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Impact of Remote Monitoring on Standardized Outcomes in Nephrology-Peritoneal Dialysis

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Introduction: This study aimed to evaluate the association between the use of remote patient monitoring (RPM) in patients on automated peritoneal dialysis (APD) and the Standardized Outcomes in Nephrology in peritoneal dialysis (SONG-PD) clinical outcomes.

Methods: A prospective and multicenter cohort study was conducted on patients with advanced chronic kidney disease on APD, recruited at 16 Spanish Hospitals, between June 1 and December 31, 2021. Patients were divided into 2 cohorts, namely patients on APD with RPM (APD-RPM) and patients on APD without RPM. The primary endpoints were the standardized outcomes of the SONG-PD clinical outcomes: PD-associated infection, cardiovascular disease (CVD), mortality rate, technique survival, and life participation (assessed as health-related quality of life [QoL]). Propensity score matching (PSM) was used to evaluate the association of RPM exposure with the clinical outcomes.

Results: A total of 232 patients were included, 176 (75.9%) in the APD-RPM group and 56 (24.1%) in the APD-without-RPM group. The mean patient follow-up time was significantly longer in the APD-RPM group than in the APD-without-RPM group (10.4 $\pm$ 2.8 vs. 9.4 $\pm$ 3.1 months, respectively; $P = 0.02$). In the overall study sample, the APD-RPM group was associated with a lower mortality rate (hazard ratio [HR]: 0.08; 95% confidence interval [CI]: 0.01 to 0.69; $P = 0.020$) and greater technique survival rate (HR: 0.25; 95% CI: 0.11 to 0.59; $P = 0.001$). After PSM, APD-RPM continued to be associated with better technique survival (HR: 0.23; 95% CI: 0.06 to 0.83; $P = 0.024$).

Conclusion: The use of RPM programs in patients on APD was associated with better survival of the technique and lower mortality rates. However, after PSM, only technique survival was significant.

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PD is a renal replacement therapy that provides continuous, safe, home-based, and cost-effective treatment for patients with end-stage renal disease, with similar or better clinical outcomes than in-center hemodialysis.[1] Although PD is home-based therapy, patients still require periodic hospital visits to receive a full assessment of treatment adequacy.[2]

In addition, the autonomy of the technique, as well as the lack of real-time monitoring, make treatment adherence an issue of great concern. The overall nonadherence rates have been reported as 2.6% to 53% for PD prescriptions and 5% to 20% for APD prescriptions.[3] Unfortunately, nonadherence to the technique is usually reported by the patient, without real documentation.[3,4]

A web-based system for remote monitoring has recently been developed, which allows patient monitoring at home by digital wireless technology.[5] This APD system, HomeChoice Claria (Baxter Healthcare, Deerfield, IL), connected to a cloud-based network, was launched in 2015.[5,6] It provides real-time monitoring and recording of APD therapy.

This 2-way communication system has an interactive interface that allows both medical and nursing staff to make prescription changes by using a remote connection, thereby reducing the need for frequent in-person visits to the PD center.[7,8]

This system might be associated with some advantages. Potentially, home treatments could be monitored daily, making it possible to detect problems early and correct potential situations of inadequate dialysis.[9,10] Furthermore, this technology allows the clinical team to know many aspects of the therapy at the patient's home in real time. Moreover, besides detecting patients' adherence to prescribed therapy, this remote monitoring might offer a safer and better-quality treatment to renal patients.[10-13]

Recently, it has been reported that the use of RPM in APD was associated with lower hospitalization rates and length of hospital stay.[12] In addition, this system provided other positive outcomes, including blood volume and arterial pressure management,[14,15] and longer survival of the technique.[16] However, these studies have diverse limitations, such as great data heterogeneity, study design, different interventions, and treatments duration.[15,17]

As a result, the SONG-PD has developed a consensus with the 5 most important outcomes for patients, caregivers, and healthcare professionals in PD. These would be (in descending order of priority): PD-infection, CVD, mortality, technique survival, and life participation.[18-20] To date, although published papers have dealt with some of these outcomes, none of them have addressed the impact of RPM on all the SONG-PD outcomes in a systematic way.[17] Therefore, the current paper aimed to evaluate the association between the use of RPM in patients on APD and the SONG-PD clinical outcomes.

METHODS

Design

This prospective, observational, and multicenter cohort study was conducted on patients with end-stage renal disease on APD, recruited at 16 Spanish Hospitals, between June 1 and December 31, 2021.

This study has been approved by the Food Research Ethics Committee of the Albacete General University Hospital with internal code No. 2020/12/145 as of 01/26/2021.

The study was conducted in accordance with the rules of the Declaration of Helsinki and all the study participants provided written informed consent before starting the study.

Study Participants

Women and men from the 16 participating hospitals who were aged ≥18 years, with end-stage renal disease on PD and APD, signed the written consent, and willing to comply with the investigators and protocol indications were included in the study.

Patients with any severe active systemic disease that generates a life expectancy of less than 3 months; those who were participating during the study or have participated in a clinical study during the last 3 months that could interfere with the current study; or pregnant or lactating women were excluded.

