Center Effects in Anemia Management of Dialysis Patients

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This study set out to determine whether there is a center effect on anemia management in hemodialysis patients. The US Renal Data System and Medicare standard analysis files were analyzed. Between-center variation and within-facility correlations in hematocrit values were examined in two separate data sets (years 2000 and 2001) and compared with simulated samples that were composed of random values that assumed no center effect. Mixed-effect models were used to adjust for multiple factors and quantify the within-facility correlation in hematocrit values. Expected hematocrit values were compared in patients who underwent dialysis at poor and superior performing facilities with fixed characteristics including epoetin α dosing. There was a wider center variation in hematocrit for the actual *versus* simulated data and a coefficient of variation of 4.1% for the former *versus* 1.7% for the latter, in both years. The within-facility correlation for hematocrit was 0.053 (95% confidence interval 0.050 to 0.056; $P < 0.001$) in 2000 with similar values in 2001 but no within-facility correlation in the simulated data. The impact of these findings was demonstrated with a difference in expected hematocrit for a patient who was treated with fixed-dosage epoetin α in the poorest *versus* best performing units (mean difference in expected hematocrit 3.06; 95% confidence interval 3.03 to 3.09; $P < 0.001$). Key attributes of a center effect on anemia management in hemodialysis have been identified. The presence of a center effect suggests that there are facility-specific processes that influence performance in dialysis anemia management and are independent of commonly titrated inputs, such as dosing of erythropoietic agents.

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One of the most important advances in dialysis has been the growing emphasis on quality improvement and the establishment of practice guidelines for the care of dialysis patients. The implementation of these guidelines has been monitored closely using clinical performance measures (CPM) that track several intermediate outcomes, including dialysis adequacy, vascular access placement, and anemia (1,2). Despite aggregate improvements in several CPM, there still are significant variations in performance across nations, regions, and networks and among facilities within networks (3). The implication of such variability in outcomes suggests a need for modification of deficient practices in centers that underperform and replication of best practices in facilities that exceed established benchmarks.

Center variations in CPM are closely related to the degree to which individuals within the same facility achieve similar results relative to their counterparts at other centers. This within-facility correlation and the associated between-center variation are referred to as a center effect. The significance of a center effect relates to what it implies about the factors that influence the CPM under examination A detected center effect is the result of center-specific factors that lead to a within-facility correlation in the CPM of interest and is independent of commonly measured inputs that can be altered at the patient level to improve performance for that outcome. The center-specific factors that contribute to the measured center effect often relate to prevailing processes that are particular to each center but may be poorly characterized. Substantial center effects have been reported for dialysis adequacy and vascular access placement, which are distinct from case-mix and patient-specific factors that are known to affect each of these quality indicators (4–7).

It is not known whether there is a center effect related to the anemia management of hemodialysis patients, but it is important to ask this question. A common strategy of providers is to use higher dosages of erythropoietic agents to improve deficiencies in anemia management; however, these drugs are expensive (8). The recognition of a center effect for this CPM may be helpful in redirecting quality improvement initiatives to factors that have a more potent or cost-effective influence on this outcome. In this study, we examined a national sample of patients with ESRD to ascertain whether there is a center effect on recorded hematocrit values from hemodialysis patients and to determine its impact on the erythropoietic management of anemia in this population.

Materials and Methods

Data Sources

This was a retrospective, observational study that was conducted on the US Renal Data System (USRDS) standard analysis files (SAF),which

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The interpretation and reporting of these data are the responsibility of the authors and in no way should be seen as an official policy or interpretation of the US government.

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are maintained on patients who have ESRD and receive hemodialysis. Several USRDS SAF were used for this study including the Patient Profile (PATIENTS) SAF, which was linked to Medicare Institutional Claims SAF with the patient identifier (USRDS_ID) to obtain hematocrit values, associated cumulative epoetin α dosages, categorical urea reduction ratio (URR) values, and evidence of parenteral iron administration. Events were obtained from Detailed Treatment History (RXHIST), Medical Evidence Form (MEDEVID), and Residence (RESIDENC) SAF. Facility characteristics were retrieved from the CMS ESRD Annual Facility (FACILITY) SAF. The Medicare inpatient hospital claims, a subset of the institutional claims, were used to calculate the duration of hospitalizations. *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) diagnosis codes from the Medicare Institutional Claims Detail and Physician/Supplier claims SAF were used to generate measures of comorbidity.

