Textbook Outcome as a Quality Metric in Living and Deceased Donor Kidney Transplantation

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BACKGROUND: Quality in kidney transplantation is measured using 1-year patient and graft survival. Because 1-year patient and graft survival exceed 95%, this metric fails to measure a spectrum of quality. Textbook outcomes (TO) are a composite quality metric offering greater depth and resolution. We studied TO after living donor (LD) and deceased donor (DD) kidney transplantation.

STUDY DESIGN: United Network for Organ Sharing data for 69,165 transplant recipients between 2013 and 2017 were analyzed. TO was defined as patient and graft survival of 1 year or greater, 1-year glomerular filtration rate of greater than 40 mL/min, absence of delayed graft function, length of stay of 5 days or less, no readmissions during the first 6 months, and no episodes of rejection during the first year after transplantation. Bivariate analysis identified characteristics associated with TO, and covariates were incorporated into multivariable models. Five-year conditional survival was measured, and center TO rates were corrected for case complexity to allow center-level comparisons.

RESULTS: The national average TO rates were 54.1% and 31.7% for LD and DD transplant recipients. The hazard ratio for death at 5 years for recipients who did not experience TO was 1.92 (95% CI 1.68 to 2.18, $p \leq 0.0001$) for LD transplant recipients and 2.08 (95% CI 1.93 to 2.24, $p \leq 0.0001$) for DD transplant recipients. Center-level comparisons identify 18% and 24% of centers under-performing in LD and DD transplantation. High rates of TO do not correlate with transplantation center volume.

CONCLUSION: Kidney transplant recipients who experience TO have superior long-term survival. Textbook outcomes add value to the current standards of 1-year patient and graft survival. (J Am Coll Surg 2022;235:624–641.

Current measures of quality in kidney transplantation focus heavily on 1-year patient and graft survival.[1,2] The Scientific Registry of Transplant Recipients (SRTR), as a contractor for the Health Resources and Services Administration, issues program-specific reports that include a five-tier quality score based in part on 1-year patient and graft survival.[3] Similarly, the American Society of Transplant Surgeons Membership and Professional Standards Committee (MPSC) has historically relied on 1-year patient and graft survival for regulatory monitoring of program performance.[4] Because current national averages for 1-year patient and graft survival after kidney transplantation exceed 97% and 95%, respectively,[5] many think that these metrics fail to capture meaningful differences

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Abbreviations and Acronyms:

AST	=	American Society of Transplantation
ASTS	=	American Society of Transplant Surgeons
DCD	=	deceased from cardiac death
DD	=	deceased donor
KDPI	=	Kidney Donor Profile Index
LD	=	living donor
MPSC	=	Membership and Professional Standards Committee
SRTR	=	Scientific Registry of Transplant Recipients
TO	=	textbook outcomes

between transplantation programs[6-8] and potentially discourage transplantation programs from listing or performing transplantation for high-risk candidates.[2,9-12] The American Society of Transplantation and American Society of Transplant Surgeons have issued a joint call for reform,[13] and the MPSC[14] and SRTR[15] are currently proposing revision of national metrics. Concurrent with this national movement[16-18] toward revised quality metrics, we investigated textbook outcome (TO) in kidney transplantation.

Textbook outcomes describe the ideal post-operative course after a specific surgical procedure.[19] TO was first described after colon cancer resection[20] and has since been applied in diverse surgical disciplines, including hepatopancreaticobiliary surgery,[21-24] vascular[25] and foregut surgery,[19,26,27] bariatrics,[28] and after specific procedures such as endoscopic retrograde cholangiopancreatography and colonoscopy.[29] The distinguishing features of TO are that the metric is composite and holistic, meaning that an overall assessment of quality is made by considering performance in multiple domains. Commonly, definitions of TO include patient survival, freedom from post-operative complications, efficient use of healthcare resources, and patient satisfaction. TO is of potential interest to multiple stakeholders, including patients, providers, payors, and regulatory bodies.

In the kidney transplantation community there are, understandably, concerns surrounding any quality metric that might be co-opted to limit or restrict transplantation.[30] Donor organs are in critically short supply, and every transplantable organ should be used.[31,32] The survival benefit of transplantation[33,34] vs dialysis is overwhelming, and even the highest-risk recipient groups with lower-than-average expected outcomes stand to benefit greatly from transplantation.[35-38] These concerns notwithstanding, transplantation is not exempt from quality measurement. Metrics that capture the full spectrum of quality allow identification of best practices and offer opportunities to streamline care, contain cost, and enhance patient satisfaction. When applied to kidney transplantation, TO offers an integrated measurement of quality that provides greater resolution than 1-year patient and graft survival.

METHODS

Using multidisciplinary input from our institution's kidney transplantation team and our outcomes research group, an initial list of parameters defining TO after kidney transplantation was created. Consideration was given to relevant clinical outcomes, complications, efficient resource use, and patient satisfaction. This ideal list was then narrowed to data available from the United Network for Organ Sharing to create a final and nationally measurable definition of TO after kidney transplantation (Table 1; complete details provided in **Supplemental Digital Content 1**, http://links.lww.com/JACS/A116).

Standard transplantation analysis and research file data for kidney transplant recipients undergoing transplantation between 2013 and 2017 were queried (based on Organ Procurement and Transplantation Network data as of September 2021). Exclusion criteria included recipient age younger than 18 years, multi-organ transplantation, and re-transplantation within 1 year. Recipients with a missing covariate (not including warm ischemia time for deceased from cardiac death [DCD] donors and percent glomerulosclerosis for biopsied kidneys) were excluded from this complete-case analysis. Covariates were chosen (Table 2; complete details provided in **Supplemental Digital Content 2**, http://links.lww.com/JACS/A116), and bivariate analysis of donor and recipient characteristics was performed using Welch's *t*-test for continuous variables and chi-square test for categorical variables. **Supplemental Digital Content 3 and 4** (http://links.lww.com/JACS/A116) list the percentage of data missing for each covariate.

Prior to fitting a logistic regression model, donor terminal creatinine was capped at 15 mg/dL, cold ischemic time was capped at 72 hours, donor age was capped at 80 years, recipient BMI was capped at 50 kg/m^2, and waitlist

Table 1. Textbook Outcomes after Kidney Transplantation

Outcomes
Patient and graft survival ≥ 1 y
1-y MDRD GFR > 40
Absence of DGF
LOS ≤ 5 d
No readmission during first 6 mo after transplantation
Absence of rejection during first year after transplantation

DGF, delayed graft function; LOS, length of stay; MDRD GFR, Modification of Diet in Renal Disease glomerular filtration rate.

Table 2. Donor and Recipient Characteristics in Living Donor Transplantation with and without Textbook Outcomes