Standardized Outcomes in Nephrology-PD Clinical Outcomes

This initiative established a core outcome set for PD studies based on a set of shared priorities for all stakeholders.[18,19] It established the 5 most important outcomes for patients, caregivers, and healthcare professionals. They include the following: (i) PD-associated infection, number of peritonitis (defined according to the Peritoneal Dialysis Society criteria)[21] per patient during the follow-up; (ii) CVD, incident CVD during follow-up (defined as the occurrence after enrolment of the first one of the following diseases: angina or acute coronary myocardial infarction, ischemic stroke, or peripheral arterial events[22]); (iii) mortality rate (number of deaths during the follow-up); (iv) technique survival (rewarded from technique failure to be positively framed)[19] (defined as composite endpoint of transfer to hemodialysis >30 days or death[23]; and (v) life participation (it is not uniformly assed in PD studies.[17,18] It is related to factors necessary for daily routines and leisure activities.[17,18] In the current study, this was assessed by a descriptive questionnaire EuroQol-5D [EQ-5D]).

EQ-5D QoL Questionnaire

EQ-5D is a popular health related QoL instrument used in the clinical evaluation of health care. Each subject self-rates his/her health in terms of 5 dimensions: mobility, self-care, usual activities, pain or discomfort, and anxiety or depression using a 3-level scale.[24] The

descriptive analysis was reported as a 5-digit number ranging from 11111 (full health) to 33333 (worst health) using the absolute and relative frequency for each profile. Furthermore, the profiles were converted to a single utility index using country-specific value sets and this index was summarized by mean and SD.

Study Groups

Patients were divided into 2 cohorts based on the use of RPM. The patients in the APD-RPM group used the HomeChoice Claria device with Sharesource technology. Patients in the APD-without-RPM used the Fresenius Sleep Safe technology (Fresenius Medical Care, Germany). In each cohort, APD therapy was implemented in accordance with the policies, guidelines, and standard procedures of the hospital clinical practice of each center participating in the study. The inclusion of each patient in the study was carried out during a first visit coinciding with their usual appointment (Patients were informed in detail about the purpose and characteristics of the study and signed the consent).

Patients included in the study had a minimum follow-up of 6 months.

Outcomes

The primary endpoints were the standardized outcomes of the SONG-PD clinical outcomes (i.e., PD-associated infection; CVD; mortality rate; technique survival; and life participation [assessed as health-related QoL, by using a descriptive questionnaire, EQ-5D]). The secondary outcomes included number of unscheduled teleconsultations; number of unscheduled face-to-face visits; number of hospital admissions per patient per year; and number of antihypertensive drugs per patient.

Statistical Analysis

A standard statistical analysis was performed using SAS v9.4 (SAS Institute Inc., Cary, NC) and R v4.2.2 (R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org; 2020).[25] Descriptive statistics number (percentage), mean and SD, and mean and 95% CI were used, as appropriate. Data were tested for normal distribution using a Shapiro-Wilks test.

To evaluate the association between RPM exposure and clinical outcomes (PD-associated infection, count of PD-associated infection, CVD, mortality, technique failure, technique failure without death, count of unscheduled teleconsultation, count of unscheduled hospital visit, count of hospitalization, and count of antihypertensive drugs), matching methods were used to compensate for the lack of randomization and to obtain unbiased estimators. PSM was used to evaluate the association of RPM exposure with the clinical outcomes. The propensity score for each subject was calculated from a logistic regression model that included all clinical and demographic variables (including Charlson comorbidity Index) as predictors of the exposure status. A 1:1 matching without replacement utilizing the nearest neighbor within caliper was utilized to match each APD-RPM subject with an APD-without-RPM subject. All APD-without-RPM cases were then randomly ordered and an APD-RPM case with a propensity score closest to the first treatment case was selected. Different calipers were used, and the one that produced a better balance (0.15) between the baseline variables was selected. The balance between groups in the matched sample was evaluated based on standardized differences, with a target value of <0.1. In addition, all categorical variables were compared with Pearson's χ^2 test and continuous variables were analyzed with paired *t*-test.

The association of RPM exposure with the PD-associated infection, unscheduled teleconsultation, and unscheduled hospital visit was estimated with odds ratio and 95% CI from logistic regression models. The association of RPM exposure with CVD, mortality, and hospitalization were estimated with HR and 95% CI from Cox regression models. The association of RPM exposure with technique survival was estimated with HR and 95% CI from Cox regression models with a transplant as competitive risk. The association of RPM exposure with the count of PD-associated infection, count of unscheduled teleconsultation, count of unscheduled hospital visit, count of hospitalization, and count of antihypertensive drugs per year of patient follow-up was estimated with incidence rate ratio and 95%CI from negative binomial regressions. All regression models included possible confounding factors, as well as the characteristics that presented statistical differences in the descriptive analysis (standardized differences >0.1).

To compare changes in QoL of individuals over time, the changes were classified in an individual's health state as better (improvement in at least 1 dimension), worse (a deterioration in at least 1 dimension), mixed (improvements and deteriorations in dimensions) or there being no change in the health state (those classified in the no-change group with the 11111 health state can be separated into their own "no problems" group) and were summarized by the absolute and relative frequency. This analysis was also analyzed by each dimension. Finally, change in the index was analyzed by mean and SD. To compare between groups of treatments, the Exact Fisher test (qualitative variable) and t-test student (quantitative variable) were performed.

