ORIGINAL ARTICLE

Correlation between right ventricular function and intradialytic hypotension in patients with chronic renal failure on regular hemodialysis

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Abstract

Background: ***The right side of the heart plays a role in maintaining pulmonary circulation and systemic hemodynamic stability. Intradialytic-hypotension (IDH) is a hemodialysis frequent complication, leading to increased morbidity-mortality. It results from impaired compensatory mechanisms, including cardiac dysfunction. This study evaluates right ventricular (RV) function in hemodialysis-patients with and without IDH using transthoracic echocardiography (TTE) and strain imaging.***

Methods: ***A cross-sectional study was conducted on 50 chronic kidney disease (CKD) patients undergoing regular hemodialysis at Al-Azhar University Hospitals. Patients divided into-two groups: 35 with IDH and 15 without. Echocardiographic parameters, including LV ejection-fraction (LVEF), global-longitudinal-strain (GLS), RV fractional-area-change (FAC), and tricuspid-annular-plane-systolic-excursion (TAPSE), were assessed.***

Results: ***IDH patients had significantly impaired RV function, with lower TAPSE (18.5 ± 1.12 mm vs. 21.5 ± 2.8 mm, p < 0.001), reduced RV FAC (36.1 ± 3.08% vs. 42.3 ± 2.35%, p < 0.001), and impaired RV GLS (-19.8 ± 1.53% vs. -23.5 ± 2.2%, p < 0.001). LV function was also compromised, with lower LVEF (55.2 ± 2.7% vs. 57.9 ± 1.83%, p < 0.001) and increased LV volumes.***

Conclusion: ***IDH is associated with significant RV dysfunction. RV GLS and TAPSE emerged as key predictors, highlighting the need for advanced echocardiographic assessments to improve risk stratification and management in hemodialysis patients.***

Keywords: Right Ventricular Function, Intradialytic Hypotension, GLS, TAPSE

1. Introduction

The right-ventricle has a pivotal role in sustaining pulmonary hemodynamics and systemic cardiovascular equilibrium. This unique physiology predisposes the RV to functional compromise in clinical scenarios marked by dynamic fluid shifts and vascular resistance alterations, such as chronic renal failure (CRF) and hemodialysis (HD).[1]

Among the most consequential dialysis-related complications is intradialytic hypotension (IDH), a condition associated with elevated morbidity and mortality. Defined by the Kidney Disease Outcomes Quality Initiative as a systolic blood pressure decline of≥20 mmHg or a mean arterial pressure reduction of≥10 mmHg requiring therapeutic intervention, IDH arises when physiological adaptations to ultrafiltration—such as vascular resistance modulation and cardiac output maintenance—become inadequate. Compromised neurovascular reflexes, including blunted sympathetic responses, exacerbate venous pooling and arteriolar dilation, precipitating acute hypotensive crises.[2-5]

Furthermore, structural cardiac anomalies, including diastolic dysfunction and left ventricular hypertrophy (LVH), impair ventricular compliance and diastolic filling, diminishing stroke volume and amplifying predisposition to IDH. Susceptibility to this complication is influenced by a constellation of factors: advanced age, DM, extended dialysis duration, lower pre-dialysis BP, female sex, and elevated body mass index (BMI).[6-8]

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Emerging evidence underscores the utility of speckle tracking echocardiography (STE) in detecting subclinical systolic dysfunction, transcending traditional reliance on LV-centric assessments. Recent investigations now implicate right ventricular dysfunction (RVD) as a critical yet underappreciated contributor to dialysis-induced hemodynamic instability.[9,10]

This study seeks to scrutinize disparities in cardiac function between IDH-prone and hemodynamically stable hemodialysis patients, with particular focus on advanced strain-based echocardiographic techniques. By leveraging transthoracic echocardiography with strain imaging, we aim to uncover nuanced myocardial impairments that conventional metrics might overlook, thereby refining risk stratification for this high-stakes complication.[11]

2. Patients and methods

This cross-sectional study was conducted at Al-Azhar University Hospitals from February 2024 to November 2024 on 50 patients with chronic kidney disease (CKD) undergoing regular hemodialysis three times weekly. The participants were divided into two groups: 35 patients who experienced intradialytic hypotension (IDH) and 15 who did not. Eligible patients were aged 18 years or older with suitable echocardiographic image quality, while those with acute renal failure, acute coronary syndrome, recent cerebrovascular events, conduction disturbances, pericardial disease, moderate valvular heart disease, chronic obstructive pulmonary disease (COPD), or poor image quality were excluded.

