Original Article

Under-Dialysis: Determinants and Clinical Correlates – Findings from a Two-Centre Retrospective Study in Nigeria

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Abstract

Background: To deliver an adequate dialysis dose, it is necessary that the dialysis frequency, erythropoietin use, blood pressure control among others, be optimized. This is in addition to treating comorbidities and minimizing complications. Adequate dialysis improves the quality of life (QOL) and reduces the morbidity and mortality rates. **Aim:** To assess the determinant and correlates of under-dialysis in these two centres. **Materials and Methods:** We analyzed 5065 prevalent dialysis treatments given to 623 participants with end-stage renal disease from two centres in Nigeria. Participants' biodata, serum biochemistry, and hematocrit of cohorts with once-, twice-, and thrice-weekly sessions were analyzed. **Results:** Males had more dialysis treatments than women. Two hundred and twenty-seven (36.4%) cohorts had weekly sessions, 296 (47.5%) had twice-weekly sessions, and 100 (16.1%) had thrice-weekly sessions. The mean age of all participants was 50.5 ± 7.9 years, and was higher in women than men, $P = 0.02$. The percentage of the elderly in the maintenance dialysis population was 13.8%. Only 19.4% of the participants meet the Kidney Disease Outcomes Quality Initiative recommendation of thrice-weekly erythropoietin, just as only 11.9% had health insurance. The dialysis dose was higher in males ($P = 0.07$), with health insurance ($P < 0.001$), frequent dialysis ($P < 0.001$), frequent erythropoietin ($P < 0.001$), higher hematocrit ($P = 0.03$), and bicarbonate ($P = 0.001$), but was lower in intradialytic hypotension compared to intradialytic hypertension, $P = 0.004$ versus $P = 0.005$. Dialysis termination and intradialytic death were negatively correlated with dialysis frequency. Health insurance, frequency of dialysis, and erythropoietin predicted the dialysis dose. **Conclusion:** Under-dialysis and suboptimal erythropoietin use were prevalent in the dialysis population and it restricted the prescribed dose which eventually gave lower dialysis doses, higher dialysis complications, and poor QOL.

Keywords: Anemia, dialysis termination, health insurance, metabolic acidosis, under-dialysis

Introduction

An adequate hemodialysis dose requires optimizing various dialysis factors which could be difficult to achieve in low-income nations (LINs), leading to malnutrition, poor fluid and blood pressure (BP) control, frequent hospitalizations, and increased morbidity and mortality.[1] Under-dialysis increases the risk of interdialytic weight gain (IDWG) and ultrafiltration volume (UFV) and higher frequencies of intradialytic hypotension (IDH) and is associated with hypoalbuminemia, anemia, cardiovascular disease, and the shorter time between dialysis initiation and death of patients on maintenance hemodialysis (MHD) in LINs.[2-5]

Under-dialysis is hardly studied in specifics in low-income settings (LISs). We studied under-dialysis and its correlates in Nigeria.

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Materials and Methods

Study design

This was a two-centre, retrospective study of dialysis sessions conducted at the dialysis suites of Federal Medical Centre Abeokuta, Nigeria (center A), and Babcock University Teaching Hospital, Ilishan-Remo, Nigeria (centre B), between January 2014 and December 2017 (centre A), and between

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September 2015 and August 2021 (centre B). A total of 5065 (centre A: 920, centre B: 4145) sessions for 623 (centre A: 121, centre B: 502) patients were studied and the sessions were grouped into three cohorts: once-, twice-, and thrice-weekly sessions.

The hospital files of the 623 patients who were dialyzed in the two centres and met the study criteria were retrieved, and variables entered included sociodemographics, educational level, health insurance, type of kidney disease, weekly dialysis and erythropoietin frequencies, BP (predialysis, half hourly through dialysis, and postdialysis), blood flow rate (BFR), UFV, vascular access dialysis duration, dialyzer size, and dialysis dose (Kt/V). Also entered were the incidence of IDH, intradialytic hypertension (IDHT), dialysis termination, infections, hospitalizations, and intradialytic death. The pre- and postdialysis renal biochemical parameters, hematocrit, and predialysis albumin (index session) were also entered.