RESULTS

Descriptive Analysis

A total of 232 patients were included, 176 (75.9%) in the APD-RPM group and 56 (24.1%) in the APD-without-RPM group. The baseline demographic and clinical characteristics of patients are shown in Table 1.

The mean age was 55.6 ± 15.2 years; 80 (34.5%) patients were women; the mean Charlson index was 4.9 ± 2.4; 62 (26.7%) patients had diabetes; 201 (86.6%) subjects had a history of hypertension, and the proportion of patients with urine output >400 ml was 72.4% (168/232). The mean follow-up time was 10.4 ± 2.8 months in the APD-RPM group and 9.4 ± 3.1 months for APD-RPM and APD-without-RPM, respectively ($P = 0.02$).

Matching Analysis

Matching analysis was performed to balance the baseline characteristics between cohorts. In Table 2, we present the balance assessment of the matched sample. The analysis shows that baseline characteristics were well-balanced after this process. The final matched sample included 56 patients in the APD-RPM cohort and 56 patients in the APD-without-RPM cohort.

Outcomes

In the overall study sample, as compared to the APD-without-RPM cohort, the APD-RPM group was associated with lower mortality rate (0.6% vs. 7.1%, respectively) (HR: 0.08; 95% CI: 0.01 to 0.69; $P = 0.022$) (Figure 1a) and greater technique survival rate (6.4% vs. 21.6%, respectively) (HR: 0.25; 95% CI: 0.11 to 0.59; $P = 0.001$) (Table 3 and Figure 2a).

After PSM (Table 4), there were no differences in mortality rates between both groups (Figure 1b), although APD-RPM compared with APD-without-RPM continued to be associated with more technique survival (5.6% vs. 21.6%) (HR: 0.23; 95% CI: 0.06 to 0.83; $P = 0.016$). Technique survival cumulative incidence of events (%) using the PSM with competing events (kidney transplant) is shown in Figure 2b. However, there were no significant differences between the 2 groups regarding the rest of both primary and secondary outcomes. In Table 5, we show the results of EQ-5D test in both groups with similar results between them.

DISCUSSION

This study aimed to evaluate whether RPM programs are clinically useful, in terms of SONG-PD, in patients with end-stage renal disease on APD. Other secondary important outcomes were also analyzed.[20] To the best of our knowledge, this is the first study assessing the impact of RPM-APD interventions in terms of all SONG-PD clinical outcomes.[18–20]

According to the results of the current study, RPM was associated with a better technique survival. Although technique survival is 1 of 5 core patient outcomes identified by the SONG-PD initiative,[19] this is a core point that not is always well represented in randomized clinical trials.[26] Factors associated with technique survival have been related with patient-related, center-related, and treatment-related.[20,27,28] In addition, peritonitis is the most common cause of technique failure.[20,21] Moreover, nonadherence to PD treatment could facilitate the development of peritonitis, although we did not observe differences in peritonitis rates in this study. RPM could increase technique survival via increasing PD prescription adherence and contributing to early identification of mechanical problems.[12]

These findings are consistent with those previously published.[16,29,30] Milan Manani *et al.*[29] compared different clinical outcomes and QoL in 2 group of patients undergoing APD, with (35 patients) and without (38 patients) remote monitoring. This study found that RPM reduced the number of emergency visits related to nephrological problems, particularly in those patients with a greater comorbidity score. However, they did not find significant differences in the number of peritonitis or the technique survival between the 2 groups.[29] Corzo *et al.*,[16] in a multicenter, retrospective, and observational study, reported less technique failure in 148 patients on APD with RPM than in 148 patients on APD without RPM controls.

Finally, the results of a systematic review and metanalysis, which included 9975 subjects from 5 countries, found that RPM was associated with better clinical outcomes, less technical failure, and better QoL. However, the current evidence is not conclusive.[31]

The current study agreed that RPM may improve technique survival. This improvement in PD survival may be mainly due to an improvement in adherence, although due to the characteristics of this study, this fact cannot be demonstrated. Therefore, there would be increasing probability of identifying mechanical problems at early stages,[12,16] which is a key goal of this type of therapy.

This study did not find differences in terms of number of peritonitis reports or number of hospitalizations, which has been reported to be associated with increased technique survival in other studies.[12,16] Other factors, such as center effect or social reasons, that have been associated with peritonitis[21] were not evaluated in this study. Technique failure was also associated with other adverse outcomes, including mortality.[32] The current study found less mortality in

Table 1. Baseline demographic and clinical characteristics in the overall study sample according to exposure status

