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Kidney Graft Survival according to the Teaching Status of a Transplant Hospital

By

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Master of Public Health

Epidemiology

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Kidney Graft Survival according to the Teaching Status of a Transplant Hospital

By

Kieran James Maroney

B.S., University of Pittsburgh, 2018

Thesis Committee Chair: Rachel Patzer, PhD, MPH

An abstract of
A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
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Abstract

Kidney Graft Survival according to the Teaching Status of a Transplant Hospital

By Kieran James Maroney

Introduction: Graft survival is an important metric in which transplant hospitals are graded, yet disparities in kidney graft survival still exist even after accounting for patient and donor characteristics. Some research shows the teaching status of a hospital has impacts on patient outcomes, however this has not been assessed in kidney transplant patients. We aim to assess how the teaching status of a transplant hospital is associated with three-year graft failure.
Methods: We examined first-time single organ kidney transplant recipients from the Scientific Registry of Transplant Recipients from January 2008 to January 2019, and linked data to the American Hospital Association Annual Survey to obtain information on teaching status of each transplant hospital determined as membership in the Council of Teaching Hospital of the Association of American Medical Colleges. Characteristics of transplant patients in teaching vs. non-teaching hospitals were compared using t-tests and chi-squared tests as appropriate. Differences in death censored three-year graft survival by teaching status were measured using the log-rank test. Using inverse probability weighting, the cause-specific association between teaching status and the cumulative incidence of three-year graft failure was assessed separately for both living and deceased donor transplants and accounted for patient clustering by transplant hospital.
Results: Of 152,603 patients, 83% were transplanted at hospitals classified as teaching hospitals. Teaching hospitals demonstrated lower three-year graft survival than non-teaching hospitals among deceased donor transplant recipients (log-rank $p<0.001$), but not living donors. The three-year rate of graft loss among deceased and living donor transplants in teaching hospitals was no different than non-teaching hospitals after adjusting for clustering, donor, recipient and hospital-level characteristics [Deceased Donor: Hazard Ratio: 1.07, 95% Confidence Interval (0.97-1.18); Living Donor: Hazard Ratio: 0.92, 95% Confidence Interval: (0.75-1.12)].
Conclusion: Transplant hospitals classified as teaching hospitals have an increased rate of graft loss among deceased donor kidney transplants compared to patients transplanted in non-teaching hospitals under specific definitions of teaching status. Future studies should examine the importance of various measurements of teaching status and processes of care that differ between teaching and non-teaching hospitals to reduce disparities in graft survival.

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Table of Contents

Introduction

End-stage renal disease (ESRD) is an irreversible disease which affects approximately 730,000 individuals in the United States and requires renal replacement therapy (1). The preferred renal replacement therapy is kidney transplantation, as it offers the highest improvement in patient survival and quality of life (2). However, not all patients are eligible or survive to receive a kidney transplant (3, 4).

After a patient receives a kidney transplantation, complications including kidney graft failure may occur where a patient's kidney function returns to a state of ESRD (1). Once a patient receives a kidney transplant, the goal is to minimize the risk of graft failure and maximize graft survival time. Patient-level characteristics identified as risk factors which influence graft survival include low socioeconomic status, limited education, increased distance to a transplant hospital, high neighborhood poverty, male gender, as well as race/ethnicities other than non-Hispanic white (4-10).

However, patient-level characteristics do not describe all the variation and disparities in kidney graft survival. Increasingly, research has focused on including transplant hospital level characteristics as risk factors for graft failure. The Centers for Medicare and Medicaid Services (CMS) require transplant centers to maintain certain survival standards to remain certified and receive reimbursement for transplant related costs, motivating transplant hospitals to discover risk factors for graft failure (11). To date, transplant hospital factors such as geographic region, transplant hospital volume, waitlist time until transplant and poor prior center-level transplant outcomes have been found to be associated with graft survival (3, 12, 13). However, many transplant hospital

characteristics remain unexplored today as traditional transplant registries do not include many hospital characteristics outside aggregated patient characteristics.

Outside the field of transplantation, the teaching status of a hospital has been defined in multiple ways such as membership in the Council of Teaching Hospitals, the presence of an American Council of Graduate Medical Education approved residency program, medical school affiliation as well as the number of interns per bed (14-16). and found to be associated with post-surgical outcomes in some complex surgeries (17-20).

