RESEARCH PAPER

The Role of N-Terminal Pro-Brain Natriuretic Peptide Levels in the Estimation of Fluid Overload in Patients with End Stage Kidney Disease on Regular Dialysis

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ABSTRACT

Background: N-terminal pro-brain natriuretic peptide may serve as a useful marker of fluid overload in cases undergoing regular hemodialysis, although its interpretation is influenced by renal dysfunction and other clinical factors.

Objective: To determine the correlation of N-terminal pro-brain natriuretic peptide levels with clinical and echocardiographic features in the assessment of fluid overload in cases with end stage kidney disease on regular hemodialysis.

Methods: This case-control study was conducted at 6th of October University Hospital from May 2025 to January 2026 and included 45 cases with end-stage kidney disease (ESKD) having regular hemodialysis at the dialysis unit during a routine midweek outpatient hemodialysis session, in addition to 45 apparently healthy adults matched for age and sex who have been recruited from the outpatient clinic as a control group.

Results: N-terminal pro-brain natriuretic peptide illustrated significant positive correlations with interdialytic weight gain ($r=0.832$), systolic blood pressure ($r=0.851$), E/e′ ratio ($r=0.866$), and inferior vena cava diameter ($r=0.859$) (all $p<0.001$), while no significant correlations were found with body mass index, dry weight, creatinine, sodium, calcium, or left atrial volume index ($p>0.05$). A cutoff of 7235.25 pg/mL showed 72% sensitivity, 95% specificity, and an area under the curve of 0.871 for fluid overload.

Conclusion: N-terminal pro-brain natriuretic peptide (NT-pro BNP) is a significant biomarker for assessment of fluid overload in ESKD cases receiving regular hemodialysis.

Keywords: N-terminal pro-brain natriuretic peptide, NT-proBNP, fluid overload, end-stage kidney disease, hemodialysis, volume status, echocardiography

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INTRODUCTION

cases suffering from ESKD have a significantly heightened probability of cardiovascular complications and mortality in contrast to the general populace. Cardiac biomarkers, especially brain natriuretic peptide (BNP) and N-terminal pro-brain natriuretic peptide (NT-proBNP), are being utilized more frequently to evaluate cardiovascular risk in these cases. (1)

Fluid excess is a predominant and clinically significant issue in cases with end-stage kidney disease. It is linked to systemic hypertension, left atrial enlargement, inflammation, malnutrition, left ventricular hypertrophy, and congestive heart failure. Conversely, the evacuation of excessive fluid during dialysis might result in intradialytic hypotension and diminished perfusion of vital organs. (2) Consequently, precise evaluation and regulation of volume status are crucial for dialysis cases to mitigate cardiovascular issues. (3)

Clinical examination remains the most commonly used method for assessing volume status in hemodialysis cases; however, it may be imprecise and unreliable. Other methods, including ultrasonographic assessment of inferior vena cava diameter, radionuclide dilution techniques, and echocardiography, may provide additional information but are relatively difficult to perform routinely. (4)

BNP and NT-proBNP have been reported to correlate with volume status and may have a potential role in the assessment of fluid overload. (5) NT-proBNP has a longer half-life than BNP and is more stable in the circulation. (6) However, NT-proBNP concentrations are also influenced by renal function, as reduced renal clearance leads to increased circulating concentrations in cases with advanced

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kidney disease. (8) In ESKD, both renal dysfunction and hemodynamic factors may therefore contribute to elevated NT-proBNP levels. (2)

In patients undergoing regular hemodialysis, elevated NT-proBNP levels may reflect both volume overload and cardiac stress. Hemodialysis itself and other factors related to ESKD may also influence NT-proBNP concentrations. (7) Furthermore, elevated NT-proBNP levels may have prognostic significance in cases with end-stage kidney disease. (9)

The goal of this work was to determine the correlation of N-terminal pro-brain natriuretic peptide levels with clinical and echocardiographic features in the evaluation of fluid overload in cases with end stage kidney disease on regular hemodialysis.

PATIENTS AND METHODS

This case-control research was done at 6th of October University Hospital from May 2025 to January 2026 and included 45 cases with ESKD undergoing regular hemodialysis at the dialysis unit during a routine midweek outpatient hemodialysis session, in addition to 45 apparently healthy adults matched for age and sex who were recruited from the outpatient clinic as a control group.

