Ultrafiltration in Patients on Automated Peritoneal Dialysis with Homechoice Claria connected to Sharesource: A Pilot Study

Yu-An Hsiao
Department of Internal Medicine, Linkou Chang Gung Memorial Hospital, Taoyuan
Ya-Chung Tian
Kidney Research Center, Department of Nephrology, Linkou Chang Gung Memorial Hospital, Taoyuan
Tzung-Hai Yen
Kidney Research Center, Department of Nephrology, Linkou Chang Gung Memorial Hospital, Taoyuan
Ming-Yang Chang
Kidney Research Center, Department of Nephrology, Linkou Chang Gung Memorial Hospital, Taoyuan
Chan-Yu Lin
Kidney Research Center, Department of Nephrology, Linkou Chang Gung Memorial Hospital, Taoyuan
Shou-Hsuan Liu (8701071@cgmh.org.tw)
Kidney Research Center, Department of Nephrology, Linkou Chang Gung Memorial Hospital, Taoyuan

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Abstract

Introduction: Fluid overload is an unavoidable problem in patients on peritoneal dialysis (PD) and is associated with poor outcomes. The aim of our study was to estimate ultrafiltration (UF) under different dextrose concentrations and clarify possible predictors of UF.

Materials and methods: Seventy patients, with 1848 daily treatment records and 8266 single dwells on automated PD through Homechoice Claria with Sharesource were followed in October 2020 and categorized into 2 groups according to the dextrose concentration (group D1.5% and D2.5%). Baseline characteristics, peritoneal membrane characteristics, and daily PD treatment records from Sharesource were obtained. We compared UF under the different conditions.

Results: Multivariate linear regression revealed that the mean fill volume (FV) per cycle (p=0.006) and dextrose concentration (p=0.000) were independent predictors of UF. The mean night UF per cycle, the mean night UF corrected by FV per cycle, and the mean night UF corrected by FV and dwelling time (DT) per cycle were 95.8 ml, 5.5%, and 5.0 ‰/minutes in group D1.5% and 220.3 ml, 12.0%, and 11.6 ‰/minutes in group D2.5%, respectively. After an approximately 120-minute DT, there was a trend toward higher UF in the low peritoneal permeability group and lower UF in the high peritoneal permeability group.

Conclusion: This retrospective study presents precise UF measurements with two solutions at different dextrose concentrations and four peritoneal transport levels. UF is positively correlated with DT and FV of the dialysate within a reasonable range. High peritoneal permeability is associated with decreased UF, and low peritoneal permeability requires a longer DT to reach the maximal UF.

Introduction

The first description of a peritoneal dialysis (PD) cycler was conceived by Boen et al. in the 1960s [1, 2], and it was able to exchange dialysate from the abdomen semiautomatically with the assistance of gravity. This was the predecessor of automated peritoneal dialysis (APD). Limited by a bulky and expensive machine, APD was not the first choice for patients on PD; rather, it was mainly used in hospitals as a temporary therapy at that time. It was not until the 1980s when upgraded cyclers were developed that APD was broadly used as home therapy [3]. However, a series of challenges arose when the treatment was performed without professional surveillance.

First, physicians can only glance at the dialysis record during the monthly visit. Most patients are unable to adequately recognize and evaluate problems, such as insufficient dialysis and the need to visit their physician earlier, which indicates that adjustment of the prescription is not concurrent [4]. This also creates a barrier in patients' perception, resulting in a lack of confidence and efficacy in performing dialysis by themselves [5–7]. Second, patient noncompliance is a major contributor to technique failure and poor outcomes. A systematic review of 204 studies reported that the rate of nonadherence of patients on PD varied from 2.6–53% [8], and noncompliant patients may have a greater risk of hospitalization, death, and rate of transfer to hemodialysis than compliant patients [8, 9].

The problems stated above all result in technique failure and underuse of APD. Fortunately, the advent of Homechoice Claria in 2015 overcame these barriers. Homechoice Claria is a remote patient monitoring system (RPM) equipped with a cloud-based platform, Sharesource. Physicians can supervise the dialysis course daily, identify possible problems and adjust the prescription in a timely manner just by logging into the Sharesource platform [3]. RPM has been used to manage chronic diseases such as cardiovascular disease and diabetes mellitus

(DM) with proven efficacy [10–12]; thus, several studies were performed to assess the advantages of RPM in patients with APD. As expected, RPM not only reduces the consumption of healthcare resources and patients' travel time but also provides reassurance to and supports the adherence of patients through continuous surveillance [6, 12–14]. It has been shown that dialysis prescriptions are modified significantly more frequently under remote monitoring-APD (RM-APD) [4, 15], and patient adherence to the prescription is more than 90% [16]. Indeed, under the personalized tailoring of prescriptions and early troubleshooting, patients on RM-APD have fewer hospitalization days, hospital visits, and nocturnal alarms and lower hospitalization rates [4, 12, 17, 18]. Additionally, RM-APD may provide better hemodynamic and fluid control [19].

