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Comparison of mortality with home hemodialysis and center hemodialysis: A national study

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Comparison of mortality with home hemodialysis and center hemodialysis: A national study. We sought to determine whether lower mortality rates reported with hemodialysis (HD) at home compared to hemodialysis in dialysis centers (center HD) could be explained by patient selection. Data are from the United States Renal Data System (USRDS) Special Study Of Case Mix Severity, a random national sample of 4,892 patients who started renal replacement therapy in 1986 to 1987. Intent-to-treat analyses compared mortality between home HD ($N = 70$) and center HD patients ($N = 3,102$) using the Cox proportional hazards model. Home HD patients were younger and had a lower frequency of comorbid conditions. The unadjusted relative risk (RR) of death for home HD patients compared to center HD was 0.37 ($P < 0.001$). The RR adjusted for age, sex, race and diabetes, was 44% lower in home HD patients (RR = 0.56, $P = 0.02$). When additionally adjusted for comorbid conditions, this RR increased marginally (RR = 0.58, $P = 0.03$). A different analysis using national USRDS data from 1986/7 and without comorbid adjustment showed patients with training for self care hemodialysis at home or in a center ($N = 418$) had a lower mortality risk (RR = 0.78, $P = 0.001$) than center HD patients ($N = 43,122$). Statistical adjustment for comorbid conditions in addition to age, sex, race, and diabetes explains only a small amount of the lower mortality with home HD.

Each year the number of patients with end-stage renal disease (ESRD) in the United States continues to increase. Information from the United States Renal Data System (USRDS) shows the prevalence count of treated ESRD has been increasing by 9 to 13% per year and by 1992 there were more than 242,000 prevalent patients [1]. Hemodialysis rather than peritoneal dialysis remains the predominant treatment modality in the United States. Among prevalent dialysis patients in 1992, 81% of patients were being treated with center hemodialysis and only one percent were receiving hemodialysis at home. This was not always the case. Previously a greater proportion of patients were treated with home hemodialysis, but use of this modality has declined progressively over the last 20 years in the United States.

This decrease in the proportion of patients treated by home hemodialysis has occurred despite reports of a substantially lower mortality rate with this modality than either center hemodialysis or continuous ambulatory peritoneal dialysis (CAPD) [2, 3]. Also, other than a successful kidney transplant, it has been reported that home hemodialysis provides the best quality of life, the most independence and the best opportunity for rehabilitation for ESRD patients [4, 5]. The difference in survival between home and center hemodialysis patients often has been attributed to patient selection, as home hemodialysis patients in general differ from patients treated in facilities in characteristics such as age, race, sex, and cause of ESRD–all factors with significant impact on survival.

Selection of patients to home or center hemodialysis may not just depend on age, sex and cause of ESRD. Patients may also be selected based on the comorbid conditions present when they start treatment. Comorbid conditions such as ischemic heart disease, cerebrovascular disease, and the patient's nutritional status also substantially alter the risk of death. The magnitude of this excess risk has been described for incident hemodialysis patients after adjustment for differences in age, sex and race using the Cox proportional hazards model [6]. This technique can be used to compare two groups of patients while adjusting for the effect of differing frequencies of known comorbid conditions.

The goals of the present study were to determine (1) whether better survival rates reported with home hemodialysis could be explained by differences in patient characteristics and comorbid conditions between patients treated at home and in hemodialysis centers, and (2) the magnitude of the relative risk while adjusting for these factors. The investigation was made possible by the availability of data from the USRDS Special Study of Case Mix Severity, a national random sample of dialysis patients starting treatment in 1986 to 1987. Data from this Special Study have also been used in a similar study comparing mortality between CAPD and hemodialysis patients [7].

Methods

Data collection

Data were obtained from the USRDS Special Study of Case Mix Severity Standard Analysis File. This file contains information abstracted in 1989 from a sample of 4,892 patients who started treatment for ESRD in 1986 and 1987. The sampling process and database construction have been described in detail elsewhere [8]. All patients in the study were Medicare-entitled for dialysis services within 90 days or less of the onset of ESRD. Data were abstracted by staff of the 18 ESRD Networks, under contract with the Health Care Financing Administration (HCFA). The

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data collection form was developed and tested by the USRDS Coordinating Center (USRDS CC), the National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK) and HCFA.