Inclusion Criteria: Males or females aged eighteen to seventy-five years who had been identified with ESKD and had been receiving regular hemodialysis for at least 3 months, three sessions per week, with each session lasting 3–4 hours. Hemodialysis was performed using standard bicarbonate dialysate and high-flux dialyzers with synthetic membranes, with a blood flow rate of 200–300 mL/min and a dialysate flow rate of 500 mL/min. The control group included apparently healthy males and females aged 18–75 years who were matched for age and sex and had no active cardiac conditions, including heart failure, arrhythmias, or ongoing ischemia, and were not known to have diabetes mellitus, hypertension, or other major comorbidities.

Exclusion Criteria: Patients with ischemic heart disease, previous cardiac surgery, previous cardiac arrest, previous gastric surgery, major surgical intervention within the preceding 6 months, malignancy or treatment for malignancy within the preceding year, active sepsis, or irregular adherence to the prescribed hemodialysis schedule.

Ethical Considerations

The research protocol has been done in line with the Declaration of Helsinki and has been reviewed and permitted by the Research Ethics Committee of the Faculty of Medicine, 6th of October University (Approval No. PMC-Me-2202012). The purpose of the research was explained to all participants, confidentiality was assured, and written informed consent has been obtained before enrollment.

Clinical Assessment

Pre-dialysis blood pressure, heart rate, height, weight, and dry weight were recorded, and interdialytic weight gain has **been calculated as the variance between pre-dialysis weight a**nd dry weight. BMI and BSA were calculated using standard formulas. Additional clinical data included age, sex, primary kidney disease, comorbidities, current medications, urine output, and type of dialysis access.

Laboratory Investigations

Routine laboratory investigations included hemoglobin, hematocrit, serum creatinine, urea, sodium, potassium, calcium, and phosphorus, which have been attained from the patients' most recent monthly laboratory reports.

NT-proBNP Measurement

Blood samples for NT-proBNP measurement have been collected before the midweek dialysis session into EDTA-containing tubes. NT-proBNP concentrations have been measured using an enzyme-linked immunosorbent assay (ELISA) with a pre-coated human NT-proBNP antibody. Following incubation with biotinylated antibody and streptavidin-HRP, substrate solution was added and the reaction has been terminated with stop solution. Absorbance has been measured at 450 nanometers.

Procedure

A standard stock solution of NT-proBNP at a concentration of 24 ng/mL has been prepared by mixing 120 microliters of the original 48 ng/mL standard with 120 µL of standard diluent, and the solution has been allowed to stand for 15 minutes with gentle agitation. Serial two-fold dilutions were then prepared to obtain standard concentrations of 12, 6, 3, and 1.5 ng/mL, while standard diluent alone was used as the zero standard. All reagents, standard solutions, and samples have been brought to room temperature prior to use. Fifty microliters of each standard solution were added to the corresponding standard wells. For sample wells, forty microliters of each sample were added, followed by ten microliters of anti-NT-proBNP antibody and 50 microliters of streptavidin-HRP, and the plate was sealed and incubated at 37°C for 60 minutes. Following incubation, the plate underwent five washes with wash buffer, with each well immersed in roughly 300 microliters of wash buffer for a period of thirty seconds to one minute per wash cycle. Following that, fifty microliters of substrate solution A was combined with fifty microliters of substrate solution B in each well, and the plate was incubated at 37°C for 10 minutes in the absence of light. Subsequently, fifty microliters of stop solution was introduced to each well, and the optical density of every well was assessed at 450 nanometers with a microplate reader within a span of 10 minutes.

Calculation of Results

A standard curve has been constructed via plotting the average optical density of each standard against its corresponding NT-proBNP concentration. A best-fit curve was generated using computer-based curve-fitting software, and regression analysis was used to determine NT-proBNP concentrations in the tested samples.

Echocardiographic Assessment

Transthoracic echocardiography has been performed before dialysis utilizing a Philips Affiniti 30 ultrasound system, with examinations performed by the same operator in most patients to minimize inter-observer variability. Left ventricular ejection fraction (LVEF) has been assessed utilizing the biplane method of disks (modified Simpson's method) from apical four- and two-chamber views.

