Revisiting Survival Differences by Race and Ethnicity among Hemodialysis Patients: The Dialysis Outcomes and Practice Patterns Study

Bruce M. Robinson,*† Marshall M. Joffe,* Ronald L. Pisoni,‡ Friedrich K. Port,‡ and Harold I. Feldman*†

**Center for Clinical Epidemiology and Biostatistics and the Department of Biostatistics and Epidemiology, and †Renal-Electrolyte and Hypertension Division, Department of Medicine, University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania; and ‡Arbor Research Collaborative for Health, Ann Arbor, Michigan*

Hemodialysis (HD) patients who are identified as belonging to racial or ethnic minority groups have longer survival than non-Hispanic white HD patients. This study sought to determine to what extent this survival difference is explained by comprehensive adjustment for measurable case-mix and treatment characteristics. A cohort analysis was conducted among 6677 patients between 1996 and 2001 in the American arm of the first phase of the Dialysis Outcomes and Practice Patterns Study, a prospective observational study. Using multivariable proportional hazards analysis, all-cause mortality by racial/ethnic category was compared before and after adjustment for other patient-level variables that are associated with mortality. Factors that influence the statistical associations of race/ethnicity with mortality were explored. The statistically significant ($P < 0.001$) associations of racial/ethnic minority categories with lower mortality in unadjusted analyses were attenuated or lost in the multivariable model. Compared with non-Hispanic white patients, the adjusted hazard ratio (HR) (95% confidence interval [CI]) for mortality was 0.86 (0.72 to 1.03) for Hispanic patients; among non-Hispanic patients, the HR (95% CI) were 0.97 (0.85 to 1.11) for black patients, 0.82 (0.56 to 1.20) for Asian patients, 0.95 (0.52 to 1.73) for Native American patients, and 0.95 (0.60 to 1.50) for patients of other races (overall $P = 0.66$). The survival advantages for racial/ethnic minority categories were explained most notably by the combined influence of unbalanced distributions of numerous demographic, morbidity, nutritional, and laboratory variables. The associations of race/ethnicity with survival varied little by duration of ESRD and were not influenced substantially by different rates of kidney transplantation among patients who were on HD. The survival advantages for racial and ethnic minority groups on HD are explained largely by measurable case-mix and treatment characteristics. Individual racial minority group or Hispanic patients should not be expected to survive longer on HD than non-Hispanic white patients with similar clinical attributes.

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Hemodialysis (HD) patients who are Hispanic or members of racial minority groups in the United States have lower mortality rates than non-Hispanic white HD patients. In 2002, US Renal Data System (USRDS) mortality rates on dialysis were 33, 30, and 37% lower (unadjusted) and 14, 10, and 35% lower (adjusted for age and gender) for patients who were identified as black, Native American, and Asian, respectively, than for patients who were identified as white (1). Adjusted mortality rates among Hispanic patients on dialysis were 23% lower than for non-Hispanic patients. Adjusted analyses of other large dialysis databases in the past two decades have demonstrated survival advantages of similar or greater magnitude compared with white or non-Hispanic white patients for patients of disparate racial or ethnic minority categories (2–16).

The association with longer survival among racial and ethnic minority groups on HD exists even though they have generally higher prevalence than non-Hispanic white patients of social characteristics that do much to explain poorer health outcomes among racial and ethnic minority groups in numerous other health care settings (17–23). Moreover, racial or ethnic minority group patients, particularly black patients, have longer survival on HD than non-Hispanic white patients despite higher prevalence of many intermediate dialysis outcomes that are linked to increased mortality (18,24–27).

On the other hand, racial and ethnic minority group patients lack access to the most effective therapies to treat chronic kidney disease and to avoid the need for dialysis. Although genetics may be contributory, potentially correctable social disparities—with respect to the prevention of mortality before ESRD, the prevention of ESRD, and the treatment of ESRD by kidney transplantation—may yield a racial and ethnic minority

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Address correspondence to: Dr. Bruce M. Robinson, Department of Medicine, University of Pennsylvania School of Medicine, 700 CRB, 415 Curie Boulevard, Philadelphia, PA 19104-6021. Phone: 215-573-1830; Fax: 215-898-0189; E-mail: brurobinson@msn.com

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group HD population that is systematically healthier than the non-Hispanic white HD population (1,18,20,26–37).

Despite the probable influence of social disparities on the selection of healthier racial and ethnic minority group patients for HD, the HD survival data nonetheless may be interpreted to indicate that individual racial and ethnic minority group patients somehow tolerate or are better suited to HD than are non-Hispanic white patients (9,18). We therefore sought to clarify understanding of the survival advantage for racial and ethnic minority group HD patients by determining to what extent it can be explained by measurable factors, including case-mix and treatment characteristics that are associated with mortality. We hypothesized that the unadjusted associations of Hispanic and racial minority group patients with improved survival would be substantially attenuated or lost after comprehensive covariate adjustment. We performed the analysis using data from the American arm of the first phase of the Dialysis Outcomes and Practice Patterns Study (DOPPS I), a large contemporary cohort of HD patients for whom detailed comorbidity, psychosocial, laboratory, and dialysis care data were available at study entry and for up to 5 yr of follow-up.

