NEIGHBORHOOD LOCATION, RURALITY, GEOGRAPHY, AND OUTCOMES OF PERITONEAL DIALYSIS PATIENTS IN THE UNITED STATES

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◆ **Background:** The adjusted 5-year survival for dialysis patients in the United States is 33%–35%, and patients treated with peritoneal dialysis (PD) have a high risk of transfer to hemodialysis (HD). No data are available on the effect of neighborhood characteristics or regional differences on the outcomes of PD patients in the United States.

◆ **Methods:** We analyzed the relationships of selected patient demographics, socio-economic characteristics of the dialysis unit's neighborhood, "rurality," and geographic location with transfer to HD and with a composite outcome of transfer to HD or death, for all PD patients in the United States who, between 2004 and 2009, used supplies manufactured by Baxter Healthcare ($n = 58\,700$).

◆ **Results:** Over a median follow-up of 18.7 months, 29% of patients transferred to HD (median time to HD transfer: 49 months), and 54% reached the composite outcome. More than 20% of the events occurred within the first 90 days of PD start. The risk for each of the study outcomes was higher for patients who had received any previous treatment with HD, for those treated in units located in areas with a higher proportion of black residents, and for those living in remote rural areas. Furthermore, the risk for reaching either of the study outcomes was consistently lower for patients treated in units located in California, Alaska, Hawaii, Guam, the Mariana Islands, and American Samoa.

◆ **Conclusions:** We observed significant regional differences in the outcomes of PD patients in the United States that have not previously been reported. Understanding the differences in clinical practice that underlie these regional differences might help to further improve PD outcomes.

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In 2009, more than a half million patients with end-stage renal disease (ESRD) resided in the United States, a population that is anticipated to continue to grow—albeit at a slower rate than previously estimated (1). Because of the limited availability of organ donors and the not-so-infrequent medical ineligibility of patients for renal transplantation, nearly all ESRD patients undergo dialysis treatment for prolonged periods of time (1).

Most dialysis patients are treated with in-center hemodialysis (HD); of the patients who choose to dialyze at home, nearly all are treated with peritoneal dialysis (PD) (1). Since the early 1990s, the survival of dialysis patients in the United States has gradually improved (1). Improvements in the survival of PD patients have outpaced those observed among patients treated with HD (2). Hence, in the most recent cohorts, no differences are observed in the adjusted survival of patients who begin treatment with in-center HD or with PD (3,4). Moreover, of patients who started treatment with PD between 2002 and 2004, significantly fewer had to transfer to in-center HD than transferred in earlier years (5).

Despite those encouraging trends, several challenges remain. First, the median life expectancy of patients starting dialysis in the United States is only about 38 months, with a 5-year adjusted survival of 33%–35% (4). Second, more than a quarter of PD patients still transfer to HD within the first 18 months (5). Thus, there is a continuing need to identify practice patterns that could further optimize the outcomes of dialysis patients in the United States.

Many studies have examined the relationships of demographic and clinical variables with the outcomes of dialysis patients. There is some evidence to suggest that the locale in which dialysis patients live and receive their care may be important determinants of relevant outcomes such as risk of death, access to renal transplantation, or in the case of PD, transfer to HD (6,7). However, there is a paucity of data on the relationship

between characteristics of the neighborhood in which PD patients receive their care and subsequent outcomes in those patients. We analyzed data for a nationally representative cohort of PD patients treated in the United States between 1 January 2004 and 31 December 2009 ($n = 58\,700$) to test the null hypothesis that, in PD patients, there is no relationship between the risk for death or for transfer to HD (time on therapy) and the socio-economic characteristics of the neighborhood, its rurality, or the geographic location in which care is received.

METHODS

DATA SOURCE

The analysis was performed using de-identified data from the Baxter Healthcare Corporation On-Call system for patients who were treated with PD for any period during 1 January 2004 – 31 December 2009. The On-Call system captures data for all PD patients in the United States who use supplies manufactured by Baxter Healthcare as a part of the home delivery system of dialysis supplies. An analysis based on data from earlier cohorts has previously been reported (8). The information collected for each patient includes age, sex, diabetes status, whether the person is new to dialysis or has been treated with HD for any period of time, and last PD modality (continuous ambulatory or automated PD). Additional information includes the owner of the treating dialysis unit and the zip code for the unit's location. Finally, the system tracks patient outcomes, grouped into these categories: transfer to HD; transplantation; continued treatment with PD, but using supplies from a different manufacturer; and other.