Apart from the advantages mentioned above, Homechoice Claria also reports details that were not available in the past, including actual treatment time, dextrose concentration, filling volume, dwell time, and the most important data —accurate ultrafiltration (UF) details [20]. Fluid overload has been an unavoidable problem in chronic PD patients [21]. A number of studies highlight the prevalence and extent of fluid overload in PD patients. The reported prevalence ranges from approximately 50% to more than 70% [22, 23], and the average volume excess measured through bioimpedance spectroscopy is more than 2 liters [24], while 20% of PD patients have a volume excess of more than 5 liters [22]. Fluid overload is associated with poor outcomes, including adverse cardiac events and mortality, in PD patients [21, 25–27], even more so than in those on hemodialysis [28]. A prospective study indicated that patients with decreased UF (< 750 ml per day) had a significantly worse survival rate [29]. Thus, it is important to monitor and control UF closely, which may be achieved through Homechoice Claria with Sharesource. Furthermore, it may be better if we can predict UF and adjust the formula in advance. However, few studies have mentioned the relationship between UF and the dextrose concentration of PD solutions or factors that may affect UF. Thus, the aim of our study is to estimate UF under different conditions, including the dextrose concentration and peritoneal equilibration test (PET), and clarify possible predictors of UF, which are helpful for adjusting the dialysate prescription.

Material And Methods

Study population and follow-up

This observational cohort study was performed in accord with the guidelines of the Declaration of Helsinki. Ethics approval (approval number 202100840B0) was obtained from the Institutional Review Board of Chang Gung Medical Foundation in Taiwan without the requirement for patient consent form because the study was a retrospective review. All the information was anonymized, delinked, and accessible only to the investigator. Finally, all primary data were collected in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

In this retrospective cohort study, we initially enrolled 163 patients at Linkou Chang Gung Memorial Hospital (CGMH) on PD through Homechoice Claria within 1 month (October 2020). We excluded 93 patients who received PD for less than three months, who had treatment records obtained from Sharesource for less than 15 days in a month, and who used more than two PD solutions with different dextrose concentrations. Overall, 70 patients were included. All patients were categorized into 2 groups according to the dextrose concentration of the PD solution (group 1: 1.5% dextrose concentration, D1.5%, N = 28; group 2: 2.5% dextrose concentration, D2.5%, N = 42).

Baseline demographic and clinical data, namely, age at enrollment in the study, sex, the presence of comorbidities including DM and cardiovascular disease (CVD), cause of end-stage renal disease (ESRD), the duration of PD at

enrollment in the study, the surgical method of PD tube implantation (laparoscopic surgery or open surgery), body mass index (BMI), daily systolic blood pressure (SBP) and diastolic blood pressure (DBP) before dialysis, residual urine, hemoglobin level (Hb), and the biochemical parameters high sensitivity C-reactive protein (hs-CRP), albumin, blood urea nitrogen (BUN), creatinine, fasting glucose, and glycated hemoglobin (HbA1c) were obtained. Residual urine was defined as a daily total urine volume of more than 100 ml. All biochemical parameters were analyzed by standard laboratory procedures using an automated analyzer and were collected in October 2020.

Peritoneal membrane characteristics

The sufficiency of PD was assessed through dialysate-to-plasma concentrations (D/P) for creatinine calculated after a 4-hour dwell, and the PET results were categorized into 4 groups: high (H), high average (HA), low average (LA), and low (L). Other parameters included D/P for urea after a 4-hour and 24-hour dwell, D/P for creatinine after a 24-hour dwell, and urine-to-plasma concentrations (U/P) for urea and creatinine after a 24-hour dwell. The glucose concentration in the dialysate after a 4-hour and 24-hour dwell and glucose concentration in 24-hour urine were also obtained. All data were collected in October 2020.

Peritoneal dialysis treatment details

Patients' treatment records from October 1, 2020, to October 31, 2020, were collected from Sharesource and analyzed. The calculations were mean night cycle (sum of night treatment cycle divided by total treatment days within the month), mean night fill volume (FV) per cycle (sum of night dialysate FV per cycle divided by total night treatment cycles within the month), mean FV per night (sum of night dialysate FV per cycle divided by total treatment days within the month), mean night dwell time (DT) per cycle (sum of night treatment time per cycle divided by total night treatment cycles within the month), mean DT per night (sum of night treatment time per cycle divided by total treatment days within the month), mean night UF per cycle (sum of night UF per cycle divided by total night treatment cycles within the month), mean UF per night (sum of night UF per cycle divided by total treatment days within the month), mean night UF corrected by night FV per cycle (mean night UF/FV per cycle; sum of every night UF per cycle divided by night FV per cycle then divided by total night treatment cycles within the month), and mean night UF corrected by night FV and night DT per cycle (mean night UF/FV/DT per cycle; night UF per cycle divided by night FV and night DT per cycle and then divided by total treatment cycles within the month).