Materials and Methods

The DOPPS

DOPPS I was conducted between 1996 and 2001. A complete description of its design has been published (38). In the United States, 142 maintenance HD facilities were selected by stratified random sampling on the basis of the 1996 adjusted mortality ratio to achieve variation in practice patterns and outcomes. At the start of the project, random samples of 20 to 40 prevalent HD patients per facility were selected. Patients who subsequently terminated care at a participating facility were replaced approximately every 4 mo, using random selection from patients who entered the facility during the interval.

Patient-level DOPPS data were abstracted from the medical record, supplemented by personal knowledge, by a study coordinator in each participating HD facility. Pertinent to this analysis were a detailed enrollment medical summary and interval medical summaries that were completed approximately every 4 mo until departure from DOPPS I. For time-varying variables, values recorded were the most recent available before each medical summary. Dates and details of hospitalizations, outpatient medical interventions, vascular access events, and departures were recorded. Patient information was collected without patient identifiers, and patient consent was obtained in compliance with local institutional review boards.

Study Data

Mortality and Censoring Events. The outcome for the study was time to all-cause mortality. Censoring events are listed in Table 1.

Race and Ethnicity. DOPPS I used the USRDS classifications for race (white, black, Asian, Native American, or other) and ethnicity (Hispanic origin or non-Hispanic origin). Data were recorded by the facility study coordinator, who classified each patient into a single race and a single ethnicity category on the basis of perceived race and ethnicity corroborated by direct patient inquiry. The distributions of patients by these racial and ethnic classifications are listed in Table 1. For these analyses, we combined racial and ethnic data into one of six racial/ethnic categories, in keeping with the social basis underlying the study hypothesis.

Patients also were asked to self-report a single racial and a single ethnic designation in a separate DOPPS patient questionnaire. Although self-reporting has been considered the most reliable method to collect race and ethnicity data (22), we did not use this classification in our analyses because of a higher proportion of missing values. The proportion of agreement of ethnicity in the medical questionnaire with

Table 1. Distributions of patients and reasons for DOPPS termination by race and ethnicity[a]

	Hispanic[b]			Non-Hispanic					Overall
	White	Black	Other/ Unspecified	White	Black	Asian	Native American	Other	
Distributions by racial/ethnic category (*n* [% of row])									
all US DOPPS patients	599 (7)	37 (<1)	215 (2)	4758 (52)	3003 (33)	279 (3)	87 (<1)	124 (1)	9102 (100)
patients in analyses[c]	484 (7)	31 (<1)	158 (2)	3342 (51)	2278 (34)	231 (3)	56 (<1)	97 (1)	6677 (100)
Reason for DOPPS termination within racial/ethnic categories (*n* [% of column])[d]									
death event									
death	157 (32)	9 (29)	34 (22)	1178 (35)	684 (30)	68 (29)	12 (21)	27 (28)	2169 (32)
withdrawal from HD[e]	14 (3)	0	4 (3)	201 (6)	50 (2)	3 (1)	3 (5)	0	275 (4)
censor event[f]									
recovery of renal function[g]	5 (1)	0	1 (<1)	44 (1)	16 (<1)	3 (1)	1 (2)	0	70 (1)
renal transplantation[g]	32 (7)	0	8 (5)	220 (7)	100 (4)	18 (8)	4 (7)	8 (8)	390 (6)
other change in RRT modality[g]	13 (3)	0	4 (3)	116 (3)	66 (3)	5 (2)	2 (4)	2 (2)	208 (3)
HD facility transfer	95 (20)	5 (16)	33 (21)	582 (17)	438 (19)	33 (14)	11 (20)	22 (23)	1219 (18)
end of DOPPS I	168 (35)	17 (55)	74 (47)	1001 (30)	924 (41)	101 (43)	23 (41)	38 (39)	2346 (35)

[a]Race and ethnicity were classified by facility study coordinator. DOPPS, Dialysis Outcomes and Practice Patterns Study; HD, hemodialysis; RRT, renal replacement therapy.
[b]Patients of Hispanic ethnicity were combined into a single category for these analyses.
[c]Patients in the analyses were in the DOPPS for at least 3 mo and had no missing data in the multivariable survival model.
[d]Among patients in the analyses.
[e]Assumed to have died on HD withdrawal date.
[f]Censored on DOPPS departure date.
[g]Sensitivity analyses addressed the possibility of informative censoring by these events. See text for details.

self-reported ethnicity was 0.93 ($\kappa = 0.87$), and among patients who did not self-identify as Hispanic, the proportion of agreement of race in the medical questionnaire with self-reported race was 0.94 ($\kappa = 0.80$).

Other Variables. Because our primary analytic goal was to estimate the associations of racial/ethnic categories with mortality after adjusting for variables that might explain the association, we identified numerous patient-level DOPPS variables that plausibly were associated with mortality. To replicate and then add to previous published analysis of the associations of race and/or ethnicity with mortality (1–15), we assigned each of these variables to one of seven covariate groups (Tables 2 and 3).

Variables in our analyses that were updated over time by the DOPPS interval medical summaries are designated in the legend to Table 3. For these variables, our primary approach was to update values during the analysis time to equal the values that were recorded most recently by the DOPPS or, for medical events, the total number over the most recent 3 mo. In an alternative approach, variables were designated as in the primary approach except that medical events were characterized over the most recent 1 mo.

