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Remote Patient Monitoring-Enabled Automated Peritoneal Dialysis and Clinical Outcomes

A Nationwide Real-World Cohort Study from Taiwan

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Key Points

- Remote patient monitoring–enabled automated peritoneal dialysis was associated with improved survival and technique survival compared with conventional automated peritoneal dialysis.
- Remote patient monitoring-enabled automated peritoneal dialysis was associated with significantly fewer annual hospitalizations compared with conventional automated peritoneal dialysis.
- The association between remote patient monitoring–enabled automated peritoneal dialysis and reduced hemodialysis transfer was more pronounced in younger patients and icodextrin users.

Abstract

Introduction Remote patient monitoring of patients on automated peritoneal dialysis (APD) enables real-time access to treatment data and has the potential to improve clinical outcomes. However, large-scale, nationwide real-world evidence comparing RPM-enabled APD (RPM-APD) with conventional APD remains limited.

Methods We conducted a nationwide retrospective cohort study using Taiwan's National Health Insurance Research Database between 2016 and 2023. Patients initiating APD in medical centers during 2016–2018 (conventional APD) were compared with those starting RPM-APD equipped with a remote monitoring device during 2020–2022. Baseline covariates were balanced using inverse probability of treatment weighting. The primary outcomes were all-cause death and hemodialysis transfer. Secondary outcomes included peritonitis, major adverse cardiac events, and hospitalization. Patients were followed until outcome occurrence, death, hemodialysis transfer, kidney transplantation, or the end of follow-up (December 31, 2019, for conventional APD and December 31, 2023, for RPM-APD).

Results Among the 2477 patients (RPM-APD, n=1258; conventional APD, n=1219), the mean age was 53.6 years, 54.6% were male, and the mean follow-up duration was 2.0 years. After inverse probability of treatment weighting adjustment, the RPM-APD group was associated with lower risks of all-cause death (4.4 versus 5.3 events per 100 person-years; hazard ratio 0.82, 95% confidence interval [CI], 0.69 to 0.99) and hemodialysis transfer (12.7 versus 15.1 events per 100 person-years; subdistribution hazard ratio 0.86, 95% CI, 0.77 to 0.96). The risks of peritonitis and major adverse cardiac events were similar between groups, whereas patients receiving RPM-APD experienced significantly fewer annual hospitalizations (1.6 versus 2.1 times; rate ratio 0.70, 95% CI, 0.68 to 0.73).

Conclusions In this Taiwan nationwide real-world cohort study with long-term follow-up, RPM-APD was associated with improved patient survival, reduced hemodialysis transfer, and fewer annual hospitalizations compared with conventional APD. These findings support a potential role for RPM-APD in contemporary peritoneal dialysis care.

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Introduction

Peritoneal dialysis (PD) is an established treatment of ESKD,[1] and automated peritoneal dialysis (APD) is widely used in many developed countries.[2] In recent years, remote patient monitoring (RPM)-enabled APD (RPM-APD) has emerged as a major development in APD care,[2] with growing recognition of its role in home dialysis.[3] By transmitting treatment data through a cloud-based platform, RPM-APD allows earlier detection of abnormalities[4] and may support safer delivery of care.[5] A cluster randomized trial from Mexico reported that RPM-APD was associated with lower risks of cardiovascular mortality, clinical adverse events, and hospitalizations over 1 year.[6]

In Taiwan, APD is a freely chosen dialysis modality.[7] RPM-APD was implemented at tertiary medical centers beginning in 2019 and became the standard approach for incident patients on APD in 2020. Given Taiwan's highly accessible health care system and favorable ESKD outcomes,[8] the incremental benefit of RPM-APD cannot be assumed and requires evaluation. Whether RPM provides additional benefit in such a setting remains uncertain and has implications for other developed health care systems.

Using Taiwan's National Health Insurance Research Database (NHIRD), we conducted a nationwide cohort study to evaluate clinical outcomes associated with RPM-APD among incident patients on APD treated at medical centers. Outcomes were selected on the basis of the Standardized Outcomes in Nephrology–Peritoneal Dialysis initiative.[9]

Methods

Data Source

This retrospective cohort study used data from Taiwan's NHIRD, which covers more than 99% of the population.[10] The database includes comprehensive claims data on demographics, diagnoses, procedures, and health care utilization. Diagnoses were coded using the International Classification of Diseases, Ninth and Tenth Revisions (ICD-9 and ICD-10). All data were deidentified before analysis. The study was approved by the Institutional Review Board of Chang Gung Memorial Hospital (approval number: 202300400B0C602), with a waiver of informed consent.

