IJKD KIDNEY DISEASES

Risk Factors and Clinical Characterization of Cardiovascular and Cerebrovascular Events in Elderly Hemodialysis Patients

Wei Liu,[#] Hong Ze Wang,[#] Ying Shi,[#] Weiqiang Shen,[#] Mingyan Dai[#]

Department of Nephrology, Deqing County People's Hospital, Huzhou 313000, Zhejiang, China
[#]Co-authors: These authors contributed same to this work.

Keywords. elderly hemodialysis patients, cardiovascular and cerebrovascular events, risk factors, clinical characteristics, correlation analysis

Original Paper

Introduction. The purpose of this study was to assess the risk factors and clinical characteristics of cardiovascular and cerebrovascular events in elderly hemodialysis patients.
Methods. Elderly patients undergoing hemodialysis (HD) at Deqing County People's Hospital in Zhejiang, China, from May 2020 to May 2023 were enrolled in this study. They were divided into two groups depending on the occurrence of cardiovascular or cerebrovascular events: the case group and the control group.
Results. A total of 106 patients were enrolled in this study. Among them, 49 patients experienced cardiovascular or cerebrovascular events, resulting in an incidence rate of 46.23%. According to whether cardiovascular or cerebrovascular events occurred, 57 patients were assigned to the control group, and 49 patients were assigned to the case group. Comparing the basic information and clinical indicators of the two groups, significant differences were observed in patients with hypertensive nephropathy and diabetic nephropathy ($P < .05$). There were also significant differences in dialysis duration, smoking history, systolic and diastolic blood pressures, uric acid, blood glucose, total cholesterol (TC), low-density lipoprotein cholesterol (TG), C-reactive protein (CRP), and PTH (parathyroid hormone) levels and platelet-to-lymphocyte ratio (PLR), between the two groups ($P < .05$). Multivariate logistic regression analysis revealed that longer dialysis duration, higher systolic and diastolic blood pressures, elevated uric acid, TC, TG, LDL-C, PTH, and blood glucose levels, smoking history, elevated PLR, and CRP were independent risk factors for cardiovascular and cerebrovascular events. The ROC curve showed that these risk factors predicted cardiovascular and cerebrovascular events in patients.
Conclusion. Patients with underlying diseases such as hypertensive or diabetic nephropathy are more likely to experience cardiovascular and cerebrovascular events. Longer dialysis duration, higher systolic and diastolic blood pressures, elevated uric acid, TC, TG, LDL-C, PTH and blood glucose levels, and boosted inflammatory reaction are risk factors for these events among elderly HD patients. The purpose of this study is to provide practical guidelines for clinical treatment. Comprehensive measures such as active intervention of risk factors, rational drug use and regular examination should be taken to improve the overall health level to the greatest extent for elderly patients with high-risk HD.

IJKD 2024;18:124-32
www.ijkd.org
DOI: 10.52547/ijkd.7877

INTRODUCTION

As the aging of the global population progresses, there is a gradual rise in the percentage of geriatric patients undergoing hemodialysis (HD) treatment.[1] Due to chronic impairment of renal function, elderly hemodialysis patients experience a significant increase in the risk of cardiovascular and cerebrovascular events with the deterioration of renal function and presence of comorbidities.[2] Cardiovascular and cerebrovascular events (CCVE), such as ischemic heart disease and ischemic stroke, not only seriously affect the quality of life of the patients but are also one of the main causes of death in HD patients.[3] According to clinical statistics, [4] most chronic kidney disease patients do not die from progression of their kidney failure, but approximately 50% die from cardiovascular and cerebrovascular complications. Therefore, gaining an in-depth understanding of the risk factors and clinical characteristics associated with cardiovascular and cerebrovascular events in hemodialysis patients is crucial for formulating prevention and management strategies. The aim of this study is to investigate the risk factors of CCVE in elderly HD patients as well as their clinical characteristics in order to provide more comprehensive interventions.

MATERIALS AND METHODS

Objectives of the Study

This was a case-control study. The study involved 106 elderly patients receiving chronic hemodialysis at Deqing County People's Hospital in Zhejiang Province, China, between May 2020 and May 2023. The patients' clinical indices and general data were collected using a case system for a 1-year follow-up in addition to questionnaires. The study included 66 male and 40 female patients, aged between 60 and 89 years, with a mean age of 68.42 years and a standard deviation of 7.12 years. The inclusion criteria were: 1) age ≥ 60 years old; 2) meet the characteristics of hemodialysis treatment; 3) stable hemodialysis time ≥ 3 months and the exclusion criteria were: 1) acute kidney injury; 2) past history of cardiovascular or cerebrovascular accidents; 3) patients with severe liver dysfunction, malignant tumors; 4) patients with previous kidney transplantation.