In a third approach, values that were assigned to time-varying variables equaled the values that were recorded for the DOPPS enrollment medical summary or the first interval medical summary with complete variable characterization. In the survival models, this approach yields hazard ratios (HR) that reflect the predicted course over a more extended follow-up than our primary approach using time-updated values, but it may attenuate the influence of time-varying variables during any shorter time interval that they may affect mortality most directly (39).

Because DOPPS I enrolled both incident and prevalent ESRD patients with ESRD, both the time-updated and enrollment approaches to characterizing time-varying variables captured values of these variables from a combination of incident and prevalent ESRD patients. We chose not to limit the analyses to incident ESRD patients to take advantage of the DOPPS design to characterize more fully the relationships of the racial/ethnic categories to survival across a wide range of ESRD duration (ESRD vintage). The possibility that the associations with survival changed with increasing ESRD vintage was examined by testing for an interaction of racial/ethnic category with ESRD vintage; this possibility also was studied less directly using the alternative analytic approaches described above.

Patient Eligibility. Multivariable model inclusion required complete covariate characterization, because missing data were not imputed. Patients were required to remain in DOPPS I for at least 3 mo, or 1 mo for the model that characterized medical events over the most recent 1 mo. No other exclusion criteria were applied.

Statistical Analyses

Our analyses of the probability of mortality as a function of racial/ethnic category used Cox proportional hazards models (39). The time at risk was from 3 mo after DOPPS enrollment (or 1 mo after DOPPS enrollment for the model that characterized medical events over 1 mo). Because some patients enrolled in the DOPPS at ESRD onset, the earliest time at risk was 3 mo after ESRD onset (or 1 mo after ESRD onset for the model that characterized medical events over 1 mo). The time at risk ended on the date of death or censoring. Because modeling survival in prevalent cohorts using biologically arbitrary time scales such as days since study entry can be subject to left-truncation bias, we used ESRD vintage as the time scale for all analyses (40,41). We stratified by center to account for the possibility of systematic, otherwise uncaptured differences among the DOPPS facilities.

Beginning with a model for the unadjusted association of racial/ethnic categories with mortality, we built a series of progressively more comprehensive multivariable models by sequentially adding each of the seven covariate groups to the model. At each step, we used backward elimination to exclude those newly added covariates for which the association with mortality had $P > 0.10$ (42,43). Unless otherwise stated, $P < 0.05$ was the criterion for statistical significance. All analyses used Stata version 8.2 (44).

Results

Descriptive Analyses

Of 9102 patients in the American arm of DOPPS I, 8179 (90%) were in the study for at least 3 mo and were included in the development of the multivariable survival model. Of these, 6677 (82%) had no missing data in the final multivariable survival model. As evidence that these 6677 patients were representative of the 9102 DOPPS patients, their similar racial and ethnic distributions are listed in Table 1. Also, the associations of race/ethnicity with survival, unadjusted and adjusted for variables that were characterized in all patients, were similar in models that included all patients (data not shown) to those in models that were restricted to the 6677 patients without missing data. For clarity of presentation, all results provided here are restricted to the 6677 patients in the final multivariable model.

Among the 6677 patients, the median time between ESRD onset and the start of the time at risk was 9.3 mo (range 3.0 mo to 30.0 yr). The median total time at risk was 15.3 mo (range 0.2 mo to 5.1 yr); the total person-time at risk was 10374 yr; 2444 deaths occurred; and the death rate was 0.24 per patient-year.

The unadjusted Kaplan-Meier survivor function for survival on HD by racial/ethnic category among these 6677 patients (Figure 1) demonstrates lower survival among non-Hispanic white patients than all five racial/ethnic minority categories ($P < 0.001$ by log rank test). In unadjusted proportional hazards analysis (Table 3), the HR (95% confidence interval [CI]) for mortality compared with non-Hispanic white patients was 0.72 (0.61 to 0.85) for Hispanic patients; among non-Hispanic patients, HR (95% CI) were 0.63 (0.57 to 0.71) for black patients, 0.68 (0.50 to 0.93) for Asian patients, 0.62 (0.35 to 1.11) for Native American patients, and 0.74 (0.52 to 1.07) for patients of other races (overall $P < 0.001$).

For all minority racial/ethnic categories except Native American, the unadjusted survival advantage attenuated modestly as ESRD vintage increased ($P = 0.003$ and 0.04 overall for the interactions of race/ethnicity with untransformed and log-transformed ESRD vintage, respectively). As illustration that the magnitude of the changes in these associations with increasing ESRD vintage generally was small, the HR (95% CI) for mortality compared with non-Hispanic white patients changed from 3 to 36 mo of ESRD vintage (for untransformed ESRD vintage) from 0.70 (0.54 to 0.93) to 0.73 (0.61 to 0.88) for Hispanic patients; among non-Hispanic patients, the HR (95% CI) changed from 0.51 (0.42 to 0.62) to 0.62 (0.55 to 0.70) for black patients, from 0.58 (0.34 to 1.00) to 0.66 (0.47 to 0.95) for Asian patients, from 0.79 (0.28 to 2.24) to 0.65 (0.36 to 1.19) for Native American patients, and from 0.23 (0.09 to 0.58) to 0.76 (0.48 to 1.20) for patients of other races.

