Received: 22 May 2020 | Revised: 22 June 2020 | Accepted: 26 June 2020

DOI: 10.1111/nep.13751

ORIGINAL ARTICLE

NEPHROLOGY WILEY

Effect of remote patient management in peritoneal dialysis on haemodynamic and volume control

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Abstract

Aim: Reduced treatment compliance in patients with peritoneal dialysis facilitates the development of fluid overload and as a result increased blood pressure and vascular stiffness in the long term. We aimed to evaluate blood pressure change and anti-hypertensive needs of patients within 1 year after the changeover to remote monitoring automated peritoneal dialysis (RM-APD) and compare the effect of RM-APD and continuous ambulatory peritoneal dialysis (CAPD) on peripheral and central haemodynamic parameters, volume status of patients and anti-hypertensive drug needs.

Methods: This was an observational and cross-sectional study. We enrolled 15 patients performing CAPD, 20 patients performing RM-APD, and 38 age, and gender-matched healthy control. We measured pulse wave velocity to assess arterial stiffness, peripheral and central haemodynamic parameters. We measured the volume status of participants via bioimpedance spectroscopy.

Results: The mean excess hydration of patients who underwent CAPD were higher than those who performed RM-APD and healthy control (P = .02). We found that mean diastolic blood pressure, heart rate, central systolic and diastolic blood pressure, and central pulse pressure were significantly different between the RM-APD, CAPD and healthy control (P = .02, P = .05, P = .007, P = .05 and P = .005, respectively). Post hoc analysis of these results showed that the differences between the groups were caused by the healthy control group and the patients with underwent CAPD. Daily anti-hypertensive drug count in patients with performing RM-APD was reduced over time (P < .001).

Conclusion: The RM-APD provides better control of peripheral blood pressure and decrease of central haemodynamic parameters via controlling the excess body water.

KEYWORDS

bioimpedance spectroscopy, peritoneal dialysis, pulse wave velocity, remote access technology

End-stage kidney disease (ESKD), is characterized by increased mortality due to major adverse cardiovascular events (MACE) including coronary artery disease (CAD), cerebrovascular disease, and peripheral artery disease and represents a worldwide health problem.[1] Lowering systolic blood pressure (SBP) significantly reduces the risk of atherosclerotic cardiovascular disease in this patient population.[2] Accumulating evidence suggests that arterial stiffness increases in dialysis patients, and it is strongly correlated with MACE.[3]

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Pulse wave velocity (PWV) as a surrogate of the stiffness of the vascular wall, is an independent predictor of MACE and all-cause mortality in the general population as well as in patients with ESKD.[4,5] Furthermore, SBP significantly correlates with increased PWV.[6]

International Society for Peritoneal Dialysis (ISPD) cardiovascular and metabolic guidelines recommended achieving euvolemia to provide better blood pressure control and to reduce MACE in patients with peritoneal dialysis (PD).[7] Clinical signs such peripheral oedema and increased central venous pressure become manifest only when a significant fluid overload occurs.[8] Bioimpedance spectroscopy (BIS) allows volume status to be assessed objectively, and studies suggest that monitoring fluid status with BIS provides a significant reduction in over-hydration with better control in SBP.[9]

Automated peritoneal dialysis (APD) cyclers were introduced in the 1960s, while remote patient management technology integrated into APD system (RPM-APD) such as cloud-based Sharesource software integrated into Homechoice Claria (Baxter Healthcare Corporation, Deerfield, Illinois) has become recently available.[10] This platform enables bidirectional data communication between patient's home and PD centre. Information such as fill volumes, alerts during treatment, drainage problems, interruption of therapy and blood pressure not within range together with prescription adjustments are continuously exchanged without the need of in person visits to the hospital.[11,12] We previously demonstrated that RM-APD provided improvement of dialysis adherence, increased ultrafiltration and better blood pressure control.[13]

Poor compliance to dialysis prescription is a common problem in patients with PD, and it is associated with decreased long-term technical survival and increased morbidity and mortality.[14] RPM-APD allows to maintain a better compliance to treatment prescription and increase patient's responsibility and participation in the maintenance of dry weight and as a consequence, blood pressure control.[15] Long-term improvement in patients' vascular stiffness and other haemodynamic parameters may be possible as a result of these positive effects on dialysis.

The aim of this study was to compare PWV, central and peripheral haemodynamic parameters, and BIS evaluation of PD patients performing RM-APD and continuous ambulatory PD (CAPD) for at least 1 year.

