Original Article

The Correlation of Volume Overload Measured by Bio Impedance Analysis and Intradialytic Hypertension in End Stage Kidney Disease Patients at Bandung Hasan Sadikin Hospital

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ABSTRACT

Background: Assessing dry weight is essential for calculating the ultrafiltration volume during dialysis. Volume overload affects hemodynamic stability including intradialytic hypertension (IDH). Using Bio Impedance Analysis (BIA) to guide fluid assessment enhances the accuracy of fluid overload evaluation.
Objective: This study aimed to find the correlation between volume overload and IDH in patients undergoing chronic dialysis at Bandung Hasan Sadikin Hospital
Methods: This is a cross-sectional study to evaluate the correlation of volume overload and IDH in patients undergoing chronic dialysis at Bandung Hasan Sadikin Hospital. Exclusion criteria were patient below the age of 18 years old, unable to performed BIA measurement. Blood pressure before, during and after dialysis session was recorded to asses IDH. BIA was measured after dialysis session. Point biserial correlation used to analyze correlation between volume overload and intradialytic hypertension. The data were analysed with SPSS version 23.0. The statistical significance was set at $P<0.05$.
Results: Ninety-seven patients enrolled, the average age was 49,9 ± 12.3 years old, 55,7% was male. There were 23,7% of patients with IDH with increasing systolic blood pressure of 19.21 mmHg (10-66). A significant correlation was observed between the incidence of IDH and the percentage of volume overload after dialysis with R coefficient 0,238 (p 0,014).
Conclusion: The majority (59.87%) of patients undergoing chronic hemodialysis had a greater dry weight based on BIA examination, 23,7% had IDH and its occurrence has a significant correlation with the percentage of volume overload after dialysis.
Keywords: Volume overload, dry weight, BIA, IDH.

Introduction

Chronic kidney disease (CKD) is a global health problem with escalating prevalence and incidence, poor prognosis, and steep costs. Globally, the total of patients undergoing kidney replacement therapy is more than 2.5 million, and is estimated to rise to 5.4 million by 2030.[1,2] The population of patients undergoing hemodialysis in Indonesia increases annually.[3]

The most prevalent complication in end-stage kidney disease (ESKD) patients is volume overload, which is closely linked to several other issues such as resistant hypertension, cardiac hypertrophy, congestive heart failure, or arterial stiffness. Therefore, volume overload is currently recognized as a crucial risk factor for unfavorable outcomes, such as all-cause or cardiovascular death.[4]

Assessing dry weight is fundamental in calculating the ultrafiltration volume during dialysis sessions. As a result, hemodynamic stability may be influenced and may lead to

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symptoms including muscle cramps, general weakness, abdominal pain, edema, dyspnea, hypotension, or hypertension during and after dialysis. Blood pressure checks conducted prior to and following dialysis, the weight increase occurring from one dialysis session to the next, and the patient's subjective symptoms have been used to determine the patient's body fluid volume excess index. Earlier studies have demonstrated that Bio Impedance Analysis (BIA) guided fluid assessment can help better assess a patient's fluid volume excess status and thereby greatly reduce patient mortality.[5–7]

Intradialytic hypertension (IDH) is a condition associated with dynamic changes in cardiac output during dialysis. The reduction in end-diastolic volume that occurs through the ultrafiltration process allows blood pressure to increase along with cardiac output. Studies of hypervolume in ESKD patients undergoing hemodialysis collectively support the practice that the initial approach in patients with IDH should be a reassessment of dry weight.[8–12]

Methods

Design and participants

We conducted a cross-sectional study to evaluate the correlation of volume overload and IDH in patient undergoing chronic dialysis at Bandung Hasan Sadikin Hospital . This study was conducted with the approval of the Research Ethical Board, Bandung Hasan Sadikin Hospital (approval number DP.04.03/D.XIV.6.5/329/2024), and all participants provided written informed consent prior to study enrollment. A total of 184 patients on chronic dialysis were enrolled in this study. Patients under the age of 18 years old, liver cirrhosis with ascites, active cancer, pulmonary oedema, patients with a history of severe illness in the past 12 weeks, and class III or class IV congestive heart failure (using the New York Heart Association classification system), including patients who had lymphedema of the limbs or had an amputation were excluded.

