ORIGINAL ARTICLE

Long Interdialytic Interval and Mortality among Patients Receiving Hemodialysis

Robert N. Foley, M.B., David T. Gilbertson, Ph.D., Thomas Murray, M.S., and Allan J. Collins, M.D.

ABSTRACT

BACKGROUND
Patients with end-stage renal disease requiring dialysis have limited tolerance of metabolic and volume-related deviations from normal ranges; in addition, the prevalence of cardiovascular disease is high among such patients. Given these problems, we hypothesized that a long interdialytic interval is associated with adverse events in patients receiving hemodialysis.

METHODS
We studied 32,065 participants in the End-Stage Renal Disease Clinical Performance Measures Project, a nationally representative sample of U.S. patients receiving hemodialysis three times weekly, at the end of calendar years 2004 through 2007. We compared rates of death and cardiovascular-related hospital admissions on the day after the long (2-day) interdialytic interval with rates on other days.

RESULTS
The mean age of the cohort was 62.2 years; 24.2% of the patients had been receiving dialysis treatment for 1 year or less. Over a mean follow-up interval of 2.2 years, the following event rates were higher on the day after the long interval than on other days: all-cause mortality (22.1 vs. 18.0 deaths per 100 person-years, $P<0.001$), mortality from cardiac causes (10.2 vs. 7.5, $P<0.001$), infection-related mortality (2.5 vs. 2.1, $P=0.007$), mortality from cardiac arrest (1.3 vs. 1.0, $P=0.004$), mortality from myocardial infarction (6.3 vs. 4.4, $P<0.001$), and admissions for myocardial infarction (6.3 vs. 3.9, $P<0.001$), congestive heart failure (29.9 vs. 16.9, $P<0.001$), stroke (4.7 vs. 3.1, $P<0.001$), dysrhythmia (20.9 vs. 11.0, $P<0.001$), and any cardiovascular event (44.2 vs. 19.7, $P<0.001$).

CONCLUSIONS
The long (2-day) interdialytic interval is a time of heightened risk among patients receiving hemodialysis. (Funded by the National Institutes of Health.)

From the United States Renal Data System (R.N.F., D.T.G., T.M., A.J.C.) and the University of Minnesota (R.N.F., T.M., A.J.C.) — both in Minneapolis. Address reprint requests to Dr. Foley at the United States Renal Data System, 914 S. 8th St., Suite S-406, Minneapolis, MN 55404, or at rfoley@usrds.org.

N Engl J Med 2011;365:1099-107.

Although some progress has been made in the past two decades, survival rates among patients receiving hemodialysis in the United States remain among the lowest in the world.[1] As in most countries, maintenance hemodialysis in the United States is typically performed three times per week, with two 1-day intervals and one 2-day interval between dialysis sessions. Depending on scheduling, the vast majority of patients do not receive dialysis between Friday and Monday or between Saturday and Tuesday. Patients with end-stage renal disease have a limited capacity to maintain homeostasis in the presence of metabolic and volume-related deviations from normal ranges, and most patients begin maintenance dialysis with overt cardiovascular disease. Thus, there has long been concern that the 2-day interdialytic interval may unnecessarily increase the risk of death.[2-4]

Daily hemodialysis treatment, which has the potential to allay these concerns, has been the focus of considerable interest in the past several years, and two well-designed clinical trials from Canada and the United States showed improvements in surrogate outcomes, such as left-ventricular mass and quality of life, with this approach.[5,6] These studies suggest a possible need to reexamine the issue of the timing and frequency of he-

Table 1. Baseline Characteristics of the Study Population.*

Characteristic	Value	Median (Interquartile Range)
Study year — % of patients		
2005	25.3	
2006	24.9	
2007	25.1	
2008	24.8	
Age — yr	62.2±15.2	63.3 (52.1–74.0)
Years of dialysis	3.8±4.2	2.5 (1.0–5.0)
≤1 Year of dialysis — % of patients	24.2	
Female sex — % of patients	45.1	
Black race — % of patients	36.3	
Hispanic ethnic group — % of patients	13.9	
Cause of end-stage renal disease — % of patients		
Diabetes	43.7	
Hypertension	28.5	
Glomerulonephritis	11.1	
Cystic kidney disease	2.5	
Other	14.1	
Vascular access — % of patients		
Fistula	44.7	
Graft	27.0	
Catheter		
≥90 days	21.0	
<90 days	6.7	
Other	0.6	
Weekly dialysis schedule — % of patients		
Monday, Wednesday, and Friday	59.2	
Tuesday, Thursday, and Saturday	40.8	

Table 1. (Continued.)

