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Research Article

In-center Automated Peritoneal Dialysis: Clinical Features, Practice Patterns, and Patient Survival From a 6-year Cohort Study in China

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Short Title: In-center automated peritoneal dialysis in China

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Abstract

Introduction: In-center automated peritoneal dialysis (APD) has been more frequently adopted in clinical practice for maintenance PD patients in China. For a better understanding of its clinical uptake, this retrospective study reviewed incident PD patients for a period of 6 years, investigating the practice pattern of in-center APD, factors associated with the use of in-center APD, and report on the patient survival compared to the non-users of APD among hospitalised PD patients.

Methods: This was a cohort study of all incident PD patients who met the inclusion criteria from 2013/01/01 to 2018/09/30, and were followed until death, cessation of PD, loss to follow-up, or 2018/12/31. Clinical characteristics, patient outcomes, and detailed data on APD sessions were recorded. We used time-dependent Cox model to estimate the variables associated with the initiation of in-center APD, and marginal structural model through inverse probability weighting to adjust for time-varying APD use on the causal pathway to all-cause mortality.

Results: A total of 651 subjects over 17501 patient-months were enrolled. Of these, 633 (97.2%) PD patients were hospitalised at least once during follow-up, and 369 (56.7%) received in-center APD at a certain point, and the timing of APD use during the first 3 months, first year and first 2 years since PD inception were 14.8%, 45.4% and 74.8%, respectively. A total of 12553 in-center APD sessions were recorded, where 85.9% used 4 bags of 5L-exchanges per prescription. Time-dependent Cox model showed that diabetes (hazard ratio (HR), 1.39, 95% confidence interval (CI), 1.09−1.76), urine output (HR 0.80, 95% CI 0.70-0.92), serum albumin (HR 0.84, 95%CI 0.72-0.99), hemoglobin (HR 0.88, 95%CI 0.77-0.99), and Ca×P (HR 1.19, 95%CI 1.06-1.35) were significantly associated with in-center

APD use. Among all hospitalised PD patients, the estimated hazard ratio corresponding to the marginal causal effect of in-center APD use on all-cause mortality was 0.13 (95% CI 0.05–0.31, P<0.001). Starting APD after the first PD year was associated with a significantly lower risk of all-cause mortality (adjusted-HR 0.56, 95%CI 0.33-0.95).
Conclusions: In-center APD is used intensively during the first 2 years of PD and is associated with certain clinical features. Overall, in-center APD use was associated with a lower risk of all-cause death when compared with non-use.

Introduction

The utilization of automated peritoneal dialysis (APD) which was originally reserved for patients with high transport status has increased over recent years, paralleled by a substantial growth of accumulating studies on APD[1]. Due to its lifestyle benefits, wider range of prescription options, and the availability of convenient automated machines, APD has become a desirable peritoneal dialysis (PD) modality for individuals with other transport characteristics. Since the establishment of high reimbursement system for kidney failure, China has experienced an unprecedented rapid increase in PD utilization[2]. By the end of 2021, PD population was 12,6372 in mainland China, with an overall PD prevalence rate of 87.55 per million population (https://www.cnrds.net).

Despite the long unavailability of icodextrin, in-center APD has been more frequently adopted in clinical practice for maintenance PD patients in China, defined as the APD treatment during hospital stay, APD regimens were prescribed according to patient's clinical condition at the time of hospitalisation. Although in-center APD mostly served as a supplementary treatment (mainly to avoid modality switch) for PD patients during the past few years in China[3], APD is expected to be a popular choice for home dialysis in the near future. Whether the higher cost of APD can be justified by its clinical benefits in terms of preservation of residual kidney function, sodium and fluid removal, glucose load, infection rate, and long-term outcomes is yet to be evaluated[4]. However, in light of the coronavirus pandemic, home-based modality and APD has attracted appreciable attention in dialysis community with regard to the integration of remote monitoring system and the feasibility of telehealth solutions[5].

To our knowledge, despite the growing utilization of in-center APD, studies on survival impact of short-term APD and clinical profile of the in-center APD receivers in China are scarce. For a better understanding of its clinical uptake, in the present study, with the aim of gaining more insights into the practice pattern of in-center APD, factors associated with the use of in-center APD, and related patient outcomes, we retrospectively reviewed incident PD patients for a period of 6 years and mainly focused on the incidence of hospital admissions, investigating in-center APD prescriptions, clinical features of the in-center APD receivers, and report on the patient survival compared to the non-users of APD among hospitalised PD patients.