Baseline characteristics	Overall $N = 232$	APD-RPM $n = 176$	APD-without-RPM $n = 56$	STD	*P* value
Demographic data					
Age, mean (SD)	55.6 (15.2)	55.4 (14.7)	55.9 (16.9)	0.03	0.84
Female sex, *n* (%)	80 (34.5)	61 (34.7)	19 (33.9)	0.02	1.00
Anthropometric data					
Height (cm), mean (SD)	168.3 (9.0)	168.7 (8.7)	167.1 (9.7)	0.16	0.28
Weight (kg), mean (SD)	76.1 (16.9)	76.8 (16.8)	74.0 (17.2)	0.16	0.29
BMI (kg/m^2), mean (SD)	26.8 (4.9)	26.9 (4.6)	26.4 (5.8)	0.09	0.54
Chronic kidney disease					
CKD cause, *n* (%)				0.32	0.85
Diabetes	39 (16.8)	28 (15.9)	11 (19.6)		
Cardiovascular disease	29 (12.5)	25 (14.2)	4 (7.1)		
Glomerulonephritis	52 (22.4)	36 (20.5)	16 (28.6)		
Interstitial nephritis	15 (6.5)	12 (6.8)	3 (5.4)		
Polycystic kidney disease	25 (10.8)	20 (11.4)	5 (8.9)		
Systemic diseases	5 (2.2)	4 (2.3)	1 (1.8)		
Family history	5 (2.2)	4 (2.3)	1 (1.8)		
Unknown	46 (19.8)	34 (19.3)	12 (21.4)		
Others	16 (6.9)	13 (7.4)	3 (5.4)		
Previous treatment, *n* (%)	73 (31.5)	52 (29.5)	21 (37.5)	0.17	0.34
Hemodialysis	45 (61.6)	33 (63.5)	12 (57.1)		
Transplant	28 (38.4)	19 (36.5)	9 (42.9)		
Distance to hospital (km), mean (SD)	23.1 (27.8)	22.9 (28.5)	23.7 (26.0)	0.03	0.85
Cause APD, *n* (%)				0.36	0.08
Patient choice	143 (61.6)	104 (59.1)	39 (69.6)		
Adequation	72 (31.0)	61 (34.7)	11 (19.6)		
Mechanical complications	17 (7.3)	11 (6.2)	6 (10.7)		
Dialysis vintage, *n* (%)				0.09	0.85
<1 yrs	144 (62.1)	108 (61.4)	36 (64.3)		
1–3 yrs	69 (29.7)	54 (30.7)	15 (26.8)		
>3 yrs	19 (8.2)	14 (8.0)	5 (8.9)		
Residual diuresis (ml), n (%)				0.11	0.80
<150 ml/d	47 (20.3)	35 (19.9)	12 (21.4)		
150–400 ml/d	17 (7.3)	14 (8.0)	3 (5.4)		
>400 ml/d	168 (72.4)	127 (72.2)	41 (73.2)		
Status				0.07	0.79
Prevalent patient	171 (73.7)	131 (74.4)	40 (71.4)		
Incidence patient	61 (26.3)	45 (25.6)	16 (28.6)		
Comorbidities					
Comorbidity index, mean (SD)	4.9 (2.4)	4.8 (2.3)	5.3 (2.8)	0.22	0.14
Hypertension, *n* (%)	201 (86.6)	149 (84.7)	52 (92.9)	0.26	0.18
Hypertension drugs, mean (SD)	2.7 (1.8)	2.7 (1.9)	2.6 (1.6)	0.06	0.73
SBP (mm Hg), mean (SD)	136.3 (20.3)	135.9 (21.0)	137.9 (18.3)	0.10	0.52
DBP (mm Hg), mean (SD)	82.6 (11.4)	82.3 (10.9)	83.4 (12.8)	0.10	0.51
Diabetes, *n* (%)	62 (26.7)	49 (27.8)	13 (23.2)	0.11	0.61
Follow-up					
Follow-up time, mos (mean)	10.1 (2.9)	10.4 (2.8)	9.4 (3.1)	0.34	0.02
Cause of censure, *n* (%)				0.83	0.03
Death	5 (10.2)	1 (3.2)	4 (22.2)		
Technique failure	20 (40.8)	11 (35.5)	9 (50.0)		
Infection	4 (20.0%)	2 (18.2%)	2 (22.2%)		
Inadequate dialysis	4 (20.0%)	2 (18.2%)	2 (22.2%)		
Mechanical	2 (10.0%)	2 (18.2%)	0 (0.0%)		
Social	1 (5.0%)	0 (0.0%)	1 (11.1%)		
Other	5 (25.0%)	3 (27.3%)	2 (22.2%)		
Not reported	4 (20.0%)	2 (18.2%)	2 (22.2%)		
Transplant	24 (49.0)	19 (61.3)	5 (27.8)		

APD, automated peritoneal dialysis; BMI, body mass index; CKD, chronic kidney disease; DBP, diastolic blood pressure; PD, peritoneal dialysis; RPM, remote patient monitoring; SBP, systolic blood pressure; SD, standard deviation; STD, standardized differences.

Table 2. Baseline demographic and clinical characteristics of the final matched sample according to exposure status