SUMMARY AT A GLANCE

This article demonstrated the role of remote monitoring for automatic peritoneal dialysis in blood pressure control. The benefit is particularly relevant in the era of COVID-19 and social distancing.

1 | METHODS

1.1 | Study population

This study was an observational and cross-sectional study that was investigating the effects of RM-APD and CAPD on brachial haemodynamic parameters and volume status of patients with PD. The study was conducted in the PD unit of Gazi university hospital from 2019 to 2020. In this unit, patients are treated with either APD or CAPD. In the year 2019, all patients treated by APD were switched to RM-APD. Blood pressure and need for anti-hypertensive drug of patients who switched from APD to RM-APD and those performing CAPD were observed and recorded monthly during the following year. PWV and BIS measurements were performed at the end of that year to evaluate the volume and haemodynamic parameters. The local Ethics Committee of Gazi University approved the design and procedures of the study in agreement with the principles of the Declaration of Helsinki and ethical standards for human experimentation. Written informed consent was obtained from all participants. The inclusion criteria of the present study were as follows: treatment by maintenance PD for at least 1 year in the same way (CAPD or RM-APD), age > 18 years, and patients who agreed to participate in the study. Exclusion criteria were the presence of active infection, malignancy, history of peritonitis within 3 months, documented peripheral artery disease (proven atherosclerosis by sonography or angiography), and patients unwilling to participate in the study. We also included the study age and sex-matched healthy control. Because PWV could be affected by age and body composition could also be affected by gender. Besides, comparing measurements with the healthy control was also important for evaluating the effectiveness of dialysis methods. If the apparent fluid overload was detected in physical examination, dialysis prescription and medical treatment were rearranged, and PWV and BIS measurements were delayed until volume status was detected normally in physical examination.

1.2 | Remote monitoring program and assessment of PWV and BIS

The same PD nurse checked the record of all the participants included in the study on the ShareSource connectivity platform daily (45 minutes for 15 patients) and kept records for 1 year. When the important alarms, including missing a treatment, lost connectivity, bypass drain were received, the physician was informed by the nurse, and the physician intervened to solve the problem (ie, contacting the patients, modification of drugs or dialysis therapy, and call for a clinical visit).

We collected PWV values using a Mobil-O-Graph PWA (I.E.M, GmbH, Stolberg, Germany), which allowed on-line pulse wave recording and automatic calculation of PWV. This device is commercially available that has been validated according to the recommendations of the European Society of Hypertension.[16,17] Measurements were performed in a quiet and temperature-controlled room (22-25°C), following the 10 minute rest period. Smoking, drinking tea, or coffee for at least 3 hours and exercise for at least 30 minutes were prohibited. Cuff size was chosen according to the circumference of the mid-upper

arm. Participants were asked to be quiet. Cuff was wrapped around the arm, and the lower end of the cuff was positioned 2 to 3 cm above the cubital fossa. Pressure waves are generated by a brachial arterial pulsation; central aortic pulse wave was derived following a plausibility and artefact analysis by these waves. Three measurements were performed in a seated position, and the average value was used for analysis. The wave measurements were uploaded to HMS client-server 5.1. Systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial blood pressure (MAP), central systolic blood pressure (cSBP), central diastolic blood pressure (cDBP), central pulse pressure (cPP), augmentation index (AIX) and PWV were obtained with the device.

Bioimpedance spectroscopy was performed by a coordinator using the body composition monitor (BCM, Fresenius Medical Care, Germany). The BCM measures at 50 frequencies over a range from 5 to 1000 kHz to determine the electrical resistance of total body water (TBW) and the extracellular water (ECW) as well as intracellular water (ICW). Measurement was performed while participants were lying in a supine position with an empty abdomen after the drainage of dialysate (for PD patients). Electrodes were attached to one hand, and one foot and results were displayed within 2 minutes. TBW, ECW, ICW, ECW/ICW ratio, over-hydration (OH), lean tissue index (LTI), fat tissue index (FTI) and body mass index (BMI) were recorded.