In this study, we aimed to determine if teaching status was a risk factor for three-year graft survival under differing definitions of teaching status, accounting for known patient and transplant hospital characteristics which may influence graft survival.

Methods

Study Design and Data Sources

This cohort study included all individual kidney transplant recipients within the United States from January 2008 to January 16th, 2019. Patients were identified using the Scientific Registry of Transplant Recipients (SRTR), a national registry which follows transplant candidates from date of waitlist registration until death (21). In order to ascertain the teaching status of each transplant hospital, the 2017 American Hospital Association's Annual Survey (AHAAS) was linked to each transplant hospital by CMS Certification Number. We excluded patients who received more than one kidney transplant, had multiple organ transplants or missing teaching status.

Study Population

A total of 192,194 patients received a kidney transplant between January 2008 and January 2019. After excluding patients who received previous kidney transplants

(N=22,766) and patients who received multiple organs during their transplant (N=6,790), our cohort included N=162,638 patients. There were 10,035 patients (6.2%) unable to be linked to hospital data, resulting in a final study cohort of 152,603 kidney transplant recipients (Fig 1).

Definition of Teaching Status

There are multiple ways we defined teaching status during this analysis. In primary analysis we defined teaching status as membership in the Council of Teaching Hospitals. In a sensitivity analysis, we defined teaching status as the presence of an American Council of Graduate Medical Education approved residency program and an affiliated medical school.

Outcomes

Our analysis examined three-year graft failure as a primary outcome as well as three-year patient mortality, which are collected in SRTR from multiple sources including the Organ Procurement Transplantation Network (OPTN), Social Security Death Master File and Hospitals for Medicare and Medicaid Services. Patients were followed from their date of transplant until date of graft failure, death date, or until their date of last known follow-up. Person-years were censored at three-years post-transplant date.

Confounders/Missing Data

Patient demographic information at ESRD diagnosis [race/ethnicity, gender, and educational attainment], medical history at time of transplant [body mass index, age, receipt of dialysis, private insurance status, and employment], donor medical information at time of transplant [age, race/ethnicity, and kidney donor profile index (KDPI) score],

transplant operative notes [human leukocyte antigen (HLA) mismatches] and transplant hospital characteristics [number of residents, number of hospital beds, hospital profit status, transplant volume and OPTN region] were considered as potential confounders in the relationship between teaching status and kidney graft loss using directed acyclic graph theory, and the principles of identifiability and exchangeability (22). Those included in the study had mostly complete information, however body mass index was missing for 1.5%, educational attainment was missing for 4.3%, employment status was missing for 11.0%, number of hospital beds was missing for 2.0% and private insurance status, receipt of dialysis, HLA mismatches, KDPI and transplant volume were missing ≤0.5%. Multiple imputation using the MICE R package was performed to account for missing data within the sample (23).

Statistical Methods

For comparisons between patients transplanted at teaching and non-teaching transplant hospitals, student's t-tests and chi squared analyses were conducted as appropriate. Absolute rates and rate differences of three-year death censored for graft loss and three-year graft loss censored for death were assessed by teaching status, year [2008-2009, 2010-2011, 2012-2013, 2014-2015, 2016-2017, 2018-2019], and OPTN region [1-11]. Patients were stratified by deceased donor or living donor status due to known associations between graft survival and donor type (1). Kaplan Meier survival curves were fit to examine how three-year death censored graft loss differed by teaching status. Cox proportional hazards models, by donor status, assessed the association between teaching status and three-year graft loss. Cox proportional hazards models reported using calendar time include the unadjusted estimates which weight based on inverse probability

of death occurring by teaching status, then a subsequent model (Model 1) was built adding donor characteristics which were considered confounders (24). A second adjusted model (Model 2) was created, adjusted for both donor and transplant recipient characteristics considered as confounders. Then, building upon the previous model, weighted adjusted estimates for the association between teaching status and graft loss were calculated after accounting for clustering by transplant hospital, as well as other hospital level variables considered as confounders (Model 3). All analyses were performed for the primary definition of teaching status, and in a sensitivity analysis secondary definitions of teaching status were explored. All analyses were performed using R Version 1.2.1335 and $p<0.05$ was determined as statistically significant for all analyses.

