

Original Article

Correlations Between Estimated Pulmonary Capillary Wedge Pressure (ePCWP) and Clinical Parameters in Hemodialysis Patients: A Clinical Study in an Iranian Referral Hospital

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Abstract

Background: Due to fluid overload, hemodialysis patients are at a high risk of cardiovascular complications. Accurate assessment of fluid status is vital for optimal management. This study investigates correlations between Estimated Pulmonary Capillary Wedge Pressure (ePCWP) and clinical parameters in hemodialysis patients to evaluate its utility in fluid management.

Materials and Methods: This clinical study included 40 hemodialysis patients from an Iranian referral hospital. Patients were selected based on strict inclusion and exclusion criteria. Data collection involved comprehensive assessments of demographic, clinical, and examination data, with baseline and post-dialysis measurements obtained. Tissue Doppler imaging and echocardiography were performed before and after dialysis, and ePCWP was calculated. Statistical analyses were conducted using IBM SPSS Statistics, version 26, to explore correlations between ePCWP, bioimpedance measures, and clinical factors.

Results: Significant post-dialysis reductions were observed in systolic blood pressure (mean difference=7.25 mmHg, $p<0.001$), diastolic blood pressure (mean difference=4.37 mmHg, $p<0.001$), and weight (mean difference=2.27 kg, $p<0.001$), alongside a decrease in extracellular water to total body water (ECW/TBW) ratio (mean difference=0.01, $p<0.001$). However, no significant difference was found in ePCWP before and after dialysis (mean difference=0.881 mmHg, $p=0.4$). Correlation analysis revealed a moderately positive correlation between ePCWP before dialysis and ECW/TBW ($r=0.359$, $p=0.023$). However, it was not significantly correlated with blood pressure and weight.

Conclusion: ePCWP demonstrates potential as a marker for fluid status in hemodialysis patients, especially in settings where bioimpedance analysis is not available. However, its clinical utility requires further validation through larger randomized controlled trials.

Keywords: Fluid management, Hemodialysis, Estimated pulmonary capillary wedge pressure (ePCWP), Cardiovascular complications

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Introduction

Patients undergoing hemodialysis face significant challenges in fluid management, contributing to cardiovascular morbidity and mortality¹⁻⁴. Accurate assessment and management of fluid status are crucial in this population to prevent adverse cardiovascular events and optimize clinical outcomes⁵⁻⁹. Traditional methods for assessing fluid status, such as blood pressure measurements and bioimpedance analysis, have limitations in capturing the complex interplay between fluid overload, cardiovascular health, and therapeutic interventions¹⁰⁻¹⁴. Estimated Pulmonary Capillary Wedge Pressure (ePCWP), derived from echocardiographic measurements, has emerged as a promising tool for assessing fluid status in hemodialysis patients¹⁵⁻¹⁷. ePCWP reflects pulmonary circulation pressure during diastole and is influenced by intravascular volume and left ventricular filling pressures^{18,19}. Studies suggest that elevated ePCWP levels correlate with increased risk of cardiovascular events and mortality in dialysis patients, highlighting its prognostic significance^{20,21}. However, its role in fluid management remains ambiguous. This study aims to explore the correlation between ePCWP and clinical parameters in hemodialysis patients, particularly its relationship with extracellular water to total body water (ECW/TBW) ratios and blood pressure, which may provide valuable insights into fluid management strategies and clinical decision-making in this high-risk population.

Methods

Study Design and Participants: This prospective before-and-after clinical study was conducted at Imam Hossein Hospital in Tehran, Iran. A total of 40 adult patients who had been undergoing maintenance hemodialysis for at least six months at Imam Hossein Hospital were recruited for the study.

Exclusion criteria included: active malignancy, uncontrolled psychiatric illness, pregnancy, history of

alcohol or intravenous drug use, known bundle branch block or other significant cardiac conduction disorders, documented arrhythmias, severe heart failure, significant valvular heart disease, and patients undergoing their first dialysis session. Only patients receiving regular hemodialysis were included; those receiving peritoneal dialysis were excluded.

