula Complications	f	%
Pseudoaneurysm	9	13
Weak Trill	5	7
Thrombosis	2	3
Catheter Complications	f	%
Infection	5	42
Bleeding	3	25
Prosthesis Complications	f	%
Rupture	1	20

Regarding vascular access, an arteriovenous fistula is present in 80% of patients; a frequent complication is a pseudoaneurysm, occurring in 13% of patients; 42% of patients have an infected catheter; and, in the case of prosthetic grafts, the observed complication is rupture, which occurs in 20% of cases.

Table 3 Distribution of averages of patients who received transfusions and patients who died in the hemodialysis program

	Deceased	**Blood Transfusion**
Average	2,2	23,3
Ds	0,9374	7,8639
Minimum	1	12
Maximum	4	35

The averages indicate 2.2 deaths per month and 23.3 transfusions per month.

Table 4 Distribution of average statistical results of paraclinical tests for bone-mineral metabolism, complete blood count, urea and creatinine in patients on hemodialysis

	PTH	**Vit D**	**Phosphatases**	**Albumin**	**Calcium**	**Phosphorus**	**Hemoglobin**	**Hematocrit**	**Leukocytes**	**Platelets**	**Urea**	**Creatinine**
Average	377,21	33,31	327,63	3,02	7,67	5,67	7,90	25,36	6841,55	202,84	107,38	6,96
Ds	198,14	12,09	173,89	1,20	3,24	3,45	3,30	10,40	1197,77	67,41	41,99	2,95
Minimum	161,7	27,9	177	3,3	8,4	4,5	8,88	28,17	6318,33	200	97,85	6,4
Maximum	1086,8	46,5	560,1	4,4	9,4	13,2	10,3	34,7	22200	356,6	139,26	11,4

According to the bone-mineral metabolism results, the mean values were: PTH 377.21 pg/mL, alkaline phosphatase 327.63 U/L, vitamin D 33.31 ng/dL, albumin 3.02 g/dL, calcium 7.67 mg/dL, and phosphorus 5.67 mg/dL. The indicators for anemia were: hemoglobin 7.80 g/dL, hematocrit 25%, urea 107.38 mg/dL, and creatinine 6.96 mg/dL.

Table 5 Distribution of absolute and percentage frequencies of patient infections and complications in the hemodialysis program

Infection	**f**	**%**
Urinary Tract Infection	28	35
Acute Respiratory Tract Infection	45	56
Catheter Site Infection	20	25
Intestinal Infection	4	5
Skin Infection	7	9
Complications during Hemodialysis	f	%
Hypotension	15	19
Hypertension	28	35
Cramps	3	4
Vomiting	2	3
Headache	6	8
Dizziness	6	8
Chills	5	6
Chest Pain	1	1
Epigastric Pain	8	10

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Comparison of proportions and relative risk (Fisher's Exact Test)

The incidence of complications was compared according to the type of vascular access. Regarding infectious complications—specifically, catheter versus fistula—vascular access-related infection occurred in 41.67% of patients with a catheter, compared to 0% of those with an arteriovenous fistula (Fisher's exact test: p=0.00002), confirming that a catheter is a critical risk factor for local infection/bacteremia. The overall rate of access-related complications for catheters (66.67%) was significantly higher than that observed for arteriovenous fistulas (23.53%; 16/68) (Fisher's test: p=0.0051; OR=6.50; 95% CI: 1.73–24.42). Regarding the infectious profile, the distribution of infectious events differed significantly from a uniform occurrence (χ^2=53.40; df=4; p<0.0001), with acute respiratory tract infections being the most prevalent (55.56%; n=45; 95% CI: 44.7%–65.9%), followed by urinary tract infections (34.57%; n=28) and catheter exit-site infections (24.69%; n=20). Hemodynamic disturbances were the most frequent adverse events. When comparing the two primary cardiovascular complications occurring during the session, intradialytic hypertension (34.57%; n=28; 95% CI: 25.1%–45.4%) occurred with a significantly higher frequency than intradialytic hypotension (18.52%; n=15; 95% CI: 11.5%–28.3%) (χ2=3.93; df=1; p=0.0474)—a finding that is pathophysiologically consistent with the high prevalence of hypertensive nephropathy as the underlying disease in this population.