Characteristic	Value	Median (Interquartile Range)
Length of dialysis session — min	217.2±33.5	213.0 (195.0–240.0)
Weight — kg		
Predialysis	81.0±22.9	77.3 (65.3–92.5)
Postdialysis	78.1±22.4	74.5 (62.7–74.5)
Interdialytic weight gain — %	3.8±3.0	3.6 (2.5–4.9)
Urea reduction ratio	0.72±0.08	0.73 (0.69–0.77)
Reported Kt/V†	1.69±12.62	1.60 (1.41–1.80)
Residual urine function used in the estimation of Kt/V — % of patients†	2.1	
Body-mass index‡	27.8±7.6	26.3 (22.7–31.2)
Serum albumin — g/dl	3.8±0.5	3.8 (3.5–4.1)
Hemoglobin — g/dl	12.0±1.5	12.0 (11.2–12.9)
Wait-listed for kidney transplant — % of patients	16.4	
Diabetes — % of patients	49.5	
Cardiovascular hospitalization in preceding 90 days — % of patients§	11.9	

* The study population consisted of 32,065 patients receiving hemodialysis. Data were missing for 203 patients regarding years of dialysis, 502 patients regarding length of dialysis session, 596 patients regarding predialysis weight, 629 patients regarding postdialysis weight, 647 patients regarding interdialytic weight gain, 154 patients regarding urea reduction ratio, 3411 patients regarding reported Kt/V, 50 patients regarding body-mass index, 197 patients regarding serum albumin, and 112 patients regarding hemoglobin. Plus–minus values are means ±SD.

† Kt/V is a measure of clearance in which K is the urea clearance of the dialyzer, t is the duration of dialysis, and V is the volume of distribution of urea in the patient.

‡ The body-mass index is the weight in kilograms divided by the square of the height in meters.

§ Cardiovascular hospitalization was defined as admission for myocardial infarction, congestive heart failure, stroke, or dysrhythmia.

modialysis sessions. Hence, in this national study, we addressed the hypothesis that the long interdialytic interval is associated with excess mortality among U.S. patients receiving hemodialysis.

Methods

Objectives

We reviewed records of patients receiving maintenance hemodialysis three times per week in the United States in the period from 2005 through 2008 and considered events on the day of the hemodialysis session after the long (2-day) interdialytic interval as compared with those on other days of the week. Our objectives were to determine if there were differences in overall mortality; cause-specific mortality, with causes grouped as cardiac, vascular, infectious, and other; cause-specific mortality for the five most commonly cited individual causes of death (cardiac arrest, withdrawal of treatment or uremia, myocardial infarction, septicemia, and stroke); cardiovascular-admission rates, a composite of first hospitalization for myocardial infarction, congestive heart failure, stroke, or dysrhythmia; and the individual components of the composite cardiovascular outcome.

Study Patients and Measurements

Participants in the End-Stage Renal Disease Clinical Performance Measures (CPM) Project were enrolled in this study. No new data were collected, and the data-abstraction forms were authorized through the National Institutes of Health clinical exemption process. The CPM Project is a series of annual cross-sectional samples examining selected components of dialysis care, including vascular access, clearance of urea during dialysis, anemia management, and serum albumin levels. All Medicare-eligible adults (≥18 years of age) receiving hemodialysis in a hemodialysis clinic on the last day of December of each study year were eligible for inclusion in the sample; a random sample of these patients was selected, with stratification according to all 18 regional end-stage renal disease networks in the United States. The sample size for each annual national survey was such that 95% confidence intervals for the prevalence of selected clinical performance measures were within 10 percentage points for each end-stage renal disease network, and a 30% oversampling strategy was used to compensate for survey nonresponse.[7-9]

In each annual survey, information about the patients' demographic and clinical characteristics and about clinical variables related to the delivery of hemodialysis was collected for the last 3 months of the preceding calendar year. Race (categories included American Indian or Alaska Native, Asian or Pacific Islander, black, white, and other or unknown) and ethnic group (Hispanic or non-Hispanic) were determined by dialysis staff members. Because of the small numbers of patients in some categories of race or ethnic group, only white and black race were considered for subgroup analysis in this study. Treatment-related variables are for December of the preceding year.