Ethical Approval

All the study participants signed the informed consent form. This study was approved by the institutional ethics committee of Deqing County People's Hospital (Ethics code: LL2023-K127).

Observation Indicators

The detailed medical and medication records of all patients participating in this study, including a history of diabetes mellitus and hypertension, were collected. The medication history mainly included the use of statins, ACE inhibitors (ACEI), Angiotensin II receptor antagonist (ARB), Erythropoietin (EPO) were collected through questionnaires: gender, age, income, body mass index (BMI), dialysis duration, smoking history, primary disease, cardiovascular or cerebrovascular events, the patient's primary disease; platelet count; hemoglobin (Hb); serum albumin (ALB); myoglobin; apolipoprotein; serum creatinine (SCr); blood glucose; blood potassium; blood calcium; blood phosphorus; systolic blood pressure ; diastolic blood pressure; uric acid (UA); blood urea nitrogen(BUN); total cholesterol (TC); Triglycerides (TG); high-density lipoprotein cholesterol (HDL-C); low-density lipoprotein cholesterol(LDL-C) ; red blood cell count; platelet/lymphocyte ratio (PLR); C-reactive protein (CRP); parathyroid hormone (PTH). Cardiovascular and cerebrovascular events included congestive heart failure, ischemic heart disease, malignant arrhythmia, myocardial infarction, cerebral hemorrhage, cerebral infarction, sudden death. Hypertension was defined as a systolic blood pressure of more than 140 mmHg and a diastolic blood pressure of more than 90 mmHg; Hemoglobin level of 110 to 120 g/L was defined as normal level in hemodialysis patients, while Hb levels of more than 120 g/L or less than 110 g/L were defined as abnormal. Fasting blood glucose (FBS) before dialysis, between 3.9 and 6.1 mmol/L was considered normal; FBS between 6.1 and 7.0 mmol/L was defined as impaired fasting glucose; Abnormal glucose metabolism was defined as BG of equal to or more than 7.0 mmol/L, in repeated measurement; Serum total cholesterol (TC) of 2.9 to 5.17 mmol/l, serum triglyceride (TG) of 0.56 to 1.7 mmol/l, high density lipoprotein cholesterol (HDL) of 0.94 to 2.0 mmol/L, and the low-density lipoprotein cholesterol (LDL-C) level in the range of 2.07~3.12 mmol/L were considered normal and dyslipidemia was defined as elevated one or more of the TC, LDL-C or TG levels. Body mass index is

calculated using the formula: BMI = weight (kg)/height (m^2); BMI of less than 18.5 kg/m^2 is classified as underweight, between 18.5 and 24.0 kg/m2 is considered normal, BMI between 24.0 and 28.0 kg/m^2 indicates overweight, and a BMI of equal to or more than 28.0 kg/m^2 suggests obesity. Patients were grouped based on the standard cut-off values for PLR of 300, PTH of 67 pg/mL, and CRP of 6 mg/L, respectively. Venous blood samples were collected after fasting for at least eight hours, and data was collected prior to the first hemodialysis.

Statistical Methods

The S-W method was used to perform normal test on the collected measurement data. When the data bit was normally distributed, the mean standard deviation (x ± s) was used to represent the measurement data, and the independent sample *t* test was used for inter-group comparison. Non-normal distribution data were represented by median (Q1, Q3), and paired *t*-test was used for comparison between groups. Percentage (%) represents counting data, and c^2 tests were used for univariate analysis. The risk factors of cardiovascular and cerebrovascular events in elderly hemodialysis patients were analyzed by Logistic multiple regression, and $P < .05$ was considered as statistically significant. The above data analysis was calculated using SPSS 26.0 statistical software.

RESULTS

General Information Analysis

One hundred and six HD patients were enrolled in this study, comprising 66 males and 40 females.; the majority of patients had a monthly income of less than 6,000 yuan; In the course of dialysis, 49 patients had cardiovascular or cerebrovascular accidents, the incidence rate was 46.23%. Comparing the basic information of the two groups of HD patients, a significant difference ($P < .05$) was observed between the two cohorts in terms of dialysis duration, whereas there was no significant difference ($P > .05$) in terms of age, gender, income, and BMI (Table 1).