Study Patients

The study conducted duplicate analyses on patients who received center hemodialysis during either one of two calendar years: 2000 and 2001. The cohort included only patients with Medicare as the primary insurer and those whose demographic information was available in either of the study years. For patients who underwent dialysis at several facilities, only records from the initial facility for a given year were included in the study. The study was designated as an exempt protocol from full institutional review board review.

Outcomes

Hematocrit was the primary outcome of interest. The key aspect of this outcome was its level of clustering within patients and facilities in the data set. Study patients had the potential for several hematocrit values reported during a calendar month of analysis; however, a majority (91.8%) had a single monthly value. Only the first hematocrit value from each calendar month was included, allowing for a maximum of 12 values per person. Among patients with more than a single monthly record, 93.1% had 0 ± 3 unit (%) difference in hematocrit value on the repeated measure. To test whether the results were sensitive to the use of the first hematocrit reading for patients with more than a single value during a month, we used alternative approaches to the analysis of hematocrit, including time-averaged values for each month, yielding no significant differences in our results. We excluded hematocrit values that were recorded to be $<15\%$ or $>60\%$ because they were assumed to be erroneous.

Covariates

Potentially confounding factors were classified at the record, patient, facility, or ecological level and were included in the multivariate models that were designed to identify and quantify center effects.

Record (Hematocrit) Level Factors

The key variables that were linked to hematocrit and included in this analysis were epoetin α dosing, dialysis adequacy, and parenteral iron administration. Medicare Institutional claims for epoetin α dosing were highly variable across billing periods and included claims from dialysis facilities but not from in-patient hospitalizations. The epoetin α dosing was aggregated into cumulative monthly dosages with no values excluded from the analysis because 99% of records had feasible values. Dialysis adequacy on the Medicare Institutional claims was classified by URR categories of <60, 60 to 65, >65 to 70, >70 to 75, and $>75\%$ and invalid/missing. The Medicare Institutional claims for iron also were complex and for the purpose of this analysis were as yes/no on the basis of whether parenteral iron was administered at dialysis sessions for the service period.

Patient Factors

Patient case-mix and demographic characteristics, including date of birth, race, gender, primary cause of ESRD, and date of first ESRD treatment, were obtained from the Patient Profile SAF, and ethnicity was obtained from MEDEVID SAF (CMS 2728 form). Biochemical parameters from the CMS 2728 were excluded because of the high proportion of missing values. Incident center hemodialysis cases were defined as those with no record of receiving center hemodialysis in previous years. In addition to the basic demographic characteristics, we constructed two case-mix variables using the Medicare Physician/Supplier Claim and Institutional claim SAF. The first was based on each patient's comorbidity using the Charlson Comorbidity Index that was based on available ICD-9 codes from all Physician/Supplier and Institutional claims in the calendar year and the method of Deyo *et al.* (9). The second was the number of hospitalized days for all patients who were included in the analysis and derived from Medicare inpatient hospital claims.

Facility Factors

The analysis included characteristics that routinely are measured and retained in the FACILITY.SAF, such as ESRD network, type and year of certification, the total number of people serviced by the center, type of ownership (nonprofit, for profit, non–federal government, federal government), and number of dialysis stations.

Ecological Factors

Ecological data were obtained from the Area Resource File, which is a county-specific health resource information system that provides data on individuals' available health resources, affluence, and living environment that can have an impact on their health outcome (9). Factor analysis was used as a means to reduce the wide array of ecological factors to a finite number of analyzable variables. The factor analysis resulted in four distinct factors. The first was designated *urbanization*, with higher values reflecting a residence in more urban areas. The second factor was *socioeconomic status*, with higher values representing exposure to a community with prevailing lower education status, greater proportion of immigrants, and lower median income. The third factor reflected parameters that characterize *health access*, in which a high value reflected more health service utilization and availability of health services in a region. The fourth factor, *poverty level*, is a composite of specific indicators of poverty, in which higher value represented communities with higher proportion of minorities, greater proportion of residences with female heads of household, more community dwellers existing below the poverty level for income, and higher infant mortality rates.

Statistical Analysis

For descriptive analyses, the study records, patients, and facilities were categorized by performance into ordinal quintiles using the record hematocrit values, which were aggregated (mean) for patient- and facility-level classification. Record-level cumulative epoetin α dosing was used to determine mean values at the patient and facility levels. Analyses that were conducted on the actual data were compared with results from a simulated sample in which the values were derived from a random distribution with a normal distribution, mean, and SD equal to those in the actual data sample. In this way, we were assured that the simulated data included records that were independent of one another,

with no within-facility correlation or effect of center on hematocrit values.