Patients from each of the 18 ESRD Networks were selected using a national randomized two-stage sampling procedure. In the first stage, the USRDS CC selected a weighted sample of 291 dialysis centers from all units nationwide with a probability proportionate to the size of the facility. To facilitate abstraction of data from patient records, this sample of dialysis centers was limited to those dialysis units located within one day's travel from the respective Network office. Individual patients within each center were sampled at random and the number of patients from each center was proportional to the facility's census.

Data collected included patient identifiers, information on health insurance, presence or absence of a variety of comorbid conditions within ten years prior to diagnosis of ESRD, physical characteristics (height, weight, nutritional status, blood pressure) measured within two to six weeks of the onset of ESRD, dialysis treatment modality on day 30 of ESRD, prescribed dose of dialysis, date of death or transplantation, psychosocial status at onset of ESRD, and ESRD-related laboratory data. A copy of the data abstraction form was published as Appendix B of the USRDS 1994 Annual Data Report [9]. Data collected by abstraction were supplemented from the USRDS database which contains longitudinal data on all Medicare ESRD patients in the United States from 1977 to the present. Most of these data were derived from the HCFA Program Management and Medical Information System. Supplemental data included date of first dialysis and date of death or transplantation. Data from the USRDS were based on a May 1993 update of the HCFA file sources, and were used to determine survival and transplant status of patients as of December 31, 1992.

Analytical methods

The analysis compared the mortality for home hemodialysis patients with that of patients treated by center hemodialysis, using the Cox proportional hazards technique [10]. Comparisons of descriptive parameters such as frequencies and means between groups were made using Student's *t*-test. The analysis used an intent-to-treat model with adjustment for age, sex, diabetes and comorbid conditions because the primary aim was to determine the effect on mortality of patient assignment to home hemodialysis at the onset of ESRD compared to center hemodialysis. An intent-to-treat analysis was felt to provide the best information to help the individual patient and their physician choose between center and home hemodialysis.

Patients were classified to three groups based on the modality of treatment at 30 days after onset of ESRD: (1) center hemodialysis; (2) home hemodialysis currently in home training; and (3) home hemodialysis already receiving treatment at home. There was concern about possible misclassification of the patients treated at home. Since home hemodialysis training generally takes 6 to 12 weeks, it appeared likely that at 30 days after onset of ESRD training for home hemodialysis would not be completed. Thus, patients classified as home hemodialysis who were already receiving treatment at home 30 days after onset of ESRD would likely have been receiving dialysis from a nurse visiting the home. At the time of the study such services were being offered by at least one large proprietary corporation. Such patients would likely have significantly greater morbidity and thus bias the outcome against home hemodialysis. Patients identified as being in home hemodialysis training were less likely to be misclassified, since patients requiring nurse-assisted dialysis in the home ordinarily would have received brief or no training. To avoid this potential misclassification bias, the primary analysis was therefore a comparison of center hemodialysis patients with only those home hemodialysis patients who were in training on day 30 after the onset of ESRD. Patients on peritoneal dialysis and all those transplanted within 30 days of the start of ESRD treatment were excluded from the analysis.

The analysis was adjusted for the confounding effects of patient age, sex, race and disease causing ESRD. The age of home hemodialysis patients ranged from 18 to 90 years. Patients younger than 18 years and older than 90 years were excluded from the sample so that the age range in the center hemodialysis group was comparable to that of the home hemodialysis patients. Within this range the effect of age was adjusted for by including age at onset of ESRD as a covariate in the proportional hazard models. Patients were stratified on sex, race, and diabetes mellitus as a cause of ESRD. In view of the relatively small number of home hemodialysis patients in the sample, the number of strata in the analysis had to be limited. There were two strata for race: white patients and a composite race category consisting of black and Native American/Alaskan Native patients. Asians (not found in the home hemodialysis sample) and any patients whose race was unknown were excluded from the study. Patients were stratified on diabetes as a cause of ESRD because of the known outcome differences between diabetic and nondiabetic ESRD patients.

Follow-up information through December 1992 was available on patients in the sample. Observations were censored at 1,500 days into the study or at the date of death or transplantation, whichever came first. As this was an intent-to-treat model, follow up was not censored at change of dialysis modality. Observations were censored at 1,500 days after the date of first treatment (more than 4 years of follow-up) because by this time substantial switching of dialysis modality might have occurred and at transplantation as it is a desired change. The dependent variable in the proportional hazards model therefore measured the time in days from 30 days after the start of ESRD treatment to the date of death or transplantation or to the end of follow-up at 1500 days.