Study Population

This study compared APD using the Homechoice Claria system (Vantive US Health care LLC, Deerfield, IL) with and without remote patient management enabled by the Sharesource connectivity platform (Vantive US Health care LLC, Deerfield, IL), which transmits treatment data through a modem. In Taiwan, Sharesource was introduced in 2019 at tertiary medical centers and became the standard approach for incident patients on APD by January 2020. Accordingly, this study focused on incident patients on APD treated at tertiary medical centers. Exposure to RPM-APD was defined by calendar period and care setting. Patients initiating APD in medical centers during 2020–2022 were classified as the RPM-APD group, reflecting system-level implementation of the Sharesource platform in Taiwan. Patient-level data on connectivity, monitoring intensity, and responses to alerts were not available in the database. For comparison, we identified a historical cohort of incident patients on APD from the same medical centers who initiated therapy between 2016 and 2018 (conventional APD group). The date of APD initiation was defined as the index date. Exclusion criteria included age younger than 18 years, missing demographic data (age, sex, or income), prior use of other APD systems, follow-up <90 days, and lack of continuous APD treatment for at least 3 months (Figure 1).

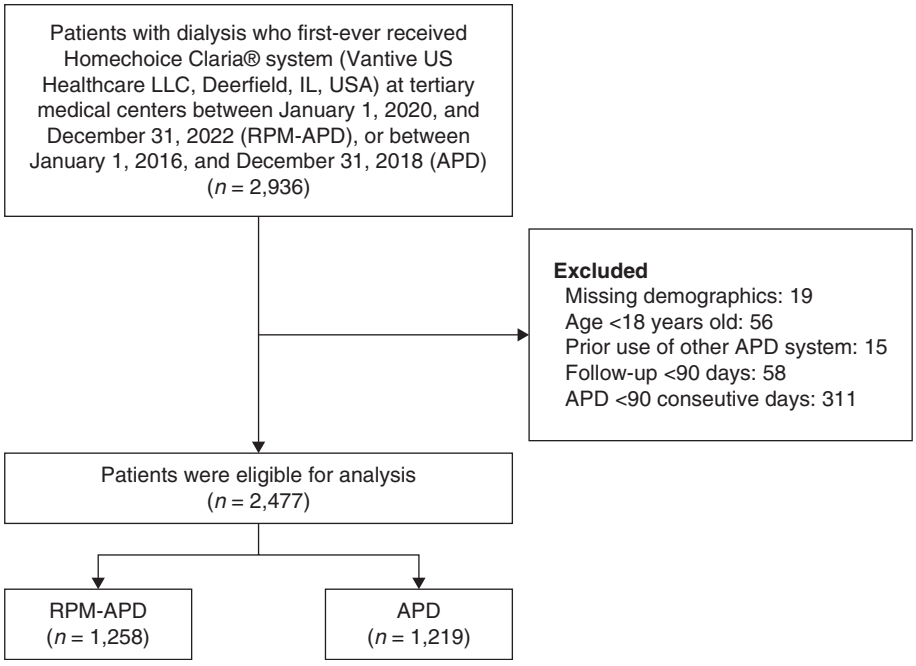


Figure 1. Flow chart illustrating the inclusion and exclusion of study participants. APD, automated peritoneal dialysis; RPM-APD, remote patient monitoring–enabled automated peritoneal dialysis.

Covariate Measurement

Covariates included demographics (age, sex, and monthly income), history of kidney transplantation, prior hemodialysis (≥3 months), interval from PD initiation to APD, comorbidities, and baseline icodextrin use. Comorbidities included diabetes mellitus, hypertension, coronary artery disease, peripheral arterial disease, and liver cirrhosis, defined as at least two outpatient diagnoses or one inpatient diagnosis within 1 year before the index date. Myocardial infarction, heart failure hospitalization, and ischemic stroke were identified on the basis ofprior hospitalization records. Malignancy was defined by the presence of a catastrophic illness certificate. Icodextrin use was defined by outpatient prescription records within 90 days after the index date. ICD codes are provided in Supplemental Table 1.

Outcome Definitions

Outcomes included all-cause death, hemodialysis transfer, peritonitis, major adverse cardiac events (MACE; ischemic stroke, acute myocardial infarction, and cardiovascular death), heart failure hospitalization, and all-cause hospitalization, as well as annual hospitalization frequency and hospital days. Mortality data were obtained from the Taiwan National Death Registry. Analyses were performed for all-cause death and additionally after excluding coronavirus disease 2019 (COVID-19)–related deaths. COVID-19–related deaths were identified from the National Death Registry maintained by the Ministry of Health and Welfare of Taiwan using the ICD-10 code U07.1. Hemodialysis transfer was defined as transition to hemodialysis lasting at least 30 days.[11] Peritonitis was identified from outpatient or inpatient diagnostic records. Ischemic stroke, acute myocardial infarction, and heart failure hospitalization were identified on the basis of principal discharge diagnoses, using previously validated definitions in the NHIRD.[12,13] Cardiovascular death was defined according to standardized definitions for cardiovascular and stroke end points.

Outcomes were assessed from the index date until occurrence of the outcome, death, hemodialysis transfer, kidney transplantation, or end of follow-up (December 31, 2019, for conventional APD; December 31, 2023, for RPM-APD), whichever came first.

Statistical Analyses

To reduce potential selection bias and confounding, inverse probability of treatment weighting (IPTW) was used to construct a weighted cohort representing the average treatment effect. Propensity scores were generated using a gradient boosting machine (10,000 trees), which has been shown to provide robust estimation,[14] incorporating all baseline covariates (Table 1). Covariate balance was assessed using absolute standardized differences, with values <0.1 indicating adequate balance.