Baseline characteristics	APD-RPM $n = 56$	APD-without-RPM $n = 56$	STD	*P* value
Demographic data				
Age, mean (SD)	56.6 (14.0)	55.9 (16.8)	0.04	0.81
Female gender, *n* (%)	14 (25.0)	19 (33.9)	0.19	0.41
Anthropometric data				
BMI (kg/m^2), mean (SD)	27.0 (4.3)	26.4 (5.8)	0.09	0.56
Chronic kidney disease				
CKD cause, *n* (%)				0.94
Diabetes	13 (23.2)	11 (19.6)	0.08	
Cardiovascular disease	3 (5.4)	4 (7.1)	0.07	
Glomerulonephritis	16 (28.6)	16 (28.6)	0.00	
Interstitial nephritis	3 (5.4)	3 (5.4)	0.00	
Polycystic kidney disease	2 (3.6)	5 (8.9)	0.19	
Systemic diseases	0 (0.0)	1 (1.8)	0.13	
Family history	1 (1.8)	1 (1.8)	0.00	
Unknown	15 (26.8)	12 (21.4)	0.13	
Others	3 (5.4)	3 (5.4)	0.00	
Previous treatment, *n* (%)	21 (37.5)	21 (37.5)	0.00	1.00
Hemodialysis	15 (71.4)	12 (57.1)		
Transplant	6 (28.6)	9 (42.9)		
Distance to hospital (km), mean (SD)	16.4 (21.6)	23.7 (26.0)	0.28	0.11
Cause APD, *n* (%)				0.97
Patient choice	38 (67.9)	39 (69.6)	0.04	
Adequation	12 (21.4)	11 (19.6)	0.05	
Mechanical complications	6 (10.7)	6 (10.7)	0.00	
Dialysis vintage, *n* (%)				0.94
<1 yrs	36 (64.3)	36 (64.3)	0.00	
1–3 yrs	14 (25.0)	15 (26.8)	0.04	
>3 yrs	6 (10.7)	5 (8.9)	0.06	
Residual diuresis (ml), *n* (%)				0.56
<150 ml/d	14 (25.0)	12 (21.4)	0.09	
150-400 ml/d	1 (1.8)	3 (5.4)	0.16	
>400 ml/d	41 (73.2)	41 (73.2)	0.00	
Status			0.12	0.68
Prevalent patient	37 (66.1)	40 (71.4)		
Incidence patient	19 (33.9)	16 (28.6)		
Comorbidities				
Comorbidity index, mean (SD)	5.38 (2.50)	5.30 (2.78)	0.02	0.89
Hypertension, *n* (%)	53 (94.6)	52 (92.9)	0.07	1.00
Hypertension drugs, mean (SD)	2.84 (2.10)	2.62 (1.60)	0.13	0.54
SBP (mm Hg), mean (SD)	137.3 (18.7)	137.9 (18.3)	0.03	0.86
DBP (mm Hg), mean (SD)	84.6 (10.3)	83.4 (12.8)	0.09	0.60
Diabetes, *n* (%)	14 (25.0)	13 (23.2)	0.04	1.00
Follow-up				
Follow-up time, months (mean)	10.4 (2.8)	9.4 (3.1)		
Cause of censure, *n* (%)				
Death	2 (40.0)	5 (27.8)		
Technique failure	2 (40.0)	9 (50.0)		
Transplant	1 (20.0)	4 (22.2)		

APD, automated peritoneal dialysis; BMI, body mass index; CKD, chronic kidney disease; DBP, diastolic blood pressure; PD, peritoneal dialysis; RPM, remote patient monitoring; SBP, systolic blood pressure; SD, standard deviation; STD, standardized differences.

the RPM-APD group in the overall study sample, but not when matching the sample.

According to the results that assessed the impact of an Internet-based instant messaging software on patients on PD, a greater degree of satisfaction and better levels of biochemical biomarkers in the remote monitoring group was observed.[33] In addition, they suggested better mortality rates in the remote monitoring group, but the events were no reported.[17,33] Conversely, Corzo *et al.*[16] did not report significant differences in mortality rates.

Furthermore, this study evaluated the role of RPM from a patient's perspective. The current study did not find significant differences in QoL between patients on

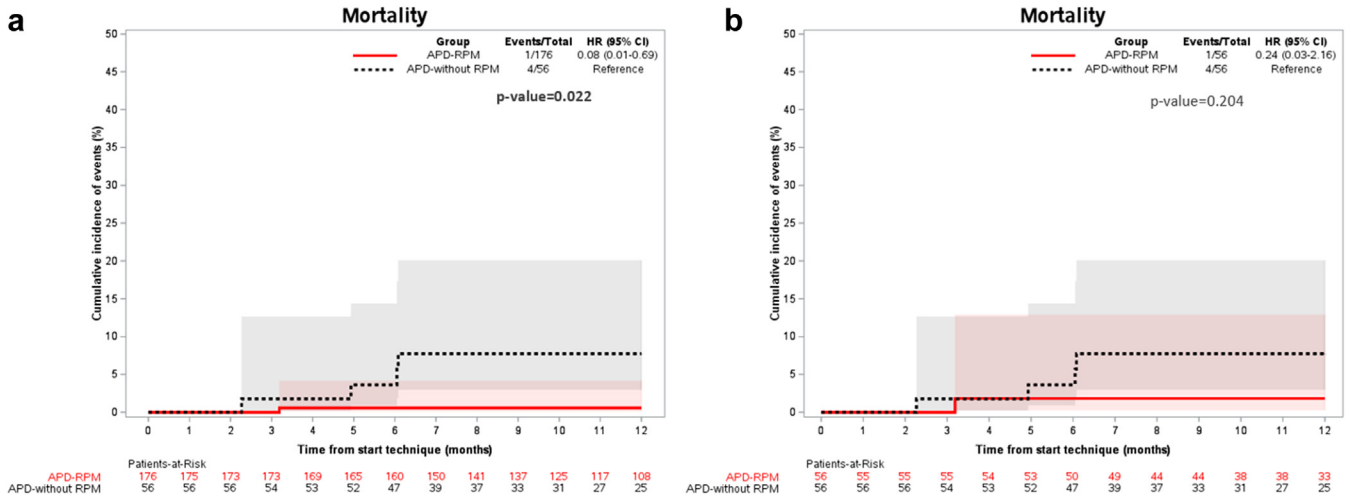

Figure 1. Overview of the mortality rates in the overall study population (a) and after propensity score matching (b). (a) In the overall study sample, mortality rates were significantly lower in the APD-RPM group than in the APD-without-RPM group (0.6% vs. 7.1%, respectively) (HR: 0.08; 95% CI: 0.01 to 0.69; $P = 0.022$). (b) After propensity score matching, no significant differences were observed in mortality rates between the 2 groups. APD, automated peritoneal dialysis; CI, confidence interval; HR, hazard ratio; RPM, remote patient monitoring.

