Variation in Cost and Quality in Kidney Transplantation

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Background. Bending the cost curve in medical expenses is a high national priority. The relationship between cost and kidney allograft failure has not been fully investigated in the United States. **Methods.** Using Medicare claims from the United States Renal Data System, we determined costs for all adults with Medicare coverage who underwent kidney transplant January 1, 2007, to June 30, 2009. We compared relative cost (observed/expected payment) for year 1 after transplantation for all transplant centers, adjusting for recipient, donor, and transplant characteristics, region, and local wage index. Using program-specific reports from the Scientific Registry of Transplant Recipients, we correlated relative cost with observed/expected allograft failure between centers, excluding small centers. **Results.** Among 19,603 transplants at 166 centers, mean observed cost per patient per center was $65,366 (interquartile range, $55,094-$71,624). Mean relative cost was 0.99 (±0.20); mean observed/expected allograft failure was 1.03 (±0.46). Overall, there was no correlation between relative cost and observed/expected allograft failure (r = 0.096, *P* = 0.22). Comparing centers with higher than expected costs and allograft failure rates (lower performing) and centers with lower than expected costs and failure rates (higher-performing) showed differences in donor and recipient characteristics. As these characteristics were accounted for in the adjusted cost and allograft failure models, they are unlikely to explain the differences between higher- and lower-performing centers. **Conclusions.** Further investigations are needed to determine specific cost-effective practices of higher- and lower-performing centers to reduce costs and incidence of allograft failure.

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A recent Institute of Medicine report titled "Best care at lower costs: the path to continuously learning health care in America" stated that more than $750 million was wasted by the U.S. health care system in 2009.[1] With the recent release of data from the Centers for Medicare & Medicaid Services (a U.S. federal government-funded health insurance plan) showing highly variable charges for several nontransplant health conditions, the challenge is to understand the sources of variation in costs.[2] Such studies can help the health care system adopt efficient models for providing high-quality care and reducing costs.

In the long run, kidney transplant is generally the most cost-effective therapeutic option available to treat end-stage renal disease (ESRD).[3] The annual cost of ESRD was $32.9 billion as of 2010. The cost of kidney transplant increased 56%, from $1.7 billion in 2005 to 2.8 billion in 2010.[4] Overall, despite its cost-effectiveness,[5,6] kidney transplant is a resource-intensive service, and graft and patient survival rates are variable. The relationship between cost and kidney allograft outcomes has not been investigated. Therefore, we describe potential drivers of increased cost, and we explore the association between cost and kidney allograft outcomes for all kidney transplant centers in the study.

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METHODS

Data Sources

We used Medicare enrollment data and claims data from the United States Renal Data System. The Medicare claims data included Part A institutional claims (inpatient, outpatient, skilled nursing facility, and home health agency) and noninstitutional Part B physician/supplier claims. We used these data to obtain demographic, comorbidity, and Medicare payment information.

This study also used data from the Scientific Registry of Transplant Recipients (SRTR). The SRTR data system includes data on all donors, waitlisted candidates, and transplant recipients in the United States, submitted by the members of the Organ Procurement and Transplantation Network (OPTN), and has been described elsewhere.[7] The Health Resources and Services Administration, U.S. Department of Health and Human Services, provides oversight of the activities of the OPTN and SRTR contractors.

The observed and expected costs and quality were measured at the individual patient level, but the final comparison was performed at the level of the transplant center.

Study Population

The study population included adult Medicare kidney transplant recipients who underwent transplant between January 1, 2007, and June 30, 2009, with Medicare as primary payer. Each patient was followed for 1 year from the date of transplant and censored at allograft failure or date of death. We excluded patients who underwent multiorgan transplant because the SRTR risk-adjusted Cox models for program-specific expected kidney graft survival exclude these transplants. Multiorgan transplants have a different set of risk factors for quality and in general incur higher costs than kidney transplant alone. Therefore, centers that perform multiorgan transplants would appear to be more costly than centers that perform kidney transplants alone.