As reported previously, information on 25 comorbid conditions was collected for the USRDS Special Study Of Case Mix Severity 1992 [8, 9]. Comorbid conditions used in the present model were selected on the basis of either (1) a priori hypotheses about their importance in explaining differences in mortality between the two groups of dialysis patients, or (2) as a result of analyses of similar comorbid conditions collected in the USRDS Special Studies Of Case Mix Adequacy and Severity. These analyses identified the conditions that were the best independent predictors of mortality in center hemodialysis patients.

Because of patient selection for home hemodialysis, some of the comorbid conditions previously found to be predictive of mortality were likely to be present among home hemodialysis patients at a substantially different frequency than among patients treated in a center. In particular, because of selection, it was felt that patients with a history of cardiac arrest or of neoplasm with metastatic spread were likely to be underrepresented, if present at all, among the home hemodialysis patients. This assumption proved correct on preliminary examination of the data set. The

frequencies of previous cardiac arrest were 0% and 1% among home and center hemodialysis patients, respectively, and the frequencies of a history of neoplasm with metastases were 0% and 2%, respectively. All these patients were excluded from the study to avoid difficulties in adjusting appropriately for these differences. Two other variables were present at a substantially lower frequency in the home hemodialysis population: patients who were felt to be clinically undernourished (2.5% vs. 14%), and those with a history of hepatic cirrhosis (0% vs. 2%). These patients also were excluded from the study.

Information was lacking for one or more covariates for some patients. If so, numeric variables with missing values such as serum albumin levels were set to the mean of observed values. Categorical covariates with missing values were set to zero, as if the comorbid condition was not present. This avoided excluding patients with small amounts of missing data from the proportional hazards model. For certain covariates a "missing variable" was created to account for a potential different mortality among subjects with missing data. In the final model, a binary variable set to one was used to indicate patients for whom a prescribed Kt/V could not be calculated.

The final proportional hazards model was adjusted by stratification for sex, race and diabetes as a cause of ESRD, and adjusted for the effect of age by inclusion of patient age at the onset of ESRD as a continuous covariate. The final model included a covariate indicating those patients treated with home hemodialysis. For these patients comparison to the reference group of center hemodialysis patients was made by calculation of a relative risk of death. Additional covariates included obesity, serum albumin level, current cigarette smoking, prescribed Kt/V or "missing prescribed Kt/V," and whether the patient had 12 years of education. Comorbid conditions included as covariates included a history of stroke, myocardial infarction, cardiac arrhythmia, peripheral vascular disease, congestive heart failure, chronic obstructive pulmonary disease, insulin therapy, and inability to walk, eat or transfer independently. Peripheral vascular disease was defined as presence of a history of peripheral vascular disease, amputation, intermittent claudication, or absent foot pulses on examination. The determination that the patient was obese was based on information in the medical record from between one month prior to the onset of ESRD to six weeks after the first treatment. Calculation of prescribed Kt/V used dialyzer-specific urea clearance derived from the manufacturer's specifications for *in vitro* clearance of urea by dialyzer blood flow, prescribed dialysis time, and patient total body water estimated from height, weight and sex.

Validity analysis

Preliminary results suggested that among the Case Mix Severity Study sample the relative risk of death adjusted for age, sex, race and disease was lower for patients whose intended treatment modality was home hemodialysis. To ensure the validity of this observation we sought evidence of such an effect for all home hemodialysis patients in the United States incident during 1986 and 1987, not just those in the Case Mix Severity Study sample.

The dialysis modality is known for Medicare patients in the national USRDS census on day 90 after start of renal replacement therapy. This information is derived from a variety of sources which include the HCFA ESRD Medical Evidence Form and Quarterly Dialysis Reports. The accuracy of this assignment of modality for home hemodialysis patients has been in doubt, as is stressed by the USRDS each year in its Annual Data Report. Under the classification system used by the USRDS, at day 90 after ESRD, a patient whose intended modality of treatment is home hemodialysis could be classified into one of two groups: (1) training for "self care" hemodialysis and currently being treated in a dialysis center, (2) treatment at home with hemodialysis. Currently the USRDS reports only those patients already being treated at home on the 90th day after starting renal replacement therapy as home hemodialysis patients. Those patients still in home hemodialysis training and dialyzing in a center are classified as center hemodialysis patients, and patients receiving nurse-assisted dialysis at home can be classified as home hemodialysis patients. We sought to more accurately define individual home hemodialysis patients, either in training or dialyzing at home at 90 days, by identifying evidence of training for self care hemodialysis. We defined adequate training for self care hemodialysis as greater than nine training sessions over a three month period; three weeks is a conservative estimate of the time required to train for home hemodialysis.

