An Incident Cohort Study Comparing Survival on Home Hemodialysis and Peritoneal Dialysis (Australia and New Zealand Dialysis and Transplantation Registry)

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Abstract

Background and objectives Home dialysis is often recognized as a first-choice therapy for patients initiating dialysis. However, studies comparing clinical outcomes between peritoneal dialysis and home hemodialysis have been very limited.

Design, setting, participants, & measurements This Australia and New Zealand Dialysis and Transplantation Registry study assessed all Australian and New Zealand adult patients receiving home dialysis on day 90 after initiation of RRT between 2000 and 2012. The primary outcome was overall survival. The secondary outcomes were on-treatment survival, patient and technique survival, and death-censored technique survival. All results were adjusted with three prespecified models: multivariable Cox proportional hazards model (main model), propensity score quintile–stratified model, and propensity score–matched model.

Results The study included 10,710 patients on incident peritoneal dialysis and 706 patients on incident home hemodialysis. Treatment with home hemodialysis was associated with better patient survival than treatment with peritoneal dialysis (5-year survival: 85% versus 44%, respectively; log-rank $P<0.001$). Using multivariable Cox proportional hazards analysis, home hemodialysis was associated with superior patient survival (hazard ratio for overall death, 0.47; 95% confidence interval, 0.38 to 0.59) as well as better on-treatment survival (hazard ratio for on-treatment death, 0.34; 95% confidence interval, 0.26 to 0.45), composite patient and technique survival (hazard ratio for death or technique failure, 0.34; 95% confidence interval, 0.29 to 0.40), and death-censored technique survival (hazard ratio for technique failure, 0.34; 95% confidence interval, 0.28 to 0.41). Similar results were obtained with the propensity score models as well as sensitivity analyses using competing risks models and different definitions for technique failure and lag period after modality switch, during which events were attributed to the initial modality.

Conclusions Home hemodialysis was associated with superior patient and technique survival compared with peritoneal dialysis.

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Introduction

Interest in home dialysis has been intensifying in the nephrology community over recent years (1). Home dialysis is frequently considered as a first-choice option for patients requiring dialysis therapy (2–5), because it is reported to improve patient autonomy and quality of life while providing equal, if not superior, outcomes compared with facility hemodialysis (HD) (6–11). From the socioeconomic perspective, home dialysis limits dialysis-related costs (12–14).

Peritoneal dialysis (PD), the most common home-based dialysis modality, has generally been associated with comparable survival with that of facility HD and possibly, superior survival in young, nondiabetic, nonoverweight patients and during the early years after RRT initiation (9,11,15–21). Similarly, cohort studies have generally reported a survival benefit of home hemodialysis (HHD) compared with facility HD, irrespective of the dialysis regimen used (8,18,22–26). However, only a few studies have directly compared clinical outcomes of PD and HHD (8,18,27), and none have specifically evaluated patients initiating RRT with a home-based modality.

The aim of this study was to compare the survival of patients on incident HHD with the survival of patients on incident PD in Australia and New Zealand between 2000 and 2012. The secondary objectives were to compare on-treatment survival, composite patient and technique survival, and death-censored technique survival between these two groups.

Materials and Methods

Study Design and Population

This observational cohort study included all adult patients on incident home dialysis in Australia and

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New Zealand between January 1, 2000 and December 31, 2012. Cohorts were defined by home dialysis modality (PD or HHD) on day 90 after RRT initiation. Patients <18 years old and those with <90 days of RRT therapy were excluded. Data were prospectively collected from each dialysis center and transmitted to the Australia and New Zealand Dialysis and Transplant (ANZDATA) Registry.

Exposure Assessment

PD was defined by treatment with continuous ambulatory PD or automated PD. HHD included all forms of HD performed in a home setting (conventional, long, frequent, or long/frequent sessions). Conventional HD machines were used to provide HHD treatments. Most Australian and New Zealand centers allow patients on HHD to dialyze without a helper. Units followed the small solute clearance targets recommended by the Caring for Australasians with Renal Impairment guidelines for PD (28) and HD (29).

Outcomes Assessment

The primary outcome was patient survival. Patients were followed until death without consideration of a switch in dialysis modality. In all analyses, data were censored at the time of kidney transplantation, loss to follow-up, kidney function recovery, and the end of the study (December 31, 2012). Follow-up time started at day 90 after RRT initiation.

Secondary outcomes included (*1*) on-treatment survival, (*2*) composite patient and technique survival, and (*3*) death-censored technique survival. On-treatment survival was defined by any death occurring with the initial home dialysis modality and up to 90 days after a switch from this modality (30). Patients were censored at the time of technique failure.

In the composite patient and technique survival assessment, patients were followed until the first occurrence of technique failure or death. Technique failure was defined as ≥90 days of facility dialysis or the other home modality to allow use of temporary HD, especially among the PD cohort (31). Any event occurring <90 days after a switch from the initial home modality was considered to have occurred while the patient was on the initial modality.

For death-censored technique survival analysis, only technique failure was considered a failure event, and data were censored at the time of death.

Covariates Assessment

All baseline characteristics were determined at the time of RRT inception; <1% of all covariate data were missing, and such patients were excluded from the analyses when applicable. In the main analysis, race was dichotomized as non-Indigenous or Indigenous, and the latter, for the purpose of the study, included Australian Aboriginals, Torres Strait Islanders, Maoris, and Pacific Islanders. Primary renal disease was categorized as GN/autoimmune and other. Late referral was defined as referral to a nephrologist <3 months before RRT initiation. eGFR (32) was calculated for each patient using creatinine at the time of RRT initiation using the four-variable Modification of Diet in Renal Disease equation without any adjustment for racial minorities considering the racial distribution in Australia and New Zealand (32,33).

Statistical Analyses

Survival times were analyzed with the Kaplan–Meier product limit method and compared between PD and HHD cohorts using the log-rank test.

Adjusted analyses were performed with three prespecified statistical approaches: (*1*) multivariable Cox proportional hazards model (main model), (*2*) propensity score (PS) Cox model with PS quintiles stratification, and (*3*) PS-matching Cox model.

Multivariable Models

The main analysis was performed with a multivariable Cox proportional hazards regression model (34). Multivariable Cox models were constructed using all of the covariates listed in Table 1. The following variables were prespecified as potential confounders and forced into the model: age, sex, race, diabetes, and primary kidney disease. Other potential confounders were removed when their exclusion did not appreciably change (<5%) the hazard ratio (HR) of dialysis modality compared with the complete model (35). The final model was on the basis of variables selected *a priori*, biologic plausibility, statistical significance, and our aim to select a parsimonious model, and it included age, sex, race, diabetes, primary renal disease, ischemic heart disease, peripheral vascular disease, and late referral. The proportional hazards assumption was visually assessed with log-minus-log plots, observed (Kaplan–Meier) and predicted (Cox) graphs, and plotting of Schoenfeld residuals.