Exclusion criteria were patients with New York Heart Association stage 4 heart failure, portal hypertension, transplanted kidney(s), pelvic masses, infections and acute illnesses, cancers, sessions <2 h or less frequent than weekly, and sessions of patients with irregular dialysis frequencies.

According to the unit's dialysis protocol:

1. Predialysis and postdialysis BP are measured manually (with a patient in the supine position) and documented
2. One milliliter of blood is withdrawn from the internal jugular catheter (to confirm patency) and discarded, predialysis samples are taken, and arterial and venous ends are flushed with heparinized saline before connecting to the machine. For newly sited femoral catheters, samples are taken before flushing with heparinized saline, but with an arteriovenous fistula, samples are taken from a vein in the contralateral arm
3. Electrolytes are analyzed using ion-selective electrode method, hematocrit is determined with hematocrit centrifuge, serum albumin, by bromocresol green method which overestimates it by about 3.5 g/dL in renal diseases. Therefore, cutoff values for normal albumin were raised by about 3–3.5 or 5.5–7 g/dl compared to the bromocresol purple or the immunonephelometric assay, respectively
4. All dialysate fluid had bicarbonate (34 mmol/L), sodium (140 mmol/L), potassium (2.0 mmol/L), and calcium (2.2 mmol/L). Unfractionated heparin 5000 IU was used for all sessions, and when the concentration was altered due to deranged clotting profile, the mean value was documented.

Definitions

In this study, hypertension with complicating chronic kidney disease (CKD) was defined as long-standing hypertension complicated by kidney disease, commonly seen from late middle age while chronic glomerulonephritis was defined as kidney disease complicated by hypertension, commonly seen in the young and early middle age, with or without preceding history of pharyngitis or skin sepsis.[6] IDH was defined as intradialytic systolic BP reduction of at least 20 mmHg with symptoms, according to the European Best Practice Guidelines, but without nursing intervention.[7] IDHT was defined as intradialytic systolic BP increase >10 mmHg.[8]

Hypertension was defined as a diagnosis of hypertension or using antihypertensive drug(s) or BP ≥140/90 mmHg.[9] Diabetes was defined as a diagnosis of diabetes or using antidiabetic drugs or fasting blood glucose >126 mmol.[10] Hypoalbuminemia was defined as serum albumin <35 mg/dL.[11] Anemia was defined as hematocrit <33%.[12] IDWG is the positive difference between the postdialysis weight of the preceding session and the predialysis weight of the index session.[13] The extraction ratio (ER), is the difference between the inlet and outlet concentration of a substance divided by the inlet concentration.[13] Targeted postdialysis weight is the predialysis weight plus administered fluid minus the UFV. Intradialytic weight loss was defined as UFV minus administered fluid.[13] Dialysis adequacy was classified as normal (Kt/V ≥1.2 or urea reduction ratio [URR] ≥65.0%), low (Kt/V 0.9–1.1 and URR 50%–64.9%), and very low (Kt/V <0.9) and URR <50%.[14]

Ethical approval

The study was approved by the Federal Medical Centre, Abeokuta Ethics Committee (FMCA/470/HREC/03/2020, NHREC/08/10–2021), and Babcock University Human Research Ethics Committee (BUHREC/723/21, NHREC/24/01/2020). Patient consent was not needed for ethical approval.

Statistical analysis

Data analysis was done with the Statistical Package for the Social Sciences (SPSS) version 22.0 (IBM, CA, USA). Continuous variables presented as means and standard deviations were compared using *t*-test while categorical variables presented as proportions and percentages were compared using Chi-square test or Fisher's exact test when variables were <5. The $P < 0.05$ was considered statistically significant. $P < 0.025$ was used in entering variables into the multiple regression model to determine independent associates of under-dialysis using backward elimination to adjust for confounders.[15] The STROBE Reporting Guidelines were adhered to in writing the manuscript.