Results

Participant Characteristics

Among 152,603 patients in the study, 83.0% were transplanted at a transplant hospital classified as teaching (Table 1). Compared to patients at non-teaching hospitals, patients at teaching hospitals were more likely to be African American (28.8% vs. 17.9%), less likely to be Hispanic (15.2% vs. 25.9%), more likely to staff higher numbers [867-1760] of physician residents to provide care (28.6% vs. 0.0%), and were more likely to receive care at a non-profit institution (72.1% vs. 55.8%). OPTN regions 1, 2, 3, 7 and 9 were more likely to transplant patients at teaching vs. non-teaching transplant hospitals while OPTN regions 4 and 6 were more likely to transplant patients at non-teaching vs. teaching transplant hospitals.

Kidney Graft Survival and Patient Mortality

Table 2 shows the absolute (crude) rates at which kidney transplant recipients experience 3-year death censored graft loss and 3-year mortality censored for graft loss by teaching status, calendar year and OPTN region. For 3-year death censored graft loss, rates were higher among teaching vs. non-teaching hospitals (Rate Difference (RD): 2.1, 95% Confidence Interval (CI) (1.1-3.1) per 1,000 person-years), and higher in earlier years (2008-2009) vs. later years (2017-2018) (RD: -2.1, CI (-4.2- -0.1) per 1,000 person-years). High variation in rates of graft loss (range: 10.4-19.4 per 1,000 person-years) and mortality (range: 12.2-22.9 per 1,000 person-years) were observed by OPTN Region (Table 2).

Kaplan-Meier survival curves demonstrated that teaching transplant hospitals have lower death censored graft survival than non-teaching transplant hospitals among deceased donor recipients ($p<0.001$) (Fig 2) but did not differ among living donors ($p=0.079$) (Fig 3). Patient death censored graft survival estimates at 1-year, 2-year and 3-year time intervals were 0.98, CI: 0.97-0.98, 0.97, CI: 0.96-0.97 and 0.95, CI: 0.95-0.95 for deceased donor recipients transplanted in teaching hospitals and 0.97, CI: 0.97-0.97, 0.96, CI: 0.96-0.96, and 0.94, CI: 0.94-0.94 for deceased donor recipients transplanted in non-teaching hospitals. For living donor recipients, death censored graft survival estimates for patients transplanted in teaching hospitals were 0.99, CI: 0.99-0.99, 0.98, CI: 0.98-0.98 and 0.97, CI: 0.97-0.98 and survival estimates were 0.99, CI: 0.99-0.99, 0.99, CI: 0.98-0.99 and 0.98, CI: 0.97-0.98 for patients transplanted in non-teaching hospitals.

Teaching Status and Graft Loss by Donor Type

In crude models, patients who received deceased donor kidneys and were transplanted at teaching transplant hospitals were more likely to experience graft failure within three years compared to deceased donor patients transplanted at non-teaching transplant hospitals (Hazard Ratio (HR): 1.22, CI: 1.13-1.32). After adjustment for hospital level characteristics and clustering by hospital, in addition to donor and recipient characteristics, there was no relationship between teaching hospitals and graft loss (HR: 1.07, CI: 0.97-1.18) (Table 3).

Living donor kidney transplant recipients transplanted at teaching transplant hospitals experienced similar relative hazard rates of three-year graft failure compared to patients transplanted at non-teaching transplant hospitals (HR: 0.88, CI: 0.75-1.01). Living donor kidney transplant recipients' incidence of three-year graft failure did not differ by teaching status after adjustment for donor, recipient and hospital factors (HR: 0.92, CI: 0.75-1.12) (Table 3).

