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Organ quality metrics are a poor predictor of costs and resource utilization in deceased donor kidney transplantation

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Abstract

Background.—The desire to provide cost-effective care has lead to an investigation of the costs of therapy for end-stage renal disease. Organ quality metrics are one way to attempt to stratify kidney transplants, although the ability of these metrics to predict costs and resource use is undetermined.

Methods.—The Scientific Registry of Transplant Recipients database was linked to the University HealthSystem Consortium Database to identify adult deceased donor kidney transplant recipients from 2009 to 2012. Patients were divided into cohorts by kidney criteria (standard vs expanded) or kidney donor profile index (KDPI) score (<85 vs 85+). Length of stay, 30-day readmission, discharge disposition, and delayed graft function were used as indicators of resource use. Cost was defined as reimbursement based on Medicare cost/charge ratios and included the costs of readmission when applicable.

Results.—More than 19,500 patients populated the final dataset. Lower-quality kidneys (expanded criteria donor or KDPI 85+) were more likely to be transplanted in older (both $P < .001$) and diabetic recipients (both $P < .001$). After multivariable analysis controlling for recipient characteristics, we found that expanded criteria donor transplants were not associated with increased costs compared with standard criteria donor transplants (risk ratio [RR] 0.97, 95% confidence interval [CI] 0.93–1.00, $P = .07$). KDPI 85+ was associated with slightly lower costs than KDPI <85 transplants (RR 0.95, 95% CI 0.91–0.99, $P = .02$). When KDPI was considered as a continuous variable, the association was maintained (RR 0.9993, 95% CI 0.999–0.9998, $P = .01$).

Conclusion.—Organ quality metrics are less influential predictors of short-term costs than recipient factors. Future studies should focus on recipient characteristics as a way to discern high versus low cost transplantation procedures.

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KIDNEY TRANSPLANTATION IS THE MOST COST-EFFECTIVE THERAPY FOR END-STAGE RENAL DISEASE (ESRD), although organ shortages limit more ubiquitous use.[1–3] Because of this supply issue, expanded criteria donor (ECD) kidneys were added to the deceased donor pool as a means of shortening wait times for subgroups of patients with ESRD[4,5]; however, nearly half of recovered ECD kidneys are discarded because of quality concerns.[6] Furthermore, the financial impact on centers that use these ECD kidneys has been questioned.[7–9] Concerns about the ability of ECD/SCD classification to accurately discriminate between high quality and lower quality organs led to the introduction of the new Kidney Allocation System in December of 2014. Instead of the binary classification used previously, the Kidney Allocation System now stratifies using kidney donor profile index (KDPI) scores, that range from 0% to 100% and are based on 10 donor factors (age, height, weight, ethnicity, history of hypertension, history of diabetes, cause of death, serum creatinine, HCV status, and DCD status).[13,16,17] A lower KDPI score is associated with better organ quality.

These stratification schema are important, because the treatment of ESRD is expensive; Medicare payments for ESRD totaled $28.6 billion in 2012 (5.6% of total Medicare payments).[11] To ensure that these expensive therapies are helping as many patients as possible, numerous studies have looked into the cost-effectiveness of ESRD treatments.[7–12] It generally is accepted that dialysis is a more expensive option than transplantation, and the 2013 US Renal Data System Annual Data Report confirmed that the per-patient yearly costs of dialysis are nearly 3 times as high as those for a transplant patients.[12] Looking even further into costs, some investigators have compared the cost-effectiveness of different types of transplantation, particularly looking at expanded versus standard criteria deceased donor kidneys[7–10]; however, because these studies tend to involve small cohorts of patients, are limited to single institutions, and report charges---a vague and inaccurate surrogate for true costs (either hospital or payer)---there is an opportunity for higher quality investigation.

Here, we performed a retrospective cohort study of transplant recipients using merged national datasets to analyze costs and resource use differences between quality metric-defined sub-types of deceased donor kidneys. Using this large dataset, we were not only able to compare expanded and standard criteria kidneys to build upon the previous literature, but we also were able to retrospectively calculate KDPI scores for our cohort and examine the relationship between KDPI scores (used as both a binary and continuous metric of quality) and costs. We hypothesized that ECD and high KDPI kidneys (KDPI 85+) may be associated with increased costs and resource use as the result of decreased organ quality.