Results

Three hundred and ninety (62.6%) males had 3404 (67.2%) sessions while 233 (37.4%) females had 1661 (32.8%) sessions. Two hundred and twenty-seven (36.4%) participants had weekly dialysis, 296 (47.5%) had twice-weekly sessions, and 100 (16.1%) had dialysis thrice weekly. The mean age of the population, males, and females was 50.5 ± 7.9 years, 48.9 ± 6.3 years, and 53.2 years, respectively, $P = 0.02$. The age group of 40.0–64.9 years had the largest proportion of participants (51.3%) and dialysis sessions (55.5%). Hypertension (42.7%) was the most common cause of CKD [Table 1]. The overweight/obese made up the largest (51.8%) proportion of participants. Majority (50.9%)

Table 1: Participant's sociodemographics and historical characteristics

Variables	All participants (*n*=623), *n* (%)	All sessions (*n*=5065), *n* (%)	Weekly sessions (*n*=1696), *n* (%)	Twice weekly sessions (*n*=2427), *n* (%)	Thrice weekly sessions (*n*=942), *n* (%)	*P*
Sex						
Males	390 (62.6)	3404 (67.2)	1073 (63.3)	1643 (67.7)	688 (73.0)	0.03
Females	233 (37.4)	1661 (32.8)	623 (36.7)	784 (32.3)	254 (27.0)	
Age (years)						
16.0-39.9	217 (34.9)	1578 (28.8)	498 (29.4)	824 (34.0)	256 (27.2)	0.004
40.0-64.9	320 (51.3)	2811 (55.5)	954 (56.2)	1283 (52.9)	574 (60.9)	
≥65.0	86 (13.8)	676 (13.7)	244 (14.4)	320 (13.1)	112 (11.9)	
Educational status						
Primary	122 (19.6)	577 (11.4)	245 (14.5)	274 (11.3)	58 (6.1)	0.001
Secondary	184 (20.5)	1545 (30.5)	528 (31.1)	745 (30.7)	272 (28.9)	
Tertiary	317 (50.9)	2943 (58.1)	923 (54.4)	1408 (58.0)	612 (65.0)	
Health insurance						
Yes	74 (11.9)	704 (13.9)	62 (3.7)	395 (16.3)	247 (26.2)	<0.001
No	549 (88.1)	4361 (86.1)	1634 (96.3)	2032 (83.7)	695 (73.8)	
Etiology of CKD						
Hypertension	266 (42.7)	2021 (39.9)	681 (40.2)	951 (39.2)	389 (41.3)	0.05
CGN	244 (39.1)	1930 (38.1)	634 (37.4)	934 (38.5)	362 (38.4)	
Diabetes	64 (10.2)	461 (9.1)	151 (8.9)	225 (9.3)	85 (9.0)	
Obstructive uropathy	35 (5.6)	471 (9.3)	122 (7.2)	255 (10.5)	94 (10.0)	
Others	15 (2.4)	182 (3.6)	108 (6.3)	62 (2.5)	12 (1.3)	
Erythropoietin (4000 IU/week)						
None	112 (18.0)	794 (15.7)	333 (19.6)	362 (14.9)	99 (10.5)	0.04
1	175 (28.1)	1243 (24.5)	488 (28.8)	558 (29.6)	237 (25.2)	
2	235 (37.7)	2118 (41.8)	650 (38.3)	1108 (40.3)	360 (38.2)	
3	101 (16.2)	910 (18.0)	225 (13.3)	399 (15.2)	246 (26.1)	
Predialysis systolic BP (mmHg)						
<140		739 (14.6)	119 (7.0)	263 (10.8)	375 (37.9)	<0.001
≥140		4326 (85.4)	1577 (93.0)	2164 (89.2)	585 (62.1)	
Predialysis diastolic BP (mmHg)						
<90		648 (12.8)	122 (7.2)	321 (13.2)	205 (21.8)	0.001
≥90		4417 (87.2)	1574 (92.8)	2106 (86.8)	737 (78.2)	

CKD: Chronic kidney disease, CGN: Chronic glomerulonephritis, IU: International unit, BP: Blood pressure

of the patients had tertiary education, just as majority (88.1%) had no health insurance. Only 19.4% of the patients were receiving erythropoietin thrice weekly.