Comparison of the clinical indices between the two groups showed that there were significant differences in blood glucose, systolic and diastolic blood pressures, history of smoking, uric acid, TC, TG, and LDL-C levels ($P < .05$), whereas there was no remarkable difference in platelets, Hb, ALB, myoglobin, lipoproteins, SCr, serum potassium, calcium, and phosphorus levels, BUN, and HDL-C levels ($P > .05$). Blood glucose (6.77 ± 2.36) mmol/L was significantly more in the case group than in the control group (5.77 ± 1.67) mmol/L ($P > .05$); systolic blood pressure (152.57 ± 12.37) mmHg was obviously higher in the case group than in the control group (152.57 ± 12.37) mmHg ($P > .05$); diastolic blood pressure in the case group was (86.35 ± 12. 34) mmHg, which was obviously above that of patients in the control group (77.75 ± 20.09) mmHg ($P > .05$); TC was (4.92 ± 1.29) mmol/L in the case group, which was obviously above that of patients in the control group (3.87 ± 0.89) mmol/L ($P > .05$); and TG 2.53 was (1.95, 3.02) mmol/L in patients in the case group, which was obviously above that of patients in the control group ($P > .05$). The TG of patients in the control group was 1.92 (1.47, 2.35) mmol/L; the LDL-C of patients in the case group was 2.88 (2.57, 3.16) mmol/L, which

Table 1. Comparison of Basic Information [x ± s, n (%)]

Group of groups	Case Group (n = 49)	Control Group (n = 57)	t/χ^2	*P*
Age, y	70.39 ± 7.16	69.61 ± 5.99	0.606	.118
Dialysis Duration, mo	24.76 ± 6.46	18.69 ± 3.24	6.244	< .001
Gender				
Male	27 (55.10)	29 (50.88)	0.277	.599
Female	22 (44.90)	28 (49.12)		
Income, Yuan/month				
≤ 3500	24	25		
3500 to 6000	19	21	0.993	.609
≥ 6000	6	11		
BMI, kg/m^2	23.54 ± 3.11	23.34 ± 3.25	0.316	.94
History of Smoking				
Yes	37 (75.51)	16 (28.07)	23.720	< .001
No	12 (24.49)	41 (71.93)		

was obviously above that of patients in the control group, which was 2.53 (2.29, 2.78) mmol/L ($P > .05$); The levels of PLR, CRP and PTH in the case group were significantly higher than those in the control group ($P > .05$), see Table 2.

Analysis of CCVE and Primary Diseases

The primary diseases of 106 patients were hypertensive nephropathy in 7 cases, diabetic nephropathy in 32 cases, chronic glomerulonephritis in 34 cases, polycystic kidney disease in 7 cases, obstructive nephropathy in 6 cases, and other etiologies in 20 cases. The primary diseases of the two groups of patients show a significant difference in the prevalence of hypertensive nephropathy and diabetic nephropathy ($P < .05$) (Table 3), suggesting that HD patients with hypertensive nephropathy and diabetic nephropathy are more likely to suffer from CCVE.

The CCVE that happened in 49 patients in the case group were cerebral hemorrhage in 8 cases (16.33%), angina pectoris in 8 cases (16.33%), myocardial infarction in 10 cases (20.41%), heart failure in 13 cases (26.53%), cerebral infarction in 6 cases (12.24%), and stroke in 4 cases (8.16%) (Figure 1).

Multifactor Logistic Regression Analysis

The occurrence and non-occurrence of cardiovascular and cerebrovascular events ("occurrence" = 1, "no occurrence" = 0) were used as the dependent variable, and the factors with

Table 2. Comparison of Clinical Indicators of Patients [x ± s, median (Q1, Q3)]