Fatal outcomes (all-cause death and MACE) were analyzed using Cox proportional hazards models, while nonfatal outcomes (hemodialysis transfer and peritonitis) with competing risk of death were analyzed using Fine and Gray models. Annual hospitalization frequency and hospital days were analyzed using Poisson regression with log-transformed follow-up duration as an offset. The study group was the sole explanatory variable in all models. Subgroup analyses for the primary outcomes (all-cause death and hemodialysis transfer) were performed by age, sex, interval from PD to APD (<3 versus ≥3 months), diabetes, prior heart failure hospitalization, cardiovascular disease, and baseline icodextrin use.

All tests were two-sided with $P < 0.05$ considered significant. Analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC).

Sensitivity Analysis

In addition to the primary definition of hemodialysis transfer (≥30 days), alternative definitions using 60 and 90 days were tested. To assess robustness, a propensity score–matched cohort was constructed using the same gradient boosting machine model, with 1:1 nearest-neighbor matching (caliper 0.2) and robust standard errors to account for within-pair clustering. In the primary analysis, patients with <90 days of follow-up were excluded. To address potential bias from early events, a sensitivity analysis including all patients was performed, with re-estimation using IPTW and reassessment of outcomes.

Because the study compared two calendar periods (RPM-APD: 2020–2022 versus conventional APD: 2016–2018), potential era effects were considered. To address this, temporal trends in 1-year outcomes among patients on PD from 2016 to 2022 were analyzed. Outcomes included all-cause mortality (excluding COVID-19–related deaths), hemodialysis transfer, and peritonitis. Incidence rates were expressed per 100 person-years, and trends were evaluated using Poisson regression with the number of patients as an offset.

Results

Baseline Characteristics

After applying the exclusion criteria, 2477 patients were included, with 1258 in the RPM-APD group (2020–2022) and 1219 in the conventional APD group (2016–2018; Figure 1). Baseline characteristics are summarized in Table 1. Before weighting, small differences were observed in age distribution, sex, income, and diabetes prevalence, while other characteristics were generally similar between groups. After IPTW adjustment, all covariates were well balanced (standardized difference <0.1). Mean follow-up durations were 2.0 and 1.9 years for the RPM-APD and conventional APD groups, respectively.

Primary Analysis

The outcomes of the original cohort data are presented in the Supplement (Supplemental Table 2). After IPTW adjustment, four outcomes demonstrated significant differences between groups: all-cause mortality, hemodialysis transfer, annual number of hospitalizations, and hospital days (Table 2). The incidence rates of all-cause death were 4.4 and 5.3 per 100 person-years in the RPM-APD and APD groups, respectively, with a significant association favoring RPM-APD (hazard ratio [HR], 0.82; 95% confidence interval [CI] 0.69 to 0.99) (Figure 2A). This association was more pronounced after excluding COVID-19–related deaths (HR,

Table 1. Baseline clinical and demographic characteristics of patients who received remote patient monitoring–enabled automated peritoneal dialysis and automated peritoneal dialysis before and after inverse probability of treatment weighting

Variable	Before IPTW			After IPTW		
	RPM-APD (n=1258)	APD (n=1219)	STD	RPM-APD (n=2471)	APD (n=2473.6)	STD
Age, yr	54.2±15.1	53.0±15.5	0.08	53.6±15.2	53.6±15.4	<0.01
Age group						
<50 yr	482 (38)	524 (43)	−0.10	40.4	40.6	<0.01
50–64 yr	452 (36)	422 (35)	0.03	35.5	35.5	<0.01
65–74 yr	218 (17)	171 (14)	0.09	15.7	15.6	<0.01
≥75 yr	106 (8)	102 (8)	<0.01	8.3	8.3	<0.01
Male	717 (57)	635 (52)	0.10	54.5	54.4	<0.01
Monthly income, NTD						
Tertile 1	311 (25)	367 (30)	−0.12	27.1	27.3	<0.01
Tertile 2	504 (40)	423 (35)	0.11	37.7	37.6	<0.01
Tertile 3	443 (35)	429 (35)	<0.01	35.2	35.1	<0.01
Previous kidney transplant	22 (2)	17 (1)	0.03	1.6	1.5	<0.01
Previous hemodialysis	43 (3)	54 (4)	−0.05	3.7	3.8	−0.01
Duration from PD initiation to APD, mo						
Median (25th–75th percentiles), mo	1.2 (0.4–3.2)	1.7 (0.7–4.2)	NA	1.3 (0.4–3.6)	1.6 (0.6–3.6)	NA
<3 mo	929 (74)	826 (68)	0.13	71.2	71.1	<0.01
3–6 mo	107 (9)	153 (13)	−0.13	10.4	10.5	<0.01
≥6 mo	222 (18)	240 (20)	−0.05	18.3	18.3	<0.01
Comorbidity						
Diabetes mellitus	590 (47)	510 (42)	0.10	44.6	44.5	<0.01
Hypertension	1127 (90)	1084 (89)	0.02	89.3	89.3	<0.01
Coronary artery disease	81 (6)	82 (7)	−0.01	6.3	6.4	<0.01
Myocardial infarction	62 (5)	48 (4)	0.05	4.3	4.2	<0.01
Peripheral arterial disease	45 (4)	43 (4)	<0.01	3.5	3.5	<0.01
Heart failure hospitalization	204 (16)	210 (17)	−0.03	16.5	16.5	<0.01
Ischemic stroke	85 (7)	83 (7)	<0.01	6.8	6.9	<0.01
Cardiovascular disease[a]	212 (17)	197 (16)	0.02	16.4	16.3	<0.01
Malignancy	102 (8)	74 (6)	0.08	7.1	7.0	<0.01
Liver cirrhosis	24 (2)	26 (2)	−0.02	1.9	1.9	<0.01
Icodextrin use at baseline	554 (44)	489 (40)	0.08	42.0	42.0	<0.01
Follow-up yr						
Mean±SD	2.0±1.0	1.9±1.0	0.10	2.0±1.0	1.9±1.0	0.12
Median (25th–75th percentiles)	2.0 (1.2–2.8)	1.8 (1.2–2.6)	NA	2.0 (1.2–2.8)	1.8 (1.1–2.6)	NA

