ISSN: 2572-3286

Uduagbamen et al. J Clin Nephrol Ren Care 2021, 7:068
DOI: 10.23937/2572-3286.1510068
Volume 7 | Issue 2
Open Access

Journal of
Clinical Nephrology and Renal Care

ORIGINAL ARTICLE

Ultrafiltration Volume: Surrogate Marker of the Extraction Ratio, Determinants, Clinical Correlates and Relationship with the Dialysis Dose

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Abstract

Background: The ultrafiltration volume, a surrogate maker of inter-dialytic weight gain and extraction ratio plays a significant contributory role in the dialysis dose but in very large amount can lead to intradialysis hypotension and its consequences of myocardial ischemia and stunning and further diminution of kidney function. Measures are needed to prescribe the optimal quantity for each session.

Method: A thousand six hundred and eighty eight dialysis sessions for 287 participants were studied. Pre and post-dialysis blood samples for electrolytes, urea and creatinine, and hematocrit were taken.

Results: The mean age, interdialytic weight gain and ultrafiltration volume were 50.7 ± 11.7 years, 2.23 ± 1.3 kg and 1.3 ± 1.1 L respectively. Greater proportions of participants were males (66.9%), had hypertension associated CKD (44.6%) and were between 35-54 years (44.3%). A greater proportion of the sessions had ultrafiltration volume 1500-1999 mL (23.6%). The ultrafiltration volume was higher in males, was positively related to the inter-dialytic weight gain, fall in interdialytic percentage oxygen saturation and inter-dialytic blood pressure rise but it was negatively correlated with age, predialysis albumin and bicarbonate, blood flow rate, dialysis duration, and dialysis dose (higher in males). Higher ultrafiltration volume was associated with intradialysis hypotension. Dialysis dose was adequate in 15.2% of the sessions. Predictors of the ultrafiltration volume were dialysis frequency, blood flow rate, dialysis duration, predialysis albumin and dialysis dose.

Conclusion: The ultrafiltration volume contributes to the dialysis dose but very high quantity could cause intradialysis hypotension. A carefully prescribed ultrafiltration volume is therefore needed to deliver optimal treatment doses and avoid complications.

Keywords

Ultrafiltration volume, Extraction ratio, Interdialytic weight gain, Intradialysis hypotension, Intradialysis hypertension, Dialysis dose

Introduction

The extraction ratio (ER), defined as the change in plasma concentration of a substance (inlet minus outlet) as a fraction of the unfiltered (inlet) concentration, is a known determinant of the inter-dialytic weight gain (IDWG) from which the ultrafiltration volume (UFV) is determined [1]. The UFV is inversely related to the residual kidney function (RKF), serum albumin, and the dialysis dose [2]. It is dependent on the IDWG and positively related to the ER [1,3]. Though UFV contributes to the dialysis dose, when in excess of vascular refilling, could lead to intradialysis hypotension (IDH), myocardial ischaemia and stunning [4]. The effectiveness of dialysis treatment is based on the contributions of the dialyzer clearance and ultrafiltration. This implies that

Citation: Uduagbamen PK, Ogunkoya JO, Nwogbe CI, Eigbe SO, Timothy OR (2021) Ultrafiltration Volume: Surrogate Marker of the Extraction Ratio, Determinants, Clinical Correlates and Relationship with the Dialysis Dose. J Clin Nephrol Ren Care 7:068. doi.org/10.23937/2572-3286.1510068

Accepted: September 21, 2021: **Published:** September 23, 2021

contribution of ultrafiltration to the dialysis dose would be depended on the extraction ratio, which when large, increases the contribution of ultrafiltration in fluid and solute removal, just as a lower extraction ratio increases the contribution of the dialyzer solute clearance to the overall dialysis dose. Urea exhibits single pool kinetics and is readily filtered unlike phosphate (middle molecule) [5]. In addition, calculating urea clearance can also be by the equilibrated Kt/V (double pool) or the weekly standard Kt/V model. Solute clearance as a function of its distribution volume (Kt/V) differs from the urea reduction ratio (URR) in its non-consideration of unfiltered plasma, and consideration of solute clearance during ultrafiltration [6,7].