Of 37 patient characteristics other than race/ethnicity that

Table 2. Distributions of enrollment patient characteristics within racial/ethnic categories ($n = 6677$)[a]

Characteristic	Distribution within Racial/Ethnic Category						P[b]
	Hispanic Ethnicity ($n = 673$)	Non-Hispanic Ethnicity					
		White ($n = 3342$)	Black ($n = 2278$)	Asian ($n = 231$)	Native American ($n = 56$)	Other ($n = 97$)	
Demographics							
age (yr; mean [SD])	57 (15)	64 (15)	57 (16)	60 (16)	57 (12)	56 (16)	<0.001
ESRD vintage (yr; mean [SD])	2.2 (3.5)	1.6 (3.1)	2.5 (3.6)	1.8 (2.7)	1.7 (2.3)	1.5 (2.1)	<0.001
male gender (%)	55	58	50	51	50	57	<0.001
ESRD cause (% column)							
diabetes	57	37	39	47	64	47	<0.001
hypertension	18	27	41	20	7	21	
glomerulonephritis	12	12	8	19	7	18	
other	12	23	12	13	21	14	
Social characteristics							
marital status: married (%)	54	57	37	55	53	64	<0.001
living arrangements: with family (%)	85	75	74	87	82	89	<0.001
education: high school graduate (%)	41	74	54	73	59	68	<0.001
Comorbidity (%)							
cardiovascular disease	57	67	54	52	61	53	<0.001
congestive heart failure	53	58	51	47	52	47	<0.001
cancer, non-skin	5	14	7	7	4	5	<0.001
gastrointestinal illness	8	9	10	10	20	9	0.16
neurologic illness	9	10	12	6	5	8	0.001
pulmonary illness	8	19	9	5	5	6	<0.001
psychiatric illness	24	30	23	9	27	12	<0.001
do-not-resuscitate status	4	7	3	4	5	6	<0.001
functional status: needs assistance (%)[c]	13	14	13	11	13	14	0.70
Medical events: ≥1 (%)[d]							
hospitalizations	24	26	25	18	20	23	0.10
outpatient procedures	23	24	19	22	14	21	<0.001
vascular access procedures	62	66	56	65	48	60	<0.001
Nutritional indicators (mean [SD])							
albumin (g/dl)	3.7 (0.5)	3.6 (0.5)	3.7 (0.5)	3.6 (0.5)	3.4 (0.7)	3.6 (0.5)	0.001
creatinine (mg/dl)	8.6 (3.5)	7.7 (2.9)	10.2 (3.8)	9.5 (3.5)	8.4 (2.6)	9.3 (3.4)	<0.001
weight (kg)	73 (18)	75 (19)	78 (21)	63 (15)	77 (21)	71 (18)	<0.001
BMI (kg/m^2)[e]	27 (6)	26 (6)	27 (7)	27 (6)	27 (6)	26 (6)	<0.001
Other laboratory measures (mean [SD])							
bicarbonate (mEq/L)	21 (4)	21 (4)	21 (4)	20 (4)	20 (4)	21 (4)	0.002
calcium-phosphorus product (mg^2/dl^2)	52 (18)	52 (18)	51 (17)	53 (19)	56 (18)	54 (19)	0.06
ferritin (ng/dl)	330 (31)	342 (31)	367 (32)	407 (32)	421 (35)	360 (28)	<0.001
hemoglobin (g/dl)	10.7 (1.5)	10.8 (1.5)	10.5 (1.6)	11.0 (1.7)	11.1 (1.4)	10.7 (1.6)	<0.001
potassium (mEq/L)	4.9 (0.8)	4.8 (0.8)	4.7 (0.8)	4.9 (0.8)	4.7 (0.7)	4.8 (0.8)	0.001
TSAT (%)	27 (15)	25 (14)	27 (16)	28 (15)	35 (14)	28 (14)	<0.001
WBC ($\times 1000$ cells/mm^3)	7.8 (2.7)	8.0 (3.0)	7.1 (2.8)	7.8 (2.6)	8.4 (2.9)	8.3 (2.5)	<0.001
HD measures							
HD time (h/wk; mean [SD])	10.3 (1.6)	10.3 (1.7)	10.8 (1.6)	9.8 (1.6)	10.3 (1.8)	10.3 (1.9)	<0.001
Kt/V_{urea} (mean [SD])[e]	1.7	1.5	1.5	1.5	1.6	1.4	0.99
SBP (mmHg; mean [SD])	145 (26)	139 (25)	143 (25)	140 (23)	141 (28)	142 (26)	<0.001
UF (L/treatment; mean [SD])	2.7 (1.3)	2.5 (1.3)	2.7 (1.4)	2.7 (1.3)	3.1 (1.5)	2.5 (1.4)	<0.001
vascular access type: catheter (%)[f]	35	42	34	27	32	39	<0.001