Unit ownership was ascribed based on the definitions of "large" and "small" dialysis organizations used by the US Renal Data System (1). For each patient, a period-prevalent unit census was calculated for that patient's first year of entry into the dataset. The census was obtained by adding the point-prevalent count on 31 December of the year of entry and the patients who started the year in the facility but whose follow-up ended before 31 December, as previously described (5). The dialysis unit zip code was used to identify the ESRD Network (Network 1 – Network 18) in which the patient was being treated. The dialysis unit zip code was also used to link the Baxter Healthcare On-Call data with demographic forecasts for residential zip codes updated for 2009, as provided by Environmental Systems Research Inc. (ESRI). The ESRI projection base comes from data reported by the US Census Bureau in 2000; it incorporates changes and

trends affecting areas for which data are tabulated and which are reported on an annual basis (9). The variables that follow were used to characterize the neighborhood location, at the level of the zip code, of the treating dialysis unit:

- Percentage of the population that is black
- Per-capita income
- Percentage of housing units occupied by owner
- Percentage of people 25 years of age or older with a high school diploma
- Percentage of people 25 years of age or older with a college degree

For each of the variables, data were grouped into quartiles based on their distribution in the general population at the level of the zip codes. The rurality of each dialysis facility was determined by linking facility zip codes with the RUCA (Rural Urban Commuting Area) codes available through the University of Washington (<http://depts.washington.edu/uwruca/ruca-download.php>). Units were grouped into the categories of "urban," "large rural," "small rural," and "remote rural" as previously described by O'Hare *et al.* (10). The facility zip codes were used to group dialysis units into one of the 18 ESRD Networks—administrative units with regulatory oversight over delivery of care—and were used to define geographic location (a detailed description is included in the footnote to Table 1).

Of the 62 948 patients with information in the Baxter Healthcare On-Call system, complete information, including zip code, was available for 58 700 (93%). Those patients constituted the study cohort.

STATISTICAL ANALYSES

Two outcomes were analyzed: transfer to HD, and PD time on therapy (PD-TOT). The PD-TOT was defined as time to transfer to HD or other reasons (predominantly secondary to death), censoring for transfer because of transplantation, or continued treatment with PD but using supplies from a different manufacturer. Analyses determined the dependence of each of the two outcomes with respect to patient-related variables, period-prevalent unit census, socio-economic characteristics of the neighborhood in which the patient received treatment, and geographic location (ESRD Network). To minimize bias from the exclusion of subjects with incomplete information, an additional category of "missing" was created for variables as appropriate. Survival analyses using Cox proportional hazards models were performed to determine the independent predictors of time to each of the two outcomes. All variables listed in Table 1 were included

TABLE 1
Characteristics and Geographic Distribution of the Study Cohort

Characteristic	Cohort period			Overall
	2004–2005	2006–2007	2008–2009	
Sample size (<i>n</i>)	18 107	19 486	21 134	58 727
Age range (%)				
<18 years	3	2	2	2
18–44 years	19	20	21	20
45–64 years	37	40	42	40
65–74 years	17	17	19	18
≥75 years	13	14	15	14
Missing	10	6	2	6
Sex (% men)	55	54	56	55
Diabetes (%)				
Yes	34	34	36	35
No	48	48	46	47
Missing	18	18	19	18
HD before PD start (%)	37	37	39	38
Automated PD (%)	74	77	80	77
Unit ownership (%)				
Large dialysis organization 1	39	39	38	39
Large dialysis organization 2	17	16	12	15
Large dialysis organization 3	1	1	2	2
Small dialysis organization 1	3	3	4	3
Small dialysis organization 2	1	2	3	2
Small dialysis organization 3	2	2	3	2
Others	36	37	38	37
Period prevalent unit census (%)				
<5	4	4	10	6
5–14	21	22	26	23
15–29	32	33	30	32
30–39	14	13	11	12
≥40	29	28	25	27
Black residents in zip codes (%)				
Quartile 1 (<0.2%)	0.5	0.5	0.7	0.6
Quartile 2 (0.2%–1.0%)	7	7	8	7
Quartile 3 (1.0%–6.8%)	37	38	38	38
Quartile 4 (≥6.8%)	56	55	54	55
Per-capita income (%)				
Quartile 1 (<\$18 229)	15	15	15	15
Quartile 2 (\$18 229–\$21 934)	16	16	16	16
Quartile 3 (\$21 394–\$26 468)	27	27	26	27
Quartile 4 (≥\$26 469)	42	43	44	43
Household units occupied by owner (%)				
Quartile 1 (<55%)	57	55	53	55
Quartile 2 (55%–65%)	26	27	27	27
Quartile 3 (65%–73%)	11	12	12	12
Quartile 4 (≥73%)	6	7	8	7
>25 Years of age with high school diploma (%)				
Quartile 1 (<77%)	21	21	21	21
Quartile 2 (77%–85%)	28	28	26	27
Quartile 3 (85%–90%)	21	23	22	22
Quartile 4 (≥90%)	30	29	31	30

TABLE 1 (cont'd.)