Medicare Costs and Relative Cost

Using Medicare claims from the United States Renal Data System, we determined Part A (inpatient, outpatient, skilled nursing facility, and home health agency) and Part B (physician services and durable medical equipment) costs for the first year after transplantation. The cost to Medicare is presented as Medicare payment per patient per year in U.S. dollars. Using national data, the expected cost was obtained from multiple linear regression models with payment per patient per year as the dependent variable adjusted for recipient, donor, and transplant characteristics; geographic region; and local wage index. The expected cost model was developed using an algorithm described previously.[8] Costs for recipients of deceased and living donor kidneys were determined separately because of the differences in adjustment factors between these 2 types of transplants. Distribution of each of these adjustment factors was reviewed, and variables were dichotomized based on the functional form that best fit the data. We used multiple regression models with the ordinary least square (OLS) estimate for deceased donor and living donor transplants separately.[9] The adjusted R-square for the OLS model with deceased donor was 0.094, and the R-square for the OLS model with living donor was 0.119. Models were constructed at the patient level and used to create the expected cost for each transplant center. The relative cost for each transplant center was obtained by dividing the observed by the expected costs for recipients of deceased donor and living donor kidneys.

Observed/Expected Allograft Failure

Using recipient and donor variables obtained from OPTN that are known to affect outcomes, SRTR calculates program-specific expected kidney graft survival using risk-adjusted Cox models, and publishes this information publicly. Using the program-specific reports, we determined observed/expected allograft failure within 1 year after transplantation for all kidney transplant centers.[10] The program-specific reports are adjusted for the following deceased donor transplant factors: cold time, donation after circulatory death, donor age, donor cause of death, donor history of diabetes, donor history of hypertension, donor kidney was pumped, donor race, donor creatinine, donor/recipient weight ratio, organ shipped outside recovery donation service area, panel-reactive antibodies (PRA), recipient underwent previous solid-organ transplant, recipient age, recipient body mass index, recipient cause of ESRD, recipient hepatitis C virus (HCV) positive, recipient race, recipient sex, dialysis duration. Program-specific reports are also adjusted for the following living donor transplant factors: donor age, donor race, recipient relationship with donor, HLA mismatches, PRA, recipient underwent previous solid-organ transplant, recipient age, recipient body mass index, recipient cause of ESRD, recipient HCV status, recipient insurance coverage, recipient race, dialysis duration. Allograft failure was defined as return to dialysis, retransplant, or death. Follow-up was censored at allograft failure. We excluded small centers with fewer than 3.69 expected allograft failures because the observed/expected allograft failures in such centers could vary dramatically with a single failure ($n = 41$ of 207, 20%).

Determining Center Performance

Simple correlation was used to determine relationships between center costs and allograft outcomes. Centers whose costs were lower than expected (observed/expected cost < 1) and whose incidence of allograft failure was lower than expected (observed/expected allograft failure < 1) were considered to be higher-performing centers. Centers whose costs were higher than expected and whose incidence of allograft failure was higher than expected were considered to be lower-performing centers. The remaining centers were considered to be intermediate-performing centers.

The observed/expected transplant rate was compared between higher- and lower-performing centers. The transplant rate is a metric for deceased and living donor transplants combined, calculated per year on the waiting list, that is published by SRTR in the program-specific reports. The expected transplant rate is adjusted for candidate age, blood type, previous transplant, time on the waiting list, peak PRA, and interaction between previous transplant and peak PRA.[10] All analyses were conducted using SAS, version 9.2 (Cary, NC).

RESULTS

Among 19,603 total transplants at 166 centers, the mean observed cost per patient per center was $65,366 (interquartile range $55,094-$71,624). Mean relative cost was $0.99 (± $0.20), and mean observed/expected allograft failure at 1 year after transplantation was 1.03 (±0.46). Mean observed

TABLE 1.

Baseline characteristics, Medicare costs, and parameter estimates from the ordinary least square, multiple regression model: deceased donor transplants