Statistical analysis

We used SPSS Statistics for Macintosh, Version 20.0, Armonk, NY: IBM Corp. to analyze our data. Categorical variables are summarized as numbers or percentages, and continuous variables are presented as the mean ± standard deviation (SD). All data were normally distributed. To compare the 2 groups, we used an independent t-test to analyze continuous variables and the chi-square test to analyze categorical variables. All p values are two-tailed, and a p value < 0.05 was considered statistically significant. Univariate linear regression analysis was used to identify the possible predictors for mean night UF per cycle. To control for confounding factors, multivariate linear regression with the enter method was used to analyze predictors identified as significant in univariate analysis.

Results

Baseline patient demographic and biochemical characteristics

In October 2020, 70 patients on APD through Homechoice Claria with Sharesource were enrolled in our study, with 1848 daily records and 8266 single dwells comprising 4933 records of 1.5% dextrose and 3333 records of 2.5%

dextrose. The baseline demographic characteristics and laboratory characteristics of patients on PD categorized according to the dextrose concentration of the PD solution are summarized in table 1. Between the 2 groups, there were no significant differences in sex, presence of comorbidities such as DM and CVD, ESRD cause, percentage of laparoscopic surgery, BMI, SBP, or DBP. The mean age was higher in D1.5% than in D2.5% (53.06 versus 44.38 years, p=0.019). The PD duration in D1.5% was shorter than that in D2.5% (29.8 versus 48.6 months, p=0.030). The residual urine was more prevalent in D1.5% than in D2.5% (753.8 versus 101.0 ml, p=0.000).

Table 1

Baseline demographic and laboratory characteristics of patients on PD categorized according to dextrose concentration of PD solution

	Total (n=70)	D1.5% (n=28)	D2.5% (n=42)	P value
Age (years)	47.86 ± 15.3	53.06 ± 16.6	44.38 ± 13.5	**0.019**
Male	35 (50.0%)	13 (46.4%)	22 (52.4%)	0.626
DM	17 (24.3%)	4 (14.3%)	13 (31.0%)	0.111
CVD	5 (7.1%)	0 (0.0%)	5 (11.9%)	0.058
ESRD cause				0.103
GN	31 (44.3%)	14 (50%)	17 (38.1%)	
HTN	11 (15.7%)	3 (10.7%)	8 (19.0%)	
DM	17 (24.3)	4 (14.3%)	13 (31.0%)	
Autoimmune	5 (7.1%)	4 (14.3%)	1 (2.4%)	
TIN	1 (1.4%)	0 (0.0%)	1 (2.4%)	
PKD	3 (4.3%)	3 (10.7%)	0 (0.0%)	
Obstructive uropathy	2 (2.9%)	0 (0.0%)	2 (4.8%)	
PD duration (month)	41.1 ± 35.8	29.8 ± 30.7	48.6 ± 37.3	**0.030**
Laparoscopic surgery	65 (92.9%)	25 (89.3)	40 (95.2)	0.343
BMI (kg/m^2)	23.9 ± 5.1	22.4 ± 4.4	24.8 ± 5.4	0.054
SBP (mmHg)	137.8 ± 18.9	136.7 ± 18.4	138.5 ± 19.4	0.696
DBP (mmHg)	83.0 ± 12.9	82.6 ± 13.1	83.2 ± 12.9	0.840
Residual urine (ml)	362.1 ± 570.9	753.8 ± 719.0	101.0 ± 183.0	**0.000**
hs-CRP (mg/L)	7.74 ± 11.60	4.65 ± 9.94	9.81 ± 12.26	0.068
Albumin (g/dL)	3.89 ± 0.41	3.86 ± 0.45	3.91 ± 0.39	0.644
Blood urine nitrogen (mg/dL)	62.39 ± 21.34	60.71 ± 16.92	63.51 ± 23.98	0.594
Creatinine (mg/dL)	12.50 ± 3.55	11.25 ± 3.78	13.34 ± 3.17	**0.015**
Fasting sugar (mg/dL)	110.0 ± 36.5	110.1 ± 31.0	110.0 ± 40.2	0.983
HbA1c (%)	6.08 ± 1.25	5.63 ± 0.69	6.38 ± 1.45	**0.014**
Hemoglobin (g/dL)	9.83 ± 1.87	9.96 ± 1.78	9.75 ± 1.94	0.634

Table 1

Baseline demographic and laboratory characteristics of patients on PD categorized according to dextrose concentration of PD solution

	Total (n=70)	D1.5% (n=28)	D2.5% (n=42)	P value

PD: peritoneal dialysis; D1.5%: dextrose concentration 1.5%; D2.5%: dextrose concentration 2.5%; DM: diabetes mellitus; CVD: cardiovascular disease; ESRD: end stage renal disease; GN: glomerulonephritis; HTN: hypertension; TIN: tubulointerstitial nephritis; PKD: polycystic kidney disease; BMI: body mass index; SBP: systolic blood pressure; DBP: diastolic blood pressure; hs-CRP: high sensitivity C-reactive protein

[a]Data are presented as n (%) or mean ± SD

There were no significant differences in hs-CRP, albumin, BUN, fasting glucose, or Hb levels. Patients in D1.5% had lower creatinine (11.25 versus 13.34 mg/dL, p=0.015) and HbA1c (5.63 versus 6.38%, p=0.014) levels than patients in D2.5%.

