

# *Comparison of Survival Between Assisted Peritoneal Dialysis and Self-Care Peritoneal Dialysis Patients Aged 70 or Older*

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## Research Article

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# Abstract

## Introduction:

Assisted PD is used as an alternative option for the growing group of frail, older ESRD patients unable to perform their own PD. This study was undertaken to investigate the outcomes of assisted PD in older patients by comparing assisted PD patients with self-care PD patients.

## Methods

This study included all patients aged 70 or older who started on PD in our hospital from 2009 to 2018. Patients were divided into assisted PD group and self-care PD group according to the independence of bag exchange, and followed up until death, PD cessation or to the end of the study (December 31, 2019). Survival curves were generated using the Kaplan-Meier method and risk factors associated with mortality, peritonitis and technique failure were evaluated using both cause-specific hazards and subdistribution hazards models.

## Results

180 patients were enrolled, including 106 (58.9%) males with a median age of 77.5 (77.2–81.2) years. Among the 180 patients, 62 patients (34.4%) were assisted. Patients in the assisted PD group were older, more likely to be female, more prevalent in DM and CVD, with a higher Charlson score than patients in the self-care PD group ( $P$  all  $< 0.05$ ). In the multivariable analysis, assisted patients had a comparable patient survival and peritonitis-free survival compared to self-care PD patients either in the Cox or in the FG models. According to a Cox model, the use of assisted PD was associated with a lower risk of technique failure (cs-HR 0.20, 95% CI 0.04–0.76), but the association lost its statistical significance in the Fine and Gray model.

## Conclusions

No significant difference in patient survival and peritonitis-free survival were found between the assisted PD patients and self-care PD patients. Moreover, assisted PD might protect older patients incapable of self-care from technique failure. Therefore, we suggested that assisted PD could be a safe and effective RRT modality for older ESRD patients who need assistance.

## Introduction

With the aging of the general population, the number of older individuals developing end-stage renal disease (ESRD) continues to rise worldwide, accompanied by a much greater demand for renal replacement therapy (RRT) among the older<sup>1,2</sup>. There was no common consensus to deliver either HD or

PD to the older ESRD patients, and several studies suggested comparable or better outcomes with PD among older patients<sup>3-6</sup>. Compared with in-center hemodialysis, peritoneal dialysis offers many potential benefits to older patients, such as less intervention in lifestyle, no need for vascular access, fewer hemodynamic variations and cost-effective, etc.<sup>7</sup> When life expectancy is perceived to be short, quality of life (QoL) may be the priority for older patients, especially the “old older”. PD has also been shown to be associated with better quality of life (QoL) and higher satisfaction with treatment<sup>3, 5, 8</sup>. However, barriers to self-care PD including multimorbidity, physical disabilities and psychosocial problems often emerged with increasing age<sup>9, 10</sup>. Assisted PD is defined as PD treatment performed at the patient’s home and with the assistance of a family member, a partner, a community nurse or a healthcare technician<sup>11</sup>. As a feasible option for patients who cannot perform their own PD exchanges, assisted PD have been developed in many countries with the aim of overcoming barriers in older and non-self-sufficient patients, and some studies suggested that the use of assisted PD could increase the utilization of PD patients among older<sup>12-14</sup>. However, whether assisted PD achieved similar outcomes to self-care peritoneal dialysis still remained controversial<sup>15</sup>. Therefore, we conducted the present study to investigate the outcomes of assisted PD in ageing patients, by comparing patients undergoing assisted PD with those on self-care PD in a cohort of older patients.

## Materials And Methods

### Patients

In our study, the cut-off for the definition of an ‘older’ individual was 70 years of age. All incident patients aged 70 or older who started on PD between 1 January 2009 and 31 December 2018 at Renji Hospital, Shanghai Jiao Tong University School of Medicine, China, were screened for eligibility. Patients had history of maintenance HD/transplantation, withdrew from PD within 3 months or with incomplete data were excluded from the study. All enrolled patients were dialyzed using lactate-buffered glucose-based PD solutions (Dianeal®, Baxter) with twin-bag system. Patients and their caregivers had received standard training after catheterization by PD dedicated nurses<sup>16</sup>. The study was approved by the Human Research Ethics Committee of Renji Hospital, Shanghai Jiao Tong University School of Medicine. All individual information was securely protected and was made available to only the investigators.

### Demographic and laboratory data

The demographic characteristics collected at baseline included age, gender, height, weight, underlying cause of ESRD and comorbid condition status such as diabetes mellitus (DM) and cardiovascular disease (CVD). Hypertension and diabetes were defined either as a comorbid disease or as the etiology of ESRD. CVD was defined as a previous history of any following condition: acute coronary syndrome, heart failure, cerebral infarction or hemorrhage, coronary artery atherosclerosis confirmed by percutaneous coronary intervention (PCI) or coronary artery bypass grafting (CABG) therapy. The Charlson comorbidity index was adopted to reflect the burden of comorbid conditions. Body mass index (BMI) was calculated as the weight (kg) divided by the square of height in meters (BMI =weight [kg]/ height [m<sup>2</sup>]).