For each patient we searched the first two Quarterly Dialysis Reports after the date of onset of ESRD for evidence of billing for training sessions for self care dialysis. Patients who had received self care training fell into three groups: (1) currently dialyzing in a dialysis center while training for self care hemodialysis; (2) trained and performing hemodialysis in a center; or (3) trained and performing self care hemodialysis at home. There was no method to differentiate which of the patients training for self care were training for treatment at home as opposed to self care in a dialysis unit. All the categories of self care hemodialysis whether at home or in a center were therefore combined. Consequently the primary analysis was a comparison of the relative risk of death of patients with training for self care hemodialysis either at home or in a dialysis unit with that of center hemodialysis patients.

The same age, race and treatment modality exclusion criteria were used in this analysis as were used in the analysis based on the Case Mix Severity Study sample. A similar proportional hazards model, with adjustment by stratification for sex, race and diabetes and with age included as a continuous covariate, was employed. The other covariate in the model indicated those patients with training for self care hemodialysis. There was no adjustment for comorbid conditions as this information was not collected on a nationwide basis during 1986 and 1987.

Results

Sample description

In the Case Mix Severity Study sample the intended mode of treatment was identified as center hemodialysis for 3,102 patients, and as home hemodialysis for 70 patients who were in training at 30 days after the onset of ESRD. Overall, home hemodialysis patients were younger (49 vs. 59 years), less likely to have diabetes as a cause of ESRD (14% vs. 30%), more likely to be white (64% vs. 59%) and male (60% vs. 51%). The relative frequencies of these parameters and of the comorbid conditions which were present at the start of ESRD treatment and used in the final model are shown in Table 1. Statistically significant differences between the groups are also indicated in the table. Most of the comorbid conditions were present at a lower frequency in patients treated by home hemodialysis.

Table 1. Patient characteristics and comorbidity in study population, data from USRDS Case Mix Severity Study 1986–1990

Patient characteristics/ comorbid factors	Center HD (N = 3102)	Home HD (N = 70)
Age *years*	59 ± 16[a]	49 ± 16[a,b]
White race %	59	64
Female sex %	49	40
Diabetes as a cause of ESRD %	30	14[b]
Active insulin therapy %	22.3	14.3
Active smoker %	16.7	12.9
Arrhythmia %	10.1	14.3
Chronic obstructive pulmonary disease %	11.2	14.3
Congestive heart failure %	38.6	24.3[b]
Less than 12 years education %	26.9	20.0
Myocardial infarction %	13.5	4.3[b]
Obese %	22.5	11.4[b]
Peripheral vascular disease %	17.8	12.9
Stroke %	10.1	2.9[b]
Unable to eat independently %	2.3	2.9
Unable to transfer independently %	9.2	8.6
Unable to walk independently %	9.3	4.3
Prescribed Kt/V	1.00 ± 0.44[a]	1.02 ± 0.43[a]
Serum albumin *g/dl*	3.5 ± 0.5[a]	3.6 ± 0.6[a,b]

[a] Data represent mean ± standard deviation
[b] Significantly different from center HD at $P < 0.05$

Table 2. Relative risk ratios for patient characteristics and comorbid factors included in final proportional hazards model, USRDS Case Mix Severity Study 1986–1990

Patient characteristic/ comorbid factor	Relative risk	P value
Home HD training at day 30	0.58[a]	0.03
Age (for each additional 10 years)	1.40	<0.001
Arrhythmia	1.10[b]	0.1
Active insulin therapy	1.30[b]	<0.001
Chronic obstructive pulmonary disease	1.18[b]	0.03
Congestive heart failure	1.20[b]	0.001
Myocardial Infarction	1.42[b]	<0.001
Peripheral vascular disease	1.14[b]	0.03
Active smoker	1.21[b]	<0.01
Less than 12 years education	0.96[b]	0.49
Obese	0.81[b]	<0.01
Prescribed Kt/V (per 0.4 increase)	1.00	0.92
Missing prescribed Kt/V	1.01	0.80
Serum albumin (per 0.2 g/dl increase)	0.92	<0.001
Stroke	1.27[b]	<0.01
Unable to eat independently	1.22[b]	0.19
Unable to transfer independently	1.15[b]	0.21
Unable to walk independently	1.15[b]	0.22