1.3 | Clinical outcomes

Hospital electronic medical records system was used for baseline information such as sex, age, medical prescription, laboratory parameters including haemoglobin, blood urea nitrogen, serum glucose, creatinine, total protein, albumin, total cholesterol, low-density lipoprotein and high-density lipoprotein. Data were collected at the time of body composition and brachial haemodynamic measurements. The dialysis solutions of the patients were also recorded. We calculated glucose weight as the sum of the products of the volume and glucose concentration for each exchange.[18] The adequacy of dialysis was determined by measuring the total weekly creatinine clearance (CrCl), which is normalized to 1.73 m^2 of the body surface area and total weekly urea

TABLE 1 Characteristics of the study population at the time of body composition and brachial haemodynamic measurements

	Total n = 73	RM-APD n = 20 (27%)	CAPD n = 15 (21%)	Healthy control n = 38 (52%)	*P*-value
Gender (%)					
Female	40 (55%)	11 (55%)	8 (53%)	21 (55%)	.9
Age (years)	53 ± 14	54.7 ± 13.6	52.8 ± 13	52.1 ± 15	.9
CKD cause (%)					
Hypertension	16 (46%)	9 (45%)	7 (47%)	—	.9
Diabetes	4 (11%)	3 (15%)	1 (7%)	—	.2
Glomerulonephritis	3 (9%)	2 (10%)	1 (7%)	—	.9
Other	5 (14%)	3 (15%)	2 (13%)	—	.9
Unknown	7 (20%)	3 (15%)	4 (26%)	—	.6
Current smoking (%)[a]	9 (12%)	3 (15%)	2 (13%)	4(10%)	.8
Alcohol consumption (%)	7 (9%)	1 (5%)	1 (7%)	5(6%)	.9
Dialysis vintage (month)[b]	34 (16-64)	29.5 (14.5-68)	40 (16-60)	—	.6
RRF (%)[b]	27 (77%)	15 (75%)	12 (80%)	—	.5
RRF (mL)[b]	475 (200-1000)	600 (200-1250)	400 (200-900)	—	.7
Laboratory parameters					
Haemoglobin (g/dL)	12.86 ± 2.02	11.2 ± 1.34	10.9 ± 1.95	14.4 ± 1.2	<.001
Glucose (mg/dL)	103 ± 34	99 ± 37	107 ± 30	78 ± 12	.2
BUN (mg/dL)	30 ± 19	46.4 ± 9.2	55 ± 9.66	13.3 ± 3.6	<.001
Creatinine (mg/dL)	4.46 ± 4.4	8.15 ± 2.99	9.4 ± 2.65	0.77 ± 0.1	<.001
Total protein (g/dL)	6.9 ± 0.5	6.58 ± 0.5	7.14 ± 0.34	7.2 ± 0.3	.001
Albumin (g/dL)	4.08 ± 0.5	3.54 ± 0.25	3.82 ± 0.3	4.45 ± 0.2	<.001
Total cholesterol (mg/dL)	220 ± 47	224 ± 63	203 ± 9.39	225 ± 36	.3
LDL (mg/dL)	136 ± 37	138 ± 47	119 ± 40	141 ± 29	.1
HDL (mg/dL)	52 ± 12	49 ± 10	45 ± 9	56 ± 13	.01

Abbreviations: BUN, blood urea nitrogen; CAPD, continuous ambulatory peritoneal dialysis; CKD, chronic kidney disease; HDL, high-density lipoprotein; LDL, low-density lipoprotein; RM-APD, remote monitoring automated peritoneal dialysis device; PD, peritoneal dialysis; RRF, residual renal function.

[a]Alcohol consumption refers at least one drink per week.

[b]Thirty-five patients was used for evaluation.

clearance (Kt/V) using the Watson formula for body water. Peritoneal solute transport was evaluated according to peritoneal equilibrium test (PET) as follows: the dialysate-to-plasma ratio of creatinine and ratio of glucose at 0 and 4 hours of the dwell.[19] Also, urinary creatinine clearance was calculated (urinary CrCl) for all the patients. Presence of more than 100 mL of urine per day was considered residual renal function (RRF). Blood pressure measurements were performed with the auscultatory device by the same nurse following the 10 minute rest period. Smoking, drinking tea or coffee and exercise for at least 30 minutes were prohibited. Cuff size was chosen according to the circumference of the mid-upper arm. Participants were asked to be quiet. Two measurements were performed in a seated position, while supporting the patient's arm (eg, resting on a desk). Average of two measurements was used. The patients were asked to perform blood pressure measurement at home, with automatically calibrated regularly and validated automatic devices. In addition, patients were asked to provide similar conditions (eg, rest minimum 10 minutes, not to smoke or drink coffee within 30 minutes). They were recommended to take blood pressure measurement twice a week. The blood pressures of the participants were recorded at monthly clinical visits and averaged with home measurement (blood pressure measurements which were shared with us on the every visit). Mean arterial blood pressure (MAP) calculated as follows; (systolic blood pressure + 2x diastolic blood pressure)/3. We used 'Δ anti-hypertensive drug (%)' for the calculation of the change of anti-hypertensive drug need per patients as follows:100-[(number of anti-hypertensive drug in the evaluated month/ number of anti-hypertensive drug in the baseline) × 00]. We determined target blood pressure as <140/90 mm/Hg for all patients. If the patient had signs of hypotension when he or she was in the euvolemic state (orthostatic hypotension, blood pressure < 110/70 mm/Hg or symptoms including nausea, blurred