Beginning in 2005, the CPM Project recorded the number of dialysis sessions that each patient received per week. Patients receiving dialysis three times per week were selected for this study, provided the last dialysis-related blood urea levels were measured on any day other than Sunday. In our study population, the date of the predialysis urea level was used to determine whether dialysis sessions were on Monday, Wednesday, and Friday or on Tuesday, Thursday, and Saturday. Of 33,927 patients screened, 1862 (5.5%) were excluded — 921 were not on a thrice-weekly hemodialysis schedule, 703 had blood urea measured on a Sunday, and 238 had both reasons for exclusion.

Publicly available United States Renal Data System (USRDS) Standard Analytical Files (SAF) were used (CPM_HD05, CPM_HD06, CPM_HD07, CPM_HD08, DEATH, HOSP1, HOSP2, PATIENTS, MEDEVID95, MEDEVID05, WAITSEQ_KI, WAITSEQ_KP), linked by the USRDS identification number (USRDS_ID). The Patients file (PATIENTS) was used to determine the date that dialysis treatment began and the original kidney disease; the Waitlist Sequence files (WAITSEQ_KI and WAITSEQ_KP) were used to determine whether patients were listed for kidney transplantation at baseline; and the Hospitalization files (HOSP1 and HOSP2) were used to determine the first hospitalization for myocardial infarction (*International Classification of Diseases, Ninth Revision, Clinical Modification* [ICD-9-CM] code 410), congestive heart failure (ICD-9-CM code 428), stroke (ICD-9-CM codes 430 through 434), and dysrhythmia (ICD-9-CM codes 426 and 427) during the follow-up period. For patients who died, the date and cause of death were determined from the Death file (DEATH) (containing data elements from Centers for Medicare and Medicaid Services [CMS] form 2746).

STATISTICAL ANALYSIS

The hemodialysis week was defined as follows: hemodialysis session 1 (HD_1) as Monday for participants on a Monday, Wednesday, and Friday schedule and as Tuesday for participants on a Tuesday, Thursday, and Saturday schedule; HD_1+1 as Tuesday or Wednesday, respectively; HD_2 as Wednesday or Thursday; HD_2+1 as Thursday or Friday; HD_3 as Friday or Saturday; HD_3+1 as Saturday or Sunday; and HD_3+2 as Sunday or Monday. Thus, HD_1 represented the hemodialysis session after the 2-day interval between sessions. Follow-up for outcome analyses began on January 1 of the survey year for the years 2005 through 2008 and ended at the earliest occurrence of the index event or on June 30, 2009, whichever came first.

Poisson regression was used to quantify event rates and associated confidence intervals in the study population and in subgroups defined by the interval since dialysis initiation, age, sex, race or ethnic group, primary cause of end-stage renal disease, type of vascular access, and status with respect to weight gain between dialysis sessions, wait-listing for a kidney transplant, diabetes, and recent cardiovascular admission. Event rates were annualized; event-rate computation accounted for the fact that only one seventh of the follow-up interval could include events on HD_1 and six sevenths of the interval (representing the other days of the week) included the other events.

For cause-specific mortality, the groupings listed on the 2004 Death Notification form (CMS-2746) were used, except that liver disease, gastrointestinal disease, and metabolic and endocrine causes were subsumed under "other" because of low event numbers; hence, the major cause-of-death categories studied were cardiac, vascular, infectious, and other.[10] In addition, we examined death rates for the five most frequently reported individual causes of death: cardiac arrest, withdrawal of dialysis or uremia, myocardial infarction, septicemia, and stroke. Data were analyzed with the use of SAS software, version 9.1 (SAS Institute).

Table 2. Annualized Mortality and Cardiovascular-Hospitalization Rates.

