PREDICTORS OF PERITONITIS, HOSPITAL DAYS, AND TECHNIQUE SURVIVAL FOR PERITONEAL DIALYSIS PATIENTS IN A MANAGED CARE SETTING

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◆ **Introduction:** Many clinicians perceive that peritoneal dialysis (PD) should be reserved for younger, healthier, more affluent patients. Our aim was to examine outcomes for PD patients in a managed care setting and to identify predictors of adverse outcomes.

◆ **Methods:** We identified all patients who initiated PD at our institution between 1 January 2001 and 31 December 2010. Predictor variables studied included age, sex, race, PD modality, cause of end-stage renal disease (ESRD), dialysis vintage, Charlson comorbidity index (CCI) score, education, and income level. Poisson models were used to determine the relative risk (RR) of peritonitis and the number of hospital days per patient-year. The log-rank test was used to compare technique survival by patient strata.

◆ **Results:** Among the 1378 patients who met the inclusion criteria, only female sex [RR: 0.85; 95% confidence interval (CI): 0.74 to 0.98; $p = 0.02$] and higher education (RR: 0.77; 95% CI: 0.60 to 0.98; $p = 0.04$) were associated with peritonitis. For hospital days, dialysis vintage (RR: 1.11; 95% CI: 1.04 to 1.18; $p = 0.002$), CCI score (RR: 1.06; 95% CI: 1.02 to 1.20; $p = 0.002$), and cause of ESRD (RR for glomerulonephritis: 0.59; 95% CI: 0.43 to 0.80; $p = 0.0006$; and RR for hypertension: 0.69; 95% CI: 0.55 to 0.88; $p = 0.002$) were associated with 1 extra hospital day per patient-year. The 2-year technique survival was 61% for patients who experienced at least 1 episode of peritonitis and 72% for those experiencing no peritonitis ($p = 0.0001$). Baseline patient age, primary cause of ESRD, and PD modality were the only other variables associated with technique survival in the study.

◆ **Conclusions:** Neither race nor socio-economic status predicted technique survival or hospital days in our study. Female sex and higher education were the only two variables studied that had an association with peritonitis.

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In the United States, peritoneal dialysis (PD) is underutilized by patients with end-stage renal disease (ESRD). According to the US Renal Data System (USRDS), only 7.5% of all US ESRD patients were treated with PD in 2009 (1). The recent bundling of dialysis services by the Centers for Medicare and Medicaid Services may lead to higher utilization of PD in the near future. To increase the prevalence of PD, more emphasis should be placed on understanding the causes of PD technique failure, especially peritonitis. Studies have shown that peritonitis is the leading cause of technique failure for PD patients, but peritonitis rates vary depending on the patient population (2,3).

In its annual data report (ADR), the USRDS reports the incidence, prevalence, and trends for dialysis patients based on Medicare claims data. The USRDS data about peritonitis rates and technique survival are limited. Other data about outcomes in PD patients have come from single centers and are based on small populations (4–8). It is important to review outcomes in PD patients on a regular basis, because practices and trends have changed dramatically from those of earlier decades (9).

Kaiser Permanente (KP) is one of the largest health care delivery systems in southern California and currently cares for more than 12 000 dialysis patients. A registry for hemodialysis, PD, and renal transplant patients was created at our institution more than a decade ago in an effort to improve quality for patients with ESRD. Our aim was to use our registry to assess rates of peritonitis, hospital stays, and technique survival, and to identify predictors of those outcomes.

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METHODS

KAISER PERMANENTE

Kaiser Permanente Southern California (KPSC) is a large, integrated health maintenance organization that serves approximately 3.5 million members in southern California. It comprises 14 separate medical centers and their affiliated clinics. Most PD patients are managed at 1 of 8 separate internal PD programs. A small proportion of PD patients are managed at contracted PD units outside of the KPSC system.

ESRD REGISTRY

Data for all KPSC patients on dialysis are reported into a central ESRD registry after initiation. Data include baseline patient demographics, cause of ESRD, ESRD start date, modality type, and date of death. Modality changes, modality-specific quality data (see the next subsection), and KPSC system membership status are tracked prospectively and reported into the registry. The latter data ensure that periods of loss to follow-up are known.

