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Case Mix, Patterns of Care, and Inpatient Outcomes Among Ontario Kidney Transplant Centers: A Population-Based Study

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Abstract

Background: Significant variation in both patient case mix and the structure of care in kidney transplantation has been previously described in the United States.

Objective: The objective of our study was to characterize patient case mix, patterns of care, and inpatient outcomes across 5 kidney transplant centers in the province of Ontario, Canada.

Design: This was a retrospective population-based cohort study using health care administrative databases.

Setting: The setting is Ontario, Canada.

Patients: We included adult (≥18 years) transplant recipients who received a primary, solitary kidney between January 1, 2000, and December 31, 2013 (N = 5037).

Methods: Using linked administrative health care databases, we characterized kidney transplant recipient and donor factors, center characteristics, provider characteristics, and inpatient outcomes across transplant centers in Ontario. To compare case mix–adjusted differences in length of stay across centers, multivariable Cox proportional hazards regression was used to obtain hazard ratios (HRs) for each center relative to the average across all centers. Center volume and provider characteristics were added to the models to examine whether these factors explain differences in length of stay across centers.

Results: We noted significant differences across transplant centers in patient race, cause of end-stage renal disease, body mass index, comorbidities, time on dialysis, and donor type. Mean annual transplant center volumes during the study period ranged between 51.5 (9.3) and 101.7 (23.9) transplants/year across centers ($P < .0001$). Physician specialty most responsible for in-hospital transplant care varied significantly across centers with the most common combination being nephrologist and urologist. Less than 31 deaths occurred in hospital during the index transplant admission but mortality risk did not differ significantly between centers. Overall, 25.1% of recipients required dialysis in hospital post transplantation (range across centers 18.3%-33.5%, $P < .0001$) and 24.7% of recipients spent time in the intensive care unit (ICU; range across centers: 5.7%-58.0%, $P < .0001$). The proportion of participants requiring dialysis did not change with time ($P = .12$), whereas the proportion staying in the ICU increased steadily over time ($P < .0001$). The median length of stay in hospital after transplantation ranged from 7 to 9 days across centers ($P < .0001$) and decreased significantly over time. After adjusting for patient case mix as well as center and provider factors, HRs for length of stay censored at the time of death ranged between 0.75 (95% confidence interval [CI]: 0.69-0.82) and 1.29 (95% CI: 1.20-1.38) across centers. Center volume and provider experience were not independently associated with length of hospital stay.

Limitations: Data were missing (0.8%-18.4%) for certain covariates of interest.

Conclusions: This study found significant heterogeneity across kidney transplant centers in case mix, practice patterns, and inpatient outcomes. Future studies are needed to examine the influence of length of stay and practice patterns on long-term outcomes such as patient/graft survival and quality of life.

Abrégé

Contexte: Des différences marquées dans la classification diagnostique des patients et la structure des soins offerts en transplantation rénale ont déjà été observées et décrites aux États-Unis.