TABLE 2 Treatment and medical evaluation of RM-APD and CAPD groups at the time of body composition and brachial haemodynamic measurements

	RM-APDn = 20	CAPDn = 15	*P*-value
PET			
Kt/v	2.17 ± 0.58	2.19 ± 0.7	.9
CrCl (mL/min)	76.5 ± 30	69.4 ± 31	.5
Urinary volume (mL)	600 (50-1250)	400 (200–900)	.7
Urinary CrCl (mL/min)	2.45 (0.3-8.2)	1.44 (0.5-8.33)	.5
Permeability (%)			
Slow	0	4 (27%)	
Average	16 (80%)	11 (73%)	
Fast	4 (20%)	0	
UF (mL)	820 ± 254	1017 ± 311	.05
Drugs			
EPO (%)	11 (55%)	6 (40%)	.3
EPO average dosage (mcg)	27 ± 13.3	13.8 ± 14	.05
Anti-hypertensive drug (%)	12 (60%)	8 (53%)	.9
RAS inhibitor	6 (60%)	1 (7%)	.08
β blocker	8 (40%)	6 (40%)	.9
CaCB	9 (45%)	9 (60%)	.3
α blocker	4 (20%)	4 (27%)	.7
Anti-hypertensive drug count	2 (0-4)	2 (0-3)	.8
Diuretic (%)	13 (65%)	10 (67%)	.9
Dialysis fluid			
Glucose weight[a] (gr/d)	186 ± 42.3	126.7 ± 30.9	.01
Dialysate volume (L/d)	9.78 (8.5-11)	6 (5.4-7)	<.001
İcodextrin	14 (70%)	9 (60%)	.5
Number (n)	1620	1580	
Volume (mL)			

Abbreviations: CAPD, continuous ambulatory peritoneal dialysis; CrCl, creatinine clearance; EPO, erythropoietin stimulating agent; PET, peritoneal equilibrium test; RM-APD, remote monitoring automated peritoneal dialysis device; UF, ultrafiltration.

[a]Average daily glucose load within 1 year for both group.

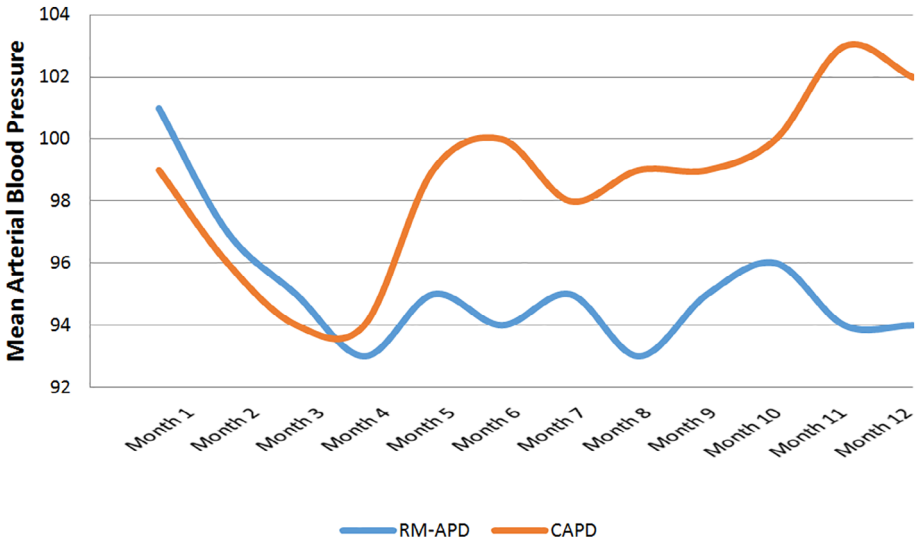
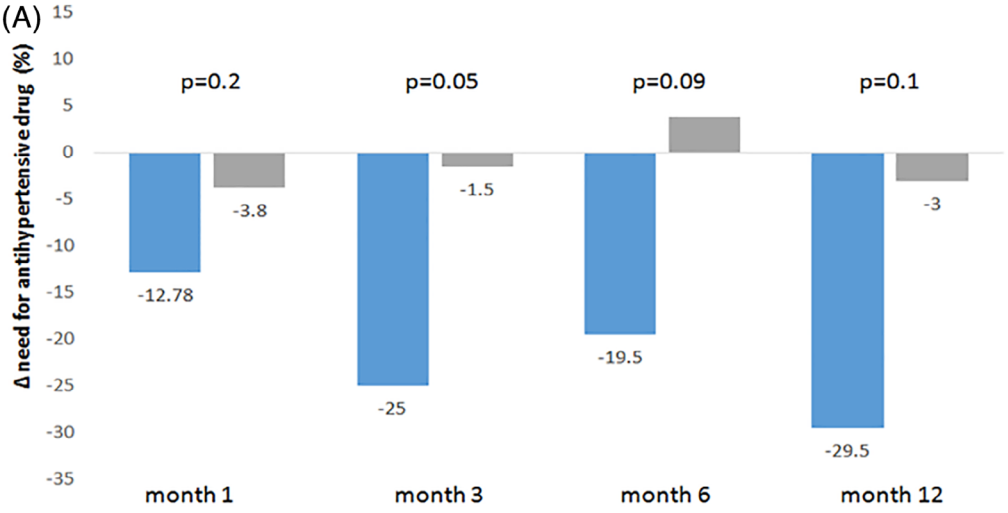