Peritoneal membrane characteristics and peritoneal dialysis treatment details

Peritoneal membrane characteristics and PD treatment details of patients on PD categorized according to the dextrose concentration of the PD solution are summarized in table 2. The 2 groups were similar with regard to D/P urea 4 hours, D/P urea 24 hours, D/P creatinine 24 hours, dialysate glucose 4 hours, U/P creatinine 24 hours, and U/P urea 24 hours. Significant differences were observed in D/P creatinine (0.61 versus 0.67, p=0.032) and PET (p=0.044, different in HA versus L, p=0.005, and LA versus L, p=0.044). Patients in D1.5% also had significantly lower values of dialysate glucose 24 hours (739.32 versus 1049.80 mg/dL, p=0.000) and urine glucose (120.21 versus 232.60 ml/dL, p=0.048) than those in D2.5%.

Between the 2 groups, no significant difference was noted in the mean night cycle, mean night FV per cycle, mean night DT per cycle, or mean DT per night. The mean FV per night was lower in D1.5% than D2.5% (7713.4 versus 8561.2 ml, p=0.006). D1.5% also had a lower mean UF per night (453.8 versus 1015.6 ml, p=0.000), mean night UF per cycle (95.8 versus 220.3 ml, p=0.000), mean night UF/FV per cycle (5.5 versus 12.0%, p=0.000), and mean night UF/FV/DT per cycle (3.74 versus 11.58 ‰/minutes, p=0.000).

Table 2

Peritoneal membrane characteristics and treatment details of patients on PD categorized according to dextrose concentration of PD solution

	Total (n=70)	D1.5% (n=28)	D2.5% (n=42)	P value
D/P creatinine 4 hours	0.64 ± 0.11	0.61 ± 0.11	0.67 ± 0.09	**0.032**
PET				**0.044**
H	6 (8.6%)	3 (10.7%)	3 (7.1%)	
HA	26 (37.1)	7 (25.0%)	19 (45.2%)	
LA	34 (48.6%)	14 (50.0%)	20 (47.6%)	
L	4 (5.7%)	4 (14.3%)	0 (0.0%)	
D/P urea 4 hours	0.91 ± 0.11	0.92 ± 0.72	0.91 ± 0.13	0.526
D/P urea 24 hours	0.80 ± 0.14	0.82 ± 0.11	0.78 ± 0.16	0.172
D/P creatinine 24 hours	0.53 ± 0.11	0.52 ± 0.14	0.54 ± 0.88	0.557
Dialysate glucose 4 hours (mg/dL)	770.62 ± 186.38	790.39 ± 176.75	757.12 ± 193.67	0.471
Dialysate glucose 24 hours (mg/dL)	932.81 ± 227.26	739.32 ± 179.09	1049.80 ± 161.42	**0.000**
U/P creatinine 24 hours	6.54 ± 5.76	5.90 ± 6.15	7.31 ± 5.31	0.423
U/P urea 24 hours	3.39 ± 1.96	3.50 ± 2.28	3.26 ± 1.52	0.697
Urine glucose (mg/dL)	171.30 ± 188.52	120.21 ± 190.57	232.60 ± 170.94	**0.048**
Mean night cycle	4.7 ± 0.7	4.5 ± 0.7	4.8 ± 0.7	0.126
Mean night FV per cycle (ml)	1803.1 ± 341.4	1742.4 ± 340.1	1843.6 ± 340.3	0.227
Mean FV per night (ml)	8276.0 ± 1423.8	7713.4 ± 1270.8	8651.2 ± 1409.9	**0.006**
Mean night DT per cycle (min)	108.2 ± 17.4	112.8 ± 19.7	105.1 ± 15.2	0.070
Mean DT per night (min)	494.9 ± 54.7	497.2 ± 53.1	493.4 ± 56.4	0.776
Mean night UF per cycle (ml)	170.5 ± 97.3	95.8 ± 76.1	220.3 ± 76.0	**0.000**
Mean UF per night (ml)	790.9 ± 420.4	453.8 ± 338.0	1015.6 ± 304.7	**0.000**
Mean night UF/FV per cycle (%)	9.4 ± 5.0	5.5 ± 4.0	12.0 ± 3.6	**0.000**
Mean night UF/FV/DT per cycle (‰/minutes)	8.97 ± 4.88	5.04 ± 3.74	11.58 ± 3.66	**0.000**