Objectifs de l'étude: L'étude visait à dresser un portrait de la patientèle et des modèles de soins offerts aux patients de cinq centres de greffe rénale de la province de l'Ontario, au Canada. On s'est également intéressé à l'évolution de l'état de santé des patients hospitalisés dans ces centres au cours de la période couverte par l'étude.
Cadre et type d'étude: Il s'agissait d'une étude de cohorte rétrospective, basée sur la population, et pour laquelle on a eu recours aux bases de données administratives du système de santé. L'étude s'est tenue dans la province de l'Ontario, au Canada.
Patients: Ont été inclus dans l'étude 5 037 adultes ayant reçu une première greffe d'un seul rein entre le 1er janvier 2000 et le 31 décembre 2013.
Méthodologie: Nous avons utilisé plusieurs bases de données administratives couplées pour définir les paramètres des donneurs et des receveurs, pour dégager les caractéristiques de chacun des centres de greffe et des fournisseurs de soins, de même que pour suivre les résultats et l'état de santé des patients hospitalisés. Afin de comparer les différences observées dans la durée de séjour à travers les établissements, ajustées en fonction de la répartition des cas, nous avons calculé les risques proportionnels avec le modèle de régression de Cox multivarié, soit les rapports de risque pour chacun des centres de greffe rénale par rapport à la moyenne établie pour l'ensemble des établissements. Le volume de patients traités dans chacun des établissements et les caractéristiques propres à chaque fournisseur de soins ont été intégrés aux modèles d'analyse afin d'établir si ces facteurs avaient une incidence sur les différences observées entre les durées de séjour expérimentées dans les cinq centres.
Résultats: Nous avons observé des différences considérables entre les cinq centres de greffe rénale analysés en regard de l'origine ethnique, des causes qui ont mené à l'insuffisance rénale terminale, de l'indice de masse corporelle et des comorbidités des patients, ainsi que du temps passé en dialyse et du type de donneur. Au cours de l'étude, le volume moyen annuel de patients traités a varié entre 51,5 (9,3) et 101,7 (23,9) transplantations par année (p<0,000 1) dans les établissements étudiés. La composition de l'équipe de médecins spécialistes variait de beaucoup d'un établissement à un autre, mais la combinaison la plus fréquente consistait en un néphrologue et un urologue. Moins de 31 patients sont décédés à l'hôpital durant leur admission pour une première transplantation, et le risque de mortalité était homogène pour les cinq centres. Dans l'ensemble, 25,1 % des receveurs ont dû subir un traitement de dialyse à l'hôpital à la suite de la transplantation (entre 18,3 et 33,5 % selon le centre; p<0,000 1) et 24,7 % ont dû séjourner à l'unité des soins intensifs (entre 5,7 et 58,0 % selon le centre; p<0,000 1). La proportion des patients ayant dû recourir à la dialyse n'a pas varié au fil du temps (p=0,12) alors que la proportion de patients admis aux soins intensifs a augmenté constamment (p<0,000 1). La durée médiane du séjour à l'hôpital post-transplantation a varié entre 7 et 9 jours dans les centres de greffe étudiés (p<0,000 1) et a largement diminué au fil du temps. Après correction pour tenir compte du mélange de cas des patients et des caractéristiques de l'établissement et des fournisseurs de soins, les rapports de risque pour la durée du séjour, censurés au moment du décès, variaient entre 0,75 (IC à 95 % : 0,69 et 0,82) et 1,29 (IC à 95 % : 1,20 et 1,38) selon les centres. Ni le volume de patients traités ni l'expérience des fournisseurs de soins n'ont été associés de manière indépendante à la durée de l'hospitalisation.
Limites de l'étude: Les données étaient manquantes (entre 0,8 et 18.4 %) pour certaines covariables d'intérêt.
Conclusion: Cette étude nous a permis d'observer une hétérogénéité importante au sein des cinq centres de greffe rénale analysés en ce qui concerne la composition de la patientèle, les schémas de pratique et les résultats pour les patients hospitalisés. Des études supplémentaires sont requises pour mesurer l'impact de la durée du séjour à l'hôpital et des schémas de pratique sur les résultats à long terme pour le patient, notamment sur la survie du greffon et du patient, de même que sur la qualité de vie du receveur.

Keywords
kidney transplantation, center variation, health services delivery, in-hospital outcomes

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What was known before

Studies from the United States have characterized differences in kidney transplant recipients across transplant centers. Variation in patterns of care and provider characteristics among Ontario kidney transplant centers has not been described.

What this adds

This large population-based study is the first to characterize differences in center- and provider-level care during kidney transplantation in Ontario. We found significant differences in patient factors, practice patterns, and provider characteristics.