Clinical Index	Case Group (n = 49)	Control Group (n = 57)	t/Z	*P*
Platelets, 10^9/L	177.17 ± 55.77	171.46 ± 45.91	0.580	.329
Hb, g/L	114.09 ± 4.64	113.75 ± 4.67	0.380	.890
ALB. g/L	37.58 ± 3.55	37.90 ± 3.08	0.500	.293
Myoglobin, mg/L	3772.17 ± 168.21	3756.90 ± 169.63	0.464	.835
Apolipoprotein, mg/L	332.52 ± 101.08	308.10 ± 104.89	1.215	.920
SCr, mmol/L	93.56 ± 7.79	94.00 ± 7.56	0.294	.778
Blood glucose, mmol/L	6.77 ± 2.36	5.77 ± 1.67	2.533	.008
Serum potassium, mmol/L	4.57 ± 1.15	4.44 ± 1.25	0.564	.329
Serum calcium, mmol/L	2.52 (2.33, 2.67)	2.53 (2.33, 2.70)	0.380	.704
Serum phosphorus, mmol/L	1.21 (1.03, 1.37)	1.20 (1.07, 1.48)	0.913	.631
Systolic Blood Pressure, mmHg	152.57 ± 12.37	130.91 ± 16.65	7.498	.044
Diastolic Blood Pressure, mmHg	86.35 ± 12.34	77.75 ± 20.09	2.602	.009
UA, mmol/L	406.53 ± 81.46	328.28 ± 76.80	5.085	.929
BUN, mmol/L	22.60 ± 4.45	21.81 ± 4.54	0.895	.825
TC, mmol/L	4.92 ± 1.29	3.87 ± 0.89	4.912	.003
TG, mmol/L	2.53 (1.95, 3.02)	1.92 (1.47, 2.35)	4.040	< .001
HDL-C, mmol/L	1.13 ± 0.27	1.10 ± 0.26	3.922	.075
LDL-C, mmol/L	2.88 (2.57, 3.16)	2.53 (2.29, 2.78)	4.230	< .001
Red blood cell count, 10^{12}/L	2.36 ± 0.71	2.47 ± 0.65	0.843	.541
PLR > 300	39 (79.59)	18 (31.58)	24.436	< .001
PLR ≤ 300	10 (20.41)	39 (68.42)		
CRP > 6 mg/L	43 (87.76)	20 (35.09)	30.315	< .001
CRP ≤ 6 mg/L	6 (12.24)	37 (64.91)		
PTH > 67 pg/mL	37 (75.51)	15 (26.32)	25.516	< .001
PTH ≤ 67 pg/mL	12 (24.49)	42 (73.68)		

Table 3. Comparison of Primary Diseases Between the Two Groups [n (%)]

Primary Disease	Case Group (n = 49)	Control Group (n = 57)	χ^2	*P*
Chronic glomerulonephritis	19 (38.78)	23 (40.35)	0.027	.869
Diabetic nephritis	9 (18.37)	3 (5.26)	4.507	.034
Hypertensive nephropathy	13 (26.53)	6 (10.53)	4.558	.032
Polycystic kidney disease	3 (6.12)	4 (7.02)	0.034	.853
Obstructive nephropathy	2 (4.08)	4 (7.02)	0.425	.514
Other	3 (6.12)	17 (29.82)	9.67	.002

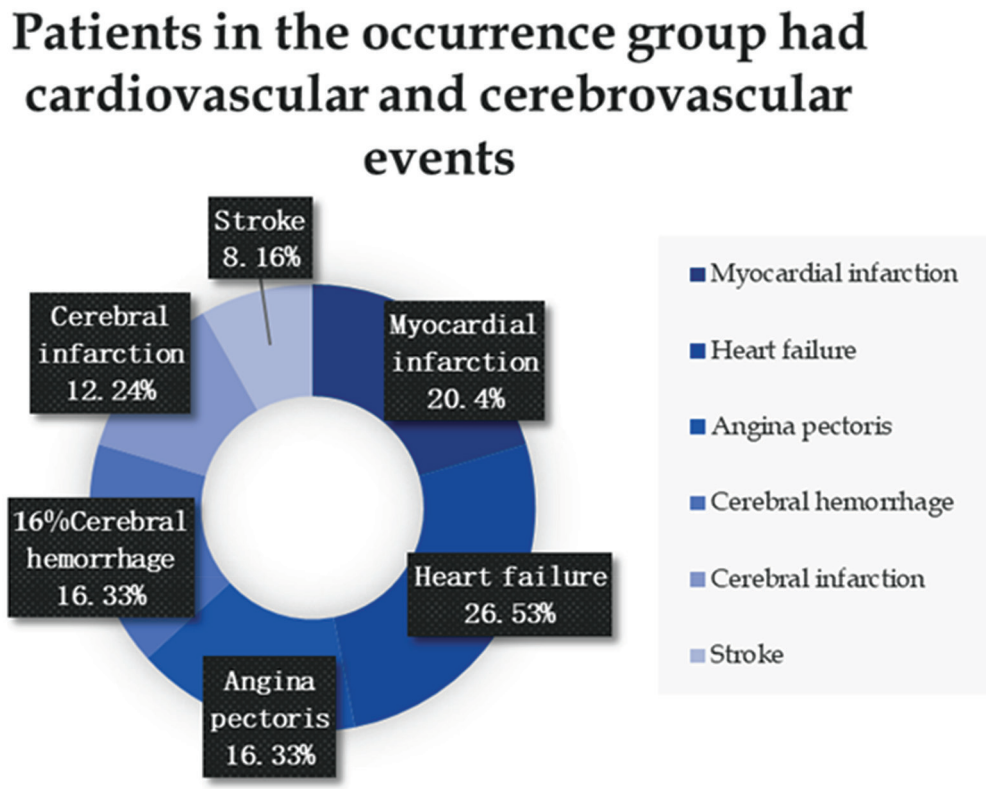

Figure 1. Distribution of Cardiovascular and Cerebrovascular Events in Patients in the Case Group