Ethical approval was obtained from the Faculty of Medicine, Al-Azhar University, and all participants provided informed consent. Detailed histories were recorded. IDH was defined as a SBP drop of ≥20 mmHg or a mean MAP reduction of ≥10 mmHg, accompanied by clinical symptoms requiring intervention.

Laboratory investigations included renal and liver function tests, complete blood count (CBC), fasting blood glucose, and lipid profile. Resting 12-lead electrocardiograms (ECG) were performed to assess electrical activity and conduction abnormalities.

Transthoracic echocardiography (TTE) was performed by expert cardiologists following ASE and EACVI guidelines.[18] Left ventricular (LV) function was evaluated using Simpson's biplane method to determine ejection fraction. Additionally, left atrial (LA) size was measured, and transmitral Doppler flow analysis was performed to assess peak E/A wave velocities and deceleration time. Tissue Doppler Imaging (TDI) was utilized to estimate LV filling pressures, specifically measuring early diastolic velocities and the E/E ratio.

For right ventricular (RV) function, several key parameters were assessed, including (TAPSE)-(FAC)-(MPI). Pulmonary artery pressure (PAP) was estimated based on tricuspid regurgitant jet velocity.

All statistical analyses were based on SPSS version 28, with a significance threshold set at $p < 0.05$, ensuring robust and reliable interpretation of the data.

3. Results

This cross-sectional study included 50 chronic kidney disease patients on regular hemodialysis, divided into two groups. Group I (35 patients) experienced interdialytic hypotension, with a mean age of 50.1 ± 10.9 years (65.7% male). Group II (15 patients) had stable hemodynamics, with a mean age of 47.8 ± 11.3 years (60% male).

Table 1. Demographic-data among the studied groups

VARIABLES		CASES GROUP (N=35)	CONTROL GROUP (N=15)	TEST	P VALUE
AGE (YEARS)	*Mean ± SD*	50.1 ± 10.9	47.8 ± 11.3	0.689	0.49[1]
	Range	(28 – 71)	(35 – 67)		
SEX (N. %)	Male	23 (65.7%)	9 (60%)	0.149	0.7[2]
	Female	12 (34.3%)	6 (40%)		
WEIGHT (KG)	*Mean ± SD*	75.9 ± 8.42	78 ± 12.23	-0.697	0.49[1]
	Range	(60 – 90)	(60 – 100)		
HEIGHT (CM)	*Mean ± SD*	168.1 ± 9.14	171.8 ± 6.17	-1.41	0.16[1]
	Range	(156 – 188)	(160 – 184)		
BMI (KG/M²)	*Mean ± SD*	27.1 ± 3.97	26.9 ± 3.27	0.100	0.92[1]
	Range	(20 – 35)	(22.2 – 33.5)		
RISK FACTORS (N. %)	HTN	14 (40%)	6 (40%)	0.00	1.00[2]
	DM	10 (28.6%)	5 (33.3%)	0.113	0.74[2]
	IHD	5 (14.3%)	3 (20%)	Fisher	0.68[3]

There was a notable statistical difference between the examined groups concerning left ventricular parameters. The cases group exhibited significantly higher LVEDV (P<0.001), LVESV (P<0.001), LV GLS (P<0.001), and LA volume (P=0.002) compared to the control group. Conversely, the cases group demonstrated a significantly lower EF than the control group (P<0.001).

Additionally, a significant statistical difference was observed between the groups regarding pulsed-wave trans-mitral inflow parameters. The cases group had a lower peak E wave, E/A ratio, and mean e' velocity in comparison to the control group, with P-values of 0.04, 0.01, and <0.001, respectively.