Introduction

There is an increasing number of Canadians living with end-stage renal disease (ESRD).[1-3] In 2014, there were 35 281 Canadians with ESRD, which increased by 38% from 2005. Kidney transplantation is associated with improved survival, better quality of life, and decreased long-term health care costs compared with dialysis.[4,5] Little is known regarding the structure of inpatient care after kidney transplantation and its impact on patient outcomes. In an American survey,[6] significant variation in the structure and processes of care (including provider type) at kidney transplant centers was demonstrated.

Length of hospital stay post kidney transplantation is important, as it has been shown to be associated with increased hospital expenses,[7,8] increased risk of readmission after discharge,[9] decreased graft survival,[10] and increased patient mortality.[10,11] The following risk factors have been found to be associated with an increased length of stay in hospital after kidney transplantation: African American race, obesity, deceased donor type, time on dialysis before transplantation, higher Charlson comorbidity index, and the presence of comorbid conditions such as cardiac disease, respiratory disease, and cancer.[8,12] To our knowledge, length of hospital stay after kidney transplantation has not been evaluated in Canada, and while center volume has been studied in association with length of hospital stay in 2 preliminary studies,[13,14] provider-level factors such as provider type and experience have not been.

The objectives of the present study are therefore to (1) describe baseline patient-level characteristics (donor and recipient) at 5 adult kidney transplant centers in Ontario; (2) characterize the type of provider caring for recipients at the time of transplant; (3) compare provider characteristics (age, years in practice, gender, country of medical training) between the sites; (4) describe in-hospital outcomes during the transplant admission including duration of stay, mortality, post-transplant dialysis, and need for intensive care unit (ICU) admission; and (5) determine whether patient characteristics, center volume, and/or provider characteristics such as type of provider and provider experience are associated with length of stay and contribute to its variation across centers.

Methods

Study Design and Setting

This was a population-based retrospective cohort study using health care databases at the Institute for Clinical Evaluative Sciences (ICES) in Ontario, Canada. Ontario has a population of approximately 13.6 million residents who have universal access to health care services. This study was approved by the institutional review board at Sunnybrook Health Sciences Centre (Toronto, Canada). The reporting of this study followed guidelines described for observational studies.[15,16] The full dataset creation plan is available from the authors upon request.

Data Sources

We used several linked datasets to create the cohort and to obtain patient, center, and provider characteristics and outcome data. These datasets were linked using unique encrypted patient-specific identifiers and analyzed at ICES. Kidney transplant recipients were identified using the Canadian Organ Replacement Register (CORR). CORR captures information on all kidney transplant recipients in Ontario. Its sensitivity to correctly identify kidney transplant recipients is 96% and positive predictive value is 98%.[17] Demographic and vital status information was ascertained from the Ontario Registered Persons Database (RPDB). RPDB provides basic demographic information on anyone with a valid Ontario health card number. Renal recipient comorbidities were captured using the Canadian Institute for Health Information Discharge Abstract Database (CIHI-DAD) and Ontario Health Insurance Plan (OHIP) Claims Database. CIHI-DAD captures information on all hospitalizations and same-day surgeries in Ontario, and OHIP provided information on Ontario physician billing claims for approximately 95% of physician services conducted in Ontario. We used similar codes to those used in prior kidney transplant studies from ICES.[17-19] We obtained provider information using the ICES Physician Database (IPDB). IPDB contains information on physician demographics, and training and practice setting from the Corporate Provider Database, the Ontario Physician Human Resources Data Centre database, and the OHIP database of physician billings.

Study Cohort

We included all adults (≥18 years) who received a first-time solitary kidney transplant in Ontario, Canada, between January 1, 2000, and December 31, 2013, using CORR. We excluded individuals with an invalid ICES key number (IKN;

a confidential ICES patient number; n = 353), who received a multiorgan transplant as this is a rare event (n = 313), were not from Ontario, had a death date prior to transplant date and therefore were invalid, had unknown age or sex (n = 14), were younger than age 18 or transplanted at a children's hospital (n = 223), and whose OHIP transplant billing or hospitalization dates did not align with transplant date (n = 117). We also excluded patients who were transplanted at one center given the small volume of transplants performed during this time period (n = 55).