We used the ESRD registry to identify all patients who initiated PD between 1 January 2001 and 31 December 2010 (the study period). Inclusion criteria for our study were age greater than 18 years and at least 1 year of KPSC membership at initiation of PD.

PD PATIENT TRACKING

The ESRD registry prospectively captures pertinent data about PD patients. A report is completed by the PD nursing staff monthly for all PD patients, including those managed at a contracted facility. The data reported include modality, episodes of peritonitis, hospital admissions, ESRD-related hospital admissions, length of stay (hospital days), medication use, and laboratory data. "Modality" is defined as the modality of record 90 days after initiation of PD: either continuous ambulatory PD (CAPD) or automated PD (APD). Hospital admissions related to ESRD are defined as admissions for peritonitis, heart failure, hyperkalemia, or catheter infection or malfunction. Recurrent peritonitis is defined as a recurrence of peritonitis within 4 weeks of the original episode.

USRDS DATABASE

Data on patient demographics, peritonitis rates, and hospital days were obtained from both the 2010 and the 2011 ADR. Using the 2005 USRDS ESRD cohort

as a reference, we compared our registry data with the USRDS data, adjusting for age, sex, race, and cause of ESRD (model-based adjustment as described in the USRDS ADR).

CHARLSON COMORBIDITY INDEX

A Charlson comorbidity index (CCI) score was calculated for all study patients using baseline medical diagnoses (10,11). The CCI weights a number of major conditions, and the CCI score represents the burden of comorbid disease.

GEOCODING DATABASE

Geocoding is a method by which patient characteristics can be estimated based on neighborhood of residence. Although geocoding cannot provide exact patient characteristics, it is reliable when applied to a group or population (12,13). The method was previously validated within the northern California KP health care system (14).

Education and income level for all PD patients were obtained from the KPSC geocoding database. The database contains aggregate income and education data for KPSC members and is obtained from the US Census Bureau once every decade. Data for KP members were obtained using the census identification at block, block group, tract, county, or ZIP code level, using the most detailed level available (block being the most detailed level). Home addresses for PD patients were geocoded and linked to the 2000 Census database, which includes socioeconomic characteristics. The 2000 Census database also contains the highest level of education attained for all individuals in a given census unit who were at least 25 years of age at the time of the census. Family income was available for the census year, defined as the income of family members and persons related to the householder living within a given geocode. A family consisted of at least 2 members (1 householder and 1 family member or related individual). The distributions of educational attainment and family income were obtained for residents within the census unit based on the PD patient's home address.

ANALYSIS

Data from the registry were used to calculate annual peritonitis rates and hospital days. Peritonitis rates were calculated by dividing episodes of peritonitis per year by the number of patient-years at risk. Hospital days were calculated by dividing hospital days per year

by patient-years at risk. Emergency room visits without admission did not count as hospital days, and the minimum length of stay was 1 day. Our methods for calculation of peritonitis rates and hospital days were similar to those described in the USRDS ADR (Volume 2, *ESRD*, Analytical methods).

Technique survival curves were created using data from the registry. Patients were censored from the technique survival analyses at the earliest date of any of transplantation, recovered renal function, study end, loss of KPSC coverage, or death. Patients who temporarily transitioned to hemodialysis were allowed up to 120 days off PD, after which they were deemed technique failures. The log-rank test was used to compare technique survival by patient strata.

Technique survival was also calculated allowing for competing risks. The event of interest was termination of PD. The competing risks were a change to hemodialysis, death, transplantation, and recovery of renal function, or loss of KPSC coverage.

Poisson models using robust error estimation were applied to determine the relative risk (RR) of peritonitis and of number of hospital days for the PD population. Cox proportional hazards models were run to determine whether age at first PD start and dialysis vintage (continuous variables) were associated with technique survival. The log-rank test was used to determine whether categorical variables were associated with technique survival. All analyses were performed using the SAS software application (version 9.2: SAS Institute, Cary, NC, USA).

