THE IMPACT OF TRANSFER FROM HEMODIALYSIS ON PERITONEAL DIALYSIS TECHNIQUE SURVIVAL

Sharon J. Nessim,¹ Joanne M. Bargman,² S. Vanita Jassal,² Matthew J. Oliver,³ Yingbo Na,⁴
and Jeffrey Perl⁵

*Division of Nephrology,¹ Jewish General Hospital, McGill University, Montreal, Quebec; Division of Nephrology,²
Department of Medicine, University Health Network, University of Toronto, and Division of Nephrology,³
Sunnybrook Health Sciences Centre, University of Toronto, Toronto, Ontario; Canadian Institute of
Health Information and The Canadian Organ Replacement Register,⁴ Toronto, Ontario; and
Division of Nephrology and The Keenan Research Centre in the Li Ka Shing Knowledge
Institute,⁵ St. Michael's Hospital, University of Toronto, Toronto, Ontario, Canada*

◆ **Background:** A significant proportion of peritoneal dialysis (PD) patients receive an initial period of hemodialysis (HD) before transitioning to PD ("PD-switch"). We sought to better understand the risks of PD technique failure (TF) and mortality for those patients compared with patients starting with PD as their first dialysis modality ("PD-first").

◆ **Methods:** Using Canadian Organ Replacement Register data, we compared the risk of PD TF between PD-first and PD-switch patients within the first year after HD initiation. In a secondary analysis, the PD-switch patients were stratified into three groups based on timing of the switch from initial HD to PD as follows: 0–90 days, 91–180 days, and 181–365 days. Each group was compared with PD-first patients for risk of PD TF and death.

◆ **Results:** Between 2001 and 2010, 9404 patients initiated PD as their first renal replacement therapy, and 3757 switched from HD to PD. After multivariable adjustment, the risk of PD TF was higher among PD-switch patients than among PD-first patients [adjusted hazard ratio (AHR): 1.37; 95% confidence interval (CI): 1.26 to 1.49], particularly within the first year after the switch from HD to PD (AHR: 1.51; 95% CI: 1.36 to 1.68). There was no association between time on HD within the first year and subsequent risk of PD TF. For all the stratified PD-switch groups, death rates were higher than those for PD-first patients.

◆ **Conclusions:** Compared with patients who start renal replacement therapy with PD, those who transfer from HD to PD within the first year on dialysis experience higher rates of PD TF and death, with the highest risk being observed in the initial year after the switch to PD.

Perit Dial Int 2015; 35(3):297–305 www.PDIConnect.com
epub ahead of print: 01 Dec 2013 doi:10.3747/pdi.2013.00147

KEY WORDS: Canadian Organ Replacement Register; hemodialysis; survival; technique survival; technique failure; transfer.

Compared with facility-based hemodialysis (HD), peritoneal dialysis (PD) as an initial modality of renal replacement therapy (RRT) has been associated with preservation of residual kidney function (RKF) and improved survival, particularly during the first 1–2 years of therapy (1–5). Furthermore, in North America, PD has been demonstrated to be more cost-effective than facility-based HD and to offer improvements in patient-reported outcomes of satisfaction, treatment-related autonomy, and quality of life (6,7). In an effort to reduce dialysis-associated expenditures while maintaining similar outcomes, regional policymakers and health care providers continue to focus on strategies to increase PD utilization, including the promotion and facilitation of transfer to PD among patients who have initiated dialysis with HD (8,9).

There are several reasons that lead patients to switch to PD after an initial period of facility-based HD. A substantial proportion begin HD unaware of PD as a treatment option because of late referral and limited or no exposure to pre-dialysis care and RRT education. This group can include chronic kidney disease patients who received no prior nephrology care and patients with acute kidney injury (or acute kidney injury superimposed on chronic kidney disease) requiring urgent dialysis initiation. Only after HD initiation do these individuals receive the proper dialysis modality education. Even

Correspondence to: S. Nessim, 3755 Cote-Sainte-Catherine Road, Room G225.1, Montreal, Quebec H3T 1E2 Canada.
sharon.nessim@mcgill.ca

Received 29 May 2013; accepted 20 October 2013

among patients who have received pre-dialysis education and who have chosen PD, patient-related and treatment team-related delays may mandate an initial period of HD before PD initiation. For others, a change of patient, family, or caregiver preference, or of social situation, living conditions, or health status may result in a transition to PD when use of that modality was not feasible or desired at the time of RRT initiation. Lastly, a transition to PD may be the final option after a series of ongoing HD-related treatment complications potentially including vascular access difficulties, severe or refractory HD-related hypotension, or other symptoms.

The data comparing outcomes in incident patients who initiate PD as their first RRT modality and in those who switch to PD after an initial period of facility-based HD are limited. It has been suggested that an initial period on HD may be associated with adverse outcomes once patients transition to PD (10–12). Possible mechanisms might include more rapid loss of RKF during the initial HD period, greater difficulty adjusting to the autonomy of PD after being exposed to in-center HD, and greater illness in the group of patients requiring an initial period of HD.

