Comorbidity and Other Factors Associated With Modality Selection in Incident Dialysis Patients: The CHOICE Study

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• Case-mix factors influence both the selection of dialysis modality and outcomes in end-stage renal disease (ESRD). A detailed characterization of the case-mix differences between peritoneal dialysis (PD) and hemodialysis (HD) patients at the onset of dialysis therapy has not been performed, despite the importance of accounting for baseline differences in future comparisons of outcomes across modality groups. We compared baseline characteristics of 279 PD and 759 HD patients enrolled in the Choices for Healthy Outcomes in Caring for End-Stage Renal Disease (CHOICE) Cohort Study, a prospective study of incident dialysis patients. Comorbidity was assessed using the Index of Coexistent Diseases (ICED), consisting of a medical record review of 19 medical conditions and an observer-based assessment of 11 physical functions. ICED scores range from 0 to 3, with higher levels reflecting more severe comorbidity. Comorbidity was less severe in PD patients than in HD patients: the proportions of patients with ICED 0-1, ICED 2, and ICED 3 were 52%, 26%, and 22%, respectively, among the PD patients and 30%, 39%, and 31%, respectively, among the HD patients ($P < 0.001$). After controlling for all other factors, the differences in comorbidity remained significant. As compared with patients with ICED 0-1, the odds of being treated with PD for patients with ICED 2 and ICED 3 were less (odds ratio [OR] and 95% confidence intervals) 0.31 (0.17 to 0.56) and 0.50 (0.28 to 0.90), respectively. The number and severity of comorbid conditions at the onset of ESRD is significantly lower in patients choosing PD, independent of other factors influencing modality selection. The increased survival of PD patients reported in recent studies may simply reflect the self- or physician-directed selection of healthier patients to PD. Adjustment for case-mix differences in patients treated with PD versus HD is essential to the assessment of the independent effect of the dialysis modality on outcomes.

INDEX WORDS: Case-mix; comorbidity; risk adjustment.

THE CHOICE OF dialysis modality is influenced by patients' social, cultural, economic, and medical circumstances, in addition to patient and physician preferences. As a result, there are fundamental differences between peritoneal dialysis (PD) and hemodialysis (HD) patients even at the onset of dialysis treatment.[1] Some of these factors are well-known predictors of survival and other outcomes.[2-9]

Studies comparing survival of PD and HD patients have reported conflicting results.[10-16] Differences in analytic methods have been postulated to account for some of the differences in results.[11-16] A common limitation of all recent US survival comparisons is the fact that analyses were adjusted for age, diabetes, and the cause of end-stage renal disease (ESRD), but not other comorbid conditions.[11,12,16] Comorbidity data has been collected in Canadian studies,[13-15] but because of well-known differences in PD utilization across countries, these results may not be generalizable to the US. Furthermore, some studies included prevalent populations.[12,16] It is crucial to distinguish between baseline comorbid conditions that influence modality selection and comorbid conditions that develop or worsen due to the dialysis treatment itself. Hence, it is necessary to study these factors at the onset of dialysis therapy, which requires assessment of an inci-

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dent population. Due to the limited case-mix data collected in prior survival comparison studies, it is uncertain whether survival differences from past studies reflect real treatment effects or baseline prognostic differences between PD and HD groups.

The Choices for Healthy Outcomes in Caring for End-Stage Renal Disease (CHOICE) Study is a Patient Outcomes Research Team (PORT) funded by the Agency for Healthcare Research and Quality.[17] One of the projects, the CHOICE Cohort Study, is a prospective study of the relationship of dialysis modality and dose to subsequent outcomes in incident dialysis patients. It includes a comprehensive cross-sectional and longitudinal assessment of comorbid factors in 279 PD and 759 HD patients between 1995 through 1999. The objective of the present report is to compare the baseline characteristics of the PD and HD patients, with special emphasis on comorbid conditions, and to assess the relationship of patient characteristics to modality selection.

METHODS

Study Design and Patient Eligibility

We conducted a cross-sectional analysis of baseline data on incident dialysis patients recruited from 81 dialysis units in 19 states of the US participating in the CHOICE Cohort Study. Patients were eligible if they had started chronic outpatient dialysis during the 3 months before enrollment, were 18 years or older, spoke English or Spanish, and gave informed consent. Home HD and hospice patients were excluded.

Patients were recruited from 79 dialysis units associated with Dialysis Clinic, Inc (DCI), who were willing to participate in the study, and from 2 dialysis units in New Haven, CT associated with Beth Israel Medical Systems that were invited to participate because of their large number of PD patients.

Data Collection

Dialysis modality at baseline was defined as the modality at 4 weeks after enrollment in the study. All forms of PD (continuous ambulatory PD, continuous cycling PD, intermittent cycling PD) were combined as a single category.