Prespecified two-way interactions were tested between dialysis modality and the following covariates: age, race, diabetes, and primary kidney disease. Interaction effects were assessed with likelihood ratio. Where an interaction was statistically significant (P values <0.05), subgroup analyses were performed. A time-varying effect of dialysis modality on outcomes was also assessed with the likelihood ratio test.

PS Models

Because the number of covariates in the main model was limited, the results were validated with two PS approaches (36). The dialysis modality at 90 days was predicted with a logistic regression model that estimated treatment assignment with all of the covariates listed in Table 1. Race was collapsed into three groups (white, Asian, and Indigenous/other). All two-way interactions involving age, race, diabetes mellitus, and primary kidney disease with other covariates were evaluated and included in the final logistic regression model when significant. The final logistic regression model included the covariates in Table 1 and the following interaction terms: age by sex, age by ischemic heart disease, race by body mass index, race by peripheral vascular disease, diabetes by body mass index, and diabetes by era. The PS obtained from this logistic regression model was evaluated with a receiver-operating curve (area under curve =0.84) and for covariate balance within quintiles of PS.

Survival times were analyzed using Cox proportional hazards models with dialysis modality as the exposure variable and stratification for PS quintiles. Finally, the continuous PS was used to perform 1:1 nearest neighbor matching without replacement (37). Survival times for the

Table 1. Baseline characteristics

Characteristic	Peritoneal Dialysis (*n*=10,710)	Home Hemodialysis (*n*=706)	*P* Value
Age (yr)	62 (50, 71)	50 (42, 58)	<0.001
Men	6082 (57)	531 (75)	<0.001
Race			<0.001
White	7389 (69)	590 (84)	
Asian	1236 (12)	47 (7)	
Aboriginal/Torres Strait Islander	601 (6)	7 (1)	
Maori	899 (8)	33 (5)	
Pacific Peoples	468 (4)	24 (3)	
Other	117 (1)	5 (1)	
Primary kidney disease			<0.001
GN/autoimmune	2662 (25)	273 (39)	
Diabetes	3739 (35)	126 (18)	
Hypertension/renovascular	1526 (14)	47 (7)	
Polycystic kidney disease	593 (6)	132 (19)	
Reflux	338 (3)	39 (6)	
Other/unknown	1852 (17)	89 (13)	
Cigarette use (current)	1458 (14)	85 (12)	0.23
Comorbidities at dialysis entry			
Chronic lung disease	1606 (15)	54 (8)	<0.001
Coronary disease	4060 (38)	122 (17)	<0.001
Periphery vascular disease	2585 (24)	61 (9)	<0.001
Cerebrovascular disease	1594 (15)	32 (5)	<0.001
Diabetes	4648 (43)	159 (23)	<0.001
Body mass index (kg/m^2)			<0.001
<20	823 (7)	32 (5)	
20–24.9	3451 (32)	177 (25)	
25–29.9	3712 (35)	248 (35)	
≥30	2682 (25)	243 (35)	
Late referral (<3 months)	2128 (20)	45 (6)	<0.001
eGFR	7.5 (5.6–9.9)	7.5 (5.8–9.4)	0.59
RRT initiation era			0.12
2000–2005	4843 (45)	298 (42)	
2006–2012	5876 (55)	408 (58)	
Country			<0.01
Australia	8090 (76)	565 (80)	
New Zealand	2620 (24)	141 (20)	

Data are presented as numbers (percentiles) or medians (interquartile ranges).

matched dialysis modality groups were compared using Cox proportional hazards models with robust SEMs. Standardized differences before and after matching were calculated (Supplemental Figure 2).

Sensitivity Analyses

Fine and Gray (38) competing risk survival models were performed with the covariates included in the main model and transplantation as the competing event. Death-censored technique failure was evaluated in a specific model with death, and transplantation was considered as a composite competing event. In a second sensitivity analysis, the definition of technique failure and the lag period after a modality switch, during which time events were attributed to the initial PD/HHD modality, were changed to 30 days (instead of 90 days for each in the main analysis). A third sensitivity analysis compared survival outcomes starting from the initiation of home dialysis training, whenever this training was initiated during the first 90 days of RRT. A fourth sensitivity model compared primary and secondary outcomes with an adjustment for the proportion of patients treated with PD (10%–40%) or HHD (2.5%–16%) in each Australian state and New Zealand. A fifth sensitivity model restricted the study cohort to patients treated with home dialysis for at least 60 days.

All statistical analyses were performed using Stata IC software (version 12.1; StataCorp, College Station, TX). A two-tailed *P* value <0.05 was considered statistically significant.

Results

The study included 11,416 patients on incident home dialysis at 90 days after RRT initiation. Of these, 10,710 patients received PD, and 706 patients received HHD (Supplemental Figure 1). Baseline characteristics stratified by dialysis modality are displayed in Table 1. Overall, patients treated with HHD were younger and healthier than patients treated with PD. Baseline characteristics of

patients included in the PS-matched cohort are presented in Supplemental Table 1.

Patient Survival

In total, 5056 events were observed in the primary analysis, with 4970 and 86 deaths in the PD and HHD cohorts, respectively. Patients with HHD had a significantly lower mortality in the unadjusted analysis (HR, 0.25; 95% confidence interval [95% CI], 0.21 to 0.32), with 1-, 2-, and 5-year survival rates of 98%, 95%, and 85%, respectively, in the HHD cohort compared with 89%, 76%, and 44%, respectively, in the PD cohort (log-rank $P<0.001$). (Figure 1). In the multivariable Cox model, the lower risk of death associated with HHD compared with PD was attenuated but still highly significant (HR, 0.47; 95% CI, 0.38 to 0.59). Similar results were found in the PS quintile–stratified (HR, 0.48; 95% CI, 0.39 to 0.60) and PS-matching (HR, 0.48; 95% CI, 0.37 to 0.62) models (Table 2; Supplemental Figures 3 and 4). Adjusted HRs for subgroups formed by age, race, diabetes status, and length of follow-up are presented in Figure 2.

Secondary Outcomes

Unadjusted mortality on home dialysis therapy (censored for technique failure) was significantly lower in the HHD cohort compared with the PD cohort (unadjusted HR, 0.17; 95% CI, 0.13 to 0.22), with 1-, 2-, and 5-year survival rates of 98%, 96%, and 87% versus 89%, 75%, and 39%, respectively, in the HHD and PD cohorts (log-rank $P<0.001$) (Figure 3). This association was also seen in the multivariable Cox proportional hazard model (HR, 0.34; 95% CI, 0.26 to 0.45) and the PS models (Table 3).

The composite risk for death or technique failure was significantly lower in the HHD group compared with the PD group (unadjusted HR, 0.26; 95% CI, 0.23 to 0.31; adjusted HR, 0.34; 95% CI, 0.29 to 0.40). Similar HRs were obtained with the PS models (Table 3).

The assessment of death-censored technique survival provided similar results, with lower unadjusted (HR, 0.37; 95% CI, 0.30 to 0.44) and adjusted (HR, 0.34; 95% CI, 0.28 to 0.41) mortality rates in the HHD cohort compared with the PD cohort. Analyses for subgroups formed by age, race, and diabetes status are displayed in Figure 2. Overall, the positive association between HHD and technique survival was attenuated in older age categories and for Indigenous patients and patients with diabetes (Supplemental Table 6).