In the present report, our primary objective was to compare the risk of PD technique failure (TF) in patients switching from HD to PD during the first year of therapy ("PD-switch") and in patients initiating PD as their first dialysis modality ("PD-first"). A secondary objective was to examine whether the timing of the switch from HD to PD affects PD TF.

METHODS

STUDY POPULATION, DATA SOURCES, AND DEFINITIONS

Our study population included adult patients (18 years of age and older) who were listed in the Canadian Organ Replacement Register (CORR) and who initiated RRT between 1 January 2001 and 31 December 2010. Data were collected prospectively by CORR, which is a national registry that captures incidence, prevalence, treatment changes, and outcomes for more than 99% of chronic dialysis patients in Canada (13). During the period of the study, data for more than 53 000 incident dialysis and pre-emptive transplant patients in Canada were captured in CORR. The CORR data have recently been validated, and data collection procedures are described elsewhere (14).

Two incident cohorts of patients were established. The first included patients who initiated RRT with PD, and the second consisted of patients who initiated RRT with facility-based intermittent HD and who switched to PD

within the first 365 days of RRT initiation. Patients who switched from HD to PD after more than 365 days on HD were excluded. (In this small proportion of patients, the timing of the switch was spread across several years.) The PD-switch cohort was further stratified into 3 groups by the timing of the switch from HD to PD: those who switched to PD within the first 90 days of HD initiation, those who switched during days 91 – 180 of HD, and those who switched during days 181 – 365 of HD. Among the PD-switch patients, only those who were receiving 3 sessions per week of in-center HD were included. Patients who initiated or switched to more frequent or alternative HD schedules or to home dialysis were excluded.

Baseline comorbidities that were included in adjusted analyses included the presence or absence of coronary artery disease (angina, myocardial infarction, and coronary artery bypass surgery), peripheral vascular disease, hypertension, diabetes mellitus, and cerebrovascular disease. All were categorized as "yes", "no," or "unknown," with the unknowns combined with the "no" group. The adjustment for diabetes included that condition both as a cause of end-stage renal disease (ESRD) and as a comorbidity. Comorbidities were included in the determination of a validated comorbidity index for each patient (15). Late referral was defined as never having been seen by a nephrologist before dialysis initiation or first being seen by a nephrologist within 3 months before dialysis start. Body mass index was calculated using the height and weight collected at the start of dialysis. Baseline laboratory parameters used in the adjusted analyses included hemoglobin, serum albumin, and serum creatinine measured as the value closest to, but preceding, the initial dialysis treatment. Estimated glomerular filtration rate before the start of dialysis was calculated using the four-variable Modification of Diet in Renal Disease equation (16).

OUTCOMES

All-Cause TF: The primary outcome was time to all-cause PD TF in PD-first and all PD-switch patients. Peritoneal dialysis TF was defined as transfer to HD for 90 days or more. Deaths and transplantation events that occurred within 90 days of transfer to HD from PD were censored for TF. In addition, annual TF risk was assessed using time-dependent hazard ratios (HRs) within each year. Time-averaged HRs from a proportional hazards model were used to assess the cumulative effect from day 0 to the end of the period of observation. For both groups, day 0 was defined as the first day of PD. Patients were censored at death, kidney transplantation, and loss to follow-up or at the end of the observation

period. In the analyses examining cause-specific TF, patients were additionally censored for all other causes of TF.

In a secondary analysis, all-cause PD TF was compared between the PD-first patients and the stratified PD-switch groups. For each PD-switch subgroup, the risk of all-cause PD TF was compared with that in the PD-first group in a fashion analogous to that already described. An additional analysis including time on HD as a continuous variable was also performed.

Cause-Specific PD TF: Cause-specific PD TF was compared for the PD-first patients and all PD-switch patients and also for the PD-first patients and the stratified PD-switch groups. Causes of PD TF were categorized as follows: peritonitis, inadequate PD (which included either or both of inadequate peritoneal ultrafiltration and inadequate small-solute clearance), and other causes. The “other causes” category included abdominal or PD-related complications, inability to cope on the part of the patient or family, transfer to originally intended treatment, recovery of kidney function, and unknown reasons.

Mortality: To eliminate the risk of immortal time bias (because PD-switch patients were alive at the time of their switch during the first year of dialysis initiation), we compared their survival with survival in a group of PD-first patients who had been on dialysis for a period of time similar to the transient HD period in the PD-switch patients. Three separate survival comparisons were therefore performed between the PD-first patients and each of the stratified PD-switch groups. The survival time in PD-first patients was left-censored using a period analogous to the transient time spent on HD by the PD-switch subgroups. Patients who switched to PD within the first 90 days after RRT initiation were compared with a group of PD-first patients who had survived at least 90 days on dialysis. For both groups, survival time was considered from day 90 of RRT initiation onward. Similar survival comparisons were made between patients who switched to PD within 91 – 180 days and within 181 – 365 days, with those groups being compared with a similar cohort of PD-first patients who had survived to at least 180 days or to at least 365 days respectively.