Sensitivity Analysis for Teaching Status

When teaching status was classified using residency training approval by Accreditation for Graduate Medical Education, 143,709 (94.2%) patients were transplanted in teaching hospitals and when medical school affiliation reported to the American Medical Association was used as teaching status 148,617 (97.4%) patients were transplanted in teaching hospitals (Table 4). Among deceased donors, teaching hospitals had no difference in graft loss rates than non-teaching hospitals (HR: 1.05, CI: 0.93-1.18) when defining teaching status by residency training approval by accreditation council for graduate medical education. After adjustment for donor, recipient and hospital

characteristics deceased donor recipients at teaching hospitals experienced higher rates of three-year graft loss than non-teaching hospitals (HR: 1.27, CI: 1.12-1.44). This relationship was also true for deceased donor recipients if medical school affiliation reported to the American Medical Association was the measure of teaching status, as both the unadjusted and fully adjusted model for teaching status and three-year graft loss was higher for teaching hospitals compared to non-teaching hospitals (HR: 1.27, CI: 1.05-1.54) and (HR: 1.23, CI: 1.01-1.51), respectively). Living donor recipients did not experience differing hazards of graft loss by the teaching status of their transplant hospital, irrespective of how teaching status was defined (Table 4).

Discussion

We aimed to investigate if teaching status was a risk factor for three-year graft survival after adjustment for other donor, patient and transplant hospital characteristics which may influence graft survival. We noted three-year kidney graft loss rates did not differ by hospital teaching status defined as a member of the Council of Teaching Hospital of the Association of America for deceased or living donor recipients after adjusting for several patient, provider and hospital-level factors. However, deceased donor recipients transplanted at teaching hospitals experienced an increased hazard of three-year graft loss when compared to non-teaching hospitals when teaching status was defined as the presence of an American Council of Graduate Medical Education approved residency program or an affiliated medical school.

Our study was not the first to examine teaching status in surgical patients, however it was the first to examine teaching status' impact on patient outcomes in a transplant population. Although not directly comparable to graft loss in kidney

transplantation, teaching status has been studied as a risk factor across various surgical disciplines with results showing various impact on mortality, higher rates of complications and length of hospital stay. In one study utilizing the National Inpatient Sample, teaching hospitals had lower in-hospital mortality for patients undergoing esophageal resection, hepatic resection or pancreatic resection compared to non-teaching hospitals, however results attenuated after adjusting for hospital volume (14). While we did not examine adjusted rates of patient mortality, we did observe attenuation in teaching status as a protective factor for three-year graft loss after adjusting for hospital volume and other hospital level characteristics among living donor recipients.

Other studies examining patient mortality noted similar findings where teaching hospitals had lower patient mortality than non-teaching hospitals (18, 19, 25, 26). It has also been noted that teaching hospitals treated patients that had higher severity of illness (19). This was not demonstrated in our study as most clinical patient characteristics did not differ by teaching status. Teaching status has also been found to be associated with worse patient outcomes among VA hospitals where teaching hospitals had "81% of the total surgical work-load" (27). In our study, 82% of patients underwent transplantation at teaching hospitals under our conservative definition of teaching status and 94% and 97% when examining secondary definitions. This relationship between distribution of transplant surgeries and patient outcomes may explain why our secondary definitions resulted in increased hazards of three-year graft loss for teaching hospitals when compared to non-teaching hospitals.

The strengths of this study include a nationally representative sample of kidney transplant recipients, with very few transplant hospitals' teaching status unable to be

ascertained. Additionally, there was minimal missing data which could bias the associations measured in this study. There is also likely very little selection bias occurring, as there is a very small risk of loss to follow-up occurring due to CMS incentivizing transplant centers to have complete reporting of patient outcomes for three years post-transplant (28). However, limitations to the study design include potential unmeasured confounding due to the inability to adjust for other hospital level factors which may influence graft survival and the teaching status of a transplant center. Moreover, limitations surrounding the definition of a teaching hospital include various measurements to ascertain and measure the teaching status, however we have mitigated this limitation by incorporating multiple definitions of teaching status into our study design which have been utilized in previous literature examining teaching status' impact on patient outcomes. Finally, a limitation of our analysis includes a lack of power as the majority of transplant hospitals are classified as teaching, which may increase type II statistical errors.

As there have been noted characteristics which differ between teaching and non-teaching transplant hospitals such as an increased likelihood to transplant additional organs, further studies focused on the identification of patient characteristics that differ by teaching status are needed (29). Upon identification of differences between teaching and non-teaching transplant hospitals, interventions can be developed to reduce the disparities present in graft survival by certain definitions of teaching status.