[a] Relative to reference group of center hemodialysis patients
[b] Relative to reference group of all patients without this factor

Relative mortality risks

The adjusted mortality risks associated with patient characteristics and comorbid conditions are shown in Table 2. For each characteristic or comorbid condition, an adjusted risk ratio is expressed relative to a selected reference group that is assigned a mortality risk of one. For example, for the variable "myocardial infarction" the at risk group is all patients with a history of myocardial infarction in the ten years prior to the start of ESRD treatment, and the reference group is all patients who do not have a history of myocardial infarction recorded. The relative risk of 1.42 indicates that the mortality rate in patients with a history of myocardial infarction was 42% higher than for patients without such a history. By means of the Cox proportional hazards model, this comparison is made while holding the effects of all other variables in the model constant.

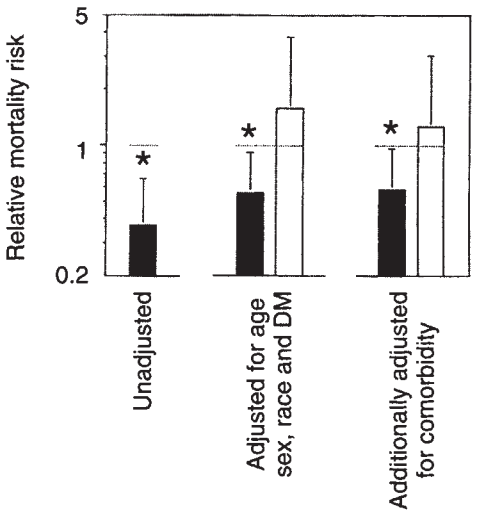

Fig. 1. *Relative mortality risk with 95% confidence intervals for patients in home hemodialysis training (■, N = 70) or dialyzing at home (□, N = 9) at day 30 after ESRD, showing the effect of adjustment for age, sex, race and diabetes mellitus.* The dotted line indicates the relative mortality risk for those patients treated with center hemodialysis (N = 3102) who are the reference group. The symbol (*) indicates those values of relative risk which are significantly different from the reference group ($P < 0.05$). Data are from USRDS Case Mix Severity Study for patients incident in 1986 to 87 with follow-up starting from day 30 after ESRD.

The results of the analysis in the Case Mix Severity Study sample are shown in Figure 1. The bar on the left shows the relative risk for home hemodialysis patients in comparison to the reference group, center hemodialysis patients, without any adjustment for patient characteristics or comorbid conditions. The relative risk ratio is 0.37, indicating a 63% reduction in the risk of death for the home hemodialysis patients [$P < 0.001$; 95% confidence interval (95% CI) 0.22, 0.60]. When this comparison is controlled for the effects of age, race, sex, and disease causing ESRD, but not allowing for the effect of comorbid conditions, the relative risk increases to 0.56 ($P = 0.02$; 95% CI 0.34, 0.92). The relative risk of 0.56 for home hemodialysis indicates that if the age distribution in this group were similar to that of the center dialysis patients, home hemodialysis would be associated with a 44% reduction in mortality risk. As would be expected, increasing age is associated with an increased mortality rate. There is a 48% higher mortality risk for each additional decade of life (RR = 1.48, $P < 0.001$).

When the Cox proportional hazards model included additional adjustment for patient characteristics and for the effect of comorbid conditions, home hemodialysis was associated with a relative risk of 0.58 ($P = 0.03$, 95% CI 0.35, 0.95). Even after adjustment for comorbid conditions, the risk of mortality for home hemodialysis patients was 42% lower than for patients treated in hemodialysis centers. Introducing adjustment for comorbid conditions explains little of the lower mortality with home hemodialysis as the relative risk of death only changes from 0.56 to 0.58. Most of the improvement in mortality with home hemodialysis is not