Data regarding health behaviors, work history, medical history, preparation for dialysis, social supports, and distance to dialysis unit was collected from the Baseline Form, a self-report questionnaire. Laboratory values for the predialysis serum albumin, creatinine and hematocrit levels, height, and weight were obtained from the Health Care Financing Administration Medical Evidence Report (HCFA Form 2728). To account for differences between laboratories in the measurement of serum albumin, the serum albumin was indexed as the percent from the lower limit of normal for each laboratory according to the following formula: % deviation from lower limit normal = (serum albumin – laboratory lower limit of normal)/laboratory lower limit of normal × 100. To standardize for variation between all laboratories, the standardized serum albumin for each patient was computed as follows: standardized albumin = % deviation × mean lower limit normal (all laboratories) + mean lower limit normal (all laboratories). Glomerular filtration rate (GFR) at the start of dialysis was calculated using a validated Modification of Diet in Renal Disease Study (MDRD) formula that uses the serum creatinine, patient age, race, and gender.[18]

Comorbidity Assessment

Comorbidity, referring to medical conditions other than the primary disease itself,[19] was assessed using the Index of Coexistent Disease (ICED), an instrument that has been used in another multicenter trial of HD patients[20] and has been validated as a predictor of death in smaller dialysis populations.[21,22] The ICED, ranging from 0-3, with 3 as the highest severity level, is a measure of both the presence and severity of different comorbid conditions. It is derived from the peak scores of the Index of Disease Severity (IDS) and the Index of Physical Impairment (IPI) using an algorithm specific to the ICED.[22]

The IDS consists of 19 categories of medical conditions, with 4 levels of severity for each condition. Information for the IDS was abstracted from dialysis unit records, hospital discharge summaries, medication lists, consultation notes, diagnostic imaging, and cardiac imaging reports. These data were collected at each dialysis unit, photocopied, and sent to New England Medical Center for abstraction and scoring. Two dialysis nurses, with prior training and experience in using the ICED, reviewed and scored all charts. The reliability of data abstraction and severity scoring was assessed by comparing peak IDS scores assigned by the nurse reviewer with a physician reviewer (N.V.A.) in 42 charts. Inter-rater reliability, assessed by the κ statistic, was high ($\kappa = 0.72$).[22]

The IPI is an observer-based assessment of 11 functional domains, each with 3 severity levels. The IPI was completed by a local dialysis nurse familiar with the patient's level of functioning, with input from a family member or caregiver, if necessary.

Statistical Analysis

Demographic, socioeconomic, and laboratory factors are described as the mean (SD) for continuous variables and frequency for dichotomous variables. Statistical significance of the differences between modalities was tested using 2-sample t tests for continuous variables and χ^2 tests for categorical variables. Highly skewed variables were summarized as the median and range and compared using nonparametric methods. Differences in the proportions of PD versus HD patients across severity levels of individual IDS and IPI categories were assessed using χ^2 tests for ordered variables (with 1 degree of freedom).

We created a multivariable regression model to identify factors that were associated with the use of PD versus HD at the onset of chronic outpatient dialysis therapy. The CHOICE

Study participants were enrolled from 81 independent clinics across the US. Physicians' preferences, regional and local economic considerations, and other factors at the dialysis clinic level likely contribute to the dialysis modality selection; however, these data were not collected in this study. A hierarchical model, with patients analyzed within clinic clusters, was used to account for the fact that these clinic level factors are more likely to be similar for patients within a clinic than among different clinics. The general form of the random intercept model is as follows: [$yij = a_j + Bx_{ij}$] in which regression models for each clinic have the same slope (B_1), but the intercepts (a_j) vary for each clinic. Thus, the differences between clinics are accounted for in the intercept terms (random effects), and the slope represents the regression coefficients of the patient level variables, which are the same across clinics (fixed effects). These analyses were performed using the GLIMMIX Macro available through SAS Statistical Software, release 8.1 (Cary, NC).

Results are reported as multivariable odds ratios (OR) with 95% confidence intervals for PD versus HD. *P* values are reported for the contribution of the categorical variables to the model and for each level of categorical variables. Variables of interest included demographic factors (age, gender, and race), cause of ESRD, socioeconomic factors (marital status, employment, level of education, social support, insurance, distance from the dialysis unit), health-related behaviors (tobacco use, use of "street" drugs), clinical/laboratory factors (interval from referral to a nephrologist until start of dialysis, body mass index (BMI), serum albumin, serum creatinine, and hematocrit), and comorbidity (ICED level).

In constructing the multivariable model, each variable with a significance level of $P > 0.05$ was removed one at a time, and the model was re-estimated. A likelihood ratio test statistic of ≤ 0.05 indicated that the removed variable contributed significantly to the model, in which case it was retained in the final model. Gender was forced into the final model because of its clinical importance. To control for potential biases inherent in stepwise variable selection, we also fit a model with all variables, and there were no large changes in the individual regression coefficients or the overall fit of the model.

We created 2 interaction terms. We hypothesized that modality use might differ across age groups according to comorbidity. It is plausible that older patients with more severe comorbidity would be less able to perform PD than younger patients with the same level of comorbidity. Secondly, we hypothesized that modality use would differ across ICED groups in patients with diabetes versus other causes of ESRD. In general, as patients become sicker with comorbidity, they are less able to perform self-care, and thus, we would expect that there would be relatively fewer patients treated with PD as comorbidity increased. However, we hypothesized that diabetics with ICED 3 scores would be more likely than nondiabetics with ICED 3 scores to receive PD due to problems of obtaining vascular access, as much of the comorbidity in diabetics relates to atherosclerotic vascular disease. We classified the cause of ESRD as a binary variable (diabetes *v* other causes) and created interaction terms with each of the ICED levels. Interaction terms were tested first in multivariate analysis including only the main effect variables of the interaction terms and were subsequently added to the fully adjusted model. A *P* value of 0.05 was considered significant for the interaction term.

