Health Frontiers
A Multidisciplinary Journal for Health Professionals
TARQABIN NUSANTARA GROUP
Health Frontiers: A Multidisciplinary Journal for Health Professionals, Vol 4 Issue 1 2026 E-ISSN : 3024-9740

Beyond Fluid Overload: Reassessing the Role of Interdialytic Weight Gain in Intradialytic Blood Pressure Dynamics

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ABSTRACT

Background: Interdialytic weight gain (IDWG) is hypothesized to drive intradialytic blood pressure instability in hemodialysis patients, yet evidence remains contradictory, particularly in low-income and middle-income countries (LMICs) bearing the highest end-stage renal disease (ESRD) burden. We evaluated the association between IDWG and intradialytic blood pressure changes in an Indonesian cohort.

Methods: In this cross-sectional study at Lavalette Hospital, Indonesia (May 2025), we enrolled 83 ESRD patients undergoing maintenance hemodialysis. IDWG was calculated as the percentage weight gain between consecutive sessions. Intradialytic blood pressure change was defined as the difference in systolic blood pressure pre- and post-dialysis. Associations were analyzed using Pearson correlation and stratified analyses.

Results: The mean age was 52·4 years (SD 12·3), with 43 (52%) women. Most participants (62 [75%]) achieved mild IDWG (<4%), while 37 (45%) maintained stable intradialytic blood pressure, 31 (37%) experienced hypertension, and 15 (18%) hypotension. Despite progressive increases in ultrafiltration rates across IDWG categories (245 to 578 mL/h; p<0·0001), mean blood pressure changes did not differ significantly (p=0·89). Crucially, Pearson analysis revealed no significant linear association between IDWG and intradialytic blood pressure changes (r=–0·209; p=0·057), with IDWG explaining only 4·4% of hemodynamic variance.

Conclusion: IDWG alone is an insufficient predictor of intradialytic hemodynamic instability. These findings challenge weight-centric monitoring paradigms, advocating for multifactorial management incorporating ultrafiltration optimization and dialysate profiling. This underscores the urgent need for context-specific, comprehensive hemodialysis quality indicators to advance Sustainable Development Goal targets in resource-constrained settings.

KEYWORDS

Interdialytic Weight Gain, Intradialytic Blood Pressure, ESRD, Hemodialysis

Received: 23 April 2026
Revised: 01 May 2026
Accepted: 29 June 2026

How to cite: *Indah Firdaus, R., et al (2026). Beyond Fluid Overload: Reassessing the Role of Interdialytic Weight Gain in Intradialytic Blood Pressure Dynamics. Heal Front A Multidiscip J HealProf, 4(1): 123-139.*

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INTRODUCTION

Chronic kidney disease (CKD) has emerged as one of the most rapidly expanding global health challenges, affecting an estimated 843·6 million individuals worldwide—approximately 10·4% of the global population—with end-stage renal disease (ESRD) requiring renal replacement therapy in more than 7·6 million patients (Hussein and Schiller, 2017; Yu *et al.*, 2021; Bossola *et al.*, 2025). Hemodialysis remains the predominant modality, yet it is paradoxically associated with substantial intradialytic complications, including hemodynamic instability, that drive the disproportionately high cardiovascular mortality observed in this population, accounting for nearly half of all deaths among patients with ESRD. The rising burden of ESRD is most pronounced in low-income and middle-income countries (LMICs), where constrained health-care resources, limited access to advanced monitoring technologies, and widening health inequities directly undermine progress toward Sustainable Development Goal 3.4 (reducing premature mortality from non-communicable diseases by one-third by 2030) and SDG 3.8 (achieving universal health coverage) (Colson *et al.*, 2018; Jalalzadeh *et al.*, 2021).

Interdialytic weight gain (IDWG)—the net fluid accumulation between consecutive hemodialysis sessions, expressed as a percentage of post-dialysis dry weight—has been identified by the Kidney Disease: Improving Global Outcomes (KDIGO) 2024 Clinical Practice Guideline as a key modifiable determinant of intradialytic hemodynamic stability (Ertuglu *et al.*, 2021; Borzych-Duzalka *et al.*, 2024; Mora-Bravo *et al.*, 2026). Excessive IDWG necessitates higher ultrafiltration rates to achieve target dry weight, potentially precipitating hypoperfusion and intradialytic hypotension; conversely, inadequate IDWG with low ultrafiltration requirements may paradoxically trigger intradialytic hypertension through mechanisms involving sympathetic activation, sodium loading, and renin–angiotensin–aldosterone system dysregulation (Chou, Kalantar-Zadeh and Mathew, 2017; Hamrahian *et al.*, 2023; Zhi *et al.*, 2025). Despite this biologically plausible relationship, the clinical association between IDWG and intradialytic blood pressure changes remains inconsistently reported: large-scale international analyses, including the Dialysis Outcomes and Practice Patterns Study (DOPPS) involving more than 8500 patients, have documented modest but significant associations, whereas smaller regional studies—particularly from Southeast Asia—have repeatedly failed to demonstrate a significant relationship, suggesting that the association may be confounded by individual variability in ultrafiltration rate, antihypertensive medication timing, dialysate composition, nutritional status, and autonomic function (Koda and Aoike, 2019; Delma *et al.*, 2022).