Sensitivity Analyses

Evaluation of study outcomes with a competing risk approach provided similar results. There were 86 deaths, 345 transplantations, and 275 other censoring events in the HHD cohort and 4970 deaths, 2088 transplantations, and 3651 other censoring events in the PD cohort. For the primary outcome and with transplantation as a competing risk event, the HR for death was 0.42 (95% CI, 0.34 to 0.52) in favor of the HHD group. The HRs for death on a specific dialysis modality and the composite of death and technique failure in the competing risk model were 0.33 (95% CI, 0.25 to 0.43) and 0.34 (95% CI, 0.29 to 0.40), respectively. In the evaluation of death-censored technique survival with death and transplantation as competing events, the protective association between HHD and technique survival was preserved (HR, 0.40; 95% CI, 0.33 to 0.48), and the interaction between age and modality persisted. Adjusted cumulative hazard curves of this model for subgroups on the basis of cross-classification of modality and age groups are displayed in Figure 4.

When the definitions of technique failure and the lag time after a modality switch were changed to 30 days (instead of 90 days), the direction and effect estimate of all outcomes remained consistent with the original analyses (Supplemental Table 2).

Finally, the separate comparison of the study's primary and secondary outcomes in models (*1*) using the initiation of home dialysis training as the starting point, (*2*) adjusting for the proportion of PD and HHD in each Australian state and New Zealand, and (*3*) restricted to a cohort of patients with ≥60 days of home dialysis provided results consistent with those in the main models (Supplemental Tables 3–5).

Discussion

In this registry study of patients on incident home dialysis, HHD was associated with superior overall patient survival, on-treatment survival, composite (patient and technique) survival, and death-censored technique survival compared with PD. These observed associations were robust across three different statistical approaches. To our knowledge, this is the first evaluation of HHD and PD outcomes in patients on incident RRT.

A previous ANZDATA Study using marginal structural models showed a significant survival benefit of HHD compared with conventional facility HD performed with either a conventional or a frequent/extended schedule. This study further described a small but significant increase in mortality among patients on PD compared with conventional facility HD. However, no direct comparison between PD and HHD was performed (18). Similarly, a recent study from New Zealand modeled the time-varying effect on survival of home dialysis compared with facility HD (8). Overall, on-treatment survival was higher with HHD (HR, 0.48; 95% CI, 0.41 to 0.56) and similar with PD (HR, 0.98; 95% CI, 0.90 to 1.06) compared with facility HD. However, this study was limited by the inclusion of prevalent patients, leading to possible survivor bias given that many patients on HHD receive sustained facility HD treatment before transitioning to HHD (27,39).

A cohort study from England and Wales also reported a survival advantage of HHD over PD (HR, 0.61; 95% CI, 0.40 to 0.93) (27). However, patients on PD included in this study were treated with PD on day 90 after RRT initiation, whereas patients included in the HHD cohort were patients on prevalent RRT (but incident HHD). This difference potentially limited the conclusions that could be drawn. Another recent study including prevalent American patients on home dialysis reported increased technique failure among patients on PD compared with patients on daily HHD (HR, 3.4; 95% CI, 2.9 to 4.0) (40). Although limited by the prevalent nature of the cohort and the specificities of American dialysis

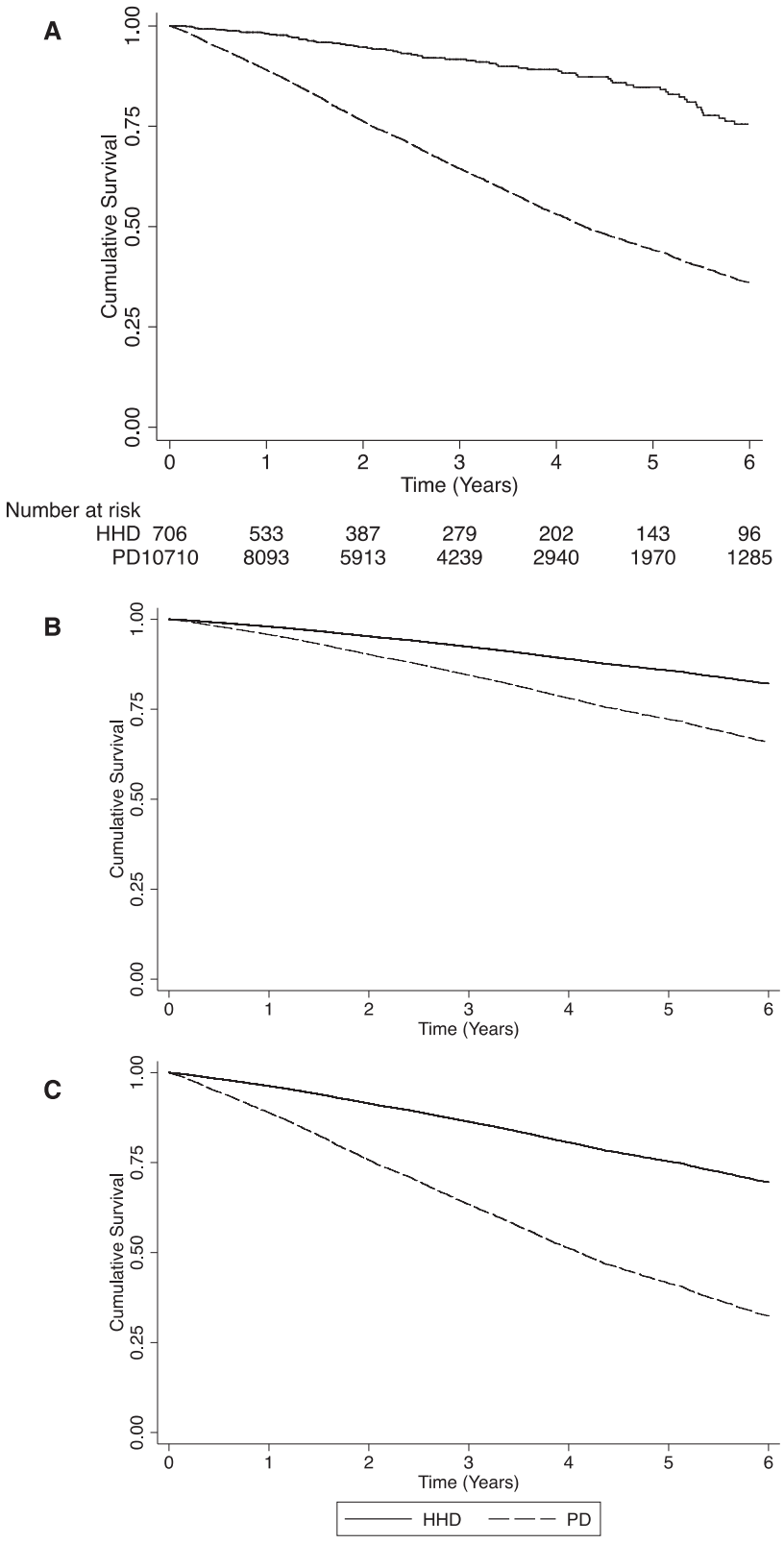

Figure 1. | **Survival curves for primary outcome.** (A) Unadjusted Kaplan–Meier survival curve (log-rank $P<0.001$). (B) Adjusted survival curve for a 50-year-old non-Indigenous man with nonglomerular kidney disease and without diabetes, coronary disease, peripheral vascular disease, and late referral ($P<0.001$). (C) Adjusted survival curve for a 60-year-old non-Indigenous woman with nonglomerular kidney disease, diabetes, and coronary disease and without peripheral vascular disease and late referral ($P<0.001$). HHD, home hemodialysis; PD, peritoneal dialysis.