METHODS

This study used data from the Scientific Registry of Transplant Recipients (SRTR). The SRTR data system includes data on all donor, wait-listed candidates, and transplant recipients in the United States, submitted by the members of the Organ Procurement and Transplantation Network (OPTN). The Health Resources and Services Administration, US Department of Health and Human Services provides oversight to the activities of the OPTN and SRTR contractors. After institutional review board approval, the SRTR database was

linked to the University HealthSystem Consortium (UHC) Clinical Database/Resource Manager.

Adult deceased donor kidney transplant recipients who underwent surgery from 2009 to 2012 populated the final dataset. ECD kidneys were defined by the United Network for Organ Sharing criteria as kidneys from older donors (≥60 years), or donor age 50–59 with 2 of the following 3 criteria: hypertension, terminal serum creatinine >1.5 mg/dL, or death from cerebrovascular accident.[14] KDPI scores were calculated by use of the online OPTN guide to calculating and interpreting the KDPI, using the 2013 scaling factor (median KDRI_RAO value amongst all kidney donors recovered during the previous year). Hospital volume tertiles were created using annual center kidney transplant volumes as described previously.[15]

Primary outcomes studied included posttransplant duration of stay; delayed graft function, defined by UNOS as requirement for dialysis within the first seven days after transplant; 30-day readmission rate; discharge disposition; and cost. Thirty-day readmission was defined as the readmission to a UHC-affiliated hospital within 30 days of index hospitalization discharge. Discharge disposition was divided into home, home with home health care, rehabilitation, and ‘‘other,’’ defined as death, discontinuation of care against medical advice, admission to that same hospital as an inpatient, or unknown. Cost, considered from a societal (ie, reimbursement) perspective, was calculated by applying each individual hospital’s cost-to-charge ratio to total hospital charges and is reported to UHC from Medicare. Differences in regional labor costs are taken into account by UHC by applying US Department of Commerce area wage indexes to the labor portion of the cost of a service. Regarding the costs of medications, pharmacy revenue codes were used to create aggregate cost data that included the costs of induction therapy. Cost was reported in 3 separate manners: index hospitalization (peritransplant hospitalization), readmission (primary readmission, if one readmission occurred less than one month following transplant), and combined (sum of index hospitalization and readmission, if applicable).

Statistical analysis was performed using SAS 9.3 and JMP 9 (SAS Institute, Cary, NC). For univariate analysis, continuous variables were compared using the Wilcoxon rank-sum test and categorical variables using the χ^2 test. A series of multivariate models were estimated for endpoints of interest. The 3 direct cost variables (total direct cost, readmission direct cost, and combined direct cost) are strongly right-skewed. To account for this distribution, we used generalized linear models with gamma distributions and log links. Duration of stay was treated as a count variable and modeled using a generalized linear model with Poisson distribution and log link. Discharge distribution is a nominal categorical variable that we modeled using a generalized logit framework. Finally, since 30-day readmission and delayed graft function are both binary variables, we used standard logistic regression to model them.

In the case of the cost variables and duration of stay, the estimated coefficients are multipliers, or risk ratios; they indicate the multiplicative effect on the dependent variable of a one-unit increase in the associated explanatory variable. For discharge disposition, readmission and delayed graft function, the results are expressed as odds ratios. In all of these models, a stepwise approach was used. Center volume, recipient sex, age, race, body

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mass index, diabetes status, hypertension status, panel reactive antibodies, albumin levels, HLA mismatches, coronary artery disease, pretransplant dialysis, and cold ischemia time were considered in the initial model. The nonsignificant variable with the greatest *P* value was dropped until the final model included only statistically significant effects. A *P* value of .05 was used as the cut-point for statistical significance for multivariable modeling.