In summary, teaching status is not a risk factor for three-year graft survival among living donor recipients of kidney transplants when examining varying definitions of teaching hospitals. Additionally, deceased donor recipients under some definitions of

teaching status had increased likelihood of three-year graft loss when compared to non-teaching hospitals, however, a future higher-powered study is suggested to further illuminate the impact of teaching status on patient outcomes in kidney transplant.

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Tables

Table 1 Characteristics of First Time Single Organ Kidney Transplant Recipients (Jan. 2008 – Jan. 16th, 2019)

	Patient Population (n=152,603)	Teaching Transplant Center (n=126,707) 83%	Non-Teaching Transplant Center (n=25,896) 17%	P-value
Patient Characteristics				
Male[A]	92578 (60.7)	76918 (60.7)	15660 (60.5)	0.485
Age at Transplant[B]	50.81 (15.69)	50.81 (15.47)	49.54 (16.69)	<0.001
Race[A]				<0.001
Caucasian	72907 (47.8)	60740 (47.9)	12167 (47.0)	
African American	41185 (27.0)	36552 (28.8)	4633 (17.9)	
Hispanic	25903 (17.0)	19200 (15.2)	6703 (25.9)	
Asian	9779 (6.4)	8247 (6.5)	1532 (5.9)	
Other Race/Ethnicity	2829 (1.9)	1968 (1.6)	861 (3.3)	
Body Mass Index[A]	28.0 (5.73)	27.99 (5.73)	27.89 (5.77)	0.015
Educational Attainment[A]				<0.001
High school or less	71148 (46.6)	58631 (46.3)	12517 (48.3)	
Some College	35573 (23.3)	29564 (23.3)	6009 (23.2)	
Bachelors/Associate	26145 (17.1)	21776 (17.2)	4369 (16.9)	
Graduate Degree	11687 (7.7)	10134 (8.0)	1553 (6.0)	
Private Insurance[B]	53227 (34.9)	45077 (35.6)	8150 (31.5)	<0.001
Unemployed[B]	90259 (59.1)	74566 (58.8)	15693 (60.6)	<0.001
Received Dialysis prior to transplant[B]	124036 (81.5)	102779 (81.3)	21257 (82.2)	<0.001
Transplant Year[B]				0.042
2008-2011	50938 (33.4)	42461 (33.5)	8477 (32.7)	
2012-2015	5335 (35.0)	44239 (34.9)	9096 (35.1)	
2016-2019	48330 (31.7)	40007 (31.6)	8323 (32.1)	
Donor Characteristics[B]				
Donor Age	39.67 (15.07)	39.92 (15.09)	38.46 (14.88)	<0.001
Race				<0.001
Caucasian	104203 (68.3)	87266 (68.9)	16937 (65.4)	
Black	19491 (12.8)	17295 (13.6)	2196 (8.5)	
Asian	4574 (3.0)	3876 (3.1)	698 (2.7)	
Hispanic	22551 (14.8)	17022 (13.4)	5529 (21.4)	
Other Race/Ethnicity	1784 (1.2)	1248 (1.0)	536 (2.1)	
HLA Mismatches	3.93 (1.59)	3.93 (1.59)	3.92 (1.57)	0.425
Living Donor	52406 (34.3)	43591 (34.4)	8815 (34.0)	0.262
KDPI Score	53.41 (27.08)	54.29 (27.10)	49.13 (26.58)	<0.001
Center Characteristics[B]				