Baseline laboratory parameters included hemoglobin, serum albumin, creatinine, urea nitrogen, uric acid, sodium, potassium, corrected calcium, phosphate, intact parathyroid hormone (iPTH), total cholesterol, total triglycerides, high-sensitivity C reaction protein (hs-CRP), estimated glomerular filtration rate (eGFR) (mL/min/m<sup>2</sup>) and fasting blood glucose were collected. The corrected calcium (mmo1/L) = total calcium (mmol/L) + (40- albumin) × 0.025 (mmol/L).

### **Small solute clearance and peritoneal transport characteristics**

All patients were evaluated small solute clearance and performed a standard peritoneal equilibration test (PET) 1-3 months after PD initiation. Small solute clearance was assessed by 24-h dialysate and urine collection, with the calculation of total weekly Kt/V and weekly CrCl normalized to 1.73m<sup>2</sup> body surface area <sup>17</sup>. Residual renal function (RRF) was calculated as an average of 24-h urine urea and creatinine clearance <sup>18</sup>. Normalized protein catabolic rate (nPCR) was calculated by the methods described by Randerson, Chapman, and Farrell and normalized to standard body weight (total body water/0.58) <sup>19</sup>.

### **Patient follow up**

The enrolled patients were divided into assisted PD group (PD exchanges performed by a family member or a domestic helper) and self-care PD group according to the independence of bag exchange, and prospectively followed up until death, transfer to permanent hemodialysis, recovery of renal function, transfer to other centers, lost to follow-up or to the end of study (December 31st, 2019). All deaths, switches to HD and peritonitis episodes during the study period were carefully tracked and recorded. Detailed causes of death, switches to HD and outcome of peritonitis during PD were also collected. Causes of death were grouped in broad categories as follows: cardiovascular, including cardiac, cerebrovascular, peripheral vascular and sudden death; infection, including peritonitis and non-peritonitis infections; cancer; gastrointestinal hemorrhage; other and unknown causes. Causes of switch to HD were grouped into peritonitis; catheter complications; inadequate dialysis and other causes. Peritonitis was diagnosed and managed in accordance with guidelines of the International Society for Peritoneal Dialysis <sup>20</sup>, and peritonitis rate was calculated as number of peritonitis episodes per patient-year at risk.

### **Outcome measures**

Outcome measures in our study included patient survival, peritonitis-free survival and technique survival. In patient and peritonitis-free survival analysis, the endpoint was death and first episode of peritonitis, respectively. In technique survival analysis, the endpoint was permanent transfer from PD to HD. For both patient and peritonitis-free survival analysis, the censored events were transfer to permanent hemodialysis, recovery of renal function, loss to follow-up, transfer to other dialysis centers, or to the end of study (December 31st, 2019). In technique survival analysis, the endpoint was permanent transfer from PD to HD, and death was regarded as censored event.

### **Statistics analysis**

The Kolmogorov–Smirnov test was used to measure data normality. Parametric data were presented as mean  $\pm$  standard deviation. Nonparametric data were described by the median value (first and third quartile). Categorical variables were presented by frequencies and percentages and were compared using chi-square tests. Normally distributed continuous variables and abnormally distributed continuous variables were compared using the independent sample t-tests and Mann-Whitney test, respectively. Kaplan-Meier and log-rank test methods were used to estimate and compare survival curves for each event of interest (death, peritonitis and transfer to HD) by comparing assisted PD group with self-care PD group. Considering the presence of competing events in this study, for multivariate analysis, risk factors for all-cause mortality, peritonitis and technique failure were evaluated by both cause-specific hazards and subdistribution hazards models<sup>21</sup>. When the event of interest was peritonitis, transfer to HD, renal transplantation, death and transfer to other centers were coded as competing events only when occurring before the first peritoneal infection. When the event of interest was death, the competing events included transfer to HD, renal transplantation and transfer to other centers. When the event of interest was technique failure, the competing events included death, renal transplantation and transfer to other centers.

Data analysis was carried out using the SPSS software package (version 22.0: SPSS, Chicago, IL, USA) and R 3.6.1 (R Foundation for Statistical Computing, Vienna, Austria; the 'cmprsk' library was used to fit the Fine and Gray regression models). All probabilities were two-tailed, and a  $p < 0.05$  was considered statistically significant.

## Results

### Study participants

A total of 180 patients were included in present study. Patient enrollment and follow-up were presented in Fig. 1. Patient characteristics were summarized in Table 1. Among the 180 patients, 62 needed assistance in performing bag exchanges (“assisted PD group”), and the remaining 118 patients were in the self-care PD group. Patients in the assisted PD group were older (80.7 (76.9–84.0) vs 75.6 (72.5–79.2) years,  $P < 0.001$ ), less likely to be male (48.4% vs 64.4%,  $P < 0.05$ ), more prevalent in diabetes (48.4% vs 33.1%,  $P < 0.05$ ) and CVD (46.8% vs 29.7%,  $P < 0.05$ ), with a higher Charlson score (7.0 (6.0–8.0) vs 6.0 (5.0–7.0),  $P < 0.001$ ) than those in the self-care PD group, and other demographic and laboratory data were similar between the two groups.