Though literature is scares in Africa concerning the UFV and its correlates, however, it is very likely that large ER and UFV would be common in low income nations (LINs), reflective of the poor treatment outcome and quality of life (QOL) in the dialysis population compared to the developed world [8,9]. We studied UFV, its determinants, clinical correlates and its relationship with the dialysis dose in Nigeria, a LIN.

Materials and Methods

This was a prospective, single-center study carried out at the dialysis suite of Babcock University Teaching Hospital, Ilishan-Remo, Nigeria and lasted for 18 months (August 2019 to January 2021). Two hundred and eighty seven patients with chronic kidney disease in end stage, according to the Kidney Disease Outcome Quality Initiative (KDOQI) 2012 criteria [10] ≥ 16 years, who had received maintenance hemodialysis (MHD) for a minimum of 4 weeks, gave informed consent and met the inclusion criteria were consecutively recruited. Patients with kidney transplant, pelvic masses, New York Heart Association (NYHA) stage 4, portal hypertension, infections, sessions less than two hours, or less than once weekly and dialysis sessions held for patients during acutely exacerbation or during hospital admission, were excluded. Each participant had a maximum of six or seven sessions.

Data Collection

Data was entered from history, examination and participants' cases notes. Retrieved variables included: Sex, age, gender, antecedent history of pharyngitis or skin sepsis, cause of CKD, vascular access type, blood flow rate (BFR),dialysis duration, IDWG, inter-dialytic blood pressure (BP) rise, interdialytic fall in percent oxygen saturation (SPO_2), predialysis hematocrit, and albumin. Participants' height and weight were measured according to standardized protocols. Participants were rested for five minutes before their vitals [temperature, SPO_2, pulse rate (PR) and BP (manually)] were measure.

Peridialysis assessment

Two predialysis blood samples were taken for serum electrolytes, urea, creatinine, and hematocrit (HCT), and serum albumin, (only index session). With an arterovenous fistula (AVF), blood was taken from a peripheral vein in the contralateral hand before placing the fistula needles. With an internal jugular catheter (IJC), patency was confirmed by withdrawing 1 ml of blood, predialysis samples were taken before flushing the portals with heparinized saline. Blood samples were taken from newly sited femoral catheters (FC) according to unit protocol. The arterial, then venous portals were connected to commence dialysis.

In increased risk of bleeding (clinical or laboratory), unfractionated heparin (5000 IU) was either reduced or withheld depending on the severity of clotting profile derangement. The vital signs were measured half hourly throughout dialysis but with IDH or IDHT, were measured quarter hourly. Whenever BFR was altered, the mean was determined. The dialysate flow rate (DFR) was 500 ml/min for all sections and bicarbonate dialysate (34 mmol/L) was used.

Post dialysis assessment

The stop dialysate flow sampling method was used: At dialysis time zero (end), dialysate flow was stopped and blood flow continued. After five minutes, blood was taken from the arterial portal, first, for electrolytes, urea and creatinine (minimizes access recirculation) and then HCT [11]. The URR was calculated from the difference in urea concentration while Kt/V was calculated with the Daugirdas second generation logarithmic estimation of single pool [12]. The bromocresol green method, which overestimate it in hypoalbuminaemia, renal diseases (including dialysis) by about 3.5 g/dl), was used in analyzing albumin. Cut-off values for normal serum albumin were therefore raised by 3.0-3.5 or 5.0-5.7 compared to the bromocresol purple or the immunophelometric assay respectively [13].

Definitions

Extraction ratio (ER) = The difference between the inlet and outlet concentration of a substance divided by the inlet concentration $[C^{in} - C_{out}]/C_{in}$ [1].

IDWG: The predialysis weight for an index session minus preceding session's post dialysis weight [14].

Interdialytic BP rise (IBPR): Predialysis BP for an index session minus preceding session's post dialysis BP [15].

Intradialysis BP fall (IBPF): The difference between the pre and post dialysis BP for an index session [15].

Targeted weight loss (TWL): Predialysis weight plus volume of administered fluid minus UFV [16].

IDH: Intradialysis fall in SBP of ≥ 20 mmHg with symptoms but without nursing intervention [17].

IDHT: Intradialysis rise in SBP > 10 mmHg [18].