A total of 625 patients (155 PD and 470 HD patients) had complete baseline data. As a sensitivity analysis, we used 2 methods to ensure that the 625 patients, from whom the model was derived, were not systematically different from the rest of the cohort. The covariate with the greatest proportion of missing data was serum albumin, missing for 288 patients: 216 HD patients (28%) and 72 PD patients (26%). It was the sole missing covariate for 236 of the 288 patients. We re-estimated the model by categorizing serum albumin and including the 236 patients with missing values for serum albumin in a separate category. The category corresponding to patients with missing values for serum albumin was not statistically significant, suggesting these patients were not different than the referent group. Also, the estimates of regression coefficients did not change substantially, again supporting the robustness of the model derived from 625 patients. Secondly, we used multiple imputations (SAS version 8.1) to impute values for patients with missing covariates, a method described elsewhere.[23] The model was re-estimated using 5 sets of imputed values for missing data. The resultant regression coefficients and standard errors from the models were averaged to produce a single OR and 95% confidence interval for each covariate. There were no significant differences between the model of 625 patients and the model of 1,038 patients with imputed values, the latter not shown. This further supports the robustness of the model derived from 625 patients with full baseline data. Finally, we also re-estimated the model after exclusion of the 2 New Haven dialysis units with a disproportionate number of PD patients to ensure results were consistent without these dialysis units.

The ICED level is an aggregate index of comorbidity. To determine whether some IDS and IPI categories were independently associated with modality use, we developed 2 additional multivariable models, in which variables for all 19 IDS categories or all 11 IPI categories, respectively, were substituted for the ICED level. These models were fully adjusted for all variables from the final model.

RESULTS

Recruitment

Approximately two-thirds of eligible patients were enrolled from the participating dialysis units. Eligible patients enrolled were similar to eligible patients not enrolled with regard to gender and age. A total of 1,041 incident dialysis outpatients were enrolled from 81 dialysis centers; 279 PD dialysis (27%) and 762 HD patients (73%). Three HD patients did not have a completed ICED at baseline and were excluded from analyses in this report. Nine hundred and twenty-one patients (89%) were from 79 dialysis units affiliated with DCI (188 PD and 733 HD patients). The remain-

ing 117 patients (11%) were from 2 dialysis units located in New Haven (91 PD and 26 HD). Patients were enrolled a median of 45 days from initiation of chronic dialysis (98% within 4 months).

Baseline Characteristics Associated With Modality Use

Table 1 shows baseline characteristics of patients treated with PD and HD, without adjustment. PD patients were on average 5 years

Table 1. Comparison of Baseline Characteristics by Dialysis Modality

	Overall (n = 1,038)	PD (n = 279)	HD (n = 759)	*P* Value
Demographic factors				
Age (yr)	57.9	53.8	59.4	< 0.001
Female (%)	46	44	46	0.54
Race (%)				< 0.001
Caucasian	67	77	63	
African American	28	19	32	
Other	5	4	5	
Cause of ESRD (%)				< 0.0001
Glomerular disease	16	20	15	
Hypertension	17	9	20	
Diabetes	47	47	47	
Polycystic kidney disease	4	6	3	
Other	16	18	15	
Socioeconomic factors (%)				
Married*	56	68	53	0.001
Working†	14	28	9	0.001
Education ≥ high school‡	70	82	66	0.001
Living alone	36	36	36	0.86
Insured§	94	95	93	0.43
Distance from dialysis unit (>30 miles)	13	28	8	< 0.001
Health-related behaviors (%)				
Smoking status				0.09
Never smoked	39	38	40	
Quit	46	51	44	
Current	15	12	16	
Prior or current use of street drugs	19	25	17	0.004
Clinical/laboratory factors				
Median interval from nephrology referral to start of dialysis (mo)	10.2	15.9	8.3	0.005¶
BMI (kg/m^2)‖	27.0 (6.7)	26.5 (5.7)	27.2 (7.0)	0.14
Serum albumin (g/dL)#	3.51 (0.69)	3.79 (0.59)	3.40 (0.69)	< 0.001
Serum creatinine (mg/dL)	8.4 (3.3)	8.3 (2.9)	8.4 (3.4)	0.72
GFR (mL/min/1.73 m^2)**	7.68 (3.34)	7.53 (2.92)	7.74 (3.49)	0.39
Hematocrit (%)	28.3 (6.0)	29.7 (5.9)	27.8 (6.0)	< 0.001

NOTE. Sample size for demographic factors ranged from 949 to 1,038; for cause of ESRD, 1,031; for socioeconomic factors, 963 to 1,005; for health-related behaviors, 927 to 974; for clinical and laboratory factors, 502 to 962.

*Married *v* single or divorced or widowed.

†Working part-time or full-time *v* retired/disabled/unemployed.

‡Greater than or equal to a high school level of education *v* less than a high school education.

§Insured with Medicare, Medicaid, or private insurance.

‖BMI based on formula using data from pre-ESRD setting (Form 2728): BMI = weight (kg)/height^2 (m^2).

¶T test after log transformation of the data.

#Standardized serum albumin (see text).

**Calculated using the MDRD formula. See text for details.

younger than HD patients. There was no gender difference between modalities. A higher proportion of PD patients were Caucasian and a lower proportion were African American.

The cause of renal disease differed by modality. A higher proportion of patients with glomerular disease received PD, while a significantly lower proportion of patients with hypertensive renal disease received PD. The proportion of patients with diabetes as the cause of ESRD did not differ among modalities.

A large number of socioeconomic factors differed by modality. A larger proportion of PD patients were married, employed, had attained at least a high school level of education, or lived far ($>$ 30 miles) from the nearest dialysis unit. There was no difference in the proportion of patients who were insured or lived alone.

Health-related behaviors differed between modalities. A higher proportion of ex-smokers were treated with PD, while current smokers more often received HD. More PD patients admitted to having used "street" drugs.