Table 2. Right ventricular dimensions among the studied groups

VARIABLES		CASES GROUP (N=35)	CONTROL GROUP (N=15)	TEST	P VALUE
BASAL (MM)	*Mean ± SD*	39.34 ± 2.58	33.13 ± 2.26	8.081	<0.001
	Range	(33 – 45)	(30 – 37)		
MID (MM)	*Mean ± SD*	32.54 ± 3.2	27.53 ± 2.32	5.459	<0.001
	Range	(26 – 37)	(24 – 31)		
LONGITUDINAL (MM)	*Mean ± SD*	76.09 ± 7.17	70.4 ± 3.98	2.876	0.006
	Range	(65 – 89)	(64 – 77)		
RV FREE WALL (CM)	*Mean ± SD*	0.51 ± 0.04	0.5 ± 0.02	0.882	0.38
	Range	(0.43 – 0.6)	(0.45 – 0.54)		
RA AREA	*Mean ± SD*	22.69 ± 5.27	19.33 ± 3.27	2.275	0.03
	Range	(14 – 32)	(14 – 26)		

Table 2 highlights a significant statistical difference between the studied groups in terms of right ventricular dimensions. The cases group exhibited larger basal (P<0.001), mid (P<0.001), and longitudinal (P=0.006) dimensions, as well as an increased RA area (P=0.03) compared to the control group.

Table 3. Right ventricular function among the studied groups

VARIABLES		CASES GROUP (N=35)	CONTROL GROUP (N=15)	TEST	P VALUE
TAPSE (MM)	*Mean ± SD*	18.5 ± 1.12	21.5 ± 2.8	-5.42	<0.001
	Range	(17 – 20)	(19 – 30)		
RV FAC (%)	*Mean ± SD*	36.1 ± 3.08	42.3 ± 2.35	-6.99	<0.001
	Range	(31 – 42)	(39 – 48)		
RV S WAVE VELOCITY (CM/S)	*Mean ± SD*	11.1 ± 1.58	12.1 ± 1.3	-2.23	0.03
	Range	(9 – 14)	(10 – 15)		
RV GLS (%)	*Mean ± SD*	-19.8 ± 1.53	-23.5 ± 2.2	6.87	<0.001
	Range	(-22 – -16)	(-28 – -20)		

Table (3) demonstrates a statistically significant difference in right ventricular function between the studied groups. The cases group exhibited lower TAPSE (P<0.001), reduced RV FAC (P<0.001), decreased RV S wave velocity (P=0.03), and lower RV GLS (P<0.001) compared to the control group.

Table 4. Pulmonary artery findings among the studied groups

VARIABLES		CASES GROUP (N=35)	CONTROL GROUP (N=15)	TEST	P VALUE
TR JET VELOCITY (M/S)	*Mean ± SD*	2.76 ± 0.37	2.63 ± 0.26	1.23	0.23
	Range	(2.2 – 3.42)	(2 – 2.9)		
TR DEGREE (N. %)	Mild	15 (42.9%)	8 (53.3%)	Fisher	0.26
	Moderate	14 (40%)	7 (46.7%)		
	Severe	6 (17.1%)	0 (0%)		
PASP (MMHG)	*Mean ± SD*	37.86 ± 8.001	33.47 ± 5.25	1.95	0.06
	Range	(25 – 52)	(22 – 40)		

Table (4) shows no significant-difference between the studied groups as regards TR jet velocity, TR degree and PASP (P>0.05).

After applying logistic regression analysis for predictors of intradialytic hypotension, LVEF, basal RV diameter, TAPSE, RV FAC, RV S wave and RV GLS can be used as independent factors for predicting intradialytic hypotension.