Mixed-effect linear models were used in the analysis to obtain estimates of the center effect on anemia. The data structure was composed of repeated measures of hematocrit for each individual in the data set, so the model accounted for the correlation within individuals, in addition to that attributable to center. As described in detail elsewhere, the principal measure of correlation, ρ, or within-facility correlation is calculated from the quotient of the between-center variance σ_b (2) in hematocrit and the total variance σ (2) in hematocrit for the population (4–6). The factors that were adjusted for in the multivariate analyses were all those that are included in Table 1. The SAS (SAS Institute, Cary, NC) MIXED procedure with RANDOM and REPEATED statements and the method of restricted maximum likelihood were used to calculate ρ estimates (10).

Results

The USRDS standard analysis files used included 2,211,867 records from 229,295 individuals who received hemodialysis at 3761 facilities in 2000 and 2,326,890 values from 244,018 individuals who received hemodialysis at 3881 facilities in 2001. With the exclusion of records for missing or extreme hematocrit and/or lacking facility identifier, the final study sample numbered 228,831 patients who received hemodialysis in 3725 facilities with 1,699,056 records in 2000. In 2001, 243,554 patients received hemodialysis in 3840 facilities, with 1,830,721 records. The characteristics of the study population in 2000, classified by ordinal quintiles of hematocrit at the record level and aggregate hematocrit at the person and facility levels are shown in Table 1. Several trends were observed, and many achieved statistical significance by virtue of the large sample size. Of note, lower monthly hematocrit values were associated with a higher cumulative monthly epoetin α dosage, a lower reported URR, and a lower likelihood of receiving parenteral iron therapy for the same month in which the hematocrit was reported. Patients with mean hematocrit values in the lower quintiles were more likely to be female and incident during the year of analysis. The level of comorbidity as reflected in the Charlson Comorbidity Index and the annual number of hospital days were higher for patients in lower hematocrit quintiles than for patients in the higher quintiles. Individuals in the lower quintiles were more likely to be retired, disabled, or unemployed than members of the higher hematocrit groups. Facilities with lower aggregate hematocrit values had fewer patients and less frequent hematocrit values drawn per year and per patient than those in the higher quintiles. The facilities with lower aggregate hematocrit values had slightly fewer stations and patients per station but were more likely to be nonprofit or government facilities than the units in the higher quintiles. These trends similarly were observed in the 2001 data set (data not shown).

The results also provide strong evidence of a center effect. The variation in facility-level aggregate hematocrit values was greater than if there were no detectable center effect, even when accounting for a substantial patient-level variation in hematocrit, which was observed in this population. Figure 1A demonstrates that the actual individual hematocrit records and the simulated data set from 2000 have comparable distribution characteristics. Figure 1B, in contrast, illustrates the broader distribution of patient-level mean hematocrit for the actual data relative to the simulated data from that year. Figure 1C depicts the distribution of facility-level mean hematocrit values on the basis of patient-level mean hematocrit values for individuals who underwent dialysis at that facility, with both the actual and the simulated data. The facility-level variation with the actual data remained wider than that observed with the simulated data. Similar findings were observed with the actual data relative to the simulated data set in 2001.

The distribution characteristics of records, patients, and facilities along with the within-facility correlation for the actual and simulated data sets are shown in Table 2. The distribution of values at the record level was comparable for both the actual and the simulated data sets in both 2000 and 2001 as indicated by equivalent coefficients of variation (CV). The CV for the distributions of aggregate hematocrit for patients and facilities decline for both data sets, with the concomitant reduction in sample size at each level. However, at both levels, the CV for the actual data are greater than the those for the simulated data, corresponding with what is shown in Figure 1, B and C. Moreover, the within-facility correlation for the actual data set was significant in both 2000 and 2001 but not attenuated after adjustment for all of the covariates listed in Table 1. In contrast, the simulated data had no within-facility correlation for either study year. The overall estimate of ρ corresponds to approximately 5% of the total sample variance in hematocrit for both the 2000 and 2001 study samples.