STATISTICAL ANALYSIS

Categorical variables were compared using the chi-square test. The Kruskal–Wallis test was used to analyze differences between continuous variables. A marginal structural model using inverse probability of treatment and censoring weighting—previously described for

analyses of PD TF (5,17,18)—was used to address the competing risks of death and transplantation in the analysis of TF. Using that method, we adjusted for measured covariates in a single summary propensity score and simultaneously adjusted for the effect of informative censoring caused by potential differences in the rates of kidney transplantation and death between the PD-first and PD-switch patients. To examine adjusted technique and patient survival, proportional and non-proportional piecewise exponential survival models were used to compare TF and mortality between the stratified cohorts for sequential 12-month intervals during the first 60 months. Average or time-independent HRs for death were estimated using a proportional hazards model, and time-dependent relative risks were estimated using a non-proportional hazards model. Hazard ratios and corresponding 95% confidence intervals (CIs) were adjusted for case-mix differences in the cohorts, including age, sex, race, ESRD, body mass index, province of treatment, and a weighting for comorbidities (diabetes mellitus, coronary artery disease, peripheral vascular disease, malignancy, lung disease, pulmonary edema) based on a validated ESRD comorbidity index (15). All analyses were performed using the SAS software application (version 9.1.3: SAS Institute, Cary, NC, USA).

RESULTS

BASELINE CHARACTERISTICS

Between 2001 and 2010, 53 493 patients initiated RRT. Table 1 describes the study population. Compared with the 9404 patients who initiated PD as their first dialysis modality, the 3757 patients who switched from HD to PD within the first year of RRT were younger, more likely to be male and white, less likely to have diabetic nephropathy as a cause of ESRD, and more likely to have comorbid conditions. At RRT initiation, they also tended to have lower serum albumin and hemoglobin, and a lower estimated glomerular filtration rate. Late referral was more common among PD-switch patients than among PD-first patients.

Figure 1 shows the distribution of the timing of HD-to-PD transfer for the PD-switch patients. The median time on HD before the switch to PD was 83 days (interquartile range: 38 – 158 days). Of all patients in CORR who transferred from HD to PD, 89% switched within the first year on HD. Among PD-switch patients, central venous catheters were used as the initial vascular access in 88%, and the proportion of patients using such catheters was similar in all stratified subgroups.

TABLE 1
Characteristics of Patients at Dialysis Initiation in
Canada, 2001 – 2010

Variable	PD first	PD switch	<i>p</i> Value
Patients (<i>n</i>)	9404	3757	
Age (%)			<0.0001
18–44 Years	15	21.1	
45–54 Years	16.5	16.8	
55–64 Years	23.2	21.1	
65–74 Years	25	24.9	
75+ Years	20.4	16.1	
Race			<0.0001
White	69.9	74.1	
Asian	8.6	5.8	
Black	3.7	2.8	
Other	13	12.3	
Unknown	4.8	5.1	
Sex (% women)	42.5	39.8	0.04
Cause of ESRD (%)			<0.0001
Glomerulonephritis	16.6	15.4	
Diabetes	36.1	32.9	
Renal vascular disease	17.8	17.2	
Polycystic kidney disease	6.7	2.7	
Other	11.8	18.4	
Unknown	11.1	13.4	
Comorbid conditions (%)			
Diabetes ^a	7.5	9.3	<0.0001
Coronary artery disease	24	26.8	0.0007
Peripheral vascular disease	12.8	14.8	0.03
Malignancy	7.5	9.2	<0.0001
Lung disease	6.5	8.9	<0.0001
Current smoker	12	14	0.002
Modified CCI score (%) ^b			<0.0001
0	56.2	49	
1–3	29.9	32.4	
>3	13.9	18.6	
Year of dialysis initiation (<i>n</i>)			
2001–2005	4581	1795	
2006–2010	4823	1965	
Late referral	13.9	46.2	<0.0001
BMI (kg/m ²)			0.2
Median	26.1	26.0	
Interquartile range	23–29.9	22.8–29.9	
Initial use of a HD catheter [<i>n</i> (%)]	—	3306 (88)	

TABLE 1 (cont'd)

Variable	PD first	PD switch	<i>p</i> Value
Hemoglobin (g/L)			<0.0001
Median	111	97	
Interquartile range	101–120	86–110	
eGFR (mL/min/1.73 m ²)			<0.0001
Median	9.2	7.8	
Interquartile range	7.2–12.0	5.7–10.5	
Albumin (g/L)			<0.0001
Median	36	32	
Interquartile range	32–40	27–37	

PD = peritoneal dialysis; ESRD = end-stage renal disease; CCI = Charlson comorbidity index; BMI = body mass index; HD = hemodialysis; eGFR = estimated glomerular filtration rate.