Assessment of Diastolic Function

Left ventricular diastolic function was evaluated using the E/A ratio, E/e′ ratio, and E-wave deceleration time. The E/A and E/e′ ratios were calculated from mitral inflow and tissue Doppler velocities, while deceleration time has been measured from the peak of the E-wave to the baseline.

Left Atrial Volume Index

Left atrial volume index (LAVI) has been assessed by measuring left atrial volume at end-systole using the biplane method of disks and indexing it to body surface area. A LAVI greater than 34 mL/m² was considered indicative of left atrial enlargement, with values of 35–41 mL/m² classified as mild dilatation, 42–48 mL/m² as moderate dilatation, and values greater than 48 mL/m² as severe dilatation.

Inferior Vena Cava Diameter and Collapsibility

Inferior vena cava (IVC) diameter and respiratory collapsibility have been assessed by ultrasonography as indicators of right atrial pressure and volume status. An IVC diameter ≤2.1 centimeters with > fifty percent inspiratory collapse indicated normal right atrial pressure, while a diameter >2.1 cm with <50% collapse indicated elevated pressure; discordant findings were considered intermediate.

Assessment of Fluid Overload

Fluid overload was assessed using clinical and echocardiographic parameters, including interdialytic weight gain, blood pressure, urine output, LAVI, diastolic filling parameters, and IVC diameter and collapsibility. NT-proBNP levels were correlated with these parameters to evaluate their relationship with fluid status in patients undergoing **regular hemodialysis.**

Statistical Analysis

Data have been analyzed applying SPSS version 28 (IBM Corp., Armonk, NY, united state of America). Quantitative and categorical data were summarized using appropriate descriptive statistics. Statistical tests included the unpaired t-test, Mann–Whitney test, Kruskal–Wallis test, Chi-square test, exact test, Spearman's correlation coefficient, and receiver operating characteristic (ROC) curve analysis. A P value under 0.05 has been deemed statistically significant.

RESULTS

Table (1): Description of cases

		Cases	
		Count	**%**
Sex	**female**	16	35.6%
	male	29	64.4%
vascular access (Arterio-venous fistula)	**yes**	34	75.6%
	no	11	24.4%
Hypertensive	**yes**	41	91.1%
	no	4	8.9%
Anti HTN med	**yes**	34	75.6%
	no	11	24.4%
Diabetic	**yes**	21	46.7%
	no	24	53.3%
HCV	**yes**	7	15.6%
	no	38	84.4%
HTN nephropathy	**yes**	17	37.8%
	no	28	62.2%
Dm nephropathy	**yes**	11	24.4%
	no	34	75.6%
Chronic GN	**yes**	5	11.1%
	no	40	88.9%
Unknown	**yes**	2	4.4%
	no	43	95.6%
polycystic	**yes**	4	8.9%
	no	41	91.1%
Stones	**yes**	2	4.4%
	no	43	95.6%
SLE	**yes**	2	4.4%
	no	43	95.6%
Pyelonephritis	**yes**	2	4.4%
	no	43	95.6%
UOP	**UOP<100 ml/day (anuric)**	11	24.4%
	UOP 100-500 ml/day (oliguric)	16	35.6%
	UOP 500-1000 ml/day (preserved)	11	24.4%
	UOP>1000 ml/day	7	15.6%
IVC collapsibility	**<50%**	25	55.6%
	50%	1	2.2%
	>50%	19	42.2%

Most were male (64.4%) and hypertensive (91.1%), with 75.6% receiving antihypertensive therapy, while 46.7% had diabetes. The most common causes of kidney disease were hypertensive nephropathy (37.8%) and diabetic nephropathy (24.4%). Most patients had urine output between 100–500 ml/day (35.6%), and IVC collapsibility was <50% in 55.6% of cases. Table (1)

Table (2): comparative analysis between clinical and laboratory parameters among studied groups