RESULTS

The final SCD/ECD dataset contained 19,527 patients, whereas the KDPI dataset contained 19,502 patients. When divided by kidney criteria, 17.9% (3,495) of the transplants were performed with ECD kidneys. Alternatively, after KDPI stratification, 11.3% (2,208) of the transplants involved high KDPI kidneys. Recipient demographics by kidney type received are displayed in Tables I and II. ECD kidneys were more likely to be transplanted into older (median of 62 vs 52 yrs), male (63.7% vs 59.3%), and diabetic (47.1% vs 31.7%) recipients (all $P < .001$). ECD kidneys were less likely to be given to sensitized patients with a panel reactive antibody >80% (6.1% vs 17.8%, $P < .001$). A greater proportion of ECD transplants were performed at high-volume centers relative to SCD transplants (32.4% vs 30.1%, $P = .01$) (Table I). Similarly, kidneys with a KDPI of 85 + were more likely to be transplanted into older (median age of 62 vs 53 years) and diabetic (45.7% vs 33.0%) recipients (all $P < .001$). High KDPI kidneys were less likely to be given to sensitized patients with a panel reactive antibody >80% (7.3% vs 16.5%, $P < .001$). A greater proportion of high KDPI transplants were performed at high-volume centers relative to low KDPI (KDPI <85) transplants (33.3% vs 30.1%) (Table II).

Unadjusted cost and resource use outcomes are displayed in Tables III and IV. ECD kidneys were associated with increased duration of stay (6 vs 5 days), 30-day readmission (34.7% vs 28.1%), delayed graft function (32.9% vs 24.8%), and discharge to rehabilitative care (4.4% vs 3.0%) compared with SCD kidneys (all $P < .001$). Before adjustment for confounding variables, ECD transplants were associated with decreased index costs ($85,505 vs $88,150), combined costs ($87,301 vs $90,287), and discharge to home (71.4% vs 77.6%) (all $P < .001$) (Table III). High KDPI kidneys are associated with increased LOS (6 vs 5 days), 30-day readmission (35.6% vs 28.5%), delayed graft function (33.3% vs 25.4%), and discharge to rehabilitative care (3.9% vs 3.2%) compared with low KDPI kidneys. Before multivariable adjustment, high KDPI kidneys were associated with decreased index costs ($84,266 vs $88,102), combined costs ($85,929 vs $90,305), and discharge to home (71.6% vs 77.1%) (all $P < .001$) (Table IV).

To control for baseline demographic differences, multivariable analyses were performed, adjusting for center volume, recipient sex, age, race, body mass index, diabetes status, hypertension status, panel reactive antibodies, albumin levels, HLA mismatches, coronary artery disease, pretransplant dialysis, and cold ischemia time. Adjusted outcomes are shown in Table V for both ECD and high KDPI kidneys (relative to SCD and low KDPI kidneys, respectively). After adjustment, ECD kidneys were still associated with increased 30-day readmission rates (odds ratio [OR] 1.35, 95% confidence interval [95% CI] 1.21–1.50, $P < .001$) and delayed graft function (OR 1.33, 95% CI 1.19–1.50, $P < .001$). However, readmission costs (risk ratio [RR] 1.08, 95% CI 0.94–1.23, $P = .29$), and combined costs

(RR 0.97, 95% CI 0.93–1.00, $P = .07$) were not shown to differ between ECD and SCD kidneys. Discharge disposition and duration of stay were also similar between groups. High KDPI kidneys were still associated with increased 30-day readmission rates (OR 1.38, 95% CI 1.21–1.58, $P < .001$) and delayed graft function (OR 1.25, 95% CI 1.09–1.45, $P = .002$). Conversely, high KDPI kidneys were associated with decreased index (RR 0.95, 95% CI 0.93–0.98, $P < .001$) and combined costs (RR 0.95, 95% CI 0.91–0.99, $P = .02$).

Table VI shows adjusted analysis (controlling for the same variables as the previous multivariable analyses) of cost based on KDPI as a continuous variable (from 0 to 100). Increasing KDPI scores correlated with a slight decrease in combined costs (RR 0.9993, 95% CI 0.999–0.9998, $P = .01$).