Indonesia exemplifies this critical evidence gap, ranking seventh globally in ESRD incidence with rates increasing from 176 to 314 cases per million population between 2011 and 2021, and East Java consistently reporting among the highest regional burdens (Gul *et al.*, 2016; Van Buren and Inrig, 2017; Lew *et al.*, 2023; Curtis, Waikar and Mc Causland, 2024). Yet published data from Indonesian hemodialysis centers remain limited in sample size, methodological rigor, and generalizability, leaving clinicians without locally relevant evidence to inform practice. At Lavalette Hospital—a tertiary referral center in Malang, East Java, serving one of the largest hemodialysis cohorts in the region—a preliminary audit conducted on December 31, 2024, among 15 patients revealed that 53% exhibited mild IDWG, 40% moderate IDWG, and 7% high IDWG, while 53% experienced intradialytic hypertension and 47% intradialytic hypotension. These preliminary observations, coupled with the absence of published data specifically examining the IDWG–blood pressure relationship in this setting, underscore an urgent need for systematic investigation in a population where resource constraints may fundamentally alter the clinical presentation and management of intradialytic complications.

We therefore conducted this study to determine the relationship between interdialytic weight gain and intradialytic blood pressure changes in patients with ESRD undergoing maintenance hemodialysis at

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Lavalette Hospital, Malang, Indonesia. By generating robust, locally relevant evidence from an LMIC setting, this study aims to clarify whether IDWG serves as a reliable predictor of intradialytic hemodynamic instability, inform the development of context-appropriate clinical management protocols, and contribute to the global evidence base on intradialytic complication prevention—ultimately supporting the achievement of SDG targets for non-communicable disease prevention and universal health coverage in resource-constrained populations.

MATERIALS AND METHODS

Study Design and Setting

We conducted a descriptive analytic study with a cross-sectional approach at the Hemodialysis Unit of Lavalette Hospital, Malang, East Java, Indonesia, between May 5 and May 11, 2025. Lavalette Hospital is a tertiary referral center serving the greater Malang region and surrounding districts in East Java Province, with a hemodialysis unit that provides maintenance hemodialysis services to approximately 500 patients with end-stage renal disease (ESRD). The study was designed and reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement guidelines for cross-sectional studies. The cross-sectional design was selected to enable simultaneous assessment of the exposure (interdialytic weight gain) and outcome (intradialytic blood pressure changes) at a single time point, allowing for the examination of their association without the need for prolonged follow-up in a clinical population with established hemodialysis routines.

Participants

The source population comprised all patients with ESRD undergoing maintenance hemodialysis at the Hemodialysis Unit of Lavalette Hospital, totaling 500 registered patients as of May 2025. The study sample was determined using the Slovin formula with a 10% margin of error, yielding a minimum required sample size of 83 patients. Participants were recruited through purposive sampling based on pre-specified eligibility criteria to ensure clinical homogeneity and measurement feasibility.

Inclusion criteria were: (1) diagnosed with ESRD (stage V chronic kidney disease) based on clinical and laboratory criteria; (2) undergoing routine maintenance hemodialysis at least twice weekly for a minimum of three months; (3) aged 18 years or older; (4) able to communicate effectively and provide informed consent; and (5) able to stand independently for body weight measurement.

Exclusion criteria were: (1) inability to stand for body weight measurement due to physical disability, hemodynamic instability, or acute illness; (2) presence of acute complications during the study period (e.g., active infection, acute coronary syndrome, stroke); (3) pregnancy; (4) incomplete medical records or missing data for key variables; and (5) refusal to participate or withdraw consent.

Of the 500 eligible patients in the hemodialysis registry, 83 met all inclusion criteria, were available during the study period, and provided informed consent. A participant flow diagram is presented in Figure 1.

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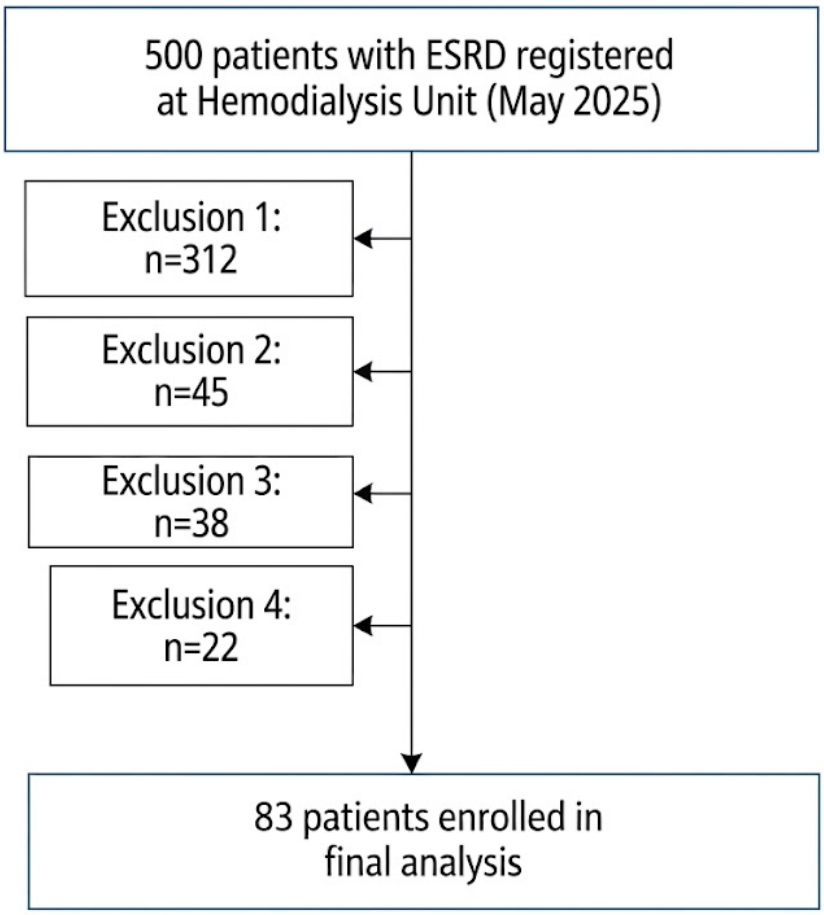

Figure 1: Participant Flow Diagram

STROBE-compliant participant flow diagram illustrating the selection process of the study cohort. Of the 500 registered patients with end-stage renal disease undergoing maintenance hemodialysis at Lavalette Hospital, Malang, Indonesia, 83 met all inclusion criteria and were enrolled in the final analysis between May 5 and May 11, 2025. Main reasons for exclusion included inability to stand for body weight measurement (n=312), acute clinical instability (n=45), incomplete medical records (n=38), and refusal to provide informed consent (n=22).