[a]At DOPPS enrollment. All variables had $P \leq 0.20$ for the unadjusted association with mortality. BMI, body mass index; Kt/V_{urea}, delivered dialysis dose; SBP, systolic BP predialysis; TSAT, transferrin saturation; UF, ultrafiltration volume removed; WBC, white blood cell count. Conversions to SI units: Albumin 1 g/dl = 10 g/L; bicarbonate 1 mEq/L = 1 mmol/L; calcium-phosphate product 1 mg^2/dl^2 = 0.08 $mmol^2/L^2$; creatinine 1 mg/dl = 88.4 μmol/L; ferritin 1 ng/ml = 2.2 pmol/L; hemoglobin 1 g/dl = 10 g/L; potassium 1 mEq/L = 1 mmol/L. Boldface indicates variables for which white patients, compared with patients of all five minority racial/ethnic categories, had unadjusted distributions associated with higher mortality; italics indicates variables for which white patients, compared with patients of all five minority racial/ethnic categories, had unadjusted distributions associated with lower mortality.

[b]By one-way ANOVA for continuous variables and χ^2 test for categorical variables.

[c]With eating or ambulating.

[d]During first 90 d of DOPPS enrollment.

[e]Among patients without missing data.

[f]Received HD through either a tunneled or non-tunneled central venous catheter.

Table 3. Progressively more comprehensive multivariable models for the associations of race/ethnicity with mortality ($n = 6677$)[a]

Model	HR for Mortality (95% CI Reference Category: Non-Hispanic White Patients [$n = 3342$])					P[b]	Variables Tested[c]
	Hispanic Ethnicity ($n = 673$)	Black ($n = 2278$)	Asian ($n = 231$)	Native American ($n = 56$)	Other ($n = 97$)		
1. Unadjusted	0.72 (0.61 to 0.85)	0.63 (0.57 to 0.71)	0.68 (0.50 to 0.93)	0.62 (0.35 to 1.11)	0.74 (0.52 to 1.07)	<0.001	Race/ethnicity
2. Demographics	0.88 (0.75 to 1.04)	0.74 (0.66 to 0.83)	0.73 (0.53 to 1.00)	0.78 (0.43 to 1.42)	0.97 (0.66 to 1.42)	<0.001	Model 1 plus gender, cause of ESRD, age, calendar year
3. Social characteristics	0.88 (0.75 to 1.04)	0.74 (0.66 to 0.83)	0.73 (0.53 to 1.00)	0.78 (0.43 to 1.42)	0.97 (0.66 to 1.42)	<0.001	Model 2 plus *marital status, living arrangements, level of education*
4. Comorbidity	0.93 (0.78 to 1.11)	0.79 (0.70 to 0.89)	0.86 (0.63 to 1.18)	0.84 (0.46 to 1.56)	1.10 (0.74 to 1.63)	0.007	Model 3 plus CVD, CHF, cancer, *GI illness, neurologic illness,* pulmonary illness, psychiatric illness, DNR status, functional status, *vascular access*
5. Nutritional indicators	0.86 (0.72 to 1.03)	0.87 (0.79 to 0.99)	0.81 (0.57 to 1.17)	0.94 (0.52 to 1.70)	0.96 (0.62 to 1.47)	0.27	Model 4 plus albumin, creatinine, weight
6. Medical events	0.84 (0.71 to 1.01)	0.86 (0.76 to 0.98)	0.81 (0.56 to 1.19)	0.99 (0.53 to 1.83)	0.94 (0.60 to 1.47)	0.18	Model 5 plus hospitalized days, outpatient procedures, vascular access procedures
7. Laboratory measures	0.84 (0.70 to 1.01)	0.96 (0.84 to 1.09)	0.83 (0.57 to 1.21)	0.96 (0.52 to 1.79)	0.92 (0.58 to 1.45)	0.52	Model 6 plus *bicarbonate,* calcium-phosphorus product, ferritin, hemoglobin, potassium, TSAT, WBC
8. HD measures	0.86 (0.72 to 1.03)	0.97 (0.85 to 1.11)	0.82 (0.56 to 1.20)	0.95 (0.52 to 1.73)	0.95 (0.60 to 1.50)	0.66	Model 7 plus *HD treatment time (delivered),* SBP, UF

[a]Models by Cox proportional hazards analysis, using ESRD vintage as time scale. Patients shown had complete covariate characterization for final multivariable model (model 8). CVD, atherosclerotic cardiovascular disease; CHF, congestive heart failure; CI, confidence interval; DNR, do not resuscitate; GI, gastrointestinal; HR, hazard ratio.

[b]For race/ethnicity, by the Wald test.

[c]Variables tested had $P \leq 0.20$ for univariable association with mortality. Other than ESRD vintage (time scale for model) and BMI and Kt/V_{urea} (excessive missing observations), all variables in Table 2 were tested. Values tested were the most recent values recorded by the DOPPS for age, nutritional indicators, laboratory measures, and HD measures; the total number over the most recent 3 mo for medical events; and enrollment values for all other variables. Other than race/ethnicity, variables with $P > 0.10$ were sequentially excluded from the multivariable models. Variables excluded are indicated by italics. All other variables were included in the final multivariable model (model 8), and all but one of these (cause of ESRD, $P = 0.02$) had $P \leq 0.01$ for the adjusted association with mortality. In ancillary models, BMI and Kt/V_{urea} did not meaningfully influence the associations of race/ethnicity with mortality.

were plausibly associated with mortality, all but two had $P \leq 0.20$ for the unadjusted association with mortality and were tested for inclusion in the multivariable model. Table 2 shows the distribution of these 35 characteristics at enrollment within racial/ethnic categories. Compared with patients of all five minority racial/ethnic categories, white patients had distributions that were associated with higher mortality for 14 characteristics but distributions that were associated with lower mortality for only two characteristics. These characteristics are identified in Table 2. Each of these characteristics had $P < 0.001$ for overall distribution by race/ethnicity.