Table 1  
Demographic and laboratory data of the study patients

Variable	All PD patients (n = 180)	Assisted PD group (n = 62)	self-care PD group (n = 118)	P value
Age (years)	77.5 (77.2–81.2)	80.7 (76.9–84.0)	75.6 (72.5–79.2)	< 0.001
Gender (male) [n (%)]	106 (58.9)	30 (48.4)	76 (64.4)	0.038
BMI (kg/m <sup>2</sup> )	22.6 (20.4–24.7)	21.9 (20.3–25.0)	23.1 (20.4–24.6)	0.606
Charlson's comorbidity index	6.0 (6.0–7.0)	7.0 (6.0–8.0)	6.0 (5.0–7.0)	< 0.001
Primary renal disease [n (%)]				
Chronic glomerulonephritis	46 (25.5)	17 (27.4)	29 (24.6)	0.678
Diabetic nephropathy	38 (21.1)	16 (25.8)	22 (18.6)	0.263
Hypertension	11 (6.1)	3 (4.8)	8 (6.8)	0.850
Polycystic kidney disease	2 (1.1)	0 (0)	2 (1.7)	0.546
Others	20 (11.1)	6 (9.7)	14 (11.9)	0.657
Unknown	63 (35.0)	20 (32.3)	43 (36.4)	0.576
Comorbidity [n (%)]				
Diabetes mellitus	69 (38.3)	30 (48.4)	39 (33.1)	0.044
Hypertension	157 (87.2)	56 (90.3)	101 (85.6)	0.366
Cardiovascular disease	64 (35.6)	29 (46.8)	35 (29.7)	0.023
others	41 (22.8)	16 (25.8)	25 (21.1)	0.482
Baseline Laboratory results*				
Hemoglobin (g/L)	86.7 ± 16.8	83.9 ± 15.5	88.2 ± 17.4	0.110

**Values expressed as mean ± standard deviation, median (25th – 75th percentile), or absolute numbers with percentages [n (%)]**

**Abbreviations:** BMI: body mass index, Hs-CRP: high-sensitivity C reaction protein, Corrected calcium: total calcium (corrected by albumin), Kt/Vurea: urea kinetics; CrCl: creatinine clearance; RRF: residual renal function; nPCR: normalized protein catabolic rate; D/Pcr: peritoneal transport characteristics

Baseline Laboratory results\* was evaluated at PD initiation (within one week before PD catheterization)

Variable	All PD patients (n = 180)	Assisted PD group (n = 62)	self-care PD group (n = 118)	P value
Albumin (g/L)	33.1 (29.1–36.4)	33.1 (28.8–36.3)	32.9 (29.9–36.6)	0.998
Creatinine (mmol/L)	663.0 (527.9–789.0)	628.5 (486.8–791.5)	674.3 (555.2–796.8)	0.231
Blood urea nitrogen (mmol/L)	26.5 (21.0–32.2)	27.6 (21.2–33.6)	26.4 (21.0–31.4)	0.405
Uric acid (mmol/L)	487.5 ± 132.0	480.4 ± 130.4	491.2 ± 133.2	0.606
Estimated glomerular filtration rate (eGFR) (mL/min/m <sup>2</sup> )	5.7 (4.5–7.2)	5.4 (4.4–7.9)	5.7 (4.5–7.0)	0.686
Sodium (mmol/L)	138.1 (136.0–142.0)	138.4 (137.0–141.2)	138.1 (136.0–142.0)	0.175
Potassium (mmol/L)	4.1 ± 0.8	4.1 ± 0.8	4.2 ± 0.7	0.590
Total cholesterol (mmol/L)	4.5 (3.8–5.2)	4.7 (3.7–5.2)	4.5 (3.9–5.4)	0.395
Total triglycerides (mmol/L)	1.3 (1.0–1.8)	1.2 (0.9–1.7)	1.4 (1.0–1.8)	0.154
Corrected calcium (mmol/L)	2.1 (2.0–2.3)	2.2 (2.0–2.3)	2.1 (2.0–2.3)	0.972
Phosphate (mmol/L)	1.8 (1.5–2.1)	1.8 (1.4–2.1)	1.8 (1.5–2.0)	0.784
Intact parathyroid hormone (iPTH) (pg/L)	275.2 (160.5–423.0)	264.0 (171.2–410.5)	285.0 (137.0–424.7)	0.938
Hs-CRP (mg/L)	4.5 (1.3–13.5)	3.8 (1.5–13.8)	5.0 (1.2–13.9)	0.654
Fasting blood glucose (mmol/L)	5.0 (4.4–5.6)	4.9 (4.5–6.1)	4.4 (4.4–5.5)	0.537
<b>Values expressed as mean ± standard deviation, median (25th – 75th percentile), or absolute numbers with percentages [n (%)]</b>				
<b>Abbreviations:</b> BMI: body mass index, Hs-CRP: high-sensitivity C reaction protein, Corrected calcium: total calcium (corrected by albumin), Kt/Vurea: urea kinetics; CrCl: creatinine clearance; RRF: residual renal function; nPCR: normalized protein catabolic rate; D/Pcr: peritoneal transport characteristics				
Baseline Laboratory results* was evaluated at PD initiation (within one week before PD catheterization)				

The indices of small solute clearance, RRF, nPCR and peritoneal transport characteristics (D/Pcr) were shown in Table 2 and there was no difference between the two groups.