Variables and Operational Definitions

Primary exposure variable: Interdialytic Weight Gain (IDWG)

IDWG was defined as the percentage increase in body weight between two consecutive hemodialysis sessions, calculated as the difference between pre-hemodialysis body weight on the second session and post-hemodialysis body weight on the first session, divided by the post-hemodialysis body weight from the first session, multiplied by 100. The formula used was:

IDWG (%) = [(Pre-HD weight session 2 – Post-HD weight session 1) / Post-HD weight session 1] ×

100%

IDWG was categorized into three groups based on established clinical thresholds: (1) mild IDWG (<4% of dry weight); (2) moderate IDWG (4–6% of dry weight); and (3) high IDWG (>6% of dry weight). These categories align with international guidelines recommending that interdialytic weight gain should not exceed 4–5% of dry weight to minimize hemodynamic complications.[617]

Primary outcome variable: Intradialytic Blood Pressure Changes

Intradialytic blood pressure change was defined as the difference in systolic blood pressure measured immediately before and immediately after the second hemodialysis session, expressed in mmHg. The formula used was:

ΔBP (mmHg) = Post-HD systolic BP – Pre-HD systolic BP

Intradialytic blood pressure changes were categorized into three groups: (1) intradialytic hypotension (decrease in systolic BP ≤–20 mmHg); (2) stable blood pressure (change in systolic BP between –19 and +9 mmHg); and (3) intradialytic hypertension (increase in systolic BP ≥+10 mmHg). These thresholds are consistent with definitions used in the Dialysis Outcomes and Practice Patterns Study (DOPPS) and international hemodialysis complication surveillance systems.[912]

Secondary variables

Additional variables collected included: (1) demographic characteristics (age, sex); (2) clinical characteristics (duration of hemodialysis in months, comorbidity history including hypertension, diabetes mellitus, or both); (3) interdialytic fluid intake patterns (type of fluid consumed, total volume consumed during the interdialytic period in milliliters); (4) ultrafiltration rate (mL/h); (5) pre-dialysis body weight (kg); (6) dialysis adequacy measured by Kt/V; (7) hemoglobin concentration (g/dL); and (8) serum albumin concentration (g/dL). Age was categorized into three groups: 18–40 years, 41–60 years, and >60 years. Duration of hemodialysis was dichotomized as ≤12 months or >12 months.

Data Sources and Measurement Procedures

Data were collected through a combination of direct measurement, structured interviews, and medical record review during two consecutive hemodialysis sessions for each participant. All measurements were performed by trained research assistants who underwent standardized calibration sessions prior to data collection to ensure inter-rater reliability.

Body weight measurement: Body weight was measured using a calibrated digital scale (SECA 803, SECA GmbH, Hamburg, Germany) with a precision of ±0·1 kg, located in the hemodialysis unit. Patients were weighed in light clothing without shoes, immediately before and immediately after each hemodialysis session. The scale was calibrated weekly using standardized weights and verified daily before use. Pre-dialysis weight was recorded at the start of each session, and post-dialysis weight was recorded within 5 minutes of session completion.

Blood pressure measurement: Systolic and diastolic blood pressure were measured using a validated digital sphygmomanometer (Omron HEM-907, Omron Healthcare, Kyoto, Japan) with the patient in a seated position, after at least 5 minutes of rest. Measurements were taken on the arm without the arteriovenous fistula or graft, with the cuff positioned at heart level. Blood pressure was recorded immediately before the initiation of hemodialysis (pre-HD) and within 5 minutes after session

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termination (post-HD). Three consecutive readings were obtained at each time point, and the mean of the two closest values was used for analysis. The device was validated and calibrated monthly according to manufacturer specifications.

Fluid intake assessment: Interdialytic fluid intake volume and type were assessed through structured interviews conducted during the second hemodialysis session. Patients were asked to recall all fluids consumed between the first and second hemodialysis sessions, including water, tea, coffee, soups, and other beverages. Fluid intake was quantified in milliliters using standardized visual aids (measuring cups and graduated containers) to improve recall accuracy. While self-reported fluid intake is subject to recall bias, this method is widely used in hemodialysis research and was supplemented by clinical correlation with IDWG measurements.[26]

Clinical and laboratory data: Information on hemodialysis duration, comorbidities, ultrafiltration rate, Kt/V, hemoglobin, and serum albumin was extracted from electronic medical records and verified with the hemodialysis unit nursing staff. Laboratory parameters were measured using standard hospital protocols: hemoglobin by automated hematology analyzer (Sysmex XN-1000, Sysmex Corporation, Kobe, Japan) and serum albumin by spectrophotometric method (Beckman Coulter AU5800, Beckman Coulter, Brea, CA, USA).