Variable	Frequency, %	Medicare cost[a]	Reference	Parameter estimate	Standard error	*P*
Overall	*n* = 14,888	68,895				
Intercept	N/A	N/A		40,870	3206	<0.0001
Donor factors						
Age (1-y increase), y	N/A	N/A	N/A	134	33	<0.0001
Race, African American	14.4	73,368	White	2887	1164	0.0132
Race, other	15.4	67,236	White	−1033	1140	0.365
Cold time, 20 to < 30 h	27.0	69,196	<20	1489	918	0.1049
Cold time, ≥ 30 h	9.2	82,408	<20	9684	1423	<0.0001
Cold time missing	8.1	69,219	<20	−139	1496	0.9258
No kidney pumped	68.2	67,759	Yes or missing	1802	944	0.0563
Donor creatinine, ≥ 1.5 mg/dL	19.3	71,269	<1.5	961	1006	0.3394
Donor/recipient weight ratio, > 1	45.1	68,336	≤1	−1896	900	0.0351
Donor/recipient weight ratio missing	3.3	72,889	≤1	1399	3373	0.6783
Donor history of diabetes: no	92.5	68,233	Yes or missing	−4183	1490	0.005
Donor history of HTN: yes	29.0	74,796	No	1232	1046	0.239
Donor history of HTN: missing	0.7	59,337	No	−9897	4831	0.0405
DCD donor: yes	12.7	72,634	No	4338	1267	0.0006
Donor cause of death CVA/TIA	42.0	72,134	No	210	907	0.8169
Deceased donor ECD	22.2	78,053	No	2989	1324	0.024
Recipient and transplant factors						
HLA ABDR mismatch 4	25.9	68,634	≤3	2663	1084	0.014
HLA ABDR mismatch 5	31.6	70,831	≤3	3575	1050	0.0007
HLA ABDR mismatch 6	15.4	71,506	≤3	4168	1277	0.0011
PRA > 30	17.4	72,980	≤30	5350	1174	<0.0001
PRA missing	2.9	72,671	≤30	−1930	2379	0.4173
Previous organ transplant: yes	13.7	71,997	No	1732	1332	0.1935
Recipient age (1-y increase)[b], y	NA	NA	N/A	21	35	0.5455
Female	38.3	69,251	Male	1689	854	0.0479
Recipient race, African American	37.3	73,138	White	2112	931	0.0233
Recipient race, other	8.4	62,423	White	−6048	1484	<0.0001
Primary cause of ESRD: diabetes	29.0	76,561	Other	2996	1414	0.0341
Primary cause of ESRD: HTN	26.3	67,795	Other	−575	1159	0.6199
Primary cause of ESRD: GN	21.4	64,390	Other	−536	1167	0.6463
BMI, < 10 kg/m^2 or missing	5.6	69,760	10– < 25	−2453	2672	0.3586
BMI, 25 to < 30 kg/m^2	32.9	67,742	10– < 25	−1119	1014	0.2699
BMI, ≥ 30 kg/m^2	31.3	71,567	10– < 25	1125	1113	0.3123
Dialysis duration ≥ 5 y	40.6	72,775	<5 years	5927	880	<0.0001
Preemptive transplant: yes	4.0	59,201	No	−5924	2037	0.0036
Preemptive transplant: missing	0.7	73,458	No	7152	4667	0.1254
HCV-positive	5.9	79,216	No	7166	1676	<0.0001
ASHD[c]	31.9	76,617	No	4213	936	<0.0001
CHF[c]	25.5	76,929	No	3827	943	<0.0001
CVA/TIA[c]	8.0	80,256	No	5829	1449	<0.0001
PVD[c]	24.3	78,630	No	4906	942	<0.0001
Other cardiac disease[c]	22.4	76,190	No	4842	965	<0.0001
COPD[c]	9.7	74,552	No	1506	1327	0.2565
Gastrointestinal bleeding[c]	3.6	80,811	No	5842	2088	0.0051
Liver disease[c]	7.8	73,609	No	1336	1465	0.3617
Dysrhythmia[c]	18.9	78,746	No	6238	1035	<0.0001
Cancer[c]	4.5	77,351	No	4527	1882	0.0162
Diabetes[c]	45.1	75,461	No	5608	1107	<0.0001
Hospital stay in 6 mo before transplant > 6 d	11.6	79,862	≤6 days	4665	1281	0.0003
New England	3.6	72,908	South Atlantic	−15,111	2644	<0.0001
Middle Atlantic	17.5	74,306	South Atlantic	−12,883	1541	<0.0001
East North Central	16.3	67,496	South Atlantic	−15,458	1412	<0.0001

Continued next page

TABLE 1. (Continued)