	Cases					Control					P value
	Mean	SD	Median	Minimum	Maximum	Mean	SD	Median	Minimum	Maximum	
Age	61.53	9.38	62.00	38.00	78.00	57.84	12.10	61.00	38.00	73.00	0.110
Dry wt (kg)	76.80	14.74	77.00	45.50	115.00	77.47	15.76	77.00	48.00	115.00	0.836
height (m)	1.69	0.12	1.69	1.47	1.95	1.73	0.13	1.74	1.51	1.94	0.115
BMI (Kg/m^2)	26.78	4.54	27.10	16.10	40.30	25.58	3.45	25.50	19.60	35.30	0.161
BSA (m^2)	1.89	0.22	1.92	1.41	2.50	1.93	0.25	1.89	1.44	2.46	0.527
IDWG (kg)	3.22	1.01	3.20	1.20	5.80	.	.	.	.	.	------
SBP (mmHg)	146.13	12.77	147.00	120.00	173.00	113.18	9.54	116.00	90.00	126.00	< 0.001
DBP (mmHg)	81.11	7.46	83.00	65.00	95.00	69.09	7.41	68.00	55.00	84.00	< 0.001
HR	72.42	7.20	70.00	61.00	89.00	77.27	10.01	77.00	61.00	97.00	0.010
Hb (g/dl)	9.55	1.22	9.20	7.30	13.00	13.36	2.32	13.70	8.00	16.90	< 0.001
HCT %	28.52	3.76	27.30	21.20	38.70	40.08	6.95	41.10	24.00	50.70	< 0.001
Cr (mg/dl)	8.94	2.37	8.66	3.19	13.90	0.88	0.24	0.85	0.51	1.40	< 0.001
urea (mg/dl)	158.51	46.55	155.00	83.00	258.00	29.69	5.46	30.00	18.00	39.00	< 0.001
Na (mEq/L)	147.02	5.31	146.00	138.00	159.00	143.01	4.33	142.80	133.00	158.00	< 0.001
K (mEq/L)	4.95	0.59	5.00	3.80	6.00	4.16	0.48	4.10	3.30	5.20	< 0.001
Ca (mg/dl)	9.16	0.88	9.10	7.70	10.90	9.40	1.06	9.60	7.30	10.90	0.255
P (mg/dl)	5.55	1.20	5.50	3.40	8.00	3.76	0.76	3.60	2.50	5.50	< 0.001

There were no statistically significant variances in age, dry weight, height, BMI, BSA, or calcium between the studied groups. Compared with controls, cases showed significantly higher SBP, DBP, creatinine, urea, sodium, potassium, and phosphorus, and significantly lower hemoglobin and hematocrit (all p below 0.001), while heart rate was also significantly different (p=0.010). Table (2)

Table (3): NT pro-bnp protein levels among studied groups

	Cases					Control					P value
	Mean	SD	Median	Minimum	Maximum	Mean	SD	Median	Minimum	Maximum	
NT-pro bnp (pg/ml)	9085.66	9749.09	5602.70	376.40	40124.80	58.49	32.26	53.20	12.20	129.40	< 0.001

Significant increase in NT pro- bnp protein concentrations in cases when compared to normal controls (p<0.001). Table (3)

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Table (4): echocardiography parameters among studied groups

	Cases					Control					P value
	Mean	SD	Median	Minimum	Maximum	Mean	SD	Median	Minimum	Maximum	
LVEF (%)	62.38	3.87	62.00	54.00	70.00	64.84	4.04	65.00	58.00	72.00	0.004
LVEDD (cm)	5.19	0.51	5.30	4.20	6.30	4.87	0.40	4.80	4.00	5.60	0.001
LVESD (cm)	3.48	0.42	3.50	2.80	4.50	3.12	0.27	3.00	2.60	3.70	< 0.001
IVST (cm)	0.91	0.15	0.90	0.70	1.40	0.82	0.09	0.80	0.70	1.00	0.002
PWT (cm)	0.88	0.11	0.90	0.70	1.20	0.81	0.09	0.80	0.70	1.10	0.002
LAD (cm)	4.06	0.29	4.00	3.60	5.10	3.28	0.30	3.20	2.50	3.90	< 0.001
LAVI (ml/m^2)	26.23	8.25	24.60	15.40	55.70	11.18	4.99	9.80	3.50	26.40	< 0.001
LVMI (g/m^2)	91.10	25.96	90.60	48.60	175.80	66.52	14.02	64.00	40.90	114.40	< 0.001
DCT (ms)	195.93	46.77	197.00	90.00	276.00	191.87	9.79	191.00	177.00	210.00	0.570
E/A ratio	1.17	0.32	1.20	0.65	1.95	1.16	0.13	1.20	1.00	1.50	0.814
E/e"ratio	9.10	2.80	8.00	5.00	16.00	5.59	1.07	6.00	4.00	7.00	< 0.001
IVC Diameter (cm)	2.14	0.17	2.10	1.70	2.50	1.66	0.12	1.70	1.40	1.90	< 0.001