Materials and Methods

Study population

This was a single-center, retrospective cohort study of all incident patients who used PD as their first kidney replacement therapy (KRT) modality in our PD center from 1 January 2013 and 30 September 2018. Inclusion criteria were patients with end stage kidney disease (ESKD) who were aged ≥18 years at the start of PD and were followed up at the PD center of the First Teaching Hospital of Tianjin University of Traditional Chinese Medicine, and were stable on PD therapy for more than 90 days. The enrolled patients were followed until death, cessation of PD, loss to follow-up, or 31 December 2018. Continuous ambulatory peritoneal dialysis (CAPD) was applied to all patients. Conventional PD solutions (1.5%, 2.5%, or 4.25% dextrose) and Y connections with double-bag systems or HomeChoice APD systems were used in all PD patients. The in-center APD is defined as receiving APD treatment during hospital stay, APD regimens were prescribed according to patient's clinical condition at the time of hospitalisation. The original inception cohort included 951 subjects who initiated PD before 30 September, 2018 with 298 deaths over 35531 patient-months follow-up. There was a total of 677 incident patients received PD catheter insertions at our PD center during 1 January, 2013 to 30 September, 2018, and none of these patients had a history of HD therapy for more than 3 months or graft failure. Among them, 20 patients dropped within the first 90 days and 6 patients had missing basic information. Thus, a total of 651 patients ranging in age from 19 to 91 years who met the inclusion criteria were enrolled in this study and were followed for a median 23.0 (interquartile range, 12.0–39.5) months up to 6 years through December, 2018, see supplementary materials for detailed flow diagram showing study algorithm. This study was registered with the Chinese Clinical Trial Registry (ChiCTR-ORC-17013852) and was conducted in adherence to the declaration of Helsinki. The protocol of this study was approved by the Chinese Ethics Committee of Registering Clinical Trial (ChiECRCT-20170088), and informed consent was exempted because only

aggregated data were received. The patient information was anonymized and de-identified prior to analysis.

Data collection

Demographic, clinical, and biochemical data were obtained from the PD center database of the First Teaching Hospital of Tianjin University of Traditional Chinese Medicine. Hospital admissions, detailed data on APD sessions, causes for the cessation of PD (transfer to hemodialysis and transplantation), and causes of death were collected from medical charts and sourced from hospital information system. Patient demographics comprised of age, gender, PD inception date, primary cause of ESKD, and comorbidities (diabetes, cardiovascular diseases, cerebrovascular diseases, and peripheral vascular diseases) were recorded at the initiation of PD. At baseline and every 3-6 months, clinical and biochemical data, including body mass index (BMI), urine output (UOP), mean arterial pressure (MAP), residual kidney function (RKF), serum albumin, hemoglobin, ferritin, sodium, potassium, calcium-phosphate product (Ca×P), intact parathyroid hormone (iPTH), creatinine, urea nitrogen, fasting blood glucose (FBG), triglyceride, cholesterol, and dialysis data (weekly total Kt/V urea, weekly total clearance of creatinine (ClCr), 4 h dialysate-to-plasma ratio of creatinine (D/Pcr, measured by a standard peritoneal equilibration test), peritoneal membrane transport status), as well as PD prescription details were collected and updated, available during study follow-up.

Primary exposure and study outcomes

The primary exposure was the time-varying PD modality (episodic use of in-center APD). The primary outcome for survival analysis was the event of all-cause death, the secondary outcome was the initiation of in-center APD.

Statistical methods

Results were expressed as mean ± standard deviation or median (interquartile range, IQR) for continuous data and percentage for categorical data when appropriate. The dosage of in-center APD was described as the total prescribed cycler volume per 1.73m^2 body surface area (BSA). Variables such as age, gender, comorbidities, and biochemical data were modeled as baseline or time-varying by carrying forward patients' last observation, as appropriate. Main analyses of this longitudinal study was focused on all incident PD patients who were hospitalised during 2013-2018. First, we evaluated variables associated with the initiation of in-center APD, time-dependent Cox model (Andersen-Gill model, A-G model) was performed to estimate factors associated with the point treatment. Second, to explore the short-term effect of in-center APD on mortality, we applied marginal structural model (MSM) through inverse probability weighting (IPW) adjusting for time-varying PD modality exposure and comorbidities to estimate the association of the use of in-center APD with patient survival. Time-dependent data set one endpoint (episodic use of in-center APD) at a time was generated using the survival library in R, consisting of T monthly waves for each of N patients for a total of N×T patient-months. Two variables were created to build time-dependent sets, time.start indicates the time at which the subject entered the study or the time at which the incident of using in-center APD last occured while time.stop corresponds to the time when the in-center APD initiated or to the end of the follow-up. The estimation involved 2 steps, step (1) estimation of stabilized weights, computed weights adjusting for confounding, and step (2) fitting A-G models to the observations weighted by step (1), estimating the causal effect of episodic in-center APD exposure using robust sandwich variance estimators. Of note, the aim of using IPW is to correct both for confounding and for forms of selection bias, given the retrospective nature of the study and the point treatment setting, the methodology has been discussed elsewhere[6][7]. As in-center APD also has an effect on hemodialysis (HD) switch, as well as on mortality, the estimated weights for HD switch were also added in the final MSM. Finally, we performed Cox proportional hazards model to evaluate the survival benefit of starting APD after the first PD year among patients who used in-center APD. Survival was generated by Kaplan-Meier and compared by log-rank test for patients dichotomized by the timing of APD initiation. We adjusted for comorbidities in all survival models, which is the main source of confounding in our study. Bootstrap validations of the fast backward step-down (with total residual AIC as the stopping rule) models were used for variable selection and model simplification. All analyses were conducted in R statistical environment version 4.1.1, with

"survival" package for survival analysis, and "rms", "ipw" packages for regression modeling strategies, and inverse probability weighting. A P-value < 0.05 was considered statistically significant.