Predialysis, the mean serum sodium, bicarbonate, chloride, hematocrit, and albumin were positively related to the frequency of dialysis treatment, $P = 0.04$, $P < 0.001$, $P = 0.05$, $P < 0.001$, and $P = 0.002$, respectively [Table 2]. Predialysis, the serum phosphate, urea, creatinine, and anion gap were negatively related to the frequency of dialysis treatment, $P = 0.001$, $P < 0.001$, $P < 0.001$, and $P = 0.001$, respectively.

There was a positive relationship between the frequency of dialysis and the BFR ($P = 0.001$) and the dialysis duration ($P = 0.004$) while there was a negative relationship between the frequency of dialysis and the UFV, $P < 0.001$ [Table 3].

IDH, dialysis termination, and intradialytic death were most likely in weekly sessions, $P = 0.002$, $P = 0.04$, and $P = 0.06$, respectively [Table 4]. IDHT was most likely in twice-weekly sessions, $P = 0.04$, and dialysis dose was highest in thrice-weekly sessions, $P < 0.001$.

The dialysis dose was positively related to the educational status (P = 0.001), frequency of dialysis (P < 0.001), and erythropoietin (P < 0.001), hematocrit (P = 0.03), and serum bicarbonate, P = 0.001 [Table 5]. The dialysis dose was negatively related to the age ($P = 0.05$) and serum creatinine ($P < 0.001$) and was more likely to be lower in IDH compared to IDHT, $P = 0.004$ versus $P = 0.005$.

From the multivariate regression analysis [Table 6], health insurance, frequency of dialysis, erythropoietin use, predialysis BP, predialysis creatinine and predialysis bicarbonate were independently associated with the dialysis dose.

Discussion

Eighty-four percent of the participants with 81.4% of the sessions were under dialyzing. Under-dialysis was associated with the female gender, aging, low socioeconomic status,

Table 2: Laboratory findings in the cohorts

Predialysis variables	Mean±SD				*P*
	All sessions (*n*=5065)	Weekly sessions (*n*=1696)	Twice weekly sessions (*n*=2427)	Thrice weekly sessions (*n*=942)	
Sodium (mmol/L)	129.6±11.4	127.3±9.3	130.1±12.9	132.5±13.7	0.04
Potassium (mmol/L)	5.6±1.8	5.9±3.8	5.4±2.2	5.0±2.3	0.03
Bicarbonate (mmol/L)	18.6±5.4	17.2±5.2	18.5±9.3	21.2±10.6	<0.001
Chloride (mmol/L)	97.6±14.2	96.6±7.4	97.7±11.0	99.1±13.6	0.04
Calcium (mmol/L)	2.1±0.9	1.9±0.7	2.1±1.0	2.4±1.3	0.001
Phosphate (mmol/L)	2.0±0.9	2.3±1.1	1.9±1.1	1.7±0.6	<0.001
Urea (mmol/L)	17.3±7.9	21.5±7.3	16.8±6.9	11.0±4.2	<0.001
Creatinine (umol/L)	602.1±34.7	667.2±41.1	592.6±21.4	509.4±17.7	<0.001
Hematocrit (%)	24.8±5.2	21.3±4.9	25.9±6.6	28.3±9.1	<0.001
Anion gap (mEq/L)	25.1±8.3	28.9±8.7	24.8±14.1	19.0±6.4	<0.001
Albumin (mg/dL)	32.9±6.6	29.6±6.1	33.5±10.5	36.9±14.7	0.002