Ethical approval was obtained from the Ethics Committee of Shahid Beheshti University of Medical Sciences, Tehran, Iran (IR.SBMU.RETECH.REC.1402.195), and informed consent was obtained from all participants.

Diagnostic Procedures and Data Collection: Baseline demographic and clinical data were systematically collected using a researcher-designed checklist aligned with the study objectives. Information was gathered through patient interviews and reviewing medical records. Pre- and post-dialysis clinical parameters were assessed by the same trained personnel to ensure consistency.

All patients underwent transthoracic echocardiography, incorporating two-dimensional imaging and tissue Doppler imaging (TDI), both before and after dialysis following a 10-minute rest period. Studies were performed in the left lateral decubitus position using standard parasternal and apical views, with measurements acquired during normal respiration. A cardiologist performed all echocardiograms according to the guidelines of the American Society of Echocardiography, and measurements were averaged over five consecutive cardiac cycles.

Echocardiographic parameters recorded included left atrial diameter, left ventricular end-diastolic and end-systolic diameters, left atrial volume, stroke volume, cardiac output, and ejection fraction. Diastolic function was assessed using pulsed-wave Doppler of transmitral flow to obtain the early diastolic filling velocity (E), and TDI was used to measure the early diastolic velocity of the mitral annulus (e'). The ePCWP was calculated using the standard formula:

$$ePCWP \approx 1.24 \times (E/e') + 1.9$$

Patients were categorized into two groups based on

their predialysis ePCWP values: those with ePCWP < 20 mmHg and those with ePCWP \geq 20 mmHg, a threshold used in previous studies to reflect elevated left-sided filling pressures and potential fluid overload.

Statistical Analysis: Statistical analysis was performed using IBM SPSS Statistics for Windows, version 26 (IBM Corp). Descriptive statistics were utilized to summarize baseline characteristics and clinical parameters. Paired t-tests were employed for variables with normal distribution to compare pre- and post-dialysis values. For non-normally distributed variables, the Wilcoxon signed-rank test was used. Correlations between ePCWP and clinical variables, including bioimpedance measures and blood pressure, were assessed using Pearson correlation coefficients. A p-value of < 0.05 was considered statistically significant.

Results

Table 1 presents a detailed overview of the baseline characteristics of the 40 hemodialysis patients enrolled in the study. The mean age was 60.5 years (SD=14.5), and 42.5% of participants were female. The mean systolic and diastolic blood pressures were 133.5 mmHg (SD=14.5) and 83.6 mmHg (SD=10.4), respectively. The mean body weight was 72.3 kg (SD=12.7), and the mean ECW/TBW ratio was 0.40 (SD=0.01).

In terms of volume status, 62.5% of patients had clinically detectable edema. Echocardiographic assessment revealed pulmonary congestion (defined as echocardiographic wedge overload) in 97.5% of patients. A dilated inferior vena cava (IVC) was observed in 47.5% of participants, while 52.5% had a normal IVC diameter. Reduced IVC collapsibility, another marker of volume overload, was present in 37.5% of patients.

Physiological Parameters Before and After Dialysis: Table 2 summarizes the changes in key physiological parameters following a single hemodialysis session. Statistically significant reductions were observed in multiple variables post-dialysis. The mean systolic blood pressure decreased by 7.25 mmHg ($p < 0.001$), and diastolic blood pressure decreased by 4.37 mmHg ($p < 0.001$). Body weight was reduced by an average of 2.27 kg ($p < 0.001$), reflecting

Table 1. Baseline Characteristics of Study Participants.

Variables	Mean	Std. Deviation
Age	60.5	14.50
Height	166.0	9.25
Weight	72.3	12.69
Bp (systolic)	133.5	14.50
Bp (diastolic)	83.6	10.37
ECW/TBW	0.4	0.01
EPCWP	19.7	5.35
Gender	Frequency	Percent
Female	17	42.5
Male	23	57.5
Edema		
No Edema	15	37.5
Edema	25	62.5
Echo overload by wedge		
No echo overload	1	2.5
Echo overload	39	97.5
Dilated IVC		
No Dilated	21	52.5
Dilated	19	47.5
Reduced IVC collapsibility		
Non-Reduced	25	62.5
Reduced	15	37.5

Table 2. Changes in physiological parameters before and after dialysis.