DISCUSSION

This is the first study addressing short-term costs and resource use after deceased donor kidney transplantation at a national level. Contrary to previous reports, our data show that ECD kidney transplants do not cost more---from a payer/provider perspective---than SCD transplants in the short term. Additionally, KDPI scores, when interpreted in both a binary and continuous manner, were not effective in predicting cost.

Historically, expanded criteria donor kidneys were implemented to expand the donor pool and classified as ECD kidneys to differentiate between the quality of standard kidneys compared with their new expanded counterparts. Similarly, KDPI scoring was introduced as a part of the new kidney allocation system as a way to more accurately match kidneys to recipients in a way that will maximize life years by placing the greatest quality kidneys with the donors likely to need them for the longest period of time.[13] In short, KDPI scores are another metric of organ quality.[17]

Numerous studies in the past have attempted to correlate expanded criteria donor kidneys with increased costs.[7–10] Saidi et al,[7] in a single-center retrospective analysis, have demonstrated increased costs of approximately $25,000 for ECD transplants compared with SCD transplants. A separate single-center retrospective study showed decreased medical center incremental margins in cases with ECD kidneys (−$5,887).[8] In an older study, Whiting et al[9] demonstrated that ECD kidneys cost $10,911 more than non-ECD transplants. Conversely, Machnicki et al[10] used the US Renal Data System to model Medicare payments and duration of stay and found that ECD status was not associated with increased payments.

Compared with currently available reports, our investigation has multiple strengths. First, we used reimbursement---rather than hospital charges---to measure financial outcomes; estimated payments are more applicable and interpretable than hospital charges when discussing true financial utilization. Additionally, the data are current (2009–2012), and capture nearly half of all kidney transplants performed in the United States during that time period. Merging of the UHC and SRTR datasets is comprehensive, providing both cost data and granular short-term clinical outcomes. After examining the effect of both expanded criteria donor status and KDPI scoring on short-term costs of kidney transplantation in a

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national analysis---controlled for multiple recipient clinical characteristics---we found no correlation between decreased organ quality and increased costs.

This study has limitations. Large academic centers and their affiliated hospitals disproportionately populate the UHC dataset. Because only one-half of the transplants performed in the United States were included in the dataset, the results could have been skewed to overrepresent the outcomes seen in these centers. As with all registry data, administrative or clinical, there are inherent limitations such as reporting/input error, missing data, and unrecognized factors that may contribute to our conclusions. Several large UHC hospitals are currently using Campath for induction therapy, which is not being charged for and may alter the charges submitted. Additionally, this study did not examine long-term clinical outcomes, nor long-term cost data (not provided in UHC), of the different types kidney transplants, although these have been studied in other investigations. This was a retrospective observational study, so there may be baseline differences between the recipient populations that were not addressed by regression modeling. However, the complexities of donor-recipient transplant matching would likely make a prospective randomized trial of costs following transplant impossible.

Using a modern, national dataset, we have shown that decreased organ quality, measured by multiple metrics, does not correlate with increased short-term costs. These data suggest that metrics designed to measure donor kidney quality are inadequate to predict cost outcomes, and that recipient characteristics may be a more influential predictor of initial costs after transplantation. Future attempts to stratify cost-effectiveness of transplant procedures should take this into account.

The University of Cincinnati’s Institutional Review Board approved this study and the Health Resources and Services Administration SRTR Project Officer and the SRTR Technical Advisory Committee approved the linkage of the two datasets. The data reported here have been supplied by the Minneapolis Medical Research Foundation as the contractor for the SRTR. The interpretation and reporting of these data are the responsibility of the author(s) and in no way should be seen as an official policy of or interpretation by the SRTR or the US Government. The Health Resources and Services Administration, US Department of Health and Human Services provides oversight to the activities of the OPTN and SRTR contractors.

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Table I.