Table 2

Peritoneal membrane characteristics and treatment details of patients on PD categorized according to dextrose concentration of PD solution

	Total (n=70)	D1.5% (n=28)	D2.5% (n=42)	P value

PD: peritoneal dialysis; D/P: dialysate/plasma; PET: peritoneal equilibration test; H: High; HA: High average; LA: Low average; L: low; U/P: urine/plasma; FV: fill volume; DT: dwell time; UF: ultrafiltration; D1.5%: dextrose concentration 1.5%; D2.5%: dextrose concentration 2.5%

[a]Data are presented as n (%) or mean ± SD

Predictors of ultrafiltration

We used univariate and multivariate linear regression models to identify the possible predictors of UF, and the results are summarized in table 3. The univariate linear regression analysis revealed that PD duration (p=0.003), residual urine (p=0.000), mean night FV per cycle (p=0.000), dextrose concentration (p=0.000), dialysate glucose 24 hours (p=0.000), and creatinine (p=0.000) were significant variables. However, in the multivariate linear regression model, only the dextrose concentration (p=0.000) and mean night FV per cycle (p=0.006) were significant, and a 1 ml increase in the FV was shown to result in a 0.123 ml increase in UF.

Table 3

Univariate and multivariate linear regression model on mean night UF per cycle

	Univariate		Multivariate	
	β ± SD	p value	β ± SD	p value
Age (years)	-0.808 ± 0.765	0.295		
Male (%)	27.803 ± 23.195	0.235		
DM (%)	8.525 ± 27.310	0.756		
CVD (%)	24.688 ± 45.406	0.066		
ESRD cause	-5.139 ± 4.428	0.250		
PD duration (month)	0.955 ± 0.309	**0.003**	0.200 ± 0.245	0.418
Laparoscopic surgery (%)	15.488 ± 45.466	0.735		
BMI (kg/m^2)	3.329 ± 2.262	0.146		
SBP (mmHg)	0.553 ± 0.622	0.377		
DBP (mmHg)	-0.063 ± 0.916	0.946		
Residual urine (ml)	-0.082 ± 0.018	0.000	-0.016 ± 0.018	0.359
Mean night cycle	-21.362 ± 16.672	0.204		
Mean night FV per cycle (ml)	0.123 ± 0.031	**0.000**	0.075 ± 0.026	**0.006**
Mean night DT per cycle (min)	0.651 ± 0.673	0.336		
Mean DT per night (min)	-0.073 ± 0.215	0.734		
Dextrose concentration (%)	124.544 ± 18.551	0.000	88.619 ± 23.476	**0.000**
D/P creatinine 4 hours	-95.483 ± 111.025	0.393		
PET	-18.904 ± 15.850	0.237		
D/P urea 4 hours	-82.924 ± 105.300	0.434		
D/P urea 24 hours	-23.453 ± 84.076	0.781		
D/P creatinine 24 hours	-116.825 ± 103.817	0.264		
Dialysate glucose 4 hours (mg/dL)	0.095 ± 0.063	0.132		
Dialysate glucose 24 hours (mg/dL)	0.199 ± 0.046	**0.000**	0.024 ± 0.048	0.608
U/P creatinine 24 hours	0.634 ± 2.614	0.809		
U/P urea 24 hours	-5.399 ± 7.660	0.485		
Urine glucose (mg/dL)	0.045 ± 0.080	0.575		
HS-CRP (mg/L)	0.320 ± 1.017	0.754		
Albumin (g/dL)	51.192 ± 28.003	0.072		

Table 3

Univariate and multivariate linear regression model on mean night UF per cycle

	Univariate		Multivariate	
	β ± SD	p value	β ± SD	p value
Blood urine nitrogen (mg/dL)	0.242 ± 0.552	0.663		
Creatinine (mg/dL)	12.611 ± 2.948	**0.000**	4.960 ± 2.549	0.056
Fasting sugar (mg/dL)	-0.139 ± 0.323	0.668		
HbA1c (%)	6.617 ± 9.375	0.483		
Hemoglobin (g/dL)	2.029 ± 6.309	0.741		

UF: ultrafiltration; DM: diabetes mellitus; CVD: cardiovascular disease; ESRD: end stage renal disease; PD: peritoneal dialysis; BMI: body mass index; SBP: systolic blood pressure; DBP: diastolic blood pressure; FV: fill volume; DT: dwell time; D/P: dialysate/plasma; PET: peritoneal equilibration test; U/P: urine/plasma; HS-CRP: high sensitivity C-reactive protein

Mean night UF and DT per cycle at dextrose concentrations of 1.5% and 2.5% categorized according to PET are summarized in table 4. Figure 1a shows night UF per cycle categorized according to PET and dextrose concentration, which revealed a decreasing trend of mean night UF per cycle in the group with high transport function. We used night FV to correct mean night UF per cycle, which is shown in figure 1b, and the trend was similar to that in figure 1a. Figure 1c and 1d present the mean night UF per cycle under dextrose concentrations of 1.5% and 2.5% categorized according to the mean DT per cycle and PET, respectively. The mean night UF per cycle increased in the group with low average transport function after 120 minutes of dwell in both D1.5% and D2.5%, while in the group with high average transport function, it decreased after 120 minutes of dwell in D1.5%.