APD with or without RPM, which was in line with other studies.[29,34] This finding might be because QoL questionnaires have not been specifically designed to assess the effect of monitoring home dialysis in life participation.[15]

Although there are several companies manufacturing different PD systems, the information comparing PD system is very limited.[35–38] This lack of evidence might be due to the thinking that all PD systems are similar, and therefore, will provide similar outcomes. However, there could be potentially clinically relevant differences between PD systems, such as differences in packaging, connectology, solution contents, or other subtle differences that might impact patients' outcomes.[38–40]

This study has some limitations that should be considered when interpreting the results. Lack of randomization and confounding factors might bias the results of the observational studies. Nevertheless, this study used matching methods to compensate for these issues. PSM entails forming matched sets of treated and untreated subjects who share a similar value of the propensity score.[41] PSM is a technique used to reduce selection bias in observational studies.[42,43] The goal of PSM is to create a sample in which treatment groups

Table 3. Clinical outcomes associated with rpm in the overall study population

Outcomes	Overall $N = 232$	APD-RPM $n = 176$	APD-without-RPM $n = 56$	OR (95% CI)[d] HR (95% CI) IRR (95% CI)	*P* value
Primary outcomes					
PD-associated infection[a]	40 (17.2)	27 (15.3)	13 (23.2)	0.60 (0.29-1.29)	0.177
Infections per patient-year	0.25 (0.62)	0.23 (0.62)	0.30 (0.63)	0.75 (0.36-1.59)	0.445
Cardiovascular disease[b]	16 (6.9)	14 (8.0)	2 (3.6)	1.94 (0.44-8.52)	0.440
Mortality	5 (2.2)	1 (0.6)	4 (7.1)	0.08 (0.01-0.69)	0.022
Technique survival[c]	21 (10.1)	10 (6.4)	11 (21.6)	0.25 (0.11-0.59)	0.001
Secondary outcomes					
Hospitalization	72 (31.0)	51 (29.0)	21 (37.5)	0.68 (0.36-1.29)	0.230
Hospitalizations per patient-year	0.43 (0.81)	0.42 (0.86)	0.45 (0.63)	0.94 (0.56-1.62)	0.825
Unscheduled teleconsultation	164 (74.2)	125 (75.8)	39 (69.6)	1.36 (0.68-2.64)	0.367
visits per patient-yr	2.81 (3.43)	3.03 (3.62)	2.16 (2.70)	1.40 (0.97-2.00)	0.064
Unscheduled hospital visit	140 (60.3)	101 (57.4)	39 (69.6)	0.59 (0.30-1.10)	0.105
visits per patient-yr	1.80 (2.61)	1.61 (2.38)	2.38 (3.21)	0.68 (0.45-1.01)	0.057
Anti-HBP drugs (drugs per patient-year)	8.44 (7.18)	8.82 (7.40)	7.21 (6.37)	1.22 (0.92-1.61)	0.160

APD, automated peritoneal dialysis; CI, confidence interval; HBP, high blood pressure; HD, hemodialysis; IRR, incidence rate ratio; OR, odds ratio; HR, hazard ratio; PD, peritoneal dialysis; RPM, remote patient monitoring.
[a]PD-associated infection is defined as the number of peritonitis reports during follow-up.
[b]Cardiovascular disease is defined as the occurrence after enrollment of the first one of the following: angina or acute coronary myocardial infarctions, ischemic stroke, and peripheral arterial events.
[c]Technique survival is defined as composite endpoint of transfer to HD >30 days or death.
[d]OR was calculated in PD-associated infection, unscheduled teleconsultation and unscheduled hospital visit from logistic regression models. HR was calculated in cardiovascular disease, mortality, technique survival and hospitalization from Cox regression models. IRR was calculated in the count of PD-associated infection, count of unscheduled teleconsultation, count of unscheduled hospital visit, count of hospitalization, and count of antihypertensive drugs from negative binomial regressions.