Statistically significant difference of LVEF (p=0.004), LVEDD (p=0.001), LVESD (p< 0.001), IVST (p=0.002), PWT (p= 0.002), LAD (p<0.001), LAVI (p<0.001), LVMI (p<0.001), E/e" ratio (p<0.001) and IVC diameter (p<0.001) while there was no statistically significant difference in DCT (p= 0.570) and E/A ratio (p= 0.814) between studied groups. Table (4)

Table (5) relation between NT pro- bnp and other parameters among cases

		NT-pro bnp(pg/ml)					
		Mean	Standard Deviation	Median	Minimum	Maximum	P value
Sex	**female**	10478.80	9399.98	8864.55	463.90	38912.40	0.236
	male	8317.03	10014.96	4004.70	376.40	40124.80	
vascular access	**yes**	8589.33	9188.46	5880.85	463.90	38912.40	0.575
	no	10619.75	11668.70	5450.20	376.40	40124.80	
Hypertensive	**yes**	9757.21	9960.54	6286.80	463.90	40124.80	0.041
	no	2202.20	1348.05	2459.00	376.40	3514.40	
Anti HTN med	**yes**	10894.12	10447.94	7235.25	463.90	40124.80	0.004
	no	3495.87	3532.79	2683.70	376.40	10984.30	
Diabetic	**yes**	10206.70	9541.70	8309.60	376.40	40124.80	0.237
	no	8104.74	10025.19	4821.90	463.90	38912.40	
HCV	**yes**	9742.51	7135.38	8163.40	873.20	20761.50	0.380
	no	8964.66	10230.99	4821.90	376.40	40124.80	
HTN nephropathy	**yes**	11235.36	11671.70	6286.80	873.20	38912.40	0.399
	no	7780.48	8335.67	4052.60	376.40	40124.80	
Dm nephropathy	**yes**	11856.13	11034.39	9419.50	695.10	40124.80	0.168
	no	8189.33	9297.51	4821.90	376.40	38912.40	
Chronic GN	**yes**	5368.34	5605.21	2822.60	376.40	14651.90	0.331
	no	9550.32	10100.22	5880.85	463.90	40124.80	
Unknown	**yes**	8520.25	4341.71	8520.25	5450.20	11590.30	0.655
	no	9111.96	9955.19	5602.70	376.40	40124.80	
polycystic	**yes**	1702.15	1403.30	1415.15	463.90	3514.40	0.015
	no	9806.00	9920.58	6286.80	376.40	40124.80	
Stones	**yes**	6412.00	3137.29	6412.00	4193.60	8630.40	0.848
	no	9210.01	9948.87	5602.70	376.40	40124.80	
SLE	**yes**	2968.50	175.93	2968.50	2844.10	3092.90	0.424
	no	9370.18	9884.59	6159.00	376.40	40124.80	
Pyelonephritis	**yes**	8992.15	9191.61	8992.15	2492.70	15491.60	1

	no	9090.01	9877.18	5602.70	376.40	40124.80	
UOP	**UOP<100 mL/day (Anuric)**	21395.11	11689.16	17196.50	5602.70	40124.80	< 0.001
	UOP 100-500 mL/day (Oliguric)	7674.59	4313.64	6296.95	2095.40	15578.90	
	UOP 500-1000 mL/day (Preserved)	3868.91	3082.95	3023.90	734.90	10984.30	
	UOP>1000 mL/day	1165.27	851.55	948.70	376.40	2822.60	
IVC collapsibility	**<50%**	13655.87	10799.42	11025.20	2052.40	40124.80	< 0.001
	50%	14651.90	.	14651.90	14651.90	14651.90	
	>50%	2779.26	2029.07	2822.60	376.40	6307.10	