FIGURE 1 Comparison of the changes of blood pressures over time in patients performing CAPD and RM-APD. Blood pressure of patients with RM-APD decreases over the time when compared to baseline ($P < .001$). MAP was significantly higher in patients with CAPD than those with RM-APD at month 12 ($P = .01$). RM-APD, remote monitoring automated peritoneal dialysis device, CAPD, continuous ambulatory peritoneal dialysis



(B)

RM-APD CAPD

Anti-hypertensive drug counts per day [mean (Inter-quartile range)]						
	Baseline	**Month 1**	**Month 3**	**Month 6**	**Month 12**	***P value***
RM-APD	3.35(1.5-5.5)	2.85 (1.5-5)	2.55 (1-4.5)	2.6 (1-4.5)	2.4 (0.5-4)	<0.001
CAPD	2.3(0-4)	2.1 (0-3)	2.3 (0-4)	2.4 (0-4)	2.2 (0-3)	0.8
P value	0.3	0.5	0.7	0.8	0.8	

FIGURE 2 A, Comparison of mean Δ need for anti-hypertensive drug between patients with RM-APD and CAPD within months. B, Anti-hypertensive drug counts for patients with RM-APD and CAPD. The anti-hypertensive drug changes within groups were analyzed based on the drug counts in the baseline. CAPD, continuous ambulatory peritoneal dialysis; MAP, mean arterial pressure; RM-APD, remote monitoring automated peritoneal dialysis device

vision, and syncope which were explained by low blood pressure), anti-hypertensive drug dose was reduced. During this period, the blood pressure of the patient was monitored, and drug dose adjustment was performed.

1.4 | Statistical analysis

Analyses were performed with SPSS 21.0.0.1 (SPSS, IBM, Armonk, New York) software for Windows. Data distribution was determined

TABLE 3 Body composition and brachial haemodynamic measurement of peritoneal dialysis patients and healthy control group after 1 year observation period