Number of Residents				<0.001
0-20	38562 (25.3)	22746 (18.0)	15816 (61.1)	
21-407	38798 (25.4)	29134 (23.0)	9664 (37.3)	
408-866	39023 (25.6)	38607 (30.5)	416 (1.6)	
867-1760	36220 (23.7)	36220 (28.6)	0 (0.0)	
Hospital Beds				<0.001
0-259	37532 (25.1)	23905 (18.9)	13627 (58.8)	
260-358	37407 (25.0)	33336 (26.4)	4071 (17.6)	
359-502	38565 (25.8)	35549 (28.1)	3016 (13.0)	
503-1300	36102 (24.1)	33649 (26.6)	2453 (10.6)	
Non-Profit	105750 (69.3)	91308 (72.1)	14442 (55.80)	<0.001
Volume-Living Donor	58.01 (48.61)	61.69 (43.84)	39.46 (64.61)	<0.001
Volume-Deceased Donor	243.51 (168.00)	273.47 (165.36)	92.56 (73.06)	<0.001
OPTN Region				<0.001
1	6816 (4.5)	6254 (4.9)	562 (2.2)	
2	19663(12.9)	18657 (14.7)	1006 (3.9)	
3	18520 (12.1)	16776 (13.2)	1744 (6.7)	
4	13772 (9.0)	5966 (4.7)	7806 (30.1)	
5	26446 (17.3)	22373 (17.7)	4073 (15.7)	
6	5423 (3.6)	2048 (1.6)	3375 (13.0)	
7	11226 (7.4)	10449 (8.2)	777 (3.0)	
8	9793 (6.4)	7728 (6.1)	2065 (8.0)	
9	9907(6.5)	9214 (7.3)	693 (2.7)	
10	13936 (9.1)	11813 (9.3)	2123 (8.2)	
11	17101 (11.2)	15429 (12.2)	1672 (6.5)	

Values are counts (percent) for categorical variables and mean (standard deviation) for continuous variables

[A]Captured at End-Stage Renal Disease Diagnosis

[B]Captured at time of transplant

KDPI: Kidney Donor Profile Index

OPTN: Organ Procurement and Transplantation Network

Region 1: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Eastern Vermont;
Region 2: Delaware, District of Columbia, Maryland, New Jersey, Pennsylvania, West Virginia, Northern Virginia
Region 3: Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, Puerto Rico
Region 4: Oklahoma, Texas
Region 5: Arizona, California, Nevada, New Mexico, Utah
Region 6: Alaska, Hawaii, Idaho, Montana, Oregon, Washington
Region 7: Illinois, Minnesota, North Dakota, South Dakota, Wisconsin
Region 8: Colorado, Iowa, Kansas, Missouri, Nebraska, Wyoming
Region 9: New York, Western Vermont
Region 10: Indiana, Michigan, Ohio
Region 11: Kentucky, North Carolina, South Carolina, Tennessee, Virginia

Table 2 Absolute Rates of 3 Year Graft Loss and Death among transplant patients, by Selected Characteristics (Jan. 2008 – Jan. 16th, 2019)

	Person Years	Graft Loss n	Death n	Graft Loss Rate[A]	Rate Difference[A]	Mortality Rate[A]	Rate Difference[A]
Teaching Status[B]							
Non-Teaching	66021.7	961	1335	14.6	Ref	20.2	Ref
Teaching	3721712.9	5351	6361	16.6	2.1 (1.1-3.1)	19.8	-0.5 (-1.6-0.7)
Calendar Year							
2008-2009	69939.7	1305	1597	18.7	Ref	22.8	Ref
2010-2011	72924.4	1331	1605	18.3	-0.4 (-1.8-1.0)	22.0	-0.8 (-2.4-0.7)
2012-2013	74013.3	1167	1377	15.8	-2.9 (-4.2- -1.5)	18.6	-4.2 (-5.7- -0.2.7)
2014-2015	77140.4	1230	1546	15.9	-2.7 (-4.1- -1.4)	20.0	-2.7 (-4.3- -1.3)
2016-2017	74071.3	954	1216	12.9	-5.8 (-7.1- -4.5)	16.4	-6.4 (-7.9- -5.0)
2018-2019	19645.5	325	362	16.5	-2.1 (-4.2- -0.1)	18.4	-4.4 (-6.6- -2.2)
OPTN Region							
1	17485.2	209	312	12.0	Ref	17.8	Ref
2	49803.4	946	1142	19.0	7.0 (5.0-9.1)	22.9	5.1 (2.7-7.5)
3	46992.0	846	1021	18.0	6.1 (4.0-8.1)	21.7	3.9 (1.5-6.3)
4	34680.0	582	649	16.8	4.8 (2.7-6.9)	18.7	0.9 (-1.6-3.3)
5	67936.4	878	1085	12.9	1.0 (-0.9-2.8)	16.0	-1.9 (-4.1-0.3)
6	14134.7	147	172	10.4	-1.6 (-3.9-0.8)	12.2	-5.7 (-8.4- -3.0)
7	28683.8	447	616	15.6	3.6 (1.5-5.8)	21.5	3.6 (1.0-6.2)
8	24946.3	377	465	15.1	3.2 (0.9-5.4)	18.6	0.8 (-1.8-3.4)
9	24579.3	467	537	19.0	7.0 (4.7-9.4)	21.8	4.0 (1.3-6.7)
10	35433.6	576	800	16.3	1.2 (-0.8-3.2)	22.6	4.7 (2.2-7.3)
11	43060.1	837	904	19.4	7.5 (5.4-9.6)	21.0	3.2 (0.7-5.6)