Characteristic	Cohort period			Overall
	2004–2005	2006–2007	2008–2009	
>25 Years of age with college degree (%)				
Quartile 1 (<18%)	8	8	7	8
Quartile 2 (18%–24%)	13	12	13	13
Quartile 3 (24%–34%)	30	30	30	30
Quartile 4 (≥34%)	49	50	51	50
Rurality (%)				
Urban	91	92	91	91
Large rural	7	7	7	7
Small rural	1	1	1	1
Remote rural	0.4	0.4	0.3	0.3
ESRD network (%) ^a				
1	4	4	3	4
2	5	5	4	5
3	2	2	2	2
4	4	3	4	4
5	6	5	5	6
6	8	10	9	9
7	5	6	7	6
8	5	6	5	6
9	9	8	8	8
10	6	5	5	5
11	6	6	5	6
12	6	5	6	5
13	4	4	4	4
14	7	7	8	7
15	4	4	5	4
16	6	5	5	5
17	6	7	7	6
18	7	8	9	8

HD = hemodialysis; PD = peritoneal dialysis; ESRD = end-stage renal disease.

^a Network 1: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont; Network 2: New York; Network 3: New Jersey, Puerto Rico, US Virgin Islands; Network 4: Delaware, Pennsylvania; Network 5: District of Columbia, Maryland, Virginia, West Virginia; Network 6: North Carolina, South Carolina, Georgia; Network 7: Florida; Network 8: Alabama, Mississippi, Tennessee; Network 9: Indiana, Kentucky, Ohio; Network 10: Illinois; Network 11: Michigan, Minnesota, North Dakota, South Dakota, Wisconsin; Network 12: Iowa, Kansas, Missouri, Nebraska; Network 13: Arkansas, Louisiana, Oklahoma; Network 14: Texas; Network 15: Arizona, Colorado, New Mexico, Nevada, Utah, Wyoming; Network 16: Alaska, Idaho, Montana, Oregon, Washington; Network 17: Northern California, Hawaii, Guam, Mariana Islands, American Samoa; Network 18: Southern California.

in the adjusted models presented here. All analyses were performed using the SAS statistical software package (version 9.2: SAS, Cary, NC, USA).

RESULTS

PATIENT AND UNIT CHARACTERISTICS AND UNADJUSTED PATIENT OUTCOMES

Table 1 summarizes the characteristics of the patients and of the neighborhoods of the units at which they

received treatment, divided by cohort period. Compared with the general population, PD patients were more likely to receive their care in neighborhoods with a larger proportion of black residents, and where substantially fewer household units were occupied by owners. Furthermore, compared with the general population, more PD patients were treated in neighborhoods with a higher per capita income and a larger proportion of people 25 years of age or older with a college degree. Finally, more than 90% of patients were treated in units located in urban areas.

PREDICTORS OF TRANSFER TO HEMODIALYSIS

Over a median follow-up of 18.7 months, 29% of PD patients transferred to HD (Table 2); the median time to transfer was 49 months. Of the study cohort, 6% transferred to HD within the first 90 days of PD start; hence, 21% of all patients who transferred to HD did so within the first 90 days. The adjusted risk of transfer to HD was higher for people 65 years of age or older, for men, for people with diabetes, and for those who had received any previous HD treatment (Table 3). The adjusted risk was also higher for patients treated in units located in neighborhoods with a higher proportion of black residents or of people with a high school diploma, living in remote rural locations, and living in Network 16 (Table 3). Conversely, the adjusted risk for transfer to HD was lower in children, in patients in whom automated PD was the last treatment modality, in patients treated in units owned by large dialysis organization 1, and in units with a period-prevalent PD patient census of 40 or higher (Table 3). Finally, patients treated in units located in Networks 9, 17, and 18 had a significantly lower adjusted risk of transfer to HD (Table 3).

PREDICTORS OF PD-TOT

Over a median follow-up period of 18.7 months, 54% of patients either transferred to HD or experienced an "other" event (predominantly death); the median time to this composite outcome was 24 months. More than 11% of the study cohort attained the composite outcome within the first 90 days of PD start. Hence, 22% of all patients who either transferred to HD or reached an "other" outcome did so within the first 90 days of PD start. The adjusted risk for reaching this endpoint was higher for people 65 years of age or older, for men, for people with diabetes, and for people who had received

any previous treatment with HD (Table 3). The adjusted risk was also higher for patients treated in units owned by large dialysis organization 2 and for those treated in units located in neighborhoods with a higher proportion of black residents or of people with a high school diploma, in units located in remote rural locations, or in units located in Networks 7 and 13 (Table 3). Conversely, the adjusted risk was lower for people less than 45 years of age in whom automated PD was the last treatment modality, and for people who were treated in units owned by large dialysis organization 1, or in units located in neighborhoods with a higher per capita income or in Networks 15, 17, and 18 (Table 3).