Table 2. Adjusted hazard ratios for mortality (primary outcome) comparing home hemodialysis with peritoneal dialysis

Models	HR	95% CI	*P* Value
Main model			
Multivariable adjustment[a]	0.47	0.38 to 0.59	<0.001
Secondary models			
PS quintile–stratified[b]	0.48	0.39 to 0.60	<0.001
PS-matching (robust)[c]	0.48	0.37 to 0.62	<0.001
Sensitivity model			
Competing risk[d]	0.42	0.34 to 0.52	<0.001

PS, propensity score; HR, hazard ratio; 95% CI, 95% confidence interval.
[a]Other variables in the multivariable model: age, sex, race (indigenous/other), primary kidney disease (GN/other), diabetes, ischemic heart disease, peripheral vascular disease, and late referral (<3 months). Peritoneal dialysis, *n*=10,685; home hemodialysis, *n*=705. Significant interaction with time×modality. Stratified models are shown in Figure 3.
[b]PS-stratified model: peritoneal dialysis, *n*=10,638; home hemodialysis, *n*=697.
[c]PS-matching model: peritoneal dialysis, *n*=682; home hemodialysis, *n*=682.
[d]Multivariable adjustment model. Transplantation was competing event.

technologies, these results are similar to those obtained in this study.

The survival advantage associated with HHD in this study as well as previous investigations (8,18,27) may have been potentially explained by improved volume control and solute clearance. Nonrandomized studies have shown higher survival in patients treated with HHD compared with conventional facility HD (18,22–26). Improvements in cardiac geometry (10,41,42), BP (10,43), and mineral metabolism (10,42) have also been reported in randomized trials comparing HHD with facility HD. Although none of these studies used PD as a comparison group, it is plausible that some of the known benefits of HHD over facility HD also apply when comparing HHD with PD. Indeed, although PD allows constant ultrafiltration, total fluid removal can sometimes be limited and possibly, lead to hypervolemia and hypertension (44–47). Comparison of clearance quality between PD and HD is limited, although it seems reasonable to postulate that patients treated with long or long/frequent HHD receive a higher dialysis dose than most patients on PD. Although the benefit of a higher dialysis dose is debatable (10,48,49), a difference in dialysis dose may have played a role in the results of this study.

Alternatively, the differential survival of patients on HHD or PD may have resulted from indication bias with residual confounding. Fundamental differences between patients choosing PD or HHD have been well described in the literature (39). Patients treated with HHD tend to be younger, have less comorbidity, and have different etiologies of primary kidney disease (8,18,27,39). They are also less likely to have late nephrology referral, another factor associated with poor clinical outcomes (50–52). Although the previous factors can be addressed by statistical adjustment, other components, such as commitment to dialysis treatment, education level, psychologic skills, social support, and economic status, are much harder to account for, especially in a registry analysis. Although PD and HHD both require a certain degree of autonomy and commitment, the relative complexity of HHD demands higher levels of empowerment, which might have accounted for the relatively small proportion of patients on HHD in this study and the problems encountered with patient recruitment in previous HHD trials (53). Nephrologists are also known to have a major influence over a patient's choice of modality, and their own opinions toward PD and HHD can contribute to differences in PD and HHD cohorts (3,54–56). Thus, the survival advantage associated with HHD in this incident cohort could be related to unmeasured differences in patients treated with PD and HHD rather than the treatment itself.

In this investigation, the association between HHD and technique survival was more important among younger patients than older patients. Interestingly, this interaction revealed a poorer PD technique survival in younger patients than older ones, even after adjustment for other covariates and taking into account transplantation and death in a competing risk model. This observation may be potentially explained by a higher rate of kidney transplantation in younger patients as well as a lower threshold to transfer to HD in the case of potential or actual PD complications.

The strengths of this study included its large sample size and multicenter design, which greatly enhanced its external validity. All patients on incident HHD and PD at all centers in Australia and New Zealand (two countries with a very high prevalence of home dialysis) were included. This study was also the first to evaluate HHD and PD outcomes among patients on incident RRT, thereby mitigating the effect of Neyman (selective survival) bias (57). The consistency of results across a range of statistical methodologies, including multivariable adjustment, PS, and competing risk analyses, supported the internal validity of the findings.

These strengths should be balanced against the study's limitations, the main ones being the potential for indication bias and residual confounding. Another limitation was the constrained depth of data collection by the ANZDATA Registry, such that important patient characteristics (education level, psychologic skills, social support, and treatment adherence) that may have confounded the relationship between home dialysis modality and outcomes were not collected. Laboratory measures, except for eGFR, could not be incorporated in the analysis. Furthermore, different PD modalities were not evaluated because of frequent shifts between them and the fact that these modalities have previously been associated with similar outcomes (58,59). Similarly, specific HHD treatment schedules were not examined because of power issues and inconsistency in classification over the study period. However, previous ANZDATA studies reported similar