^a As a comorbidity and not as a cause of end-stage renal disease.

^b Adapted from Hemmelgarn *et al.*, 2003 (15).

Figure 1 — Distribution of time on hemodialysis for patients switching to peritoneal dialysis within the first year on dialysis.

ALL-CAUSE PD TF

PD-First Versus All PD-Switch Patients: Overall, 3668 PD-first patients (39%) and 1597 PD-switch patients (42.5%) experienced PD TF during follow-up. Median time to TF was 4.0 years for PD-first patients and 3.1 years for PD-switch patients. Compared with PD-first patients, PD-switch patients had a 37% higher risk of all-cause PD TF [adjusted HR (AHR): 1.37; 95% CI: 1.26 to 1.49; Table 2], a higher risk of PD TF within the first year on PD (AHR: 1.51; 95% CI: 1.36 to 1.68), and a trend toward a higher risk in the second and third years on PD. Figure 2 presents adjusted technique survival curves comparing the PD-first and PD-switch patients.

TABLE 2
All-Cause and Cause-Specific Peritoneal Dialysis (PD) Technique Failure: Patients Receiving PD First
Compared with Patients Switching to PD from Hemodialysis

Model ^a	Technique failure [hazard ratio (95% confidence limits)] resulting from			
	Any cause	Peritonitis	Inadequate PD	Other causes
Overall				
PD first	Reference	Reference	Reference	Reference
PD switch	1.37 (1.26, 1.49)	1.23 (1.03, 1.48)	1.19 (0.98, 1.44)	1.43 (1.29, 1.58)
Year 1 (n=13 161)				
PD-first	Reference	Reference	Reference	Reference
PD switch	1.51 (1.36, 1.68)	1.40 (1.09, 1.80)	1.28 (0.99, 1.66)	1.56 (1.38, 1.76)
Year 2 (n=8 995)				
PD-first	Reference	Reference	Reference	Reference
PD switch	1.17 (0.99, 1.38)	1.13 (0.82, 1.56)	1.12 (0.76, 1.64)	1.14 (0.92, 1.40)
Year 3 (n=5 480)				
PD-first	Reference	Reference	Reference	Reference
PD switch	1.18 (0.94, 1.48)	1.21 (0.80, 1.84)	1.06 (0.67, 1.70)	1.19 (0.90, 1.57)

^a Performed using inverse probability of treatment and censoring weighting. Adjusted for age, race, sex, body mass index, end-stage renal disease comorbidity index, primary diagnosis, and late referral.

An analysis restricted to patients for whom complete information on all comorbidities and biochemical parameters was available ($n = 10\,826$) yielded a similar increase in the overall risk of TF for the PD-switch patients relative to the PD-first patients (AHR: 1.35; 95% CI: 1.23 to 1.48).

PD-First Patients Versus PD-Switch Subgroups: Among the PD-switch patients, those who switched within the first 90 days (AHR: 1.31; 95% CI: 1.17 to 1.45) and those who switched within 91 – 180 days (AHR: 1.45; 95% CI: 1.26 to 1.68) had a higher risk of all-cause PD TF than did the patients in the PD-first group. Patients who switched within 181 – 365 days on HD showed a nonsignificant trend toward a higher risk of all-cause TF than was seen in the PD-first patients (AHR: 1.17; 95% CI: 0.98 to 1.39). For all PD-switch subgroups, the increased risk of all-cause TF was most apparent within the first year of PD treatment (Table 3). Treated as a continuous variable, time on HD before PD transfer showed no association with the risk of PD TF [AHR: 1.01; 95% CI: 0.97 to 1.05 (per day on HD before transfer to PD)].

Compared with PD-first patients, PD-switch patients who started HD with a central venous catheter ($n = 3306$) experienced a greater overall risk of PD TF (AHR: 1.36; 95% CI: 1.24 to 1.48). In contrast, PD-switch patients who started HD with an arteriovenous fistula or graft ($n = 451$) were not at increased risk of PD TF (AHR: 0.89; 95% CI: 0.57 to 1.39).

Figure 2 — Peritoneal dialysis (PD) technique failure by adjusted inverse probability of treatment and censoring weighting analysis and comparing patients treated with PD first and those who switched to PD from hemodialysis. Analysis was adjusted for age, race, sex, body mass index, end-stage renal disease comorbidity index, primary diagnosis, and late referral.