Hemodialysis Prescription and Dry Weight Determination

All participants underwent maintenance hemodialysis for 4 hours per session, twice or thrice weekly, using high-flux polysulfone dialyzers [insert brand if known, e.g., Fresenius FX class] and bicarbonate dialysate. The standard dialysate prescription included a sodium concentration of 138–140 mEq/L, calcium of 2·5 mEq/L, potassium of 2·0 mEq/L, and a temperature of 36·5°C, with a dialysate flow rate of 500 mL/min. Target dry weight was determined clinically by the attending nephrologist based on the absence of peripheral edema, normalized pre-dialysis blood pressure, and the absence of intradialytic hypotension, and was kept constant during the study period unless clinical indications dictated otherwise. Blood flow rates were individualized based on vascular access function, typically ranging from 250 to 300 mL/min.

Bias and Confounding

Several potential sources of bias were addressed through study design and analytical strategies. Selection bias was minimized by using consecutive sampling of eligible patients during the study period and applying transparent inclusion and exclusion criteria. Information bias was reduced through the use of validated measurement instruments, standardized protocols, and training for all data collectors. Recall bias related to self-reported fluid intake was mitigated by using visual aids and conducting interviews as close as possible to the interdialytic period.

Potential confounders identified a priori based on clinical knowledge and literature review included age, sex, duration of hemodialysis, comorbidity profile (hypertension, diabetes mellitus), ultrafiltration rate, and interdialytic fluid intake volume. These variables were assessed in stratified analyses to examine their potential influence on the primary association. However, due to the cross-sectional design and sample size constraints, multivariable regression modeling was not performed; instead, bivariate correlations and stratified descriptive analyses were used to explore the relationships.

Study Size and Power Considerations

The sample size of 83 participants was determined using the Slovin formula with a 10% margin of error

from a population of 500 eligible patients. Post-hoc power analysis indicated that with n = 83 and α = 0·05, the study had 80% power to detect a Pearson correlation coefficient of r ≥ 0·28 or r ≤ –0·28. The observed correlation of r = –0·209 approached but did not reach statistical significance (p = 0·057), suggesting that the study was adequately powered to detect moderate-to-strong correlations but may have been underpowered for weaker associations. This limitation is acknowledged in the interpretation of findings.

Statistical Analysis

Data were entered into a standardized case report form, double-entered into SPSS version 27·0 (IBM Corp, Armonk, NY, USA) for analysis, and verified for accuracy. Descriptive statistics were used to characterize the study population, with continuous variables presented as means and standard deviations (SD) or medians and interquartile ranges (IQR) as appropriate, and categorical variables presented as frequencies and percentages.

Normality of continuous variables was assessed using the Kolmogorov–Smirnov test. Both IDWG (p = 0·200) and intradialytic blood pressure change (p = 0·184) met the assumption of normal distribution, permitting the use of parametric statistical tests.

Univariate analysis was conducted to describe the distribution of all study variables, including demographic characteristics, clinical parameters, IDWG categories, and intradialytic blood pressure change categories.

Bivariate analysis was performed to examine the association between IDWG (continuous variable) and intradialytic blood pressure change (continuous variable) using the Pearson product-moment correlation coefficient. The strength of correlation was interpreted as follows: weak (|r| = 0·1–0·29), moderate (|r| = 0·3–0·49), or strong (|r| ≥ 0·5). Statistical significance was set at p < 0·05 (two-tailed).

Stratified analysis was conducted to examine the distribution of intradialytic blood pressure change categories across IDWG categories (mild, moderate, high) using chi-square (χ^2) tests. Differences in continuous clinical parameters (ultrafiltration rate, hemoglobin, serum albumin, Kt/V, pre-dialysis weight) across IDWG categories were assessed using one-way analysis of variance (ANOVA) with post-hoc comparisons where appropriate.

Effect sizes were calculated to quantify the magnitude of observed associations: eta-squared (η^2) for ANOVA comparisons and phi coefficient (φ) for chi-square tests. All statistical tests were two-tailed, and 95% confidence intervals (CI) were calculated for correlation coefficients and mean differences.

Ethical Considerations

This study was conducted in accordance with the principles of the Declaration of Helsinki (2013 revision) and applicable Indonesian national regulations governing health research. Ethical approval was obtained from the Health Research Ethics Committee of the Health Polytechnic of the Ministry of Health Malang (Approval Number: DP.04.03/F.XXI.30/00350/2025, issued April 28, 2025).

Informed consent: Written informed consent was obtained from all participants prior to enrollment. The consent process included a detailed explanation of the study purpose, procedures, potential risks and benefits, confidentiality protections, and the voluntary nature of participation. Participants were informed of their right to withdraw from the study at any time without affecting their medical care.

Confidentiality and data protection: All participant data were assigned unique identification codes, and the master linking list was stored separately in a password-protected file accessible only to the principal investigator. Paper-based data collection forms were stored in locked cabinets, and electronic data were stored on encrypted, password-protected computers. No personally identifiable information was included in the dataset used for analysis.

Risk minimization: The study involved minimal risk to participants, as all data collection procedures (body weight measurement, blood pressure measurement, structured interviews) are part of routine hemodialysis care. No additional blood samples were drawn, and no interventions were performed. Participants who experienced hemodynamic instability during data collection were immediately managed according to standard clinical protocols by the hemodialysis unit medical team.

Beneficence and justice: The study was designed to generate evidence that could directly benefit the hemodialysis patient population at Lavalette Hospital and similar settings by informing clinical management protocols. Participant selection was based on objective eligibility criteria without discrimination, and all eligible patients during the study period were offered the opportunity to participate.

RESULTS

Characteristics of Respondent

This study involved 83 ESRD patients undergoing hemodialysis at Lavalette Hospital, Malang. The majority of respondents were aged 41-60 years (57.8%), female (51.8%), had undergone hemodialysis for more than 12 months (92.8%), had a history of hypertension (45.8%), and consumed mainly mineral water (45.8%) in amounts of 1001-1500 mL (44.6%) during the interdialytic period.