DISCUSSION

It has long been recognized that PD patients change dialysis modality more frequently than HD patients do. However, many of these transfers are potentially preventable. Hence, studies that examine predictors of transfer to HD are invaluable in identifying areas that need to be targeted for further quality improvement. The present analysis, from a contemporary and nationally representative cohort of PD patients in the United States, identifies several predictors of outcomes of PD patients—some of which have neither been studied nor recognized previously:

1. In the United States, more than 1 in 5 adverse outcomes (transfer to HD or "other" event) occurred within 90 days of PD start.
2. Patients who had received any previous treatment with HD experienced significantly worse outcomes.
3. The socio-economic characteristics of the neighborhoods in which the PD patients received their care did not have any meaningful effect on outcomes; the only exception seems to be the worse outcomes for patients

TABLE 2
Outcome of Patients by Cohort Period

Outcome	Cohort period			Overall
	2004–2005	2006–2007	2008–2009	
Median follow-up (months)	18.7	19.0	18.5	18.7
Continued treatment (%)				
With PD	14	27	59	34
With PD using supplies from different manufacturer	1	1	1	1
Transfer to HD (%)	37	33	18	29
Transplantation (%)	17	13	6	12
Other (%)	32	26	17	25

PD = peritoneal dialysis; HD = hemodialysis.

TABLE 3
Summary of Adjusted Technique Survival Analyses with Time to Transfer to Hemodialysis As Outcome and a Composite Outcome of Time to Either Transfer to Hemodialysis or Other Event

Variable	Time to transfer to HD [hazard ratio (95% confidence interval)]	Time to either transfer to HD or other event [hazard ratio (95% confidence interval)]
Age		
<18 Years	0.78 (0.68 to 0.89)	0.80 (0.72 to 0.90)
18 to 44 Years	1.00 (0.95 to 1.04)	0.85 (0.82 to 0.88)
45 to 64 Years	1.00	1.00
65 to 74 Years	1.14 (1.09 to 1.19)	1.41 (1.37 to 1.46)
75+ Years	1.21 (1.15 to 1.27)	1.81 (1.75 to 1.87)
Missing	1.23 (1.15 to 1.30)	1.29 (1.23 to 1.35)
Sex		
Male	1.04 (1.01 to 1.07)	1.03 (1.00 to 1.05)
Female	1.00	1.00
Diabetes		
Yes	1.29 (1.24 to 1.34)	1.32 (1.28 to 1.35)
No	1.00	1.00
Unknown	1.25 (1.19 to 1.30)	1.30 (1.26 to 1.34)
Last PD modality		
CAPD	1.00	1.00
APD	0.58 (0.56 to 0.61)	0.58 (0.57 to 0.60)
Previous HD treatment		
Yes	1.32 (1.28 to 1.36)	1.34 (1.31 to 1.38)
No	1.00	1.00
Unit ownership		
Large dialysis organization 1	0.94 (0.90 to 0.97)	0.96 (0.94 to 0.99)
Large dialysis organization 2	1.04 (0.99 to 1.09)	1.05 (1.02 to 1.09)
Large dialysis organization 3	1.07 (0.94 to 1.21)	0.94 (0.86 to 1.04)
Small dialysis organization 1	0.99 (0.90 to 1.09)	0.94 (0.87 to 1.01)
Small dialysis organization 2	1.00 (0.89 to 1.13)	1.04 (0.96 to 1.14)
Small dialysis organization 3	1.03 (0.93 to 1.15)	1.00 (0.93 to 1.09)
Others	1.00	1.00
Period prevalent unit census		
<5	1.00	1.00
5 to 14	1.03 (0.95 to 1.11)	1.03 (0.97 to 1.09)
15 to 29	0.98 (0.91 to 1.05)	1.02 (0.97 to 1.08)
30 to 39	0.97 (0.89 to 1.05)	1.01 (0.95 to 1.07)
≥40	0.91 (0.84 to 0.98)	1.02 (0.96 to 1.08)
Study cohort		
2004 to 2005	1.00	1.00
2006 to 2007	1.07 (1.03 to 1.11)	1.04 (1.01 to 1.07)
2008 to 2009	1.02 (0.97 to 1.06)	1.08 (1.04 to 1.11)
Black residents in zip codes		
Quartile 1 (<0.2%)	1.00	1.00
Quartile 2 (0.2% to 1.0%)	1.03 (0.98 to 1.08)	1.04 (1.01 to 1.08)
Quartile 3 (1.0% to 6.8%)	1.08 (1.03 to 1.14)	1.06 (1.02 to 1.10)
Quartile 4 (≥6.8%)	1.14 (1.07 to 1.22)	1.06 (1.01 to 1.11)
Per capita income		
Quartile 1 (<\$18 229)	1.00	1.00
Quartile 2 (\$18 229 to \$21 934)	0.98 (0.93 to 1.03)	0.97 (0.93 to 1.01)
Quartile 3 (\$21 394 to \$26 468)	0.94 (0.88 to 1.00)	0.93 (0.89 to 0.98)
Quartile 4 (≥\$26 469)	0.94 (0.87 to 1.02)	0.94 (0.89 to 1.00)