APD, automated peritoneal dialysis; IPTW, inverse probability of treatment weighting; NA, not applicable; NTD, New Taiwan dollar; PD, peritoneal dialysis; RPM-APD, remote patient monitoring–enabled automated peritoneal dialysis; STD, standardized difference.
Data are presented as frequency (percentage), mean±SD or median (25th–75th percentiles).
[a]Any one of coronary artery disease, myocardial infarction, peripheral arterial disease, and stroke.

0.78; 95% CI 0.64 to 0.94). For hemodialysis transfer, incidence rates were 12.7 and 15.1 per 100 person-years, respectively (subdistribution hazard ratio [SHR] 0.86, 95% CI, 0.77 to 0.96; Figure 2B). In analyses limited to the first year, both outcomes were comparable between groups (Supplemental Table 3). RPM-APD was also associated with fewer hospitalizations and shorter annual hospital stays (Table 2).

Subgroup Analysis

In the IPTW-adjusted cohort, the subgroup analysis showed that the favorable effect of RPM-APD on all-cause mortality was more pronounced in patients without diabetes than in those with diabetes (HR 0.58 versus 0.97; P for interaction = 0.01). The association was otherwise consistent across subgroups (Figure 3A). For hemodialysis transfer, a stronger association was observed in nonelderly patients (SHR 0.79 versus 1.09 in the elderly; P for interaction = 0.03). In addition, patients receiving icodextrin at baseline showed a greater association with reduced hemodialysis transfer (SHR 0.72 for users versus 1.02 for nonusers; P for interaction = 0.002; Figure 3B).

Sensitivity Analysis

When the definition of hemodialysis transfer was extended, the association with RPM became more pronounced (Supplemental Figure 1). After propensity score matching, 1100 patients remained in each group with well-balanced baseline characteristics (Supplemental Table 4). Although the associations with all-cause death and hemodialysis transfer were no longer statistically significant, effect estimates were consistent with the primary analysis. RPM-APD remained associated with fewer hospitalizations and hospital days (Supplemental Table 5). After removing the exclusion criteria for patients with <90 days of follow-up, baseline characteristics are listed in Supplemental Table 6. The association between RPM-APD and all-cause mortality was attenuated (HR, 0.86; 95% CI, 0.73 to 1.03, P = 0.10) but remained significant after excluding COVID-19–related deaths (HR, 0.82; 95% CI, 0.69 to 0.98,

Table 2. Follow-up outcomes of the study cohorts after inverse probability of treatment weighting

Outcome	RPM-APD (n=2471.0)		APD (n=2473.5)		HR/SHR/RR of RPM-APD (95% CI)	P Value
	Event Rate (%) or Mean±SD	Incidence (95% CI)[a]	Event Rate (%) or Mean±SD	Incidence (95% CI)[a]		
All-cause death	8.8	4.4 (3.8 to 5.0)	9.8	5.3 (4.6 to 5.9)	0.82 (0.69 to 0.99)	0.04
All-cause death, excluding COVID-19	8.3	4.1 (3.6 to 4.7)	9.8	5.3 (4.6 to 5.9)	0.78 (0.64 to 0.94)	0.008
Hemodialysis transfer	25.3	12.7 (11.7 to 13.7)	28.1	15.1 (13.9 to 16.2)	0.86 (0.77 to 0.96)	0.007
Peritonitis	24.7	13.9 (12.8 to 15.0)	21.8	13.1 (12.0 to 14.2)	1.08 (0.96 to 1.21)	0.18
MACE[b]	7.8	4.0 (3.4 to 4.5)	8.6	4.7 (4.0 to 5.3)	0.84 (0.69 to 1.02)	0.08
Ischemic stroke	1.5	0.7 (0.5 to 1.0)	2.1	1.1 (0.8 to 1.4)	0.69 (0.45 to 1.06)	0.09
Acute myocardial infarction	3.3	1.7 (1.3 to 2.0)	2.7	1.5 (1.1 to 1.8)	1.11 (0.80 to 1.53)	0.53
Cardiovascular death	4.0	2.0 (1.6 to 2.4)	4.6	2.5 (2.0 to 2.9)	0.79 (0.61 to 1.04)	0.09
Heart failure hospitalization	1.2	0.6 (0.4 to 0.8)	0.9	0.5 (0.3 to 0.7)	1.20 (0.69 to 2.09)	0.51
All-cause hospitalization	71.1	58.7 (56.0 to 61.4)	68.0	57.3 (54.6 to 60.1)	1.03 (0.96 to 1.10)	0.45
Number of hospitalizations per yr	1.6±2.9	NA	2.1±9.2	NA	0.70 (0.68 to 0.73)	<0.001
Number of hospital d per yr	11.2±29.4	NA	12.0±32.5	NA	0.93 (0.92 to 0.94)	<0.001