Characteristic	Textbook outcomes		p Value
	Yes	No	
Total, n (%)	10,869 (54.1)	9,233 (45.9)	
Recipient characteristic			
Age, y, mean [SD]	49 [14]	50 [14]	*
Sex, n (%)			*
Male	6,888 (63.4)	5,722 (62.0)	
Female	3,981 (36.6)	3,511 (38.0)	
BMI, kg/m^2, mean [SD]	27.6 [5.3]	28.1 [5.5]	<0.0001
Ethnicity, n (%)			*
White	6,867 (63.2)	6,354 (68.8)	
Black	1,335 (12.3)	1,196 (13.0)	
Hispanic	1,825 (16.8)	1,170 (12.7)	
Asian	711 (6.5)	385 (4.2)	
American Indian/Alaska Native	40 (0.4)	44 (0.5)	
Hawaiian/Pacific Islander	30 (0.3)	23 (0.2)	
Multiracial	61 (0.6)	61 (0.7)	
ABO, n (%)			0.6056
A	4,197 (38.6)	3,627 (39.3)	
AB	1,438 (13.2)	1,239 (13.4)	
B	442 (4.1)	384 (4.2)	
O	4,792 (44.1)	3,983 (43.1)	
Primary diagnosis, n (%)			<0.0001
Type I diabetes	303 (2.8)	316 (3.4)	
Type II diabetes	1,777 (16.3)	1,797 (19.5)	
HTN	1,794 (16.5)	1,371 (14.8)	
PKD	1,454 (13.4)	1,133 (12.3)	
Graft failure	595 (5.5)	696 (7.5)	
IgA nephropathy	1,037 (9.5)	628 (6.8)	
SLE	334 (3.1)	289 (3.1)	
Other	3,575 (32.9)	3,003 (32.5)	
Peripheral vascular disease, n (%)			<0.0001
Yes	782 (7.2)	923 (10.0)	
No	10,087 (92.8)	8,310 (90.0)	
HX of malignancy, n (%)			<0.0001
Yes	955 (8.8)	1,008 (10.9)	
No	9,914 (91.2)	8,225 (89.1)	
HX of liver TX, n (%)			<0.0001
Yes	981 (9.0)	1,053 (11.4)	
No	9,888 (91.0)	8,180 (88.6)	
Karnofsky functional status at TX, n (%)			<0.0001
0%-40%	113 (1.0)	243 (2.6)	
50%-70%	2,844 (26.2)	2,780 (30.1)	
80%-100%	7,912 (72.8)	6,210 (67.3)	
Serum albumin, g/dL, mean [SD]	3.95 [0.55]	3.89 [0.59]	<0.0001
CPRA, %, mean [SD]	10 [24]	13 [26]	<0.0001
Predialysis, n (%)			<0.0001
Yes	5,515 (50.7)	5,180 (56.1)	
No	5,354 (49.3)	4,053 (43.9)	

(Continued)

Table 2. Continued

Characteristic	Textbook outcomes		p Value
	Yes	No	
Creatinine at TX, mg/dL, mean [SD]	7.09 [3.49]	7.14 [3.52]	0.3174
Waitlist time, d, mean [SD]	373 [422]	404 [466]	<0.0001
HLA match, n (%)			<0.0001
0/6	1,240 (11.4)	1,198 (13.0)	
1/6	2,377 (21.9)	2,121 (23.0)	
2/6	1,895 (17.4)	1,694 (18.3)	
3/6	2,679 (24.6)	2,143 (23.2)	
4/6	1,452 (13.4)	1,191 (12.9)	
5/6	490 (4.5)	371 (4.0)	
6/6	736 (6.8)	515 (5.6)	
CMV risk group, n (%)			0.5058
D–/ R–	2,783 (25.6)	2,357 (25.5)	
D–/ R+	2,362 (21.7)	1,986 (21.5)	
D+/ R+	1,855 (17.1)	1,650 (17.9)	
D+/ R–	3,869 (35.6)	3,240 (35.1)	
Donor characteristic			
Age, y, mean [SD]	42 [12]	45 [12]	<0.0001
BMI, kg/m^2, mean [SD]	26.9 [4.1]	27.0 [4.1]	0.0204
Ethnicity, n (%)			<0.0001
White	7,378 (67.9)	6,699 (72.6)	
Black	1,051 (9.7)	968 (10.5)	
Hispanic	1,731 (15.9)	1,128 (12.2)	
Asian	544 (5.0)	314 (3.4)	
American Indian/ Alaska Native	32 (0.3)	28 (0.3)	
Hawaiian/Pacific Islander	19 (0.2)	16 (0.2)	
Multiracial	114 (1.0)	80 (0.9)	
Hypertension, n (%)			<0.0001
Yes	403 (3.7)	446 (4.8)	
No	10,466 (96.3)	8,787 (95.2)	
Diabetes, n (%)			0.5888
Yes	8 (0.1)	5 (0.1)	
No	10,861 (99.9)	9,228 (99.9)	
HCV status, n (%)			0.0487
Positive	202 (1.9)	208 (2.3)	
Negative	10,667 (98.1)	9,025 (97.7)	
Tobacco use, n (%)			0.0003
Yes	2,720 (25.0)	2,516 (27.3)	
No	8,149 (75.0)	6,717 (72.7)	
Cold ischemia time, h, mean [SD]	2.07 [3.53]	2.41 [4.14]	<0.0001
Donor creatinine, mg/dL, mean [SD]	0.82 [0.21]	0.83 [0.19]	0.0036
Urine protein, n (%)			0.4505
Positive	420 (3.9)	338 (3.7)	
Negative	10,449 (96.1)	8,895 (96.3)	

*p Values are not included for variables included in the calculation of glomerular filtration rate and definition of textbook outcomes.

CMV, cytomegalovirus; CPRA, calculated panel reactive antibody; HCV, hepatitis C virus; HLA, human leukocyte antigen; HTN, hypertension; HX, history; IgA, immunoglobulin A; PKD, polycystic kidney disease; SLE, systemic lupus erythematosus; TX, transplantation.

time was capped at 20 years. Purposeful selection[39] was chosen as the variable selection technique for multivariable logistic regression. All covariates with a bivariate p value of less than 0.0001 were initially included in model fitting but systematically dropped when the maximum p value of the variable failed to meet the retention criteria ($p < 0.0001$) and failed to change at least one parameter estimate by 50% or greater. Dropped variables were retested for inclusion. Categorical variables were separated into component parts, and when any part met criteria for inclusion in purposeful selection, the entire categorical variable was included in the model. The final cut-offs chosen ($p < 0.0001$ and 50% change in parameter estimate) were selected by iteratively rerunning purposeful selection with intent to sensibly reduce the model. The least absolute shrinkage and selection operator[40] technique was then used to assess further possible reduction of the model using cross-validation to find the optimal shrinkage value λ, repeatedly fitting the model with nine-tenths of the data and withholding one-tenth of the data for evaluation of λ for 10 iterations.

The resulting logistic regression was used to calculate odds ratios with 95% CI. p Values were used to rank the variables with respect to their effect on the model. To make odds ratios comparable across variables, continuous variables were standardized by transforming to SDs from the respective variable's mean. Impactful variables were incorporated as linear predictors into a nomogram for predicting TO after kidney transplantation. The nomogram was validated using a bootstrapping technique with resampling performed 1,000 times. Unselected samples were used to generate averaged receiver operating curves (ROC) and mean C statistics reflecting predictive accuracy of the nomograms. Sixty-four percent of recipients were included in the training dataset (the sampled), and 36% of recipients were included in the validation dataset (the non-sampled). Conditional survival analyses were performed using standard Kaplan-Meier and Cox proportional hazards techniques with TO set as the conditional variable.

Center-level quality was calculated as the ratio of observed to expected TO rate. Expected log-odds of TO for each center were calculated based on averaging the patient-level expected values from the purposeful selection logistic regression model. Bootstrapping was used to calculate 95% CI for the observed:expected ratio, using 1,000 bootstrap samples stratified by center. Margins of error for each center were based on half differences between the 2.5th and 97.5th bootstrap percentiles. SAS (9.4 TS1M3) and R software (R 3.6.1) were used for analyses.

RESULTS

There were 81,938 kidney transplants performed between 2013 and 2017. A total of 69,165 transplants (84.4%, 20,102 LD, 49,063 DD) had complete data and were captured in this national complete-case analysis of TO. Details of missing data are provided in **Supplemental Digital Content 3 and 4** (http://links.lww.com/JACS/A116). Textbook outcome was defined as patient and graft survival of 1 year or longer, 1-year modification of diet in renal disease glomerular filtration rate of greater than 40 mL/min/1.73 M^2, absence of delayed graft function, length of stay of 5 days or less, no hospital re-admissions during the first 6 months after transplantation, and absence of allograft rejection during the first year after transplantation (Table 1). TO was experienced by 54.1% (95% CI 53.4% to 54.8%, range 0% to 89.7%) of LD transplant recipients and 31.7% (95% CI 31.2% to 32.1%, range 0.9 to 66.3%) of DD transplant recipients. In both cohorts, prolonged length of stay was the most common reason for failure to achieve TO, with hospital readmissions, rejection episodes, and low 1-year glomerular filtration rate also contributing (Fig. 1). In DD transplant recipients, delayed graft function was the second most common reason for failure to achieve TO.