Identification of Patient, Center, and Provider Characteristics

Transplant recipients were classified by the center at which their transplant occurred using the CORR facility code number. Information on the transplant center was obtained using CORR, OHIP, and IPDB. We identified physicians who provided care to transplant recipients during their admission by linking the patient IKN with an encrypted physician number using the OHIP database. We identified the most responsible surgeon and most responsible physician by using the following OHIP transplant-related billing codes: S435 (surgical transplant fee) and G412 (nephrology component of renal transplant) which is specific for the day of the transplant. The surgical transplant fee code has been validated for identifying kidney transplant recipients.[17] Provider characteristics including specialty type, age, years since graduation, sex, and country of graduation were obtained from IPDB.

Outcomes

Outcomes of interest, defined at the individual recipient level, included length of transplant hospital admission, admission to the ICU and step-down unit during the transplant hospital admission using CIHI-DAD billing codes limited to those transplanted after March 30 2002, death during the initial transplant admission, and need for dialysis in hospital post transplant (dialysis start at least 2 days post transplant).

Statistical Analysis

All statistical analyses were performed using SAS (Statistical Analysis Software) version 9.4 (SAS Institute, Cary, North Carolina). We used descriptive statistics to summarize characteristics of patients at the time of transplant by center. Continuous variables were described using mean and standard deviation (SD) when the data followed a normal distribution or median and interquartile range (IQR) if not normally distributed. Frequencies and percentages were used for categorical data. The statistical significance of differences across transplant centers was examined using analysis of variance (ANOVA) or Kruskal-Wallis tests for continuous variables and chi-square tests or Fisher exact test for categorical variables. Center volume was calculated as average annual volume (the total number of primary solitary kidney transplants performed at a given center over the number of years performing transplants during this study period) as well as total number of transplants per year for each center. We categorized the study period into 3 time periods: January 1, 2000, to December 31, 2004; January 1, 2005, to June 30, 2009; and July 1, 2009 to December 31, 2013. For each center, we calculated the proportion of transplant patients seen by each type of provider. This was calculated as the number of patients who saw the provider type divided by the total number of transplants at that center with a transplant billing code. For each type of provider, the provider mean age and years since graduation were calculated. We also calculated the proportions of encounters with Canadian trained providers and with male providers. For each type of provider, we calculated the years of experience as years since graduation. For each patient, we calculated the average provider experience of the care team as the average years since graduation of the providers linked to a given patient.

We assessed change in length of stay over time using the Kruskal-Wallis test and the chi-square trend test for proportion of patients requiring dialysis and requiring the ICU. We were unable to analyze and report the change in number of deaths with time due to the small number of events. We did not present variables that were missing more than 20% data including distance from hospital, class 2 panel reactive antibody (PRA) peak, PRA method, and cold ischemia time.

To account for differences in patient case mix across transplant centers, we used fixed effects multivariable Cox proportional hazards regression with the event of interest defined as hospital discharge censored at the time of in-hospital death. Adjusted hazard ratios (HRs) with 95% confidence intervals (CIs) were calculated for each transplant center, relative to the average across all centers. Our models adjusted for the following patient characteristics: recipient age, sex, race, cause of ESRD, BMI, Charlson comorbidity index, pretransplant dialysis modality (none vs hemodialysis or peritoneal dialysis), time on dialysis before transplantation, time era of transplant (as defined above), donor source, and donor age. A center with an HR and both limits of its 95% confidence interval below 1 implies that the center has a significantly longer length of stay than the average after accounting for patient case mix, while a center with an HR and both limits of its 95% confidence interval above 1 implies that the center has a significantly shorter length of stay compared with the average. On the contrary, a center with a confidence interval including 1 implies the length of stay is not significantly different than the average after accounting for patient case mix, center volume, and provider characteristics.