The observed within-facility correlation in hematocrit did vary across certain facility characteristics. Table 3 shows a stronger degree of within-facility correlation among facilities that were classified as nonprofit relative to that observed in units that were designated as for-profit. The within-facility correlation in hematocrit also varied across facilities that were classified by census and number of hematocrit values measured per year. Facilities in the quintile with the lowest patient census and fewest measurements of hematocrit had the highest degree of within-facility correlation. A more modest variation was observed across facilities that were classified into those with the greatest number of stations *versus* those with the fewest. The within-facility correlation in hematocrit did not vary for the other facility-level factors included in the study.

The potential clinical consequence of the detected center effect on anemia management is illustrated in Table 4, where the expected (model-estimated) hematocrit is listed for individuals who had fixed characteristics and underwent dialysis at units that belonged to either the lowest or the highest quintile facilities on the basis of aggregate hematocrit. The results are presented for patients within several strata designated by fixed levels of cumulative monthly epoetin α dosage, URR, and incidence *versus* prevalence for the year 2000. All other characteristics were held constant across the strata. Table 4 reveals that in individuals across all subgroups examined, the difference between expected hematocrit when dialyzed in the lowest *versus* highest quintile of facilities averaged 3.06 percentage points (95% confidence interval 3.03 to 3.09) and ranged from 2.66 to 3.48. Similar results were obtained when the fixed characteristics of the

Table 1. Characteristics of records, patients, and facilities in the 2000 USRDS dialysis population included in study[a]