Variable	Frequency, %	Medicare cost[a]	Reference	Parameter estimate	Standard error	P
East South Central	5.7	55,359	South Atlantic	−13,218	1875	<0.0001
West North Central	6.0	61,844	South Atlantic	−13,593	1828	<0.0001
West South Central	11.1	63,358	South Atlantic	−10,673	1452	<0.0001
Mountain	4.4	53,589	South Atlantic	−24,386	2156	<0.0001
Pacific	13.2	67,070	South Atlantic	−19,019	2110	<0.0001
Cohort year, 2008	39.5	69,582	2007	4455	871	<0.0001
Cohort year, 2009	21.1	75,652	2007	10,790	1046	<0.0001
Wage index, 0.9285-0.9981	25.1	67,992	<0.9285	8860	1155	<0.0001
Wage index, 0.9982-1.1170	25.4	73,095	<0.9285	16,775	1294	<0.0001
Wage index, > 1.1170	25.7	72,770	<0.9285	20,009	1792	<0.0001

Note: Includes all centers. For determining the center performance, small centers with fewer than 3.69 expected allograft failures were excluded because the observed/expected allograft failures in such centers could vary dramatically with a single failure (n = 41 of 207, 20%).
[a] Per patient per year in year 1 after transplantation.
[b] Mean recipient age was 52.8 years (interquartile range, 43-63 years).
[c] Comorbid conditions in the 6 months before transplantation.
DCD, donation after circulatory death; BMI, body mass index; COPD, chronic obstructive pulmonary disease; CVA/TIA, cerebrovascular accident/transient ischemic attack; ECD, expanded criteria donor; HLA ABDR, human leukocyte antigen A, B, and DR; GN, glomerulonephritis; HTN, hypertension.

cost for the 14,888 deceased donor kidney recipients was $66,637 per patient per center. Several factors were independently associated with increased costs for deceased donor transplants (Table 1).

Mean observed cost for the 4715 living donor kidney recipients at 165 centers was $61,149 per patient per center (interquartile range, $50,221-$67,701), much lower than for deceased donor recipients. Only 1 donor factor, age, was independently associated with increased costs for living donor transplants (Table 2).

The distribution of cost and observed/expected allograft survival are shown in Figure 1 (panel A). There was no correlation between relative cost and observed/expected allograft failure (r = 0.096, $P = 0.22$; Figure 1, panel B). At 53 centers (32%), survival was better and costs were lower than expected; at 38 centers (23%), costs were higher and survival was worse (Figure 1, panel B). Higher-performing centers (centers whose costs and incidence of allograft failure were both lower than expected) were more likely to have the following characteristics compared with lower-performing centers (centers whose costs and incidence of allograft failure were both higher than expected): fewer deceased donor transplants, more white recipients, fewer African American recipients, lower incidence of diabetes as the primary cause of ESRD, recipients with lower body mass index, less frequent retransplant, more frequent preemptive transplant, and lower incidence of congestive heart failure (CHF) (Table 3). However, because these factors were accounted for in both the cost and the allograft failure models, they are likely not the drivers of the differences. Geographical distribution of higher- and lower-performing centers also differed, with a trend toward significance, despite adjustment for the local wage index. Higher-performing centers were more likely to be located in the West North Central and South Atlantic regions and less likely to be located in the New England, Middle Atlantic, and East South Central (Table 4).

DISCUSSION

As the pressure to contain costs and maintain and improve outcomes for kidney transplants recipients intensifies, an improved understanding of the relationships between these 2 variables is imperative. We found that several factors were independently associated with increased costs of kidney transplants. Immunologic factors such as increased PRA and increased HLA mismatches were significantly associated with cost, as were donor age, cold ischemia time, pretransplant dialysis duration, and pretransplant hospitalizations. Higher costs were also associated with several common comorbid conditions. However, despite these many associations, there was no relationship between relative cost and observed/expected allograft failure. Recipient and donor characteristics at higher-performing centers with lower costs and better outcomes differed from characteristics at lower-performing centers. However, these characteristics were accounted for in our adjusted cost and allograft failure models. Our data suggest a slight trend toward favorable performance being associated with regional differences in clinical practice, despite adjustment for the local wage index. These differences suggest that process and structure of care need to be assessed in future studies as a means to improve both costs and outcomes.

The cost containment debate reached a new level with implementation of the Affordable Care Act.[11] The Centers for Medicare & Medicaid Services recently released data on the highly variable hospital charges for 100 common medical conditions,[2] meant to highlight the lack of standardized charges and encourage the health care sector to closely consider best practices to reduce charges. Another study demonstrated that the national aggregate hospital charges for kidney transplant procedures rose from $0.9 billion in 1998 to $31 billion in 2008.[12] In the present study, we considered cost in terms of Medicare expenditures. We found no correlation between costs and observed/expected allograft failure for all kidney transplant centers in the study. This finding is similar to findings of a recent systematic review by Hussey et al,[13] who noted an inconsistent association between health care quality and cost primarily in non-transplant settings. Of the 61 studies included in the review, 21 (34%) found a positive or mostly positive association, 18 (30%) found a negative or mostly negative association, and 22 (36%) found an inconsistent or no association. The review included a total of 20 expenditure-based studies; 5 showed a positive association,

TABLE 2.