	Healthy controln = 38	RM-APDn = 20	CAPD[a]n = 15	*P*-value
Body composition				
OH (mL)	300 (−400 to 500)	730 (0-1150)	1313 (100-2500)	.02
TBW (L)	34.3 ± 6.6	32.8 ± 8.4	32.07 ± 6.6	.5
ECW/ICW ratio	0.85 ± 0.09	0.93 ± 0.12	0.96 ± 0.1	.003
BMI (kg/m^2)	26.8 ± 4.34	27.7 ± 4.18	28.08 ± 4.5	.5
LTI (kg/m^2)	13.2 ± 2.77	12.58 ± 3.68	11.87 ± 2.33	.3
FTI (kg/m^2)	13.84 ± 5.16	14.76 ± 4.9	15.65 ± 5.74	.5
Brachial haemodynamic parameters				
SBP (mm/Hg)	118.2 ± 11.3	122 ± 15	126.3 ± 20.26	.2
DBP (mm/Hg)	78.5 ± 8.88	81.5 ± 10.8	87.2 ± 12.35	.02
MAP (mm/Hg)	97.4 ± 10.7	99.2 ± 12.2	105.7 ± 15.4	.1
Heart rate (beat/min)	73.7 ± 13	79 ± 15	82.7 ± 11.2	.05
Pulse pressure	41.4 ± 9.8	40.5 ± 10.7	39.2 ± 11.77	.8
cSBP (mm/Hg)	112.4 ± 11.7	121.1 ± 17.8	128.3 ± 22.4	.007
cDBP (mm/Hg)	79.9 ± 9.85	82.1 ± 11.36	88.4 ± 14.6	.05
cPP (mm/Hg)	32.9 ± 6.72	39.4 ± 12.2	44.4 ± 18.01	.005
Augmentation pressure	8.28 ± 4.18	9.35 ± 6.1	10.99 ± 6.5	.2
AIX	24.08 ± 10.2	23.6 ± 12.3	25.33 ± 11.5	.9
PWV (m/s)	7.18 ± 1.6	7.85 ± 1.8	8.05 ± 1.57	.09

Abbreviations: AIX, augmentation index; BMI, body mass index; CAPD, continuous ambulatory peritoneal dialysis; cDBP, central diastolic blood pressure; cPP, central pulse pressure; cSBP, central systolic blood pressure, DBP, diastolic blood pressure; ECW/ICW, extracellular water/intracellular water; FTI, fat tissue index, LTI, lean tissue index; MAP, mean arterial blood pressure; OH, over-hydration; PWV, pulse wave velocity; RM-APD, remote monitoring automated peritoneal dialysis device; SBP, systolic blood pressure; TBW, total body water.

[a]In post hoc analysis, the difference between the groups was found to be caused by the control group and the CAPD.

using the Kolmogorov-Smirnov test. The homogeneity of variables was determined using the One-way ANOVA homogeneity of variance test. Continuous variables are reported as means and SD or as median and inter-quartile range according to data distribution. Categorical variables are reported by percentages. When we compared changes for anti-hypertensive drug count and MAP within the RM-APD group, we used the paired sample *t*-test. The Student's *t*-test or the Mann-Whitney *U* test were used to compare continuous variables according to the data distribution. The χ^2 test was used to compare categorical variables. If we compare more than two groups, Kruskal Wallis test was used for numerical variables, and the Chi-square trend test was used for categorical variables. Post hoc analysis was used to determine the statistical difference between more than two groups. Pearson correlation analysis was used to show the correlation between PWV and demographic, other haemodynamic and body composition. A value of $P \leq .05$ was considered statistically significant.

2 | RESULTS

We evaluated 49 patients with peritoneal dialysis. We excluded 14 patients from the study. Seven of them was performing peritoneal dialysis less than 1 year, two of them had peritonitis within 3 months, three of them had documented peripheral artery disease and two of them did not want to participate to the study. As a result, we enrolled 15 patients performing CAPD, 20 patients performing RM-APD (35 patients), and 38, age, and gender-matched healthy control in this study. The mean age of total study population was 53 ± 14 years. Forty (55%) of total patients were female, and median dialysis vintage time of patients was 34 (16-64) months. While the most common cause of chronic kidney disease (CKD) was hypertension (n = 16, 46%), 77% (27/35) of total patients had RRF during study enrollment. These 73 patients were divided into three groups according to PD modality as RM-APD (n = 20, 27%), CAPD (n = 15, 21%) and as healthy control (n = 38, 52%). When demographic parameters were compared, there was no statistical difference between groups. While mean haemoglobin, total protein, albumin and HDL were significantly higher in healthy control ($P < .001$, $P = .001$, $P < .001$ and $P = .01$, respectively), mean BUN and creatinine were found to be high in patients with CAPD and RM-APD ($P < .001$, for both). Other laboratory parameters were similar between groups (Table 1). The results obtained after the PET test were summarized in Table 2, and only the daily UF amount of patients who underwent CAPD was found to be significantly higher than those who performed RM-APD (1017 ± 311 vs 820 ± 254 mL, $P = .05$). When we evaluated the medical treatment of patients, we found that need for weekly erythropoietin, daily mean

TABLE 4 Correlation of pulse wave velocity with the other demographic, haemodynamic and body composition parameters (n = 73 patients)