Table 2  
Small solute clearance and peritoneal transport characteristics

Variable	All PD patients (n = 180)	Assisted PD group (n = 62)	self-care PD group (n = 118)	P value
Small solute clearance				
Total Kt/V urea	2.08 (1.74–2.43)	2.10 (1.78–2.50)	2.07 (1.70–2.41)	0.460
Total CrCl (L/week/1.73m <sup>2</sup> )	68.9 (55.9–87.2)	68.8 (54.0–92.1)	68.9 (55.9–86.7)	0.744
RRF (ml/min/1.73m <sup>2</sup> )	3.09 (1.67–5.04)	3.03 (1.62–5.24)	3.05 (1.64–5.09)	0.931
nPCR (g/kg/day)	0.82 (0.71–0.96)	0.82 (0.72–0.95)	0.82 (0.70–0.97)	0.930
D/Pcr	0.65 (0.56–0.75)	0.66 (0.56–0.71)	0.64 (0.57–0.75)	0.994
<b>Values expressed as mean ± standard deviation, median (25th – 75th percentile), or absolute numbers with percentages [n (%)]</b>				
<b>Abbreviations:</b> Kt/Vurea: urea kinetics; CrCl: creatinine clearance; RRF: residual renal function; nPCR: normalized protein catabolic rate; D/Pcr: peritoneal transport characteristics				

## Patient Outcomes

Patient outcomes were summarized in Table 3. The median follow-up was 32.5 months (inter-quartile range, 20.7–43.7 months) for the assisted PD group and 33 months (inter-quartile range, 12.9–49.7 months) for the self-care PD group. By the end of the study, 100 (55.6%) patients died, 16 (8.9%) patients switched to HD, 6 (3.3%) patients were transferred to other centers, 1 (0.6%) patient was lost to follow-up, 1 (0.6%) patient was dialysis-independent and 54 (30.0%) patients were still on PD. The causes of death were similar in two groups and the leading cause of death was cardiovascular disease (30.0%), followed by infection (27.0%), unknown causes (14.0%), cancer (12.0%), other causes (11.0%) and gastrointestinal hemorrhage (6.0%). During the study period, a total of 101 episodes of peritonitis were recorded. The peritonitis rate was 0.155 episode per patient-year in the assisted PD group and 0.216 episode per patient-year in the self-care PD group, respectively. By the end of the study, a total of 16 patients transferred to HD. The reasons for transferring to HD were similar in two groups and peritonitis was responsible for 7/16 (44%) of transferring to HD.

Table 3  
Outcomes of the patients

Variable	All PD patients	Assisted PD group	self-care PD group	P value
Follow-up (months)	32.5 (15.7–42.7)	32.5 (20.7–43.7)	33.0 (12.9–49.7)	< 0.001
Outcomes [n (%)]	<b>n = 180</b>	<b>n = 62</b>	<b>n = 118</b>	
Death	100 (55.6)	39 (62.9)	61 (51.7)	0.150
Transfer to HD	16 (8.9)	3 (4.8)	13 (11.0)	0.166
Transfer to other centers	6 (3.3)	0 (0)	6 (5.1)	0.095
Recovery of renal function	2 (1.1)	1 (1.6)	1 (1.0)	1.000
Dialysis independent	1 (0.6)	0 (0)	1 (1.0)	1.000
Lost to follow-up	1 (0.6)	0 (0)	1 (1.0)	1.000
Still on PD	54 (30.0)	19 (30.6)	35 (29.7)	0.891
Causes of death [n (%)]	<b>n = 100</b>	<b>n = 39</b>	<b>n = 61</b>	
Cardiovascular disease	30 (30)	11 (28.2)	19 (31.1)	0.754
Cardiac	18 (22.0)	7 (17.9)	11 (18.0)	0.991
Cerebrovascular	3 (3.0)	0 (0)	3 (4.9)	0.279
Peripheral vascular	1 (1.0)	1 (2.6)	0 (0)	0.390
Sudden death	8 (8.0)	3 (7.7)	5 (8.2)	0.102
Infection	27 (27)	12 (30.8)	15 (24.6)	0.497
Peritonitis	3 (3)	0 (0)	3 (4.9)	0.421
Non-peritonitis infections	24 (24.0)	12 (30.8)	12 (19.7)	0.205
Cancer	12 (12)	3 (7.7)	9 (14.8)	0.457
Gastrointestinal hemorrhage	6 (6.0)	1 (2.6)	5 (8.2)	0.400
Others	11 (11.0)	4 (10.3)	7 (11.5)	0.849
Unknown	14 (14.0)	4 (10.3)	10 (16.4)	0.371
Causes of switch to HD [n (%)]	<b>n = 16</b>	<b>n = 3</b>	<b>n = 13</b>	

Failed treatment for peritonitis\* was defined as discontinuation of PD including temporary or permanent transfer to hemodialysis or peritonitis-related deaths; Peritonitis-related deaths included death directly caused by active peritonitis or within 4 weeks of a peritonitis episode, or any death during hospitalization for peritonitis.