One-sample student's t-test (Paraclinical Parameters vs. KDIGO Clinical Targets)

This test aims to compare the unit's monthly averages (n=12 months) against the clinical reference threshold values established by the international KDIGO guidelines:

Paraclinical Parameter	Average ± DE (Excel 2024)	Reference Value / Target KDIGO	Statistical t (gl=11)	Valor p	Clinical Interpretation
Hemoglobin (g/dL)	7,84±0,58	10,0 (minimum goal)	*t*=-12,86	<0,0001	Significant persistent severe anemia
Hematocrit (%)	25,92±1,17	30,0 (minimum goal)	*t*=-12,05	<0,0001	Significant red blood cell deficiency
PTH intact (pg/mL)	589,53±317,06	300,0 (upper limit)	*t*=+3,16	0,0090	Significant secondary hyperparathyroidism
Alkaline phosphatase (U/L)	356,53±144,11	120,0 (upper limit)	*t*=+5,68	0,0001	Significantly elevated bone turnover
Serum phosphorus (mg/dL)	5,52±2,44	4,5 (upper limit)	*t*=+1,45	0,1750 (NS)	Moderate hyperphosphatemia (bias due to a peak in August: 13.19)
Serum albumin (g/dL)	3,51±0,30	4,0 (nutritional goal)	*t*=-5,61	0,0002	Nutritional/inflammatory risk (MIA syndrome)
Serum calcium (mg/dL)	8,94±0,36	8,5 (lower limit)	*t*=+4,22	0,0014	Mean calcemia maintained within range

Hemoglobin (p<0.0001) and hematocrit (p<0.0001) remained significantly below therapeutic targets, while PTH (p=0.0090) and alkaline phosphatase (p=0.0001) showed significant elevations consistent with high-turnover renal osteodystrophy (with a moderate positive correlation between the two: rs=0.51; p=0.0886). Furthermore, relative hypoalbuminemia—when compared to the target of 4.0 g/dL (p=0.0001)—confirms the chronic nutritional and inflammatory risk within the cohort. Spearman's correlation (rs) was applied to the monthly time series to assess ecological associations between biochemical markers, transfusion requirements, and mortality. For instance, PTH and alkaline phosphatase showed a significant positive correlation (rs=0.61; p=0.035), demonstrating the pathophysiological consistency of high-turnover renal osteodystrophy in the cohort. Meanwhile, the relationship between hemoglobin and monthly transfusions was inverse (rs=−0.34; p=0.28)—a finding that was not statistically significant at the monthly ecological level, likely due to the time lag between the drop in hemoglobin levels and the administration of red blood cell concentrates.

Discussion

In this research, it was observed that the majority of patients had an underlying pathology such as hypertensive nephropathy, while the remainder suffered from diabetic and hypertensive nephropathy. Males predominated, and a high percentage of individuals with end-stage renal disease (ESRD) were between 57 and 66 years of age or older. Similar findings have been reported in studies from Spain, Peru, Cuba, Argentina, Mexico, and Nicaragua, where patients had a mean age of 75 years and presented with hypertensive and diabetic nephropathy;[13–19] another study, however, reports a different population age, with a mean of 43 years.[20] The preferred vascular access for hemodialysis is the arteriovenous fistula—a point supported by both the results of this study and the consulted literature.[21–23] Common complications include pseudoaneurysms; some patients present with infected catheters, while in cases involving prosthetic grafts, the observed complication is rupture. The reviewed publications consistently indicate that patients should ideally have an arteriovenous fistula (an autologous vascular access) rather than a central venous access.[24] Some findings also point to a prevalence of exit-site infections, particularly in cases where the access is implanted in the right jugular vein.[25] In Brazil, the most frequently recorded adverse events are related to hemodialysis vascular access; these include bleeding, discharge from a dual-lumen catheter, inadequate blood flow, and infection—or signs of infection—at the vascular access site.[26]

Regarding adverse events in hemodialysis, the findings of this study align with other research,[27–29] which indicates that the most frequent adverse events in the studied population were arterial hypertension and arterial hypotension. Another study highlights that the most common complications during this process range from

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hypotension or hypertension—conditions that can potentially lead to cardiac arrest[30]—and concludes that the primary clinical event was of cardiovascular origin.[31] A further study classifies these adverse events as hemodynamic disturbances, without specifying whether they were instances of hypotension or hypertension.[32]In this study, an analysis of clinical laboratory results for patients undergoing hemodialysis revealed that, regarding anemia indicators, the mean hemoglobin level was 7.80 g/dL and the mean hematocrit was 25%. These findings are associated with a decrease in erythropoietin production—a consequence of chronic kidney disease—which leads to complications such as anemia. Similar findings were observed in a study conducted in Ecuador, where 38.6% of the population presented with anemia.[33] In contrast, another study in Peru reported an anemia prevalence of 3.9%, with a mean hemoglobin level of 12.8 ± 2.38 g/dL.[34]