Bivariate analyses of donor and recipient characteristics associated with TO for LD (Table 2) and DD (Table 3) transplant recipients show that younger recipients with fewer comorbid conditions (higher BMI, peripheral vascular disease, reduced Karnofsky functional status), pre-dialysis status, shorter waiting time to transplantation, and lower calculated panel of reactive antibody score are more likely to experience TO. Recipients with polycystic kidney disease and those with immunoglobulin A nephropathy were more likely to experience TO, whereas recipients with diabetes, hypertension, or allograft failure were less likely to experience TO. For recipients of LD allografts, younger donors without hypertension and with shorter cold ischemic times were more likely to be associated with TO. For recipients of DD allografts, most component parts of the low kidney donor profile index (KDPI) (young age, low BMI, absence of hypertension and diabetes, low terminal creatinine, and non-DCD status) favor TO. Donor positivity for hepatitis C did not reduce the odds of TO, nor did Public Health Service increased risk status. Collectively, kidneys biopsied were less likely to result in TO, and DD allografts allocated locally or regionally with short cold ischemic times were strongly associated with TO.

The top eight covariates associated with TO for LD recipients in multivariable modeling are shown in Figure 2A, all with a p value of less than 0.0001. Recipient

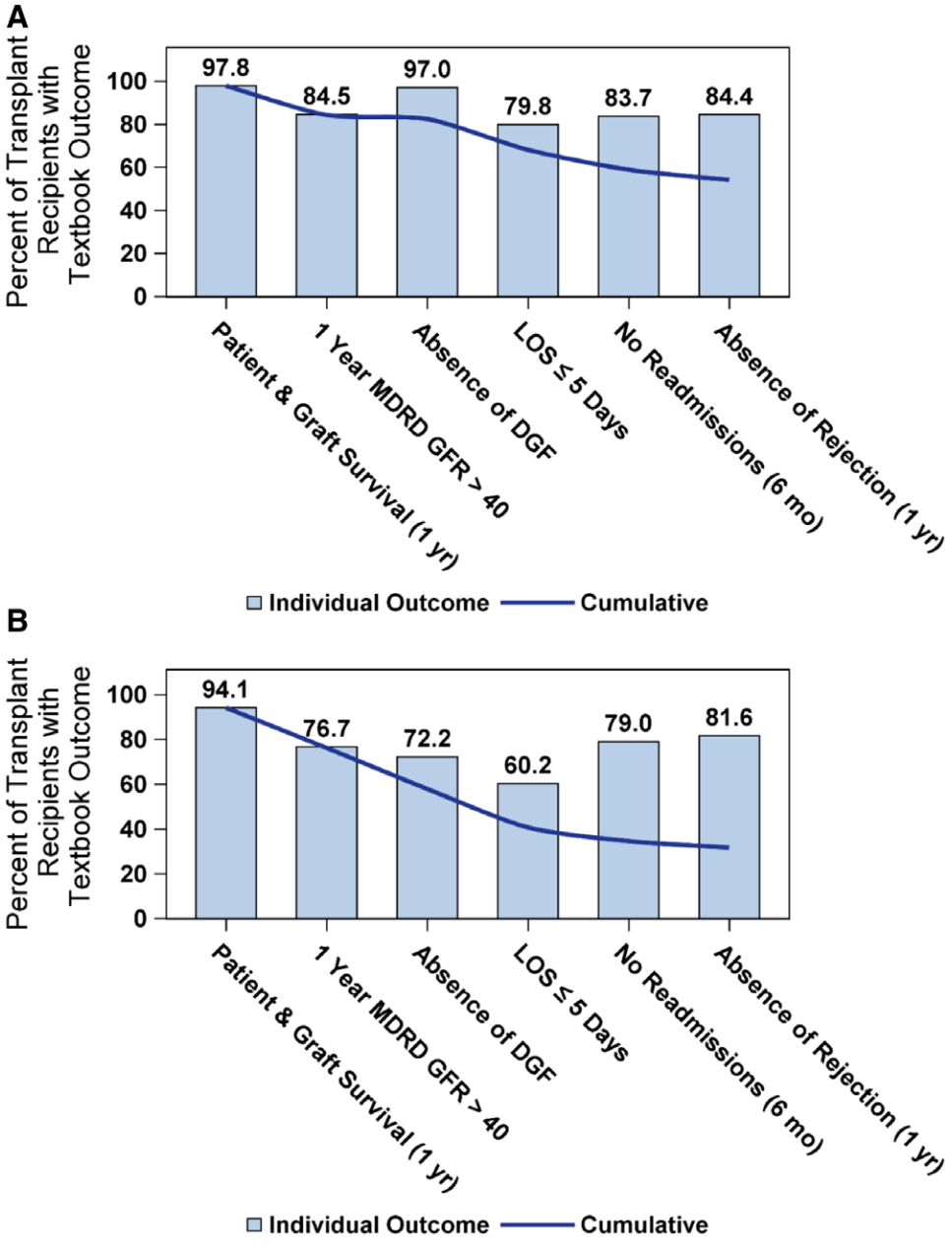


Figure 1. National textbook outcomes rate by individual quality domain. (A and B) textbook outcomes after kidney transplantation in a national cohort of 20,102 living donor (A) and 49,063 deceased donor (B) transplant recipients. Bars represent the percentage of recipients achieving threshold for textbook outcomes in each quality domain. Lines represent the cumulative percentage of textbook outcomes achieved across all quality domains. DGF, delayed graft failure; GFR, glomerular filtration rate; LOS, length of stay; MDRD, modification of diet in renal disease.

diagnoses of hypertension (odds ratio [OR] 1.13, [1.04 to 1.24]) and immunoglobulin A nephropathy (OR 1.33, [1.19 to 1.48]), specific donor ethnicities, and higher recipient serum albumin (OR 1.08, [1.04 to 1.11]) favor TO, whereas reduced Karnofsky function status (OR 0.43, [0.34 to 0.54]), older donor age (OR 0.81, [0.79 to 0.83]), recipient dialysis (OR 0.82, [0.78 to 0.87]), higher recipient BMI (OR 0.93, [0.90 to 0.95]), and longer cold ischemic time (0.92, [0.90 to 0.95]) reduce the likelihood of TO. When integrated into a predictive nomogram (Fig. 3A), these eight covariates yield an averaged receiver operating curve with a C statistic of 60.1 in the validation

Table 3. Donor and Recipient Characteristics in Deceased Donor Transplantation with and without Textbook Outcomes