significant differences screened in the univariate analysis were used as the independent variables, which were brought into the binary Logistic stepwise regression model for analysis. The assignment of binary variables is shown in Table 4. The results showed that prolonged dialysis duration, high systolic blood pressure, high diastolic blood pressure, high UA, high TC, high TG, high LDL-C, and high blood glucose level were independent risk factors for cardiovascular and cerebrovascular events ($P < .05$) (See Table 5).

ROC Curve Predictive Value

The results of the diagnostic value of the ROC curve showed that all of the above mentioned risk factors had a better predictive effect on the occurrence of CCVE in elderly HD patients; among them, systolic blood pressure had the largest area under the ROC curve, with an AUC of 0.865 (95% CI: 0.798 to 0.932), $P < .001$, a sensitivity of 85.7%, and a specificity of 79.8%, which indicated that the systolic blood pressure predicted the occurrence of CCVE in patients with a higher accuracy in the study. CCVE in patients was more accurate (Table 6) (Figure 2).

DISCUSSION

Hemodialysis is a renal replacement treatment for patients with acute and chronic kidney failure.[5] Cardiovascular and cerebrovascular events are common serious complications in elderly patients undergoing HD, with high incidence and poor

Table 4. Assignment Table

Factors	Assignment of Value
Whether cardiovascular and cerebrovascular events occurred	"Occurrence" = 1, "Non-occurrence" = 0
Any history of smoking	"Yes" = 1, "No" = 0
PLR	"> 300" = 1, "< 300" = 0
CRP	"> 6 mg/L" = 1, "≤ 6mg/L" = 0
PTH	"> 67 pg/mL" = 1, "≤ 67pg/mL" = 0

Table 5. Multivariate Logistic Regression Analysis

	B	SE	Wald	*P*	Exp (B) OR	The 95% CI for EXP (B)	
						Lower Limit	Upper Limit
Duration of dialysis	0.391	0.161	5.872	.015	1.479	1.078	2.03
Systolic blood pressure	0.143	0.053	7.389	.007	1.154	1.041	1.279
Diastolic blood pressure	0.072	0.042	2.869	.09	1.074	0.989	1.167
UA	0.02	0.009	4.498	.034	1.02	1.002	1.039
TC	1.22	0.568	4.617	.032	3.387	1.113	10.307
TG	1.447	0.61	5.625	.018	4.252	1.286	14.062
LDL-C	4.267	1.838	5.39	.02	71.329	1.944	17.488
Blood glucose	0.247	0.103	5.812	.016	1.281	1.047	1.566
History of smoking	0.376	0.145	6.722	.010	1.456	1.096	1.935
PLR	0.018	0.008	4.740	.029	1.018	1.002	1.034
CRP	0.109	0.047	5.428	.020	1.115	1.017	1.221
PTH	2.172	0.680	10.211	.001	8.779	2.316	33.277

Table 6. Diagnostic Value of Risk Factors and Occurrence of Cardiovascular and Cerebrovascular Events in Patients

Factor	AUC	Sensitivity	Specificity	Asymptotic 95% CI		*P*
				Lower limit	Upper limit	
Duration of dialysis	0.794	0.714	0.789	0.701	0.888	< .001
Systolic blood pressure	0.865	0.857	0.702	0.798	0.932	< .001
Diastolic blood pressure	0.623	0.939	0.368	0.516	0.729	.03
UA	0.763	0.653	0.789	0.672	0.855	< .001
TC	0.746	0.694	0.754	0.65	0.843	< .001
TG	0.728	0.571	0.877	0.628	0.828	< .001
LDL-C	0.739	0.714	0.684	0.645	0.833	< .001
Blood glucose	0.624	0.408	0.877	0.515	0.733	.029
History of smoking	0.737	0.755	0.719	0.640	0.835	< .001
PLR	0.740	0.796	0.684	0.643	0.833	< .001
CRP	0.763	0.878	0.649	0.670	0.856	< .001
PTH	0.746	0.755	0.737	0.650	0.842	< .001