Table 4

Mean night UF, fill volume, and dwelling time per cycle at dextrose concentrations of 1.5% and 2.5% categorized according to peritoneal equilibration test

DC(%)	PET (number)	Mean night UF per cycle (ml)	Mean night UF/FV per cycle (%)	Mean night DT per cycle (minutes)	Mean night UF/FV/DT per cycle (‰/minutes)
1.5	L (4)	147.4 (88~216)	8.7 (5.9~11.5)	111.5 (96.9~129.6)	8.0 (4.5~11.7)
	LA (14)	100.6 (42~214)	5.7 (2.4~12.0)	115.9 (82.5~171.2)	5.0 (2.3~12.2)
	HA (7)	106.4 (23~273)	6.0 (1.1~10.5)	103.4 (78.1~137.4)	5.9 (1.0~8.6)
	H (3)	-20.3 (-128~100)	-1.0 (-7.1~6.3)	121.6 (119.1~126.3)	-0.8 (-6.0~5.3)
	Total (28)	95.8 (-128~273)	5.5 (-7.1~12.0)	112.8 (78.1~171.2)	5.0 (-6.0~12.2)
	p value	**0.019**	**0.006**	0.485	**0.008**
2.5	LA (20)	236.4 (67~418)	12.6 (3.4~20.7)	108.6 (75.1~144.6)	11.7 (3.3~20.6)
	HA (19)	210.3 (118~342)	11.8 (7.6~20.1)	103.3 (88.7~133.1)	11.6 (8.1~21.4)
	H (3)	176.5 (76~246)	9.9 (5.1~14.3)	93.1 (88.5~97.6)	10.8 (5.2~15.3)
	Total (42)	220.3 (67~418)	12.0 (3.4~20.7)	105.1 (75.1~144.6)	11.6 (3.3~21.4)
	p value	0.337	0.485	0.203	0.928

UF: ultrafiltration; DC: dextrose concentration; PET: peritoneal equilibration test; FV: fill volume; DT: dwell time; L: low; LA: Low average; HA: High average; H: High

[a]Data are presented as mean (range)

Discussion

To the best of our knowledge, our study is the first real-world study with a large amount of precise data obtained by using Homechoice Claria with Sharesource, which empowers us to accurately analyze the UF under different conditions such as the dextrose concentration and PET results. Between the two groups, D2.5% had a longer PD duration and less residual urine than D1.5%. This is reasonable because as time passes, the longer the PD duration is, the greater the renal function decrease, which may cause a decrease in residual urine. Our study emphasizes precise UF, its predictive factors, and influential factors.

Few trials have investigated UF at different dextrose concentrations, not to mention the real-world treatment details. Net UF is composed of transcapillary UF and lymphatic absorption from the peritoneal cavity. Transcapillary UF is mainly driven by osmotic pressure through the dialysate glucose gradient but is also affected by transcapillary

hydrostatic pressure, whereas lymphatic absorption is mainly governed by intraperitoneal hydrostatic pressure and remains almost unchanged throughout the dialysis period [30–32]. In our study, the mean night UF per cycle was 95.8 ml in D1.5% and 220.3 ml in D2.5% (Table 2), which was significantly different. The mean night UF/FV per cycle was 5.5% (ranging from − 7.1–12.0%) in D1.5% and 12.0% (ranging from 3.4–20.7%) in D2.5%. Corrected by the DT, the mean night UF/FV/DT per cycle was 5.0 ‰/min in D1.5% and 11.6 ‰/min in D2.5% (Table 4). This is in line with the theory that the greater the osmotic pressure caused by the glucose gradient is, the greater the UF increase. Previous trials reported that the UF percentage ranged from − 3.50–16.50% with 1.5% dextrose [33–36], 10.50–18.76% with 2.5% dextrose [31, 34, 35, 37–39], 30.60–51.40% with 4.25% dextrose [33–35], and 11.7–12.62% with mixed dextrose concentrations [40, 41], with the same FV (2 liters) and different DTs (ranging from 1.5 hours to 6 hours). The UF/FV/DT values ranged from 0.97 to 6.07 ‰/min with 1.5% dextrose [35, 36] and 2.93 to 11.85 ‰/min with 2.5% dextrose [31, 35, 37–39]. Our results were all in accordance with previous trials.