	Textbook outcomes		
Characteristic	**Yes**	**No**	**p Value**
Total, n (%)	15,533 (31.7)	33,530 (68.3)	
Recipient characteristic			
Age, y, mean [SD]	51 [13]	54 [13]	*
Sex, n (%)			*
Male	9,025 (58.1)	20,528 (61.2)	
Female	6,508 (41.9)	13,002 (38.8)	
BMI, kg/m^2, mean [SD]	27.8 [5.3]	28.5 [5.4]	0.0011
Ethnicity, n (%)			*
White	6,320 (40.7)	12,636 (37.7)	
Black	4,945 (31.8)	12,042 (35.9)	
Hispanic	2,776 (17.9)	5,796 (17.3)	
Asian	1,180 (7.6)	2,262 (6.7)	
American Indian/Alaska Native	134 (0.9)	387 (1.2)	
Hawaiian/Pacific Islander	82 (0.5)	147 (0.4)	
Multiracial	96 (0.6)	260 (0.8)	
ABO, n (%)			<0.0001
A	5,765 (37.1)	11,836 (35.3)	
AB	2,038 (13.1)	4,384 (13.1)	
B	972 (6.3)	1,669 (5.0)	
O	6,758 (43.5)	15,641 (46.6)	
Primary diagnosis, n (%)			<0.0001
Type I diabetes	303 (2.0)	831 (2.5)	
Type II diabetes	3,090 (19.9)	9,073 (27.1)	
HTN	3,916 (25.2)	8,087 (24.1)	
PKD	1,332 (8.6)	2,217 (6.6)	
Graft failure	1,018 (6.6)	2,701 (8.1)	
IgA nephropathy	820 (5.3)	1,116 (3.3)	
SLE	504 (3.2)	925 (2.8)	
Other	4,550 (29.3)	8,580 (25.6)	
Peripheral vascular disease, n (%)			<0.0001
Yes	1,303 (8.4)	3,820 (11.4)	
No	14,230 (91.6)	29,710 (88.6)	
HX of malignancy, n (%)			<0.0001
Yes	1,192 (7.7)	3,117 (9.3)	
No	14,341 (92.3)	30,413 (90.7)	
HX of liver TX, n (%)			<0.0001
Yes	1,889 (12.2)	4,685 (14.0)	
No	13,644 (87.8)	28,845 (86.0)	
Karnofsky functional status at TX, n (%)			<0.0001
0%-40%	269 (1.7)	1,039 (3.1)	
50%-70%	6,041 (38.9)	14,282 (42.6)	
80%-100%	9,223 (59.4)	18,209 (54.3)	
Serum albumin, g/dL, mean [SD]	3.98 [0.57]	3.95 [0.56]	<0.0001
CPRA, %, mean [SD]	26 [37]	26 [38]	0.4964
Predialysis, n (%)			<0.0001

(Continued)

Table 3. Continued

Characteristic	Textbook outcomes		p Value
	Yes	No	
Yes	12,359 (79.6)	28,982 (86.4)	
No	3,174 (20.4)	4,548 (13.5)	
Creatinine at transplantation, mg/dL,mean [SD]	8.39 [3.79]	8.55 [3.57]	<0.0001
Waitlist time, d, mean [SD]	890 [796]	962 [837]	<0.0001
HLA match, n (%)			<0.0001
0/6	2,114 (13.6)	5,178 (15.4)	
1/6	4,820 (31.0)	10,475 (31.2)	
2/6	4,255 (27.4)	9,170 (27.3)	
3/6	2,173 (14.0)	4,710 (14.0)	
4/6	808 (5.2)	1,672 (5.0)	
5/6	211 (1.4)	521 (1.6)	
6/6	1,152 (7.4)	1,804 (5.4)	
CMV risk group, n (%)			0.0464
D–/ R–	2,084 (13.4)	4,328 (12.9)	
D–/ R+	4,093 (26.4)	9,044 (27.0)	
D+/ R+	2,763 (17.8)	5,716 (17.0)	
D+/ R–	6,593 (42.4)	14,442 (43.1)	
Donor characteristic			
KDPI, mean [SD]	38 [25]	48 [26]	<0.0001
Age, y, mean [SD]	35 [16]	40 [16]	<0.0001
BMI, kg/m^2, mean [SD]	27.1 [7.0]	28.2 [7.2]	<0.0001
Ethnicity, n (%)			<0.0001
White	10,686 (68.8)	23,046 (68.7)	
Black	2,155 (13.9)	4,620 (13.8)	
Hispanic	2,096 (13.5)	4,407 (13.1)	
Asian	329 (2.1)	789 (2.4)	
American Indian/Alaska Native	107 (0.7)	171 (0.5)	
Hawaiian/Pacific Islander	53 (0.3)	104 (0.3)	
Multiracial	107 (0.7)	393 (1.2)	
Hypertension, n (%)			<0.0001
Yes	3,244 (20.9)	10,343 (30.8)	
No	12,289 (79.1)	23,187 (69.2)	
Diabetes, n (%)			<0.0001
Yes	878 (5.7)	2,715 (8.1)	
No	14,655 (94.3)	30,815 (91.9)	
Cause of death, n (%)			<0.0001
Anoxia	5,829 (37.5)	12,871 (38.4)	
Cerebrovascular/stroke	3,390 (21.8)	9,682 (28.9)	
Head trauma	5,806 (37.4)	9,928 (29.6)	
CNS tumor	68 (0.4)	131 (0.4)	
Other	440 (2.8)	918 (2.7)	
Terminal creatinine, mg/dL, mean [SD]	1.08 [0.86]	1.28 [1.16]	<0.0001
HCV status, n (%)			0.2840
Positive	948 (6.1)	1964 (5.9)	
Negative	14,585 (93.9)	31,566 (94.1)	

(Continued)

Table 3. Continued

Characteristic	Textbook outcomes		p Value
	Yes	No	
DCD, n (%)			<0.0001
Yes	2,318 (14.9)	7,537 (22.5)	
No	13,215 (85.1)	25,993 (77.5)	
Biopsy, n (%)			<0.0001
Yes	6,126 (39.4)	18,600 (55.5)	
No	9,407 (60.6)	14,930 (44.5)	
Glomerulosclerosis, n (%)			<0.0001
0-5	4,659 (76.4)	13,185 (71.2)	
6-10	856 (14.0)	2,990 (16.1)	
11-15	327 (5.4)	1,158 (6.3)	
16-20	140 (2.3)	613 (3.3)	
20+	120 (2.0)	572 (3.1)	
Tobacco use, n (%)			<0.0001
Yes	2,595 (16.7)	7,128 (21.3)	
No	12,938 (83.3)	26,402 (78.7)	
Allocation, n (%)			<0.0001
Local	11,563 (74.4)	23,548 (70.2)	
National	2,228 (14.3)	5,809 (17.3)	
Regional	1,742 (11.2)	4,173 (12.4)	
Cold ischemia time, h, mean [SD]	16.61 [8.33]	18.35 [8.91]	<0.0001
Warm ischemia time (DCD only), h, mean [SD]	22 [14]	23 [14]	†
Increased risk donor, n (%)			<0.0001
Yes	3,599 (23.2)	6,584 (19.6)	
No	11,934 (76.8)	26,946 (80.4)	
Clinical infection, n (%)			0.0484
Yes	11,386 (73.3)	24,292 (72.4)	
No	4,147 (26.7)	9,238 (27.6)	
Kidney pumped, n (%)			0.0021
Yes	4,975 (32.0)	11,209 (33.4)	
No	10,558 (68.0)	22,321 (66.6)	

*p Values are not included for variables included in the calculation of glomerular filtration rate and definition of textbook outcomes.
†p Value not included because more than 50% of data were missing for this variable.
CMV, cytomegalovirus; CPRA, calculated panel reactive antibody; DCD, deceased from cardiac death; HCV, hepatitis C virus; HLA, human leukocyte antigen; HTN, hypertension; HX, history; IgA, immunoglobulin A; KDPI, Kidney Donor Profile Index; PKD, polycystic kidney disease; SLE, systemic lupus erythematosus; TX, transplantation.

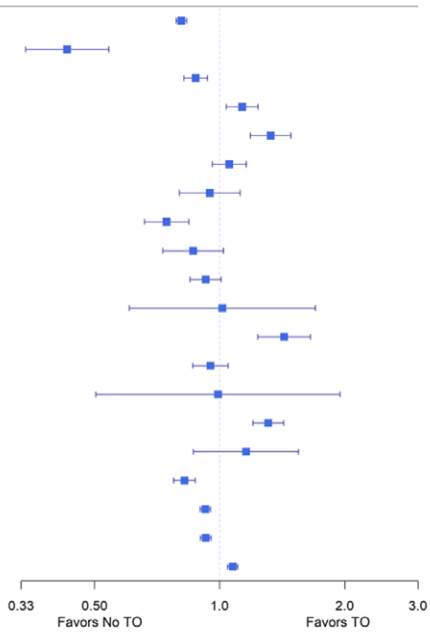
dataset (**Supplemental Digital Content 5** at http://links.lww.com/JACS/A116 displays least absolute shrinkage and selection operator reduction analysis [A] and averaged ROC curve [B]).