SD: Standard deviation

Table 3: Prescribed dialysis for the cohorts

Variables	All sessions (*n*=5065), *n* (%)	Weekly sessions (*n*=1696), *n* (%)	Twice weekly sessions (*n*=2427), *n* (%)	Thrice weekly sessions (*n*=942), *n* (%)	*P*
BFR (mL/min)					
<300	1105 (21.8)	467 (27.5)	508 (20.9)	126 (13.4)	0.001
≥300	3960 (78.2)	1229 (72.5)	1919 (79.1)	816 (86.6)	
Dialysis duration (h)					
<4	157 (3.1)	76 (4.5)	72 (3.0)	9 (1.0)	0.004
≥4	4908 (96.9)	1620 (95.5)	2355 (97.0)	933 (99.0)	
Ultrafiltration volume (L)					
<2	2334 (46.1)	839 (49.5)	1236 (50.9)	683 (72.5)	<0.001
≥2	2731 (53.9)	857 (50.5)	1191 (49.1)	259 (27.5)	
Dialyzer surface area (m^2)					
Low flux (1.3/1.4)	121 (2.4)	42 (2.5)	61 (2.5)	18 (1.9)	0.04
High flux (1.7/1.8)	4944 (97.6)	1654 (97.5)	2366 (97.5)	924 (98.1)	

BFR: Blood flow rate

Table 4: Dialysis complications and outcome in cohorts

Variables	All sessions (*n*=5065), *n* (%)	Weekly sessions (*n*=1696), *n* (%)	Twice weekly sessions (*n*=2427), *n* (%)	Thrice weekly sessions (*n*=942), *n* (%)	*P*
IDH					
Yes	942 (18.6)	385 (22.7)	458 (18.9)	99 (10.5)	0.002
No	4123 (81.4)	1311 (77.3)	1969 (81.1)	843 (89.5)	
IDHT					
Yes	1109 (2.9)	341 (20.1)	583 (24.0)	185 (19.6)	0.04
No	3956 (78.1)	1355 (79.9)	1844 (76.0)	757 (80.4)	
Dialysis dose (kt/V)					
Mean±SD	1.18 (0.7)	1.11 (0.5)	1.18 (0.9)	1.31 (1.1)	<0.001
<0.9	1667 (32.9)	675 (39.8)	815 (33.6)	177 (18.8)	<0.001
0.9-1.1	2603 (51.4)	856 (50.5)	1262 (52.0)	485 (51.5)	
≥1.2	795 (15.7)	165 (9.7)	350 (14.4)	280 (29.7)	
Dialysis termination					
Yes	157 (3.1)	73 (4.3)	70 (2.9)	14 (1.5)	0.04
No	4968 (96.9)	1623 (95.7)	2357 (97.1)	928 (98.5)	
Intradialytic death					
Yes	9 (0.2)	6 (0.4)	2 (0.1)	1 (0.1)	0.06
No	5057 (99.8)	1690 (99.6)	2425 (99.9)	941 (99.9)	

IDHT: Intradialytic hypertension, IDH: Intradialytic hypotension, SD: Standard deviation