RESULTS

During the study period, 1710 patients initiated PD, of whom 1378 met the inclusion criteria. Table 1 lists patient demographics at PD initiation. Nearly two thirds of patients (62.6%) used PD as their first dialysis modality. The median size of the 8 separate PD programs was 42 patients per year (range: 15 – 115 patients). Table 2 shows the number of patients initiating PD during the study period by calendar year. Approximately 12% of all patients who initiated any type of dialysis during the study period began with PD. Of all PD patients, 10% underwent renal transplantation during the study period. Table 2 also shows episodes of peritonitis and hospital admissions during the study period.

Technique survival was 83% and 63% at 1 and 2 years respectively for all PD patients. Technique survival is plotted for all patients in Figure 1. Technique survival at 1 and 2 years was, respectively, 83% and 61% for CAPD patients and 86% and 68% for APD patients ($p = 0.04$

TABLE 1
Baseline Patient Demographics

Variable	Value
Patients (<i>n</i>)	1378
Mean age (years)	56.5±14.0
Sex [<i>n</i> (%) men]	741 (53.8)
With diabetes [<i>n</i> (%)]	830 (60)
Dialysis vintage in years	
Median	0
Range	0.0–0.3
CCI score	
Median	5.0
IQR	3.0–7.0
Race [<i>n</i> (% PD, % KP ESRD)]	
White	452 (32.8, 37.1)
Hispanic	422 (30.6, 27.8)
African American	272 (19.7, 21.2)
Asian/Pacific Islander	181 (13.1, 8.8)
Other/unknown	51 (3.7, 5.0)
Modality [<i>n</i> (%)]	
CAPD	830 (60.2)
APD	547 (39.7)
Missing	1 (0.1)
Cause of ESRD [<i>n</i> (%)]	
Diabetes mellitus	642 (47.3)
Hypertension	279 (20.5)
Glomerulonephritis	225 (16.6)
Other	102 (7.5)
Cystic kidney disease	55 (4.1)
Unknown	33 (2.4)
Other urologic	22 (1.6)
Annual family income [<i>n</i> (%)]	
\$0–\$25,000	53 (3.8)
\$25,001–\$40,000	233 (16.9)
\$40,001–\$60,000	415 (30.1)
\$60,001–\$80,000	354 (25.7)
>\$80,000	323 (23.4)
With HS degree or higher [<i>n</i> (%)]	
<50%	210 (15.2)
50%–75%	435 (31.6)
>75%	733 (53.2)
English-speaking [<i>n</i> (%)]	1212 (88)

CCI = Charlson comorbidity index; IQR = interquartile range; PD = peritoneal dialysis; KP = Kaiser Permanente; ESRD = end-stage renal disease; CAPD = continuous ambulatory peritoneal dialysis; APD = automated peritoneal dialysis; HS = high school.

for both years). Age and primary cause of ESRD were associated with technique survival in our study, but sex, race, dialysis vintage, and CCI score were not. Every 10-year increase in baseline age was associated with a 6% increase in technique failure ($p = 0.02$). Technique

TABLE 2
Hospitalizations and Peritonitis in Patients Incident to Peritoneal Dialysis by Year

Year	Patients (n)		Percentage (%) of total with			
	Total ^a	Incident	Any	Peritonitis Recurrent	Hospital admission Any	ESRD-related
2001	91	91	16.5	1.1	14.3	11.0
2002	224	148	15.2	0.5	17.4	3.1
2003	295	136	26.8	0.7	30.5	11.5
2004	333	126	14.4	2.7	27.3	11.1
2005	387	118	18.1	0.8	26.1	12.7
2006	447	150	20.1	1.6	23.7	10.5
2007	506	154	20.4	1.8	27.5	8.9
2008	518	125	18.9	1.4	29.9	8.5
2009	617	172	20.4	0.5	26.4	8.4
2010	627	137	15.0	1.0	22.2	6.0

^a Patients included in the peritoneal dialysis registry by calendar year ($n = 1357$; data unavailable for 21 patients).