Clinical and laboratory factors that may partly reflect predialysis care also differed between the modalities. The median interval from the first visit to a nephrologist until starting dialysis was longer for PD patients. The level of renal function (GFR calculated using MDRD formula) did not differ between PD and HD patients at the start of dialysis. PD patients had higher predialysis values of standardized serum albumin and hematocrit. Mean serum creatinine and BMI prior to the start of dialysis did not differ between modalities.

Prevalence and Severity of Comorbid Conditions

The distribution of IDS and IPI categories and ICED levels in PD and HD patients are shown in Figs 1 through 3. PD patients had significantly ($P < 0.05$) lower IDS scores for 5 of 19 IDS categories (congestive heart failure, arrhythmias, other heart disease, respiratory diseases, and gastrointestinal diseases), as shown in Fig 1. Also, the mean number of IDS conditions reported per patient was significantly less for PD patients (5.0 *v* 6.0, $P < 0.001$).

PD patients had significantly lower IPI scores than HD patients ($P < 0.05$) for 7 of 11 IPI categories (circulatory, respiratory, neurological, mental status, feeding, ambulatory, and visual

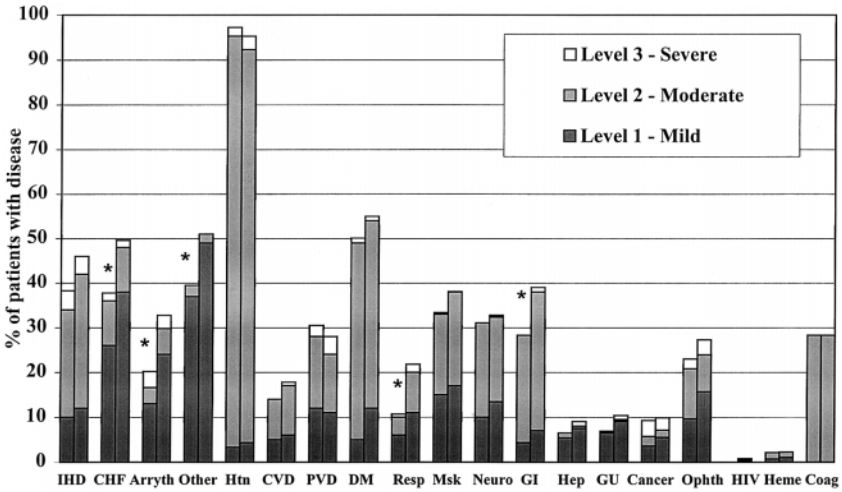

Fig 1. Distribution of IDS categories in PD and HD patients at baseline in the CHOICE Cohort Study (left bars, PD; right bars, HD). Each bar represents the percent of patients with disease, with shading corresponding to the 3 severity levels (IDS 1, 2, or 3). The remaining percent are those without disease in that category (IDS 0). *The distribution of IDS scores (0-3) was significantly ($P < 0.05$ by χ^2 tests) lower in PD *v* HD patients for the following IDS categories: congestive heart failure, arrhythmias, other heart disease, respiratory diseases, and gastrointestinal diseases. IHD, ischemic heart disease; CHF, congestive heart failure; arrhythmia; other, other heart disease; htn, hypertension; CVD, cerebrovascular disease; PVD, peripheral vascular disease; DM, diabetes mellitus; RESP, respiratory; msk, musculoskeletal; neuro, nonvascular nervous system; GI, gastrointestinal disease; hep, hepatobiliary disease; GU, urogenital disease; cancer, malignancy; ophth, ophthalmologic; HIV, HIV and AIDS; Heme, hematologic; coag, anticoagulation.

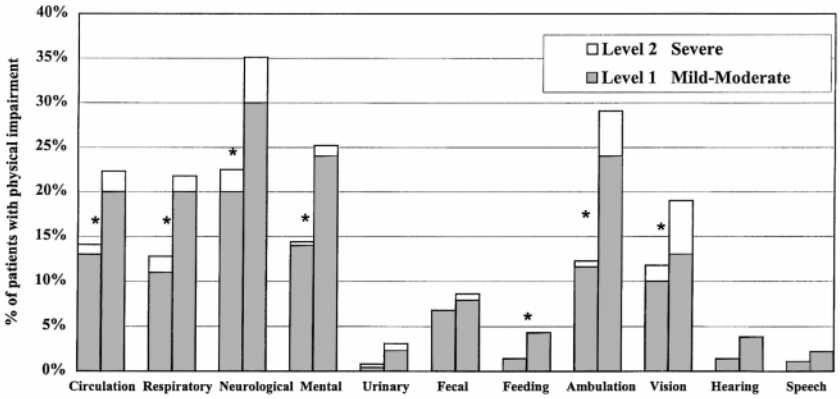

Fig 2. Distribution of IPI categories in PD and HD patients at baseline in the CHOICE Cohort Study (left bars, PD; right bars, HD). Each bar represents the percent of patients with impairment, with shading corresponding to the 2 severity levels (IPI 1 or 2). The remaining percent are those without impairment in that category (IPI 0). *The distribution of IPI scores (0-2) was significantly ($P < 0.05$) lower among PD patients in the following IPI categories: circulatory, respiratory, neurologic, mental status, feeding, ambulatory, and visual impairments.

impairments), as shown in Fig 2. Overall, PD patients had a lower mean number of IPI conditions per patient (1.0 *v* 1.9, $P < 0.001$).

Because of their lower IDS and IPI scores, PD patients had lower ICED scores ($P < 0.001$) (Fig 3). Only 48% of PD patients had ICED levels of 2 or 3, whereas 70% of HD patients had ICED levels of 2 or 3.