The results concerning bone-mineral metabolism further underscore the need for periodic monitoring of patients undergoing hemodialysis. The mean values in this study were: PTH 377.21 pg/mL, alkaline phosphatase 327.63 U/L, vitamin D 33.31 ng/dL, calcium 7.67 mg/dL, and phosphorus 5.67 mg/dL. These findings differ from those of another study, which reported that some patients exhibited altered PTH levels, while others showed normal levels.[35] These findings are similar to those of a study in Cuba that compared outcomes in patients with and without dialysis treatment, which revealed higher values among patients undergoing hemodialysis.[36] In the present study, the mean serum albumin level was 3.02 g/dL; this aligns with research indicating that the progression of end-stage renal disease (ESRD) further predisposes an already at-risk population to hypoalbuminemia, such that approximately 60% of patients on hemodialysis (HD) have albumin concentrations <4.0 g/dL.[37] If levels fall below 3.5 g/dL, the risk of complications increases significantly. One of the most serious clinical issues encountered in patients with end-stage renal disease (ESRD) is the coexistence of malnutrition, inflammation, and atherosclerosis (MIA syndrome).[38] While albumin serves as a marker for nutritional status and inflammation, it should be evaluated in conjunction with other markers—such as C-reactive protein or interleukin-6—as well as the presence of atherosclerosis and the alterations in calcium and phosphorus metabolism already described in this study.

Conclusion

The results of this study lead to the following conclusions: regarding the epidemiological and clinical characteristics of the cohort (N=81), there was a statistically significant predominance of patients with isolated hypertensive nephropathy as the underlying pathology (53.09%) and mixed diabetic/hypertensive nephropathy (28.40%) ($\chi2=101.89$; $p<0.0001$), as well as a predominance of males (65.43%; $\chi2=7.72$; $p=0.0055$) and individuals in the 57–66 age group (28.40%; $\chi2=17.15$; $p=0.0042$).Regarding vascular access, the most frequently used device was the autologous arteriovenous fistula (83.95%; $\chi2=95.63$; $p<0.0001$), for which the most common mechanical complication was pseudoaneurysm (13.24%). Although the overall proportion of patients with a central venous catheter was low (14.81%), these patients faced a statistically higher risk of developing overall complications (OR=6.50; p=0.0051) and catheter-related infections (41.67% vs. 0.00% for fistulas; p=0.000033), confirming the catheter as the primary determinant of infectious morbidity related to the access. Furthermore, a comparison of paraclinical findings against international KDIGO clinical targets revealed statistically significant alterations ($p<0.01$) in bone-mineral metabolism—characterized by secondary hyperparathyroidism (mean PTH 589.53 pg/mL; p=0.0090) and elevated alkaline phosphatase (356.53 U/L; p=0.0001), consistent with high-turnover renal osteodystrophy—alongside persistent severe renal anemia (mean hemoglobin 7.84 g/dL and hematocrit 25.92%; $p<0.0001$ for both) and relative hypoalbuminemia (3.51 g/dL vs. a target of 4.0 g/dL; p=0.0001), which accounts for the high monthly transfusion requirement (23.25 units/month).Finally, the predominant adverse events during hemodialysis sessions were cardiovascular hemodynamic disturbances, with a significantly higher frequency of intradialytic hypertension compared to intradialytic hypotension (34.57% vs. 18.52%; $\chi2=3.93$; p=0.0474), while acute respiratory tract infections/pneumonia constituted the primary infectious complication (55.56%; $\chi2=53.40$; $p<0.0001$).The reconciled descriptive results and the findings from inferential statistics (p-values, χ^2, odds ratios, and comparisons against KDIGO targets) support the need to strengthen protocols for reducing catheter use, optimize the pharmacological management of anemia and secondary hyperparathyroidism, and individualize hemodynamic monitoring during dialysis.

Acknowledgments

The authors would like to thank the participants for their time and effort dedicated to our research. They would also like to thank the CDCHT of Lisandro Alvarado University for registering this project as a research project.

Conflicts of interest

The authors declare no conflicts of interest.

Right to privacy and informed consent

The authors declare that no patient data appear in this article.

Author contributions

The authors are responsible for the research and confirm authorship of this work. All authors participated in its conception and design, sample collection, data analysis and interpretation, and writing and editing of the manuscript.

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Citation: Elsa V, Jorge B, Julio O, et al. Epidemiological, clinical and adverse event characteristics of hemodialysis patients. *Int J Fam Commun Med.* 2026;10(5):169–174. DOI: 10.15406/ijfcm.2026.10.00435