Dialysis dose: Normal (Kt/V ≥ 1.2 and URR ≥ 65.0%),

low (Kt/V 0.9-1.1 and URR 50.0-64.9%) and very low (Kt/V < 0.9 and URR < 50.0%).

Hypertension associated CKD: Long standing hypertension leading to kidney disease common in elderly and late middle age.

Chronic glomerulonephritis: Kidney disease leading to hypertension common in the young and early middle aged, with or without antecedent history of pharyngitis or skin sepsis.

Statistical analysis

Data was analyzed using statistical package for social sciences (SPSS) version 22.0 (IBM, CA, USA). Continuous variables with means were compared using t-test. Categorical variables as proportions and percentages were compared using Chi square test or fisher's exact test. The P-value < 0.05 was considered statistically significant. Variables with P < 0.025 were entered into a multiple regression model to determine independent predictors of UFV using backward elimination to adjust for confounders (Table 1).

This study was approved by the Babcock University Human Research Ethics Committee (BUHREC/723/19, NHREC/24/01/2018).

The STROBE reporting guidelines was used in the preparation of this manuscript.

Results

Two hundred and eighty seven participants had 1688 dialysis sessions. The mean age of the population was 50.7 ± 11.7 years, males 50.1 ± 7.8 years and females 51.9 ± 8.9 years. More males than females participated in the study (66.9% vs. 33.1%), and the highest proportion of participants (44.3%), were in the 35-54 age group (Table 2). Participants with once, twice and thrice weekly sessions had 504 (29.9%), 797 (47.2%) and 387 (22.9%) respectively. The mean IDWG and UFV were highest in participants in the 35-54 years group, P = 0.001, and among the causes of CKD. Participants with CGN had the highest IDWG and UFV, P < 0.001

Table 1: Multivariate regression analysis of independent predictors of extraction ratio.

Variables	OR	95% CI	P-value
Age	2.08	1.56-3.94	0.05
Frequency of dialysis	3.83	1.97-5.86	0.03
Frequency of erythropoietin	2.49	1.77-5.06	0.05
Predialysis diastolic BP	2.08	2.25-4.22	0.05
Predialysis albumin	4.87	0.34-5.47	< 0.001
Predialysis hematocrit	3.03	2.67-4.79	0.05
Predialysis Creatinine	4.74	1.83-6.36	0.001
Predialysis bicarbonate	4.99	2.57-7.83	< 0.001
Dialysis duration	3.93	1.45-5.95	0.001
Blood flow rate	3.14	1.73-3.41	0.02
Kt/V	6.56	2.53-7.27	< 0.001

OR: Odds Ratio; CI: Confidence Interval; BP: Blood Pressure.

Table 2: Sociodemographic and clinical characteristics of study population.

Variable	Frequency N = 287 (%) (Mean ± SD)	Hemodialysis Sessions N = 1688 (%) (Mean ± SD)
Sex		
Males	192 (66.9)	1124 (66.6)
Females	95 (33.1)	564 (33.4)
Age, *years*		
16-34	61 (21.2)	351 (20.8)
35-54	127 (44.3)	756 (44.8)
55-74	81 (28.2)	482 (28.5)
≥ 75.0	18 (6.3)	99 (5.9)
Etiology		
Hypertension	128 (44.6)	755 (44.7)
Chronic glomerulonephritis	98 (34.2)	589 (34.9)
Diabetes	33 (11.4)	184 (10.9)
Obstructive uropathy	18 (6.3)	102 (6.1)
Others	10 (3.5)	58 (3.4)

Table 3: Relationship between interdialytic weight gain and ultrafiltratiom volume.