APD, automated peritoneal dialysis; CI, confidence interval; COVID-19, coronavirus disease 2019; HR, hazard ratio; MACE, major adverse cardiac events; NA, not applicable; RPM-APD, remote patient monitoring–enabled automated peritoneal dialysis; RR, relative risk; SHR, subdistribution hazard ratio.
Data are presented as frequency (percentage) or mean±SD.
[a]Number of events per 100 person-year.
[b]Any one of ischemic stroke, myocardial infarction, and cardiovascular death.

P = 0.03). The association with reduced hemodialysis transfer remained consistent (SHR, 0.86; 95% CI, 0.77 to 0.95; Supplemental Table 7).

Figure 4 illustrates the temporal trends of PD prevalence and related outcomes in Taiwan. The annual number of patients on PD remained stable at approximately 8000 per year (P for trend = 0.37; Figure 4A). Furthermore, the 1-year outcomes after the first PD treatment within each calendar year—including all-cause mortality, hemodialysis transfer, and peritonitis—showed no significant temporal changes (Figure 4, B–D).

Discussion

To our knowledge, this is the first nationwide cohort study to evaluate clinical outcomes associated with RPM-APD. RPM-APD was associated with lower risks of all-cause mortality and hemodialysis transfer, as well as

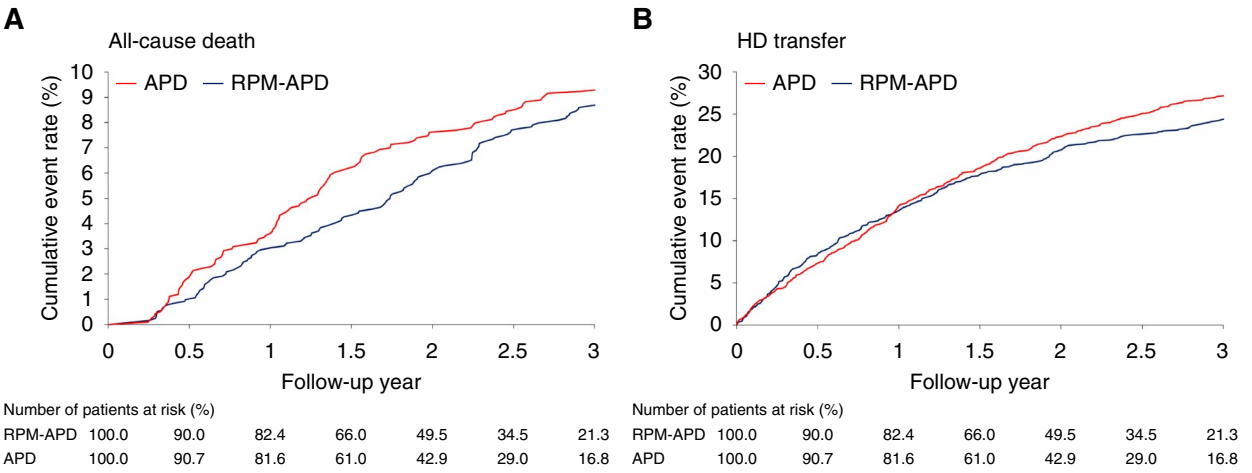


Figure 2. RPM-APD was associated with lower risks of all-cause death and hemodialysis transfer compared with conventional APD. Cumulative event rates of all-cause death (A) and hemodialysis transfer (B) among patients receiving RPM-APD versus APD in the IPTW-adjusted cohort. CI, confidence interval; IPTW, inverse probability of treatment weighting. Figure 2 can be viewed in color online at www.cjasn.org.