Event	% of Patients with Event	Rate per 100 Person-Yr (95% CI)			
		Overall	Event Occurred on Day after 2-Day Interdialytic Interval		
			Yes	*No*	*P Value*
Death					
All causes*	41.1	18.6 (18.3–18.9)	22.1 (21.2–23.0)	18.0 (17.7–18.4)	<0.001
Cardiac cause	17.4	7.9 (7.7–8.1)	10.2 (9.6–10.8)	7.5 (7.3–7.7)	<0.001
Vascular cause	2.7	1.2 (1.1–1.3)	1.2 (1.0–1.4)	1.2 (1.1–1.3)	0.9
Infection	4.8	2.2 (2.1–2.3)	2.5 (2.2–2.9)	2.1 (2.0–2.2)	0.007
Other cause	16.3	7.4 (7.2–7.6)	8.2 (7.6–8.7)	7.2 (7.0–7.5)	0.001
Specific causes†					
Cardiac arrest	2.4	1.1 (1.0–1.1)	1.3 (1.1–1.6)	1.0 (0.9–1.1)	0.004
Dialysis withdrawal	4.3	1.9 (1.8–2.1)	2.0 (1.7–2.3)	1.9 (1.8–2.1)	0.8
Myocardial infarction	10.3	4.6 (4.5–4.8)	6.3 (5.8–6.8)	4.4 (4.2–4.5)	<0.001
Septicemia	2.3	1.0 (0.9–1.1)	1.2 (1.0–1.4)	1.0 (0.9–1.1)	0.06
Stroke	1.5	0.7 (0.6–0.8)	0.7 (0.6–0.9)	0.7 (0.6–0.8)	0.8
Cardiovascular hospitalization					
Myocardial infarction	9.0	4.2 (4.1–4.4)	6.3 (5.9–6.9)	3.9 (3.7–4.0)	<0.001
Congestive heart failure	33.1	18.8 (18.4–19.2)	29.9 (28.7–31.1)	16.9 (16.6–17.3)	<0.001
Stroke	7.1	3.3 (3.2–3.5)	4.7 (4.3–5.1)	3.1 (3.0–3.3)	<0.001
Dysrhythmia	25.9	13.6 (13.3–13.9)	20.9 (19.9–21.9)	11.0 (10.8–11.3)	<0.001
Any cardiovascular event	45.8	28.8 (28.3–29.3)	44.2 (42.7–45.8)	19.7 (19.3–20.0)	<0.001

* All deaths were assigned to one of the four broad groups of causes listed.
† The five most frequently reported individual causes of death are listed.

RESULTS

CHARACTERISTICS OF THE STUDY PARTICIPANTS

Baseline characteristics of the study population are shown in Table 1. The mean age was 62.2 years; 24.2% of the patients had been receiving dialysis treatment for 1 year or less, 45.1% were women, 36.3% were black, and 13.9% were Hispanic. Diabetes mellitus was the cause of end-stage renal disease in 43.7% of the patients, and for 27.7%, a catheter was used for vascular access for hemodialysis.

Over a mean follow-up period of 2.2 years, 41.1% of the study population died, 17.4% from cardiac causes, 2.7% from vascular causes, and 4.8% from infectious causes; 9.0% of the patients were admitted to the hospital with myocardial infarction, 33.1% with congestive heart failure, 7.1% with stroke, 25.9% with dysrhythmia, and 45.8% with any of these cardiovascular events (Table 2). The following event rates were higher on the day after the long interdialytic interval than on other days: all-cause mortality (22.1 deaths vs. 18.0 per 100 person-years), mortality from cardiac causes (10.2 vs. 7.5), infection-related mortality (2.5 vs. 2.1), mortality from cardiac arrest (1.3 vs. 1.0), mortality from myocardial infarction (6.3 vs. 4.4), and admissions for myocardial infarction (6.3 vs. 3.9), congestive heart failure (29.9 vs. 16.9), stroke (4.7 vs. 3.1), dysrhythmia (20.9 vs. 11.0), and any cardiovascular event (44.2 vs. 19.7). Although most event rates were highest on the day after the long interdialytic interval, a sawtooth pattern was apparent for all-cause mortality, mortality from cardiac causes, and cardiovascular admissions, with event rates lower on the day before and the day after a dialysis session (Fig. 1).