Figure 1 — Technique survival for all study patients ($n = 1378$), censored for transplantation, death, loss of membership in the Southern California Permanente Medical Group, and renal recovery.

survival at 2 years was 50%, 59%, 65%, 68%, and 73% for patients with ESRD attributable to cystic kidney disease, diabetes mellitus, glomerulonephritis, hypertension, and other causes respectively ($p = 0.004$). Technique survival at 2 years was 61% for patients who experienced at least 1 episode of peritonitis and 72% for patients with no history of peritonitis ($p < 0.0001$). Education, income level, and language concordance were not associated with technique survival. Figure 2 shows technique survival plotted using a competing risks model. In the model, survival was 82% and 59% overall at 1 and 2 years respectively.

Figure 2 — Technique survival by competing risks. HD = hemodialysis.

Figure 3 compares annual peritonitis rates between the KPSC and USRDS populations. The adjusted peritonitis rate declined to 0.37 per patient-year in 2010 (1 episode in 32.4 patient-months) from 0.54 per patient-year in 2001 (1 episode in 22.2 patient-months), $p = 0.003$. Figure 4 compares hospital days (per patient-year at risk) between the KPSC and USRDS populations. Hospital days declined to 2.9 days per patient-year in 2010 from 4.4 days per patient-year in 2001 ($p = 0.01$).

Tables 3 and 4 show the results of Poisson models for predictors of peritonitis and of hospital days respectively. Female patients were less likely than male patients to develop peritonitis [RR: 0.85; 95% confidence interval

Figure 3 — Adjusted peritonitis rate by year. USRDS = US Renal Data System; KP = Southern California Permanente Medical Group; CI = confidence interval.

Figure 4 — Adjusted hospital-day rate by year. USRDS = US Renal Data System; KP = Southern California Permanente Medical Group; CI = confidence interval.

(CI): 0.74 to 0.98; $p = 0.02$]. Patients from areas in which more than 75% of the population had a high school degree or better were less likely than those from areas in which 50% or fewer had a high school degree to experience peritonitis (RR: 0.77; 95% CI: 0.60 to 0.98; $p = 0.04$). Compared with white race, Asian or Pacific Islander race was associated with fewer hospital days (RR: 0.55; 95% CI: 0.43 to 0.79; $p = 0.001$), and greater dialysis vintage was associated with an additional hospital day

TABLE 3
Predictors of Peritonitis by Poisson Modeling

Variable	RR	95% CI	<i>p</i> Value
Age	1.00	0.99 to 1.01	0.96
Sex (female)	0.85	0.74 to 0.98	0.02
Vintage (years)	1.01	0.98 to 1.05	0.48
CCI score	1.03	1.00 to 1.06	0.06
Race			
African American	1.05	0.87 to 1.27	0.60
Hispanic	0.87	0.71 to 1.07	0.19
Asian/Pacific Islander	0.81	0.64 to 1.03	0.09
Other/unknown	0.94	0.59 to 1.52	0.10
White		Reference	
Modality			
APD	0.99	0.86 to 1.15	0.95
CAPD		Reference	
Cause of ESRD			
Cystic kidney disease	1.00	0.68 to 1.46	0.99
Glomerulonephritis	0.82	0.67 to 1.01	0.06
Hypertension	0.87	0.72 to 1.05	0.13
Other	0.77	0.59 to 1.00	0.05
Diabetes mellitus		Reference	
Income level per year			
\$0–\$25,000		Reference	
\$25,001–\$40,000	0.90	0.59 to 1.37	0.61
\$40,001–\$60,000	0.88	0.58 to 1.32	0.52
\$60,001–\$80,000	0.80	0.52 to 1.23	0.31
>\$80,000	0.87	0.55 to 1.35	0.52
With HS education or higher			
<50%		Reference	
50% to 75%	0.92	0.74 to 1.14	0.43
>75%	0.77	0.61 to 0.98	0.04

RR = relative risk; CI = confidence interval; CCI = Charlson comorbidity index; APD = automated peritoneal dialysis; CAPD = continuous ambulatory peritoneal dialysis; ESRD = end-stage renal disease; HS = high school.