Results

A total of 651 subjects who meets inclusion criteria with 17501 patient-months were analysed. Of these, 633 (97.24%) PD patients were hospitalised at least once, 369 (56.68%) received in-center APD at a certain point during follow-up. Of a total of 651 patients, 367 patients (56.37%) were male, 224 patients (34.41%) were diabetic, and CVDs prevalence in our cohort were 53.61% for cardiovascular disease, 21.81% for cerebrovascular disease, and 2.46% for peripheral arterial disease. Table 1 summarizes the baseline demographic and clinical features of the present cohort, comparing these characteristics by whether patients received in-center APD or not. At baseline more patients comorbid diabetes, cardiovascular and cerebrovascular disease among those who received in-center APD. Over a median follow-up of 23 months, we ascertained 123 cases of death, where 55 (44.72%) cases were attributable to cardiovascular or cerebrovascular diseases (CVDs), 49 (39.84%) cases were recorded as multiple organ failure, and 9 (7.32%) cases were caused by infection.

Practice patterns of in-center APD

We split the longitudinal data with APD sessions, corresponding to each patient's dialysis month. During the period of study, a total of 900 prescriptions of in-center APD treatment were collected and analyzed. Figure 1 demonstrates the distribution of in-center APD treatment during patient dialysis months, a non-normal distribution was recorded with a median 14 (IQR, 6–25) dialysis months. The timing of APD use during the first 3 months, first year and first 2 years since PD inception were 14.8%, 45.4% and 74.8%, respectively. Figure 2 shows the APD prescription pattern. A total of 12553 in-center APD sessions were recorded, where 10782 (85.9%) APD sessions used 4 bags of 5L-exchanges, most common combinations were 2 bags of 1.5% dextrose PD solutions (PDS) plus 2 bags of 2.5% dextrose PDS (34.94%), 3 bags of 1.5% dextrose PDS plus 1 bags of 2.5% dextrose PDS (24.79%), and 4 bags of 1.5% dextrose PDS plus 0 bags of 2.5% dextrose PDS (21.04%). The average dosage of APD was 19.37 L/1.73 m^2, with a median dosage of 19.22 (IQR, 17.21-20.84) L/1.73 m^2.

Factors associated with the use of in-center APD

A total of 880 incidents of in-center APD use corresponding to their patient months were analysed using couting process style in time-dependent Cox models. For comparison's sake, all subjects enrolled in the study who were hospitalised during follow-up were modeled. Before introducing all individual-level covariates into full model, quick redundancy was performed on the set of predictors, using threshold of 0.75 for R^2. As no redundant variable was detected, hierarchical cluster analysis was performed to check collinearity. Factors in the final models for the initiation of APD use were age (continuous), male (dichotomized), diabetes (dichotomized), cardiovascular diseases (dichotomized), high average and high transporters (dichotomized), BMI (continuous), MAP (continuous), UOP (continuous), serum albumin (continuous), hemoglobin (continuous), Ca×P (continuous), and Total Kt/V urea (continuous). The results from the time-dependent Cox model (A-G model) showed that diabetes (hazard ratio (HR), 1.39, 95% confidence interval (CI), 1.09−1.76, *p*=0.007), lower UOP (HR 0.80, 95% CI 0.70-0.92, *p*=0.001), serum albumin (HR 0.84, 95%CI 0.72-0.99, *p*=0.034) and hemoglobin (HR 0.88, 95%CI 0.77-0.99, *p*=0.039), and higher Ca×P (HR 1.19, 95%CI 1.06-1.35, *p*=0.004) were significantly associated with the initiation of in-center APD. Detailed result from the A-G model is shown in Table 2.

The effect of in-center APD on all-cause mortality

We focused on the patients who were hospitalised during 2013-2018 (N=633), a total of 113 deaths corresponding to their patient months were modeled. To assess the short-term effect of in-center APD on patient survival, we performed A-G model adjusting for individual-level confounders with all-cause mortality as the outcome of interest. Table 3 illustrates the HRs of the point treatment for mortality from different modeling approaches. After adjusting the factors associated with APD use, the causal effect of time-varying in-center APD use on all-cause mortality was 0.14 (95%CI 0.06-0.35, p<0.001). Factors such as age (HR 1.43, 95%CI 1.00-2.02, *p*=0.047), diabetes (HR 1.67, 95%CI 1.12-2.49, *p*=0.012), cardiovascular diseases (HR 1.79, 95%CI 1.16-2.76, *p*=0.009), UOP (HR 0.64, 95%CI 0.41-0.99, *p*=0.049), serum albumin (HR 0.43, 95%CI 0.31-0.60, *p*<0.001) were strongly associated

with all-cause mortality for the present cohort. After adjusting for possible confounding by time-varying variables from the aforementioned conditional model using IPW, the estimated hazard ratio corresponding to the marginal causal effect of in-center APD on mortality was 0.13 (95% CI 0.05–0.31, p<0.001). We further evaluated the relationship between timing of in-center APD use and all-cause mortality among patients who used in-center APD (N=369). In single variable model, the HR for all-cause mortality in association with starting APD after the first PD year was 0.41 (95%CI 0.25-0.69, p<0.001). After introducing individual-level covariates, such as age, male gender, comorbidities (diabetes, CVDs), the adjusted HR for all-cause mortality was 0.56 (95%CI 0.33-0.95). Figure 3 shows the comparison of Kaplan-Meier survival curves for in-center APD users with the different timing of APD initiation (before the first PD year VS after the first PD year), and a significant difference between groups was observed (p<0.001).