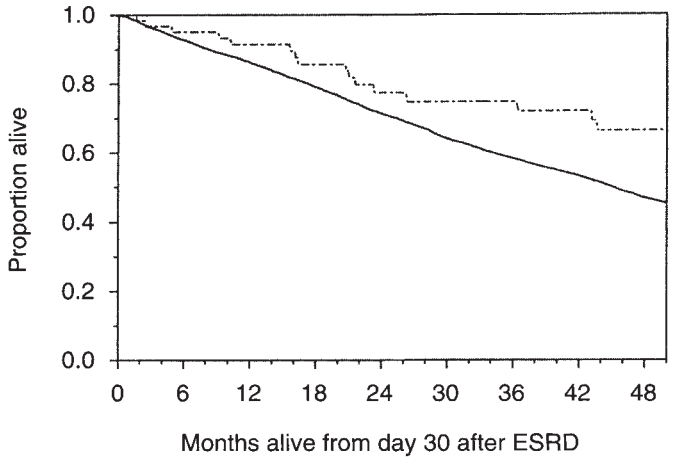

Fig. 2. *Cox estimates of survival using an intent-to-treat model for patients in home hemodialysis training at day 30 after onset of ESRD (—·—, N = 70) compared to center hemodialysis patients (——, N = 3102) after adjustment for age, sex, race, diabetes and comorbid conditions (P = 0.03).* The curves are for patients with overall average characteristics. Data are from USRDS Case Mix Severity Study for patients incident in 1986 to 87 with follow-up from day 30 after ESRD.

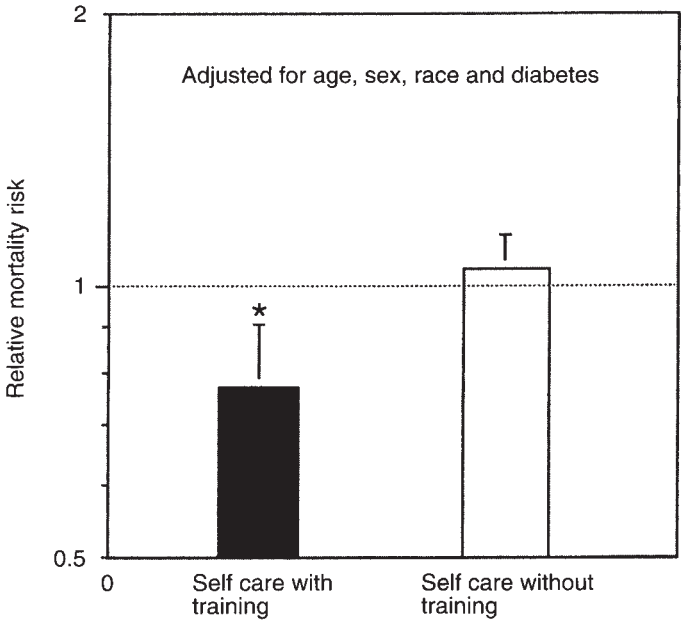

Fig. 3. *Relative mortality risk with 95% confidence intervals for self care hemodialysis with training (N = 418) and without training (N = 1184), adjusted for age, sex, race and diabetes mellitus.* The dotted line indicates the risk for those patients treated in a hemodialysis center and not practicing self care (N = 43122) who are the reference group. Data are from the USRDS census of Medicare patients incident during 1986 to 87 with 1500 days follow-up from determination of dialysis modality at day 90 after ESRD.

explained by this model despite covariate controls for age and comorbid factors and stratification on sex, race and diabetes.

Figure 2 shows the result for the full proportional hazards model, adjusted for age, sex, race, diabetes and comorbid conditions and presented as a survival curve. The proportionality of the Cox proportional hazards model was checked by using a time dependent covariate for each time point on the curve. The assumption of proportionality proved to be valid. The more obvious stepwise decline in the home hemodialysis group occurs as a result of the small sample size. By 1,500 days 16 patients (23%) in the home hemodialysis group had died and 18 (26%) had been censored due to transplantation. In the center hemodialysis group by 1,500 days 1,644 patients (53%) had died and 453 (15%) had been censored due to transplantation. This disparity in the proportion censored due to transplantation in the two groups occurs because of the 10 years difference in average age between home and center hemodialysis patients. When only those patients under 55 years of age at onset of ESRD were considered, the proportion censored due to transplantation was equal in each group (35%) and the relative risk of death for home hemodialysis training adjusted for age, race, sex, diabetes and comorbid conditions declined to 0.22 ($P = 0.01$).