prognosis.[6] Therefore, it is of a significance to systematically analyze the risk factors and clinical characteristics of cardiovascular and cerebrovascular events in elderly HD patients to provide clinicians with better prevention and management strategies. Clinically, Wu Yinghua[7] found that hypertension and high levels of total cholesterol can be used as risk factors for cardiovascular and cerebrovascular events in young and middle-aged individuals, while this study did not look for the risk factors for cardiovascular and cerebrovascular events in elderly HD patients. The current study analyzed the cardiovascular and cerebrovascular events in elderly HD patients and found that longer dialysis duration, high systolic and diastolic blood pressures, elevated uric acid, TC, TG, and LDL-C levels, high blood glucose level, history of smoking, and increased PLR, CPR, are risk factors for CCVE. Studies have shown[8-10] that as dialysis duration increases, elderly HD patients may experience a decline in nutritional status, with an increased risk of inflammation. This, in turn, could lead to the formation and instability of atherosclerotic plaques, thereby increasing the occurrence of cardiovascular events. PLR and CRP are widely used for the evaluation of inflammation. Inflammation may cause endothelial cell injury, leading to the release of inflammatory mediators and adhesion molecules by damaged endothelial cells. These substances attract white blood cells and promote their migration across the vascular wall, thereby triggering local inflammation and promoting the formation of atherosclerotic plaques. Plaque formation not only leads to vascular stenosis but also increases the risk of rupture and releasing plaque substances into the vascular lumen. This process can cause platelet aggregation and thrombosis, ultimately resulting in cardiovascular and cerebrovascular events. Several studies have shown[11-13] that hypertension can lead

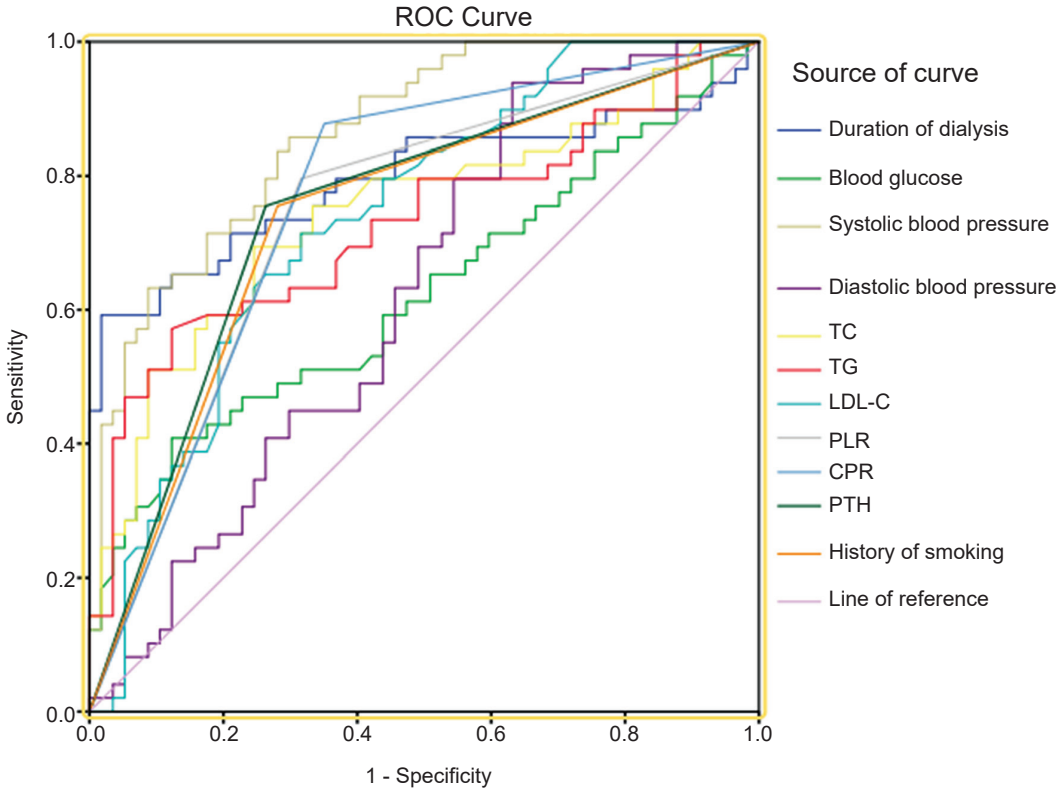

Figure 2. ROC Curves of Risk Factors for the Diagnosis of Cardiovascular Events in Patients