TABLE 3 (cont'd.)

Variable	Time to transfer to HD [hazard ratio (95% confidence interval)]	Time to either transfer to HD or other event [hazard ratio (95% confidence interval)]
Household units occupied by owner ^a		
Quartile 1 (<55%)	1.00	1.00
Quartile 2 (55% to 65%)	0.97 (0.93 to 1.01)	1.01 (0.98 to 1.05)
Quartile 3 (65% to 73%)	0.98 (0.93 to 1.03)	1.02 (0.98 to 1.07)
Quartile 4 (≥73%)	0.99 (0.94 to 1.05)	1.03 (0.99 to 1.07)
>25 Years with high school diploma		
Quartile 1 (<77%)	1.00	1.00
Quartile 2 (77% to 85%)	1.06 (1.01 to 1.12)	1.04 (1.00 to 1.08)
Quartile 3 (85% to 90%)	1.06 (0.98 to 1.13)	1.04 (0.99 to 1.10)
Quartile 4 (≥90%)	1.12 (1.02 to 1.21)	1.10 (1.03 to 1.17)
>25 Years with college degree		
Quartile 1 (<18%)	1.00	1.00
Quartile 2 (18% to 24%)	1.04 (0.98 to 1.09)	1.03 (0.99 to 1.07)
Quartile 3 (24% to 34%)	1.05 (0.98 to 1.12)	1.02 (0.97 to 1.07)
Quartile 4 (≥34%)	1.02 (0.93 to 1.11)	0.98 (0.92 to 1.04)
Rurality		
Urban	1.00	1.00
Large rural	1.00 (0.93 to 1.06)	1.04 (0.99 to 1.09)
Small rural	1.01 (0.86 to 1.19)	1.01 (0.90 to 1.13)
Remote rural	1.33 (1.05 to 1.69)	1.23 (1.02 to 1.47)
ESRD network ^a		
1	0.91 (0.82 to 1.01)	1.06 (0.99 to 1.14)
2	0.94 (0.86 to 1.03)	0.94 (0.88 to 1.01)
3	1.05 (0.93 to 1.19)	1.05 (0.95 to 1.15)
4	1.02 (0.93 to 1.13)	1.06 (0.98 to 1.14)
5	0.93 (0.85 to 1.01)	1.04 (0.98 to 1.11)
6	1.00	1.00
7	1.06 (0.98 to 1.15)	1.06 (1.00 to 1.13)
8	1.00 (0.92 to 1.08)	1.03 (0.97 to 1.09)
9	0.92 (0.85 to 0.99)	0.98 (0.92 to 1.04)
10	0.93 (0.86 to 1.02)	1.05 (0.98 to 1.12)
11	0.95 (0.87 to 1.04)	1.03 (0.97 to 1.10)
12	0.99 (0.91 to 1.08)	1.04 (0.98 to 1.11)
13	1.07 (0.98 to 1.18)	1.10 (1.03 to 1.18)
14	1.00 (0.92 to 1.09)	0.98 (0.92 to 1.04)
15	1.05 (0.95 to 1.15)	0.91 (0.85 to 0.98)
16	1.12 (1.02 to 1.23)	1.06 (0.99 to 1.13)
17	0.86 (0.79 to 0.94)	0.82 (0.77 to 0.88)
18	0.86 (0.79 to 0.94)	0.79 (0.74 to 0.85)

HD = hemodialysis; PD = peritoneal dialysis; CAPD = continuous ambulatory peritoneal dialysis; APD = automated peritoneal dialysis; ESRD = end-stage renal disease.