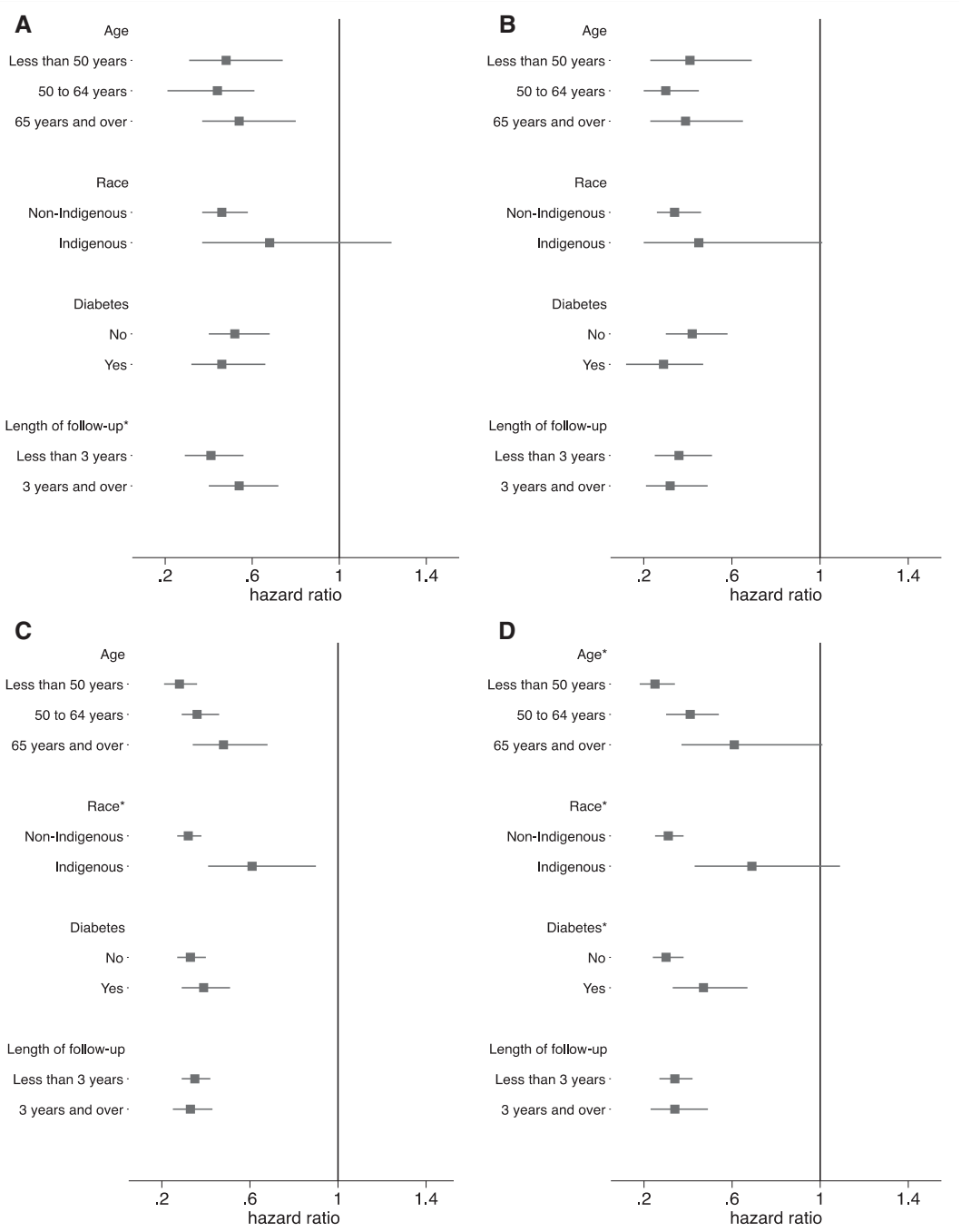

Figure 2. | **Subgroup analyses for primary and secondary outcomes.** Hazard ratios for home hemodialysis relative to peritoneal dialysis (adjusted in multivariable models) by age group, race, and diabetes status for (A) overall mortality, (B) on-treatment mortality, (C) composite of mortality and technique failure, and (D) technique failure only. *P value for interaction <0.05.

outcomes with intensive and conventional HHD, with both being superior to conventional facility HD (18). It should also be acknowledged that a large proportion of patients on HHD in a previous study received 5 hours three times per week (considered standard treatment in Australia and New Zealand), which is more than in many other countries (60). Importantly, this study did not assess the outcomes of patients initiated on home dialysis after >90 days of RRT, which is a situation more frequently encountered among patients treated with HHD than PD (18). Although the study design allowed for the evaluation of incident cohorts (thereby mitigating immortal bias), it may not be representative of overall HHD cohorts, and the study results should not be extrapolated to prevalent home dialysis cohorts. Finally, the findings of this study might not apply to other countries with less experience in

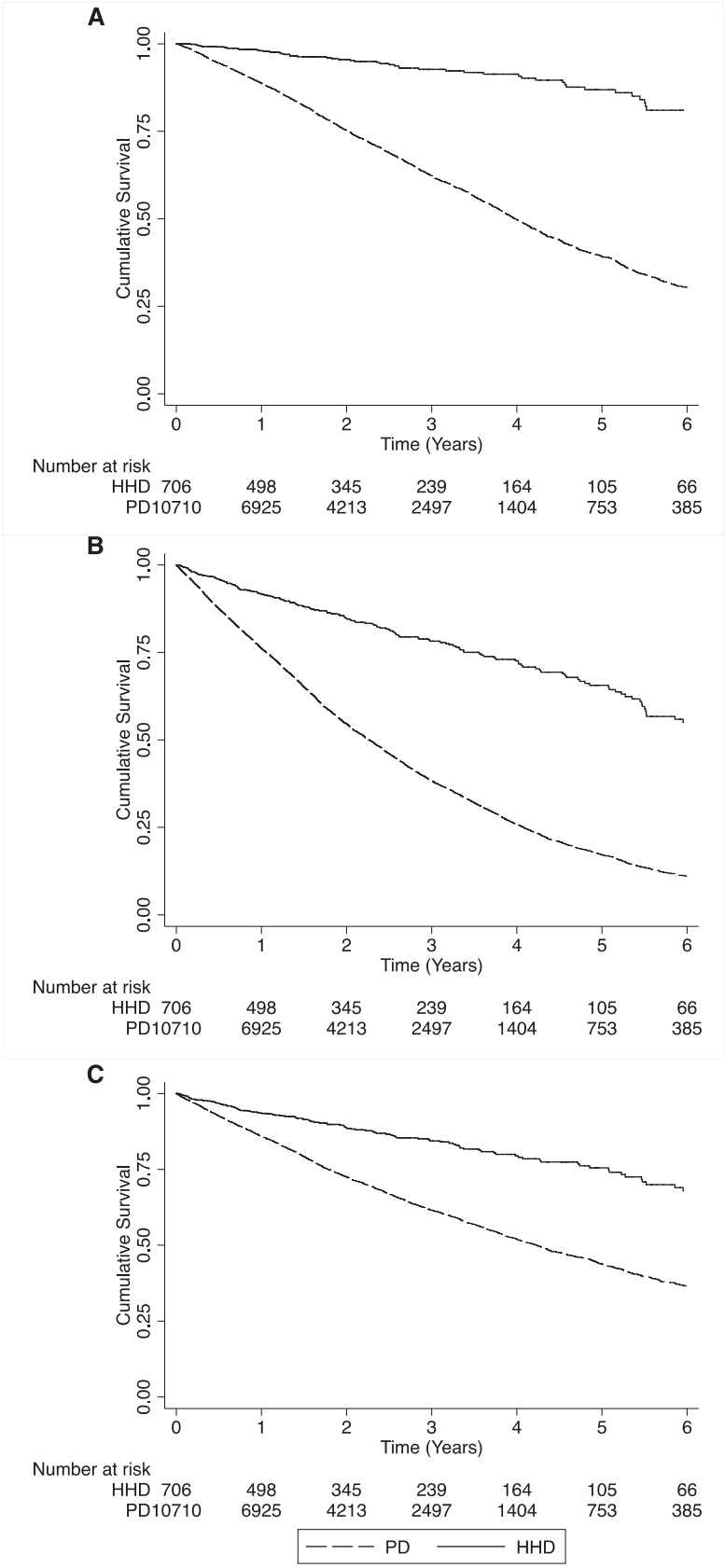

Figure 3. | **Survival curves for secondary outcomes.** Unadjusted Kaplan–Meier curves for (A) on-treatment survival, (B) patient and technique survival, and (C) death-censored technique survival. Log-rank $P<0.001$ for panels (A), (B), and (C). HHD, home hemodialysis; PD, peritoneal dialysis.