Baseline characteristics, Medicare costs, and parameter estimates from the ordinary least square, multiple regression model: living donor transplants

Variable	Frequency, %	Medicare cost [a]	Reference	Parameter estimate	Standard error	*P*
Overall	*n* = 4715	64,881				
Intercept	N/A	N/A		51,114	4486	<0.0001
Donor factors						
Age (1-y increase), y	N/A	N/A	N/A	138	60	0.0206
Race, African American	15.4	70,749	White	−784	3528	0.8242
Race, other	19.8	61,536	White	−2380	1903	0.211
Relationship with donor: yes	60.2	64,504	No	458	1762	0.7947
Relationship with donor: missing	0.04	27,782	No	−35,359	31,495	0.2616
Recipient and transplant factors						
HLA ABDR mismatch 4	15.1	64,294	≤3	−29	2172	0.9895
HLA ABDR mismatch 5	17.1	67,395	≤3	3894	2099	0.0637
HLA ABDR mismatch 6	10.9	66,958	≤3	2940	2414	0.2232
PRA > 30	8.9	74,738	≤30	8620	2443	0.0004
PRA, missing	24.6	73,124	≤30	7,599	1579	<0.0001
Previous organ transplant: yes	13.3	74,447	No	2671	2491	0.2838
Recipient age (1-y increase),[b] y	NA	NA		−185	53	0.0004
Female	39.1	67,506	Male	3180	1384	0.0216
Recipient race, African American	18.2	70,547	White	1835	3286	0.5766
Recipient race, other	6.5	56,710	White	−5745	2819	0.0416
Primary cause of ESRD: diabetes	26.2	72,438	Other	6268	2357	0.0079
Primary cause of ESRD: HTN	20.3	62,442	Other	1550	1954	0.4277
Primary cause of ESRD: GN	24.0	62,670	Other	678	1804	0.7071
BMI < 10 kg/m^2 or missing	6.3	81,927	10– < 25	13,987	2842	<0.0001
BMI 25- < 30 kg/m^2	30.5	62,366	10– < 25	2094	1649	0.2042
BMI 30 kg/m^2	28.1	67,829	10– < 25	5334	1707	0.0018
Dialysis duration ≥ 5 y	18.1	74,242	<5 years	5482	2152	0.0109
Preemptive transplant: yes	14.6	55,869	No	−5489	1962	0.0052
Preemptive transplant: missing	3.5	60,754	No	−4340	3603	0.2284
HCV positive	4.0	73,601	No	361	3379	0.9149
ASHD[c]	30.4	69,918	No	1545	1638	0.3455
CHF[c]	22.7	75,026	No	4590	1694	0.0068
CVA/TIA[c]	8.0	70,422	No	−1374	2454	0.5755
PVD[c]	21.1	76,602	No	7020	,670	<0.0001
Other cardiac disease[c]	22.2	73,279	No	2740	1656	0.0981
COPD[c]	9.3	78,206	No	11590	2278	<0.0001
Gastrointestinal bleeding[c]	3.5	77,038	No	4075	3553	0.2515
Liver disease[c]	7.1	72,290	No	4725	2566	0.0656
Dysrhythmia[c]	17.6	71,893	No	4531	1800	0.0119
Cancer[c]	6.1	73,335	No	7816	2744	0.0044
Diabetes[c]	40.3	70,898	No	3677	1939	0.058
Hospital stay in 6 mo before transplant > 4 d	19.7	79,995	≤4 days	8831	1786	<0.0001
New England	5.1	66,012	South Atlantic	−22,398	3933	<0.0001
Middle Atlantic	15.4	67,701	South Atlantic	−18,919	2908	<0.0001
East North Central	19.5	62,345	South Atlantic	−20,964	2297	<0.0001
East South Central	4.2	51,502	South Atlantic	−19,313	3731	<0.0001
West North Central	8.5	65,385	South Atlantic	−11,927	2961	<0.0001
West South Central	9.1	56,548	South Atlantic	−18,936	2766	<0.0001
Mountain	6.9	53,528	South Atlantic	−25,584	3041	<0.0001
Pacific	15.1	61,540	South Atlantic	−21,253	3279	<0.0001
Cohort year 2008	38.4	66,376	2007	5129	1465	0.0005
Cohort year 2009	20.8	69,038	2007	8651	1758	<0.0001
Wage index 0.9424 to 1.0275	26.1	71,101	<0.9424	14,238	2032	<0.0001
Wage index 1.0276 to 1.1295	24.9	63,393	<0.9424	10,241	2211	<0.0001
Wage index > 1.1294	25.8	67,890	<0.9424	17,803	2945	<0.0001