^a Network 1: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont; Network 2: New York; Network 3: New Jersey, Puerto Rico, US Virgin Islands; Network 4: Delaware, Pennsylvania; Network 5: District of Columbia, Maryland, Virginia, West Virginia; Network 6: North Carolina, South Carolina, Georgia; Network 7: Florida; Network 8: Alabama, Mississippi, Tennessee; Network 9: Indiana, Kentucky, Ohio; Network 10: Illinois; Network 11: Michigan, Minnesota, North Dakota, South Dakota, Wisconsin; Network 12: Iowa, Kansas, Missouri, Nebraska; Network 13: Arkansas, Louisiana, Oklahoma; Network 14: Texas; Network 15: Arizona, Colorado, New Mexico, Nevada, Utah, Wyoming; Network 16: Alaska, Idaho, Montana, Oregon, Washington; Network 17: Northern California, Hawaii, Guam, Mariana Islands, American Samoa; Network 18: Southern California.

treated in neighborhoods with a larger proportion of black residents.

4. Patients treated in units located in remote rural areas seem to have worse outcomes.
5. Patients in Network 17 and 18 (California, Alaska, Guam, Hawaii, the Mariana Islands, and American Samoa) consistently have better outcomes than those observed in other parts of the country.

Our study also validates some important findings previously reported: older patients, those with diabetes mellitus, and those treated in units with fewer PD patients have a higher risk for adverse outcomes.

To our knowledge, this study is the first to demonstrate that, in the United States, 1 in 5 of all PD patients who transfer to HD or who die, do so within 90 days of therapy start. The observed higher risk for adverse outcomes in the first 90 days occurred regardless of dialysis vintage. Previous studies that have examined the outcomes of PD patients in the United States have frequently excluded data from the first 90 days (5,8). Our study indicates that exclusion of the first 90 days would lead to an underestimation of the risk of adverse outcomes. Moreover, our findings are consistent with two recent reports from Europe. In a study from Switzerland, 40% of all patients who dropped out from PD did so within the first 6 months (11). Similarly, 13%–17% of all transfers to HD or deaths among PD patients enrolled in the Netherlands Cooperative Study on the Adequacy of Dialysis (NECOSAD) occurred within the first 3 months of therapy (12). Those findings are also consistent with studies from the United States that show a higher risk for death within the first few months of dialysis start (HD or PD)—both for new patients and for those who restart dialysis after a failed renal allograft (13,14). Detailed analysis of data from the NECOSAD study demonstrated that, although infectious complications remained the most common reason for transfer to HD, catheter-related problems accounted for a disproportionately larger share of transfers during the first 12 months (12). That finding suggests that close attention to surgical technique at the time of PD catheter placement and to early institution of practices that reduce the risk for infection may minimize the higher early risk seen in PD patients.

More than one third of patients who start PD in the United States have previously received treatment with HD; consistent with earlier reports, those patients had worse outcomes (8,15). Patients on PD who have previously received HD treatment potentially belong to one of two categories. Many of these patients are likely to be people who have received inadequate pre-dialysis care or modality education, and who have initiated emergent

HD pending transfer to PD. Inadequate pre-dialysis care has been associated with poor outcomes after initiation of dialysis (16). Furthermore, PD patients who have been treated with HD for even a short period of time have a more rapid loss of residual renal function—an important determinant of patient outcome (17). Alternatively, some of these patients are those in whom HD is no longer possible (through lack of vascular access, for instance) or desirable (for example, in the setting of hemodynamic instability). In a recent analysis, such patients also have poorer outcomes when treated with PD (18). Efforts that enhance timely referral of patients to nephrologists and that support early modality education may reduce the need for temporary HD in patients who choose PD as their treatment modality. Whether such an emphasis will lead to improvement in outcomes of PD patients remains speculative.

Our study also demonstrates that neither the economic characteristics (per-capita income or percentage of household units occupied by owner) nor the educational attainment (percentage of people 25 years of age or older with a high school diploma or college degree) of the neighborhood has either a large or a consistent effect on any outcome. To our knowledge, this study is the first that has examined the association of neighborhood characteristics with outcomes in PD patients. Our findings are consistent with a recent report that was unable to find any association of neighborhood income with outcomes in patients treated with HD (19). Together, these studies suggest that universal insurance coverage and access to care associated with a diagnosis of ESRD may mitigate the adverse effects of poverty and limited educational attainment on health-related patient outcomes. Furthermore, our findings suggest that a home dialysis modality such as PD may be successfully undertaken by patients across income and educational strata.

A higher risk for technique failure, but a lower risk for death has previously been reported for black patients treated with PD (5,20). However, in the present analysis, patients treated in units located in neighborhoods with a larger proportion of black residents had both a higher risk of transfer to HD and of reaching the composite outcome. This higher risk was not attributable to the income or educational attainment of the population. Our findings of a higher risk for death for patients treated in units located in neighborhoods with a larger proportion of black residents are consistent with a previous report that examined the same question in populations in which the overwhelming majority of patients were treated with HD (6). In that study, patients treated in units located in neighborhoods with a larger proportion of black residents were less likely to meet clinical performance targets (6).