[A]Rate per 1,000 Person Years

[B]Teaching defined as Member of Council of Teaching Hospital of the Association of America

OPTN: Organ Procurement and Transplantation Network;
Region 1: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Eastern Vermont;
Region 2: Delaware, District of Columbia, Maryland, New Jersey, Pennsylvania, West Virginia, Northern Virginia
Region 3: Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, Puerto Rico
Region 4: Oklahoma, Texas
Region 5: Arizona, California, Nevada, New Mexico, Utah
Region 6: Alaska, Hawaii, Idaho, Montana, Oregon, Washington
Region 7: Illinois, Minnesota, North Dakota, South Dakota, Wisconsin
Region 8: Colorado, Iowa, Kansas, Missouri, Nebraska, Wyoming
Region 9: New York, Western Vermont
Region 10: Indiana, Michigan, Ohio
Region 11: Kentucky, North Carolina, South Carolina, Tennessee, Virginia

Table 3 Results of Multivariable Analysis of Transplant Center Teaching Status with Three-Year Graft Loss for First Time Single Organ Kidney Transplant Recipients by Donor Type (Jan. 2008 – Jan. 16th, 2019)

	Crude Model	Model 1	Model 2	Model 3
Deceased Donor				
Non-Teaching	Ref	Ref	Ref	Ref
Teaching[A]	1.22 (1.13-1.32)	1.15 (1.06-1.24)	1.06 (0.98-1.15)	1.07 (0.97-1.18)
Living Donor				
Non-Teaching	Ref	Ref	Ref	Ref
Teaching[A]	0.88 (0.75-1.01)	0.84 (0.72-0.97)	0.85 (0.73-0.99)	0.92 (0.75-1.12)

[A]Teaching defined as Member of Council of Teaching Hospital of the Association of America
Model 1-Deceased Donor: Adjusted for Kidney Donor Profile Index, Transplant Year
Model 1-Living Donor: Adjusted for Donor Age, Donor Gender, Donor Race/ethnicity, Transplant Year
Model 2: Model 1 + Candidate Diagnosis, Age at Transplant, Educational Attainment, Candidate race/ethnicity, human leukocyte antigen mismatches, Private insurance status, Employment status, Receipt of Dialysis, Diabetes status, Hypertension status, COPD status
Model 3: Model 2 + Profit Status, OPTN Region, Number of Residents, Number of Hospital Beds, Transplant Volume and Clustering by Hospital

Table 4 Sensitivity Analysis of Teaching Status Ascertainment and Three-Year Graft Loss for First Time Single Organ Kidney Transplant Recipients by Donor Type (Jan. 2008 – Jan. 16th, 2019)

	Original Definition	New Teaching Status Definitions	
Method of Exposure Assessment	Member of Council of Teaching Hospital of the Association of America	Residency Training approved by Accreditation Council for Graduate Medical Education	Medical School Affiliation reported to American Medical Association
Teaching Hospital Patients	126,707 (83.0%)	143,709 (94.2%)	148,617 (97.4%)
Living Donor			
Crude	0.88 (0.75-1.01)	1.02 (0.79-1.31)	0.86 (0.62-1.19)
Adjusted[A]	0.92 (0.75-1.12)	0.99 (0.76-1.29)	0.88 (0.62-1.26)
Deceased Donor			
Crude	1.22 (1.13-1.32)	1.05 (0.93-1.18)	1.27 (1.05-1.54)
Adjusted[B]	1.07 (0.97-1.18)	1.27 (1.12-1.44)	1.23 (1.01-1.51)