Table 5: Relationship between participant's variables and the dialysis dose

Variables	Kt/V<1.2 (*n*=4270), *n* (%)	Kt/V≥1.2 (*n*=795), *n* (%)	OR	95% CI	*P*
Sex					
Males	2849 (83.7)	555 (16.3)	0.32	0.02–0.91	0.07
Females	1421 (85.6)	240 (14.4)			
Age (years)					
<65	3754 (84.0)	717 (16.0)	1.10	0.69–1.38	0.05
≥65	516 (86.9)	78 (13.1)			
Educational attainment					
Less than tertiary	1899 (89.5)	223 (10.5)	4.12	2.86–5.93	0.001
Tertiary	2371 (80.6)	572 (19.4)			
Health insurance					
Yes	504 (71.6)	200 (28.4)	5.84	2.55–6.16	<0.001
No	3766 (86.4)	595 (13.6)			
Etiology of CKD (diabetes)					
Yes	143 (88.8)	18 (11.2)	2.44	1.93–4.12	0.04
No	4127 (84.2)	777 (15.8)			
Dialysis session/week					
≤2	3695 (89.6)	428 (10.4)	7.95	0.46–9.03	<0.001
3	575 (61.0)	367 (39.0)			
Erythropoietin (400 IU)					
≤2	3582 (90.5)	378 (9.5)	7.65	2.48–9.46	<0.001
3	688 (62.3)	417 (33.70)			
Predialytic systolic BP					
<140	506 (68.5)	233 (31.5)	6.25	0.37–6.26	<0.001
≥140	3764 (87.0)	562 (13.0)			
Predialytic diastolic BP					
<90	449 (69.3)	199 (30.7)	6.02	2.94–7.95	<0.001
≥90	3821 (86.5)	596 (13.5)			
Predialytic hematocrit					
<33	3862 (84.8)	693 (15.2)	2.64	1.49–3.12	0.03
≥33	408 (80.0)	102 (20.0)			
Predialytic bicarbonate (mol/L)					
<22.0	3742 (85.9)	613 (14.1)	4.56	4.02–8.11	0.001
>22.0	528 (74.4)	182 (25.6)			
Predialytic creatinine (umol/L)					
<600	621 (61.4)	390 (38.6)	7.93	2.72–9.42	<0.001
>600	3649 (90.0)	405 (10.0)			
BFR (mL/min)					
<300	998 (90.3)	107 (9.7)	4.68	3.65–7.86	0.001
>300	3272 (82.6)	688 (17.4)			
Ultrafiltration volume (L)					
<2	2080 (89.1)	254 (10.9)	4.11	2.42–5.99	0.001
≥2	2190 (80.2)	541 (19.8)			
IDH					
Yes	839 (87.1)	101 (12.9)	2.18	0.94–3.15	0.04
No	3431 (83.7)	694 (16.3)			
IDHT					
Yes	960 (86.6)	149 (13.4)	1.47	1.05–2.10	0.05
No	3310 (83.7)	646 (16.3)			
Dialysis termination					
Yes	132 (84.1)	25 (4.9)	4.68	1.67–5.23	0.001
No	4138 (84.3)	770 (15.7)			
Intradialytic death					
Yes	8 (88.9)	1 (11.1)	2.42	2.01–4.69	0.04*
No	4262 (84.3)	794 (15.7)			

*Fisher's exact test. OR: Odds ratio, CI: Confidence interval, CKD: Chronic kidney disease, IU: International unit, BP: Blood pressure, IDHT: Intradialytic hypertension, IDH: Intradialytic hypotension, BFR: Blood flow rate

Table 6: Multiple regression analysis

Variables	aOR	95% CI	*P*
Educational attainment	3.05	2.26-3.16	0.05
Health insurance	5.11	1.84-5.73	<0.001
Dialysis session/week	12.32	7.69-15.36	<0.001
Erythropoietin	7.32	4.81-9.51	<0.001
Predialysis systolic BP	5.31	2.25-6.02	<0.001
Predialysis bicarbonate	4.22	3.94-5.47	0.003
Predialysis creatinine	10.38	6.62-15.35	<0.001
Blood flow rate	14.28	3.84-15.49	<0.001
Ultrafiltration volume	3.07	1.73-3.46	0.05
Dialysis termination	3.95	3.11-6.04	0.04

BP: Blood pressure, BFR: Blood flow rate, CI: Confidence interval, aOR: Adjusted odds ratio

lack of health insurance, higher predialysis BP, significant intradialytic BP variations, anemia, metabolic acidosis, dialysis termination, and intradialytic death. The finding that only 18.6% of the sessions met the thrice weekly recommended by the Kidney Disease Outcomes Quality Initiative, highlights the likely consequences of under dialysis which, in this study, was associated with a higher severity of morbidities.[16] Dyselectrolytemia (particularly hyperkalemia) that was more common with the under-dialyzed in our study is often associated with poor quality of life (QOL) and can induce myocardial hyperexcitability, arrhythmias, and cardiac arrest.[17] The greater fluid and solute accumulation in the interdialytic periods in the under-dialyzed lead to higher osmotic gradients across dialyzer membranes, just as it increases the risk of heart failure, stroke, and myocardial infarction (MI) and accelerates kidney disease progression.[2,13]