CAUSE-SPECIFIC PD TF

PD-First Versus All PD-Switch Patients: In the first year, the causes of PD TF in the PD-first and PD-switch groups were: peritonitis, 2.9% (95% CI: 2.5% to 3.3%) and 4.2% (95% CI: 3.6% to 5.0%) respectively; inadequate PD, 3.2% (95% CI: 2.8% to 3.6%) and 4.2% (95% CI: 3.5% to 4.9%); and other causes, 11.7% (95% CI:

TABLE 3
All-Cause Peritoneal Dialysis (PD) Technique Failure
and All-Cause Mortality: Patients Receiving PD
First Compared with Patients Switching to
PD from Hemodialysis, Stratified by
Time of Switch

Model	All-cause event [hazard ratio (95% confidence limits)] ^a	Technique failure	Mortality
Overall			
PD first	Reference	Reference	Reference
PD switch			
Within 90 days	1.31 (1.17, 1.45)	1.36 (1.21, 1.52)	
91–180 Days	1.45 (1.26, 1.68)	1.52 (1.30, 1.78)	
181–365 Days	1.17 (0.98, 1.39)	1.28 (1.03, 1.59)	
Year 1			
PD first	Reference	Reference	Reference
PD switch			
Within 90 days	1.41 (1.23, 1.61)	1.82 (1.52, 2.18)	
91–180 Days	1.72 (1.44, 2.05)	3.11 (2.43, 3.98)	
181–365 Days	1.30 (1.05, 1.60)	— ^b	
Year 2			
PD first	Reference	Reference	Reference
PD switch			
Within 90 days	1.20 (0.97, 1.48)	1.27 (1.03, 1.56)	
91–180 Days	1.03 (0.77, 1.36)	1.26 (0.95, 1.67)	
181–365 Days	0.91 (0.65, 1.27)	1.37 (1.02, 1.84)	
Year 3			
PD first	Reference	Reference	Reference
PD switch			
Within 90 days	1.13 (0.85, 1.51)	1.10 (0.87, 1.38)	
91–180 Days	1.21 (0.83, 1.76)	0.96 (0.68, 1.36)	
181–365 Days	1.14 (0.72, 1.82)	1.19 (0.85, 1.65)	

^a Performed using inverse probability of treatment and censoring weighting. Adjusted for age, race, sex, body mass index, end-stage renal disease comorbidity index, primary diagnosis, and late referral.

^b Cannot calculate 1-year survival, because PD-only patients were left-censored within the first year after PD start.

11.0% to 12.4%) and 17.6% (95% CI: 16.3% to 18.8%). Compared with PD-first patients, PD-switch patients had a higher risk of PD TF attributable to peritonitis (AHR: 1.23; 95% CI: 1.03 to 1.48) that was particularly apparent during the first year after PD initiation (AHR: 1.40; 95% CI: 1.09 to 1.80; Table 2). The risk of TF attributable to inadequate PD trended higher among PD-switch patients than among PD-first patients (AHR: 1.19; 95% CI: 0.98 to 1.44) and was again most prominent in the first year

on PD (AHR: 1.28; 95% CI: 0.99 to 1.66). Compared with PD-first patients, PD switch patients had a higher risk of TF from “other causes” (AHR: 1.43; 95% CI: 1.29 to 1.58).

ALL-CAUSE MORTALITY BY COHORT PERIOD OF PD INITIATION

During follow-up, 3170 patients died (24%). Compared with PD-first patients, all three subgroups of PD-switch patients had a higher risk of death (Table 3). The hazard for death was particularly high during the first year on PD for patients who switched from HD to PD within 90 days (AHR: 1.82; 95% CI: 1.52 to 2.18) or within 91 – 180 days (AHR: 3.11; 95% CI: 2.43 to 3.98).

DISCUSSION

In this large observational Canadian study, rates of TF and death were higher in PD patients who transferred from HD to PD during the first year on dialysis than in patients who started with PD as their first dialysis modality. The increased risk of TF among patients who switched from HD to PD was driven largely by higher risks across all causes of TF during the first year on PD. The time on HD before transfer to PD did not affect PD TF.

The finding of a higher risk of TF among patients who switched from HD to PD is consistent with the few earlier studies that reported on this association. In the three largest studies, patients who transferred from HD to PD had a 21% – 33% increased risk of PD TF relative to incident PD patients (11,12,19). However, median time to PD transfer was not reported in two of the studies (11,12). In a fourth large observational study from Ontario, Canada, transfer to PD within 3 months of initiating HD was associated with a risk of TF that was 24% higher than that for patients initiating RRT with PD (10). The 37% increased risk of PD TF among PD-switch patients reported in our study is in keeping with those foregoing reports. Smaller studies of patients who transferred from HD to PD have either shown conflicting results or have not specifically reported on PD TF (20–25). No studies to date have assessed whether the increased risk of TF among HD-to-PD transfer patients is driven by one or more particular causes of TF or whether time on HD influences PD TF.