Table 5. ROC curve analysis of RV FAC, RV GLS, TAPSE, S wave, EF and LV GLS in predicting intradialytic hypotension

VARIABLES	CUT POINT	SENSITIVITY (%)	SPECIFICITY (%)	PPV (%)	NPP (%)	UC (%)
RV FAC	40	80%	77.14%	60%	90%	0.857
RV GLS	-20	73.33%	65.71%	47.83%	85.19%	0.767
TAPSE	20	80%	74.29%	57.14%	89.66%	0.817
S WAVE	11	93.33%	42.86%	41.18%	93.75%	0.697
BASAL RV	30	73.33%	54.29%	40.74%	82.61%	0.624
EF	58	86.67%	85.71%	72.22%	93.75%	0.890
LV GLS	-21.8	73.33%	54.29%	40.74%	82.61%	0.704

A (ROC) analysis was performed to establish optimal cutoff values for identifying intradialytic hypotension (IDH). Among the measured parameters, right-ventricular fractional area change (RV FAC) demonstrated the highest sensitivity (80%) and specificity (77.14%) at a cutoff value of 40, with an area under the curve (AUC) of 0.857. Similarly, RV global longitudinal strain (RV GLS) exhibited a sensitivity of 73.33% and specificity of 65.71% at a cutoff of -20 (AUC = 0.767).

Tricuspid-annular-plane-systolic-excursion (TAPSE) showed strong predictive capability with a sensitivity of 80% and specificity of 74.29% at a cutoff of 20 (AUC = 0.817). The S wave velocity had the highest sensitivity (93.33%) but lower specificity (42.86%) at a cutoff of 11 (AUC = 0.697). Basal right ventricular (RV) diameter showed moderate predictive value with an AUC of 0.624 at a cutoff of 30.

For left ventricular parameters, left ventricular ejection fraction (LVEF) was a strong predictor of IDH, with a sensitivity of 86.67% and specificity of 85.71% at a cutoff of 58 (AUC = 0.890). Additionally, left ventricular global longitudinal strain (LV GLS) had a sensitivity of 73.33% and specificity of 54.29% at -21.8 (AUC = 0.704). These findings emphasize the significance of echocardiographic measures in identifying patients at risk for IDH.

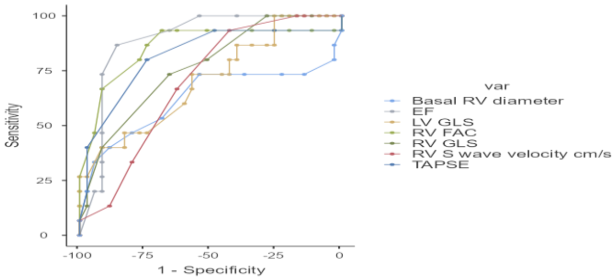

Figure 1. ROC-curve of RV FAC, RV GLS, TAPSE, S wave, EF and LV GLS in predicting intradialytic hypotension

4. Discussion

This cross-sectional analysis enrolled 50 adults with chronic kidney disease (CKD) undergoing thrice-weekly hemodialysis, aiming to dissect cardiac functional disparities between those developing intradialytic hypotension (IDH) and hemodynamically stable counterparts. By employing transthoracic echocardiography augmented with strain imaging, we sought to uncover distinctive patterns of left (LV) and right ventricular (RV) dysfunction that might illuminate novel diagnostic or prognostic insights into this dialysis-associated complication.

Diastolic dysfunction also featured prominently in IDH, characterized by a depressed E/A ratio (0.85 ± 0.16 vs. 0.99 ± 0.17; $p = 0.01$), reduced average e' velocity (7.68 ± 1.33 cm/s vs. 9.47 ± 0.51 cm/s; $p < 0.001$), and enlarged left atrial volume (23.4 ± 6.37 mm vs. 17.5 ± 3.83 mm; $p = 0.002$)—collectively signaling impaired relaxation and elevated filling pressures.[12,13]

Notably, IDH patients demonstrated marked impairments in both ventricular systems compared to stable peers, highlighting intricate cardiac-hemodynamic interplay during dialysis. RV dysfunction emerged as a pivotal factor, with IDH cohorts displaying significantly diminished TAPSE (TAPSE: 18.5 ± 1.12 mm vs. 21.5 ± 2.8 mm; $p < 0.001$), a cornerstone metric for RV longitudinal performance. Compromised RV contractility was further evidenced by reduced fractional area change (FAC: 36.1 ± 3.08% vs. 42.3 ± 2.35%; $p < 0.001$). Strikingly, RV-global-longitudinal-strain (GLS) is a sensitive marker of sub-clinical myocardial dysfunction.[14,15] was profoundly impaired in IDH patients (-19.8 ± 1.53% vs. -23.5 ± 2.2%; $p < 0.001$), underscoring its role in hemodynamic vulnerability.