	R^2	*P*-value
Age	0.898	<.001
Dialysis treatment	0.223	.06
Smoking	−0.76	.6
OH	0.274	.02
TBW	0.040	.7
ECW/ICW ratio	0.514	<.001
BMI	0.139	.2
LTI	−0.125	.3
FTI	0.105	.4
MAP	0.485	<.001
cSBP	0.501	<.001
cDBP	0.342	.004
cPP	0.337	.005
Pulse pressure	0.393	.001
Augmentation pressure	0.499	<.001
AIX	0.164	.2

Abbreviations: AIX, augmentation index; BMI, body mass index; cDBP, central diastolic blood pressure; cPP, central pulse pressure; cSBP, central systolic blood pressure; ECW/ICW, extracellular water/intracellular water; FTI, fat tissue index; LTI, lean tissue index; MAP, mean arterial pressure; OH, over-hydration; RRF, residual renal function; TBW, total body water.

glucose load and daily dialysate volume were significantly higher in patients with performing RM-APD than those patients with underwent CAPD (27 ± 13.3 vs 13.8 ± 14 mcg, 186 ± 42.3 vs 126.7 ± 30.9 g/dL and 9.78(8.5-11) vs 6(5.4-7) L/d; P = .05, P = .01, and P < .001, respectively). Although the number of patients who need anti-hypertensive drug was similar between the two groups, we found during the office blood pressure measurement that control of blood pressure of patients who performed RM-APD improved over time and the MAP was significantly better at the end of the observation period than the patients who underwent CAPD (P = .01) (Figure 1). Figure 2 was depicted to demonstrate the change in daily anti-hypertensive drug amount over time. According to Figure 2, statistically significant decrease was observed in the daily anti-hypertensive drug count in patients with performing RM-APD over time (P < .001, for all months). In addition, the reduction in anti-hypertensive drug need was more pronounced in the third month in patients performing RM-APD than the patients who underwent CAPD (P = .05).

Comparison of the body composition and brachial haemodynamic parameters of patients performing RM-APD and CAPD with the healthy control group were summarized in Table 3. According to measurements, the mean EWC/ICW ratio and mean excess hydration of patients who underwent CAPD were higher than those who performed RM-APD and healthy control (0.96 ± 0.1 vs 0.93 ± 0.12 vs 0.85 ± 0.09 and 1313 (100-2500) vs 730 mL (0-1150) vs 300 mL (−400-500), P = .02 and P = .003, respectively). Post hoc analysis revealed that significant difference was between healthy control and CAPD (P = .04 for excess hydration and P = .008 for ECW/ICW ratio), but the difference between RM-APD and CAPD did not reach statistical significance (P = .5 for excess hydration and P = .7 for ECW/ICW ratio). In addition, post hoc analysis showed that healthy controls and PD patients on RM-APD had comparable body composition results (P = .08 for excess hydration and P = .1 for ECW/ICW ratio). When we compared the brachial haemodynamic parameters, we found that mean DBP, heart rate, cSBP, cDBP and cPP were significantly different between the three groups (P = .02, P = .05, P = .007, P = .05 and P = .005, respectively). Post hoc analysis of these results showed that the differences between the groups were caused by the healthy control group and the patients with underwent CAPD, for all significant variables. Similar to body composition, the difference between RM-APD and CAPD did not reach statistical significance (P = .6, P = .4, P = .2, P = .8 and P = .1, in the post hoc analysis, respectively) Although the difference of mean PWV, which is an important indicator of arterial stiffness, between the three groups was not significant, a positive correlation was found with age, OH, ECW/ICW ratio, MAP, cSBP, cDBP, cPP, pulse pressure and augmentation pressure (R^2 = 0.898, R^2 = 0.274, R^2 = 0.514, R^2 = 0.485, R^2 = 0.501, R^2 = 0.342, R^2 = 0.337, R^2 = 0.393 and R^2 = 0.499, respectively) (Table 4).

3 | DISCUSSION

The RM-APD is a relatively new technology that increases the patients' adherence to treatment but has little data in the literature in terms of clinical consequences. Our results showed that patients performing RM-APD for a year had comparable volume status to healthy control. This possibly provides increased blood pressure control with the less anti-hypertensive drug over time. We also showed a trend towards lower PWV in the RM-APD group but not reaching statistical significance when compared to the CAPD group. Over-hydration and some of the important brachial haemodynamic parameters, which were associated with high PWV, could be better controlled with performing RM-APD.