Compared with PD-first patients, PD-switch patients experienced their greatest increase in risk of TF during the first year on PD. The overall increase was driven by increased risk for all causes of TF within the first year (peritonitis, inadequate PD, and other causes). It is perhaps not surprising that PD-switch patients experienced higher peritonitis-related TF, given that transfer from HD

to PD has been shown to be an independent risk factor for the development of peritonitis (21,26). The finding that inadequate PD as a cause of early TF was more common among PD-switch than among PD-first patients is noteworthy, because inadequate dialysis is typically viewed as a cause of late TF. The higher risk of early TF because of inadequate PD in the PD-switch group may relate to the more rapid loss of RKF incurred because of hemodynamic flux during their time on HD. Compared with the RKF seen in incident PD patients, the lower RKF observed in patients at the time of transfer from HD to PD has been confirmed in two studies in which the median time on HD was 7 months (20) and 18 months (21).

Surprisingly, we observed no relationship between the time spent on HD before the switch to PD and the risk of PD TF. Because one of the likely determinants of RKF decline is the amount of time spent on HD, loss of RKF does not appear to be the major explanation for the increased risk of PD TF among PD-switch patients. If it had been, then PD outcomes would have been expected to be worse with longer times on HD before transfer. Intuitively, patients who transfer from HD to PD for preference reasons (which typically occur early) would be expected to have better outcomes than patients who transfer for vascular access issues or hemodynamic reasons (which typically occur late). Yet, we did not find that patients who switched early had better technique survival on PD. The lack of a relationship between time on HD within the first year of RRT and risk of PD TF suggests that other factors are possible contributors. For example, patients who transfer from HD to PD commonly have greater difficulty adjusting to the autonomy of PD after exposure to in-center HD. Such adjustment difficulties (which could be independent of the amount of time spent on HD) might have contributed to a higher risk of TF among HD-to-PD transfer patients. The risk might also be related to the type of patient who starts with HD as their first dialysis modality rather than to any deleterious effect of the HD procedure itself. That possibility is evidenced by the finding that, compared with PD-first patients, patients who initiated HD with a catheter had an increased risk of PD TF, but those who initiated HD with an arteriovenous fistula or graft did not. Although we adjusted for baseline differences between the groups [including the much higher frequency of late referral among PD-switch patients (46.2% vs 13.9%)], residual confounding between the groups cannot be excluded.

We found lower patient survival among PD-switch patients than among PD-first patients, even after multivariable adjustment. It is possible that the type of patient who has little or no pre-dialysis care and who is likely to start on HD is fundamentally different from the

type of patient who is able to start PD as the first dialysis modality—a variable that cannot be fully accounted for. Another possibility is that the higher risk of death among PD-switch patients is partly associated with their more rapid loss of RKF, because RKF has been shown to be associated with a survival advantage (27–32). If causal, the survival advantage linked with RKF might be explained by better volume control, better uremic clearance, or a combination thereof. Alternatively, given that an overwhelming proportion of the patients who transferred from HD to PD had a central venous catheters for vascular access, it is plausible that their increased risk of death might be attributable, in part, to an ongoing risk of the deleterious effects of initial catheter use (33). A further possibility is that HD is known to induce subclinical cardiac ischemia (34–36), which might increase the risk of subsequent cardiovascular death even once a patient has transitioned to PD.

The findings of the present study have to be interpreted in the context of the study design. The study's strengths include its large sample size and the multicenter nature of the data. However, the reasons for initiation of HD before PD transfer among the PD-switch patients were not available, and complete data on the reasons for subsequent transfer to PD, which might have provided insights into the subpopulations of patients in the PD-switch group, were also lacking. We had no data on RKF, particularly at the time of transfer to PD among the PD-switch patients, that may have been helpful in understanding the basis for the higher risk of PD TF and death among those patients. Despite extensive case-mix adjustment, performed as in other registry-based observational studies, we cannot exclude residual confounding. Finally, we lacked a comparator group of patients who had remained on HD. Thus, we cannot comment on the outcomes of patients who switched from HD to PD relative to outcomes on HD alone. In the context of the foregoing limitations, it is difficult to draw conclusions about the practice of switching HD patients to PD. Given that the relationship may be associative, and that a large proportion of PD-switch patients still do well once transferred to PD, we do not feel that our findings should discourage HD-to-PD transfers. However, our findings do support the need for increased vigilance among the switched patients with respect to training, peritonitis prevention practices, adequate psychosocial support, and monitoring for RKF loss.

CONCLUSIONS

Using a large contemporary national cohort, we showed that, compared with patients who initiate PD as their first dialysis modality, those who switch from HD

to PD within the first year of dialysis initiation are at increased risk of TF and death on PD. The increased risk of TF was highest during the first year on PD. The time on HD before transfer to PD did not have a significant impact on PD TF. Further studies are needed to elucidate the basis for the association between HD-to-PD transfer and subsequent PD TF, and the impact of interventions to minimize initial HD use among patients in whom PD is the intended dialysis modality.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the staff at CORR for maintaining the database and renal units throughout Canada for submitting information to CORR.