Relationship of Comorbidity to Other Baseline Characteristics

We compared patient factors across ICED severity levels in PD and HD groups separately (Table 2). Associations and trends were generally in the same direction for both modalities for the following: patients with higher ICED levels were older, more often Caucasian, more often had diabetes as the cause of ESRD, less often had glomerular disease as the cause of ESRD, and less often worked, had a shorter interval from nephrologist referral to the start of dialysis, had lower predialysis serum albumin and serum creatinine levels, and started dialysis at higher levels of renal function (calculated GFR). Even though the number of IDS and IPI categories per patient is not part of the ICED scoring algorithm, patients with higher ICED levels had more IDS and IPI categories per patient. Again, the HD patients had more IDS and IPI categories reported per patient than PD patients across each ICED subgroup.

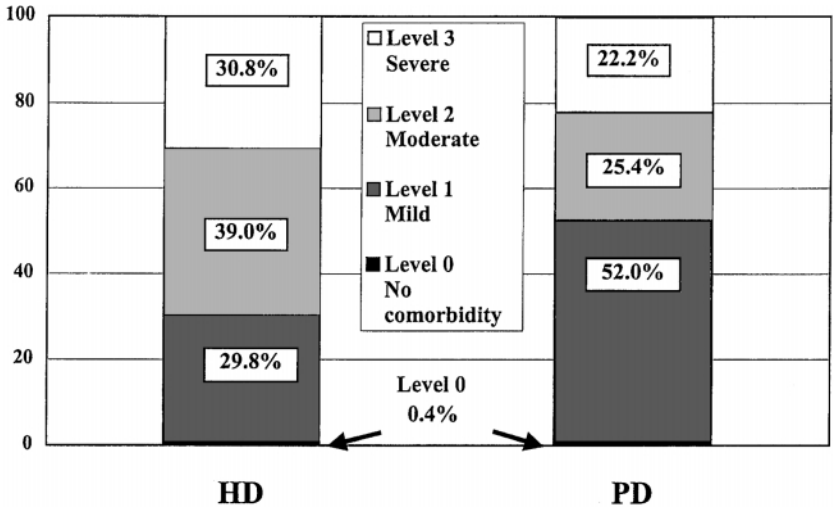

Fig 3. Distribution of comorbidity (ICED Levels) in PD *v* HD patients at baseline in the CHOICE Cohort Study. The proportion of PD *v* HD patients within ICED levels (0-3) was significantly different ($P < 0.001$).

Table 2. Relationship of Comorbidity to Other Baseline Factors

	PD				HD			
	Level 0-1 n = 146	Level 2 n = 71	Level 3 n = 62	*P* Value	Level 0-1 n = 229	Level 2 n = 296	Level 3 n = 234	*P* Value
Demographic factors								
Age (yr)	51	57	58	< 0.001	56	62	59	< 0.001
Female (%)	43	49	42	0.60	45	45	49	0.60
Race (%)				0.15				0.15
Caucasian	72	82	81		58	62	70	
African American	21	17	18		36	33	26	
Other	7	1	1		6	5	4	
Cause of ESRD (%)				< 0.001				< 0.001
Glomerular disease	30	14	3		22	16	7	
Hypertension	9	10	10		23	21	16	
Diabetes	32	63	61		34	47	59	
Polycystic kidney disease	9	3	3		6	2	3	
Other	20	10	23		15	14	15	
Socioeconomic factors (%)								
Married	72	60	67	0.23	50	54	53	0.60
Working	37	19	18	0.005	13	9	5	0.02
Education > high school	82	80	85	0.74	71	64	65	0.25
Living alone	39	44	31	0.40	34	40	33	0.21
Insured	90	94	95	0.06	95	96	94	0.80
Distance to dialysis unit > 30 miles	26	27	35	0.48	9	7	9	0.80
Health-related behaviors (%)								
Smoking Status				0.19				0.80
Never Smoked	44	31	30		41	41	18	
Quit	43	58	60		39	47	15	
Current	13	11	9		41	43	16	
Prior or current use of street drugs	26	25	23	0.90	18	15	16	0.70
Clinical/laboratory factors								
Median time from nephrology referral to start of dialysis (mo)	21.8	13.9	12.6	0.03*	12.9	7.9	4.9	0.03*
BMI (kg/m^2)	26.8 (5.8)	26.6 (6.3)	25.4 (5.0)	0.30	26.9 (6.6)	27.6 (7.6)	27.0 (6.6)	0.45
Serum albumin (g/dL)	3.7 (0.60)	3.6 (0.46)	3.4 (0.61)	0.007	3.3 (0.6)	3.3 (0.6)	3.1 (0.6)	0.004
Serum creatinine (mg/dL)	8.6 (2.8)	8.3 (3.3)	7.6 (2.7)	0.08	8.9 (3.2)	8.6 (3.6)	7.6 (3.1)	< 0.001
Hematocrit (%)	30.1 (5.9)	28.4 (4.5)	30.0 (7.1)	0.14	27.3 (7.3)	28.0 (5.1)	28.1 (5.9)	0.40
GFR mL/min/1.73 m^2	7.09 (2.10)	7.53 (3.18)	8.60 (3.94)	0.001	7.32 (3.28)	7.51 (3.43)	8.43 (3.67)	0.005
Median no. of comorbid conditions (per patient)†								
IDS categories	4.0	6.0	7.1	< 0.001	5.0	6.0	7.0	< 0.001
IPI categories	0‡	1.0	2.0	< 0.001	0‡	2.0	3.0	< 0.001

NOTE. Data are presented as proportions (%) or mean (SD) for each ICED level for PD or HD patients, separately.