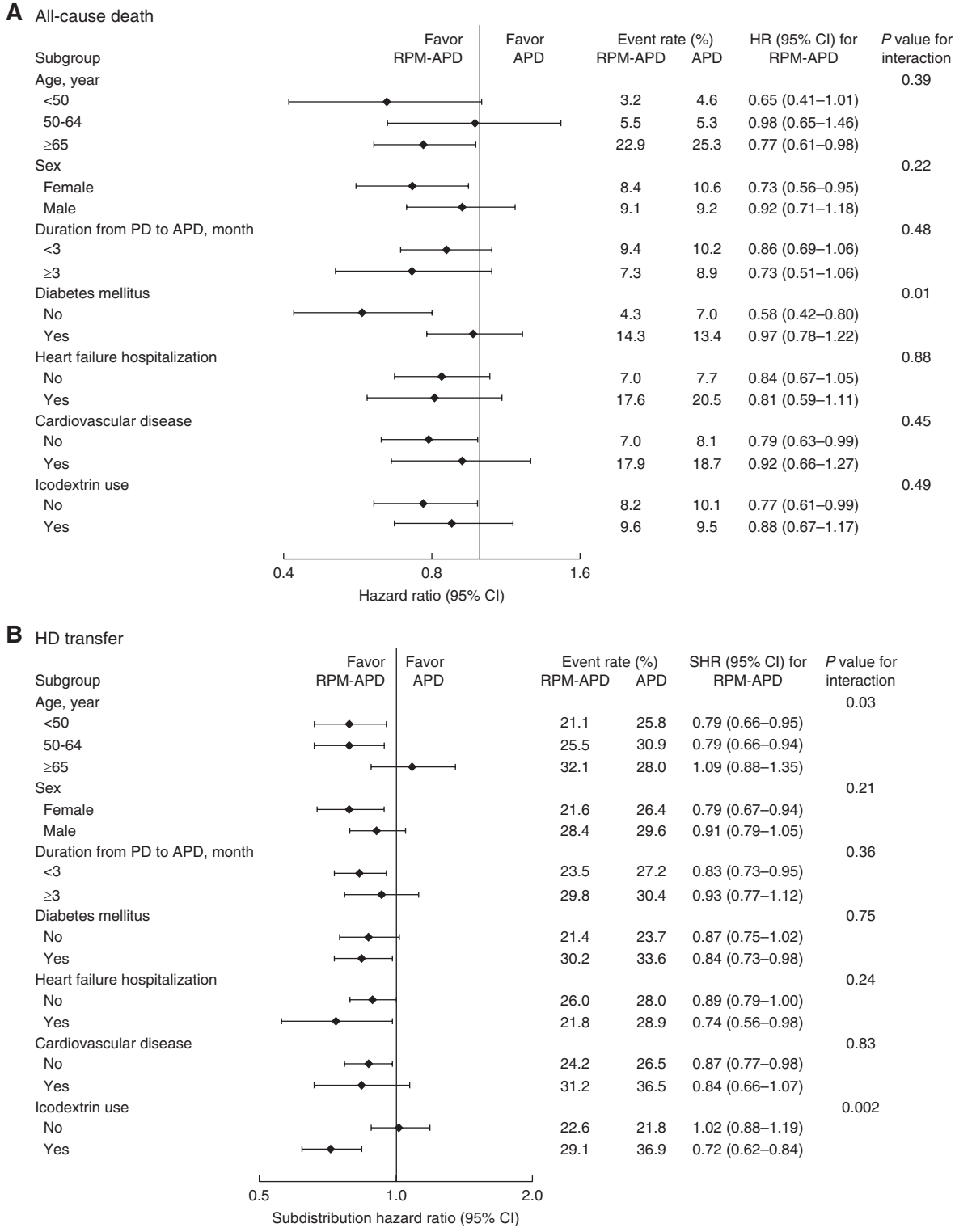


Figure 3. Associations of RPM-APD with clinical outcomes were generally consistent across subgroups, with heterogeneity observed for selected patient characteristics. Subgroup analyses of all-cause death (A) and hemodialysis transfer (B) among patients receiving RPM-APD versus APD in the IPTW-adjusted cohort. HR, hazard ratio; SHR, subdistribution hazard ratio.

reduced hospitalization burden, compared with conventional APD. International studies suggest that RPM may facilitate earlier detection of abnormalities,[4] enable timely intervention,[15] and reduce hospitalization.[16] These findings are consistent with our results. However, the observed mortality reduction was modest and varied across analytical approaches and should be interpreted with caution.