Table 3. Adjusted hazard ratios for secondary outcomes comparing home hemodialysis with peritoneal dialysis

Models	HR	95% CI	*P* Value
Death on specific dialysis modality (on-treatment mortality)			
Main model			
Multivariable adjustment	0.34	0.26 to 0.45	<0.001
Secondary models			
PS quintile stratification	0.34	0.25 to 0.44	<0.001
PS-matching (robust)	0.32	0.23 to 0.44	<0.001
Death or technique failure (composite outcome)			
Main model			
Multivariable adjustment[a]	0.34	0.29 to 0.40	<0.001
Secondary models			
PS quintile stratification	0.33	0.28 to 0.39	<0.001
PS-matching (robust)	0.32	0.26 to 0.38	<0.001
Technique failure only			
Main model			
Multivariable adjustment[b]	0.34	0.28 to 0.41	<0.001
Secondary models			
PS quintile stratification	0.33	0.27 to 0.40	<0.001
PS-matching (robust)	0.32	0.25 to 0.40	<0.001

Other variables in the multivariable model: age, sex, race (Indigenous/other), primary kidney disease (GN/other), diabetes, ischemic heart disease, peripheral vascular disease, and late referral (<3 months). PS, propensity score; HR, hazard ratio; 95% CI, 95% confidence interval.

[a]Significant interactions with race×modality. Stratified models are shown in Figure 3.

[b]Significant interactions with age×modality, race×modality, and diabetes×modality. Stratified models are shown in Figure 2.

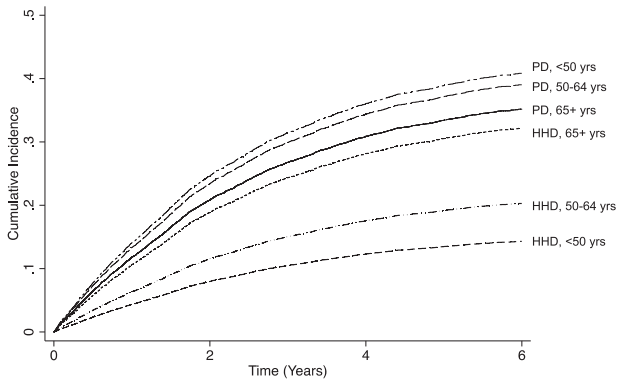

Figure 4. | Cumulative incidence function of technique failure censored for death and stratified by age group and modality in competing risk model. Transplantation and death defined as competing events. HHD, home hemodialysis; PD, peritoneal dialysis.

home dialysis or different home dialysis practices and technologies.

In conclusion, treatment with HHD on day 90 after RRT initiation was associated with a 2-fold higher survival compared with treatment with PD. Whether this advantage is because of the dialysis treatment itself or related to intrinsic patient differences remains uncertain.