Metabolic acidosis and CKD bone mineral disease (BMD) are conditions often associated with end-stage renal disease (ESRD) and hence are expected to be more prevalent with under-dialysis. It would, therefore, be expected that many under-dialyzed individuals would not meet the Kidney Disease: Improving Global Outcomes (KDIGO) recommendation of a serum bicarbonate concentration (SBC) of at least 22 mmol/L.[18] Hypoalbuminemia was more common in under-dialyzed individuals; this mirrors previous findings and partly results from the poor dialytic clearance of anorexic cytokines, leading to suppressed appetite.[3,11] Hypoalbuminemia stimulates the antidiuretic hormone (ADH) leading to higher salt-poor water retention and IDWG. Anemia, a correlate of under-dialysis, is associated with increased plasma volume and higher IDWG and could be complicated by heart failure in ESRD, in addition to worsening cardiovascular profile and cardiac enlargement.[12]

A greater percentage of the participants were receiving dialysis twice weekly; this is not in agreement with findings from the developed nations as insurance coverage even for most of the poor ensures the availability of regular dialysis treatment but mirrors findings from a large population-based study in Indians.[19-21] The lower hematocrit in the under-dialyzed also underscores the contribution of anemia prevention and treatment, to overall treatment outcome.[12] Under-dialysis is commonly associated with low-frequency usage of erythropoietin, a relatively expensive component of RRT. Higher IDWG is expected with increasing severity of anemia due to higher plasma volume. The more severe form of metabolic acidosis (MA) among the under-dialyzed is in agreement with studies that reported a higher prevalence of MA with lower dialysis doses.[22] The negative relationship between the SBC and the occurrence of CKD-BMD could explain the findings of lower SBC and dialysis doses, in conjunction with higher phosphate that was seen in the under-dialyzed, and this mirrors the findings by Woodell *et al*.[23]

The positive relationship between the dialysis dose and the dialysis frequency is in agreement with previously reported findings. The dialysis dose is reported to be positively related to BP control; under-dialysis would, therefore, increase the risk and incidence of intradialytic hypotension (IDH) and IDHT.[5,9,14] An adequate dialysis dose minimizes the IDWG, the ER, and eventually the dialysis UFV, thereby reducing the frequencies of IDH.[14,19,20] This perhaps explains why the triage of complexities, made up of under-dialysis, IDH, and inadequate dialysis dose, is more common in LISs.[5,6,14]

Due to widespread availability of various forms of health insurance in the developed nations, even the poor commonly assess health care relatively easier compared to the poor in underdeveloped nations and particularly in low socioeconomic settings.[24] Prior to kidney transplant, dialysis sessions and treatment of anemia in ESRD happen to be the two most expensive treatment modalities, and their availability to the health-insured and the wealthy, therefore, gives them a double-edge advantage over the poor. This is reflected in the very wide differences between the mean dialysis dose of cohorts dialyzing thrice weekly (which met the minimum expected dose) and those dialyzing less frequently.[24]

Under-dialysis seem to pose some challenges to the nephrologist in prescribing the dialysis dose as the combined effect of lower dialysis doses, worse MA, and anemia entailed higher IDWG. This would necessitate higher UFV in the next session and could in turn heighten the risk of IDH that could be complicated by dialysis termination and intradialytic death, as were found in this study, and similar to findings by Chou and Kalantar-Zadeh.[25] Apart from limiting the UFV, preventing IDH may also involve restrictions on the BFR, resulting in lower dialysis doses. Dialysis termination has always remained a major challenge in the MHD population, particularly among the poor as the lower dose necessitates the need to fast forward the next session, and considering the stress some of these patients go through in securing funds for a session, its prevention becomes a task the nephrologist must carry out. Although low flux dialyzers (LFDs) were hardly used in these cohorts, in situation where they are widely available, the nephrologist might be compelled to reduce the rate of use

of high flux dialyzers (HFDs) to reduce the incidence of IDH despite the relative advantages of HFDs over the LFDs.[6,14]