*Statistical tests of the differences across ICED subgroups were performed using analysis of variance of the data after natural log transformation.

†Medians are used because the IPI was not normally distributed. Significance was tested across ICED levels using nonparametric methods (Kruskal-Wallis test).

‡By definition, the IPI score of a patient with ICED 0-1 is 0.

Factors Associated With Modality Selection in the Multivariable Model

Table 3 shows factors associated with the modality selection after multivariable adjustment, as derived from 625 patients (155 PD and 470 HD patients) with complete baseline data. In comparison to patients aged 45 to 65, the odds of an older patient (> 65) receiving PD were significantly less (OR of 0.53 [0.30 to 0.93]). There was no difference in modality use between genders. In comparison to Caucasians, the odds of PD in African Americans was also significantly less (OR 0.35 [0.18 to 0.68]). In comparison to patients with glomerular diseases, the odds of PD in patients with hypertensive nephrosclerosis were significantly less (OR 0.30 [0.12 to 0.80]), but were greater for patients with diabetic renal disease (OR 2.6 [1.3 to 5.0]).

Certain socioeconomic factors remained associated with modality selection after multivariable adjustment. As compared with patients who were unemployed, disabled, or retired, those who were employed had significantly higher odds of being treated with PD (OR 4.4 [2.3 to 8.7]). Patients living more than 30 miles from the nearest dialysis unit also had significantly higher odds of receiving PD (OR of 5.3 [2.8 to 10.2]). Marital status and level of education did not remain significant predictors of PD use after adjustment for other factors.

Higher serum albumin concentration and lower BMI were independently associated with treatment with PD. For a 0.1 g/dL increase in serum albumin, the odds of PD were higher (OR 1.17 [1.12 to 1.23]) and for each 1.0 kg/m^2 increase in BMI, the odds of PD were lower (OR 0.94 [0.91 to 0.98]).

After controlling for other factors, higher ICED level was associated with a lesser relative preference for PD versus HD. Compared with those with no to mild comorbidity (ICED 0-1), the odds of PD in patients with moderate comorbid-

Table 3. Multivariable Analysis of Factors Associated With the Use of PD *v* HD at the Start of Dialysis

Variable	Odds Ratio (PD *v* HD)	95% Confidence Interval	*P* Value
Age (yr)			0.08*
<45 yr	0.81	0.42–1.6	0.54
45-65	1.0	Reference	—
>65 yr	0.53	0.30–0.93	0.03
Female *v* male	1.03	0.64–1.63	0.92
Race			0.002*
Caucasian	Reference		
African American	0.35	0.18–0.68	0.002
Other	2.5	0.65–9.5	0.19
Cause of ESRD			< 0.0001*
Glomerular diseases	Reference	1.0	—
Hypertension	0.30	0.12–0.80	0.02
Diabetes mellitus	2.6	1.3–5.0	0.005
Polycystic kidney disease	0.98	0.03–3.2	0.97
Other	1.7	0.76–3.9	0.20
Employment (workers)	4.4	2.3–8.7	< 0.0001
Distance from clinic (>30 miles)	5.3	2.8–10.2	< 0.0001
Serum albumin (per 0.1 g/dL)	1.17	1.12–1.23	< 0.0001
BMI (per 1 kg/m^2)	0.94	0.91–0.98	0.003
ICED level			0.0005*
ICED 0-1	1.0	Reference	—
ICED 2	0.31	0.17–0.56	0.0001
ICED 3	0.50	0.28–0.90	0.021

NOTE. The model was estimated from 625 patients (155 PD and 470 HD) with complete data. The final model includes only those variables that remained significant ($P < 0.05$) after adjustment. The variables that were tested, but did not remain significant in the adjusted model, were marital status (married *v* other), education, prior street drug use, smoking status, living alone, time from first nephrologist visit to first dialysis, predialysis hematocrit, and serum creatinine. Odds ratios of <1.0 indicate a lesser use of PD than the reference group. For examples, the odds of PD in patients greater than 65 years old are 0.53 times the odds of PD in patients between the ages 45 to 65 (referent group).

*The contribution of the variable as a whole to the model was tested for statistical significance.

ity (ICED 2) were significantly lower (OR 0.31 [0.17 to 0.56]) and were also lower for those with severe comorbidity (ICED 3) (OR 0.50 [0.28 to 0.90]). The difference in OR for PD between patients with ICED 3 versus ICED 2 was nonsignificant ($P = 0.14$).

The use of PD did not differ among older versus younger patients as comorbidity severity increased. The interaction term (AGExICED) was not significant in the model adjusted for main effects (*P* value 0.17), nor in the fully adjusted model (*P* value 0.89). We also tested for a differential use of PD with increasing ICED levels in diabetics versus nondiabetics. We used a binary variable in place of the 5-leveled cause of ESRD variable, and thus the referent group changed from glomerulonephritis to nondiabetic causes of ESRD grouped together. The interaction term (DMxICED) was significant ($P < 0.001$); however, the fit of the model was unchanged from the final adjusted model that used a 5-level categorical variable for the cause of ESRD. The significance of the interaction term likely reflects the loss of information resulting from the use of a binary variable for cause of ESRD, and we thus chose not to include it in the final model.