Sensitivity analysis

A separate analysis examined the effect of including in the primary model the nine patients who were already receiving hemodialysis at home 30 days after the onset of ESRD. As previously noted, these patients were excluded initially because of possible misclassification into this category of those patients receiving nurse-assisted hemodialysis at home. Data were analyzed in the same fashion as above, considering these two subcategories of home hemodialysis patients separately and then combined. When compared to center hemodialysis patients, the age, race, sex, and diabetes adjusted relative risk of death for these nine patients was 1.57 ($P = 0.32$, 95% CI 0.65, 3.79). This decreased to 1.25 ($P = 0.62$) after adjustment for comorbid conditions, implying these patients had higher overall co-morbidity than the center hemodialysis patients. This suggests the original assumption was correct that those patients already dialyzing at home within 30 days of starting ESRD treatment had a higher degree of co-morbidity. When both categories of home hemodialysis patients were considered together, the age-adjusted relative risk was 0.66 ($P = 0.06$, 95% CI 0.43, 1.02). This was unchanged after adjustment for comorbid conditions.

Validity analysis

Once similar exclusion criteria of age, race and dialysis modality were applied to all patients in the national USRDS database, a total of 43,281 center hemodialysis patients were identified. A further 418 self care patients were identified who fulfilled the minimum training requirement, 133 of these were being treated at home and 285 were being treated in center. Of the patients being treated in dialysis centers, 63 were performing self care and 222 were training for self care hemodialysis at home or in a center. The relative risk of death for the 418 self care patients with training identified in the national USRDS database compared to the reference group of 43,122 center hemodialysis patients was 0.78 ($P = 0.02$, 95% CI 0.67, 0.90). The 1184 patients being treated with self care hemodialysis but without evidence of training had a relative risk of 1.04 ($P = 0.26$, 95% CI 0.98, 1.12). These results are illustrated in Figure 3.

When the self care group dialyzing in a center at day 90 was subdivided by number of training sessions, the relative risk for those patients with training ($N = 285$) was 0.76 ($P = 0.003$, 95% CI 0.63, 0.91) and for those without training ($N = 166$) was 1.02

($P = 0.89$, 95% CI 0.82, 1.26). For those patients being treated at home with evidence of training ($N = 133$) the relative risk was 0.81 ($P = 0.13$, 95% CI 0.62, 1.06), and for those dialyzing at home without evidence of training ($N = 1085$) the relative risk was 1.05 ($P = 0.25$, 95% CI 0.97, 1.14). In all cases the reference group was identical, being the 43,122 center hemodialysis patients not practicing self care.

Discussion

A number of previous studies have shown advantages for patients treated by home hemodialysis as compared to those treated by center hemodialysis and by CAPD. These differences include a lesser mortality [2, 3] and better quality of life, increased independence and more opportunity for rehabilitation [4, 5]. However, many have regarded these differences as merely a reflection of the effects of selection of patients with fewer comorbid conditions to home hemodialysis or the experience of a single program. This is the first study to analyze the differences in mortality risk between home hemodialysis and center hemodialysis adjusting for comorbid conditions and using a nationwide random sample of patients. It is also the first such study to sample patients starting treatment over a relatively short time period, so being less sensitive to any improvements or other changes in treatment for the two groups with time. The results show a striking benefit of reduced mortality risk for patients selected for treatment by home hemodialysis. Confirmatory evidence for this finding is provided by a further study among the Medicare entitled hemodialysis patients in the national USRDS database. Those patients with evidence of training for self care hemodialysis had a 22% reduction in the risk of death after adjustment for the effects of age, sex, race and diabetes as a cause of ESRD.

Both these analyses used an 'intent-to-treat' model since its results are most useful for advising patients. It is recognized that some patients will likely switch between center and home hemodialysis after the study assignment of dialysis modality. Patients for whom home hemodialysis is planned may not complete training and may stay on center hemodialysis; patients who finish training and start hemodialysis at home may become ill and transfer to center hemodialysis. If they die after changing modality, under the intent-to-treat method of analysis, their death would still be considered as a death occurring on home hemodialysis, not center hemodialysis. Part of the higher mortality due to center hemodialysis is in fact then attributed to home hemodialysis. Conversely, the improved survival among those patients who had switched to home hemodialysis would be attributed to center hemodialysis. The effect of patients switching dialysis modality is to reduce the apparent outcome difference between the two treatments. Therefore, our use of an intent-to-treat analysis method in this study may have lead to a conservative estimate of the difference in survival between the two treatments, the real effect may be greater than reported.