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References

1. Rivara MB, Mehrotra R: The changing landscape of home dialysis in the United States. *Curr Opin Nephrol Hypertens* 23: 586–591, 2014
2. Ghaffari A, Kalantar-Zadeh K, Lee J, Maddux F, Moran J, Nissenson A: PD first: Peritoneal dialysis as the default transition to dialysis therapy. *Semin Dial* 26: 706–713, 2013
3. Ludlow MJ, George CR, Hawley CM, Mathew TH, Agar JW, Kerr PG, Lauder LA: How Australian nephrologists view home dialysis: Results of a national survey. *Nephrology (Carlton)* 16: 446–452, 2011
4. Osterlund K, Mendelssohn D, Clase C, Guyatt G, Nesrallah G: Identification of facilitators and barriers to home dialysis selection by canadian adults with ESRD. *Semin Dial* 27: 160–172, 2014
5. Kidney Health Australia: *A Model for Home Dialysis, Australia*, Adelaide, South Australia, Australia, 2012
6. Finkelstein FO, Schiller B, Daoui R, Gehr TW, Kraus MA, Lea J, Lee Y, Miller BW, Sinsakul M, Jaber BL: At-home short daily hemodialysis improves the long-term health-related quality of life. *Kidney Int* 82: 561–569, 2012
7. Jaber BL, Lee Y, Collins AJ, Hull AR, Kraus MA, McCarthy J, Miller BW, Spry L, Finkelstein FO; FREEDOM Study Group: Effect of daily hemodialysis on depressive symptoms and postdialysis recovery time: interim report from the FREEDOM (Following Rehabilitation, Economics and Everyday-Dialysis Outcome Measurements) Study. *Am J Kidney Dis* 56: 531–539, 2010
8. Marshall MR, Walker RC, Polkinghorne KR, Lynn KL: Survival on home dialysis in New Zealand. *PLoS ONE* 9: e96847, 2014
9. Mehrotra R, Chiu YW, Kalantar-Zadeh K, Bargman J, Vonesh E: Similar outcomes with hemodialysis and peritoneal dialysis in patients with end-stage renal disease. *Arch Intern Med* 171: 110–118, 2011
10. Rocco MV, Lockridge RS Jr., Beck GJ, Eggers PW, Gassman JJ, Greene T, Larive B, Chan CT, Chertow GM, Copland M, Hoy CD, Lindsay RM, Levin NW, Ornt DB, Pierratos A, Pipkin MF, Rajagopalan S, Stokes JB, Unruh ML, Star RA, Kliger AS, Kliger A, Eggers P, Briggs J, Hostetter T, Narva A, Star R, Augustine B, Mohr P, Beck G, Fu Z, Gassman J, Greene T, Daugirdas J, Hunsicker L, Larive B, Li M, Mackrell J, Wiggins K, Sherer S, Weiss B, Rajagopalan S, Sanz J, Dellagrottaglie S, Kariisa M, Tran T, West J, Unruh M, Keene R, Schlarb J, Chan C, McGrath-Chong M, Frome R, Higgins H, Ke S, Mandaci O, Owens C, Snell C, Eknoyan G, Appel L, Cheung A, Derse A, Kramer C, Geller N, Grimm R, Henderson L, Prichard S, Roecker E, Rocco M, Miller B, Riley J, Schuessler R, Lockridge R, Pipkin M, Peterson C, Hoy C, Fensterer A, Steigerwald D, Stokes J, Somers D, Hilkin A, Lilli K, Wallace W, Franzwa B, Waterman E, Chan C, McGrath-Chong M, Copland M, Levin A, Sioson L, Cabezon E, Kwan S, Roger D, Lindsay R, Suri R, Champagne J, Bullas R, Garg A, Mazzorato A, Spanner E, Rocco M, Burkart J, Moossavi S, Mauck V, Kaufman T, Pierratos A, Chan W, Regozo K, Kwok S; Frequent Hemodialysis Network (FHN) Trial Group: The effects of frequent nocturnal home hemodialysis: The Frequent Hemodialysis Network Nocturnal Trial. *Kidney Int* 80: 1080–1091, 2011
11. Yeates K, Zhu N, Vonesh E, Trpeski L, Blake P, Fenton S: Hemodialysis and peritoneal dialysis are associated with similar outcomes for end-stage renal disease treatment in Canada. *Nephrol Dial Transplant* 27: 3568–3575, 2012
12. Klarenbach S, Manns B: Economic evaluation of dialysis therapies. *Semin Nephrol* 29: 524–532, 2009
13. Walker R, Marshall MR, Morton RL, McFarlane P, Howard K: The cost-effectiveness of contemporary home haemodialysis modalities compared with facility haemodialysis: A systematic review of full economic evaluations. *Nephrology (Carlton)* 19: 459–470, 2014
14. Karopadi AN, Mason G, Rettore E, Ronco C: Cost of peritoneal dialysis and haemodialysis across the world. *Nephrol Dial Transplant* 28: 2553–2569, 2013
15. Stack AG, Murthy BV, Molony DA: Survival differences between peritoneal dialysis and hemodialysis among "large" ESRD patients in the United States. *Kidney Int* 65: 2398–2408, 2004
16. Vonesh EF, Snyder JJ, Foley RN, Collins AJ: Mortality studies comparing peritoneal dialysis and hemodialysis: What do they tell us? *Kidney Int Suppl* 103: S3–S11, 2006
17. Liem YS, Wong JB, Hunink MG, de Charro FT, Winkelmayer WC: Comparison of hemodialysis and peritoneal dialysis survival in The Netherlands. *Kidney Int* 71: 153–158, 2007
18. Marshall MR, Hawley CM, Kerr PG, Polkinghorne KR, Marshall RJ, Agar JW, McDonald SP: Home hemodialysis and mortality risk in Australian and New Zealand populations. *Am J Kidney Dis* 58: 782–793, 2011
19. McDonald SP, Marshall MR, Johnson DW, Polkinghorne KR: Relationship between dialysis modality and mortality. *J Am Soc Nephrol* 20: 155–163, 2009
20. Jaar BG, Coresh J, Plantinga LC, Fink NE, Klag MJ, Levey AS, Levin NW, Sadler JH, Kliger A, Powe NR: Comparing the risk for death with peritoneal dialysis and hemodialysis in a national cohort of patients with chronic kidney disease. *Ann Intern Med* 143: 174–183, 2005
21. Termorshuizen F, Korevaar JC, Dekker FW, Van Manen JG, Boeschoten EW, Krediet RT; Netherlands Cooperative Study on the Adequacy of Dialysis Study Group: Hemodialysis and peritoneal dialysis: Comparison of adjusted mortality rates according to the duration of dialysis: Analysis of The Netherlands Cooperative Study on the Adequacy of Dialysis 2. *J Am Soc Nephrol* 14: 2851–2860, 2003
22. Blagg CR, Kjellstrand CM, Ting GO, Young BA: Comparison of survival between short-daily hemodialysis and conventional hemodialysis using the standardized mortality ratio. *Hemodial Int* 10: 371–374, 2006
23. Weinhandl ED, Liu J, Gilbertson DT, Arneson TJ, Collins AJ: Survival in daily home hemodialysis and matched thrice-weekly in-center hemodialysis patients. *J Am Soc Nephrol* 23: 895–904, 2012
24. Johansen KL, Zhang R, Huang Y, Chen SC, Blagg CR, Goldfarb-Rumyantzev AS, Hoy CD, Lockridge RS Jr., Miller BW, Eggers PW, Kutner NG: Survival and hospitalization among patients using nocturnal and short daily compared to conventional hemodialysis: A USRDS study. *Kidney Int* 76: 984–990, 2009
25. Lockridge RS, Kjellstrand CM: Nightly home hemodialysis: Outcome and factors associated with survival. *Hemodial Int* 15: 211–218, 2011
26. Nesrallah GE, Lindsay RM, Cuerden MS, Garg AX, Port F, Austin PC, Moist LM, Pierratos A, Chan CT, Zimmerman D, Lockridge RS, Couchoud C, Chazot C, Ofsthun N, Levin A, Copland M, Courtney M, Steele A, McFarlane PA, Geary DF, Pauly RP, Komenda P, Suri RS: Intensive hemodialysis associates with improved survival compared with conventional hemodialysis. *J Am Soc Nephrol* 23: 696–705, 2012
27. Nitsch D, Steenkamp R, Tomson CR, Roderick P, Ansell D, MacGregor MS: Outcomes in patients on home haemodialysis in England and Wales, 1997-2005: a comparative cohort analysis. *Nephrol Dial Transplant* 26: 1670–1677, 2011
28. Johnson D, Brown F, Lammi H, Walker R; Caring for Australians with Renal Impairment (CARI): The CARI guidelines. Dialysis adequacy (PD) guidelines. *Nephrology (Carlton)* 10[Suppl 4]: S81–S107, 2005
29. Kerr P, Perkovic V, Petrie J, Agar J, Disney A; Caring for Australians with Renal Impairment (CARI): The CARI guidelines. Dialysis adequacy (HD) guidelines. *Nephrology (Carlton)* 10[Suppl 4]: S61–S80, 2005
30. Jun M, Jardine MJ, Gray N, Masterson R, Kerr PG, Agar JW, Hawley CM, van Eps C, Cass A, Gallagher M, Perkovic V: Outcomes of extended-hours hemodialysis performed predominantly at home. *Am J Kidney Dis* 61: 247–253, 2013
31. Cho Y, Badve SV, Hawley CM, McDonald SP, Brown FG, Boudville N, Clayton P, Johnson DW: Peritoneal dialysis outcomes after temporary haemodialysis transfer for peritonitis. *Nephrol Dial Transplant* 29: 1940–1947, 2014
32. Levey AS, Bosch JP, Lewis JB, Greene T, Rogers N, Roth D; Modification of Diet in Renal Disease Study Group: A more accurate method to estimate glomerular filtration rate from serum creatinine: A new prediction equation. *Ann Intern Med* 130: 461–470, 1999
33. Mathew TH, Johnson DW, Jones GR; Australasian Creatinine Consensus Working Group: Chronic kidney disease and automatic reporting of estimated glomerular filtration rate: Revised recommendations. *Med J Aust* 187: 459–463, 2007
34. Cox D: Regression models and life-tables. *J R Stat Soc Series B Stat Methodol* 34: 187–220, 1972