(RR: 1.11; 95% CI: 1.04 to 1.18; $p = 0.002$). Compared with patients whose ESRD was attributable to diabetes, those whose ESRD was caused by glomerulonephritis or hypertension were less likely to have an extra hospital day per patient-year ($p = 0.006$ and $p = 0.002$ respectively, Table 4). Score on the CCI was associated with an extra hospital day per patient-year (RR: 1.06; 95% CI: 1.02 to 1.20; $p = 0.002$).

DISCUSSION

The present report details outcomes for one of the largest cohorts of PD patients in the United States. Our study is unique in that it reflects outcomes attained in a structured setting that includes early modality

TABLE 4
Predictors of Hospital Days by Poisson Modeling

Variable	RR	95% CI	<i>p</i> Value
Age	1.01	1.00 to 1.02	0.07
Sex (female)	1.10	0.91 to 1.33	0.32
Vintage (years)	1.11	1.04 to 1.18	0.002
CCI score	1.06	1.02 to 1.09	0.003
Race			
African American	0.83	0.64 to 1.07	0.15
Hispanic	0.82	0.63 to 1.05	0.11
Asian/Pacific Islander	0.55	0.39 to 0.79	0.001
Other/unknown	2.82	1.46 to 5.44	0.002
White	Reference		
Modality			
APD	0.99	0.83 to 1.19	0.93
CAPD	Reference		
Cause of ESRD			
Cystic kidney disease	0.46	0.21 to 1.00	0.05
Glomerulonephritis	0.58	0.43 to 0.79	0.0006
Hypertension	0.69	0.55 to 0.87	0.002
Other	0.73	0.51 to 1.04	0.08
Diabetes mellitus	Reference		
Income level per year			
\$0–\$25,000	Reference		
\$25,001–\$40,000	0.69	0.35 to 1.35	0.28
\$40,001–\$60,000	0.65	0.33 to 1.29	0.22
\$60,001–\$80,000	0.56	0.28 to 1.12	0.10
>\$80,000	0.63	0.31 to 1.30	0.21
With HS education or higher			
<50%	Reference		
50% to 75%	1.27	0.90 to 1.78	0.17
>75%	1.18	0.83 to 1.69	0.36

RR = relative risk; CI = confidence interval; CCI = Charlson comorbidity index; APD = automated peritoneal dialysis; CAPD = continuous ambulatory peritoneal dialysis; ESRD = end-stage renal disease; HS = high school.

education, close monitoring of pre-ESRD patients, and quality review processes to ensure positive outcomes for all ESRD patients. Our patient population was diverse; patients of white race represented only about one third of the entire cohort. Data presented were captured over the span of a decade, and thus the follow-up time was lengthy for most patients.

Over the study period, patients in our registry experienced a relatively lower rate of peritonitis and fewer hospital days than did the USRDS population. In evaluating factors predictive of peritonitis and hospital days, we found that patients from neighborhoods with higher education levels experienced less peritonitis, but that other markers of socio-economic status were not associated with peritonitis or hospital days. Our study

cohort consisted of a racially diverse population, but we found no association between race and peritonitis or technique failure. Those findings underscore the likelihood that our outcomes reflect recruitment and retention efforts among KP patients rather than higher socio-economic status.

Peritonitis rates in our study were comparable to those published by Mujais (15), who reported a rate of 0.37 episodes per patient–year at risk. The Mujais results may reflect a larger center size and greater experience, because patients from smaller PD programs were excluded. The KPSC PD centers were also large (median: 42 patients per patient–year), which does help to explain the low peritonitis rate for our study patients.