There are several possible explanations for the difference between the two treatments. First, there is undoubtedly substantial selection of the type of patients who enter home hemodialysis training. Home hemodialysis training requires a major commitment of time and effort by the patient and their hemodialysis partner. The most motivated patients and families tend to be selected and such patients are more likely to be compliant with medication, diet and dialysis prescription. Selection may also occur based on the severity of comorbid conditions at onset of ESRD. In this study, when adjusting for co-morbidity, we assumed each comorbid condition was either present or absent. There may be a gradation of severity of disease that such a simple response may not provide sufficient information to adjust for fully. For example, patients in both groups may have a history of coronary artery disease, but in general the home hemodialysis group may contain patients with less severe disease. The present findings may be in part a result of selection of home hemodialysis patients with less severe abnormalities in coronary artery, cerebral or peripheral vascular disease. Such selection might be detected by a more complete measure of co-morbidity. However, the magnitude of the observed effect for the home hemodialysis group is such that a more refined method of adjusting for co-morbidity is likely to explain only a portion of the observed difference between the two groups.

Perhaps other unmeasured comorbid conditions are important. We did include variables which we hypothesized could be important in explaining differences between the two groups. For example, we thought that socioeconomic status and the highest educational level the patient achieved could differ between the center and home hemodialysis patients. We included a covariate for estimated household income by using data from the US Bureau of the Census to determine the median household income for the zip code area of each patient's residence. When estimated household income derived in this fashion was analyzed as a continuous covariate, no statistically significant effect was found. As an individual's income is likely to show substantial collinearity with the highest achieved level of education, the income variable was removed from the final model.

Could the difference be due to factors other than co-morbidity? A possible explanation for the difference between the patient groups is adequacy of dialysis. In the data set, the prescribed Kt/V values come from the time when both groups of patients were dialyzing in a center shortly after starting ESRD treatment. Once home, patients are not constrained by a rigid facility schedule and subsequently home hemodialysis patients may have had a higher dose of dialysis (Kt/V) on average as a result of longer dialysis times. At the time these data were collected, there was increasing concern about the relatively high mortality in United States dialysis patients compared with patients in Europe and Japan [11]. Based on the same database as this study, it was shown that the prescribed dose of hemodialysis was low relative to European patients [12]. Thus, many center hemodialysis patients eventually would be underdialyzed, resulting in an increased mortality during the relatively long observation period of this study. Increased attention is now being paid to dialysis adequacy among hemodialysis patients. In this analysis the prescribed Kt/V among center hemodialysis patients during 1986 to 1987 was 1.0, while recent data from Wave 1 of the USRDS Dialysis Morbidity and Mortality Study suggests that by 1993 the prescribed Kt/V among incident patients had risen to 1.23 (unpublished observation). If the dose of dialysis has risen disproportionately among center hemodialysis patients the difference we observed in mortality between the two hemodialysis modalities may currently be narrowing.

Could the better survival with home hemodialysis be a result of the treatment environment? In patients with type 1 diabetes mellitus, the best results are found in those patients who know most about their own treatment and who can make appropriate adjustments themselves to achieve optimal control. In the elderly, those who remain active despite their infirmities adjust much

better to aging than those who become inactive and more dependent on others for their needs and satisfactions [13]. Twenty years ago Blagg and Scribner [14] pointed out the importance of fostering independence and avoiding loss of control on the part of the dialysis patient and development of what has been called "learned helplessness" [15]. Independence is best encouraged by allowing patients to take responsibility for their own well-being. This is maximized by training patients to perform self care hemodialysis at home. We would speculate that home dialysis removes patients from the dialysis center where nurses and physicians tend to create dependence, and where the presence of other patients with serious medical problems lead them to develop an image of themselves as ill. As a result of doing their own dialysis, home hemodialysis patients may become more knowledgeable about their illness and treatment and so are more likely to receive adequate dialysis and therefore live longer than patients dialyzing in a center.

We find a substantial survival advantage associated with hemodialysis at home compared to hemodialysis in a dialysis center which persists after adjustment for patient characteristics and comorbid conditions. An epidemiological study can only show associations but cannot prove causation. The selection of patients to home hemodialysis is such that any retrospective adjustment of risk based on patient characteristics and comorbid conditions will always be less than perfect. The observation of a 42% lower mortality risk for home hemodialysis patients suggests that a true advantage likely exists. However, only a prospective study with randomization of potential home hemodialysis patients to one of the two modalities can provide definitive confirmation of this observation.

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