Paired Differences	Mean difference	Std. Deviation	p-value
BP systolic before/after	7.25	11.09	0.00
BP diastolic before/after	4.37	8.10	0.00
Weight before/after	2.27	1.24	0.00
ECW/TBW before/ after	0.01	0.01	0.00
EPCWP before/after	0.88	6.64	0.40

effective fluid removal. A significant reduction was also observed in the ECW/TBW ratio, with a mean change of 0.01 ($p < 0.001$), indicating a measurable improvement in fluid balance.

In contrast, there was no statistically significant change in the ePCWP values before and after dialysis (mean difference=0.88 mmHg, $p=0.40$). This lack of change suggests that ePCWP may not be sensitive to acute fluid shifts within a single dialysis session, or that the predialysis fluid status was already well-managed in

Table 3. Correlation between EPCWP before dialysis and other clinical parameters.

Parameters	Statistics	EPCWP	ECW/TBW	Bp (systolic)	Bp (diastolic)	Weight
EPCWP	Pearson Correlation	1	0.359*	0.071	0.045	-0.189
	Sig. (2-tailed)	-	0.023	0.665	0.783	0.243
ECW/TBW(Total)	Pearson Correlation	0.359*	1	0.139	0.089	-0.026
	Sig. (2-tailed)	0.023	-	0.393	0.584	0.875
Bp (systolic)	Pearson Correlation	0.071	0.139	1	0.808**	0.289
	Sig. (2-tailed)	0.665	0.393	-	0.000	0.070
Bp (diastolic)	Pearson Correlation	0.045	0.089	0.808**	1	0.313*
	Sig. (2-tailed)	0.783	0.584	0.000	-	0.049
Weight	Pearson Correlation	-0.189	-0.026	0.289	0.313*	1
	Sig. (2-tailed)	0.243	0.875	0.070	0.049	-

this patient cohort. These findings are discussed further in relation to fluid status assessment tools and their limitations in the Discussion section.

EPCWP Predialysis Correlations: Table 3 displays the correlation analysis between ePCWP before dialysis and various clinical parameters. A moderate positive correlation was observed between predialysis ePCWP and the ECW/TBW ratio ($r=0.359$, $p=0.023$), suggesting that higher left-sided filling pressures may be associated with greater extracellular fluid volume. No significant correlations were found between ePCWP and systolic blood pressure ($r=0.071$, $p=0.665$), diastolic blood pressure ($r=0.045$, $p=0.783$), or body weight ($r=-0.189$, $p=0.243$), though a weak negative trend with weight was noted.

Additionally, strong internal correlations were found between systolic and diastolic blood pressure ($r=0.808$, $p<0.001$), and a mild but statistically significant positive correlation was observed between diastolic blood pressure and weight ($r=0.313$, $p=0.049$), which may reflect fluid status influences on systemic hemodynamics.

EPCWP Post-Dialysis Correlations: As shown in Table 4, post-dialysis ePCWP demonstrated a non-significant trend toward a positive correlation with the ECW/TBW ratio ($r=0.289$, $p=0.071$), indicating that higher fluid overload may continue to reflect in elevated ePCWP, although not reaching statistical significance. Correlations with systolic ($r=0.094$, $p=0.563$) and diastolic blood pressure ($r=-0.033$, $p=0.840$) remained

Table 4. Correlation between EPCWP after dialysis and other clinical parameters.

Parameters	Statistics	EPCWP	ECW/TBW	BP (systolic)	BP (diastolic)	Weight
EPCWP	Pearson Correlation	1	0.289	0.094	-0.033	-0.035
	Sig. (2-tailed)	-	0.071	0.563	0.840	0.832
ECW/TBW (Total)	Pearson Correlation	0.289	1	0.053	-0.002	-0.171
	Sig. (2-tailed)	0.071	-	0.743	0.988	0.291
Bp (systolic)	Pearson Correlation	0.094	0.053	1	0.616**	0.255
	Sig. (2-tailed)	0.563	0.743	-	0.000	0.112
Bp (diastolic)	Pearson Correlation	-0.033	-0.002	0.616**	1	0.324*
	Sig. (2-tailed)	0.840	0.988	0.000	--	.041
Weight	Pearson Correlation	-0.035	-0.171	0.255	0.324*	1
	Sig. (2-tailed)	0.832	0.291	0.112	0.041	-

non-significant. Similarly, a weak and non-significant negative correlation was observed between ePCWP and weight ($r=-0.035$, $p=0.832$).