For DD recipients, 10 covariates were strongly associated with TO in multivariable modeling (Fig. 2B), all with a p value of less than 0.0001. Recipient variables reducing the likelihood of TO included dialysis time (OR 0.60, 95% CI [0.57 to 0.63]), high BMI (OR 0.87, [0.86 to 0.89]), re-transplantation status (OR 0.72, [0.68 to 0.77]), and increased wait time to transplantation (OR 0.91, [0.89 to 0.93]). High KDPI (OR 0.76, [0.74 to 0.78]), high donor terminal creatinine (OR 0.78, [0.76 to 0.80]), older donors (OR 0.85, [0.83 to 0.88]), and DCD donors (OR 0.55, [0.52 to 0.58]) reduced the likelihood of TO. Use of a kidney perfusion pump strongly increased the likelihood of TO (OR 1.27, [1.21 to 1.33]), and long cold ischemic times decreased the likelihood of TO (OR 0.85, [0.84 to 0.87]). Our predictive nomogram (Fig. 3B) for these 10 covariates yields an averaged ROC with a C statistic of 66.3 in the validation dataset (**Supplemental Digital Content 6** at http://links.lww.com/JACS/A116 displays least absolute shrinkage and selection operator reduction analysis [A] and averaged ROC curve [B]).

A

Odds Ratios for Textbook Outcome

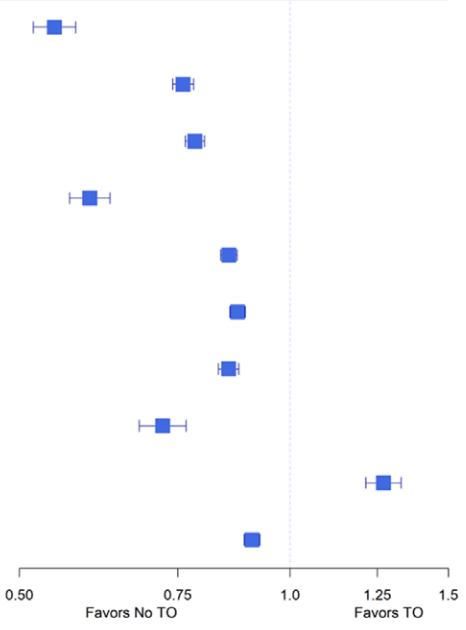
Predictor	Reference	Odds Ratio	Rank
Older Donor Age		0.81 (0.79-0.83)*	1
Functional Status	0 to 40% vs 80-100%	0.43 (0.34-0.54)	2
	50-70% vs 80-100%	0.88 (0.82-0.93)	
Recipient Diagnosis	HTN vs Other	1.13 (1.04-1.24)	3
	IgA Nephropathy vs Other	1.33 (1.19-1.48)	
	PKD vs Other	1.05 (0.96-1.16)	
	SLE vs Other	0.95 (0.80-1.12)	
	Graft Failure vs Other	0.75 (0.66-0.84)	
	Type I Diabetes vs Other	0.86 (0.73-1.02)	
	Type II Diabetes vs Other	0.93 (0.85-1.01)	
Donor Ethnicity	American Indian/Alaska Native vs White	1.01 (0.61-1.70)	4
	Asian vs White	1.43 (1.23-1.65)	
	Black vs White	0.95 (0.86-1.05)	
	Hawaiian/Pacific Islander vs White	0.99 (0.50-1.95)	
	Hispanic vs White	1.31 (1.20-1.43)	
	Multiracial vs White	1.16 (0.86-1.55)	
Recipient on Dialysis	Yes vs No	0.82 (0.78-0.87)	5
Longer Cold Ischemic Time		0.92 (0.90-0.95)*	6
Higher Recipient BMI		0.93 (0.90-0.95)*	7
Greater Serum Albumin		1.08 (1.04-1.11)*	8



B

Odds Ratios for Textbook Outcome

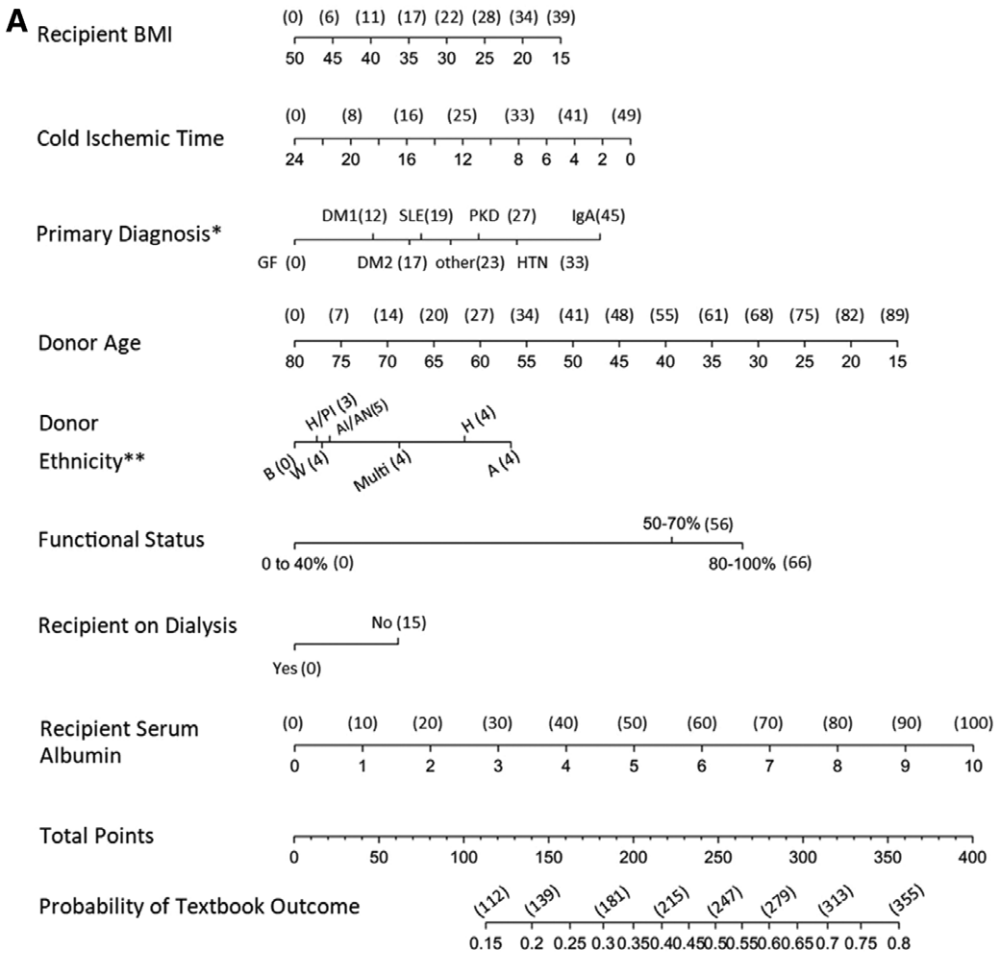
Predictor	Reference	Odds Ratio	Rank
DCD Donor	Yes vs No	0.55 (0.52-0.58)	1
Higher KDPI		0.76 (0.74-0.78)*	2
Higher Donor Creatinine		0.78 (0.76-0.80)*	3
Recipient Dialysis Status	Yes vs No	0.60 (0.57-0.63)	4
Longer Cold Ischemic Time		0.85 (0.84-0.87)*	5
Higher BMI		0.87 (0.86-0.89)*	6
Older Donor Age		0.85 (0.83-0.88)*	7
Recipient Re-Transplant	Yes vs No	0.72 (0.68-0.77)	8
Kidney Pump Utilized	Yes vs No	1.27 (1.21-1.33)	9
Increased Recipient Years on Waiting List		0.91 (0.89-0.93)*	10



*Standardized Odds Ratio

Figure 2. Variables identified as predictive of textbook outcomes (TO) in multivariable regression. (A) Top eight predictors of TO in living donor recipients. (B) Top 10 predictors of TO in deceased donor recipients. DCD, deceased from cardiac death; HTN, hypertension; IgA, immunoglobulin A; KDPI, kidney donor profile index; PKD, polycystic kidney disease; SLE, systemic lupus erythematosus.