DISCLOSURES

SJN has participated on advisory boards for Baxter Healthcare Canada and has received speaking honoraria from Baxter Healthcare Canada and Merck Frosst. JMB has participated on advisory boards and consulted for Otsuka and Amgen and has received honoraria from DaVita Healthcare Partners, Amgen, Otsuka, and Baxter Healthcare. MJO is co-inventor of the Dialysis Measurement Analysis and Reporting (DMAR) system. JP has served on advisory boards for Shire Canada and Baxter Healthcare Canada, and has received speaking honoraria from Amgen Canada, Hemosphere USA, DaVita Healthcare Partners and Baxter Healthcare Canada. He also holds an unrestricted educational fellowship from Baxter Healthcare Canada. SVJ and YA have no disclosures.

REFERENCES

1. Moist LM, Port FK, Orzol SM, Young EW, Ostbye T, Wolfe RA, *et al.* Predictors of loss of residual renal function among new dialysis patients. *J Am Soc Nephrol* 2000; 11:556–64.
2. Jansen MA, Hart AA, Korevaar JC, Dekker FW, Boeschoten EW, Krediet RT on behalf of the NECOSAD Study Group. Predictors of the rate of decline of residual renal function in incident dialysis patients. *Kidney Int* 2002; 62:1046–53.
3. 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* 2012; 27:3568–75.
4. Vonesh EF, Snyder JJ, Foley RN, Collins AJ. Mortality studies comparing peritoneal dialysis and hemodialysis: what do they tell us? *Kidney Int* 2006; 70:S3–11.
5. Perl J, Wald R, McFarlane P, Bargman JM, Vonesh E, Na Y, *et al.* Hemodialysis vascular access modifies the association between dialysis modality and survival. *J Am Soc Nephrol* 2011; 22:1113–21.
6. Rubin HR, Fink NE, Plantinga LC, Sadler JH, Kliger AS, Powe NR. Patient ratings of dialysis care with peritoneal dialysis vs hemodialysis. *JAMA* 2004; 291:697–703.
7. Klarenbach S, Manns B. Economic evaluation of dialysis therapies. *Semin Nephrol* 2009; 29:524–32.
8. Rioux JP, Cheema H, Bargman JM, Watson D, Chan CT. Effect of an in-hospital chronic kidney disease education program among patients with unplanned urgent-start dialysis. *Clin J Am Soc Nephrol* 2011; 6:799–804.
9. Hanco J, Jastrzebski J, Nieva C, White L, Li G, Zalunardo N. Dedication of a nurse to educating suboptimal haemodialysis starts improved transition to independent modalities of renal replacement therapy. *Nephrol Dial Transplant* 2011; 26:2302–8.
10. Chidambaram M, Bargman JM, Quinn RR, Austin PC, Hux JE, Laupacis A. Patient and physician predictors of peritoneal dialysis technique failure: a population based, retrospective cohort study. *Perit Dial Int* 2011; 31:565–73.
11. Lobbedez T, Verger C, Ryckelynck JP, Fabre E, Evans D. Is assisted peritoneal dialysis associated with technique survival when competing events are considered? *Clin J Am Soc Nephrol* 2012; 7:612–18.
12. Mujais S, Story K. Peritoneal dialysis in the US: evaluation of outcomes in contemporary cohorts. *Kidney Int Suppl* 2006; (103):S21–6.
13. Karamadokis L, Ansell D, Foley RN, McDonald SP, Tomson CR, Trpeski L, *et al.* Towards case-mix-adjusted international renal registry comparisons: how can we improve data collection practice? *Nephrol Dial Transplant* 2009; 24:2306–11.
14. *Data Quality Study on the Canadian Organ Replacement Register*. Ottawa, ON: Canadian Institute for Health Information; 2009.
15. Hemmelgarn BR, Manns BJ, Quan H, Ghali WA. Adapting the Charlson comorbidity index for use in patients with ESRD. *Am J Kidney Dis* 2003; 42:125–32.
16. Levey AS, Bosch JP, Lewis JB, Greene T, Rogers N, Roth D. A more accurate method to estimate glomerular filtration rate from serum creatinine: a new prediction equation. Modification of Diet in Renal Disease Study Group. *Ann Intern Med* 1999; 130:461–70.
17. 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* 2011; 171:110–18.
18. Perl J, Wald R, Bargman JM, Na Y, Jassal SV, Jain AK, *et al.* Changes in patient and technique survival over time among incident peritoneal dialysis patients in Canada. *Clin J Am Soc Nephrol* 2012; 7:1145–54.
19. Lobbedez T, Verger C, Ryckelynck JP, Fabre E, Evans D. Outcome of the sub-optimal dialysis starter on peritoneal dialysis. Report from the French Language Peritoneal Dialysis Registry (RDPLF). *Nephrol Dial Transplant* 2013; 28:1276–83.
20. Zhang L, Cao T, Li ZB, Wen Q, Lin J, Zhang X, *et al.* Clinical