Variable	All PD patients	Assisted PD group	self-care PD group	P value
Peritonitis	7 (43.8)	2 (66.7)	5 (38.5)	0.550
Catheter complications	2 (12.5)	0 (0)	2 (15.4)	0.546
Inadequate dialysis	0 (0)	0 (0)	0 (0)	
Others	7 (43.8)	1 (33.3)	6 (46.2)	0.425
Peritonitis				
Total number of episodes	101	28	73	
Peritonitis rate (episode per patient-year)	0.195	0.155	0.216	
Peritonitis-free [n (%)]	118 (65.6)	39 (62.9)	79 (66.9)	0.587
Failed treatment for peritonitis * [n (%)]	16 (8.9)	5 (8.1)	11 (9.3)	0.778
Failed treatment for peritonitis* was defined as discontinuation of PD including temporary or permanent transfer to hemodialysis or peritonitis-related deaths; Peritonitis-related deaths included death directly caused by active peritonitis or within 4 weeks of a peritonitis episode, or any death during hospitalization for peritonitis.				

## Patient Survival And Predictors Of All-cause Mortality

As shown in Fig. 2A, assisted PD patients had comparable patient survival to self-care PD patients (Log-rank  $X^2 = 1.060$ ,  $P = 0.303$ ). When using a Cox model for the analysis, advanced age (cs-HR 1.09, 95% CI 1.04–1.14, Table 4), comorbid with CVD (cs-HR 1.87, 95% CI 1.23–2.83, Table 4), lower hemoglobin (cs-HR 0.99, 95% CI 0.97–0.99, Table 4) and low RRF group, compared to high RRF group (cs-HR 1.78, 95% CI 1.18–2.71, Table 4) were independent predictors for all-cause mortality. In the Fine–Gray (FG) model, advanced age (sd-HR 1.05, 95% CI 1.01–1.09, Table 4), comorbid with CVD (sd-HR 1.59, 95% CI 1.05–2.41, Table 4) and low RRF group, compared to high RRF group (sd-HR 1.81, 95% CI 1.21–2.72, Table 4) were independent predictors for all-cause mortality. However, for both models, the use of assisted PD was not associated with all-cause mortality.

Table 4  
Adjusted cs-HRs (Cox model) and sd-HR (Fine and Gray model) for each event

Variable	Death		Peritonitis		Transfer to HD	
	cs-HR (95% CI)	sd-HR (95% CI)	cs-HR (95% CI)	sd-HR (95% CI)	cs-HR (95% CI)	sd-HR (95% CI)
Age	1.09 (1.04–1.14) <sup>***</sup>	1.05 (1.01–1.09) <sup>*</sup>	1.05 (0.99–1.11)	1.01 (0.95–1.09)	1.15 (1.02–1.31) <sup>*</sup>	1.05 (0.89–1.24)
Male Gender	1.22 (0.78–1.91)	1.26 (0.80–1.98)	1.16 (0.68–1.99)	1.07 (0.61–1.86)	0.30 (0.07–1.36)	0.39 (0.11–1.34)
BMI	0.99 (0.93–1.06)	0.94 (0.89–1.00)	1.07 (0.99–1.16)	1.06 (0.96–1.17)	1.31 (1.11–1.55) <sup>**</sup>	1.25 (1.02–1.54) <sup>*</sup>
Diabetes	0.85 (0.55–1.32)	1.06 (0.68–1.64)	0.95 (0.55–1.64)	1.02 (0.59–1.76)	0.35 (0.11–1.10)	1.64 (0.67–4.05)
CVD	1.87 (1.23–2.83) <sup>*</sup>	1.59 (1.05–2.41) <sup>*</sup>	0.85 (0.48–1.51)	0.62 (0.35–1.11)	1.17 (0.30–4.48)	0.40 (0.09–1.78)
Hemoglobin	0.99 (0.97–0.99) <sup>*</sup>	0.99 (0.98–1.00)	0.99 (0.97–1.00)	0.99 (0.98–1.01)	0.99 (0.96–1.03)	1.00 (0.97–1.03)
Albumin	1.00 (0.97–1.03)	0.99 (0.96–1.02)	1.00 (0.96–1.03)	0.99 (0.96–1.02)	1.05 (0.96–1.16)	1.06 (0.97–1.15)
RRF group <sup>a</sup>						
High RRF group	Reference	Reference	Reference	Reference	Reference	Reference
Low RRF group	1.78 (1.18–2.71) <sup>**</sup>	1.81 (1.21–2.72) <sup>**</sup>	0.70 (0.41–1.21)	1.22 (0.69–2.13)	1.79 (0.43–7.38)	0.43 (0.08–2.20)
PD						
Self-PD	Reference	Reference	Reference	Reference	Reference	Reference

Abbreviations: cs-HR, cause-specific hazard ratio; sd-HR, subdistribution hazard ratio; CI: confidence interval; BMI: body mass index; CVD: cardiovascular disease; RRF: residual renal function.

<sup>a</sup> RRF group was defined as: High RRF group, Residual Renal Function (RRF) > median; Low RRF group, Residual Renal Function (RRF) < median.

\*P < 0.05, \*\*P < 0.01, \*\*\*P < 0.001.

Variable	Death		Peritonitis		Transfer to HD	
Assisted-PD	1.40 (0.88– 2.21)	1.08 (0.70– 1.65)	1.34 (0.73– 2.46)	1.22 (0.69– 2.13)	0.20 (0.04– 0.76)*	0.40 (0.14– 1.15)
Abbreviations: cs-HR, cause-specific hazard ratio; sd-HR, subdistribution hazard ratio; CI: confidence interval; BMI: body mass index; CVD: cardiovascular disease; RRF: residual renal function.						
<sup>a</sup> RRF group was defined as: High RRF group, Residual Renal Function (RRF) > median; Low RRF group, Residual Renal Function (RRF) < median.						
*P < 0.05, **P < 0.01, ***P < 0.001.						