Figure 2 summarizes mortality and cardiovascular-admission rates for all patients and for 25 subgroups defined by the prior duration of dialysis therapy, age, sex, race or ethnic group, cause of end-stage renal disease, type of vascular access, and status with respect to weight gain between dialysis sessions, wait-listing for a kidney trans-

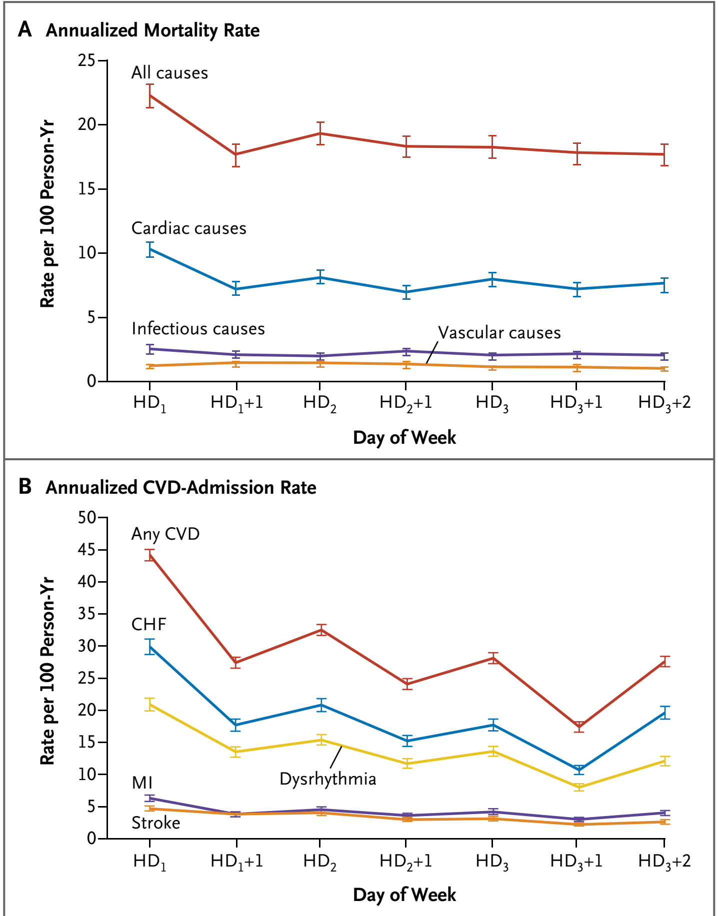


Figure 1. Annualized Mortality and Cardiovascular-Admission Rates on Different Days of the Dialysis Week.

I bars represent 95% confidence intervals. CHF denotes congestive heart failure, CVD cardiovascular disease, HD_1 the day of the first hemodialysis session of the week, HD_1+1 the day after the first session, HD_2 the day of the second hemodialysis session, HD_2+1 the day after the second session, HD_3 the day of the third hemodialysis session, HD_3+1 the day after the third session, HD_3+2 the second day after the third session, and MI myocardial infarction.

Figure 2 (facing page). Annualized Mortality and Cardiovascular-Admission Rates on the Day after the Long Interdialytic Interval and on Other Days, According to Subgroup.