Discussion/Conclusion

With more than half of the incident PD patients being prescribed in-center APD at least once, our study identified several interesting features of in-center APD utilization. First of all, patients who received in-centered APD were more likely to be diabetic, with more reduced UOP, having difficulties managing anemia, malnutrition, mineral-bone disorder or achieving dialysis adequacy. Secondly, the uptake of in-center APD peaked at the first 2 years of PD, around 75% of the in-center APD sessions took place at certain point during the first 2 dialysis years. Thirdly, the most common in-center APD prescriptions was 4 bags of 5L-exchanges, 2 bags of 1.5% dextrose PDS plus 2 bags of 2.5% dextrose PDS was the mostly used combination, reflecting the need for both ultrafiltration and clearance. Furthermore, in-center APD use was associated with a lower risk of all-cause mortality, suggesting a significant short-term survival benefit associated with in-center APD when compared with non-use. To our knowledge, this is the first study to explore in-center APD use among incident PD patients. In general, in-center APD is a non-conventional use, which happened when CAPD patient being hospitalized, largely differs from home-based APD. As it was shown in the present study that the average BSA calibrated APD dosage was 19.37 liters, much larger from the APD prescription details (6.57-11.0 L/1.73 m^2) reported by Peritoneal Dialysis Outcomes and Practice Patterns Study (PDOPPS)[8]. Other than HD switch, in-center APD served as a rescue measure for PD patients encounter problems with fluid balance, dialysis adequacy, peritonitis episodes, et cetera, hence in-center APD is limited to certain groups of patients, which was further explored in our study.

During a period of 6-year follow-up, CVDs was the leading cause of death, which is consistent with previous studies[9][10]. Our study showed that diabetes, reduced RKF, worse management of mineral-bone disorder, and low serum albumin and hemoglobin levels were significantly associated with in-center APD use. As it was recently proposed by American Heart Association, blood pressure, extracellular volume, and mineral and bone disorder were the major cardiovascular risk factors among home dialysis patients[11].Fluid balance and adequate solute removal has been major challenges and key treatment goal in PD. One recent international cohort study showed that volume overload at PD inception and/or at 6 months was significantly associated with a higher risk of technique failure[12]. Another prospective multi-center cohort study confirmed that relative volume overload was independently associated with higher mortality risk, and the improvement of fluid balance over time was associated with better patient survival[13]. Compared to CAPD, APD has been more akin to HD, which offers the possibility to increase dialysate flow rate, achieving better solute clearance and water removal[14]. In the past decades, efforts have been made towards an optimization of APD use to cope with volume overload and better solute removal, such as adapted APD regimen[15] and bimodal APD prescription[16].

After adjusting for individual-level confounders, survival on in-center APD was generally better than that of non-users of APD.Results from the time-dependent A-G model using IPW demonstrated a significant survival benefit associated with the short-term use of APD in our study. Not surprisingly, older age, cardiovascular diseases, UOP, and serum albumin were significantly related to all-cause mortality. Of note, lower level of UOP and serum albumin were also associated with in-center APD use, suggesting cardiovascular risk, RKF loss, and malnutrition/inflammation are the main targets of struggle in the present PD cohort. In our point treatment setting, in-center APD use was not

consecutive, differs from the literature comparing home-based APD and CAPD groups. Futhermore, when evaluating the effect of different timing of APD initiation, K-M survival curves suggested a better survival probability when starting in-center APD after the first PD year. However, evidence for the survival with APD versus CAPD was inconsistent, and there's paucity of data available regarding the technique survival, peritoneal membrane function, and health-related quality of life[17]. One large cohort study from mainland China demonstrated that APD was associated with a lower all-cause mortality risk compared with CAPD, and survival benefit was only observed during the first 4 dialysis years[18]. Another retrospective cohort study from Taiwan showed that mortality risk was similar between the two sub-modalities of PD, but APD demonstrated better technique survival, especially for patients who were male, aged 50-65 years, diabetic, high-average and high transporters, and without CVD[19]. Wisam Bitar et al. reported a better survival of APD and home HD over CAPD from an inception cohort study in Finland, where APD and home HD shared similar 5-year survival probability[20].