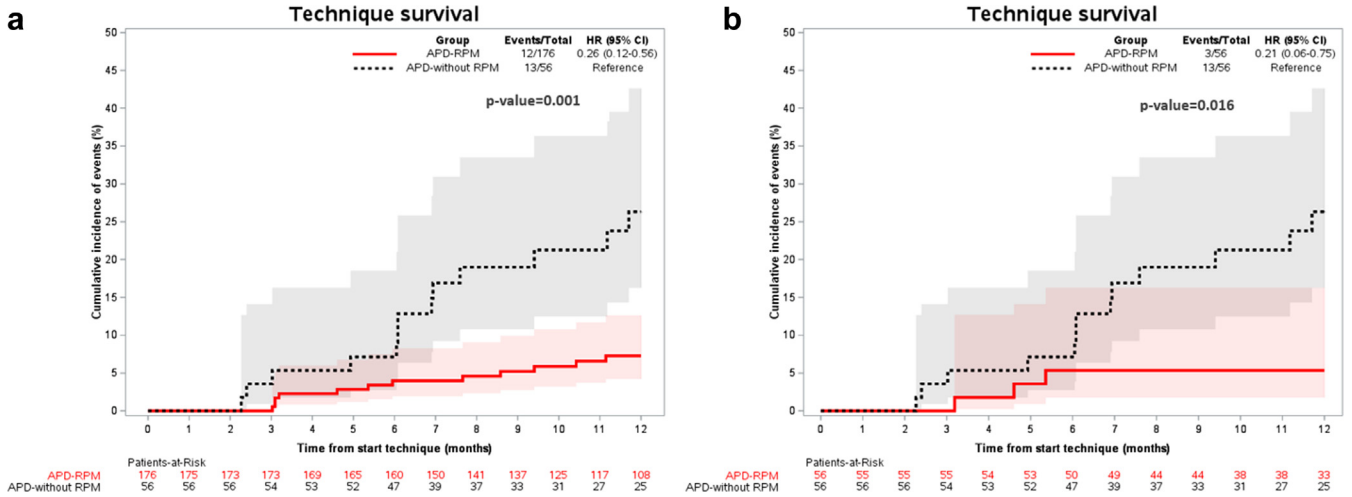

Figure 2. Overview of the technique survival rates in the overall study population (a) and after propensity score matching (b). (a) In the overall study, population technique survival rate was significantly lower in the APD-without-RPM than in the APD-RPM group (6.4% vs. 21.6%, respectively) (HR: 0.25; 95% CI: 0.11 to 0.59; $P = 0.001$). (b) After propensity score matching, technique survival continued to be significantly lower in the APD-without-RPM group than in the APD-RPM group (5.6% vs. 21.6%) (HR: 0.23; 95% CI: 0.06 to 0.83; $P = 0.016$). APD, automated peritoneal dialysis; CI, confidence interval; HR, hazard ratio; RPM, remote patient monitoring.

are balanced on baseline covariates. Logistic regression (the method used in the current study) is the most used method for estimating the propensity score.[41-43] An additional limitation is comparing 2 devices from 2 different manufacturers. It would be more accurate to use the same device in the 2 groups (APD-RPM vs. APD-without RPM). It has been previously reported that PD systems manufactured by different companies may be associated with important differences in PD technique survival.[38] Therefore, we cannot unequivocally conclude that the findings of this study are due exclusively to RPM. An adequately powered randomized study should be conducted to evaluate this issue. Finally, this study included incident patients and might not reflect outcomes in prevalent patients with long dialysis vintage.

Nevertheless, as strength, it should be mentioned its multicenter nature and the fact that it included a large number of patients. The current study was conducted at third-level hospitals, which may reflect the reality of the APD throughout the Spanish territory. We are unaware of previous reports

Table 4. Clinical outcomes associated with RPM in the matched sample

Outcomes	APD-RPM $N = 56$	APD-without RPM $N = 56$	OR (95% CI)[d] HR (95% CI) IRR (95% CI)	*P* value
Primary outcomes				
PD-associated infection[a]	12 (21.4)	13 (23.2)	0.90 (0.37-2.21)	0.821
Infections per patient-yr	0.34 (0.79)	0.30 (0.63)	1.11 (0.49-2.56)	0.792
Cardiovascular disease[b]	9 (16.1)	2 (3.6)	3.92 (0.84-18.2)	0.081
Mortality	1 (1.8)	4 (7.1)	0.24 (0.03-2.16)	0.204
Technique survival[c]	3 (5.6)	11 (21.6)	0.23 (0.06-0.83)	0.016
Secondary outcomes				
Hospitalization	19 (33.9)	21 (37.5)	0.86 (0.39-1.86)	0.693
Hospitalizations per patient-yr	0.46 (0.74)	0.45 (0.63)	1.04 (0.59-1.81)	0.890
Unscheduled teleconsultation	43 (81.1)	39 (69.6)	1.87 (0.78-4.71)	0.168
visits per patient-yr	3.15 (3.30)	2.16 (2.70)	1.46 (0.95-2.23)	0.081
Unscheduled hospital visit	31 (55.4)	39 (69.6)	0.54 (0.25-1.17)	0.120
visits per patient-yr	1.55 (2.56)	2.38 (3.21)	0.65 (0.39-1.08)	0.099
Anti-HBP drugs (drugs per patient-yr)	9.59 (8.74)	7.21 (6.37)	1.33 (0.96-1.84)	0.087

APD, automated peritoneal dialysis; CI, confidence interval; HBP, high blood pressure; HD, hemodialysis; HR, hazard ratio; IRR, incidence rate ratio; OR, odds ratio; PD, peritoneal dialysis; RPM, remote patient monitoring.
[a]PD-associated infection is defined as the number of peritonitis reports during follow-up.
[b]Cardiovascular disease is defined as the occurrence after enrollment of the first one of the following: angina or acute coronary myocardial infarctions, ischemic stroke, and peripheral arterial events.
[c]Technique survival is defined as composite endpoint of transfer to HD >30 days or death.
[d]OR was calculated in PD-associated infection, unscheduled teleconsultation and unscheduled hospital visit from logistic regression models. HR was calculated in cardiovascular disease, mortality, technique survival and hospitalization from Cox regression models. IRR was calculated in the count of PD-associated infection, count of unscheduled teleconsultation, count of unscheduled hospital visit, count of hospitalization, and count of antihypertensive drugs from negative binomial regression.