Parameter	Lowest Quintile	Second Quintile	Third Quintile	Fourth Quintile	Highest Quintile	*P*
Hematocrit (n = 1,699,056)						
range in values	15.0 to 31.3	31.3 to 33.9	33.9 to 35.7	35.7 to 37.8	37.8 to 60.0	
no. of records	339,812	339,811	339,811	339,811	339,811	
epo dose (units)[b]	89,459.6 ± 74,644.2	71,299.8 ± 61,824.9	63,351.4 ± 55,356.5	59,784.7 ± 52,332.7	58,620.5 ± 51,041.9	<0.0001[d]
epo dose (units) per hct	3197.3 ± 2780.0	2184.6 ± 1898.3	1824.4 ± 1595.8	1631.6 ± 1429.3	1459.8 ± 1275.1	<0.0001
intravenous iron (per record)[c]						
yes	142,368 (41.9)	142,980 (42.1)	147183 (43.3)	155,162 (45.7)	168,676 (49.6)	<0.0001[e]
no	197,444 (58.1)	196,831 (57.9)	192628 (56.7)	184,649 (54.3)	171,135 (50.4)	
URR (column%)						
<60%	31,813 (9.4)	21,910 (6.4)	18,866 (5.6)	18,437 (5.4)	21,083 (6.2)	<0.0001
60 to 65%	31,177 (9.2)	27,338 (8.0)	26,238 (7.7)	26,307 (7.7)	29,103 (8.6)	
65 to <70%	63,548 (18.7)	65,495 (19.3)	66,696 (19.6)	67,944 (20.0)	70,567 (20.8)	
70 to <75%	84,320 (24.8)	96,740 (28.5)	101,691 (29.9)	102.478 (30.2)	100,650 (29.6)	
≥75%	98,599 (29.0)	108,083 (31.8)	109,429 (32.2)	10,145 (32.1)	103,678 (30.5)	
missing	30,355 (8.9)	20,245 (6.0)	16,891 (5.0)	15,500 (4.6)	14,730 (4.3)	
Patients (n = 228,831)						
range in values	15.0 to 32.1	32.1 to 33.9	33.9 to 35.1	35.1 to 36.5	36.5 to 58.8	
no. of patients	45767	45766	45766	45766	45766	
records per patient	5.0 ± 3.9	7.7 ± 4.0	8.6 ± 3.8	8.7 ± 3.7	7.0 ± 4.0	<0.0001
cumulative epo dose (units)	87,661.3 ± 65,672.3	74,600.0 ± 50,789.1	61,981.7 ± 42,510.5	55,311.8 ± 38,176.7	50,354.0 ± 37,856.2	<0.0001
cumulative epo dose per hct	3032.3 ± 2347.7	2275.8 ± 1557.4	1809.4 ± 1245.3	1559.6 ± 1082.0	1333.5 ± 1008.8	<0.0001
gender						
male	22,905 (50.1)	22,763 (49.7)	23,245 (50.8)	24,154 (52.8)	25,918 (56.6)	<0.0001
female	22,862 (50.0)	23,003 (50.3)	22,521 (49.2)	21,612 (47.2)	19,848 (43.4)	
age (yr)	59.1 ± 17.7	59.4 ± 16.7	59.5 ± 16.5	59.2 ± 16.7	58.4 ± 17.0	<0.0001
race						
white	25,334 (55.4)	25,268 (55.2)	25,279 (55.2)	25,247 (55.2)	25,320 (55.3)	<0.0001
black	17,928 (39.2)	17,651 (38.6)	17,426 (38.1)	17,375 (38.0)	17,409 (38.0)	
other	2505 (5.5)	2847 (6.2)	3061 (6.7)	3144 (6.9)	3037 (6.6)	
incidence						
yes	15,947 (34.8)	8975 (19.6)	6623 (14.5)	6637 (14.5)	9039 (19.8)	<0.0001
no	29,820 (65.2)	36,791 (80.4)	39,143 (85.5)	39,129 (85.5)	36,727 (80.3)	
Charlson Comorbidity Index	4.5 ± 3.1	4.0 ± 2.9	3.6 ± 2.7	3.4 ± 2.7	3.4 ± 2.7	<0.0001
hospital days during year	25.8 ± 29.5	18.7 ± 24.7	13.8 ± 21.1	12.2 ± 19.4	12.2 ± 19.8	<0.0001
cause of ESRD						
hypertension	18,359 (40.1)	19,176 (41.9)	18,947 (41.4)	18,728 (40.9)	18,528 (40.5)	<0.0001
diabetes	11,657 (25.5)	12,020 (26.3)	12,198 (26.7)	12,334 (27.0)	12,289 (26.9)	
other	15,751 (34.4)	14,570 (31.8)	14,621 (32.0)	14,704 (32.1)	14,949 (32.7)	
employment						
unemployed	8160 (17.8)	7774 (17.0)	7538 (16.5)	7708 (16.8)	8174 (17.9)	<0.0001
employed	2398 (5.2)	2473 (5.4)	2622 (5.7)	2663 (5.8)	3162 (6.9)	
retired	14,457 (31.6)	14,282 (31.2)	14,213 (31.1)	14,102 (30.8)	13,772 (30.1)	
disabled	8030 (17.6)	7413 (16.2)	7273 (15.9)	7174 (15.7)	7097 (15.5)	
other	3086 (6.7)	3177 (6.9)	3376 (7.4)	3264 (7.1)	3159 (6.9)	
missing	9636 (21.1)	10,647 (23.3)	10,744 (23.5)	10,855 (23.7)	10,403 (22.7)	
ecological factors						
health access	0.16 ± 0.92	0.19 ± 0.92	0.18 ± 0.92	0.16 ± 0.90	0.17 ± 0.92	<0.0001
socioeconomic status	to 0.26 ± 1.03	−0.29 ± 0.99	−0.31 ± 1.00	−0.25 ± 1.06	−0.23 ± 1.11	<0.0001
poverty factor	0.53 ± 1.27	0.45 ± 1.22	0.41 ± 1.20	0.39 ± 1.19	1.22 ± 0.41	<0.0001
urban factor	2.06 ± 3.05	1.96 ± 2.85	1.97 ± 2.80	1.99 ± 2.75	2.00 ± 2.79	<0.0001
intravenous iron (during year)						
yes	25,752 (56.3)	31,694 (69.3)	33,349 (72.9)	33,987 (74.3)	33,073 (72.3)	<0.0001
no	20,015 (43.7)	14,072 (30.8)	12,417 (27.1)	11,779 (25.7)	12,693 (27.7)	
Facilities (n = 3725)						
range in values	15.3 to 33.6	33.6 to 34.2	34.2 to 34.8	34.8 to 35.4	35.4 to 43.8	
no. of facilities	745	745	745	745	745	
no. of patients	49.8 ± 42.2	65.0 ± 43.4	66.9 ± 43.4	65.9 ± 43.8	59.6 ± 41.2	<0.0001
no. of records	347.5 ± 335.0	483.8 ± 354.3	506.8 ± 351.4	494.6 ± 350.8	447.9 ± 331.4	<0.0001
records per patient	6.0 ± 2.4	7.1 ± 1.5	7.3 ± 1.5	7.2 ± 1.4	7.0 ± 1.7	<0.0001
cumulative epo dose (units)	62,064.0 ± 23,405.1	63,967.3 ± 17,024.5	65,345.2 ± 17,138.1	65,191.9 ± 16,050.8	65,796.7 ± 17,400.8	0.03
cumulative epo dose per hct per patient	1994.1 ± 775.7	1972.6 ± 534.5	1982.2 ± 529.7	1944.0 ± 484.3	1908.6 ± 507.2	0.0005
stations	15.1 ± 8.5	16.4 ± 8.2	16.4 ± 8.0	16.9 ± 8.2	16.0 ± 8.0	<0.0011
patients per station	4.0 ± 3.0	4.4 ± 2.3	4.8 ± 3.0	4.6 ± 2.5	4.4 ± 2.2	0.0001
profit status						
profit	454 (61.0)	553 (74.2)	620 (83.2)	649 (87.1)	643 (86.3)	<0.001
nonprofit and government	276 (37.1)	189 (25.4)	119 (16.0)	94 (12.6)	97 (13.0)	
missing	15 (2.0)	3 (0.4)	6 (0.8)	2 (0.3)	5 (0.7)	