As in the predialysis analysis, systolic and diastolic blood pressure remained strongly correlated ($r=0.616$, $p<0.001$), and diastolic blood pressure showed a mild positive correlation with weight ($r=0.324$, $p=0.041$).

These findings suggest that while ePCWP correlates moderately with ECW/TBW before dialysis, its utility in reflecting acute fluid shifts post-dialysis remains limited, supporting the need for further investigation in larger, controlled studies.

Discussion

Principal finding: This study explored the relationship between ePCWP and fluid status indicators in hemodialysis patients. Predialysis, ePCWP demonstrated a moderate positive correlation with ECW/TBW, indicating a possible association between elevated left-sided filling pressures and extracellular volume overload. No significant associations were observed between ePCWP and systolic or diastolic blood pressure. A weak, non-significant negative correlation was seen with weight. Post-dialysis, similar trends persisted, although correlations were weaker and did not reach statistical significance. Internal consistency was observed in expected correlations between systolic and diastolic blood pressure, as well as between diastolic blood pressure and body weight.

Clinical implications: The observed correlations between ePCWP levels and clinical parameters, such as ECW/TBW ratios and blood pressure, provide valuable insights for clinicians and policymakers²²⁻²⁴. Understanding the relationship between ePCWP and ECW/TBW ratios before and after dialysis could aid in the early identification of fluid overload in patients undergoing hemodialysis, potentially leading to more timely interventions to manage fluid balance. Furthermore, ePCWP may offer clinical value as a non-invasive surrogate marker for assessing fluid status, particularly in settings where bioimpedance analysis is not available^{17,25,26}. Its moderate association with ECW/TBW before dialysis indicates potential utility in identifying patients with chronic extracellular volume overload. However, the absence of significant ePCWP changes post-dialysis and its lack of correlation with blood pressure metrics suggest limitations in its

responsiveness to acute fluid shifts.

This emphasizes the complexity of fluid management in these patients, underscoring the importance of individualized treatment strategies tailored to patient-specific characteristics²⁷⁻³¹.

For clinicians, this highlights the need for multimodal fluid assessment strategies. While ePCWP may support decision-making in long-term fluid management, it should not replace direct measures such as bioimpedance or ultrafiltration monitoring. The data also reinforce the importance of individualized care, given the heterogeneity in fluid response among dialysis patients. This study has several limitations. First, the sample size ($n = 40$) limits statistical power and generalizability. Second, the cross-sectional before-and-after design, while useful for capturing dialysis-related changes, does not account for longer-term trends or outcomes. Third, measurements were performed at only one time point pre- and post-dialysis, potentially overlooking dynamic changes in ePCWP and fluid status. Additionally, potential confounders, including residual kidney function, medication use, and comorbid cardiovascular conditions, were not fully accounted for. Lastly, the interpretation of ePCWP is limited by the variability in echocardiographic estimation techniques, and this should be validated against invasive hemodynamic data in future research.

Conclusion

This study contributes to a growing body of evidence suggesting that estimated PCWP, derived from echocardiographic measures, may serve as a supportive tool in fluid status assessment in hemodialysis patients. Its moderate correlation with ECW/TBW ratios before dialysis supports its potential role in identifying volume overload, particularly in settings where access to bioimpedance technology is limited. However, its limited responsiveness to acute fluid shifts warrants caution in short-term assessment. Larger, longitudinal studies with standardized methods and more comprehensive clinical data are necessary further to define the role of ePCWP in dialysis-related fluid management.

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Conflict of interest

The authors further declare that they have no conflict of interest.

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