Furthermore, residence in a black-majority neighborhood had a greater negative impact on the outcomes of white patients (6). Neither the previous nor the present study was able to ascertain why ESRD patients treated in units in neighborhoods with a larger proportion of black residents have poorer outcomes. This question should be explored in the future.

Although patients treated in units in remote rural areas had a significantly and consistently higher risk of transfer to HD and of reaching the composite outcome, the outcomes of patients treated in units located in small rural areas were no different from those observed for units in urban areas. Studies to date indicate that substantially fewer units in small and remote rural locations in the United States offer support for PD (10,21). Based on rural residence, disparities in the outcomes of patients having a variety of chronic diseases such as asthma and HIV have been reported from the United States in the past. However, to our knowledge, the association of rural residence with outcomes in PD patients in the United States has heretofore not been addressed. In a study from Canada, PD patients living in remote areas had a lower risk for transfer to HD, but a higher risk for death (7). The reason why residence in remote areas is associated with better technique survival in Canada, but worse in the United States, is unclear. Longer driving times have been associated with a higher risk for death in HD patients (22). However, in a study that included subjects treated overwhelmingly with HD, a higher risk for death with remote rural residence was seen only among Hispanic white patients (10). Future studies need to examine the reasons that limit the availability of home dialysis in remote rural locations, and the access-to-care and practice patterns that may lead to poorer outcomes for patients regardless of dialysis modality. An understanding of those issues would be important to reduce health care disparities arising from rural residence.

We also observed substantial geographic variations, the most consistent observation being a better outcome for patients treated in Networks 17 and 18 (California, Alaska, Hawaii, Guam, the Mariana Islands, and American Samoa). The proportion of dialysis patients treated with PD in each of those Networks is higher than the national average; however, there was no consistent association between PD use in a Network and patient outcomes. For example, the hazard for transfer to HD was highest for patients treated in Network 16—the Network with the highest PD uptake. By contrast, even though PD uptake in Network 15 was below the national average, the risk for the composite outcome was significantly lower. It is likely that differences in either unmeasured patient characteristics or practice patterns underlie the observed

geographic differences in outcomes. Understanding differences in clinical practice patterns that lead to consistently better outcomes in some parts of the country has the potential to further improve the outcome of PD patients. Finally, our study confirms the observation of lower risk of transfer to HD for patients treated in units with a larger number of PD patients (5,23,24). Larger units might have the experience and expertise, practice patterns, and clinical resources (such as access to a good surgeon) that smaller units might not have. The relationship between unit census and PD technique survival suggests that many of the transfers of PD patients to HD are potentially preventable.

The greatest strength of the current study is its large sample size and use of a contemporary cohort. Furthermore, the cohort represents about 80% of all patients treated with PD in the United States, and hence it provides considerable external validity. However, the study is not without limitations. First, information on patient demographics and clinical comorbidity was limited. We were therefore unable to determine if any of the associations reported here are potentially confounded by unknown demographic or clinical confounders. Second, variables related to neighborhood, rurality, and ESRD Network refers to the dialysis unit and not to the individual patient. Third, causes of transfer to HD or of death were not available. Fourth, we did not adjust for the “for-profit” status of dialysis units; our analyses were adjusted for unit ownership, and because only one of the three large dialysis organizations is not-for-profit, we did not deem such an adjustment to be necessary.

CONCLUSIONS

This analysis of a large and contemporary cohort of PD patients in the United States allowed us to identify risks within treatment phases, patient subgroups, and facilities that should be specifically targeted using continuous quality improvement programs. Patients are particularly vulnerable during the first 90 days and need intensive management during that period. Older patients and those with diabetes or with experience of previous HD treatment have a worse outcome, and hence deserve special attention. Patients on PD who are treated in units located in neighborhoods with a larger proportion of black residents and in remote rural locations have poorer outcomes, as has previously been reported for HD patients. Thus, such units need to provide greater support for both dialysis modalities to ensure the best patient outcomes. Finally, lessons from units located in Networks 17 and 18 need to be learned so as to identify best demonstrated clinical practices that could be used

in other parts of the country. Hopefully, such efforts would allow for recent improvements in the outcomes of PD patients to be sustained.