## Peritonitis-free Survival And Predictors Of Peritonitis

As shown in Fig. 2B, assisted PD patients had comparable peritonitis-free survival to self-care PD patients (Log-rank  $X^2 = 0.048$ ,  $P = 0.827$ ). In both Cox and Fine–Gray (FG) models, there was no association between the use of assisted PD and peritonitis-free survival, and no variables were found to be significantly associated with peritonitis-free survival ( $P > 0.05$ ).

## Technique Survival And Predictors Of Technique Failure

As shown in Fig. 2C, assisted PD patients had comparable technique survival to self-care PD patients (Log-rank  $X^2 = 1.888$ ,  $P = 0.169$ ). In the multivariable analysis, assisted PD (cs-HR 0.20, 95% CI 0.04–0.76, Table 4) was protective against the risk of transfer to HD in the Cox model, while advanced age (cs-HR 1.15, 95% CI 1.02–1.31, Table 4) and higher BMI (cs-HR 1.31, 95% CI 1.11–1.55, Table 4) were associated with an increased risk of technique failure. However, in the Fine–Gray (FG) model, the use of assisted PD was not associated with technique survival and higher BMI (sd-HR 1.25, 95% CI 1.02–1.54, Table 4) could predict technique failure in this population.

## Discussion

The present study compared the outcomes between assisted PD patients and self-care PD patients aged 70 or older to investigate the safety and effectiveness of assisted PD in older patients. The results showed that in our cohort, assisted PD patients had a comparable patient survival and peritonitis-free survival to self-care PD patients. Moreover, assisted PD might protect older patients incapable of self-care from technique failure.

The demographic and clinical characteristics of the study cohort varied between the assisted group and self-care group. Patients in the assisted PD group were older, more likely to be female, more prevalent in diabetes and cardiovascular disease and carried a heavier burden of comorbid diseases than patients in the self-care PD group. Similar to our study, Boyer et al. showed that patients starting PD with assistance

were older than those starting unassisted (70.0 (61.5–78.3) vs 58.7 (43.8–69.2) years)<sup>12</sup>. In another study from France, Lobbedez et al. reported that assisted PD patients were older ( $74 \pm 10.4$  vs  $52 \pm 18.6$  years,  $P < 0.001$ ) and presented more comorbidity (CCI  $7 \pm 2.5$  vs  $4.3 \pm 2.4$ ,  $P < 0.05$ ) compared with self-care patients<sup>22</sup>. These findings indicated that patients requiring assistance were often frail and older individuals, with physical disability or cognitive impairment, and had multiple comorbidities.

The causes of death were similar in assisted PD group and self-care PD group. It is well documented that cardiovascular disease is the most common cause of deaths in PD patients<sup>23,24</sup>. In our study, cardiovascular disease remained the leading cause of death in older PD patients, accounted for up to 30.0% of deaths. However, we found that infection was also a major cause of death, accounted for up to 27.0% of deaths, and the majority of which was due to non-peritonitis infections. Our finding indicated that older PD patients were prone to non-peritonitis infection, this might be a result of a high prevalence of DM, physical disabilities, poor nutrition and immunodeficiency. Therefore, aggressive prevention and treatment of infection is essential for older PD patients. In patient survival, we found that assisted PD patients had similar survival rate with self-care PD patients. In concordance with our study, Smyth et al. reported that there was no difference in patient survival rates between assisted PD patients and self-care PD patients<sup>17</sup>. Querido et al. also found that assisted PD patients had similar survival rate with self-care PD patients<sup>25</sup>. However, in contrast with our results, some studies reported poorer survival rate was observed in assisted PD patients compared to self-care PD patients. Data from the French Peritoneal Dialysis Registry (RDPLF) for 1613 patients older than 75 years of age showed that the survival rate of assisted PD patients, whether assisted by family members or nurses, was lower than patients on self-care PD<sup>26</sup>. The potential causes for the differences in patient survival may be due to the fact that assisted PD in our cohort was provided by one trained dedicated person (e.g., spouse), so the training and daily assistance could be detailed and tailored, and caregivers were more aware of the condition of the patients. However, in the report from the RDPLF, patients were assisted by private community nurses and it is not patient-specific. Besides, several studies have demonstrated that family and social support is associated with improved outcomes in chronic conditions, including end-stage renal disease (ESRD)<sup>27–29</sup>. In china, spouses and the younger generations are encouraged to take care of older PD patients. As PD exchanges were performed by their family members or domestic helper at home, patients have a high level of family support, which may be associated with better patient management and improved survival. Another retrospective study of PD included patients over 65 years of age in Taiwan also suggested that older patients on assisted PD had a poorer patient survival rate than self-care PD patients<sup>30</sup>. As the author mentioned in discussion, the possible explanation may be that the assisted-care program for older patients was adopted as early as 1984 in Taiwan, the quality of the training system, which might determine the outcome of assisted PD, was worse than it is now. In consist with other studies, our results showed that advanced age, comorbid with CVD, lower hemoglobin and low RRF group, compared to high RRF group were independent predictors for mortality when using a Cox regression model, while advanced age, comorbid with CVD and low RRF group, compared to high RRF group were independent predictors for

mortality in the Fine–Gray (FG) model, which were well-recognized prognostic factors for mortality in older PD patients demonstrated by numerous studies<sup>31–35</sup>.