Conditional survival analyses with achievement of TO set as the conditional variable reveal significant long-term survival advantage for LD and DD transplant recipients (Fig. 4). Eighty-three percent of the patient cohort had 5-year survival data available and were included in the analysis. The unadjusted hazard ratio for death at 5 years is 1.92 (95% CI 1.68 to 2.18, p ≤ 0.0001) for LD transplant recipients who do not experience TO and 2.08 (95% CI 1.93 to 2.24, p ≤ 0.0001) for DD transplant recipients who do not experience TO.



Primary Diagnosis*	Donor Ethnicity**
Graft Failure (0)	Black (0)
Type I Diabetes (12)	Hawaiian/Pacific Islander (3)
Type II Diabetes (17)	White (4)
SLE (19)	American Indian/Alaska Native (5)
Other (23)	Multiracial (15)
PKD (27)	Hispanic (25)
HTN (33)	Asian (32)
IgA Nephropathy (45)	

Figure 3. Nomograms for predicting probability of textbook outcomes. (A and B) Point assignments for nomograms predicting the probability of textbook outcomes for living donor (A) and deceased donor (B) recipients with an accompanying scale for conversion of the point score to probability (percent). A, Asian; AI/AN, American Indian/Alaska Native; B, Black; DCD, deceased from cardiac death; DM, diabetes mellitus; GF, graft failure; H, Hispanic; H/PI, Hawaiian/Pacific Islander; HTN, hypertension; IgA, immunoglobulin A; KDPI, kidney donor profile index; Multi, multiracial; PKD, polycystic kidney disease; SLE, systemic lupus erythematosus; W, White.

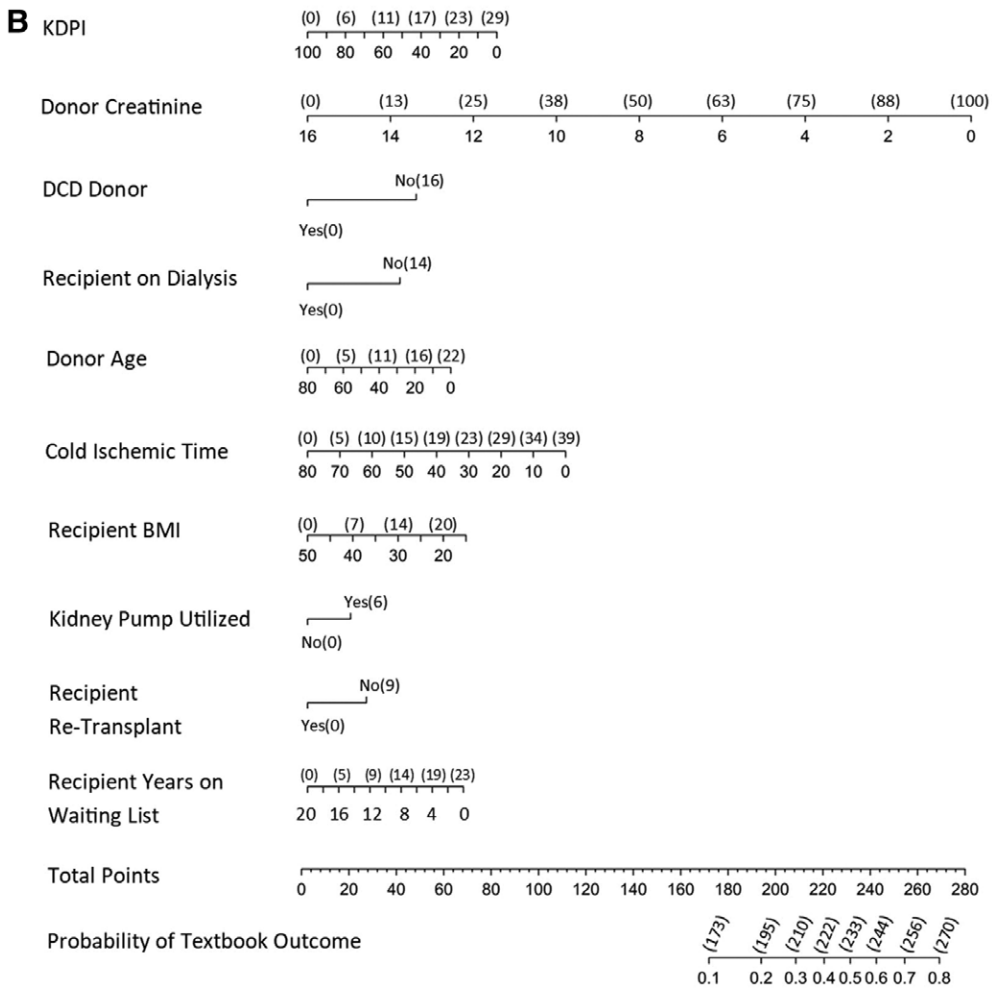


Figure 3. Continued

Center-level expected TO rates, which account for the complexity of the donor and recipient case mix at each center, were derived by entering center data into the logistic regression model powering the LD or DD nomogram. These expected rates were then compared with observed TO rates (Fig. 5). In LD kidney transplantation, 23% of centers exceed performance expectations, 59% perform as expected, and 18% are identified as under-performing. In DD kidney transplantation, 26% of centers exceed performance expectations, 50% perform as expected, and 24% are identified as under-performing. There is little correlation between high center-level transplant rates and high transplant center volume.

DISCUSSION

In this 5-year national analysis of TO in kidney transplantation, 54.1% of LD recipients and 31.7% of DD recipients experienced TO. When discussing TO in the context of kidney transplantation, it is essential to understand that, unless TO was not achieved because of patient death or graft loss (2.2% of LD transplants and 5.9% of DD transplants), transplantation was still of enormous benefit to the recipient. Most non-TOs are not failures; they simply represent a more complicated course to freedom from dialysis. Delayed graft function will occur with regularity if the available donor organ pool is maximized,[41,42] and the negative effects of delayed graft function do not outweigh the risks of remaining waitlisted.[31] Likewise, if rejection rates drop too low, then complications of over-immunosuppression, including cytomegalovirus and other opportunistic infections, will rise.[43,44] Nonetheless, TO forces holistic consideration of performance in multiple domains, and conditional survival analyses demonstrate a significant 5-year survival advantage for patients who experience TO. Individual transplantation programs can look within the