The final model was also adjusted for clinic. We found 6 clinics in which the odds of receiving PD were significantly higher than in other clinics. This result suggests that there was variation in the use of PD at clinics in the CHOICE Study, although it may not reflect true clinical practice because of the deliberate oversampling of PD patients from all clinics. Although the hierarchical modeling attempts to control for the differential use of PD at various clinics, we re-estimated the full model after excluding the 2 dialysis units from New Haven that had a higher proportion of PD patients than the DCI dialysis units. The magnitude and statistical significance of the regression coefficients were the same as the model that includes the New Haven dialysis units except for hypertensive nephrosclerosis, which was no longer significant (data not shown).

Relationship of IDS and IPI Categories and Modality Use

We assessed the contribution of individual IDS and IPI categories to modality use in separate multivariable models. Only 2 categories, malignancy (more PD) and gastrointestinal conditions (less PD) were significantly and independently related to modality. Of the IPI categories, only one category (respiratory impairment) was significantly related to modality (less PD use). These results suggest that, in general, the presence of an individual disease or impairment does not influence modality use, but the combination of diseases and impairments, weighted according to severity (ie, ICED score), does influence modality use.

DISCUSSION

Within the US there is significant variation in PD utilization. Factors responsible for variation are not completely understood, but may include patients' clinical characteristics, medical judgement, physicians' and patients' preferences, and differences in physician and facility reimbursement.[24] A detailed characterization of differences in PD versus HD patients in the present study shows the extent by which these patient groups differ at the onset of chronic dialysis therapy.

We observed fewer and less severe comorbid conditions in the PD group ($P < 0.001$). Overall, 48% of PD patients had moderate or severe comorbid conditions (ICED levels 2-3) versus 70% of HD patients. In addition, fewer PD patients were affected with congestive heart failure, arrhythmias, other heart diseases, respiratory diseases, and gastrointestinal diseases, and the severity of disease was also lower for those with disease in these categories as compared with HD patients. PD patients also had fewer physical impairments, which may serve as an even stronger predictor of adverse outcomes than medical diagnoses.[25,26]

After controlling for other significant factors, comorbidity remained a strong independent predictor of modality use. The OR for selecting PD over HD for ICED 2 versus ICED 0-1 was 0.31 (0.17 to 0.56) and for ICED 3 versus ICED 0-1, it was 0.50 (0.28 to 0.90). Overall, we interpret the relationship between more severe comorbidity and the lesser preference for PD as a reflection of the greater physical and mental demands required of patients who perform PD and of the greater acceptance of the more dependent lifestyle of HD for patients who are more constrained by comorbid illness.

It was interesting to find that PD use did not

decrease incrementally as comorbidity severity increased. Possibly, this may reflect a "comorbidity threshold" in modality selection, whereby HD is recommended preferentially for patients with either moderate or severe comorbidity. Alternatively, there may be some types of patients with severe comorbidity for whom PD is preferable. For example, anticipated difficulty in obtaining vascular access in patients with peripheral vascular disease or difficulty with hemodynamic shifts associated with HD in patients with cardiac disease may favor the selection of PD in some patients with diabetes or severe comorbidity. We did not directly survey patients and physicians to determine which factors contributed to modality selection in this study; thus, it is difficult to tell which of these alternative explanations is correct.

The association of serum albumin to modality selection is strong, even after adjustment for comorbidity, and this has many possible meanings.[27] A low serum albumin may reflect the presence of comorbid conditions, malnutrition, or an underlying inflammatory and catabolic state, which has not yet resulted in clinical disease that is captured by the ICED, but which leads physicians and patients to select HD versus PD. The fact that both factors (ICED and serum albumin concentration) were independently associated with modality selection suggests both factors provide a better assessment of the full extent of comorbidity than either factor alone.

In addition to differences in comorbidity, we also identified important demographic and socioeconomic differences between PD and HD patients at the start of dialysis. As in other studies, PD patients were younger than HD patients.[28] However, after adjusting for other factors in the multivariable model, age did not contribute significantly to modality use (*P* value 0.08 for the contribution of age to the model). This would suggest that physiologic age and not chronologic age is more important in the selection of dialysis modality in the US. African Americans were less than half as likely to choose PD, which suggests unmeasured social or cultural differences, as the relationship remained significant even after adjustment for all other factors. As expected, PD was less frequently selected for patients with higher BMI, likely due to the physicians' concerns of achieving adequate catheter function or clearance in obese patients. Even after adjustment for comorbidity and other factors, patients with diabetic renal disease were most likely to use PD. As described earlier, this may reflect a relative preference for PD in patients with more severe comorbidity, which was not accounted for by the ICED score (for example, anticipated difficulty with HD due to peripheral vascular disease or cardiac disease). On the other hand, patients with hypertensive nephrosclerosis were least likely to choose PD, although this finding did not remain significant when re-estimated without the 2 dialysis units from New Haven. Nonetheless, the direction of the association still suggests less PD use in those with hypertensive nephrosclerosis, which may be explained by the higher incidence of this diagnosis among African Americans (who were less likely to use PD). Practical considerations, such as longer distance from the dialysis unit and employment, were independently associated with a greater relative preference for PD. As reported in the Dialysis Morbidity and Mortality Study (DMMS) Study,[29] we find longer pre-ESRD care was associated with the use of PD, and the level of renal function at first dialysis was higher for PD patients, likely a result of the lower frequency of late referrals in the PD group. This relationship did not remain significant in the multivariable model, probably because of confounding by the other covariates that also described patients more likely to be referred early to their nephrologist.

