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 ≤ 0.0001) for LD transplant recipients and 2.08 (95% CI 1.93 to 2.24, p ≤ 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. © 2022 The Author(s). Published by Wolters Kluwer Health, Inc. on behalf of the American College of Surgeons. This is an open-access article distributed under the terms of the Creative Commons Attribution-Non Commercial-No Derivatives License 4.0 [CCBY-NC-ND], where it is permissible to download and share the work provided it is properly cited. The work cannot be changed in any way or used commercially without permission from the journal.)

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
between transplantation programs and potentially discourage transplantation programs from listing or performing transplantation for high-risk candidates. The American Society of Transplantation and American Society of Transplant Surgeons have issued a joint call for reform, and the MPSC 14 and SRTR15 are currently proposing revision of national metrics. Concurrent with this national movement 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. TO was first described after colon cancer resection and has since been applied in diverse surgical disciplines, including hepatopancreatobiliary surgery, vascular and foregut surgery, and after specific procedures such as endoscopic retrograde cholangiopancreatography and colonoscopy. 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. Donor organs are in critically short supply, and every transplantable organ should be used. The survival benefit of transplantation vs dialysis is overwhelming, and even the highest-risk recipient groups with lower-than-average expected outcomes stand to benefit greatly from transplantation. 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/m², and waitlist

### 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

### 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 | Yes | No | p Value |
|---------------|-----|----|---------|
| 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/m², 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      | <br> 7.09 [3.49] | 7.14 [3.52] | 0.3174 |
| Creatinine at TX, mg/dL, mean [SD] | 73 [422] | 404 [466] | <0.0001 |
| Waitlist time, d, mean [SD] | 373 | 404 [466] | <0.0001 |
| HLA match, n (%) | 1,240 (11.4) | 1,198 (13.0) | <0.0001 |
| 0/6             | 2,377 (21.9) | 2,121 (23.0) | <0.0001 |
| 1/6             | 1,895 (17.4) | 1,694 (18.3) | <0.0001 |
| 2/6             | 2,679 (24.6) | 2,143 (23.2) | <0.0001 |
| 3/6             | 1,452 (13.4) | 1,191 (12.9) | <0.0001 |
| 4/6             | 490 (4.5) | 371 (4.0) | <0.0001 |
| 5/6             | 736 (6.8) | 515 (5.6) | <0.0001 |
| 6/6             | 2,783 (25.6) | 2,357 (25.5) | <0.0001 |
| D−/ R−          | 1,051 (9.7) | 968 (10.5) | <0.0001 |
| D+/ R+          | 1,731 (15.9) | 1,128 (12.2) | <0.0001 |
| D+/ R−          | 544 (5.0) | 314 (3.4) | <0.0001 |
| CMV risk group, n (%) | 42 [12] | 45 [12] | 0.5058 |
| Age, y, mean [SD] | 26.9 [4.1] | 27.0 [4.1] | <0.0001 |
| BMI, kg/m², mean [SD] | 0.82 [0.21] | 0.83 [0.19] | <0.0001 |
| Ethnicity, n (%) | 7,378 (67.9) | 6,699 (72.6) | <0.0001 |
| White           | 1,051 (9.7) | 968 (10.5) | <0.0001 |
| Black           | 1,731 (15.9) | 1,128 (12.2) | <0.0001 |
| Hispanic        | 544 (5.0) | 314 (3.4) | <0.0001 |
| Asian           | 32 (0.3) | 28 (0.3) | <0.0001 |
| Hawaiian/Pacific Islander | 19 (0.2) | 16 (0.2) | <0.0001 |
| Multiracial     | 114 (1.0) | 80 (0.9) | <0.0001 |
| Hypertension, n (%) | 403 (3.7) | 446 (4.8) | 0.5888 |
| Yes             | 8 (0.1) | 5 (0.1) | <0.0001 |
| Diabetes, n (%) | 10,466 (96.3) | 8,787 (95.2) | <0.0001 |
| No              | 10,861 (99.9) | 9,228 (99.9) | <0.0001 |
| HCV status, n (%) | 202 (1.9) | 208 (2.3) | 0.0487 |
| Positive        | 10,667 (98.1) | 9,025 (97.7) | <0.0001 |
| No              | 2,720 (25.0) | 2,516 (27.3) | <0.0001 |
| Tobacco use, n (%) | 8,149 (75.0) | 6,717 (72.7) | <0.0001 |
| Yes             | 2,07 (3.53) | 2,41 (4.14) | <0.0001 |
| No              | 10,449 (96.1) | 8,895 (96.3) | 0.0036 |
| Cold ischemia time, h, mean [SD] | 0.82 [0.21] | 0.83 [0.19] | <0.0001 |
| Donor creatinine, mg/dL, mean [SD] | 420 (3.9) | 338 (3.7) | 0.4505 |
| Urine protein, n (%) | 10,449 (96.1) | 8,895 (96.3) | <0.0001 |

*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 erythematous; TX, transplantation.
time was capped at 20 years. Purposeful selection\(^\text{39}\) 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\(^\text{40}\) technique was then used to assess further possible reduction of the model using cross-validation to find the optimal shrinkage value \(\lambda\), repeatedly fitting the model with nine-tenths of the data and withholding one-tenth of the data for evaluation of \(\lambda\) 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
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.
| Characteristic                  | Textbook outcomes Yes | No | p Value |
|--------------------------------|-----------------------|----|---------|
| **Recipient characteristic**   |                       |    |         |
| Total, n (%)                   | 15,533 (31.7)         | 33,530 (68.3) |          |
| 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/m², 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/m², 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)
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]).
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.

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.
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, and the negative effects of delayed graft function do not outweigh the risks of remaining waitlisted. Likewise, if rejection rates drop too low, then complications of over-immunosuppression, including cytomegalovirus and other opportunistic infections, will rise. 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
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 M², 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 and by the Centers for Medicare and Medicaid Services 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 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.
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

![Figure 5.](image)

(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.
into question the inclusion of hepatitis C status in the calculation of KDPI.\textsuperscript{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\textsuperscript{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.\textsuperscript{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\textsuperscript{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, intra-operative 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.\textsuperscript{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,\textsuperscript{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,\textsuperscript{14} the MPSC has revealed its plans to implement four new transplantation metrics in January 2022. If approved, 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\textsuperscript{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.\textsuperscript{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.\textsuperscript{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, 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.

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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 wait-list outcomes, transplant rate, post-transplant survival, and more. Stakeholders have focused heavily on 1-year survival as a quality measure for transplant programs. National 1-year patient and graft survival rates after kidney transplantation are 95% and 97%, respectively, and variation in survival outcomes among kidney transplant programs continues to decrease. However, post-transplant complication rates and healthcare use vary widely among transplant programs despite relatively similar patient and graft survival rates, 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. 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.

In this issue of JACS, Schenk and colleagues 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 ≤ 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. Therefore, despite being risk adjusted, TO