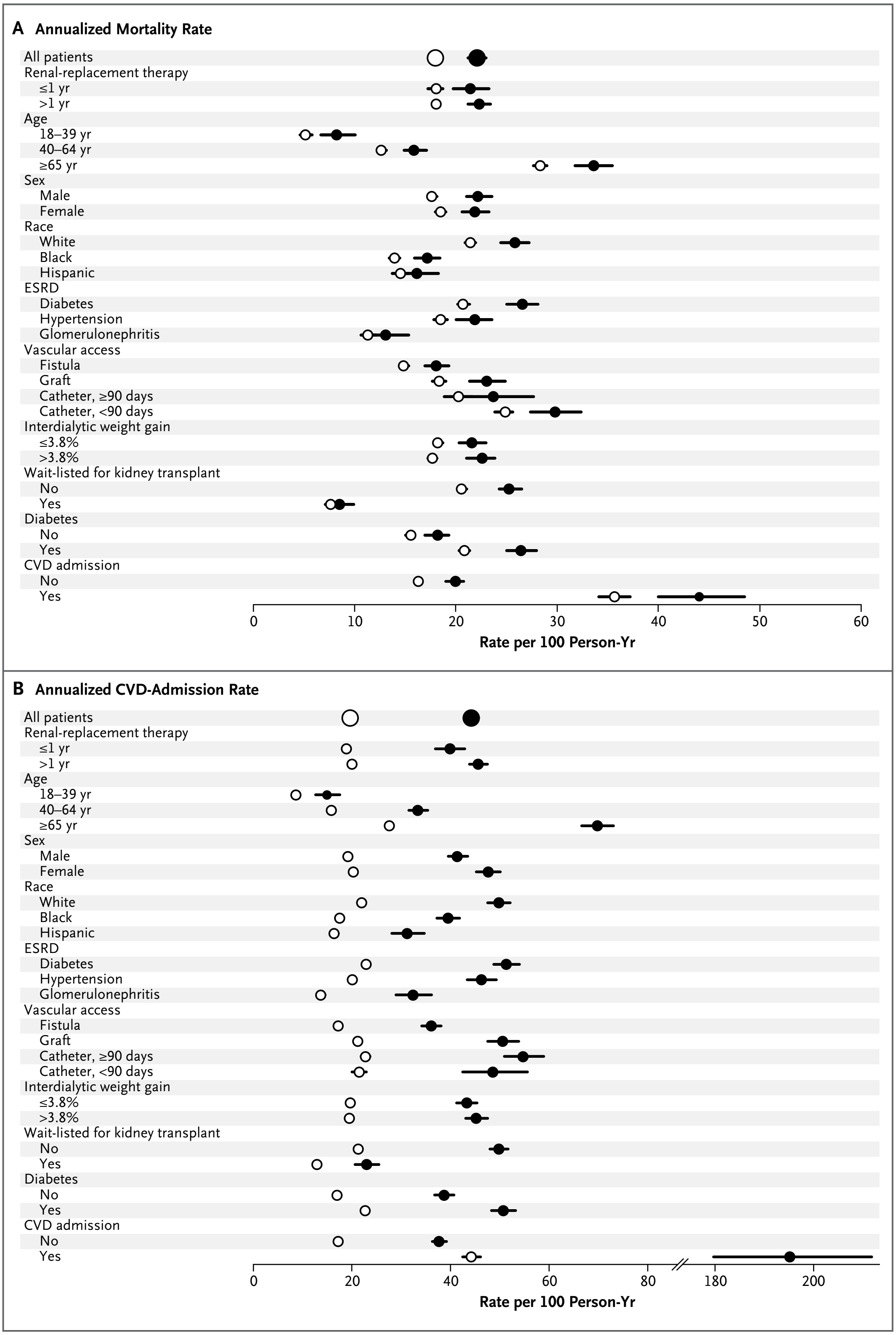
Events on the day after the long (2-day) interdialytic interval are indicated by a black circle, and events on other days are indicated by an open circle. The horizontal bars represent 95% confidence intervals. CVD denotes cardiovascular disease, and ESRD end-stage renal disease.

plant, diabetes, and recent cardiovascular admission. Nonoverlapping 95% confidence intervals were observed throughout, except for death rates in the following subgroups: Hispanic ethnic group, end-stage renal disease from glomerulonephritis, use of a catheter for dialysis access for at least 90 days, and wait-listed for a transplant.

DISCUSSION

In this study of a relatively contemporary, representative population of U.S. adults receiving hemodialysis, we found that most events studied occurred more frequently on the day after the long interdialytic interval than on other days, including all-cause mortality, mortality from cardiac causes, infection-related mortality, mortality from cardiac arrest, and mortality from myocardial infarction. Similar patterns were observed for hospital admissions with myocardial infarction, congestive heart failure, stroke, dysrhythmia, and any of these cardiovascular events. Subgroup analyses suggested that this excess of adverse events on the day after the long interdialytic interval was close to being a generalized phenomenon.

Despite the widespread clinical impression that the end of the long interdialytic interval is a time of heightened risk, comparatively few studies have examined associations between outcomes and hemodialysis schedules. The results of these studies, which have examined sudden death and cardiac arrest, have been similar to those reported here for death from cardiac arrest.[4,11-13] For example, Bleyer et al.[4] reported 7-day patterns of sudden death and death from cardiac causes in U.S. patients receiving hemodialysis between 1977 and 1997. Although proportions of deaths from noncardiac causes were homogeneous, Mondays and Tuesdays were overrepresented for sudden death and death from cardiac causes.[4] Another study showed substantial escalations in the risk of sudden death during the 12-hour period starting with the dialysis procedure and during the 12-hour period at the end of the weekend interval.[14] Karnik et al.[11] examined 400 cardiac arrests that occurred on dialysis units between October 1998 and June 1999, among 77,000 patients receiving hemodialysis at units affiliated with Fresenius Medical Care North America. The rate of cardiac arrest was 7 per 100,000 hemodialysis sessions, equivalent to 1.1 per 100 person-years with a typical thrice-weekly hemodialysis schedule; cardiac arrest occurred more frequently on Mondays, and the associated mortality was 60% during the first 48 hours after the arrest.