Data were missing for the following variables: recipient race (10.0%), cause of ESRD (7.9%), Charlson comorbidity index (5.5%), BMI (16.9%), donor type (0.75%), and donor age (0.79%). Prior to performing our analyses, we performed

multiple imputation using the fully conditional specification (FCS) method which does not assume a joint distribution but instead applies a separate conditional distribution for each of the imputed variables.[20] For categorical values, we used the discriminant method, and for continuous variables, linear regression was applied. We conducted 10 imputations using 100 burn-in iterations. Multivariable analyses were conducted for each imputation dataset and combined across datasets using Rubin's rules.[21]

Results

Patient Case Mix

The final cohort included 5037 kidney transplant recipients (Figure 1). The mean (SD) age of the overall cohort was 50.9 (13.5) years, 63.1% were male, and 63.4% were Caucasian. The most common cause of ESRD was glomerulonephritis (33.4%). Just less than half (42.0%) received a living donor kidney. Variation in recipient and donor characteristics across centers is described in Table 1. The majority of recipient and donor factors varied significantly across the centers including important known prognostic variables such as race, cause of ESRD, time on dialysis, and presence of diabetes. The proportion of missing data in recipient and donor variables ranged between 0.75% and 18.4% with PRA having the most missing values.

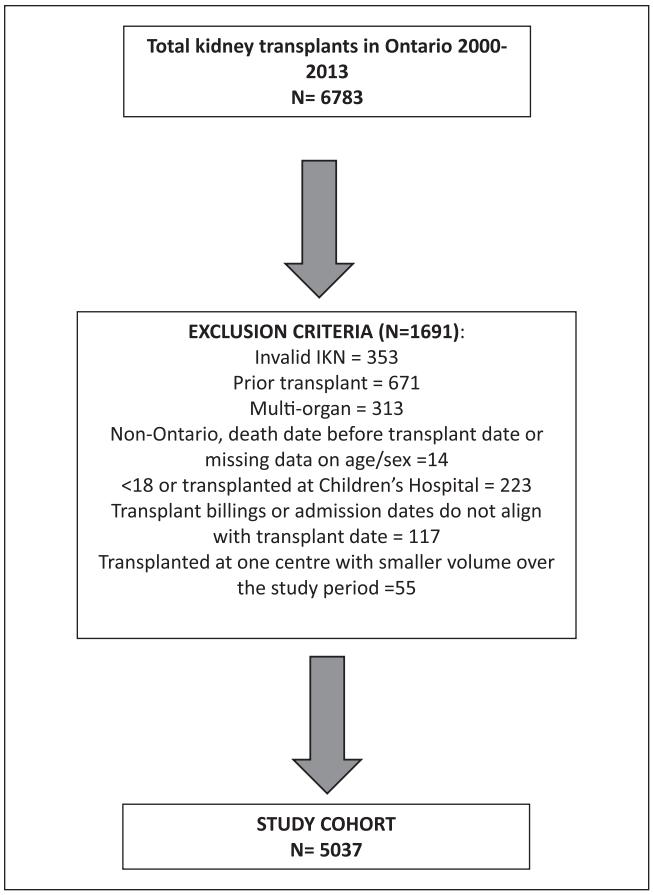

Figure 1. Study cohort creation.
Note. IKN = Institute for Clinical Evaluative Sciences key number.

Practice Patterns

Average annual kidney transplant volume ranged between 51.5 (9.3) and 101.7 (23.9) across the 5 centers ($P < .0001$). There was significant variation in transplant volume by center (Figure 2). The proportion of patients seen by a provider type varied significantly across centers (Table 2). The majority of patients (85.3%) saw a nephrologist, and this proportion ranged between 82.5% and 94.7% across centers ($P < .0001$). The type of surgeon also varied across centers. Urologists performed all transplant in 3 centers, while in the other 2, there was a mixture of urologists and general surgeons. The proportion of patients who had a urologist perform their transplant ranged between 43.5% and 94.8%, and the proportion who had a general surgeon ranged between 0% and 51.3% across centers (both $P < .0001$). A total 63.5% of patients had a combination of nephrologist and urologist as their care providers; this proportion ranged between 37.5% and 78.5% and varied significantly across centers ($P < .0001$). Nephrologist and urologist was the most common combination of care providers (Table 2).