One would have expected a higher prevalence of IDHT in cohorts dialyzing thrice weekly due to lesser IDWG, smaller intradialytic (membrane) osmotic gradients, and UFV compared to cohorts receiving twice-weekly sessions. The occurrence of higher predialysis BPs in the latter most likely led to a higher frequency of IDHT in them. The lower proportion of females in the study and even the fewer dialysis received by females agree with previous studies that found a gender bias in accessing health-care, incident, and prevalent hemodialysis sessions, occasioned by their lower educational attainment, socioeconomic differences, and cultural practices. Males were found to receive 58.7% of the sessions in Egypt.[26]

The proportion of the elderly in this study is lower than the 29.5% reported in Brazil, and comparatively much lower than the 49%–84% incident rates reported from the United States, Canada, the United Kingdom, and Europe.[27] Despite the higher mortality rate among the elderly in the dialysis population, the percentage of the elderly in the MHD population in these countries would still be higher than the 13.8% found in this study, due to the comparatively higher life span in these advanced nations. The positive relationship between participants' educational attainment and the dialysis frequency is similar to findings from many developing nations. The wider coverage of health insurance in the developed nations tends to bridge this gap.[28] The challenges associated with decision making, whether to initial dialysis or continue conservative treatment measures in the elderly (based on comorbidities and projected time to death), would have contributed to the lower frequency of elderly and the percentage of sessions received by them, particularly in LISs.

The percentage of the health insured was much lower than those reported in other developing nations such as India (35%) and Egypt (58.8%). A study that assessed dialysis treatment in 125 nations based on the World Health Organization classification of economic scales of nations reported that 12% of dialysis patients were paying out of pocket, although the less developed among these nations are expected to record significantly higher percentages.[29] In Nigeria, with the average cost of a dialysis session of USD55, a monthly national minimum wage of USD 50 and an abysmally low rate of health insurance, dialysis frequencies, and doses are expected to be suboptimal, in association with a higher profile of dialysis complications, as were found in this study.[24]

Under-dialysis is a major factor behind the lesser time between dialysis initiation and death of most patients on MHD in most LINs; however, it is worth remembering that in most LISs, initiation of dialysis is commonly delayed compared with the developed nations.[6,24] Higher UFVs, incidence of IDH, and IDHT would necessitate a higher rate of dialysis termination further worsening the burden on patients and their relatives, particularly with the common practice of not reusing dialyzers.[7,29]

Limitations

The automated BP monitor (ABPM) used in BP dynamics was not available in the interdialytic period. The dry weight of participants that would have helped in formulating the dialysis prescription, was not determined. The contribution of the residual kidney function to solute clearance was not known as it was not determined. The blood PH, a better marker of acid-base balance, was not assessed. However, the two-centre design strengthens the study.

Conclusion

We found a high prevalence of under-dialysis among the MHD population. Two significant differences in the delivered dialysis regimen of RRT between the advanced nations and the LINs seem to be the fewer sessions and suboptimal anemia correction in LINs. These mostly account for the socioeconomic and health burden associated with under-dialysis that encompasses anemia, metabolic acidosis, fluid overload, poor intra- and interdialytic BP control, and dialysis termination. These all contribute to the worse derangement in serum biochemical parameters, lower QOL, and higher morbidity and mortality among the MHD population in LINs. Increased funding of the renal health care by philanthropists, governments, donor agencies, and religious bodies, in addition to increased enlightenment programme, would be needed to improve the delivery of an effective dialysis regimen in LINs.

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Conflicts of interest

There are no conflicts of interest.

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