35. Mickey RM, Greenland S: The impact of confounder selection criteria on effect estimation. *Am J Epidemiol* 129: 125–137, 1989
36. Rosenbaum P, Rubin D: The central role of the propensity score in observational studies for causal effects. *Biometrika* 70: 41–55, 1983
37. Leuven E, Sianesi B: *PSMATCH2: Stata Module to Perform Full Mahalanobis and Propensity Score Matching, Common Support Graphing, and Coraviate Imbalance Testing (2003), Version 4.0.11*, 2014
38. Fine J, Gray R: A propotional hazards model for the subdistribution of a competing risk. *J Am Stat Assoc* 94: 496–509, 1999
39. Rioux JP, Bargman JM, Chan CT: Systematic differences among patients initiated on home haemodialysis and peritoneal dialysis: the fallacy of potential competition. *Nephrol Dial Transplant* 25: 2364–2367, 2010
40. Suri RS, Li L, Nesrallah GE: The risk of hospitalization and modality failure with home dialysis [published online ahead of print March 18, 2015]. *Kidney Int* 10.1038/ki.2015.68
41. Culleton BF, Walsh M, Klarenbach SW, Mortis G, Scott-Douglas N, Quinn RR, Tonelli M, Donnelly S, Friedrich MG, Kumar A, Mahallati H, Hemmelgarn BR, Manns BJ: Effect of frequent nocturnal hemodialysis vs conventional hemodialysis on left ventricular mass and quality of life: A randomized controlled trial. *JAMA* 298: 1291–1299, 2007
42. Walsh M, Manns BJ, Klarenbach S, Tonelli M, Hemmelgarn B, Culleton B: The effects of nocturnal compared with conventional hemodialysis on mineral metabolism: A randomized-controlled trial. *Hemodial Int* 14: 174–181, 2010
43. McGregor DO, Buttimore AL, Lynn KL, Nicholls MG, Jardine DL: A comparative study of blood pressure control with short in-center versus long home hemodialysis. *Blood Purif* 19: 293–300, 2001
44. Chen YC, Lin CJ, Wu CJ, Chen HH, Yeh JC: Comparison of extracellular volume and blood pressure in hemodialysis and peritoneal dialysis patients. *Nephron Clin Pract* 113: c112–c116, 2009
45. Ferreira-Filho SR, Machado GR, Ferreira VC, Rodrigues CF, Proença de Moraes T, Divino-Filho JC, Olandoski M, McIntyre C, Pecoits-Filho R; BRAZPD study investigators: Back to basics: Pitting edema and the optimization of hypertension treatment in incident peritoneal dialysis patients (BRAZPD). *PLoS ONE* 7: e36758, 2012
46. Papakrivopoulou E, Booth J, Pinney J, Davenport A: Comparison of volume status in asymptomatic haemodialysis and peritoneal dialysis outpatients. *Nephron Extra* 2: 48–54, 2012
47. Van Biesen W, Williams JD, Covic AC, Fan S, Claes K, Lichodziejewska-Niemierko M, Verger C, Steiger J, Schoder V, Wabel P, Gauly A, Himmele R; EuroBCM Study Group: Fluid status in peritoneal dialysis patients: The European Body Composition Monitoring (EuroBCM) study cohort. *PLoS ONE* 6: e17148, 2011
48. Eknoyan G, Beck GJ, Cheung AK, Daugirdas JT, Greene T, Kusek JW, Allon M, Bailey J, Delmez JA, Depner TA, Dwyer JT, Levey AS, Levin NW, Milford E, Ornt DB, Rocco MV, Schulman G, Schwab SJ, Teehan BP, Toto R; Hemodialysis (HEMO) Study Group: Effect of dialysis dose and membrane flux in maintenance hemodialysis. *N Engl J Med* 347: 2010–2019, 2002
49. Chertow GM, Levin NW, Beck GJ, Depner TA, Eggers PW, Gassman JJ, Gorodetskaya I, Greene T, James S, Larive B, Lindsay RM, Mehta RL, Miller B, Ornt DB, Rajagopalan S, Rastogi A, Rocco MV, Schiller B, Sergeyeva O, Schulman G, Ting GO, Unruh ML, Star RA, Kliger AS, Kliger AS; FHN Trial Group: In-center hemodialysis six times per week versus three times per week. *N Engl J Med* 363: 2287–2300, 2010
50. Mendelssohn DC, Curtis B, Yeates K, Langlois S, MacRae JM, Semeniuk LM, Camacho F, McFarlane P; STARRT Study investigators: Suboptimal initiation of dialysis with and without early referral to a nephrologist. *Nephrol Dial Transplant* 26: 2959–2965, 2011
51. Nadeau-Fredette AC, Tennankore KK, Kim SJ, Chan CT: Suboptimal initiation of home hemodialysis: Determinants and clinical outcomes. *Nephron Clin Pract* 124: 132–140, 2013
52. Goldstein M, Yassa T, Dacouris N, McFarlane P: Multidisciplinary predialysis care and morbidity and mortality of patients on dialysis. *Am J Kidney Dis* 44: 706–714, 2004
53. Sergeyeva O, Gorodetskaya I, Ramos R, Schiller BM, Larive B, Raimann JG, Ting GO, Eggers PW, Chertow GM, Levin NW; Frequent Hemodialysis Network Trials Group: Challenges to enrollment and randomization of the Frequent Hemodialysis Network (FHN) Daily Trial. *J Nephrol* 25: 302–309, 2012
54. Tong A, Palmer S, Manns B, Craig JC, Ruospo M, Gargano L, Johnson DW, Hegbrant J, Olsson M, Fishbane S, Strippoli GF: Clinician beliefs and attitudes about home haemodialysis: A multinational interview study. *BMJ Open* 2: 2, 2012
55. Van Biesen W, van der Veer SN, Murphey M, Loblova O, Davies S: Patients' perceptions of information and education for renal replacement therapy: An independent survey by the European Kidney Patients' Federation on information and support on renal replacement therapy. *PLoS ONE* 9: e103914, 2014
56. Castledine CI, Gilg JA, Rogers C, Ben-Shlomo Y, Caskey FJ: Renal centre characteristics and physician practice patterns associated with home dialysis use. *Nephrol Dial Transplant* 28: 2169–2180, 2013
57. Delgado-Rodríguez M, Llorca J: Bias. *J Epidemiol Community Health* 58: 635–641, 2004
58. Lan PG, Johnson DW, McDonald SP, Boudville N, Borlace M, Badve SV, Sud K, Clayton PA: The association between peritoneal dialysis modality and peritonitis. *Clin J Am Soc Nephrol* 9: 1091–1097, 2014
59. Rabindranath KS, Adams J, Ali TZ, MacLeod AM, Vale L, Cody J, Wallace SA, Daly C: Continuous ambulatory peritoneal dialysis versus automated peritoneal dialysis for end-stage renal disease. *Cochrane Database Syst Rev* 2: CD006515, 2007
60. Tentori F, Zhang J, Li Y, Karaboyas A, Kerr P, Saran R, Bommer J, Port F, Akiba T, Pisoni R, Robinson B: Longer dialysis session length is associated with better intermediate outcomes and survival among patients on in-center three times per week hemodialysis: results from the Dialysis Outcomes and Practice Patterns Study (DOPPS). *Nephrol Dial Transplant* 27: 4180–4188, 2012

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