Intriguingly, pulmonary-artery-systolic-pressure (PASP) and tricuspid regurgitation severity did not differ between groups ($p > 0.05$), implying that RV dysfunction in IDH stems from intrinsic myocardial impairment rather than pulmonary hypertension. This aligns with theories of disrupted RV-arterial coupling and ventricular interdependence, where RV inefficiency compromises LV filling during rapid ultrafiltration-induced hypovolemia.[16,17]

Mechanistically, RV dysfunction may hinder pulmonary circulation efficiency and LV preload adaptation during fluid shifts, predisposing to hypotension. Logistic regression identified RV GLS as an independent IDH predictor, with a cutoff of -20% yielding 73.3% sensitivity and 65.7% specificity. Similarly, TAPSE ≤20 mm predicted IDH with 80% sensitivity and 74.3% specificity, advocating for routine integration of these echocardiographic parameters in dialysis risk stratification.[18,19]

Beyond RV anomalies, subtle yet significant LV perturbations were observed. While LV ejection fraction (LVEF) was largely preserved, it trended lower in IDH patients (55.2 ± 2.7% vs. 57.9 ± 1.83%; $p < 0.001$). LV GLS, a robust detector of incipient systolic dysfunction, was markedly reduced (-19.4 ± 1.71% vs. -23.1 ± 1.43%; $p < 0.001$), suggesting that even marginal systolic declines may destabilize hemodynamics. Elevated LV volumes—end-diastolic (137 ± 13.5 ml vs. 102 ± 13.6 ml) and end-systolic (58.2 ± 7.02 ml vs. 42.5 ± 6.15 ml; both $p < 0.001$)—reflected chronic volume-pressure overload, emblematic of CKD cardiomyopathy. Such subclinical LV dysfunction, detectable via GLS, likely exacerbates dialysis-related instability.[10,11]

Contrasting with Abd Elshafey W et al.'s comparison of 114 HD patients to healthy controls[19], our study stratified 50 HD participants into IDH (n=35) and stable (n=15) subgroups, emphasizing hemodynamic volatility within the dialysis population. While both studies reported analogous RV dilation in HD patients, our IDH cohort exhibited more pronounced RV enlargement (basal: 39.34 ± 2.58 mm vs. 33.13 ± 2.26 mm; mid: 32.54 ± 3.2 mm vs. 27.53 ± 2.32 mm; longitudinal: 76.09 ± 7.17 mm vs. 70.4 ± 3.98 mm; $p \leq 0.006$). Moreover, IDH patients had severer RV systolic deficits (TAPSE: 18.5 ± 1.12 mm vs. 21.5 ± 2.8 mm; FAC: 36.1 ± 3.08% vs. 42.3 ± 2.35%; $p < 0.001$). Unlike Abd Elshafey W et al., who noted elevated Doppler Tie indices in HD patients, our analysis found no PASP differences, reinforcing that IDH-linked RV dysfunction arises from contractility deficits rather than pulmonary pressure anomalies.

A novel contribution lies in our receiver operating characteristic (ROC) analysis, establishing TAPSE <20 mm, FAC <40%, and RV GLS >-20% as robust IDH predictors—metrics absent in prior work. TAPSE and FAC exhibited high diagnostic accuracy (AUCs: 0.817 and 0.857, respectively), advocating their clinical utility in pre-dialysis risk assessment.

4. Conclusion

Intramedullary fixation of mid-shaft clavicular Intradialytic hypotension (IDH) in hemodialysis patients is closely linked to right ventricular dysfunction, significantly affecting hemodynamic stability.

Disclosure

The authors have no financial interest to declare in relation to the content of this article.