The peritonitis rate was 0.155 episode per patient-year in the assisted PD group and 0.216 episode per patient-year in the self-PD group, respectively. In our cohort, peritonitis-free survival was comparable between assisted patients and self-care patients. Similarly, Xu et al.<sup>24</sup> reported that assisted PD patients overall had a similar peritonitis-free time compared with self-care PD patients. Smyth et al.<sup>17</sup> reported that there was no association between the use of assisted PD and peritonitis-free survival. In another report from the RDPLF, Benabed et al.<sup>19</sup> showed that in 3598 diabetic patients between 1 January 2002 and 31 December 2012, nurse-assisted PD patients had a lower risk of peritonitis compared with self-care PD patients while family-assisted PD had no protective effect against peritoneal infection. Verger et al. reported that nurse assistance was associated with a higher risk of peritonitis in APD patients, however, when home visits were made regularly by nurses from the PD center, assisted PD was not associated with a higher risk of peritoneal infection<sup>18</sup>. Taken together, these results demonstrated that the use of assisted PD was not associated with peritonitis-free survival.

With regard to technique survival, a significant technique survival benefit was demonstrated in assisted patients compared to self-care patients in the Cox model, but the association lost its statistical significance in the Fine–Gray (FG) model. Consistent with our results, report from the RDPLF which analyzed 9822 incident patients starting PD between January 2002 and December 2010 suggested that assisted patients had a lower risk for transfer to HD compared with self-care patients<sup>36</sup>. Querido et al. also found that technique survival was better in assisted PD patients compared with self-care patients<sup>25</sup>. As older patients who engaged independently in PD usually suffer from poor physical strength, cognitive dysfunction, vision impairment and deafness, which are all conditions that may affect the ideal operation for PD, we suggested that for some frail older patients unable to perform ideal self-dialysis, proper assistance should be provided to reduce the risk of PD technique failure, thereby prolonging the duration of PD. Besides, in concordance with previous studies, higher BMI was associated with increased risk of technique failure either in the Cox or in the FG model, and advanced age could predict technique failure in the Cox model, which were independent predictors of technique failure reported by several previous studies<sup>32,37</sup>.

Our study also has several limitations. First, it was a retrospective design. Second, our study was a single-centered study. Third, we did not collect the data regarding the quality of life (QoL) in our study, which is an important outcome measure in older patients. From the perspective of gaining high-quality evidence, better designed studies, such as prospective studies with larger sample sizes and multi-center participation, is clearly warranted.

In conclusion, our results showed that in a cohort of patients aged 70 or older, assisted PD patients had comparable patient survival and peritonitis-free survival to self-care PD patients. Moreover, assisted PD might protect older patients incapable of self-care from technique failure. Therefore, we suggested that

poor self-care ability alone should not be used as a barrier to PD treatment and assisted PD could be a safe and effective modality of RRT for older patients incapable of self-care.

## Abbreviations

ESRD  
end-stage renal disease; PD:peritoneal dialysis; HD:hemodialysis; DM:diabetes mellitus;  
CVD:cardiovascular disease; PCI:percutaneous coronary intervention; CABG:coronary artery bypass grafting; BMI:body mass index; iPTH:intact parathyroid hormone; Hs-CRP:high-sensitivity C reaction protein; eGFR:estimated glomerular filtration rate; corrected calcium:total calcium (corrected by albumin); PET:peritoneal equilibration test; Kt/Vurea:urea kinetics; CrCl:creatinine clearance; RRF:residual renal function; nPCR:normalised protein catabolic rate; D/Pcr:peritoneal transport characteristics); cs-HR:cause-specific hazard ratio; sd-HR:subdistribution hazard ratio; CI:confidence interval.

## Declarations

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### Author Contributions

SQ participated in the design of the study, analysis of data and draft the manuscript. YH and LZ participated in clinical data collection. YZ and YJ helped to perform the statistical analysis. NZ guided and supported this study. FW conceived of the study, and participated in its design and coordination and helped to draft the manuscript.

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### Availability of data and materials

The datasets analyzed during the current study are available from the corresponding author on reasonable request.

### Ethics approval and consent to participate

All procedures performed in studies were in accordance with the ethical standards of Renji Hospital on human experimentation and with the Helsinki Declaration of 1975, as revised in 2000.The study was

approved by the Human Research Ethics Committee of Renji Hospital, Shanghai Jiao Tong University School of Medicine. The informed consent was exempted as a retrospective study by the Human Research Ethics Committee of Renji Hospital, Shanghai Jiao Tong University School of Medicine.

### **Consent for publication**

Not applicable.

### **Competing interests**

The authors have no conflicts of interest to declare.