Variable	All Participants N = 287 (%)	Dialysis (%) Sessions N = 1688 (%) Mean ± SD	Interdialytic Weight Gain N = 1688 (%) Mean ± SD	Ultrafiltration Volume N = 1688 (%)	t-test	P-value
Sex						
Males	192 (66.9)	1124 (66.6)	2.4 ± 1.1	1.5 ± 1.1	2.1	0.05
Females	95 (33.1)	564 (33.4)	1.9 ± 1.0	1.1 ± 0.9	1.8	0.06
Age, *years*						
16-34	61 (21.3)	351 (20.8)	2.3 ± 1.3	1.4 ± 0.8	1.8	0.05
35-54	127 (44.2)	756 (44.8)	2.7 ± 1.0	1.6 ± 0.9	2.6	0.001
55-74	81 (28.2)	482 (28.5)	1.6 ± 0.6	1.0 ± 0.6	1.0	0.8
> 75	18 (6.3)	99 (5.9)	1.2 ± 0.5	0.9 ± 0.4	0.4	1.6
Etiology of CKD						
Hypertension	128 (44.6)	755 (44.7)	2.2 ± 1.6	1.2 ± 1.1	1.2	0.05
CGN	98 (34.1)	589 (34.9)	2.6 ± 1.4	1.4 ± 1.2	4.1	< 0.001
Diabetes	33 (11.5)	184 (10.9)	1.5 ± 0.7	1.0 ± 1.0	0.9	1.0
OU	18 (6.3)	102 (6.1)	1.9 ± 1.3	1.4 ± 1.0	1.0	0.9
Others	10 (3.5)	58 (3.4)	2.0 ± 1.0	1.6 ± 1.1	0.9	1.1
Predialysis BMI, kg/m^2						
< 19.5		137 (8.1)	1.6 ± 1.1	0.8 ± 0.3	0.9	0.8
19.5-24.9		654 (38.8)	2.2 ± 1.2	1.3 ± 1.0	1.2	0.06
> 25.0		897 (53.1)	2.4 ± 1.6	1.5 ± 1.2	1.3	0.05
Interdialytic systolic BP increase, *mmHg*						
0-19.9		189 (11.2)	1.7 ± 0.7	0.7 ± 0.4	1.4	0.03
20-39.9		1154 (68.4)	2.1 ± 1.4	1.3 ± 1.1	1.1	0.05
> 40.0		345 (20.4)	2.8 ± 1.5	2.1 ± 1.1	0.8	0.07
Interdialytic diastolic BP increase, *mmHg*						
0-9.9		197 (11.7)	1.6 ± 0.9	0.6 ± 0.3	2.9	0.02
10-19.9		1141 (67.6)	2.1 ± 1.3	1.3 ± 1.0	1.5	0.05
> 20.0		350 (20.7)	3.1 ± 1.4	2.2 ± 1.3	2.2	0.04

CKD: Chronic Kidney Disease; CGN: Chronic Glomerulonephritis; OU: Obstructive Uropathy; BMI: Body Mass Index; BP: Blood Pressure.

Table 4: Dialysis induced variations in participants' clinical characteristics.

Variables	Predialysis N = 1688 (%) Mean ± SD	Postdialysis N = 1688 (%) Mean ± SD	P-value
Mean BMI, kg/m^2	24.62 ± 9.34	23.73 ± 6.34	0.02
Mean SPO_2	93.98 ± 11.84	98.08 ± 11.99	< 0.001
Mean systolic BP, mmHg	163.68 ± 14.66	140.62 ± 12.15	< 0.001
Mean diastolic BP, mmHg	98.52 ± 8.93	88.95 ± 6.49	< 0.001

BMI: Body Mass Index; SPO_2: Percent Oxygen Saturation; BP: Blood Pressure.

(Table 3). The IJC, FC and AVF were used in 957 (56.7%), 442 (26.2%) and 289 (17.1%) sessions. There were significant differences between the mean pre and post dialysis BMI (P = 0.002), SPO_2 (P < 0.001), SBP (P < 0.001) and DBP, P < 0.001, (Table 4). The mean IDWG and UFV were 2.23 ± 1.3 kg and 1.3 ± 1.1 L. The mean occurrence time of IDH was 71.6 ± 10.4 minutes and IDHT 169.6 ± 12.4 minutes. The risk of IDHT was highest with UFV < 1000 mL while the risk of IDH was highest with an UFV > 4000 mL, P = 0.04 (Table 5). The mean dialysis dose was 1.16 ± 0.4 (males 1.21 ± 0.3, and females 1.07 ± 0.5). The mean dialysis dose was adequate, low and very low in 15.2%, 48.9% and 35.9% sessions respectively. UFV < 1000 L was associated with very low dialysis dose (Kt/V < 0.9) while UFV ≥ 4000 L was associated with an adequate dialysis dose (Kt/V ≥ 1.2), P < 0.001 (Table 6). Participants who had dialysis less than thrice weekly had a total of 1301 (77.1%) sessions while those on thrice weekly dialysis had a total of 387 (22.9%) sessions (Table 7). The UFV was positively correlated with the

Table 5: Relationship between ultrafiltration volume and intradialysis complications.