Study Covariate

Data on the patients' medical background, including their medical history, cause of kidney failure with corresponding replacement therapy, antihypertensive treatment, and duration of hemodialysis were collected from medical records. Blood pressure measurements were taken prior to, during, and following the dialysis session to assess intradialytic hypertension. BIA was measured after dialysis session. Given the individual need to remain standing for roughly 2 minutes before measurements are recorded using the TANITA BIA machine, only participants who can grip the arm holders of the machine using both hands and remain standing unassisted are included in the assessment. Extracellular Water (ECW) and Total Body Water (TBW) were measured and dry weight of patient was estimated based on an ECW/TBW ratio of 0,38.[13,14] The approach for determining dry weight is as follows:

Dry weight = Body weight − overhydrated ECW

(ECW − overhydrated ECW) ÷ (TBW − overhydrated ECW) = 0.380

Dry weight = Body weight – [[ECW – (0.380 × TBW)] ÷ (1 − 0.380)]

Patient with predicted dry weight meet with calculated dry weight measured by BIA were excluded. Volume overload (VO) was defined as excess body weight after undergoing dialysis substract by the amount of ultrafiltration in dialysis session.

Statistical analysis

Data were analysed using SPSS 23.0 and expressed as mean ± standard deviation or as median value (interquartile range) for data displaying skewed distribution. Differences in mean values between two groups were analysed with an unpaired t-test , while data with skewed distributions were compared using the Mann-Whitney U test.

The associations between variables were defined by Spearman's coefficient, correlation between categorical and numerical were defined by point biserial correlation and chi-square tests were used to determine the relationships between

categorical variables. A *p* values less than 0.05 were considered significant.

Results

Baseline characteristics including demographics and laboratory findings

Of 181 patients who had ongoing chronic dialysis at Bandung Hasan Sadikin Hospital, 22 patients were excluded because they could not undergo BIA examination, 62 patients had a dry weight that matched the BIA measurement, and 97 patients enrolled in this study. Table 1 presents a summary of the demographic data for the 97 patients. The average age calculated was 49,9 ± 12.3 years old; 55,7% were male participants and 44,3% were female participants. HD vintage was 3,8 year (2,2-7,5), most of them were hypertensive nephrosclerosis (26,8%) as the underlyng disease of ESKD, their dialysis adequacy (Kt/V) were near to appropriate 1.75 (1,59-1,95). Laboratory finding showed albumin at the level 3,88 ± 0.31 mg/dl, sodium 137,41 ± 2,77 mmol/L , kalium 4,63 ± 0,81mg/dl and serum creatinine 12.88 ± 3.35 mg/dl . Fourty two of the participant had high blood pressure before dialysis session and 23,7% had IDH. In pregeriatric and geriatric group high blood pressure before dialysis found in 21,6% and 4,1% respectively and IDH found in 11,3% and 4,1% respectively. The most widely used antihypertensive drug is Calcium Chanel Blocker (73.2%), followed by Angiotensin Receptor Blocker (50.52%), Beta Blocker and ACE Inhibitor.