Authorship

All authors have a substantial contribution to the article

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Conflicts of interest

There are no conflicts of interest.

References

1. Poorzand H, Sharifipour F, Kerachian A. Echocardiographic parameters in patients with and without hypotension during dialysis. J Cardiovasc Imaging. 2021;29(3):123-130.
2. Soliman RA, Fawzy M, Kandil H. Assessment of hypotension during dialysis as a manifestation of myocardial ischemia in patients with chronic renal failure. Egypt J Crit Care Med. 2014;3(2):89-97.
3. Bayya A, Rubinger D, Linton DM, Sviri S. Evaluation of intradialytic hypotension using impedance cardiography. Int Urol Nephrol. 2011;43(2):567-573.
4. Hekmat R, Ahmadi M, Fatehi H. Correlation between asymptomatic intradialytic hypotension and regional left ventricular dysfunction in hemodialysis patients. Iran Heart J. 2011;12(1):45-52.
5. Sarafidis PA, Kamperidis V, Loutradis C. Haemodialysis acutely deteriorates left and right diastolic function and myocardial performance. Nephrol Dial Transplant. 2017;32(8):1402-1410.
6. Selby NM, Lambie SH, Camici PG. Occurrence of regional left ventricular dysfunction in patients undergoing standard and biofeedback dialysis. Am J Kidney Dis. 2006;47(5):873-882.
7. Assa S, Hummel YM, Voors AA. Changes in left ventricular diastolic function during hemodialysis sessions. Am J Nephrol. 2013;38(5):348-357.
8. Loutradis C, Sarafidis PA, Papadopoulos CE. The ebb and flow of echocardiographic cardiac function parameters in relationship to hemodialysis treatment in patients with ESRD. J Am Soc Nephrol. 2018;29(5):1503-1514.
9. Odudu A, McIntyre CW. An update on intradialytic cardiac dysfunction. Semin Dial. 2016;29(5):435-445.
10. Assa S, Hummel YM, Voors AA. Hemodialysis-induced regional left ventricular systolic dysfunction and inflammation: a cross-sectional study. Am J Nephrol. 2014;40(1):44-52.
11. Hung MJ, Chen CY, Lee CC. Echocardiographic assessments reveal septal e/e' ratio as an independent predictor of intradialytic hypotension in maintenance hemodialysis patients with preserved ejection fraction. Diagnostics (Basel). 2021;11(12):2266.
12. Krenning BJ, Voormolen MM, Geleijnse ML, Three-dimensional echocardiographic analysis of left ventricular function during hemodialysis. Nephron Clin Pract. 2007;107(2):c43-c50 .
13. Liang Y, Nie Y, Zhang Z. Hemodialysis-induced regional left ventricular systolic dysfunction. Hemodial Int. 2016;20(3):346-355.
14. Chiu DYY, Green D, Abidin N. Echocardiography in hemodialysis patients: uses and challenges. Am J Kidney Dis. 2014;64(6):1013-1021.
15. Assa S, Hummel YM, Voors AA. Hemodialysis-induced regional left ventricular systolic dysfunction: prevalence, patient and dialysis treatment-related factors, and prognostic significance. Clin J Am Soc Nephrol. 2012;7(10):1633-1640.
16. Ruffmann K, Mandelbaum A, Bommer J. Doppler echocardiographic findings in dialysis patients. Nephrol Dial Transplant. 1990;5(6):426-432.
17. Aoyama Y, Kajimoto K, Hori M. Predicting factors of intradialytic hypotension in the last half of hemodialysis therapy. Ren Replace Ther. 2021;7(1):12.
18. Mitchell C, Rahko PS, Blauwet LA. Guidelines for Performing a Comprehensive Transthoracic Echocardiographic Examination in Adults: Recommendations from the American Society of Echocardiography. J Am Soc Echocardiogr. 2019;32(1):1-64.
19. Abd Elshafey W, Abd-Elsamei M, Kandeel N, Soliman M. Assessment of right ventricular function in patients with chronic renal failure on regular dialysis by echocardiography. Zagazig Univ Med J. 2021;27(1):1-8.