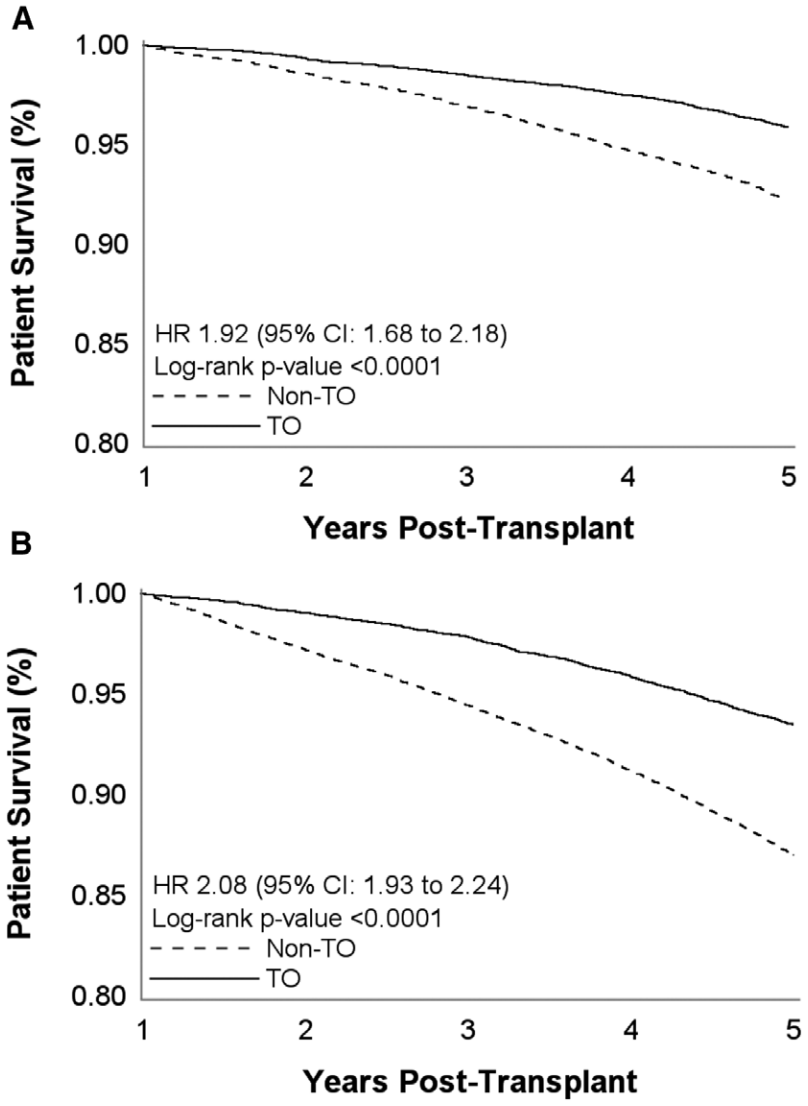


Figure 4. (A and B) Five-year conditional survival analysis for living donor (A) and deceased donor (B) kidney transplant recipients who have and have not achieved a textbook outcome (TO). HR, hazard ratio.

domains of TO and identify areas for quality improvement that will enhance long-term patient survival.

It is also important to acknowledge that thresholds in definitions of TO are arbitrary. Had we set the threshold for length of stay less than 5 days or the 1-year glomerular filtration rate threshold greater than 40 mL/min/1.73 M^2, fewer patients would have achieved TO. When crafting TO as a metric, it is necessary to distribute the spectrum of true patient outcomes about a mean to create composite outcomes that are neither common nor unachievable. These principles apply to any benchmarking effort.

Collectively, the results of our bi- and multivariate analyses support the well-known truism that healthier surgical candidates receiving higher-quality donor organs have better outcomes. The greater value of these analyses is in providing a means for risk adjustment between centers. By "processing" all of the patients undergoing transplantation at a given center through our predictive nomograms, we derive an expected TO rate that can be compared with the center's actual TO rate. This observed:expected methodology is very similar to that used currently by SRTR in their program ratings[45-47] and by the Centers for Medicare and Medicaid Services[48] to compare quality across hospitals. Average case complexity at each center is accounted for, which should allay perennial complaints that quality metrics penalize transplantation centers deliberately using higher-risk donor organs or performing transplantation on sicker recipients.

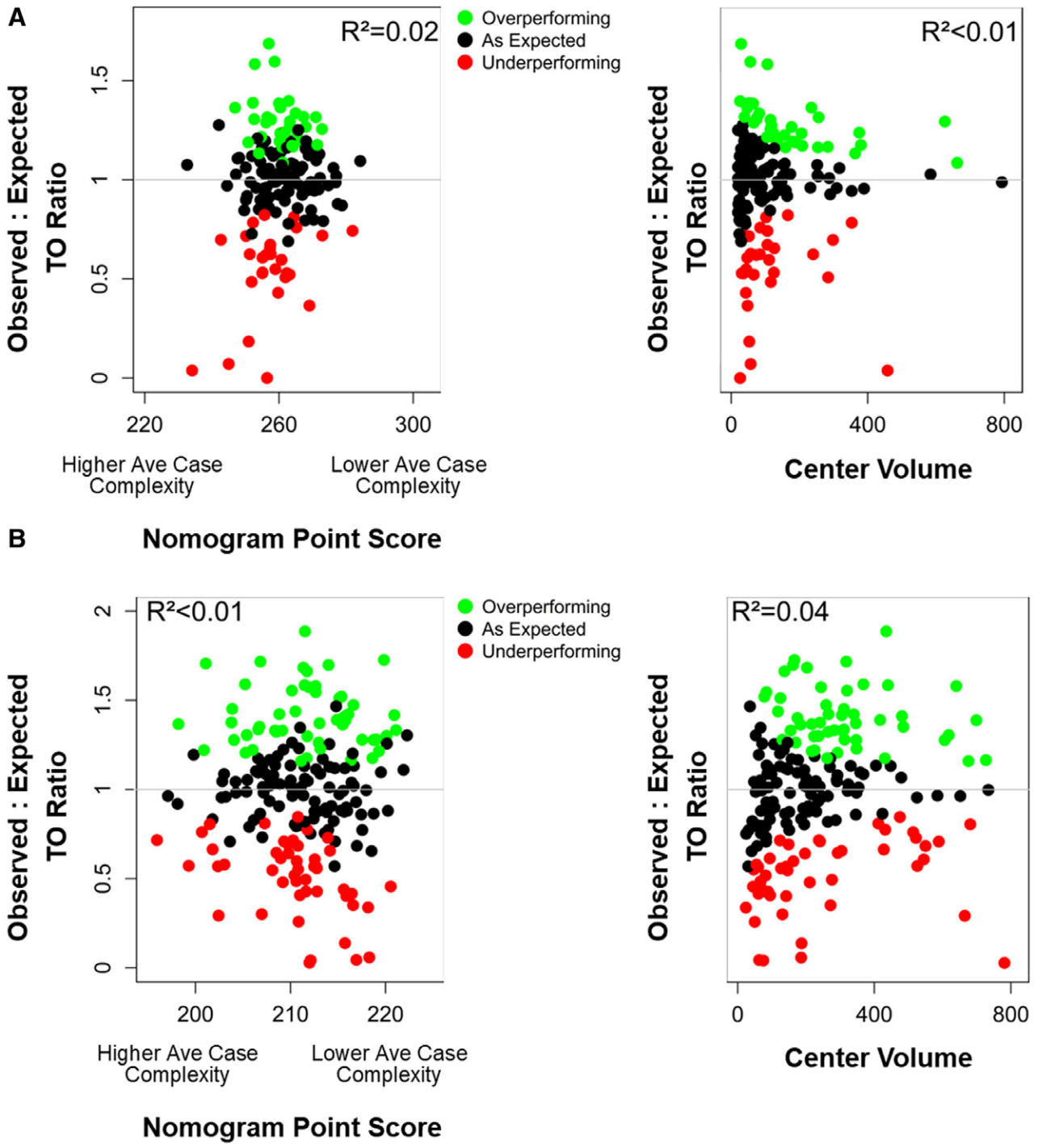


Figure 5. (A and B) Observed:expected textbook outcomes (TO) rates by center for living donor (A) and deceased donor (B) kidney transplant recipients as a function of (left) center-level average case complexity and (right) center volume. Over-performing and under-performing centers have observed:expected ratios greater or less than 1 with 95% confidence.

We note with interest that neither donor positivity for hepatitis C nor Public Health Service increased risk status decreased the odds of TO in DD kidney transplantation. Presumably this reflects a younger donor age and preserved nephron mass in donors infected with hepatitis C or engaged in high-risk behaviors, and these results call

into question the inclusion of hepatitis C status in the calculation of KDPI.[49,50] We also note that local and regional allocation of DD kidneys strongly favor TO. It is common knowledge that the national kidney allocation policy changes implemented on March 15, 2021[51,52] have led to a significant increase in nationally allocated kidneys, which, in turn, has led to large increases in delayed graft function rates. Our data argue that delayed graft function and national allocation are strongly unfavorable for recipients, and as iterative review of these allocation policy changes occurs, it will be imperative to show benefits that outweigh these disadvantages. Last, we were surprised to find that use of a kidney perfusion pump increased odds of TO in DD transplantation. Prior studies have shown mixed results from non-oxygenated hypothermic perfusion.[53-56] Pumped kidneys often "look" better to the transplant surgeon at the time of reperfusion and sometimes produce urine faster. We suspect that these factors combine to reduce length of stay, thereby increasing the odds of TO. The possibility that reduced length of stay offsets the increased cost of hypothermic perfusion should be investigated.