Table 5. Quality of life (EQ-5D-3L)

	APD-RPM *n* = 109	APD-without RPM *n* = 37	*P-value*
Baseline, *n* (%)			
11111	41 (37.6%)	12 (32.4%)	
11112	14 (12.8%)	5 (13.5%)	
11122	9 (8.3%)	3 (8.1%)	
11121	5 (4.6%)	2 (5.4%)	
11221	2 (1.8%)	2 (5.4%)	
22222	6 (5.5%)	0 (0.0%)	
Others	32 (29.4%)	13 (35.1%)	
EQ Index, mean (SD)	0.84 (0.24)	0.74 (0.38)	0.064
Follow-up			
11111	48(44.0%)	11 (29.7%)	
11121	2 (1.8%)	4 (10.8%)	
11122	6 (5.5%)	4 (10.8%)	
11112	16 (14.7%)	3 (8.1%)	
11221	1 (0.9%)	2 (5.4%)	
11222	3 (2.8%)	2 (5.4%)	
Others	33 (30.7%)	11 (29.7%)	
EQ Index, mean (SD)	0.86 (0.25)	0.80 (0.24)	0.198
Evolution of QoL[a]			
Overall			
Change EQ Index, mean (SD)	0.01 (0.2)	0.06 (0.3)	0.262
No problems	35 (32.1%)	8 (21.6%)	
With problems	74 (67.9%)	29 (78.4%)	
No change	32 (43.2%)	8 (27.6%)	
Improve	24 (32.4%)	9 (31.0%)	
Worsen	11 (14.9%)	9 (31.0%)	
Mixed change	7 (9.5%)	3 (10.3%)	
Mobility			0.594
No problems	78 (71.6%)	25 (67.6%)	
With problems	31 (28.4%)	12 (32.4%)	
No change	16 (51.6%)	5 (41.7%)	
Improve	8 (25.8%)	5 (41.7%)	
Worsen	7 (22.6%)	2 (16.7%)	
Self-care			0.853
No problems	95 (87.2%)	31 (83.8%)	
With problems	14 (12.8%)	6 (16.2%)	
No change	8 (57.1%)	4 (66.7%)	
Improve	4 (28.6%)	1 (16.7%)	
Worsen	2 (14.3%)	1 (16.7%)	
Usual activities			0.407
No problems	76 (69.7%)	21 (56.8%)	
With problems	33 (30.3%)	16 (43.2%)	
No change	17 (51.5%)	5 (31.2%)	
Improve	9 (27.3%)	6 (37.5%)	
Worsen	7 (21.2%)	5 (31.2%)	
Pain/discomfort			0.278
No problems	66 (60.6%)	17 (45.9%)	
With problems	43 (39.4%)	20 (54.1%)	
No change	20 (46.5%)	10 (50.0%)	
Improve	16 (37.2%)	4 (20.0%)	
Worsen	7 (16.3%)	6 (30.0%)	
Anxiety/depression			0.607
No problems	58 (53.2%)	17 (45.9%)	
With problems	51 (46.8%)	20 (54.1%)	
No change	32 (62.7%)	10 (50.0%)	
Improve	12 (23.5%)	6 (30.0%)	
Worsen	7 (13.7%)	4 (20.0%)	

APD, automated peritoneal dialysis; EQ, EuroQol; PD, peritoneal dialysis; RPM, remote patient monitoring; QoL; quality of life.
[a]Classifies the change in an individual's health state as better (improvement in at least 1 dimension), worse (a deterioration in at least 1 dimension), mixed (improvements and deteriorations in dimensions), or there being no change in the health state. Those classified in the "no change group" with the 11111 health state can be separated into their own "no problems" group.

conducted in similar circumstances or populations that have included such many patients. Although there is evidence of studies that have included a larger number of patients,[6,16] these were conducted on environments that reflect a very different reality, which therefore limit the applicability of their results to our daily practice.

CONCLUSIONS

According to the results of this study, the use of RPM programs in patients on APD was associated with more technique survival. Although in the overall population, the use of RPM programs in patients on APD was associated with lower mortality rate, such findings were not observed after PSM. RPM programs could be a safe and effective strategy for improving PD technique survival. Despite the promising results of the current study, randomized clinical trials using SONG-PD outcomes are needed to confirm these findings.

DISCLOSURE

All the authors declared no competing interests.

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DATA AVAILABILITY STATEMENT

The data sets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

AUTHOR CONTRIBUTIONS

Conceptualization, methodology, formal analysis, investigation, and supervision were done by FJC-P, AO-C, and JP-M. All authors met the ICMJE authorship criteria. All authors made substantial contributions to conception, design, analysis, and interpretation of data; contributed to writing the article; provided critical revision of the manuscript; and approved the final version.

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