[a]epo, epoetin α ; hct, hematocrit; URR, urea reduction ratio; USRDS, US Renal Data System.
[b]Continuous variables expressed as means ± SD.
[c]Categorical variables expressed as n (%).
[d]ANOVA.
[e]χ^2.

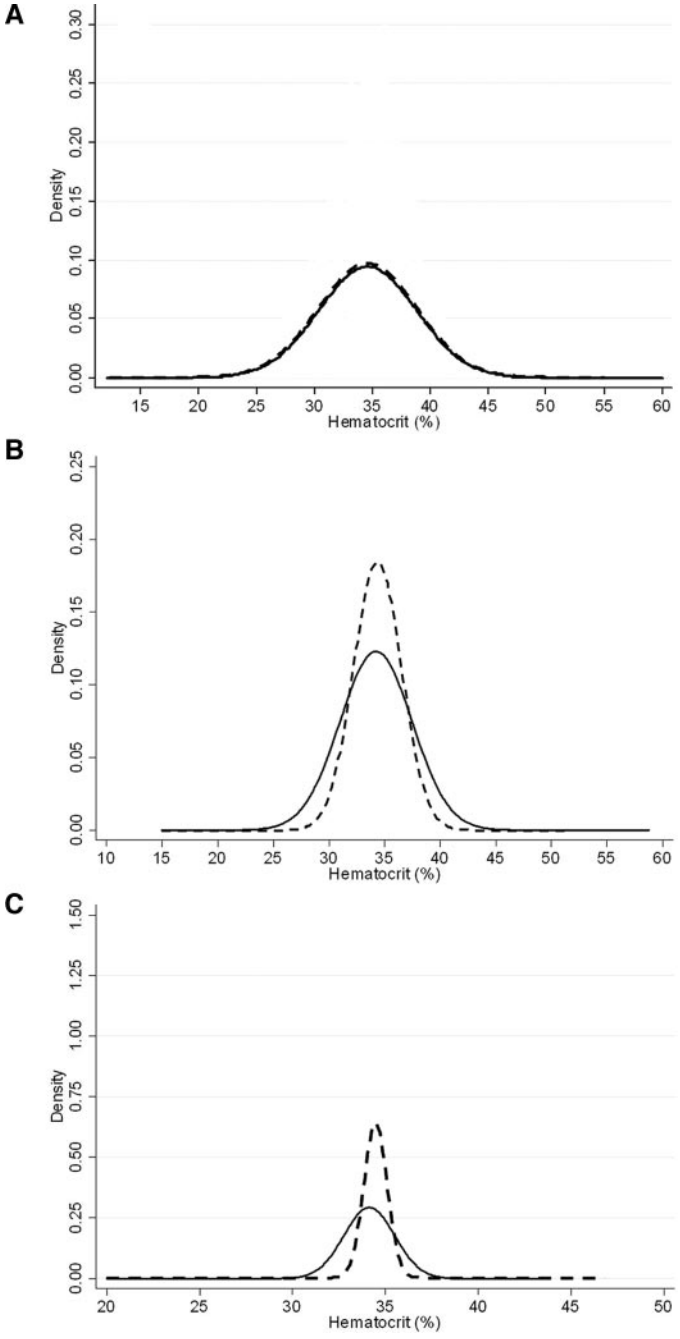

Figure 1. Frequency distribution from 2000 US Renal Data System data. (A) Actual (solid) and simulated (dashed) record-level hematocrit values. (B) Patient-level aggregate actual and simulated hematocrit values. (C) Facility-level aggregate of patient-level aggregate actual and simulated hematocrit values.

index person who was being treated for anemia were varied. Table 4 also illustrates the results of a duplicate analysis with expected hematocrit values listed for patients using the simulated data, with the same fixed characteristics. The simulated data show no difference across facilities that remained classified by their actual performance rank. Similar results were seen with the 2001 data set (data not shown).