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REFERENCES

1. United States Department of Health and Human Services, Public Health Service, National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases, U.S. Renal Data System (USRDS). *2009 Annual Data Report*. 2 vols. Bethesda, MD: USRDS; 2009.
2. Mehrotra R, Kermah D, Fried L, Kalantar-Zadeh K, Khawar O, Norris K, *et al*. Chronic peritoneal dialysis in the United States: declining utilization despite improving outcomes. *J Am Soc Nephrol* 2007; 18:2781–8.
3. Weinhandl ED, Foley RN, Gilbertson DT, Arneson TJ, Snyder JJ, Collins AJ. Propensity-matched mortality comparison of incident hemodialysis and peritoneal dialysis patients. *J Am Soc Nephrol* 2010; 21:499–506.
4. 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.
5. Mehrotra R, Chiu YW, Kalantar-Zadeh K, Vonesh E. The outcomes of continuous ambulatory and automated peritoneal dialysis are similar. *Kidney Int* 2009; 76:97–107.
6. Rodriguez RA, Sen S, Mehta K, Moody-Ayers S, Bacchetti P, O'Hare AM. Geography matters: relationships among urban residential segregation, dialysis facilities, and patient outcomes. *Ann Intern Med* 2007; 146:493–501.
7. Tonelli M, Hemmelgarn B, Culleton B, Klarenbach S, Gill JS, Wiebe N, *et al*. Mortality of Canadians treated by peritoneal dialysis in remote locations. *Kidney Int* 2007; 72:1023–8.
8. Mujais S, Story K. Peritoneal dialysis in the US: evaluation of outcomes in contemporary cohorts. *Kidney Int Suppl* 2006; (103):S21–6.
9. *ESRI Demographic Update Methodology: 2009/2014*. Redlands, CA: Environmental Systems Research Inc.; 2009.
10. O'Hare AM, Johansen KL, Rodriguez RA. Dialysis and kidney transplantation among patients living in rural areas of the United States. *Kidney Int* 2006; 69:343–9.
11. Descoedres B, Koller MT, Garzoni D, Wolff T, Steiger J, Schaub S, *et al*. Contribution of early failure to outcome on peritoneal dialysis. *Perit Dial Int* 2008; 28:259–67.
12. Kolesnyk I, Dekker FW, Boeschoten EW, Krediet RT. Time-dependent reasons for peritoneal dialysis technique failure and mortality. *Perit Dial Int* 2010; 30:170–7.
13. Gill JS, Rose C, Pereira BJ, Tonelli M. The importance of transitions between dialysis and transplantation in the care of end-stage renal disease patients. *Kidney Int* 2007; 71:442–7.
14. Rao PS, Schaubel DE, Jia X, Li S, Port FK, Saran R. Survival on dialysis post-kidney transplant failure: results from the Scientific Registry of Transplant Recipients. *Am J Kidney Dis* 2007; 49:294–300.
15. 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.
16. Hasegawa T, Bragg-Gresham JL, Yamazaki S, Fukuhara S, Akizawa T, Kleophas W, *et al*. Greater first-year survival on hemodialysis in facilities in which patients are provided earlier and more frequent pre-nephrology visits. *Clin J Am Soc Nephrol* 2009; 4:595–602.
17. Kim DJ, Park JA, Huh W, Kim YG, Oh HY. The effect of hemodialysis during break-in period on residual renal function in CAPD patients. *Perit Dial Int* 2000; 20:784–5.
18. Portolés J, Del Peso G, Fernández-Reyes MJ, Bajo MA, López-Sánchez P. Previous comorbidity and lack of patient free choice of technique predict early mortality in peritoneal dialysis. *Perit Dial Int* 2009; 29:150–7.
19. Eisenstein EL, Sun JL, Anstrom KJ, Stafford JA, Szczech LA, Muhlbaier LH, *et al*. Do income level and race influence survival in patients receiving hemodialysis? *Am J Med* 2009; 122:170–80.
20. Jaar BG, Plantinga LC, Crews DC, Fink NE, Hebah N, *et al*. Timing, causes, predictors and prognosis of switching from peritoneal dialysis to hemodialysis: a prospective study. *BMC Nephrol* 2009; 10:3.
21. Walker DR, Inglese GW, Sloand JA, Just PM. Dialysis facility and patient characteristics associated with utilization of home dialysis. *Clin J Am Soc Nephrol* 2010; 5:1649–54.
22. Moist LM, Bragg-Gresham JL, Pisoni RL, Saran R, Akiba T, Jacobson SH, *et al*. Travel time to dialysis as a predictor of health-related quality of life, adherence, and mortality: the Dialysis Outcomes and Practice Patterns Study (DOPPS). *Am J Kidney Dis* 2008; 51:641–50.
23. Mehrotra R, Khawar O, Duong U, Fried L, Norris K, Nissenson A, *et al*. Ownership patterns of dialysis units and peritoneal dialysis in the United States: utilization and outcomes. *Am J Kidney Dis* 2009; 54:289–98.
24. Plantinga LC, Fink NE, Finkelstein FO, Powe NR, Jaar BG. Association of peritoneal dialysis clinic size with clinical outcomes. *Perit Dial Int* 2009; 29:285–91.