To our knowledge, the Case-Mix Severity Study of 1989[28] (a special study of the 1989 US Renal Data System [USRDS]) is the only other study in which detailed comorbidity data was reported from a large sample of incident dialysis patients. In that study, trained chart reviewers also abstracted data from the medical record. As in the CHOICE Cohort Study, the Case-Mix Severity Study showed that PD patients had fewer comorbid conditions. However, there are some important differences to consider between the method of comorbidity assessment in the CHOICE Cohort Study and in the USRDS Case-Mix Severity Study. The ICED is a more comprehensive list of medical conditions and impairments and records severity levels for each category of disease and impairment. Measuring the severity or extent of a comorbid illness is superior to simply identifying the presence of a

disease when assessing patient risk.[30] In addition, items of the ICED are aggregated into a final score based on severity, thus enabling the effects of more than one comorbid condition to be considered, while conserving statistical power to adjust for the many other factors that differ between PD and HD.

A recent report emphasizes the need for comprehensive chart–review-based comorbidity data collection to provide accurate and complete reporting of comorbid conditions. Longenecker et al[31] compared the validity of HCFA Form 2728 data for 17 medical conditions with data collected from medical record review using the ICED in the CHOICE Study. Overall, the sensitivity of Form 2728 averaged across all 17 conditions was low (58%), suggesting significant underreporting of comorbid conditions on Form 2728. The DMMS Wave 2 reported similar results.[32]

We have shown that PD patients are less sick at the onset of ESRD; consequently, if case-mix factors are not measured and controlled for, survival estimates will be biased in favor of the PD group. When incident patients are studied and the nonproportionality of the hazard ratio of PD and HD over time is accounted for, the most recent analyses of USRDS[11] suggest that PD is associated with superior survival in the first 2 years after dialysis initiation in all subgroups except female and male diabetics over the age of 55, in whom the risk of mortality is higher and equal, respectively, to that of HD patients. After the first year, the survival between groups becomes equivalent, except for older female diabetics treated with PD who remain at a higher mortality risk than HD patients. Whether this changing mortality ratio of PD:HD is the effect of changes in peritoneal membrane transport characteristics and loss of residual renal function in PD patients over time or simply represents a higher initial death rate of sicker HD patients with a lag in death rate of the more healthy PD patients is unknown,[11] because these analyses did not measure baseline comorbidity in the PD and HD groups. Because results are likely to overestimate a benefit of PD, it is entirely possible that PD is equivalent or even inferior to HD. In fact, a recent Canadian study[15] reported similar findings as in the US, with an early survival advantage of PD; however, after accounting for differences in comorbidity between the 2 groups (HD patients were sicker), this apparent survival advantage of PD was no longer present. Analyses of the CHOICE Study, adjusted for the case-mix factors that differ between these groups at baseline, will enable an unbiased comparison of survival in PD- versus HD-treated patients over time.

There are strengths and limitations of these analyses. To our knowledge, this is the most comprehensive comparison of comorbidity and other factors in PD and HD patients at the onset of dialysis. The CHOICE cohort appears representative of the 1997 US incident dialysis population,[33] apart from the deliberate oversampling of PD patients and a slightly younger mean age. In addition, despite the deliberate oversampling for PD patients in this study, this cohort of PD patients is representative of the US incident PD population.[11] Detailed comorbidity data was collected from chart review and weighted according to clinically defined severity scales. Moreover, all laboratory data consisted of predialysis values and baseline demographic data, and records for comorbidity review were restricted to those recorded prior to or within 4 months of starting dialysis. Thus, the observed relationships truly reflect the association of modality with baseline factors rather than outcomes of dialysis care.

There are some limitations of our analysis. First, baseline factors were assessed at the onset of dialysis, which for many patients was after the time of modality selection. Possibly, comorbidity might have differed in the several months before the onset of ESRD, when patients and providers were deciding on the modality. Studies of the evolution of comorbid conditions in patients with earlier stages of renal disease (chronic renal insufficiency) will be necessary to answer this question. Second, although the CHOICE Cohort consists of over 1,000 incident dialysis patients, the number of patients within some subcategories was small, because the ICED records a large number of IDS and IPI categories, further divided into 3 or 4 severity levels. Statistical power may not have been adequate to show differences that truly exist. Also, it is possible that certain severe comorbid conditions and/or patterns of comorbid diseases may influence physicians or patients to prefer PD, which may not have been captured in the ICED score

itself. Third, we examined an extensive list of sociodemographic and clinical factors that influence the decision to use PD or HD, but it is likely that there are some cultural, social, and other unmeasured factors at the patient level that are not represented. Also, the physician's preferences relating to his or her familiarity of one modality over the other, patient education programs prior to the start of ESRD, physician reimbursement, and other economic considerations were not captured in the model, but have been shown to be influential in PD utilization trends.[24,34] We did not collect this information and, thus, cannot estimate the relative influence of these factors over factors related more directly to the patient's medical and social/cultural circumstances. Fifth, PD utilization rates and the factors motivating PD use in the US differ from those in other countries; hence, these results are likely only generalizable to this country.

In summary, we compared baseline factors in a large, representative cohort of incident HD and PD patients participating in the CHOICE Cohort Study. We used the ICED to provide a detailed description of the presence and severity of comorbid conditions at the onset of ESRD. Using multivariable analysis, we found that PD patients had less severe comorbidity, and that this relationship persisted after controlling for all other factors associated with modality selection. However, the absence of a graded relationship, in which PD use decreased incrementally as comorbidity severity increased, suggests that there may be a subgroup of patients with severe comorbidity who are preferentially treated with PD. Follow-up results of the CHOICE Cohort Study, comparing outcomes of incident HD and PD patients, with adjustment for baseline comorbidity and other factors, should clarify the relative contribution of baseline and treatment factors to dialysis outcomes.

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