Variables	All Participants N = 1688 (%)	IDH N = 335 (%)	Insignificant BP Changes N = 952 (%)	IDHT N = 401 (%)	P-value
Ultrafiltration Volume, *mL*					
< 1000	187 (11.1)	5 (1.5)	118 (12.4)	64 (16.0)	< 0.001
1000-1499	346 (20.5)	46 (13.7)	205 (21.5)	95 (23.7)	
1500-1999	399 (23.6)	79 (23.6)	231 (24.3)	89 (22.2)	
2000-2499	317 (18.8)	93 (27.8)	175 (18.4)	49 (12.2)	
2500-2999	228 (13.5)	66 (19.7)	111 (11.7)	51 (12.7)	
3000-3499	123 (7.3)	34 (10.1)	61 (6.4)	28 (7.0)	
3500-3999	65 (3.8)	9 (2.7)	39 (4.1)	17 (4.2)	
> 4000	23 (1.4)	3 (0.9)	12 (1.2)	8 (2.0)	

Table 6: Relationship between ultrafiltration volume and the dialysis dose.

Variables	All Sessions	Kt/V < 0.9 N = 610 (%)	Kt/V 0.9-1.1 N = 822 (%)	Kt/V > 1.2 N = 256 (%)	P-value
UFV, mL					
Mean	1.31 ± 1.10	1.22 ± 0.70	1.31 ± 1.03	1.48 ± 1.11	< 0.001
< 1000	187 (11.1)	88 (14.4)	69 (8.4)	30 (11.7)	< 0.001
1000-1499	346 (20.5)	111 (18.2)	162 (19.7)	73 (28.5)	
1500-1999	399 (23.6)	142 (23.3)	189 (23.0)	68 (27.6)	
2000-2499	317 (18.8)	129 (21.2)	159 (19.3)	29 (11.3)	
2500-2999	228 (13.5)	82 (13.4)	121 (14.7)	25 (9.8)	
3000-3499	123 (7.3)	42 (6.9)	69 (8.4)	12 (4.6)	
3500-3999	65 (3.8)	11 (1.8)	40 (4.9)	14 (5.4)	
> 4000	23 (1.4)	5 (0.8)	13 (1.6)	5 (2.0)	

UFV: Ultrafiltration volume.

BFR, P = 0.002 and the dialyzer surface area (DSA), P = 0.03 but negatively correlated the frequency of erythropoietin administration, P = 0.001. The UFV was higher in males, was inversely associated with age (P = 0.002) and positively related to predialysis creatinine, P < 0.001 (Table 7).

Variables that were significantly associated with UFV (P < 0.025), were analyzed in a multivariate model to determine independent predictors of UFV using backward elimination to adjust for confounders (Table 1). Dialysis frequency (OR-3.83, CI-1.97-5.86), duration (OR-3.93, CI-1.45-4.95), BFR (OR-3.14, 1.73-341) and Kt/V (OR-6.56, CI-2.53-7.27) predicted the UFV.

Discussion

We found a positive relationship between the UFV and IDWG, a surrogate marker of the extraction ratio, the BMI, the interdialytic BP increase and predialysis creatinine. The UFV was negatively related with age, predialysis albumin. The UFV was also negatively correlated with dialysis duration, BFR, dialyzer surface area and the dialysis dose. The direct relationship between the UFV and the IDWG mirrors findings by Depner, et al. [1,6] as treatment goals involve the removal of retained fluid and waste. Higher IDWG are commonly followed by large UFV as part of the target of minimizing the interdialytic extraction ratio. Assimon, et al. [19] and Slinin, et al. [20] found higher ultrafiltration volume with higher IDWG.