Recipient demographics by SCD versus ECD kidneys

Variable	*SCD*, N/*median*	ECD, N/*median*	P *value*
Recipient sex, male	9,507 (59.3%)	2,226 (63.7%)	<.001
Recipient age, y	52 (IQR 42–61)	62 (IQR 56–68)	<.001
Recipient race			.132
White	7,232 (45.1%)	1,595 (45.6%)	
Black	5,339 (33.3%)	1,107 (31.7%)	
Other	3,463 (21.6%)	793 (22.7%)	
Recipient BMI	27.7 (IQR 24.0–32.0)	28.0 (IQR 24.7–32.0)	<.001
Recipient diabetes	5,075 (31.7%)	1,646 (47.1%)	<.001
Recipient HTN	11,398 (85.0%)	2,443 (87.0%)	.005
Recipient albumin			<.001
<3.0	868 (6.5%)	155 (5.3%)	
3.0–4.49	10,327 (77.3%)	2,394 (81.7%)	
4.5+	2,159 (16.2%)	380 (13.0%)	
Peak PRA ≥80%	2,708 (17.5%)	204 (6.1%)	<.001
Recipient pretransplant dialysis	14,171 (88.8%)	3,123 (89.6%)	.36
HLA mismatch	4 (IQR 3–5)	5 (IQR 4–5)	<.001
Recipient angina/CAD	755 (6.5%)	212 (8.7%)	<.001
Cold ischemia time	16.1 (IQR 11.0–22.9)	17.8 (IQR 12.1–25.0)	<.001
Center volume			.012
HV	4,823 (30.1%)	1,133 (32.4%)	
MV	5,477 (34.2%)	1,186 (33.9%)	
LV	5,734 (35.8%)	1,176 (33.7%)	
KDPI score	42 (IQR 23–60)	85 (IQR 77–92)	<.001

Values are *n* (%) unless otherwise stated.

BMI, Body mass index; *CAD*, coronary artery disease; *ECD*, expanded criteria donor; *KDPI*, kidney donor profile index; *HLA*, human leukocyte antigen; *HTN*, hypertension; *HV*, high volume; *IQR*, interquartile range; *LV*, low volume; *MV*, medium volume; *PRA*, panel-reactive antibody; *SCD*, standard criteria donor.

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Table II.

Recipient demographics by high and low KDPI donor kidneys

Variable	*KDPI <85*, *N/median*	*KDPI 85+*, *N/median*	**P** *value*
Recipient sex, male	10,361 (59.9%)	1,356 (61.4%)	.17
Recipient age, y	53 (IQR 43–62)	62 (IQR 55–68)	<.001
Recipient race			.018
White	7,876 (45.6%)	940 (42.6%)	
Black	5,690 (32.9%)	748 (33.9%)	
Other	3,725 (21.5%)	520 (23.6%)	
Recipient BMI	27.8 (IQR 24.1–32.1)	27.5 (IQR 24.2–31.4)	.01
Recipient diabetes	5,702 (33.0%)	1,008 (45.7%)	<.001
Recipient HTN	12,297 (84.9%)	1,525 (88.5%)	<.001
Recipient albumin			.002
<3.0	918 (6.4%)	102 (5.4%)	
3.0–4.49	11,180 (77.7%)	1,524 (81.2%)	
4.5+	2,287 (15.9%)	250 (13.3%)	
Peak PRA ≥80%	2,751 (16.5%)	155 (7.3%)	<.001
Recipient pretransplant dialysis	15,307 (88.9%)	1,964 (89.3%)	.50
HLA mismatch	4 (IQR 3–5)	5 (IQR 4–5)	<.001
Recipient angina/CAD	836 (6.7%)	126 (8.5%)	.01
Cold ischemia time	16.1 (IQR 11.0–22.9)	18.3 (IQR 13.0–26.0)	<.001
Center volume			<.001
HV	5,208 (30.1%)	736 (33.3%)	
MV	5,864 (33.9%)	793 (35.9%)	
LV	6,219 (36.0%)	679 (30.8%)	
ECD status	1,705 (9.9%)	1,789 (81.0%)	<.001

Values are *n* (%) unless otherwise stated.

BMI, Body mass index; *CAD*, coronary artery disease; *ECD*, expanded criteria donor; *KDPI*, kidney donor profile index; *HLA*, human leukocyte antigen; *HTN*, hypertension; *HV*, high volume; *IQR*, interquartile range; *LV*, low volume; *MV*, medium volume; *PRA*, panel reactive antibody; *SCD*, standard criteria donor.

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Table III.