to abnormal vascular endothelial function and structural changes in vessel walls, making them susceptible to damage. Hypertension also increases lipid deposition and inflammatory reactions within vessel walls, leading to the development of atherosclerosis. This further raises the incidence of cardiovascular and cerebrovascular events in HD patients. In elderly hemodialysis patients, hyperuricemia and hypertension may interact with each other, increasing the risk of cardiovascular and cerebrovascular events.[14] Excessive levels of uric acid have been found[15-17] to potentially form uric acid crystals under certain circumstances, contributing to gout occurrence. Gout is associated with hypertension development as well[18-19], which further elevates the risk of cardiovascular and cerebrovascular events. The interaction between hypertension and high uric acid on the occurrence of cardiovascular and cerebrovascular events in elderly patients with HD can be further studied. Cholesterol and triglycerides accumulate excessively in the bloodstream, easily depositing on the inner walls of blood vessels, forming arterial plaques. This gradually narrows the blood vessel lumen, obstructing blood flow, and may even lead to thrombus formation, triggering cardiovascular events such as myocardial infarction, stroke, and others.[20-22] Studies have found[23-24] that hyperglycemia impairs fibrinolytic function in vivo and reduces fibrinolytic activity. This weakens thrombolytic ability, promotes easy formation and stability of thrombosis, thereby increasing the risk of cardiovascular and cerebrovascular events. The study by Carmine Izzo *et al.*[25] indicates that elevated levels of PTH may promote the deposition of phosphate within the walls of blood vessels, leading to vascular calcification, stiffening of the vessels, and consequently increasing the risk of cardiovascular events. Therefore, active interventions targeting these risk factors are expected to reduce the incidence of such events among elderly hemodialysis patients while improving their quality of life and prognosis. However, it should be noted that there is significant variability among elderly hemodialysis patients. Therefore, when developing individualized treatment plans, it is necessary to comprehensively consider factors such as the patient's condition, comorbidities, and lifestyle.

CONCLUSION

To sum up, patients with hypertensive nephropathy and diabetic nephropathy with primary diseases are more likely to have cardiovascular and cerebrovascular events. Long dialysis age, high systolic blood pressure, high diastolic blood pressure, high UA level, high lipids, high blood sugar level, inflammatory reaction and high PTH level are risk factors for cardiovascular and cerebrovascular events in elderly HD patients. The purpose of this study is to provide practical guidelines for clinical treatment. Comprehensive measures such as active intervention of risk factors, rational drug use and regular examination should be taken to improve the overall health level to the greatest extent for elderly patients with high-risk HD.

ACKNOWLEDGMENTS

We would like to appreciate cooperation of the department of Nephrology, Deqing County People's Hospital.

Consent for Publication

Manuscript is approved by all authors for publication.

Availability of Data and Materials

The data and materials of this experiment are available.

Competing Interests

No conflict of interest exits in this manuscript.

Author Contributions

Wei Liu were responsible for conception and design. HongZe Wang was responsible for manuscript writing. Ying Shi was responsible for collection and assembly of data. Weiqiang Shen and Mingyan Dai were responsible for data analysis and interpretation. All authors were responsible for manuscript writing. All authors were responsible for the final approval of the manuscript.