NT-proBNP levels were significantly higher in hypertensive cases and in those receiving antihypertensive medications, while patients with polycystic kidney disease had significantly lower levels. Urine output was strongly associated with NT-proBNP concentrations, with the highest levels observed in anuric patients and the lowest in those with urine output >1000 mL/day (p<0.001). Similarly, reduced IVC collapsibility was related to significantly higher NT-proBNP concentrations (p< below 0.001). No significant associations were observed with sex, vascular access, diabetes mellitus, HCV infection, or most underlying renal etiologies. Table (5)

Table (6): association between NT pro-bnp and clinical, laboratory and echocardiography parameters

	NT-pro bnp (pg/ml)		
	Correlation Coefficient	**P value**	**N**
Age	0.314	0.036	45
Dry wt (kg)	-0.161-	0.292	45
height (m)	-0.255-	0.091	45
BMI (Kg/m^2)	-0.047-	0.762	45
BSA (m^2)	-0.220-	0.147	45
IDWG (kg)	0.832	< 0.001	45
SBP (mmHg)	0.851	< 0.001	45
DBP (mmHg)	0.698	< 0.001	45
HR	-0.177-	0.245	45
Hb (g/dl)	-0.772-	< 0.001	45
HCT %	-0.781-	< 0.001	45
Cr (mg/dl)	0.095	0.534	45
urea (mg/dl)	0.384	0.009	45
Na (mEq/L)	0.255	0.090	45
K (mEq/L)	0.318	0.033	45
Ca (mg/dl)	-0.058-	0.706	45
P (mg/dl)	0.498	< 0.001	45
LVEF (%)	-0.468-	0.001	45
LVEDD (cm)	-0.070-	0.645	45
LVESD (cm)	0.128	0.400	45
IVST (cm)	0.713	< 0.001	45
PWT (cm)	0.677	< 0.001	45
LAD (cm)	0.745	< 0.001	45
LAVI (ml/m^2)	0.124	0.418	45
LVMI (g/m^2)	0.520	< 0.001	45
DCT (ms)	-0.630-	< 0.001	45
E/A ratio	0.644	< 0.001	45
E/e`ratio	0.866	< 0.001	45
IVC Diameter (cm)	0.859	< 0.001	45

Correlation analysis demonstrates several significant associations between NT-proBNP levels and clinical, NT-proBNP illustrated significant positive correlations with age, IDWG, SBP, DBP, urea, potassium, and phosphorus,

and significant negative correlations with hemoglobin and hematocrit. Regarding echocardiographic parameters, significant positive correlations were observed with IVST, PWT, LAD, LVMI, E/A ratio, E/e′ ratio, and IVC diameter, while significant negative correlations were found with LVEF and DCT. The strongest positive correlations were detected with E/e′ ratio (r=0.866, p below 0.001), IVC diameter (r=0.859, p<0.001), SBP (r=0.851, p<0.001), and IDWG (r=0.832, p<0.001). Insignificant associations were detected with dry weight, height, BMI, BSA, heart rate, creatinine, sodium, calcium, LVEDD, LVESD, or LAVI (p>0.05). Table (6)

Table (7): diagnostic accuracy of studied markers

Area Under the Curve	P value	95% Confidence Interval				
		Lower Bound	Upper Bound	Cut off	Sensitivity %	Specificity %
0.871	< 0.001	0.769	0.973	7235.25	72	95

NT pro – bnp showed that the best chosen cut- off level was 7235.25, at which sensitivity was 72% and specificity was 95%. The AUC was 0.871. Table (7)

DISCUSSION

The present study showed a predominance of males and hypertension among hemodialysis patients, with hypertensive nephropathy being the most common underlying renal disease. Reduced urine output and IVC collapsibility <50% were also common findings. Rage et al. (10) similarly reported a male predominance among maintenance hemodialysis patients, with males representing 66.1% of their study population, which was close to the 64.4% observed in the present study. Al-Saray and Ali (11) also demonstrated a high prevalence of volume excess in maintenance hemodialysis patients, with 93% having IVC collapsibility <50%; however, this proportion was higher than the 55.6% observed in the present study, which may reflect variances in case characteristics and methods utilized to assess volume status.