Multivariable Analyses

Table 3 shows that the associations of racial/ethnic minority categories with lower mortality were attenuated or lost in progressively more comprehensive multivariable models. In the final multivariable model (model 8), the HR (95% CI) for mortality compared with non-Hispanic white patients was 0.86 (0.72 to 1.03) for Hispanic patients; among non-Hispanic patients, the HR (95% CI) were 0.97 (0.85 to 1.11) for black patients, 0.82 (0.56 to 1.20) for Asian patients, 0.95 (0.52 to 1.73) for Native American patients, and 0.95 (0.60 to 1.50) for patients of other races (overall $P = 0.66$). Twenty-five other variables (identified in Table 3) met inclusion criteria for the final multivariable model ($P \leq 0.10$), and all but one of these (cause of ESRD, $P = 0.02$) had $P \leq 0.01$ for the adjusted association with mortality. Model diagnostics revealed no evidence of substantial multiple collinearity. There were no statistically significant interactions between racial/ethnic category and variables that were indicative of overall health status among HD patients, including categorized levels of albumin ($P = 0.16$), creatinine ($P = 0.48$), ferritin ($P = 0.99$), and hemoglobin ($P = 0.32$), as well as erythropoietin dosing ($P = 0.97$).

As evidence that the adjusted associations of race/ethnicity with survival did not change with increasing ESRD vintage, there was no statistically significant interaction between racial/ethnic category and ESRD vintage ($P = 0.21$ and 0.58 for untransformed and log-transformed ESRD vintage, respectively) in the final multivariable model. Consistent with this finding, the adjusted associations of race/ethnicity with survival in a model that was restricted to patients with ESRD vintage <12 mo at DOPPS enrollment were similar to those in the primary analysis, although the precision of estimates for the least com-

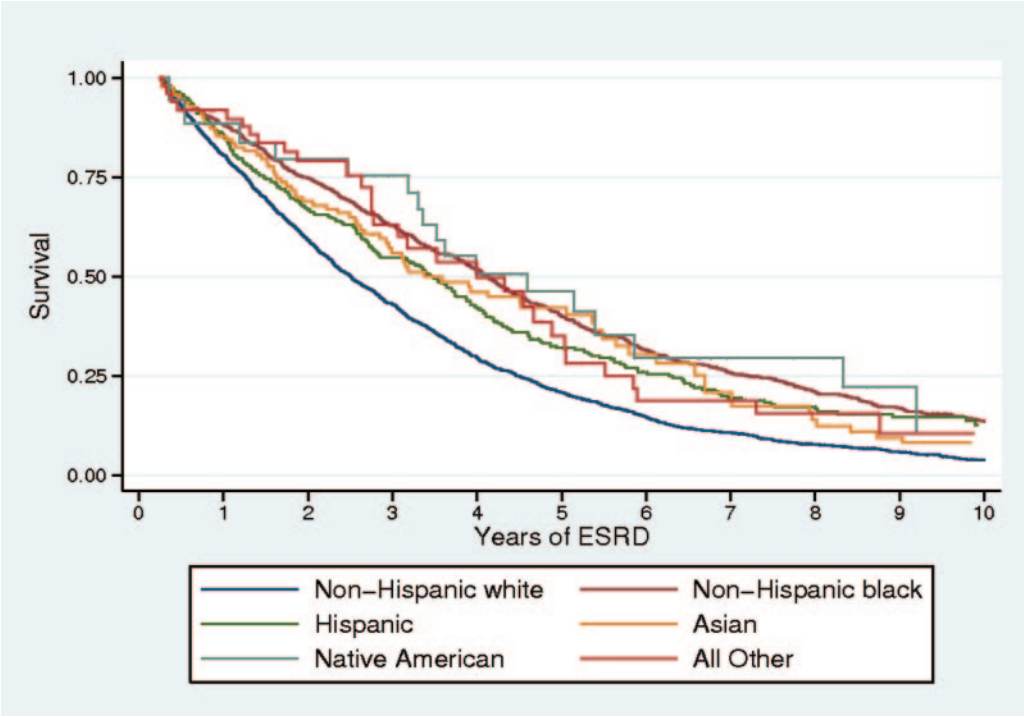

Figure 1. Kaplan-Meier survivor function for unadjusted survival on hemodialysis by race/ethnicity among patients with ESRD for at least 3 mo. $P < 0.001$ by log rank test.

mon racial/ethnic categories notably was limited by the small sample size and number of events.