A Annualized Mortality Rate
All patients
Renal-replacement therapy
≤1 yr
>1 yr
Age
18–39 yr
40–64 yr
≥65 yr
Sex
Male
Female
Race
White
Black
Hispanic
ESRD
Diabetes
Hypertension
Glomerulonephritis
Vascular access
Fistula
Graft
Catheter, ≥90 days
Catheter, <90 days
Interdialytic weight gain
≤3.8%
>3.8%
Wait-listed for kidney transplant
No
Yes
Diabetes
No
Yes
CVD admission
No
Yes
0
10
20
30
40
50
60
Rate per 100 Person-Yr
B Annualized CVD-Admission Rate
All patients
Renal-replacement therapy
≤1 yr
>1 yr
Age
18–39 yr
40–64 yr
≥65 yr
Sex
Male
Female
Race
White
Black
Hispanic
ESRD
Diabetes
Hypertension
Glomerulonephritis
Vascular access
Fistula
Graft
Catheter, ≥90 days
Catheter, <90 days
Interdialytic weight gain
≤3.8%
>3.8%
Wait-listed for kidney transplant
No
Yes
Diabetes
No
Yes
CVD admission
No
Yes
0
20
40
60
80
180
200
Rate per 100 Person-Yr

For deaths that occurred on days when dialysis was scheduled, our study did not allow us to determine whether death occurred before, during, or after the time of the scheduled dialysis session; similarly, studying the effect of missed dialysis sessions on outcomes was not possible, and whether patients were assigned to morning or evening shifts was unknown. Missed or shortened dialysis treatments are known to be much more frequent in the United States than elsewhere, an occurrence that is associated with higher mortality.[15,16] Regarding the timing of dialysis shifts, one study examined outcomes for 6939 patients in the United States who began treatment with hemodialysis between 1990 and 1993. Shift-associated mortality differences were present, but only in patients 60 years of age or older, with the lowest mortality during the morning shift, intermediate mortality during the afternoon shift, and the highest mortality during the evening shift.[17] Morning-shift patients also had lower mortality in the study by Bliwise et al.[18]

Because the same population was considered when comparing outcome rates on different days, it seems unlikely that unmeasured coexisting conditions could account for the findings. As with all nonexperimental designs, causes and effects cannot be identified with certainty, and interpretations should be made with caution. For example, one could argue that because mortality and cardiovascular-admission rates are highest on the hemodialysis day after the long interdialytic interval, hemodialysis itself is responsible, and adverse outcomes could be avoided by not providing dialysis at all. This somewhat counterintuitive hypothesis is not supported by the observation that on weekends adverse-event rates were lowest on the first day after a dialysis session, intermediate on the next day, and highest on the day of the next dialysis session. To date, randomized, controlled trials have failed to conclusively identify interventions that reduce rates of cardiovascular events and death among patients receiving hemodialysis.

Apart from its nonexperimental design, the study has other limitations, including the use of retrospective data and dependence on administrative codes to identify cardiovascular events. In addition, attribution of cause-specific death is likely to be of limited accuracy in the population studied. Accurate estimates of residual renal function were not available. That being said, it was interesting that the subgroup of patients with less than 1 year of prior dialysis treatment, unlike the overall study population, did not have higher-than-expected mortality after the long interdialytic interval. Finally, cost information was not collected; given that hospitalization is very costly in the dialysis population, it might be relevant to compare the upstream costs of an extra dialysis session every 2 weeks with the downstream costs associated with the use of other health care resources.

Despite its limitations, this study has some attractive features. By design, it was broadly representative of the overall U.S. dialysis population. Regarding the long interdialytic interval, findings were similar within subgroups and across outcomes, with higher mortality, especially for deaths from cardiac causes, and higher rates of hospital admission for cardiovascular events. Unexplained disparities in event rates appeared to be clinically meaningful in several instances. Hence, this study provides clinical equipoise for a controlled trial of how dialysis services are provided.