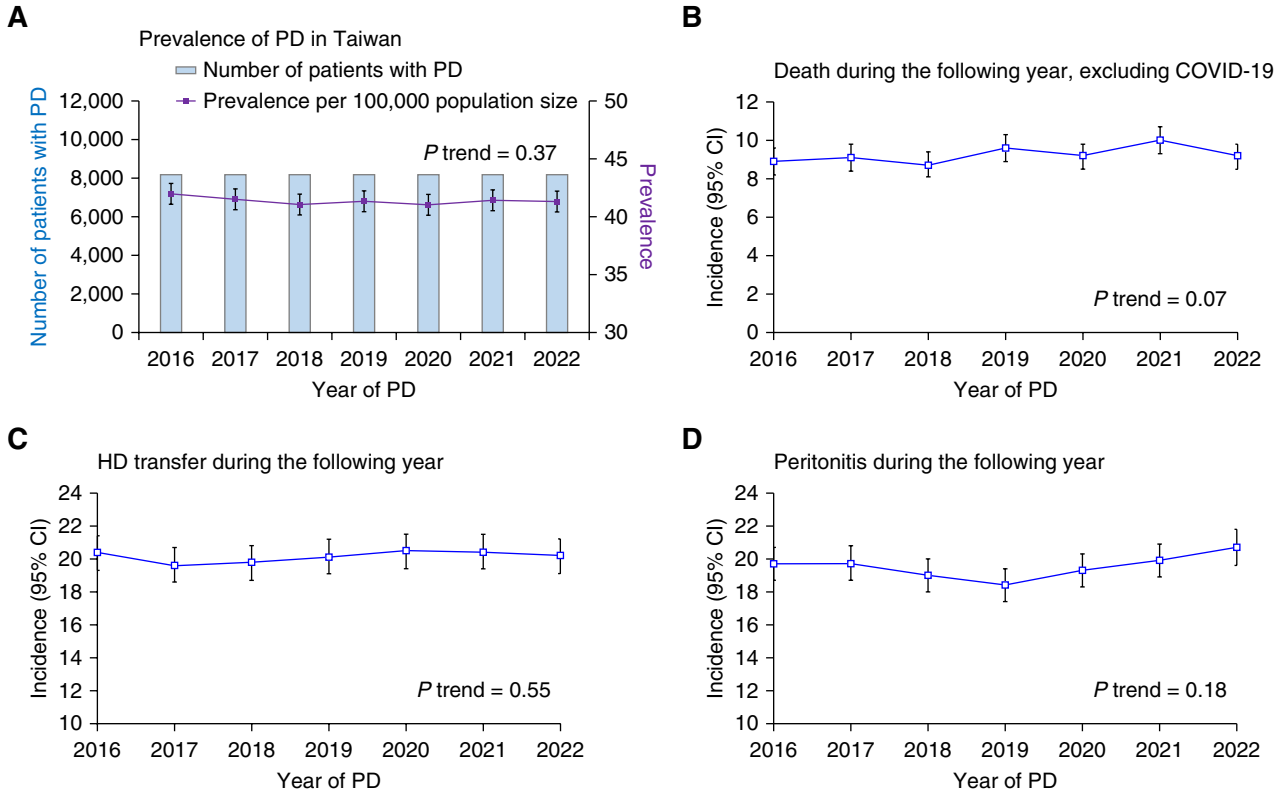


Figure 4. PD prevalence and 1-year clinical outcomes in Taiwan remained stable from 2016 to 2022. Temporal trend of the prevalence of PD in Taiwan (A), and 1-year outcomes after the first PD treatment within each year, including all-cause mortality excluding COVID-19–related deaths (B), hemodialysis transfer (C), and peritonitis (D). COVID-19, coronavirus disease 2019; PD, peritoneal dialysis. Figure 4 can be viewed in color online at www.cjasn.org.

In Taiwan, RPM-APD has been implemented as a system-level care model across tertiary medical centers since 2019, rather than as an optional intervention. Accordingly, defining RPM exposure by calendar period and care setting reflects a pragmatic real-world implementation. This is supported by reports from multiple centers across Taiwan, which have demonstrated improved treatment adherence,[17] reduced peritonitis risk,[18] and consistent signals of favorable clinical outcomes.[19,20] In addition, national initiatives promoting PD and remote monitoring have been incorporated into the National Health Insurance framework to enhance PD care quality.[21] Together, these findings support the interpretation that RPM-APD in Taiwan reflects an actively managed care model rather than passive data collection.

In our study, RPM-APD was also shown to lower the risk of hemodialysis transfer, a clinically meaningful outcome. Early discontinuation of PD is often driven by several mechanisms, including inadequate dialysis, mechanical problems, and psychosocial stress.[22] RPM-APD may mitigate these risks by improving treatment adherence and enabling earlier identification of treatment-related issues.[4,23] In addition, enhanced monitoring and patient support may contribute to better clinical stability and prolonged PD use. Sensitivity analyses using stricter definitions of hemodialysis transfer showed a more pronounced association, suggesting that early detection and timely intervention may help prevent permanent transition to hemodialysis and facilitate continuation of PD.

Because peritonitis rates were similar between groups, the observed reduction in hemodialysis transfer is unlikely to be primarily driven by infectious complications. Instead, it may reflect noninfectious mechanisms related to improved treatment monitoring and timely intervention. These findings are consistent with prior studies suggesting that remote monitoring, including both device-integrated and non–device-integrated systems, may be associated with improved technique survival through enhanced treatment visibility and more timely intervention.[24,25] In addition, randomized trial data[6] demonstrating reductions in adverse events and hospitalizations related to cardiovascular disease, fluid overload, and insufficient dialysis efficiency may provide context for the trend toward lower MACE observed in our study.