Unadjusted comparison of costs and resource use ECD vs SCD kidneys

Variable	***SCD*, N/*median***	***ECD*, N/*median***	**P *value***
Duration of stay	5 (IQR 4–7)	6 (IQR 4–8)	<.001
Index cost	$88,150 (IQR 71,697–117087)	$85,504.5 (IQR 70,553.8–108,780.5)	<.001
Readmission cost	$4,998 (IQR 2,748.5–9,887.3)	$5,057 (IQR 2,682–10,179)	.854
Combined cost	$90,287 (73,050–120,553)	$87,301 (72,595.8–114,288.5)	<.001
30-day readmission	4,510 (28.1%)	1,213 (34.7%)	<.001
DGF	3,957 (24.8%)	1,147 (32.9%)	<.001
Discharge status			<.001
Home	12,446 (77.6%)	2,495 (71.4%)	
HHHC	2,968 (18.5%)	809 (23.2%)	
Rehab	487 (3.0%)	154 (4.4%)	
Other	133 (0.8%)	37 (1.1%)	

DGF, Delayed graft function; *ECD*, expanded criteria donor; *HHHC*, home with home health care; *IQR*, interquartile range; *SCD*, standard criteria donor.

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Table IV.

Unadjusted comparison of costs and resource use by high and low KDPI kidneys

Variable	*KDPI <85*, N/*median*	*KDPI 85+*, N/*median*	P *value*
Duration of stay	5 (IQR 4–7)	6 (IQR 4–8)	<.001
Index cost	$88,102 (IQR 71,763–117,306)	$84,266 (IQR 69,258–101,689)	<.001
Readmission cost	$5,003 (IQR 2,732–9,921)	$5,056 (IQR 2,745–10,097)	.89
Combined cost	$90,305 (73,178–120,896)	$85,929 (71,553–107,280)	<.001
30-day readmission	4,924 (28.5%)	787 (35.6%)	<.001
DGF	4,366 (25.4%)	731 (33.3%)	<.001
Discharge status			<.001
Home	13,337 (77.1%)	1,581 (71.6%)	
HHHC	3,253 (18.8%)	518 (23.5%)	
Rehab	554 (3.2%)	86 (3.9%)	
Other	147 (0.9%)	23 (1.0%)	

DGF, Delayed graft function; *ECD*, expanded criteria donor; *HHHC*, home with home health care; *IQR*, interquartile range; *SCD*, standard criteria donor.

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Table V.

Adjusted outcomes for ECD versus SCD and high versus low-KDPI kidney transplants

	ECD transplant outcomes			*KDPI 85+ outcomes*		
Variable	*OR/RR*	*95% CI*	**P** *value*	*OR/RR*	*95% CI*	**P** *value*
Index cost	0.98	0.95–0.997	.029	0.95	0.93–0.98	<.001
Readmission cost	1.08	0.94–1.23	.29	0.98	0.83–1.15	.79
Combined cost	0.97	0.93–1.00	.07	0.95	0.91–0.99	.02
Duration of stay	1.03	0.97–1.09	.39	1.02	0.95–1.09	.66
30-day readmission	1.35	1.21–1.50	<.001	1.38	1.21–1.58	<.001
DGF	1.34	1.19–1.50	<.001	1.25	1.09–1.45	.002
DD HHHC vs rehab	1.10	0.81–1.49	.53	1.42	0.97–2.09	.075
DD home vs rehab	1.03	0.78–1.37	.83	1.31	0.91–1.89	.15
DD other vs rehab	0.72	0.35–1.45	.35	0.77	0.31–1.95	.59

CI, Confidence interval; *DD*, discharge disposition; *DGF*, delayed graft function; *HHHC*, home with home health care; *LOS*, length of stay; *OR*, odds ratio; *RR*, risk ratio.

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Table VI.

Adjusted outcomes based on increasing continuous KDPI scores

Variable	*RR*	*95% CI*	P *value*
Index cost	0.9995	0.9992–0.9998	.002
Readmission cost	1.00	0.99–1.003	.53
Combined cost	0.9993	0.9987–0.9998	.01

CI, Confidence interval; *RR*, risk ratio.