Supported by a contract (HHSN267200715002C) from the National Institute of Diabetes and Digestive and Kidney Diseases.

Disclosure forms provided by the authors are available with the full text of this article at NEJM.org.

We thank United States Renal Data System colleagues Beth Forrest for regulatory assistance and Shane Nygaard for assistance with manuscript preparation, and Nan Booth, M.S.W., M.P.H., for editorial assistance with an earlier version of the manuscript.

REFERENCES

1. United States Renal Data System. 2010 USRDS annual data report: atlas of chronic kidney disease and end-stage renal disease in the United States. 2010 ed. Bethesda, MD: National Institute of Diabetes and Digestive and Kidney Diseases, 2010.
2. Kjellstrand CM, Rosa AA, Shideman JR, Rodrigo F, Davin T, Lynch RE. Optimal dialysis frequency and duration: the "unphysiology hypothesis". Kidney Int Suppl 1978;13:S120-S124.
3. Kjellstrand CM, Evans RL, Petersen RJ, Shideman JR, Von Hartitzsch B, Buselmeier TJ. The "unphysiology" of dialysis: a major cause of dialysis side effects? Kidney Int Suppl 1975;7:30-4.
4. Bleyer AJ, Russell GB, Satko SG. Sudden and cardiac death rates in hemodialysis patients. Kidney Int 1999;55:1553-9.
5. Culleton BF, Walsh M, Klarenbach SW, et al. Effect of frequent nocturnal hemodialysis vs conventional hemodialysis on left ventricular mass and quality of life: a randomized controlled trial. JAMA 2007;298:1291-9.
6. Chertow GM, Levin NW, Beck GJ, et al. In-center hemodialysis six times per week versus three times per week. N Engl J Med 2010;363:2287-300. [Erratum, N Engl J Med 2011;364:93.]
7. Owen WF Jr, Szczech L, Johnson C, Frankenfield D. National perspective on iron therapy as a clinical performance

measure for maintenance hemodialysis patients. Am J Kidney Dis 1999;34:Suppl 2:S5-S11.
8. 2000 Annual report: ESRD clinical performance measures project. Baltimore: Office of Clinical Standards and Quality, 2000.
9. Reliability report for the 2000 ESRD CPM annual report. Baltimore: Office of Clinical Standards and Quality, 2000.
10. Centers for Medicare and Medicaid Services. ESRD death notification: end stage renal disease medical information system. (http://www.usrds.org/2008/rg/forms/05_2746_Death_Notification_2004.pdf.)
11. Karnik JA, Young BS, Lew NL, et al. Cardiac arrest and sudden death in dialysis units. Kidney Int 2001;60:350-7.
12. Genovesi S, Valsecchi MG, Rossi E, et al. Sudden death and associated factors in a historical cohort of chronic haemodialysis patients. Nephrol Dial Transplant 2009;24:2529-36.
13. Lafrance JP, Nolin L, Senécal L, Leblanc M. Predictors and outcome of cardiopulmonary resuscitation (CPR) calls in a large haemodialysis unit over a seven-year period. Nephrol Dial Transplant 2006;21:1006-12.
14. Bleyer AJ, Hartman J, Brannon PC, Reeves-Daniel A, Satko SG, Russell G. Characteristics of sudden death in hemodialysis patients. Kidney Int 2006;69:2268-73.
15. Bleyer AJ, Hylander B, Sudo H, et al. An international study of patient compliance with hemodialysis. JAMA 1999;281:1211-3.
16. Saran R, Bragg-Gresham JL, Rayner HC, et al. Nonadherence in hemodialysis: associations with mortality, hospitalization, and practice patterns in the DOPPS. Kidney Int 2003;64:254-62.
17. Abbott KC, Reynolds JC, Trespalacios FC, Cruess D, Agodoa LY. Survival by time of day of hemodialysis: analysis of United States Renal Data System Dialysis Morbidity and Mortality Waves III/IV. Am J Kidney Dis 2003;41:796-806.
18. Bliwise DL, Kutner NG, Zhang R, Parker KP. Survival by time of day of hemodialysis in an elderly cohort. JAMA 2001;286:2690-4. [Erratum, JAMA 2002;287:192.]