Table 1. Baseline characteristics

Variable	N=97
Age (year), mean ± SD	49.9 ± 12.3
Pregeriatric (45-65 yo)	61 (62,9)
Geriatric (>65 yo)	11 (11,3)
Gender, n (%)	
Male	54 (55.7)
Female	43 (44.3)
HD vintage (year), median (IQR)	3.8 (2.2 – 7.5)
ESKD etiology, n (%)	
NA	29 (29.9)
Hypertensive Nephrosclerosis	26 (26.8)
Primary Glomerulopathy	18 (18.6)
Diabetic Nephropathy	14 (14.4)
Chronic pyelonephritis	2 (2.1)
Polycystic kidney	1 (1.0)
Nephritis Lupus	1 (1.0)
Obstructive Nephropathy	2 (2.0)
Others	4 (4.1)
Comorbidity, n (%)	
Hypertension	37 (38.1)
Diabetes melitus	12 (12.4)
Cardiovascular disease	9 (9.3)
SLE	1 (1.0)
Gastrointestinal disease	1 (1.0)
Laboratory, mean ± SD	
Albumin (g/dL)	3.88 ± 0.31
Kreatinin (µmol/L)	12.88 ± 3.35
Natrium (mmol/L)	137.41 ± 2.77

Variable	N=97
Kalium (mmol/L)	4.63 ± 0.81
Adequacy (Kt/V), median (IQR)	1.75 (1.59 – 1.95)
Pre HD hypertension, n (%)	42 (43.3)
Pregeriatric	21 (21,6)
Geriatric	4 (4,1)
IDH , n (%)	23 (23.7)
Pregeriatric	11 (11,3)
Geriatric	4 (4,1)
Antyhypertension agent, n (%)	
ACE (Ramipril)	2 (2,06)
ARB (Candesartan, Telmisartan, Valsartan)	49 (50,52)
CCB (Amlodipin, Nifedipin)	71 (73,2)
B Blocker (Bisoprolol, Cervedilol)	21 (21,65)
Others (Clonidin, Methyldopa)	3 (3,09)

Body weight distribution and volume overload

As Shown at Table 2, body weight before hemodialysis (pre-HD) had a median of 59.0 kg with an interquartile range (IQR) of 50.5 to 65.5 kg. After hemodialysis (post-HD), median body weight decreased to 55.5 kg (IQR 48.3 – 63.8 kg). Dry body weight, which is the ideal body weight calculated base.

Table 2. Body weight distribution and volume overload

Variable	N=97
Body weight	
Pre HD (kg), median (IQR)	59.0 (50.5 – 65.5)
Post HD (kg, median (IQR)	55.5 (48.3 – 63.8)
Dry weight based on BIA (kg), median (IQR)	52.6 (46.65 – 61.2)
Ultrafiltrasi (liter), median (IQR)	2.7 (2.3 – 3.3)
Volume Overload	
Pre HD (%), median (IQR)	8.9 (6.3 – 10.9)
Post HD (%), median (IQR)	4.1 (2.5 – 5.6)
Post HD (liter), mean ± SD	2.47 ± 1.30

Notes: SD=Standard Deviation, IQR=Inter Quartile Range

Ultrafiltration volume, which is the amount of fluid removed during hemodialysis, had a median of 2.7 liters, with an IQR of 2.3 to 3.3 liters. Before hemodialysis, fluid overload showed a median of 8.9% of body weight, with an IQR ranging from 6.3% to 10.9%. After hemodialysis, fluid overload was lowered to a median of 4.1% (IQR 2.5% – 5.6%). In absolute terms, the average excess fluid after hemodialysis is 2.47 liters with a standard deviation of 1.30 liters.

Blood pressure measurement

Blood pressure measurement before dialysis session had systolic blood pressure 142.10 ± 17.27 mmHg and during dialysis session tend to decrease from 144.44 ± 18.89 mmHg in 1st hour to 138.88 ± 21.33 mmHg after dialysis session. While diastolic blood pressure 82.11 ± 6.85 mmHg before dialysis and also tend to decrease to 79.12 ± 11.65 after dialysis session. As mention before, Fourty two of the participant had high blood pressure before dialysis session and 23,7% had IDH. The median of systolic blood pressure increasing in the IDH group was 19.21 mmHg (10-66) as shown in Table 3.