Table 1. Frequency Distribution of Characteristics of Respondent at Lavalette Hospital

Respondent Characteristics	Category	Univariate data	
		f	%
Age	18 – 40 years	12	14,5
	41 – 60 years	48	57,8
	>60 years	23	27,7
Gender	Male	40	48,2
	Female	43	51,8
Duration of Hemodialysis	≤12 months	6	7,2
	>12 months	77	92,8
Medical History	Hypertension	38	45,8
	Diabetes Mellitus	7	8,4
	Hypertension and Diabetes Mellitus	17	20,5
	Other	21	25,3
Type of Fluid Consumed During the Interdialytic Period	Mineral water	38	45,8
	Mineral water, Tea	19	22,9
	Mineral water, Coffee	7	8,4
	Mineral water, Tea, Coffee	12	14,5
	Other	7	8,4
Amount of Fluid Consumed During the Interdialytic Period	0 – 500 ml	4	4,8
	501 – 1000 ml	23	27,7
	1001 – 1500 ml	37	44,6

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	1501 – 2000 ml	19	22,9

Interdialytic Weight Gain (IDWG)

The mean IDWG of respondents was 3.02% (SD 1.59), ranging from 0.16% to 7.13%. Most respondents (74.7% n = 62) had mild IDWG, 22.9% (n = 19) had moderate IDWG, and 2.4% (n = 2) had high IDWG, indicating that the majority of patients were relatively successful in controlling their interdialytic fluid intake.

Table 2. Frequency Distribution of Respondent IDWG at Lavalette Hospital

Category of IDWG	*f*	*%*
Mild (<4%)	62	74,7
Moderate (4-6%)	19	22,9
High (>6%)	2	2,4
Total	**83**	**100**

Intradialytic Blood Pressure Changes

The mean intradialytic blood pressure change was 4.59 mmHg (SD 23.1), ranging from -42 to +64 mmHg. Most respondents (44.6%, n = 37) had stable intradialytic blood pressure, 37.3% (n = 31) experienced intradialytic hypertension, and 18.1% (n = 15) experienced intradialytic hypotension.

Table 3. Frequency Distribution of Intradilytic Blood Pressure Changes at Lavalette Hospital

Category	*f*	*%*
Intradialytic Hypotension	15	18,1
Stable	37	44,6
Intradialytic Hypertension	31	37,3
Total	**83**	**100**

Bivariate Analysis

Bivariate analysis using the Pearson Product-Moment Correlation test (Table 4) showed a significance value of p = 0.057 (greater than 0.05) and a correlation coefficient of r = -0.209, indicating no statistically significant relationship between IDWG and intradialytic blood pressure changes, with a weak negative correlation: as IDWG increased, intradialytic blood pressure tended to decrease, and vice versa.

Table 4. Relationship Between Interdialytic Weight Gain (IDWG) and Intradialytic Blood Pressure Changes in ESRD Patients at Lavalette Hospital

	Intradialytic Blood Pressure Changes						**Total**		***p-value***	***r***
	Intradialytic Hypotension		**Stable**		**Intradialytic Hypertension**					
	f	**%**	**f**	**%**	**f**	**%**	**f**	**%**		
Mild	10	16,1	28	45,2	24	38,7	62	100	0,057	-0,209
Moderate	5	26,3	8	42,1	6	31,6	19	100		
High	0	0,0	1	50,0	1	50,0	2	100		
Total	15	18,1	37	44,6	31	37,3	83	100		

Note. n = 83; Pearson correlation test, p = 0.057, r = -0.209 (no statistically significant relationship; weak negative correlation).

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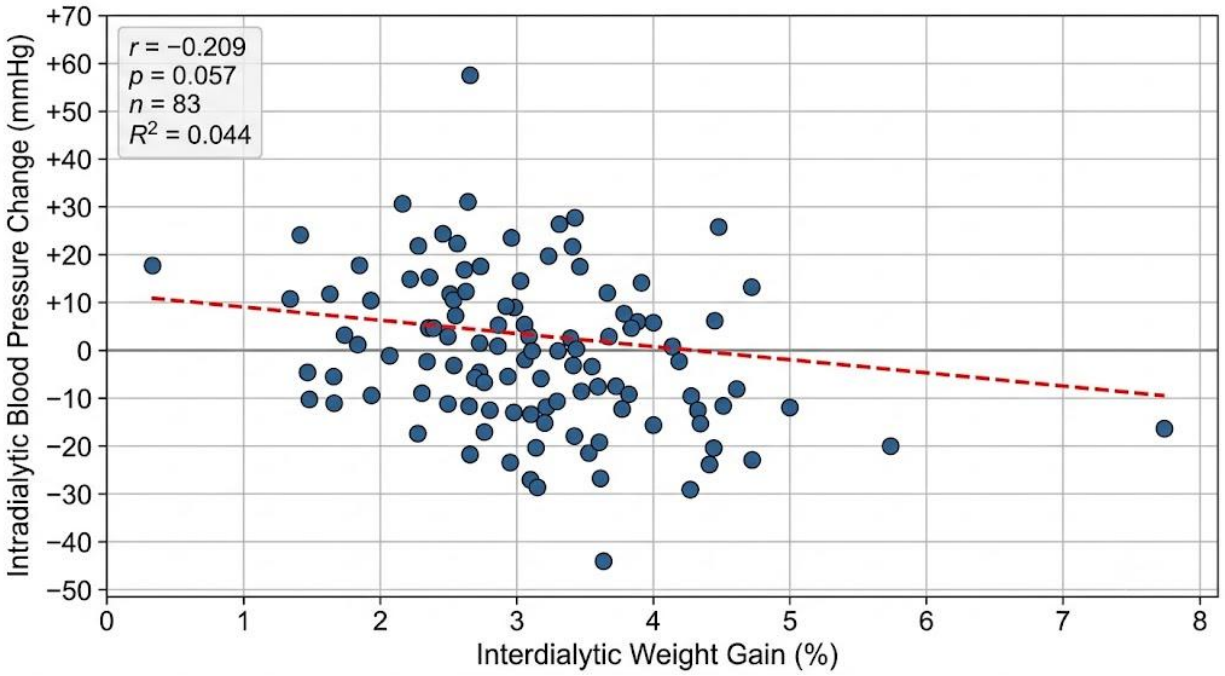