Analyses that used the DOPPS enrollment values for time-varying covariates yielded similar adjusted associations between racial/ethnic category and mortality as the primary modeling approach using time-updated values. In a multivariable model that was analogous to the final multivariable model (model 8) in Table 3 but using DOPPS enrollment values, the HR (95% CI) for mortality compared with non-Hispanic white patients was 0.91 (0.76 to 1.08) for Hispanic patients; among non-Hispanic patients, the HR (95% CI) were 0.92 (0.81 to 1.04) for black patients, 0.81 (0.58 to 1.13) for Asian patients, 0.85 (0.49 to 1.48) for Native American patients, and 1.06 (0.73 to 1.55) for patients of other races (overall $P = 0.52$).

Analyses that added time from months 1 to 3 after DOPPS enrollment also yielded similar adjusted associations between racial/ethnic category and mortality. In a multivariable model that was analogous to the final multivariable model (model 8) in Table 3 but including 7025 patients, the HR (95% CI) for mortality compared with non-Hispanic white patients was 0.87 (0.73 to 1.04) for Hispanic patients; among non-Hispanic patients, the HR (95% CI) were 0.96 (0.85 to 1.09) for black patients, 0.82 (0.58 to 1.16) for Asian patients, 0.98 (0.57 to 1.69) for Native American patients, and 0.80 (0.51 to 1.25) for patients of other races (overall $P = 0.58$).

Explaining Survival Differences by Race/Ethnicity

We considered the possibility that the unadjusted survival advantage for racial/ethnic minority categories on HD might be due in part to violation of the independent censoring assumption. Table 1 shows that the proportion of patients who were censored because of transplantation, renal function recovery, or change in renal replacement therapy modality (all potentially informative censoring events) was low overall and was similar across racial/ethnic groups. To assess the limits of these censoring events on the unadjusted associations with mortality by race/ethnicity, we modeled the HR for mortality under the extreme assumption that all patients who were censored for these reasons survived until the study's end. Extending the total person-time at risk by 1981 years (19%), the unadjusted HR (95% CI) for survival compared with non-Hispanic white patients was 0.74 (0.62 to 0.89) for Hispanic patients; among non-Hispanic patients, the unadjusted HR (95% CI) were 0.68 (0.60 to 0.76) for black patients, 0.62 (0.44 to 0.87) for Asian patients, 0.61 (0.33 to 1.12) for Native American patients, and 0.80 (0.52 to 1.22) for patients of other races (overall $P < 0.001$). These HR were similar to the unadjusted HR in Table 3. Likewise, HR in adjusted analyses that incorporated the same assumption were similar to the adjusted HR in Table 3. Because we know of no data to suggest that non-Hispanic white patients who were censored because of transplantation, renal function recovery, or change in renal replacement therapy modality would be expected to survive longer if they remained on HD than racial or ethnic minority group patients who were censored for these reasons, we did not perform analyses that accounted for this possibility.

Next, we identified the influence of each variable in the

multivariable model on the statistical associations of race/ethnicity with mortality. To do so, we used seemingly unrelated estimation (45,46) to estimate and formally test the effect of excluding each variable individually from the final multivariable model on the associations of each racial/ethnic category with mortality (data not shown). Consistent with the "unfavorable" unadjusted distributions among white patients for numerous patient characteristics in Table 2, the survival advantages for racial/ethnic minority categories compared with non-Hispanic white patients most notably were explained (attenuated) in the multivariable model by the combined effect of small but statistically significant contributions of many different variables.

Among these variables, younger age was a key explanatory variable for each racial/ethnic minority category, and nutritional indicators had sizable but variable influences among the racial/ethnic minority categories. For example, higher creatinine levels attenuated much of the survival advantage for non-Hispanic black and Asian patients; adjustment for albumin levels attenuated the survival advantage for Asian and Native American patients but accentuated the survival advantage for Hispanic patients; and adjustment for body weight accentuated the survival advantages compared with non-Hispanic white patients for all racial/ethnic minority categories except non-Hispanic black patients.

Discussion

The increased burden of ESRD among racial and ethnic minority groups has been recognized since before the initiation of the federally funded ESRD program in 1972. The survival advantage among racial and ethnic minority group patients on dialysis has been reported repeatedly thereafter (1–16), but its causes and implications are poorly understood (9,18). We now report that the survival advantages of Hispanic and racial minority group HD patients are substantially attenuated or lost by comprehensive adjustment for case-mix and treatment characteristics that are associated with mortality. The validity of our findings is supported by the significance of the adjusted associations with mortality for numerous patient characteristics other than race/ethnicity that are commonly linked to higher mortality (Table 3). The findings generalize to the maintenance HD population in the United States because the American arm of DOPPS I is a nationally representative sample (38) and because of the similarity between the unadjusted survival advantages for racial/ethnic minorities that we report and those in previous studies (1–16).

In contrast to our study, these disparate previous studies of HD recipients in the United States or Canada reported that adjustment for case-mix and laboratory variables yielded persistent survival advantages for racial/ethnic minority groups (1–16). The overall adjusted point estimates for survival relative to white or non-Hispanic white patients were 0.78 (9) and 0.92 (3) for nonwhite patients; 0.55 (5), 0.60 (8), 0.66 (12), 0.75 (11), 0.78 (4), 0.84 (2), 0.87 (15), and 0.90 (6) for African-American, black, or non-Hispanic black patients; 0.47 (6) and 0.67 (8) for Mexican-American patients; 0.76 (12) for Hispanic patients; 0.73 (11) for South Asian patients; 0.61 (11) for Southeast Asian patients; 0.75 (10) for Asian American patients; and 0.60 (16) for Asian and Pacific Islander patients. All were statistically significant except for the 0.90 (6) and 0.92 (3) estimates for black and nonwhite patients, respectively.