Table 3. Blood pressure variation before, during and after dialysis

BP measurement	n	Systolic		Diastolic	
		Mean ± SD	Median (IQR)	Mean ± SD	Median (IQR)
Before Dialysis	97	142.10 ± 17.27	140 (130 – 150)	82.11 ± 6.85	80 (80 – 90)
1st hour	97	144.44 ± 18.89	140 (140 – 158)	82.13 ± 7.63	80 (80 – 90)
2nd hour	97	143.22 ± 19.73	140 (130 – 160)	81.48 ± 7.87	80 (80 – 90)
3rd hour	97	142.79 ± 20.72	140 (130 – 160)	80.65 ± 10.66	80 (80 – 90)
4th hour	97	142.44 ± 20.43	140 (130 – 160)	79.20 ± 15.33	80 (80 – 90)
5th hour	97	139.68 ± 21.64	140 (120 – 160)	78.46 ± 13.19	80 (80 – 80)
After Dialysis	97	138.88 ± 21.33	140 (120 – 152.25)	79.12 ± 11.65	80 (80 – 90)
Average	97	141.34 ± 17.15	141 (130 – 153.5)	80.36 ± 6.23	80 (78 – 84)
Maximum	97	153.44 ± 19.75	150 (140 – 170)	86.11 ± 7.03	90 (80 – 90)

Notes: SD=Standard Deviation, IQR=Inter Quartile Range

Table 4 shows that the factor that has a significant relationship with the incidence of IDH is the percentage of volume overload after dialysis, which means that the greater the percentage of volume overload after dialysis, the greater the likelihood of IDH. Table 5 shows that when the study subjects were divided based on non-geriatric, pre-geriatric and geriatric age groups, it appears that in the non-geriatric and geriatric groups there was a significant relationship between the amount of ultrafiltration and the incidence of IDH, which means that the smaller the ultrafiltration volume, the more likely IDH is. While in the pregeriatric group, a significant relationship was found in the percentage of fluid excess after HD according to Table 4.

Table 4. Correlation of Body Weight, Ultrafiltration and Volume overload to the Incidence of IDH

Variable	IDH	
	R coefficient	P value
Body weight		
Before HD (kg)	-0.088	0.194
After HD (kg)	-0.109	0.144
Ultrafiltration volume (liter)	-0.141	0.084
Volume overload		
Before HD (%)	0.110	0.143
After HD (%)	**0.238**	**0.014***
After HD (liter)	-0.102	0.161

Analysis with point biserial correlation, *significancy p<0.05

Table 5. Correlation of Body Weight, Ultrafiltration and Volume overload to the Incidence of IDH in difference age groups

Variable	Non Geriatric (n=30)		Pre Geriatric (n=57)		Geriatric (n=10)	
	IDH		IDH		IDH	
	R coefficient	P value	R coefficient	P value	R coefficient	P value
Body weight						
Before HD (kg)	-0.233	0.108	-0.019	0.444	-0.237	0.255
After HD (kg)	-0.197	0.149	-0.07	0.302	-0.209	0.281
Ultrafiltration volume (liter)	**-0.429**	**0.009***	0.141	0.147	**-0.660**	**0.019***
Volume overload						
Before HD (%)	-0.161	0.197	0.218	0.052	-0.299	0.200
After HD (%)	0.116	0.299	**0.274**	**0.024***	0.087	0.405
After HD (liter)	-0.093	0.312	-0.140	0.149	-0.211	0.279

Analysis with point biserial correlation, *significancy p<0.05, non-geriatric: <45 yo, pre-geriatric 45-65 yo, geriatric > 65 yo

Correlation of Age, BMI, Albumin, Sodium, Potassium and MIS to volume overload

Several factors related to volume overload are seen in Table 6, it appears that age, BMI and potassium levels are related to volume overload. Age factors have an effect on the whole, meaning that the older the age the more frequent the occurrence of volume overload, while BMI factors have an effect especially on the IDH group, where the lower the BMI the more likely volume overload is to occur. Low potassium levels appear to be related to volume overload in all groups, meaning that the lower the potassium levels the more likely volume overload is to occur.