Discussion

In this study, we identified a wide center variation in hematocrit and a significant within-facility correlation in hematocrit across USRDS facilities in 2000 and 2001. These are key attributes of a center effect related to dialysis anemia management. The findings are notable in that they contrast with the narrow variation across centers and absent correlation within facilities for the simulated data, for which there was no center effect. The results support the conclusion that hematocrit values within facilities are correlated and that centers diverge in their performance in anemia management, even after adjustment for clinical inputs that often are manipulated to improve this CPM. This conclusion is substantiated further by the demonstrated difference in expected hematocrit for patients with fixed characteristics, including dosage of epoetin α, and cared for at either the best or the worst performing facilities. Moreover, the varying size of the within-facility correlation across facility categories, including frequency of ordering hematocrit, suggests that there are higher order processes and practice patterns that may be characteristic of the different types of facilities and are responsible for the center effect.

Several studies have suggested that the correction of anemia in dialysis patients reduces hospitalization, morbidity, and mortality in this chronically ill population (10–14). These reports along with modifications in reimbursement for erythropoietic agents (15) has led to widespread utilization of erythropoietic agents in dialysis patients. However, the validity of using anemia as an indicator of outcomes in dialysis patients has been revisited because the purported association of anemia with survival in this population is less than conclusive and based on mostly observational or smaller studies (16,17). Some have suggested that the ratio of epoetin α dosing to hematocrit is indicative of underlying comorbidity and inflammation in dialysis patients and may be a better predictor of mortality than hematocrit without adjustment for use of epoetin α (18,19).

Here, we focus our considerations on hematocrit as a measure of the quality of dialysis care and make the assertion that improvements in anemia management can be achieved only partially with altered dosing of erythropoietic agents. We have applied a unique approach to examine the processes of care that accounts for increments in quality improvement beyond those that are achieved with standard clinical measures. These findings are consistent with other studies that have suggested that patient and regional variability in achieved hematocrit reflects different approaches to anemia management in this population (20,21). Moreover, the quotient of epoetin α dosing to achieved hematocrit, which is a similar expression to what we used in Table 4, has been proposed as an important measure of quality of care, in addition to its consideration as a marker of inflammation (21).

In interpreting this retrospective study's results, one must consider the possibility that unmeasured variables may account for the study findings' leading to the conclusion that there is center effect on dialysis anemia management. However, we used the extensive USRDS data sets to adjust for multiple factors that are relevant to the association between facility and anemia. In addition, we linked census data to the USRDS files

Table 2. Distribution characteristics of record, patient, and facility means and within-facility correlation (ρ) for hct using actual and simulated data[a]

Parameter	Mean (CV)			Within-Facility Correlation (95% CI)	
	Record	Patient	Facility	Crude	Adjusted*
2000					
actual	34.6 (12.1%)	34.2 (9.6%)	34.4 (4.1%)	0.056 (0.053 to 0.059)	0.053 (0.050 to 0.056)
simulated	34.5 (12.2%)	34.5 (6.3%)	34.5 (1.7%)	0	0
2001					
actual	34.8 (12.1%)	34.5 (9.2%)	34.7 (4.1%)	0.054 (0.051 to 0.057)	0.052 (0.049 to 0.055)
simulated	34.8 (12.1%)	34.8 (6.0%)	34.8 (1.7%)	0	0

[a]CI, confidence interval; CV, coefficient of variation.
[b]Adjusted for all factors in Table 1. Multivariate models included 98.3 and 98.3% of all records, 93.8 and 92.9% of patients, and 98.6 and 98.8% facilities for 2000 and 2001, respectively.