Using more comprehensive covariate adjustment, our results (Table 3) are notably different. The unadjusted survival advantage compared with non-Hispanic white patients was nearly lost for non-Hispanic black patients (0.97 [95% CI 0.85 to 1.11]) and was more substantially attenuated than previously reported for Hispanic (0.86 [95% CI 0.72 to 1.03]) and Asian patients (0.82 [95% CI 0.56 to 1.20]). We also report marked attenuation of the point estimate for the survival advantage for Native American patients, although the small sample size limits its interpretation of this finding. Overall, these results provide several key insights into the longer survival of Hispanic and racial minority group patients receiving maintenance HD.

Most clearly, the results demonstrate that individual racial minority group or Hispanic patients should not be expected to survive much or any longer than otherwise "identical" non-Hispanic white patients (identical, at least, with respect to all case-mix and treatment characteristics for which we adjusted). As a result, there is no rationale for the patient-level treatment biases, conscious or otherwise, that may exist because of the widely known population-level survival advantages for Hispanic and racial minority group HD patients. Proposed biases include complacent treatment of racial and ethnic minority group patients on the basis of the contention that they somehow tolerate HD better and may be less apt to benefit from transplantation than non-Hispanic white patients (18), as well as less attentive treatment of non-Hispanic white HD patients because of the sense that their racial or ethnic classification dooms many of them to poor survival irrespective of care provided (3).

In addition to this predictive inference, our results yield insight into the causes of longer survival among racial and ethnic minority group HD patients. First, their survival advantage is not substantially explained by possible informative censoring events, including transplantation among patients who are already on HD. This finding results principally from relatively low rates of transplantation among HD patients and modest absolute rate differences by race/ethnicity (Table 1), despite the widely known racial and ethnic disparities in access to kidney transplantation (1,18,20,27–37). Transplantation that is undertaken preemptively before dialysis initiation is unobservable with the DOPPS data.

Second, the descriptive analyses that we present (Figure 1 and related text) indicate that the survival advantage for racial/ethnic minority group HD patients exists at or very soon after ESRD onset, a finding that is consistent with USRDS data (1). Because the survival advantage that we observed for racial/ethnic minority categories on HD largely is lost by covariate adjustment, racial and ethnic minority group patients selected for HD at ESRD onset are healthier in measurable ways than non-Hispanic white patients. In turn, the health advantage among racial and ethnic minority groups at later ESRD vintages likely is because they are healthier at ESRD onset. An alternative adverse influence of HD on non-Hispanic white patients

that is unrelated to health status at ESRD onset cannot be ruled out, but we know of no biologic rationale for this possibility.

Third, the survival advantages for racial/ethnic minority categories compared with non-Hispanic white patients were explained (attenuated) in the multivariable survival model by the combined influences of many different variables. Whereas the influences of younger age (across racial/ethnic minority categories) and higher creatinine levels (among black patients) on the associations with lower mortality are widely known (1,3), the influences across racial/ethnic categories of other case-mix variables, such as pulmonary and psychiatric comorbidity (data not shown), are novel. The variable direction of the effect of nutritional indicators—including creatinine level, albumin level, and weight—on the associations of various racial/ethnic categories with mortality merits further investigation.

We caution that the identification of these variables that explain the statistical associations of race/ethnic category with survival may be a biased means to understand the reasons for differences in survival by race and ethnicity (47,48). Unbalanced distributions of variables (*e.g.*, age, creatinine level) by racial/ethnic categories may have social or biologic (genetic) causes or both. For most clinical outcomes, social attributes explain racial and ethnic differences more completely than biologic attributes (21–23). In this context, we believe that a combination of social causes that yield a healthier minority racial/ethnic population at ESRD onset more plausibly explains the survival advantages for disparate racial and ethnic minority groups on HD than a combination of biologic causes before and possibly after ESRD onset. However, these analyses cannot distinguish directly the relative contribution of biologic and social causes to the survival differences on HD by race and ethnicity.

Conclusion

We confirm previous observations that Hispanic and racial minority group HD patients, as a whole, have significantly longer survival than non-Hispanic white HD patients. However, our study demonstrates that these survival advantages largely are explained by measurable case-mix and treatment characteristics. This finding refutes the notion that individual Hispanic or racial minority group patients should be expected to survive longer on HD than non-Hispanic white patients with similar clinical attributes. In addition, we provide evidence that the survival advantage observed for racial and ethnic minority groups on HD largely is because these racial and ethnic minority patients are healthier than non-Hispanic white patients at ESRD onset. Although disparities that contribute to the increased burden of ESRD and HD among racial and ethnic minority groups have been identified, further studies and initiatives are needed to identify additional causes, to develop interventions that effectively address these causes, and to implement these interventions.

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