Table 6. Correlation of Age, BMI, Albumin, Sodium, Potassium and MIS to volume overload

Variable	All (n=85)		IDH (n=19)		Non IDH (n=66)	
	Volume overload after HD (%)		Volume overload after HD (%)		Volume overload after HD (%)	
	R coefficient	P value	R coefficient	P value	R coefficient	P value
Age (yo)	**0.221**	**0.021***	0.285	0.119	0.189	0.064
BMI	**-0.228**	**0.018***	**-0.630**	**0.002***	-0.093	0.229
Albumin (g/dL)	0.121	0.135	0.015	0.476	0.184	0.070
Sodium (mmol/L)	-0.083	0.225	-0.075	0.380	-0.114	**0.181**
Potassium (mmol/L)	**-0.337**	**0.001***	**-0.404**	**0.043***	**-0.316**	**0.005***
MIS	-0.002	0.492	-0.075	0.381	-0.015	**0.452**

Analysis using Rank Spearman correlation, *significancy p<0.05

Discussion

Of the 162 patients undergoing routine hemodialysis, 97 included in this study had a dry weight still above the dry weight predicted by BIA measurements. Of all the patients involved in this study, 23 patients (23.7%) experienced intra-dialytic hypertension, this figure is nearly identical to that reported in the study by Van Buren et al with a prevalence of 22.3%, and another study led by Inrig et al. al had a lower prevalence, namely 12.2% and 13.2%.[8,12]

In research conducted by Inrig et al, the characteristics of patients who experienced intradialytic hypertension were older, lower dry weight, lower creatinine, lower albumin and more use of anti-hypertensive drugs.[8,12] In this study, the factors that were directly correlated with intradialytic hypertension were the percentage of volume overload after dialysis and ultrafiltration volume during dialysis in the non-geriatric and geriatric groups, while age, BMI and potassium factors were indirectly correlated with the incidence of volume overload in the study subjects.

Research on the correlation between potassium levels and intradialytic hypertension is usually associated with the concentration of dialysate used, for instance, a study by Dolson et al revealed that low potassium dialysate levels were associated with the occurrence of intradialytic hypertension. It is not yet known whether low potassium levels are associated with vasoconstriction of blood vessels.[8]

Prospective observations are needed to see the effect of adjusting dry weight as measured by BIA on reducing the incidence of intradialytic hypertension in patients undergoing chronic dialysis.

Conclusion

This research shows that, the majority (59.87%) of patients undergoing chronic hemodialysis at Hasan Sadikin Hospital Bandung have a greater dry weight based on BIA examination, have a volume overload percentage of 8.9% before hemodialysis and 4.1% after hemodialysis. Of all the patients involved in this study, 23 patients (23.7%) experienced intra-dialytic hypertension, the factors that were directly correlated with intradialytic hypertension were the percentage of volume overload after dialysis and ultrafiltration volume during dialysis in the non-geriatric and geriatric groups, while age, BMI and potassium factors were indirectly correlated with the incidence of volume overload.

Limitations of the Study

However, several limitations to this study should be acknowledged. First, the cross-sectional design limits the capacity to establish causality between hemodialysis adequacy and inflammation. The data provides a snapshot of the relationship at a single point in time, so it is difficult to determine the changes in Kt/V over time that may differentially impact inflammatory markers. Moreover, the modest sample of the study is 45 patients, which may limit the relevance of the result to the general CKD5 patient population. There are other possible influencing factors, including comorbid conditions or variations in dialysis protocols, that were not fully completely considered in the analysis.

Declarations

Ethics approval and consent to participate

This study received approval from the Ethics Committee of the Hasan Sadikin Hospital Bandung under reference number DP.04.03/D.XIV.6.5/329/2024.

Competing interests

There are no conflicts of interest in writing this article.

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Author's Contribution

Idea/concept: MI. Design: MI. Control/supervision: RB, RS, LD. Data collection/ processing: MI. Analysis/interpretation: MI, RB, RS, LD. Literature review: - Writing the article: MI. Critical review: - All authors have critically reviewed and approved the final draft and are

responsible for the content and similarity index of the manuscript.

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