[A]Adjusted for Donor Age, Donor Gender, Donor Race/Ethnicity, Year of Transplant, Candidate Diagnosis, Candidate Age at Transplant, Candidate Education, Candidate Race/Ethnicity, HLA Mismatches, Private Insurance Status, Receipt of Dialysis, Employment Status, Diabetes Status, Hypertension Status, COPD Status, Hospital Profit Status, Organ Procurement Transplantation Network Region, Living Donor Transplant Volume, Number of Residents, Number of Beds and clustering by Hospital

[B]Adjusted for KDPI Score, Year of Transplant, Candidate Diagnosis, Candidate Age at Transplant, Candidate Education, Candidate Race/Ethnicity, HLA Mismatches, Private Insurance Status, Receipt of Dialysis, Employment Status, Diabetes Status, Hypertension Status, COPD Status, Hospital Profit Status, Organ Procurement Transplantation Network Region, Deceased Donor Transplant Volume, Number of Residents, Number of Beds and clustering by Hospital

Figures

Figure 1 Study Flow Chart Describing Inclusion, Exclusion, and Data Linkage

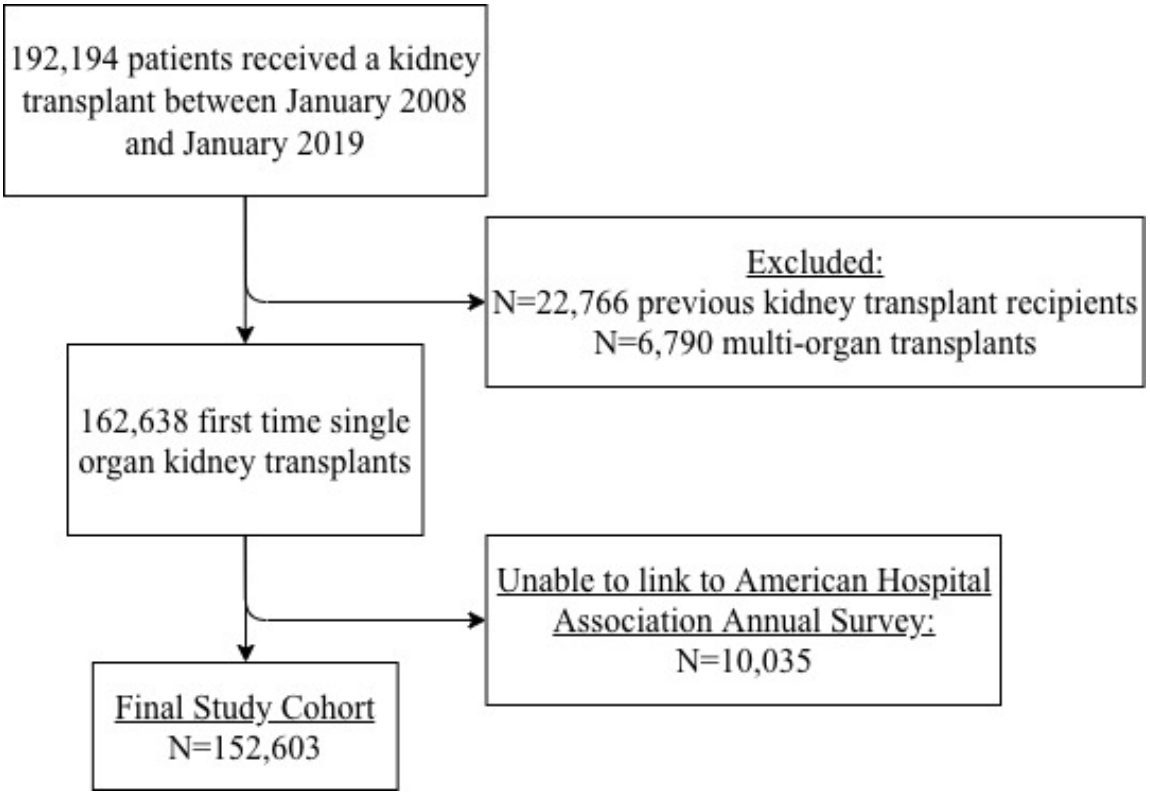

Figure 2 Three-Year Death Censored Graft Loss by Teaching Status for First Time Deceased Donor Kidney Transplant Recipients (2008-2019)

Figure 3 Three-Year Death Censored Graft Loss by Teaching Status for First Time Living Donor Kidney Transplant Recipients (2008-2019)