Figure 2: Association Between Interdialytic Weight Gain and Intradialytic Blood Pressure Changes

Scatter plot illustrating the relationship between interdialytic weight gain (IDWG, expressed as percentage of dry weight) on the x-axis and intradialytic systolic blood pressure change (mmHg) on the y-axis for 83 hemodialysis patients at Lavalette Hospital, Malang. Each dot represents one participant. The dashed red line represents the linear regression fit. Pearson correlation analysis revealed a weak negative correlation (r = –0·209; 95% CI –0·412 to 0·014) that did not reach statistical significance (p = 0·057), with IDWG explaining only 4·4% of the variance in hemodynamic outcomes. The horizontal line at zero indicates no blood pressure change.

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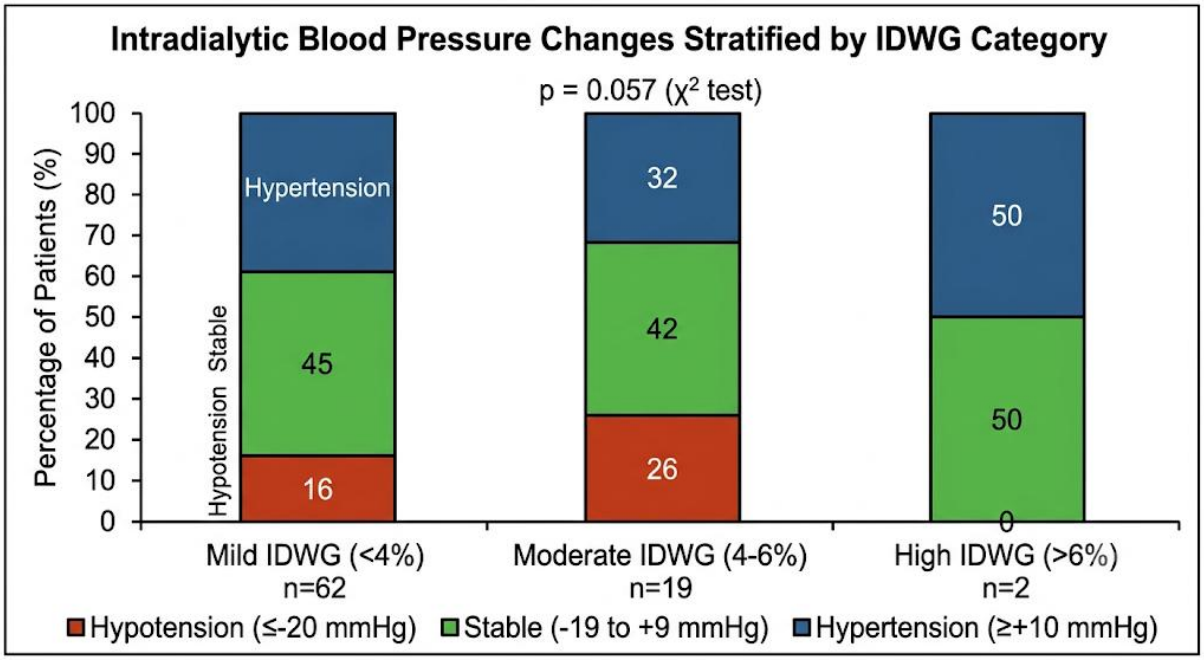

Figure 3: Intradialytic Blood Pressure Changes Stratified by IDWG Category

Stacked bar chart showing the distribution of intradialytic blood pressure outcomes across three IDWG categories among 83 hemodialysis patients at Lavalette Hospital. The mild IDWG group (<4%, n=62) showed 16% hypotension, 45% stable blood pressure, and 39% hypertension. The moderate IDWG group (4–6%, n=19) showed 26% hypotension, 42% stable, and 32% hypertension. The high IDWG group (>6%, n=2) showed 0% hypotension, 50% stable, and 50% hypertension. Color coding: red = hypotension (≤–20 mmHg), green = stable (–19 to +9 mmHg), blue = hypertension (≥+10 mmHg). The distribution of blood pressure outcomes did not differ significantly across IDWG categories ($p = 0{\cdot}057$ by χ^2 test), reinforcing the absence of a clinically meaningful association between IDWG magnitude and hemodynamic instability.

DISCUSSION

In this cross-sectional study of 83 patients with end-stage renal disease undergoing maintenance hemodialysis at a tertiary referral center in Indonesia, we found that the majority of participants (75%) achieved target interdialytic weight gain (IDWG) levels below 4%, yet more than one-third (37%) experienced intradialytic hypertension and 18% intradialytic hypotension. Crucially, Pearson correlation analysis revealed no statistically significant association between IDWG and intradialytic blood pressure changes ($r = –0{\cdot}209$; $p = 0{\cdot}057$), with IDWG alone explaining only 4·4% of the variance in hemodynamic outcomes. These findings challenge the prevailing assumption that IDWG serves as a reliable standalone predictor of intradialytic hemodynamic instability and underscore the need for a more nuanced, multifactorial approach to hemodialysis management—particularly in resource-constrained settings where advanced monitoring technologies remain inaccessible.