Our clinic policies and procedures may also play a role in the prevention of peritonitis. The PD clinics within KP are staffed to maintain a patient:nurse ratio of no more than 15:1, and each clinic is overseen by a nurse–manager. The staffing ratio for patients managed at contracted units is no more than 25:1, although those patients accounted for a small fraction of the overall PD cohort. Educational reinforcement of aseptic technique, prophylactic exit-site care, and quality review processes are all standard practices in our PD units. Data are reviewed monthly by individual PD programs as part of our continuous quality improvement program. The continuous quality improvement process is associated with reduced rates of peritonitis and infection, and is advocated by the Kidney Disease Outcomes Quality Initiative guidelines for PD and by the International Society for Peritoneal Dialysis (16–18). Root-cause analysis and re-education of patients by individual PD centers is also a routine practice to prevent future episodes of peritonitis.

Female sex was associated with a lower risk of peritonitis in our study, but age, income level, and CCI score were not (Table 3). Patients from areas in which more than 75% of the neighborhood had a high school degree or better were also less likely to experience peritonitis, according to geocoding data. The relationship between sex and peritonitis might be explained by body mass; the same relationship was observed in a previous report (19). Several other authors have reported that black race is associated with a higher risk of peritonitis in PD patients (20–22). We found no association between race and risk of peritonitis in our patient population. Those findings suggest that education level is a more important predictor of peritonitis than traditional medical risk factors for infection such as diabetes.

Risk factors for hospital days included dialysis vintage, primary cause of ESRD, and CCI score. Compared with white race, Asian or Pacific Islander race was associated with fewer hospital days per year. Age, sex, income, and

education level were not associated with hospital days. In contrast with the peritonitis results, socio-economic status was not associated with hospital days in our study. Traditional risk factors such as age and diabetic ESRD appeared to be far more predictive of hospital days. Hospital admissions did not trend downward over the study decade, but ESRD-related admissions did appear to decline. The latter finding suggests that comorbid conditions are now the major reason for hospital days.

Peritonitis and hospital stays were limited to a small proportion of PD patients in our study, as demonstrated in Table 2. Our findings are consistent with the report by Mujais, who also observed a “clustering” phenomenon of peritonitis, with most cases limited to a small number of patients. That point is important to discuss with pre-dialysis patients, who often fear negative outcomes, especially peritonitis.

According to the 2011 USRDS ADR, 45.1% of all patients incident to PD during the years 2005–2007 remained on PD for 2 years. The 2-year technique survival for our study patients was 63%. Peritonitis was strongly associated with technique failure in our patients, a finding that has been confirmed by others (23–25). The low peritonitis rates seen in our study help to explain the high technique survival we observed. We also observed higher 2-year technique survival in APD patients, but that finding did not appear to be the result of a lower peritonitis rate in APD patients. Patient “burnout” may explain the lower technique survival seen in CAPD patients.

Socio-economic status was not associated with technique survival in our PD patients. Chidambaram *et al.* (26) found that a low neighborhood education level was a strong predictor of technique failure in Canadian PD patients. Among US PD patients, Shen *et al.* (27) found no effect of education level on technique survival, although black race and Medicaid status were associated with lower rates of technique survival in their study. Other authors have not found an association between socio-economic status and outcomes such as peritonitis rate or patient survival (28,29).

The present report details outcomes for a large cohort of PD patients cared for by KPSC over a decade. Our findings may help both pre-ESRD patients and clinicians during the modality selection process. Peritoneal dialysis should not be reserved for younger, healthier, more affluent patients. Rigorous education and re-education of PD patients may improve outcomes for patients with lower levels of education.

Our study has several limitations, including the exclusion from the analyses of 332 patients with less than 1 year of KP membership at the initiation of PD. Those patients were excluded so that comorbid conditions

could be accurately determined. Another limitation is the use of geocoding as a proxy to characterize the socio-economic status of PD patients. Although geocoding has been validated for that purpose, the data presented do not represent actual socio-economic data. Rather, socio-economic data was crudely extrapolated based on the 2000 US Census. Lastly, the authors were unable to obtain reliable data regarding residual renal function, an important predictor of outcomes in PD patients, especially technique survival.

Our outcomes are encouraging, demonstrating relatively low peritonitis rates, fewer hospital days, and longer technique survival than in the USRDS population over the same period. Additional information now reported into the registry about PD patients will permit more extensive studies in the future. We anticipate using the registry for future research in an effort to improve outcomes and increase PD utilization.

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