Note: Includes all centers. For determining the center performance, small centers with fewer than 3.69 expected allograft failures were excluded because the observed/expected allograft failures in such centers could vary dramatically with a single failure (n = 41 of 207, 20%).

[a] Per patient per year in year 1 after transplantation.

[b] Mean recipient age was 50.0 years (interquartile range, 38-63 y).

[c] Comorbid conditions in the 6 months before transplantation.

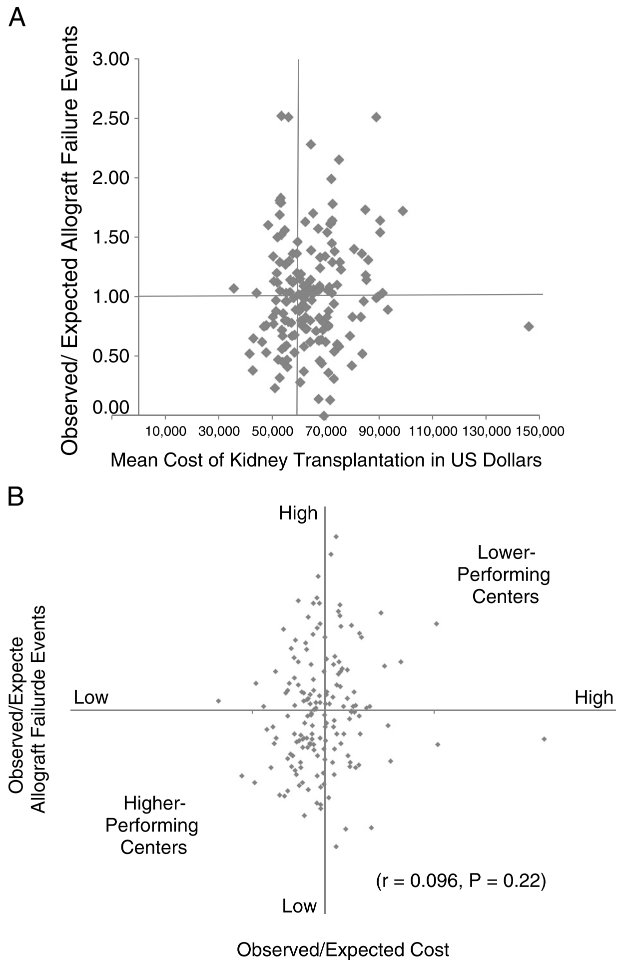

FIGURE 1. A and B, Variation in unadjusted cost of kidney transplant and allograft failure outcomes (panel A), and variation in adjusted cost of kidney transplant and allograft failure outcomes (panel B).

5 showed a negative association, and 10 were indeterminate. An included study by Englesbe et al[14] demonstrated that low-quality centers cost Medicare an additional $1185 per kidney transplant, thus noting a negative association. Quality was described as postoperative 30-day mortality.[14] Six-month mortality for patients in the study was less than 5%. The Institute of Medicine has studied variation in costs; with current trends toward cost containment, it is crucial that the kidney transplant service adopt evidence-based practices that will maintain quality at low costs.[15] For example, centers may vary in lengths of stay due to variation in duration of intravenous induction agents, such as thymoglobulin after kidney transplant. Centers that use a full dose of calcineurin inhibitors immediately after transplant rather than delaying until onset of allograft function may have longer lengths of stay and potentially higher costs.[16]

Geographic variation in cost of care has been described for many other diseases[17] and was first described as early as 1973.[18] We found geographic differences in the distribution of higher-, lower-, and intermediate-performing centers across different regions, but with only a trend toward statistical significance. Regional differences in clinical practice patterns may possibly explain some of the variation in cost and quality of outcomes, but are not necessarily a strong driver of differences after adjustment for the local wage index. Graft survival correlates inversely with decreasing organ quality[19]; thus, it is not a surprise that marginal organs increased the costs of transplant. Organ quality defined by cold ischemia time, donation after circulatory death status, and expanded criteria donor status was independently associated with increased costs (Table 1), consistent with finding of other studies.[20-23] However, these and other donor factors were accounted for in the adjusted analysis.