Table 3. Within-facility correlation for hct by facility characteristics

Facility Characteristics	2000	2001
Profit	0.047 (0.044 to 0.049)	0.045 (0.042 to 0.047)
Nonprofit	0.082 (0.072 to 0.091)	0.089 (0.079 to 0.099)
No. of patients in facility		
lowest	0.100 (0.090 to 0.120)	0.110 (0.091 to 0.124)
highest	0.045 (0.041 to 0.050)	0.042 (0.038 to 0.047)
No. of stations		
lowest	0.079 (0.069 to 0.089)	0.083 (0.073 to 0.093)
highest	0.048 (0.043 to 0.053)	0.049 (0.044 to 0.054)
Hct values per patient in facility		
lowest	0.100 (0.087 to 0.110)	0.110 (0.094 to 0.120)
highest	0.051 (0.045 to 0.056)	0.044 (0.040 to 0.049)

to control for socioeconomic conditions, which may contribute to patient preferences for specific dialysis units and have the potential to bias our measurement of a center effect. The complexity and the size of the data set and computations prevented the use of time-dependent exposure to relevant factors such as iron therapy or epoetin α dosing per session. Moreover, the USRDS data sets did not offer dialysis adequacy as a continuous variable but rather as a categorical variable, which was included in all multivariate analyses. Despite these limitations, the findings reported are consistent with the observations made for other CPM and support the concept of a center effect on performance measures in dialysis.

The within-center correlation in hematocrit is smaller than previously reported for dialysis adequacy (4–6). We attribute this difference in magnitude to the additional variance component for within-patient correlation in hematocrit. The within-patient correlation was illustrated in the distribution of patient-level mean hematocrit values that had a wider CV than that shown for the facility means. This patient effect likely is due to the certain interconnectedness of repeat measures of a hematocrit within an individual and, in contradistinction to the center effect, likely is a function of biologic factors. However, in the mixed-effect model, this intrapatient correlation was treated as an adjustment factor and was considered separately from the findings at the center level. The magnitude of the impact of the center effect was conveyed best by the difference in achieved hematocrit at low *versus* high performing units. It is plausible that the average difference in achieved hematocrit of 3% corresponds to a significant difference in subsequent mortality as has been suggested in the previously cited literature (12–14).

As the dialysis population in the United States grows and becomes more heterogeneous and increasingly expensive to care for, it will be important to improve our understanding of facility variations in practice and their cost-effectiveness in delivery of care. The recognition of center effects related to CPM directs attention to the importance of facility processes as an additional dimension of any strategy to correct deficiencies in performance. Further work is necessary to understand the elements that account for the center effect on any CPM. These studies are likely to require quasi-experimental methods to measure these factors. Moreover, the methods that were applied here have been suitable to examine CPM that can be expressed as continuous variables such as dialysis adequacy and anemia. Further work will be needed to adapt the currently used methods to examine outcomes such as hospitalization or mortality, which are expressed as rates and are likely to have more significance than the surrogate markers that are used for CPM.

Table 4. Difference in expected hct values for a median-aged black male[a] receiving a fixed dose of epoetin alfa at a facility in the lowest versus highest quintile of centers grouped by aggregate hematocrit in the 2000 and across strata for incidence versus prevalence, and dialysis adequacy defined by URR

Epo Dose	Time on Hemodialysis	URR	Difference in Expected Hct between Facilities (Actual Data; Mean [95% CI])	Difference in Expected Hct between Facilities (Simulated Data; Mean [95% CI])
25% quintile (low dose)	Incident	<60	3.3 (3.2 to 3.4)	0.1 (−0.2to0.3)
		≥75	2.9 (2.8 to 3.0)	0.0 (−0.2to0.1)
	Prevalent	<60	3.0 (2.9 to 3.1)	0.1 (−0.1to0.2)
		≥75	2.7 (2.6 to 2.8)	−0.1 (−0.2to0.0)
Median (middle dose)	Incident	<60	3.4 (3.2 to 3.5)	0.1 (−0.1to0.2)
		≥75	3.0 (2.9 to 3.1)	−0.1 (−0.2to0.0)
	Prevalent	<60	3.1 (3.0 to 3.2)	0.0 (−0.1to0.1)
		≥75	2.7 (2.7 to 2.8)[b]	−0.1 (−0.2to0.0)
75% quintile (high dose)	Incident	<60	3.5 (3.4 to 3.6)	0.0 (−0.1to0.2)
		≥75	3.1 (3.0 to 3.2)	−0.1 (−0.2to0.0)
	Prevalent	<60	3.2 (3.1 to 3.3)	0.0 (−0.2to0.1)
		≥75	2.8 (2.8 to 2.9)[b]	−0.2 (−0.1to0.0)

[a]With diabetes, disabled, using iron therapy, and other continuous variables set at median for population, including Charlson Comorbidity Index, number of days in the hospital, health access, socioeconomic, poverty, urbanization, number of stations per center, number of patients per center, total patients per station, number of hct measures per patient, and for-profit facility type.

[b]CI boundaries are rounded to the first decimal.

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Disclosures

None.

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