Notably, among the studies mentioned above, the lowest UF (3.50% with 1.5% dextrose, 10.50% with 2.5% dextrose, and 30.60% with 4.25% dextrose) was noted in a 6-hour dwell study by Heimburger O et al. [35]. In this study, the intraperitoneal dialysate volume versus time curve and net UF rate over time demonstrated an initial positive net UF (mainly driven by dextrose osmotic pressure), then an isovolemic period (15 to 120 minutes, 90 to 240 minutes, and 120 to 240 minutes for 1.5%, 2.5%, and 4.25% dextrose, respectively), and finally, a fluid reabsorption period that was similar for all three solutions. This highlights the relationship between the DT and the UF, which is not linear. The maximal net UF rate occurs within the first few minutes of the dialysate dwell (ranging from 4.3 to 6 ml/min, 8 ml/min, and 12.8 to 14 ml/min during the first 15 minutes, 90 minutes, and 90 minutes for 1.5%, 2.5%, and 4.25% dextrose, respectively [35, 42]), and the maximal net UF is achieved when the transcapillary UF rate equals the lymphatic absorption rate, that is, dynamic equilibrium is achieved between osmotic pressure, transcapillary hydrostatic pressure, and lymphatic absorption [31, 43], which occurs within 85 to 140 minutes with 1.5% dextrose, 140 to 160 minutes with 2.5% dextrose, and 197 to 254 minutes with 4.25% dextrose, according to previous studies [31, 33, 34, 42, 43]. The net UF decreases after equilibrium is broken, and lymphatic absorption plays a dominant role. These studies give an explanation for our result. In the univariate linear regression model for mean night UF per cycle in D2.5%, we found a significant difference in mean night DT per cycle, in which a 1-minute increase in mean night dwell time per cycle would result in a 2.24 ml increase in UF ($p = 0.003$, not shown in the table). This may be because the mean night DT per cycle of the D2.5% group was 105.1 minutes, which is below the range of the time to reach the maximal net UF, as mentioned above (140 to 160 minutes); thus, before reaching equilibrium, the net UF increases as the DT gets longer. For D1.5%, there was no significant difference. We presume this is because the mean DT per cycle of D1.5% was 112.8 minutes and was within the range of the time to reach equilibrium (85 to 140 minutes), which means that the maximal net UF is achieved and even enters to the fluid reabsorption period.

In addition to the dextrose concentration, which was not considered in the studies above, peritoneal membrane characteristics were evaluated. Similar to what was suggested in other studies [25, 32, 41], there was a trend of correlation between high peritoneal transport status and decreased UF in both D1.5% and D2.5% in our results (Figs. 1a & 1b). Additionally, the dialysate DT to reach the maximal net UF was longer in patients with lower peritoneal permeability than in those with higher peritoneal permeability. In a study by Alp Akonur et al. using 2.5% dextrose dialysate [44], the peak DT according to UF was 2.5 hours in the high peritoneal transport type and 4 hours in the low-average peritoneal transport type. This gives an explain for our result—UF increased in the group with low average transport function after a 120-minute dwell at both the 1.5% and 2.5% dextrose concentrations, while in the group with high average transport function, UF decreased after a 120-minute dwell at the 1.5% dextrose concentration (Figs. 1c & 1d).

UF is also affected by intraperitoneal pressure (IPP) and the dialysate FV [45, 46]. In a comparison of the UF between dialysis with a 2- and 3-liter exchange of 1.5% dextrose dialysate, Krediet RT et al. revealed that the UF was lower in the 3-liter exchange due to the increased water reabsorption rate, which is related to IPP [47], while another study demonstrated that the maximal net UF was achieved when the dialysate FV was 2286 ml and the UF then decreased secondary to the increased IPP [37]. This explains our result revealing that the mean night FV per cycle was positively correlated with mean night UF per cycle ($p = 0.006$) because our mean night FV was 1803.1 ml with a median of 1799.0 ml, which had not yet reached the maximal UF. This also indicates that there is still room for improvement in our dialysis prescription.

In conclusion, our study presents precise UF measurement with two solutions at different dextrose concentrations and four peritoneal transport levels. UF is positively correlated with the DT and FV of the dialysate within a reasonable range. High peritoneal permeability is associated with decreased UF, and low peritoneal permeability needs a longer dwell time to reach the maximal UF.

Due to the retrospective nature of our study, there are some limitations. First, the number of enrolled patients was not large enough to counterbalance the effect of some extrema, especially in the different PET groups. Second, because the kinetics of fluid transport during PD are not available, we used the average method to correct UF with the FV and DT, although the UF versus time curve was not linearly correlated, as indicated in the studies mentioned above. Finally, we did not take intraperitoneal residual volume into account. Different dialysate dextrose concentrations will affect intraperitoneal residual volume [35] and further influence the UF calculated by FV minus the drained volume.

Declarations

Ethics approval and consent to participate

Ethical approval was obtained from the Institutional Review Board of Chang Gung Medical foundation in Taiwan (approval number: 202100840B0).