We took advantage of a 6-year incident PD cohort, adjusting individual-level confounders. Our study contributes to the currently limited literature on the clinical features and impact of in-center APD use among PD patients. However, our findings should be considered in the context of the following limitations. First of all, as a single-center retrospective study with limited number of patients and observed events, ascertainment bias, type two error cannot be avoided, and the results could neither be generalized to all patients nor prove causation. Secondly, selection bias cannot be ignored, given patients who didn't survive the first 90 days were excluded in this study. Thirdly, socio-economic, medication, and health services data were not included in our analyses, since in-center APD only took place during hospitalisations, there's certain financial considerations in the background. Finally, the methodology of analyses in this study has pitfalls as we were unable to exclude informative censoring bias, nor residual confounding. Although MSM was applied to control for time-varying confounders affected by point treatment, yet it can only achieve balance on known factors, and the number of balancing variables were limited by sample size.

In conclusion, driven by the need for both ultrafiltration and clearance, in-center APD is used intensively during the first 2 years of PD, and is associated with certain clinical features of the CAPD patients. Overall, in-center APD use was associated with a lower risk of all-cause death when compared with non-usea.

Statements

Acknowledgement

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Statement of Ethics

This study was conducted ethically in accordance with the World Medical Association Declaration of Helsinki. This study was registered with the Chinese Clinical Trial Registry (ChiCTR-ORC-17013852) and was conducted in adherence to the declaration of Helsinki. The protocol of this study was approved by the Chinese Ethics Committee of Registering Clinical Trial (ChiECRCT-20170088), and informed consent was exempted because only aggregated data were received. The patient information was anonymized and de-identified prior to analysis.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

SC.H. and T.R. was responsible for the research idea. SC.H., T.R., B.Y., and HB.C. were responsible for the study design and data analysis. SC.H., B.Y., and M.P. were responsible for data acquisition. SC.H., T.R., B.Y., and M.P. were responsible for data interpretation and visualization. XF.G., HT.Y., and HB.C. were responsible for manuscript review. HT.Y. and HB.C. were responsible for supervision. Each author contributed important intellectual content during manuscript drafting and revision. All authors accept accountability for the overall work by ensuring that questions pertaining to the accuracy or integrity of any portion of the work are appropriately investigated and resolved.

Data Availability Statement

Data available on request. Data is not publicly available due to ethical reasons, further enquiries can be directed to the corresponding author.