One limitation of our study is that our definition of TO was formulated using multidisciplinary input from providers at our center. Formal "adoption" of TO in kidney transplantation would likely require a national survey to reach consensus on definition. Halpern and colleagues[57] recently studied TO in 557 kidney transplant recipients at their center. Their definition was markedly similar to ours, but it included re-intervention, ICU readmission, intraoperative complication, and absence of a Foley catheter at discharge. Many of these same features were proposed in our internal discussions but proved impossible to reliably measure in United Network for Organ Sharing datasets highlighting a well-recognized need for improved data collection in transplantation.[16,58,59] In national analyses, we were forced to use prolonged length of stay and hospital readmission as a surrogate catch-all for significant complications necessitating escalation of care. Notably, the Duke authors report $50,000 less in total inpatient charges for patients who achieve TO. Similarly, Medicare payments among patients undergoing hepatopancreatic surgery who achieved TO were markedly lower than those for patients who did not,[60] indicating that well-crafted definitions of TO measure value.

A second limitation of our study is that only 83% of the cohort has reached maturity with 5-year outcome data available. We deliberately selected patients undergoing transplantation between 2013 and 2017 to have a large contemporary national cohort with medium-term follow-up data available. Because the conditional survival analysis includes all patients with 5-year follow-up available and is free from selection bias, we think that it is highly unlikely that longer-term follow-up will significantly change results.

In a recent webinar,[14] the MPSC has revealed its plans to implement four new transplantation metrics in January 2022. If approved, then these will include waitlist mortality rate ratio, offer acceptance rate ratio, 90-day survival rate ratio, and conditional 1-year survival rate ratio. These metrics are specifically geared to detect patient safety issues and do not take into consideration aspects of efficiency, cost, and perceived elements of patient satisfaction that are included in our definition of TO. The MPSC proposal is broader in that it encompasses elements of pre-surgical care, including waitlist mortality and organ offer acceptance. We did not include waitlist mortality or time to transplantation in our definition of TO because the primary medical care of patients awaiting transplantation is not provided exclusively by the transplantation center, and time to transplantation is strongly influenced by the business practices of independently operating organ procurement organizations. Specific proposals for new metrics from the SRTR Task 5 Initiative[15] have not yet been released.

A final limitation of our study is that our formulation of TO measures outcome quality for transplants a center chooses to perform but does not take into consideration donor allografts or potential recipients turned away. TO is adjusted for donor and recipient risk and therefore should not encourage risk aversion, but the psychology and behavioral patterns of risk and loss aversion in transplantation are well described.[61] At present, newly implemented patterns of broader sharing in national kidney allocation policy are "leveling the playing field" between centers and "averaging out" differences in organ procurement organization performance. Enormous gains are predicted to result from more aggressive kidney donor use.[62] Policy should be crafted to encourage and reward maximal donor use, and TO should not factor into calculations of risk tolerance.

Quality measurement can serve to protect patient safety, encourage efficient use of healthcare resources, promote equity in access to care, and lead to discovery and sharing of best practices. No single quality measure accomplishes all of these objectives. TO is ideally suited to transplantation programs wishing to compare their performance with that of peer institutions and improve performance in specific domains. Programs that successfully increase TO rates will see improved long-term patient survival. We are actively working to correlate TO with patient satisfaction, and we do believe that TO should be a patient-facing

metric, helping patients to understand their transplantation experience. TO has little use in the regulatory aspects of kidney transplantation because most patients who fail to experience TO still achieve the enormous health benefits of freedom from dialysis. It is important to note that large and small transplantation centers can achieve high observed:expected TO ratios. Given the enormous geographic disparities in access to kidney care throughout the US,[63,64] it is important to develop policies that support small and large transplantation programs delivering high-quality care.

CONCLUSIONS

Myopic focus on 1-year patient and graft survival interferes with quality measurement and dissemination of best practices in transplantation. We define TO in kidney transplantation as patient and graft survival of 1 year or longer, a 1-year glomerular filtration rate greater than 40 mL/min, absence of delayed graft function, length of stay of 5 days or less, no readmissions during the first 6 months, and no episodes of rejection during the first year after transplantation. Applying this definition to a large national contemporary cohort of transplant recipients reveals a meaningful and risk-adjusted spectrum of quality. The hazard ratio for death at 5 years for transplant recipients who do not experience TO is increased 2-fold.Disclaimer: The data reported here have been supplied by the United Network for Organ Sharing as the contractor for the Organ Procurement and Transplantation Network (OPTN). 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 OPTN or the US Government.

Author Contributions

Study conception and design: Schenk, Logan, Brock, Washburn
Acquisition of data: Logan, Sneddon
Analysis and interpretation of data: Schenk, Logan, Sneddon, Han
Drafting of manuscript: Schenk, Logan, Faulkner
Critical revision: Schenk, Logan, Brock, Washburn

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Invited Commentary

Permission to Reach: In Search of New Quality Metrics in Transplantation

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In transplantation, the Scientific Registry of Transplant Recipients (SRTR) releases biannual program-specific reports that cover a wide range of metrics related to waitlist outcomes, transplant rate, post-transplant survival, and more.[1] Stakeholders have focused heavily on 1-year survival as a quality measure for transplant programs.[2] National 1-year patient and graft survival rates after kidney transplantation are 95% and 97%, respectively,[3] and variation in survival outcomes among kidney transplant programs continues to decrease.[4] However, post-transplant complication rates and healthcare use vary widely among transplant programs despite relatively similar patient and graft survival rates,[2] indicating that short-term survival outcomes have lost their potency to detect differences in post-transplant quality of care. More sensitive metrics are needed to measure post-transplantation quality and identify opportunities for process improvement.

To evaluate quality, the concept of textbook outcome (TO) is emerging as a novel metric in surgical research. TO is a composite and holistic metric of relevant clinical outcomes and resource use that together represent the "ideal" outcome after complex surgical procedures.[5] Components of TO typically include absence of major complications, readmission, prolonged length of stay, and in-hospital mortality. TO has been reported in multiple surgical subspecialties and, more recently, solid organ transplantation.[6,7]

In this issue of *JACS*, Schenk and colleagues[8] publish their findings on TO in kidney transplantation using national data from the Organ Procurement and Transplantation Network. Almost 70,000 kidney transplant recipients were included in the study, and TO was defined as patient and graft survival of 1 year or longer, 1-year glomerular filtration rate of greater than 40 mL/min, absence of delayed graft function, length of stay of 5 days or less, no readmissions for 6 months after transplantation, and no rejection episodes for 1 year after transplantation. Using this definition of TO, the national average TO rates were 54.1% and 31.7% for living donor and deceased donor kidney transplantation, respectively. Importantly, these results were risk adjusted to yield an observed-to-expected outcome ratio for each kidney transplant program, enabling risk-adjusted comparisons across transplant programs. Depending on donor type, 23% to 26% of kidney transplant programs exceeded expected performance, and 18% to 24% were underperforming. The hazard ratio for death at 5 years for recipients who did not experience TO was significantly increased (hazard ratio 1.92 for living donor transplant recipients and 2.08 for deceased donor transplant recipients, both $p \leq 0.0001$).

It should be emphasized that, even when a patient does not achieve TO, they will derive substantial benefit from receiving a kidney transplant compared with remaining on dialysis.[9] Therefore, despite being risk adjusted, TO