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and analysed during the current study are available in the Sharesource repository, https://na.sharesource.com.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

All authors have made substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data. YAH and SHL have been involved in drafting the manuscript or revising it critically for important intellectual content. SHL have given final approval of the version to be published. All authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All authors read and approved the final manuscript.

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Figures

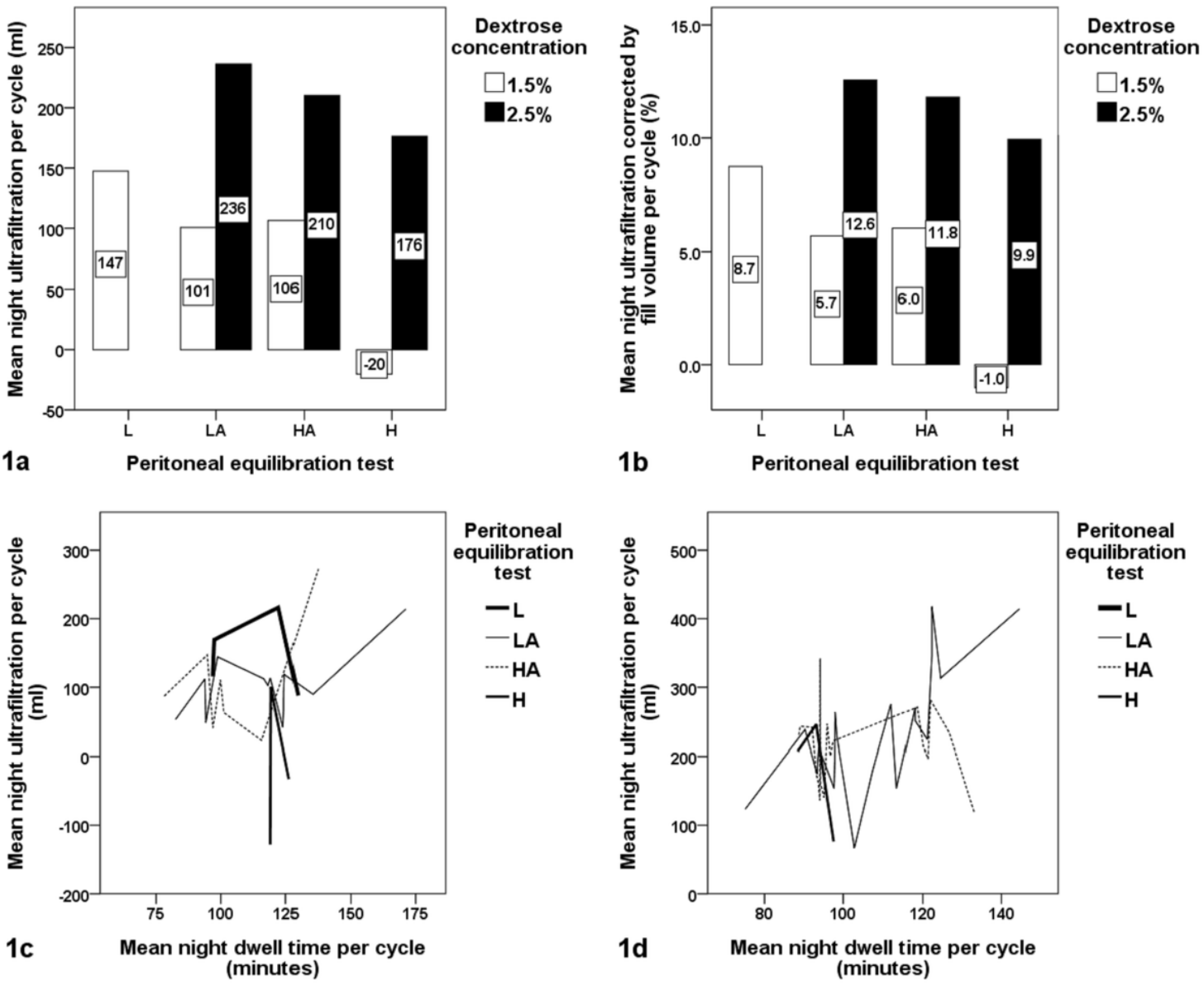

Figure 1

Ultrafiltration categorized according to peritoneal equilibration test, dextrose concentration, and dwell time. 1a: Mean night ultrafiltration per cycle categorized according to peritoneal equilibration test and dextrose concentration. 1b: Mean night ultrafiltration corrected by fill volume per cycle categorized according to peritoneal equilibration test and dextrose concentration. 1c: Mean ultrafiltration per cycle at dextrose concentration 1.5% categorized according to mean night dwell time per cycle and peritoneal equilibration test. 1d: Mean ultrafiltration per cycle at dextrose concentration 2.5% categorized according to mean night dwell time per cycle and peritoneal equilibration test.