The higher UFV in males agrees with findings by Ipema, et al. [21] who reported that males were more likely to have higher IDWG and therefore higher ultrafiltration rates and volumes. Our finding is however not in agreement with some earlier studies that found higher UFVs with females [19,20]. The higher dialysis dose in males could explain their higher UFV as the positive relationship between the dialysis dose and the UFV is well reported in previous studies [20,21]. Due to solute removal during ultrafiltration, higher UFVs are expected to give higher dialysis doses. The European Best Practices Guidelines (EBPG) and the KDOQI had recommended that dialysis should target fluid and solute clearance [22,23]. The higher weight in males could also contribute to their higher dialysis doses and UFVs, similar to findings by Flythe, et al. [24] who reported a positive association between body weight and UFV. The inverse relationship between UFV and age mirrors findings that found higher UFV in the younger age groups [20,25]. The very high UFV in chronic glomerulonephritis further buttresses the inverse association between higher UFV and age group as CGN is commoner in the lower age group of a CKD cohort [26,27]. The inverse relationship between SPO_2 and UFV is in agreement with earlier findings that hypoxaemia is

Table 7: Relationship between ultrafiltration volume and participants' characteristics.

Variables	UFV < 2L N = 922 (%) Mean ± SD	UFV > 2L N = 766 (%) Mean ± SD	OR	95% CI	P-value
Sex					
Males	515 (45.8)	609 (54.2)	2.04	1.13-3.19	0.05
Females	407 (72.2)	157 (27.8)			
Age, *years*					
< 65	692 (50.3)	685 (49.7)	3.99	1.67-6.50	0.002
> 65	230 (74.0)	81 (26.0)			
Dialysis sessions/week					
< 3	553 (42.5)	748 (57.5)	4.60	3.88-10.24	< 0.001
3	369 (95.3)	18 (4.7)			
Erythropoietin *4000 IU*					
< 3/week	632 (47.4)	702 (52.6)	4.02	1.73-7.64	0.001
3/week	290 (81.9)	64 (18.1)			
BMI, kg/m^2					
< 25.0	521 (65.9)	270 (34.1)	2.18	1.46-5.89	0.04
> 25.0	401 (44.7)	496 (55.3)			
Predialysis BP, *mmHg*					
Systolic BP < 140	251 (75.6)	81 (24.4)	1.96	1.17-3.05	0.005
Systolic BP > 140	671 (49.5)	685 (50.5)			
Diastolic BP < 90	307 (93.0)	23 (7.0)	3.08	2.07-6.45	0.004
Diastolic BP > 90	615 (45.3)	743 (54.7)			
Predialysis haematocrit, *%*					
< 33.0	769 (51.9)	714 (48.1)	3.61	3.44-7.19	0.002
> 33.0	153 (74.6)	52 (25.4)			
Predialysis albumin, *mg/L*					
< 35	720 (53.5)	733 (46.5)	4.22	2.94-8.95	< 0.001
> 35	202 (69.6)	33 (30.4)			
Predialysis creatinine, *umol/L*					
< 500	715 (73.3)	261 (26.7)	4.93	1.94-9.26	< 0.001
> 500	207 (29.1)	505 (70.9)			
Predialysis bicarbonate, *mmol/L*					
< 22	723 (49.5)	737 (50.5)	5.72	4.05-13.23	< 0.001
> 22	199 (87.3)	29 (12.7)			
Dialysis duration, *hours*					
< 4	16 (29.6)	38 (70.4)	4.97	2.73-11.02	< 0.001
4	906 (54.8)	728 (45.2)			
Dialyzer surface area, m^2					
1.3/1.4	18 (75.0)	6 (25.0)	3.01	1.46-5.83	0.03
1.7/1.8	904 (54.3)	760 (45.7)			
Blood flow rate, *ml/min*					
< 350	551 (72.3)	211 (27.7)	3.94	3.34-6.78	0.002
> 350	371 (40.1)	555 (59.9)			
Kt/V					
< 1.2	864 (61.4)	544 (38.6)	5.11	2.60-9.93	< 0.001
> 1.2	58 (20.7)	222 (79.3)			
URR, %					
< 65	886 (63.2)	515 (36.8)	5.4	1.88-9.82	< 0.001
> 65	36 (12.5)	251 (87.5)			

UFV: Ultrafiltration; OR: Odd Ratio; CI: Confidence Interval; BMI: Body Mass Index; BP: Blood Pressure; URR: Urea Reduction Ratio.