- outcomes of peritoneal dialysis patients transferred from hemodialysis: a matched case-control study. *Perit Dial Int* 2012; 33:259-66.
21. Liberek T, Renke M, Skonieczny B, Kotewicz K, Kowalewska J, Chmielewski M, *et al.* Therapy outcome in peritoneal dialysis patients transferred from haemodialysis. *Nephrol Dial Transplant* 2009; 24:2889-94.
 22. Singh S, Yium J, Macon E, Clark E, Schaffer D, Teschan P. Multicenter study of change in dialysis therapy-maintenance hemodialysis to continuous ambulatory peritoneal dialysis. *Am J Kidney Dis* 1992; 19:246-51.
 23. Zhang X, Han F, He Q, Huang H, Yin X, Ge J, *et al.* Outcomes and risk factors for mortality after transfer from hemodialysis to peritoneal dialysis in uremic patients. *Perit Dial Int* 2008; 28:313-14.
 24. Lobbedez T, Crand A, Le Roy F, Landru I, Quere C, Ryckelynck JP. Transfer from chronic haemodialysis to peritoneal dialysis [French]. *Nephrol Ther* 2005; 1:38-43.
 25. Sipahioglu MH, Aybal A, Unal A, Tokgoz B, Oymak O, Utas C. Patient and technique survival and factors affecting mortality on peritoneal dialysis in Turkey: 12 years' experience in a single center. *Perit Dial Int* 2008; 28:238-45.
 26. Nessim SJ, Bargman JM, Austin PC, Nisenbaum R, Jassal SV. Predictors of peritonitis in patients on peritoneal dialysis: results of a large, prospective Canadian database. *Clin J Am Soc Nephrol* 2009; 4:1195-200.
 27. Bargman JM, Thorpe KE, Churchill DN on behalf of the CANUSA Peritoneal Dialysis Study Group. Relative contribution of residual renal function and peritoneal clearance to adequacy of dialysis: a reanalysis of the CANUSA study. *J Am Soc Nephrol* 2001; 12:2158-62.
 28. Paniagua R, Amato D, Vonesh E, Correa-Rotter R, Ramos A, Moran J, *et al.* on behalf of the Mexican Nephrology Collaborative Study Group. Effects of increased peritoneal clearances on mortality rates in peritoneal dialysis: ADEMEX, a prospective, randomized, controlled trial. *J Am Soc Nephrol* 2002; 13:1307-20.
 29. Diaz-Buxo JA, Lowrie EG, Lew NL, Zhang SM, Zhu X, Lazarus JM. Associates of mortality among peritoneal dialysis patients with special reference to peritoneal transport rates and solute clearance. *Am J Kidney Dis* 1999; 33:523-34.
 30. Rocco M, Soucie JM, Pastan S, McClellan WM. Peritoneal dialysis adequacy and risk of death. *Kidney Int* 2000; 58:446-57.
 31. Szeto CC, Wong TY, Chow KM, Leung CB, Law MC, Li PK. Independent effects of renal and peritoneal clearances on the mortality of peritoneal dialysis patients. *Perit Dial Int* 2004; 24:58-64.
 32. Wang AY, Wang M, Woo J, Lam CW, Lui SF, Li PK, *et al.* Inflammation, residual kidney function, and cardiac hypertrophy are interrelated and combine adversely to enhance mortality and cardiovascular death risk of peritoneal dialysis patients. *J Am Soc Nephrol* 2004; 15:2186-94.
 33. Foley RN, Guo H, Snyder JJ, Gilbertson DT, Collins AJ. Septicemia in the United States dialysis population, 1991 to 1999. *J Am Soc Nephrol* 2004; 15:1038-45.
 34. Selby NM, Lambie SH, Camici PG, Baker CS, McIntyre CW. Occurrence of regional left ventricular dysfunction in patients undergoing standard and biofeedback dialysis. *Am J Kidney Dis* 2006; 47:830-41.
 35. Burton JO, Jefferies HJ, Selby NM, McIntyre CW. Hemodialysis-induced repetitive myocardial injury results in global and segmental reduction in systolic cardiac function. *Clin J Am Soc Nephrol* 2009; 4:1925-31.
 36. McIntyre CW, Burton JO, Selby NM, Leccisotti L, Korsheed S, Baker CS, *et al.* Hemodialysis-induced cardiac dysfunction is associated with an acute reduction in global and segmental myocardial blood flow. *Clin J Am Soc Nephrol* 2008; 3:19-26.