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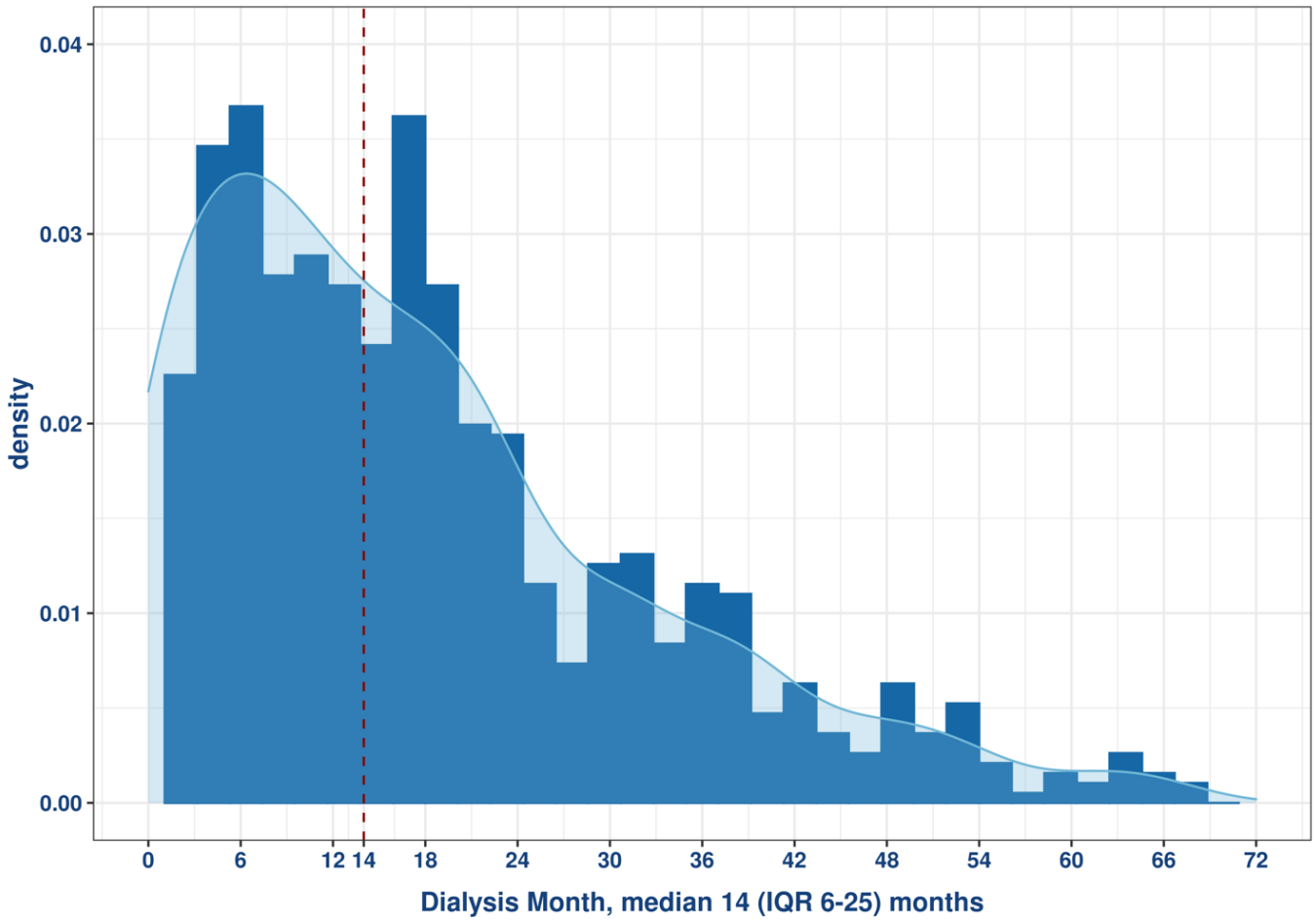
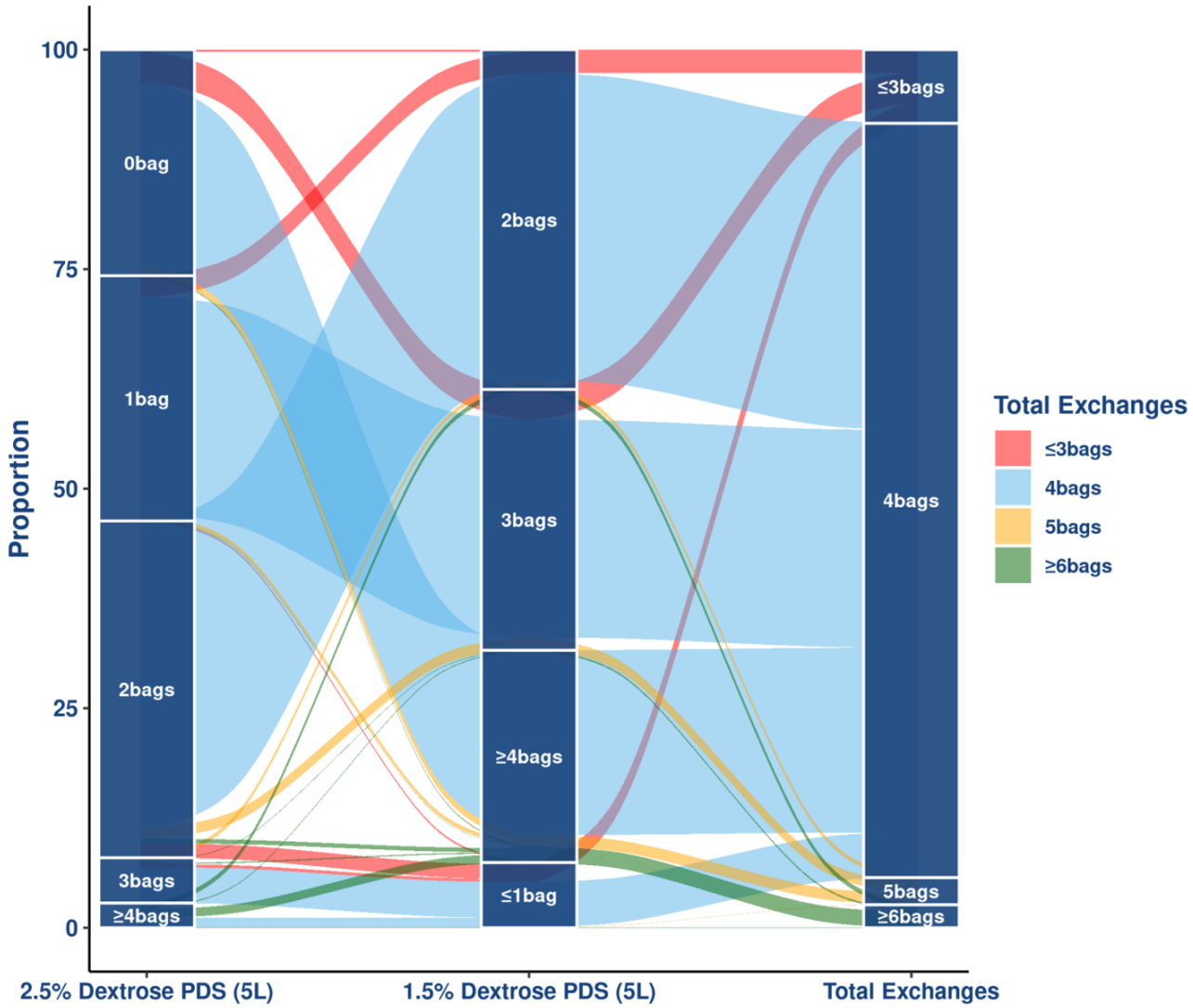
Figure Legends

Fig. 1. The distribution of in-center APD treatment during patient dialysis months, the red dot line represents the median month (N=900); IQR, interquartile range. APD, automated peritoneal dialysis.

Fig. 2. APD prescription patterns during the period of study (N=12553, 2013-2018); PDS, peritoneal dialysis solutions. APD, automated peritoneal dialysis.

Fig. 3. Patient survival probability among in-center APD user by the timing of APD initiation (N=369). APD, automated peritoneal dialysis, PD, peritoneal dialysis.