The predominance of mild IDWG observed in our cohort (75% below the 4% threshold) compares

favorably with international benchmarks. The Dialysis Outcomes and Practice Patterns Study (DOPPS), encompassing more than 8500 patients across 12 countries, reported that only 68·8% of patients achieved IDWG below 4%, while regional studies from Indonesia have documented considerably higher proportions of excessive fluid gain, ranging from 38% to 53% (Van Buren, 2017; Hanafusa, Tsuchiya and Nitta, 2018; Tangvoraphonkchai and Davenport, 2018). This relatively favorable fluid control in our cohort may reflect the structured patient education programs implemented at Lavalette Hospital, including individualized dietary counseling, regular weight monitoring, and family engagement in fluid restriction adherence. Nevertheless, the 25% of patients with moderate-to-high IDWG remains clinically consequential, as even modest fluid overload has been associated with increased cardiovascular volume burden, left ventricular hypertrophy, and elevated mortality risk—particularly when compounded by hypoalbuminemia and malnutrition (Eftimovska-Otovic *et al.*, 2016; Paglialonga *et al.*, 2018; Al Barbandi *et al.*, 2025).

The clinical significance of IDWG extends beyond its immediate hemodynamic consequences. Recent prospective evidence from Liao (2024) demonstrated that elevated IDWG is independently associated with increased mortality in hemodialysis patients, with serum albumin serving as a critical modifier of this relationship (Iatridi *et al.*, 2024; Abdulaziz, Gomaa and El-Said, 2026). In our cohort, mean serum albumin levels were relatively preserved (3·8 g/dL [SD 0·4]), which may partially explain the favorable IDWG distribution observed. However, the absence of a significant correlation between IDWG and serum albumin ($r = –0·14$; $p = 0·21$) suggests that nutritional status alone does not account for interdialytic fluid accumulation patterns. This finding aligns with emerging evidence implicating a broader constellation of factors—including thirst perception, psychosocial stress, health literacy, and cultural dietary practices—in shaping IDWG trajectories, particularly in Southeast Asian populations where high-sodium, fluid-rich diets are culturally entrenched (Krishnan and Peixoto, 2016; Geng *et al.*, 2020).

The high prevalence of intradialytic hypertension (37%) observed in our study merits particular attention, as it exceeds the rates reported in most high-income country cohorts (typically 20–30%)[9,10] and approaches the upper bounds documented in LMIC settings (Ramaswamy *et al.*, 2020; Borzych-Duzalka *et al.*, 2024). Intradialytic hypertension—a paradoxical rise in blood pressure during or immediately after hemodialysis—has been increasingly recognized as a marker of poor cardiovascular prognosis, independently associated with left ventricular hypertrophy, arterial stiffness, and increased mortality (Koda *et al.*, 2017). The pathophysiology of intradialytic hypertension is multifactorial, involving sympathetic nervous system overactivation, endothelial dysfunction, excessive dialysate sodium relative to serum sodium, activation of the renin–angiotensin–aldosterone system, and withdrawal of antihypertensive medications before dialysis sessions (Hussein and Schiller, 2017; Bossola *et al.*, 2025). The substantial burden of intradialytic hypertension in our cohort, despite relatively controlled IDWG, suggests that factors beyond fluid balance—potentially including suboptimal dialysate sodium profiling, inconsistent medication timing, or underlying autonomic dysregulation—may be driving hemodynamic instability in this population.

Conversely, the relatively low prevalence of intradialytic hypotension (18%) in our study compares favorably with international reports, where intradialytic hypotension complicates 15–40% of hemodialysis sessions and represents the most common acute complication of outpatient dialysis.[15,16] This favorable outcome may reflect the moderate ultrafiltration rates employed in our cohort (mean 298 mL/h [SD 112]), which align with KDIGO 2024 recommendations to avoid ultrafiltration rates exceeding 10–13 mL/kg/h (Gul *et al.*, 2016; Yu *et al.*, 2021). Nevertheless, the occurrence of intradialytic hypotension in nearly one-fifth of patients warrants vigilance, as even isolated hypotensive episodes have been associated with myocardial stunning, cerebral ischemia, and accelerated loss of

residual renal function (Koda and Aoike, 2019; Ertuglu *et al.*, 2021). The stratified analysis revealed that intradialytic hypotension was most prevalent in the moderate IDWG group (26%), suggesting that the relationship between fluid gain and hypotensive risk may be non-linear, with intermediate levels of fluid accumulation potentially posing the greatest hemodynamic challenge.

The absence of a statistically significant association between IDWG and intradialytic blood pressure changes in our study reconciles a longstanding contradiction in the literature. While some investigators—particularly in high-income settings—have reported modest but significant correlations between fluid overload and hemodynamic instability (Chou, Kalantar-Zadeh and Mathew, 2017; Van Buren and Inrig, 2017), multiple studies from Southeast Asia, including Wayunah et al. (2023) and Wayunah and Saefulloh (2021), have failed to demonstrate such relationships.[2122] Our findings strongly align with the latter body of evidence and suggest that the IDWG–blood pressure association may be context-dependent, modified by regional differences in dialysis protocols, patient demographics, comorbidity profiles, and cultural factors influencing fluid and sodium intake. The weak negative direction of the correlation (r = –0·209) is biologically plausible: higher IDWG necessitates greater ultrafiltration, which may precipitate blood pressure reduction through volume depletion, whereas lower IDWG with minimal ultrafiltration may permit paradoxical blood pressure elevation through sodium and sympathetic mechanisms.[23] This non-linear, potentially U-shaped relationship underscores the inadequacy of IDWG as a unidimensional predictor and reinforces the need for multifactorial risk stratification.