TABLE 3.

Characteristics of higher- versus lower-performing centers

Variable	Higher-performing centers[a]	Lower-performing centers[b]	*P*
Total centers	53	38	
Total recipients	6839	4635	
Deceased donor (%)	72.9	77.8	<0.0001
Recipient age (mean ± SD), y	52.6 ± 13.9	51.8 ± 13.9	0.0042
Recipient age, y (%)			0.0697
18–30	8.3	8.8	
31–44	20.3	21.6	
45–59	35.5	36.0	
≥60	35.9	33.7	
Female (%)	38.2	38.1	0.9464
Race (%)			<0.0001
White	63.0	59.4	
African American	29.1	33.9	
Other	7.9	6.7	
Primary cause of ESRD (%)			0.0094
Diabetes	28.2	29.3	
Hypertension	23.7	25.7	
Glomerulonephritis	22.3	20.7	
Other	25.9	24.3	
BMI, kg/m^2 (%)			<0.0001
<10 or missing	7.7	1.7	
10- < 25	30.8	33.6	
25- < 30	32.1	34.2	
≥30	29.4	30.5	
Dialysis duration, y (%)			0.0746
<2	25.4	25.9	
2- < 5	41.0	39.0	
≥5	33.6	35.2	
Previous organ transplant: yes (%)	13.4	14.8	0.0454
Preemptive: yes (%)	7.5	6.1	0.0024
Length of stay in days 6 mo previous transplant (mean ± SD)	2.72 ± 5.23	3.00 ± 6.06	0.009
Comorbid conditions in 6 mo before transplantation (%)			
Atherosclerotic heart disease	32.2	32.6	0.7111
CHF	23.4	26.7	<0.0001
CVA/TIA	7.8	7.6	0.792
PVD	23.0	24.5	0.0583
Other cardiac disease	20.9	23.9	0.0001
COPD	9.6	9.2	0.4626
Gastrointestinal bleeding	3.6	3.5	0.8847
Liver disease	7.4	8.9	0.0041
Dysrhythmia	18.4	19.7	0.0985
Cancer	4.8	5.2	0.2709

[a] Higher-performing centers: observed/expected costs < 1, observed/expected allograft failure < 1.
[b] Lower-performing centers: observed/expected cost > 1, observed/expected allograft failure > 1.

TABLE 4.

Percentage of centers with various performance characteristics within each geographic region. each row adds up to 100%

	Center performance				
Region	Higher[a]	Intermediate, allograft outcomes worse than expected[b]	Intermediate, cost higher than expected[c]	Lower[d]	P^e
New England	16.7	33.3	25	25	0.057
Middle Atlantic	23.3	26.7	13.3	36.7	0.057
South Atlantic	44.5	37	11.1	7.4	0.57
East North Central	25	16.6	29.2	29.2	0.087
East South Central	12.5	50	0	37.5	0.061
West North Central	54.5	0	27.3	18.2	Reference
West South Central	35	25	20	20	0.29
Mountain	36.3	18.2	18.2	27.3	0.39
Pacific	34.8	26.1	26.1	13	0.27

[a] Higher-performing centers: observed/expected costs < 1, observed/expected allograft failure < 1.
[b] Intermediate-performing centers with worse allograft outcomes than expected: observed/expected cost < 1, observed/expected allograft failure > 1.
[c] Intermediate-performing centers with higher cost than expected: observed/expected cost > 1, observed/expected allograft failure < 1.
[d] Lower-performing centers: observed/expected cost > 1, observed/expected allograft failure > 1.
[e] *P* value comparing proportion of higher-performing centers versus centers with other cost and outcome characteristics, within each geographic region.