In our study, RPM-APD was associated with lower mortality. Notably, Taiwan experienced peak COVID-19–related mortality during the RPM-APD period[26]; however, this association persisted and became more pronounced after excluding COVID-19–related deaths. Cardiovascular disease is a major cause of death in patients on PD,[27] and RPM-APD was associated with favorable trends toward lower risks of ischemic stroke and cardiovascular death in our study, potentially related to

improved fluid management and BP control.[23,28] Improved treatment adherence may also contribute, given its known association with mortality in patients on PD.[29] In addition, reduced hospitalization in the RPM-APD group may further support the observed association with improved survival.[30]

We examined the timing of RPM effects on the two primary outcomes. No significant differences in mortality or hemodialysis transfer were observed within the first year of follow-up. The delayed separation of cumulative event curves (Figure 2, A and B) suggests that early differences in observational studies may reflect selection bias rather than true treatment effects. These findings highlight the importance of sustained RPM exposure to achieve potential benefits and are consistent with prior randomized data showing delayed improvements in mortality and technique outcomes.[5]

Subgroup analyses showed that the reduced risk of hemodialysis transfer with RPM was mostly pronounced among the icodextrin users. In Taiwan, icodextrin is preferentially prescribed to PD patients with higher peritoneal transport status under the current reimbursement policies, a group potentially more responsive to APD, suggesting a synergistic effect with RPM on modality durability. Younger patients on APD also seemed to derive greater benefits, possibly reflecting lower baseline adherence[31] and greater potential for improvement with closer clinical follow-up. By contrast, the association with reduced mortality was more evident among patients without diabetes, suggesting that those with diabetes—who have higher competing mortality risks—may require additional care beyond RPM alone.

This study has several strengths, including the use of a nationwide database with extended follow-up, accurate identification of patients on APD using reimbursement codes, and the application of multiple analytic approaches, including IPTW and propensity score matching. Outcomes were defined using validated codes aligned with Standardized Outcomes in Nephrology–Peritoneal Dialysis priorities, supporting the robustness of the findings.

Several limitations should be acknowledged. First, a historical APD cohort was used as the comparator because RPM-APD had been widely implemented at medical centers after a defined time point, raising the possibility of era effects. However, national data indicate stable PD patient numbers and 1-year outcomes over time, and our sensitivity analyses support the robustness of the findings. Other limitations include the lack of laboratory data, ultrafiltration volumes, dialysis adequacy and residual kidney function, important determinants of outcomes in patients on PD. Although PD vintage was balanced between groups and national registry data suggest similar eGFR at PD initiation across study periods,[32] residual confounding cannot be excluded. In addition, the use of icodextrin—restricted under Taiwan's reimbursement policy to patients with higher transport characteristics—was similar between groups, indirectly supporting comparability in peritoneal transport status and treatment intensity. Heterogeneity in RPM implementation across institutions may partly explain discrepancies with single-center studies.[15] More broadly, the lack of consensus and formal guidelines for RPM-APD remains an important challenge.[33] Finally, owing to the nature of the NHIRD database, patient-level data on connectivity status, monitoring frequency, and responses to alerts were not available. Therefore, the intensity and fidelity of RPM implementation could not be directly assessed. Information on technique failure causes and peritonitis microbiology was also not available, limiting further mechanistic interpretation.

In conclusion, RPM-APD was associated with improved clinical outcomes in incident patients on APD, including lower risks of mortality, hemodialysis transfer, and hospitalization. These findings support the role of RPM-APD as an important component of contemporary APD care. Future efforts should focus on standardizing RPM health care pathways and developing targeted strategies for high-risk groups, particularly patients with diabetes, to further enhance patient outcomes.

Disclosures

Disclosure forms, as provided by each author, are available with the online version of the article at https://links.lww.com/CJN/C819.

Author Contributions

Conceptualization: Chan Ip Chan, Ben-Chung Cheng, Chi-Jung Chung, Mu-Chi Chung, Chih-Yu Yang, Tung-Min Yu.
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Data Availability Statements

Data belong to a third party, and authors are not authorized to share the data. Identity of Third Party: Taiwan National Health Insurance. Reason for Restriction: The data that support the findings of this study are available from the Taiwan NHIRD but restrictions apply to the availability of the data, which were used under license for the current study, and so are not publicly available.

Supplemental Material

This article contains supplemental material online, published as provided by the authors, at https://links.lww.com/CJN/C820.

Supplemental Table 1. ICD diagnostic codes for diseases used in the study.

Supplemental Table 2. Follow-up outcomes of the original study cohorts.

Supplemental Table 3. One-year primary outcomes of RPM-APD and conventional APD after IPTW.

Supplemental Table 4. Baseline clinical and demographic characteristics of patients who received RPM-APD and APD in the propensity score-matched cohort.

Supplemental Table 5. Follow-up outcomes of the study cohorts in the propensity score-matched cohort.

Supplemental Table 6. Baseline clinical and demographic characteristics of patients who received RPM-APD and APD before and after IPTW, without excluding patients with follow-up <90 days.

Supplemental Table 7. Follow-up outcomes of the study cohorts after IPTW, without excluding patients with follow-up <90 days.

Supplemental Figure 1. Incidence of hemodialysis transfer defined by different duration thresholds among patients receiving RPM-APD versus APD in the IPTW-adjusted cohort.

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