Compared with controls, hemodialysis cases had significantly greater blood pressure, heart rate, creatinine, urea, sodium, potassium, and phosphorus, with lower hemoglobin and hematocrit, while age, dry weight, BMI, BSA, and calcium showed no significant differences. Wang et al. (2) reported that volume overload was common among hemodialysis patients and revealed an independent relation among NT-proBNP and overhydration, supporting the importance of volume-related abnormalities in this population. Similarly, Helal et al. (12) found markedly elevated NT-proBNP concentrations in hemodialysis cases compared with healthy controls, while no significant associations were detected with BMI or dry weight, which is consistent with the lack of significant variances in these parameters in the present research.

NT-proBNP concentrations were markedly elevated in ESKD cases than in healthy controls (p<0.001). Ooi et al. (13) similarly demonstrated a significant relation between NT-proBNP and hydration status in dialysis patients and reported a positive correlation between NT-proBNP and extracellular water/total body water ratio. In contrast, Booth et al. (14) suggested that elevated NT-proBNP in dialysis patients was not necessarily explained by cardiac dysfunction alone and might predominantly reflect volume-related factors together with other conditions such as malnutrition. This indicates that elevated NT-proBNP in ESKD is likely multifactorial and should be interpreted within the overall clinical context.

Echocardiographic assessment showed significant differences in most structural and functional parameters, including LVEF, ventricular dimensions, wall thickness, LAD, LAVI, LVMI, E/e′ ratio, and IVC diameter, while DCT and E/A ratio were not significantly different. Kim et al. (15) reported significant differences in IVST and left ventricular posterior wall thickness between dialysis patients with volume overload and those with normal volume status, supporting the association between excess volume and cardiac remodeling. Conversely, Wang et al. (2) demonstrated that NT-proBNP remained independently related to objectively measured overhydration even following adjustment for cardiac function, suggesting that echocardiographic abnormalities alone may not completely account for elevated NT-proBNP and that the biomarker may provide additional information regarding systemic fluid excess.

NT-proBNP was significantly greater in hypertensive cases, those receiving antihypertensive medications, patients with lower urine output, and those with reduced IVC collapsibility. Roberts et al. (16) similarly demonstrated progressively lower NT-proBNP concentrations with increasing residual renal function and urine output in maintenance hemodialysis patients, supporting the inverse relationship between residual urine production and NT-proBNP observed in the present study. In contrast, Furlan et al. (17) reported that IVC diameter and IVC collapsibility were not independent predictors of NT-proBNP after adjustment for other cardiac and volume-related variables, suggesting that NT-proBNP reflects multiple interacting determinants rather than intravascular volume alone.

Correlation analysis showed that NT-proBNP was significantly related to several clinical, laboratory, and echocardiographic parameters, with particularly strong positive correlations with E/e′ ratio, IVC diameter, systolic blood pressure, and interdialytic weight gain, and negative correlations with LVEF and DCT. Lee et al. (18) similarly reported that NT-proBNP was significantly associated with overhydration and inversely associated with ejection fraction, with progressively increasing NT-proBNP concentrations according to the severity of diastolic dysfunction. These observations strongly support the

present findings linking NT-proBNP with both fluid status and cardiac function. In contrast, Furlan et al. (17) found that interdialytic weight gain was not an independent predictor of NT-proBNP following multivariable adjustment, although E/e′ remained independently related to NT-proBNP. This difference highlights the multifactorial nature of NT-proBNP elevation in dialysis patients and suggests that filling pressure may sometimes have a greater independent influence than simple interdialytic weight accumulation.

ROC analysis showed good diagnostic performance of NT-proBNP for fluid overload, with an AUC of 0.871, a cutoff value of 7235.25 pg/mL, 72% sensitivity, and 95% specificity. Ooi et al. (13) similarly reported good diagnostic performance of NT-proBNP for the identification of hypervolemia, with an AUC of 0.80. Although their reported cutoff and diagnostic indices differed from those of the present study, likely because of differences in dialysis modality and patient characteristics, both studies support the usefulness of NT-proBNP in the assessment of volume status.

CONCLUSION

NT-pro BNP is a significant biomarker for evaluation of fluid overload in ESKD cases receiving regular hemodialysis.

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