Patients with CKD and also ESRD are at a high risk of developing MACE as a result of accelerated atherosclerosis and vascular stiffness secondary to traditional and uremic-specific risk factors.[5,20] Pulse wave velocity is a simpler and more applicable measurement way of arterial stiffness, and it has been shown that arterial stiffness is an independent predictor of all-cause and cardiovascular mortality.[5,6] Elevated blood pressure contributes to atherosclerosis via increasing arterial wall circumferential stress and the development of endothelial dysfunction.[21] In this context, the positive correlation between high blood pressure and PWV has been shown in the literature.[6,21] One the other hand, evidence from studies suggests that central pressure is a better predictor of MACE than brachial pressure.[22,23] Because, major organs including heart, kidneys and brain, are exposed to central rather than brachial pressure. In our study, we determined that the central blood pressure measurements of patients who underwent

CAPD were significantly higher than healthy control. On the other hand, trend towards higher central blood pressure components was determined in the CAPD group compared to the RM-APD group. Moreover, the increased central blood pressure was observed, although the brachial measurements of all study groups were similar.

Although the peripheral blood pressure of patients was similar to a healthy population, the fact that central blood pressure components were significantly higher, especially in patients who underwent CAPD, suggests that other factors may also be effective in central blood pressure control. Over-hydration, which is an essential step in blood pressure control, is a complicated problem in dialysis patients. It has shown that 47% to 67% of PD patients have subclinical hypervolemia.[8] European Body Composition Monitoring Study demonstrated that only 40% of PD patients was normovolemic.[24] Konings et al demonstrated that more than a third (36.6%) of patients with performing PD were over-hydrated, but without hypertension or other clinical signs.[25] They also showed that ECW was significantly related to eccentric left ventricular hypertrophy. Another observational cohort study demonstrated that a significant increase in fluid volume was not linked to a significant increase in blood pressure.[26] Our results were parallel to the literature in context with the volume status and the blood pressure. Patients who underwent CAPD had more fluid in the extracellular area than patients who performed RM-APD. This may explain why patients who underwent CPAD had higher central blood pressure than patients with performing RM-APD and especially healthy controls, even though there was similar mean peripheral blood pressure in all groups.

Peritoneal dialysis is the dominant home-based dialysis therapy worldwide, and it is estimated that between 9.7% to 16.3% of the total dialysis population in developed countries, including the USA, Europe and Canada.[10] Non-adherence to APD prescription was reported to be 5% to 20% in the literature.[14] Although non-adherence to APD is reported in one out of five patients, the overall non-adherence rates to PD prescription were 2.6% to 85% in the literature.[14,27-29]

One of the technological advances made to increase patients' adherence to treatment was the new APD device, which is named homechoice Claria, launched by Baxter in 2015. This new technology provides to transfer therapy and biometric data of the patient to the clinician via the internet.[30] This allows the physician to monitor the patient in real time. It has been shown that dialysis prescription adherence became more than 90% with the use of RM-APD.[31] We observed an improvement in patients' office blood pressure measurements, with approximately 30% less anti-hypertensive drugs in patients with performing RM-APD at the end of 1 year observation period.

On the other hand, no significant change was observed in the blood pressure of patients who underwent CAPD during this period with the need for almost similar drug count. The possible cause of this condition is due to increased treatment adherence of patients who switched from conventional APD treatment to RM-APD. In addition, monitoring the patients in real time could ensure timely intervention of clinicians. Both conditions could provide permanency in ultrafiltration and closer to dry weight. Also, being closer to dry weight may be concluded with better blood pressure control and lower central haemodynamic parameters with less anti-hypertensive drugs.

The study has several limitations. First, the number of patients was low due to the single-centre design of the study. This may have caused not to reach a statistical difference of over-hydration, PWV and some blood pressure measurements and the need for drug assessments during the observation period. Second, this study was observational and cross-sectional. The design of the study does not fully reveal the relationship between haemodynamic parameters and dry weight preservation. Because of the positive effects of RM-APD on blood pressure control, central haemodynamic parameters and fluid status, a prospective randomized controlled study, which could provide measurements at different time points and compare over time for each individual patient, should be designed

In conclusion, cardiovascular mortality is the most important problem in patients with ESRD in the long term. The most crucial risk factor for the development of MACE is central and peripheral blood pressure elevation. RM-APD provides control of peripheral blood pressure and decrease of central haemodynamic parameters via controlling the excess body water.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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How to cite this article: Yeter HH, Karacalik C, Eraslan E, Akcay OF, Derici U, Ronco C. Effect of remote patient management in peritoneal dialysis on haemodynamic and volume control. *Nephrology*. 2020;enep13751. https://doi.org/10.1111/nep.13751