Funding

Not applicable

REFERENCES

1. Li Y, Zhang D, Ma Q, Diao Z, Liu S, Shi X. The Impact of Frailty on Prognosis in Elderly Hemodialysis Patients: A Prospective Cohort Study. Clin Interv Aging. 2021;16:1659-1667.
2. Ding Z, Fan Y, Yao C, Gu L. The association between the serum uric acid to creatinine ratio and all-cause mortality in elderly hemodialysis patients. BMC Nephrol. 2022;23(1):177.
3. Zhang Q, Yin K, Zhu M, et al. Combining Pulse Wave Velocity With Galectin-3 to Predict Mortality and Cerebrovascular and Cardiovascular and cerebrovascular events in Hemodialysis Patients. Front Med (Lausanne). 2020;7:579021.
4. Xing Z, Wang Y, Gong K, Chen Y. Plasma C4 level was associated with mortality, cardiovascular and cerebrovascular complications in hemodialysis patients. BMC Nephrol. 2022;23(1):232.
5. Cozzolino M, Mangano M, Stucchi A, et al. Cardiovascular disease in dialysis patients. Nephrol Dial Transplant. 2018;33:iii28-iii34.
6. Huang WH, Lin JL, Lin-Tan DT, et al. Impact of living environment on 2-year mortality in elderly maintenance hemodialysis patients. PLoS One. 2013;8(9):e74358.
7. Wu Y, Xiong Y, Wang P, et al. Risk factors of cardiovascular and cerebrovascular diseases in young and middle-aged adults: A meta-analysis. Medicine (Baltimore). 2022;101(48):e32082.
8. Ly J, Chan CT. Impact of augmenting dialysis frequency and duration on cardiovascular function. ASAIO J. 2006;52(6):e11-4.
9. Wu Y, Huang B, Zhang W, et al. The interaction analysis between advanced age and longer dialysis vintage on the survival of patients receiving maintenance hemodialysis. J Int Med Res. 2022;50(4):3000605221088557.
10. Fujisaki K, Tanaka S, Taniguchi M, et al. Study on Dialysis Session Length and Mortality in Maintenance Hemodialysis Patients: The Q-Cohort Study. Nephron. 2018;139(4):305-312.
11. Ying Q, Mao Y, Xie X, et al. Multicenter Investigation of the Initial Hemodialysis Vascular Access and Its Related Factors in Hangzhou of China. Biomed Res Int. 2021;2021:6628139.
12. Wang T, Li Y, Wu H, et al. Optimal blood pressure for the minimum all-cause mortality in Chinese ESRD patients on maintenance hemodialysis. Biosci Rep. 2020;40(8):BSR20200858.
13. Takahashi R, Uchiyama K, Washida N, et al. Mean annual intradialytic blood pressure decline and cardiovascular and cerebrovascular events in Japanese patients on maintenance hemodialysis. Hypertens Res. 2023;46(6):1536-1546.
14. Chaudhary NS, Bridges SL Jr, Saag KG, et al. Severity of Hypertension Mediates the Association of Hyperuricemia With Stroke in the REGARDS Case Cohort Study. Hypertension. 2020;75(1):246-256.
15. Jin M, Yang F, Yang I, et al. Uric acid, hyperuricemia and vascular diseases. Front Biosci (Landmark Ed). 2012 Jan 1;17(2):656-69.
16. Ndrepepa G, Kufner S, Cassese S, Joner M, Xhepa E, Wiebe J, Sager HB, Kessler T, Laugwitz KL, Schunkert H, Kastrati A. A Ten-Year Follow-Up Study of the Association

Between Uric Acid and Adverse Cardiovascular Events in Patients With Coronary Artery Disease. Am J Cardiol. 2024 Apr 1;216:19-26.

17. Sosa F, Shaban M, Lopez J, Duarte GJ, Jain S, Khizar A, Vittorio T, Mishra R, Rodriguez Guerra M. Impact of Hyperuricemia and Urate-Lowering Agents on Cardiovascular Diseases. Clin Med Insights Cardiol. 2024 Mar 24;18:11795468241239542.
18. Cox P, Gupta S, Zhao SS, et al. The incidence and prevalence of cardiovascular diseases in gout: a systematic review and meta-analysis. Rheumatol Int. 2021 Jul;41(7):1209-1219.
19. Méndez-Salazar EO, Martínez-Nava GA. Uric acid extrarenal excretion: the gut microbiome as an evident yet understated factor in gout development. Rheumatol Int. 2022;42(3):403-412.
20. Lamprea-Montealegre JA, Katz R, Scharnagl H, et al. Triglyceride-Rich Lipoproteins, Apolipoproteins, and Atherosclerotic Cardiovascular and cerebrovascular events Among Patients with Diabetes Mellitus and End-Stage Renal Disease on Hemodialysis. Am J Cardiol. 2021;152:63-68.
21. Refaat H, Sany D, Mohab A, et al. Comparing Dialysis Modality and Cardiovascular Mortality in Patients on Hemodialysis and Peritoneal Dialysis. Adv Perit Dial. 2016;32:22-31.
22. Wu Y, Xiong Y, Wang P, et al. Risk factors of cardiovascular and cerebrovascular diseases in young and middle-aged adults: A meta-analysis. Medicine (Baltimore). 2022;101(48):e32082.
23. Zhao Y, Song P, Zhu C, et al. Relationship between physical performance and mild cognitive impairment in elderly hemodialysis patients is modified by the presence of diabetes: A multicenter cross-sectional study. Front Endocrinol (Lausanne). 2022;13:897728.
24. Kashyap S, An I, Kn S, R H. A mathematical model for thrombotic risk assessment in type 2 diabetes. Bioinformation. 2023 Sep 30;19(9):971-975.
25. Izzo C, Secondulfo C, Bilancio G, Visco V, Virtuoso N, Migliarino S, Ciccarelli M, Di Pietro P, La Mura L, Damato A, Carrizzo A, Vecchione C. Chronic Kidney Disease with Mineral Bone Disorder and Vascular Calcification: An Overview. Life (Basel). 2024 Mar 21;14(3):418.

Correspondence to:
Hong Ze Wang
Department of Nephrology, Deqing County People's Hospital, Huzhou 313000, Zhejiang, China
E-mail: 137694547@qq.com
E-mail: lwsky729@163.com

Received November 2023
Revised December 2023
Accepted January 2024