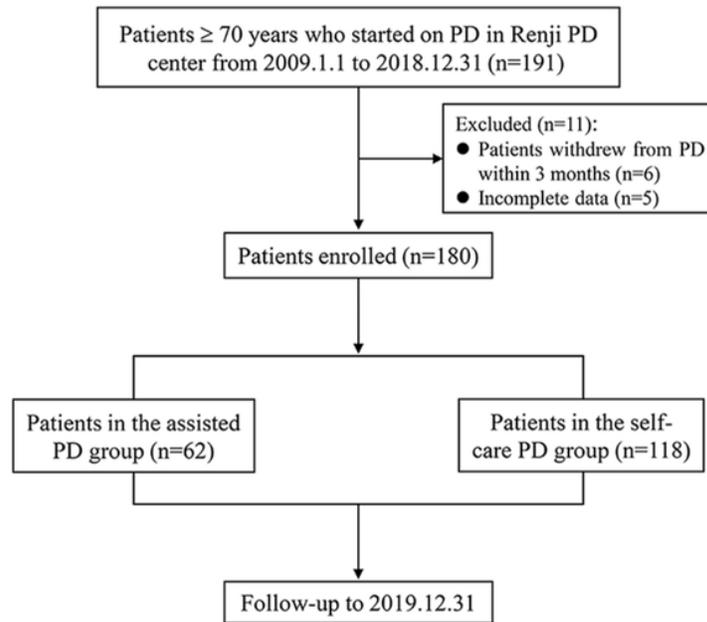
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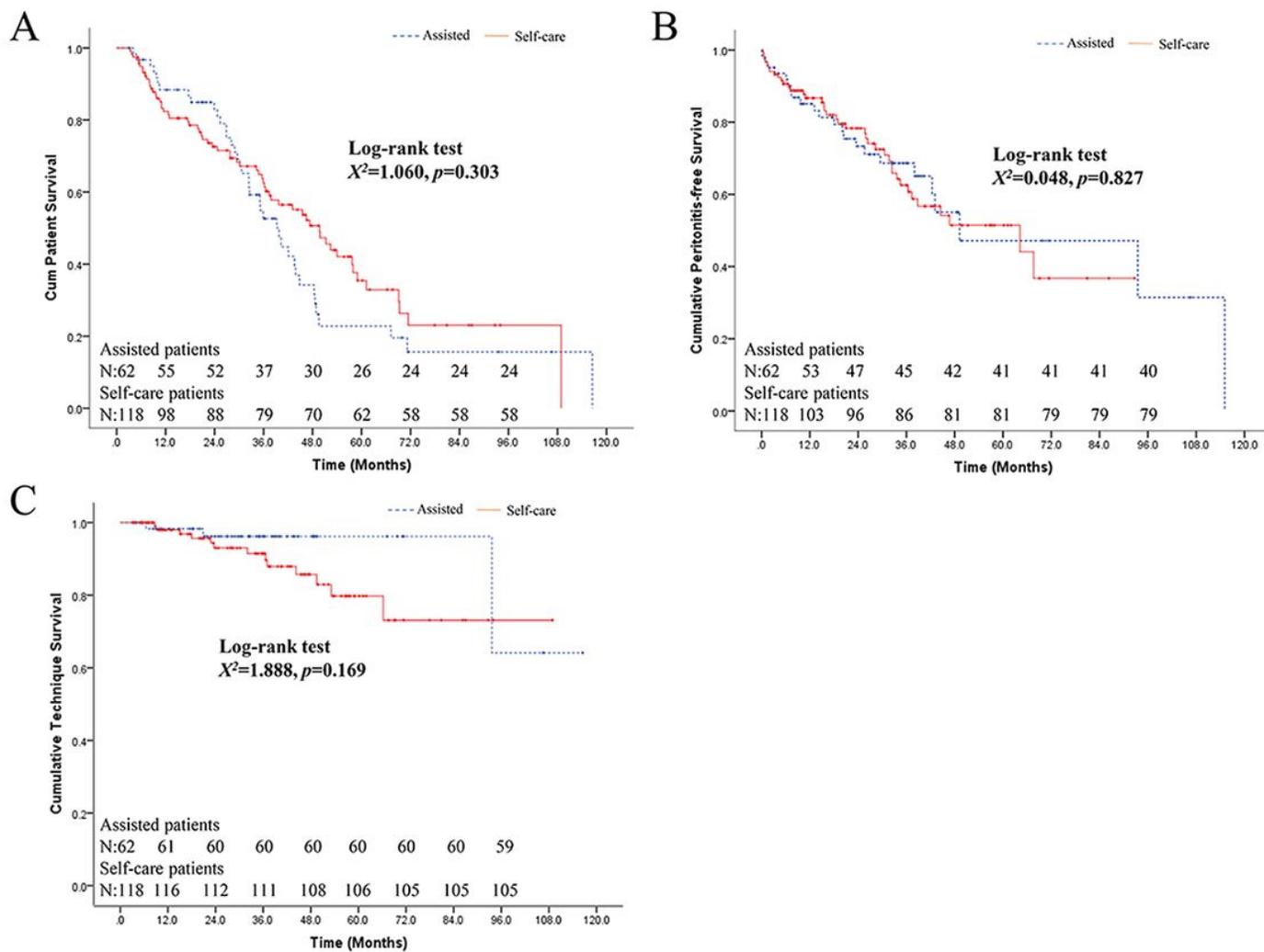
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## Figures



**Figure 1**

Patient enrollment and follow-up. Abbreviations: PD peritoneal dialysis; HD hemodialysis.



**Figure 2**

Kaplan-Meier curves by assistance for patient survival (A), peritonitis-free survival (B) and technique survival (C).