worse just before a dialysis session and least immediate post dialysis [28]. We found a positive relationship between the interdialytic BP rise and UFV. Higher UFV have been reported in Africa Americans (AAs) [19,25]. The poorer control of hypertension in AAs (who are genetically related to our study population) coupled with poor compliance with the use of BP lowering drugs, is expected to produce lower dialysis doses, higher extraction ratio, IDWG and ultrafiltration volume [29]. The inverse relationship between the UFV and the predialysis values of serum albumin, bicarbonate and haematocrit in our study mirror findings from studies that reported that the extraction ration, IDWG and UFV increases with derangement in serum biochemical parameters [29-31]. Prolonged dialysis session allow for reductions in UFR in those prone to IDH, the lower dose from this is compensated for by increased dose from dialysis prolongation hence preventing IDH is worth it [25].

The positive relationship between the UFV and the dialyzer surface area (DSA) in this study mirrors findings by Manduell, et al. who reported that contribution of DSA to the dialysis dose is enhanced by larger surface area allowing higher diffusive exchange, solute and plasma filtration across the dialyzer membrane. And this could be implicated in intradialysis complications related to membrane incompartibility [32]. The greater exchange across the dialyzer membrane is also enhanced by the higher blood flow rates that are associated with lager surfaces [33]. The augmentation in dialyzer membrane performances through the use of more than a single dialyzer arranged in series or parallel further increases the surface area available for fluid and solute exchange across the membranes, although this could worsen protein catabolism and dialyzer protein wasting associated with larger dialyzers [34]. We found a negative correlation between the UFV and the frequency of administration of the erythropoiesis stimulating agents (ESAs). The higher hemoglobin concentration that results from regular use of the ESAs increases the red cell volume and reduces the plasma volume, the extraction ratio and the IDWG, necessitating reductions in the ultrafiltration rate. The higher red blood cell volume (RBCV) associated with higher EPO doses could lead to increased plasma viscosity and reduced dialyzer blood flow. This could lead to lower exchanges and filtration across dialyzer membrane, dialyzer blood clotting and possibly dialysis termination [35].

We found the most important determinant of the UFV to be the delivered dose of the previous session. There is the need to optimize overall patient preparation in MHD as the UFR, while being tailored to increase dialysis dose, remove waste and control hypertension, should be closely regulated in order to avoid IDH. Our finding of the occurrence of IDH earlier than the IDHT agrees with findings by Straver, et al. [36] who reported that about 60% of the targeted UFV is remove within the first two intradialytic hour while 40% is filtered in the last 2 intradialytic hours. Poor plasma refilling coupled with a possible poor cardiac reserve should therefore be borne in mind by the nephrologist in prescribing the UFV for each dialysis session.

We encountered some limitations, first, we couldn't determine participants' dry weight to access its contribution to the delivered dose. We could not determine residual kidney function (RKF). Some dialysis timings were not very regular. We didn't involve any ultrafiltration monitoring/manipulating devices and the single-centre design and our inability to determine 24 hour urine output also limited us. The large sample size, and the prospective design were the strength of this study.

Conclusion

The UFV, with a mean of 1.3 ± 1.1 L was positively related to the IDWG (a surrogate maker of the extraction ratio) and was higher in males, and was positively correlated with the BMI, interdialytic BP rise and predialysis creatinine as it was negatively related to the age, dialysis frequency, SPO_2, predialysis serum albumin, dialysis duration, BFR and dialysis dose. Higher UFVs were risks for IDH which occurred earlier than IDHT. The prescribed UFV should aim to deliver optimal doses while preventing wide intra and inter-dialytic BP variations.

Acknowledgement

We thank the nurses, technicians and supporting staffs of the dialysis unit.

Financial Support

None.

Ethical Approval

This study was approved by the Babcock University Human Research Ethics Committee (BUHREC/723/19, NHREC/24/01/2018). All participants gave informed consent before the study.

Conflict of Interest

None declared.

Declaration

This manuscript has not been presented in part or in whole at any seminar, conference or online and has not been published nor under any consideration by any journal.

Authors' Contribution

All authors had full access to the data, contributed to the study, approved the final version for publication, and take responsibility for its accuracy and integrity.

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