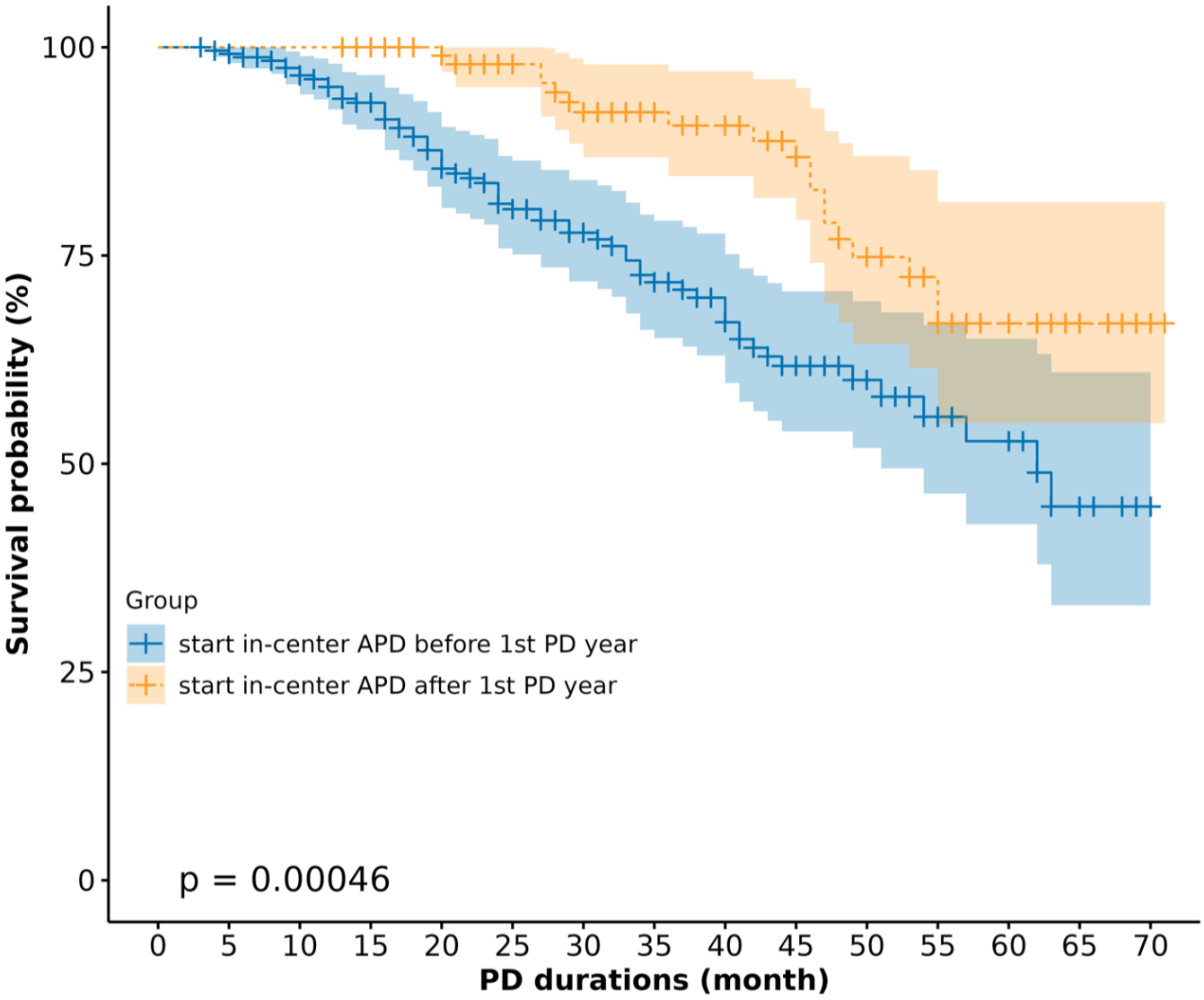


Table 1. Baseline demographic and clinical features of the enrolled patients overall (N=651) and by outcomes of interest during 2013-2018.