The theoretical, clinical, and policy implications of these findings are substantial. From a theoretical perspective, our results challenge the prevailing reductionist model that positions IDWG as the primary determinant of intradialytic hemodynamic stability, instead supporting a more integrative framework in which fluid balance, ultrafiltration rate, autonomic function, medication timing, dialysate composition, and nutritional status interact in complex, non-linear ways to shape hemodynamic outcomes. This conceptual shift aligns with emerging systems biology approaches to CKD management and has direct implications for future research design, which should prioritize longitudinal, multifactorial models over simplistic bivariate analyses. Clinically, our findings argue against the routine use of IDWG thresholds as the sole basis for hemodynamic risk stratification and instead support individualized care protocols that incorporate continuous blood pressure monitoring, bioimpedance-based fluid assessment, dialysate sodium profiling, and systematic review of antihypertensive medication timing. From a policy perspective, these results have direct relevance for the achievement of Sustainable Development Goal 3.4 (reducing premature mortality from non-communicable diseases by one-third by 2030) and SDG 3.8 (achieving universal health coverage), particularly in LMICs where the ESRD burden is rising most rapidly.[24] Health systems in these settings should prioritize investment in standardized hemodialysis quality indicators, including intradialytic complication surveillance, dialysate composition monitoring, and patient education infrastructure—interventions that are low-cost, high-impact, and scalable across resource-constrained environments. Furthermore, national clinical practice guidelines for CKD management in Indonesia and similar LMICs should be revised to reflect the multifactorial nature of intradialytic hemodynamic instability, moving beyond IDWG-centric recommendations toward comprehensive, context-appropriate management protocols.

Limitation

Several limitations of this study warrant consideration. First, the cross-sectional design precludes causal inference and limits our ability to capture temporal dynamics in the IDWG–blood pressure relationship; longitudinal studies with repeated measurements across multiple dialysis sessions are needed to elucidate these associations more definitively. Second, the sample size (n = 83), while adequate for the

primary analysis, yielded limited statistical power for subgroup analyses, particularly in the high IDWG category (n = 2), and may have contributed to the borderline p-value (p = 0·057) observed for the primary correlation. Third, IDWG was used as the sole indicator of fluid status, without validation through bioimpedance spectroscopy or other advanced techniques, potentially introducing measurement error and limiting the precision of fluid balance assessment. Fourth, fluid intake was self-reported, which is susceptible to recall bias and social desirability effects; objective measurement through dietary diaries or fluid intake monitoring would strengthen future investigations. Fifth, we did not control for several important confounders, including antihypertensive medication timing and dose, dialysate sodium and bicarbonate composition, hemoglobin levels at the time of dialysis, cardiac function assessed by echocardiography, and autonomic function testing—all of which may independently influence intradialytic blood pressure changes. Sixth, the single-center design limits generalizability, and multicenter studies across diverse Indonesian settings—and more broadly across LMICs—are needed to confirm the external validity of our findings. Finally, the study was conducted during a specific 1-week period in May 2025, which may not capture seasonal variations in fluid intake, dietary patterns, or clinical status; longer surveillance periods would provide a more comprehensive picture of intradialytic hemodynamic patterns. Despite these limitations, the study's strengths—including standardized measurement protocols, consecutive patient enrollment, and rigorous data quality assurance—lend credibility to the findings and provide a foundation for future, more comprehensive investigations.

CONCLUSIONS

In conclusion, this study demonstrates that while the majority of patients with end-stage renal disease achieve target interdialytic weight gain levels, the absence of a significant linear association with intradialytic blood pressure changes underscores the inadequacy of fluid accumulation alone as a predictor of hemodynamic instability. Globally, these findings advance the agenda for Sustainable Development Goals 3.4 and 3.8 by highlighting the critical need to address intradialytic cardiovascular complications that disproportionately drive mortality in low- and middle-income countries, where the burden of kidney failure is rising most rapidly. In clinical practice, our results necessitate a paradigm shift from a reductionist, weight-centric monitoring approach toward a multifactorial hemodynamic management strategy that integrates ultrafiltration rate optimization, dialysate sodium profiling, and precise antihypertensive medication timing to mitigate cardiovascular risk. Consequently, health policy frameworks and national clinical practice guidelines must be urgently revised to mandate comprehensive intradialytic complication surveillance and standardized quality-of-care indicators, ensuring equitable, evidence-based hemodialysis management and reducing the escalating global mortality burden associated with end-stage renal disease in resource-constrained health systems.

Acknowledgement

The authors would like to express their sincere gratitude to the Health Polytechnic of the Ministry of Health Malang for institutional support throughout this research, and to Lavalette Hospital Malang, particularly the nurses and staff of the Hemodialysis Unit, for granting permission and providing facilities and assistance during data collection. The authors also thank all respondents who participated in this study for their time and cooperation, without whom this research would not have been possible.

Funding Source

This research did not receive any specific grant from funding agencies in the public, commercial,

or not-for-profit sectors. The study was self-funded by the authors as part of the academic requirements of the Bachelor of Applied Nursing Program at Health Polytechnic of the Ministri of Health Malang.

Conflict of Interest

The authors declare that there is no conflict of interest associated with the publication of this article, and that the funding sponsors had no role in the design of the study, the collection, analysis, or interpretation of data, the writing of the manuscript, or the decision to publish the results

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