Greater degree of HLA mismatch and higher PRA score were significantly associated with increased costs (Table 1, Table 2). Among deceased donor transplants, African American race was associated with increased costs. Numerous studies have described inferior kidney graft survival and increased acute rejection rates among African American recipients, and have attributed these findings to a combination of socioeconomic and immunological differences.[24,25] Studies have also shown that allograft failure rates are higher for African American recipients, likely due to rejection.[26] Because African American recipients are more likely to be overrepresented among transplant recipients than in the general donor population, they undergo transplant with more HLA mismatches.

Similarly, comorbid conditions, such as diabetes, CHF, atherosclerotic heart disease, peripheral vascular disease (PVD), obesity, and HCV were significantly associated with increasing costs.[27] In the published literature, preexisting recipient cardiovascular disease (presence of myocardial infarction, CHF, ischemic heart disease, PVD, unstable angina, or cardiac arrest) has been associated with decreased graft and recipient survival following kidney transplant.[28,29]

Recipient diagnosis of PVD was associated with increased costs. Recent studies show that kidney allograft and patient survival are inferior for patients with PVD compared with patients without PVD, likely due to increased risk of amputation (particularly in diabetic patients), allograft ischemia, significant morbidity, and poor patient survival.[30]

Recipient HCV-positive status was also associated with increased costs in recipients of deceased donor kidneys. Posttransplant allograft and patient survival are worse for HCV-positive kidney transplant recipients than for HCV-negative recipients,[31] and HCV-positive recipients are more likely to develop proteinuria, chronic rejection, infections, glomerulonephritis, and new-onset diabetes after transplant.[32]

The high costs associated with obese patients undergoing kidney transplant could be explained by increased risk of surgical complications, including longer operative times, prolonged hospitalizations, higher rates of reintubation, more frequent intensive care unit admissions, and greater incidence of wound complications.[33,34]

Higher costs were also noted with prolonged dialysis duration for both deceased donor and living donor kidney recipients. The adverse effects of dialysis are duration dependent and include increased rates of delayed graft function and acute rejection, and increased progression of cardiovascular disease.[35]

Overall costs for deceased donor kidney transplant recipients were higher than for living donor recipients. This finding is similar to findings discussed by Axelrod et al,[36] who showed that the costs of providing transplant care increased significantly with transplants in higher-risk recipients and use of marginal organs. However, we found no correlation between costs and observed/expected allograft failure, possibly because many transplant centers that accept high-risk donors or recipients with comorbid conditions have created cost-effective management systems. For example, careful selection of appropriate transplant candidates with comorbid conditions may also explain lack of correlation detected in our study. The variability in costs and outcomes may more likely be due to significant variation in the structure and processes of care for kidney transplant recipient.[37] A direct, in-depth comparison of the structure and processes of care between consistently higher- and lower-performing centers would assist in identifying factors that drive costs and affect outcomes.

Our study has several limitations. Our cost data were limited to Medicare beneficiaries while data on observed/expected allograft failure included all patients in the centers. We did not separate the outcomes for Medicare beneficiaries; however, it is unlikely that transplant centers treat Medicare patients differently from non-Medicare patients. Also, removing patients with private payers would reduce the sample size at many centers and potentially reduce the precision of quality estimates. We do not have access to cost data for private payers; hence, the association between cost and quality may limit the generalizability of the information to non-Medicare beneficiaries. However, the cost to private payers is generally higher than the cost to Medicare. The study could be confounded by unmeasured differences in recipient characteristics. A few variables were missing for some transplant recipients (Tables 1 and 2), but sensitivity analysis excluding these recipients did not change the lack of correlation between allograft outcomes and cost (data not shown). Our models did not use the kidney donor risk index[38] because it was not in use during the timeframe of the study cohort. However, we used all the variables used to calculate it except donor height. Lastly, we did not account for kidney acquisition costs, which include payments for the pretransplant workup and acquiring the kidney allograft. Organ acquisition is a pass-through payment that is reported on the annual hospital cost reports and then embedded into general Medicare hospital payments. Therefore, it is not feasible to assign kidney acquisition costs to an individual transplant.

In conclusion, to the best of our knowledge, this is the first study to describe the association of cost and quality in kidney transplantation at 1 year after transplantation. There was no association between relative cost and observed/expected allograft failure. Future evaluation of the variation in process and structure of care between high- and low-performing centers might provide insight into best practices to help decrease costs and maintain high quality. We hope that reporting on these costs and outcomes will encourage further work aimed at determining best practices for achieving high quality at low cost.

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