Variables	Total N =651	Non-users of APD N =282	In-center APD users N =369
		Median (IQR) or n%	
Male (%)	367 (56.37%)	157 (55.67%)	210 (56.91%)
Diabetes (%)	224 (34.41%)	111 (39.36%)	181 (49.05%)
Cardiovascular disease (%)	349 (53.61%)	143 (50.71%)	206 (55.83%)
Cerebrovascular disease (%)	142 (21.81%)	57 (20.21%)	85 (23.04%)
Peripheral arterial disease (%)	16 (2.46%)	7 (2.48%)	9 (2.44%)
Primary cause for end stage kidney disease			
Glomerulonephritis (%)	280 (43.01%)	128 (45.39%)	152 (41.19%)
Diabetic Kidney Disease	225 (34.56%)	85 (30.14%)	140 (37.94%)
Polycystic kidney disease	15 (2.30%)	10 (3.55%)	5 (1.36%)
Hypertension (%)	100 (15.36%)	46(16.31%)	54 (14.63%)
Others (%)	31 (4.76%)	13 (4.61%)	18 (4.88%)
Age (years)	59 (47 −66)	58 (48 −66)	59 (46−67)
Body mass index (kg/m^2)	23.44 (20.48−26.12)	23.44 (20.29−25.80)	23.53 (20.57−26.37)
Mean arterial pressure (mmHg)	105.00 (101.00−111.00)	106.00 (101.00−112.00)	105.00 (101.00−111.00)
Blood urea nitrogen (mmol/L)	14.95 (12.00−19.14)	15.59 (12.30−19.48)	14.44 (11.85−18.54)
Serum creatinine (μmol/L)	568.05 (446.72−696.16)	569.65 (462.22−691.04)	565.30 (444.42−702.16)
Fasting blood glucose (mmol/L)	4.81 (4.32−5.77)	4.76 (4.24−5.60)	4.85 (4.37−5.94)
Serum albumin (g/L)	31.00 (28.02−33.77)	31.50 (28.55−34.40)	31.15 (28.50−34.35)
Hemoglobin (g/L)	90.00 (82.00−98.25)	90.75 (82.00−98.50)	89.00 (82.00−98.00)
Calcium (mmol/L)	2.01 (1.90−2.11)	2.03 (1.93−2.12)	1.99 (1.89−2.10)
Phosphorus (mmol/L)	1.51 (1.26−1.75)	1.51 (1.27−1.73)	1.50 (1.26−1.77)
Calcium×Phosphorus	2.98 (2.48−3.58)	3.00 (2.53−3.57)	3.31 (2.68−3.85)
iPTH (pg/ml)	363.40 (210.70−585.80)	361.70 (217.07−546.45)	366.80 (198.20−616.00)
Potassium (mmol/L)	4.00 (3.70−4.30)	4.00 (3.74−4.39)	4.00 (3.70−4.30)

Sodium (mmol/L)	140.15 (138.30−141.72)	140.07 (138.60−141.40)	140.20 (138.25−142.10)
Total cholesterol (mmol/L)	4.39 (3.69−5.15)	4.33 (3.69−5.00)	4.46 (3.74−5.25)
Triglyceride (mmol/L)	1.57 (1.15−2.16)	1.51 (1.14−2.05)	1.60 (1.17−2.27)
RKF (ml/min/m^2)	2.71 (0.82−4.52)	2.84 (0.74−4.65)	2.49 (0.96−4.50)
Total ClCr (ml/min/m^2, weekly)	53.90 (44.26−70.85)	55.12 (44.26−73.12)	53.43 (44.26−68.87)
Total Kt/V urea (weekly)	1.54 (1.18−2.06)	1.55 (1.18−2.07)	1.51 (1.19−2.05)
Urine output (ml/day)	859.00 (600.00−1138.00)	866.00 (600.00−1157.50)	850.00 (600.00−1138.00)
4h D/Pcr	0.61 (0.54−0.70)	0.61 (0.55−0.71)	0.62 (0.54−0.70)
High-average & high transporter	254 (39.02%)	102 (36.17%)	152 (41.19%)

Abbreviation: APD, automated peritoneal dialysis, IQR, interquartile range, iPTH, intact parathyroid hormone, RKF, residual kidney function, ClCr, clearance of creatinine, D/Pcr, dialysate-to-plasma ratio of creatinine.
Continuous ambulatory peritoneal dialysis (CAPD) was applied to all patients. Non-users of APD, patients were on CAPD during hospital stay. In-center APD users, patients used APD during hospital stay.

Table 2. Factors associated with the use of in-center APD from the time-dependent Cox model (N=633).

Variables	Hazard ratio (lower 95%CI-upper 95%CI)	*p* value
Age (year)	1.01 (0.85-1.19)	0.908
Male	0.97 (0.74-1.27)	0.820
Diabetes	1.39 (1.09-1.76)	0.007
Cardiovascular disease	1.01 (0.79-1.30)	0.935
Body mass index (kg/m^2)	1.05 (0.94-1.17)	0.409
Urine output (ml/day)	0.80 (0.70-0.92)	0.001
Serum albumin (mmol/L)	0.84 (0.72-0.99)	0.034
Hemoglobin (mmol/L)	0.88 (0.77-0.99)	0.039
Ca×P	1.19 (1.06-1.35)	0.004
Total Kt/V urea	0.88 (0.77-1.00)	0.059
High-average & high tranporters	0.93 (0.76-1.13)	0.472

Abbreviation: CI, confidence interval, APD, automated peritoneal dialysis, Ca×P, calcium-phosphate product.

Table 3. Association of episodic use of in-center APD with all-cause mortality in the peritoneal dialysis cohort (N = 633) using different modeling approaches.

Models	Hazard ratio of in-center APD use (lower 95%CI-upper 95%CI)	*p* value
Single variable model	0.13 (0.05-0.31)	<0.001
Full-adjusted A-G model	0.14 (0.06-0.35)	<0.001
Marginal structural model with IPW	0.13 (0.05-0.31)	<0.001

Abbreviation: CI, confidence interval, APD, automated peritoneal dialysis, A-G model, Andersen-Gill model, IPW, inverse probability weighting.