Provider Characteristics

There were 185 physicians across 5 centers providing the initial care during the transplant admissions from 2000 to 2013. This included nephrologists (n = 66), surgeons (n = 67; urologists and general surgeons) and fellows (specialist undertaking further training; n = 32), and internists and family physicians (n = 20). The characteristics of these physicians are summarized in Table 3. Overall, the majority of encounters were with male providers, and this varied between 71.8% and 100% depending on the specialty. The proportion of encounters with male providers varied significantly by center for nephrologists, urologists, and fellows. Overall, the proportion of encounters with providers who were Canadian graduates ranged between 61.0% and 97.8% depending on the specialty and varied significantly by center for nephrologists, urologists, general surgeons, and fellows. There were significant differences across centers in the provider age and years since graduation for all provider types (all $P < .0001$).

Patient Outcomes

Table 4 describes between-center variation in patient outcomes that occurred during the initial transplant hospitalization. The overall median (IQR) length of the initial transplant admission was 8 (7-12) days and the median time varied significantly across centers from 7 to 9 ($P < .0001$). The overall length of stay decreased significantly with time: 9 (7-14) in

Table 1. Characteristics of Kidney Transplant Recipients and Donors Across Centers at the Time of Transplant.

Patient characteristics	Overall cohort (N = 5037)	Center A (n = 720)	Center B (n = 909)	Center C (n = 1206)	Center D (n = 1395)	Center E (n = 807)	*P* value[a]
Age, y, mean (SD)	50.9 (13.5)	51.2 (13.6)	51.5 (13.1)	50.7 (13.6)	50.5 (13.6)	51.0 (14.0)	.44
Age, n (%)							
18-34	690 (13.7)	90 (125)	119 (13.1)	164 (13.6)	197 (14.1)	120 (14.9)	
35-49	1473 (29.2)	229 (31.8)	249 (27.4)	365 (30.2)	405 (29)	225 (27.9)	
50-59	1348 (26.8)	181 (25.1)	244 (26.8)	318 (26.4)	393 (28.2)	212 (26.3)	
60-69	1183 (23.5)	156 (21.6)	229 (25.2)	292 (24.2)	317 (22.7)	189 (23.4)	
≥70	343 (6.8)	64 (8.9)	68 (7.5)	67 (5.6)	83 (5.9)	61 (7.6)	
Male, n (%)	3177 (63.1)	467 (64.9)	592 (65.1)	725 (60.1)	865 (62.0)	528 (65.4)	.04
Race, n (%)							
Caucasian	3194 (63.4)	525 (72.9)	659 (72.5)	577 (47.8)	792 (56.8)	641 (79.4)	
African	361 (7.2)	39 (5.4)	22 (12.4)	133 (11.0)	155 (11.1)	12 (1.3)	
Asian	345 (6.8)	37 (5.1)	27 (3.0)	158 (13.1)	103 (7.4)	20 (2.5)	
Other	634 (12.6)	48 (6.7)	50 (5.5)	228 (18.9)	239 (17.1)	69 (8.5)	
Unknown	503 (10.0)	71 (9.9)	151 (16.6)	110 (9.1)	106 (7.6)	65 (8.1)	<.0001
Cause of ESRD, n (%)							
Glomerulonephritis	1684 (33.4)	225 (31.3)	280 (30.8)	435 (36.1)	479 (34.3)	265 (32.8)	
Diabetes	990 (19.7)	180 (25.0)	181 (19.9)	190 (15.8)	280 (20.1)	159 (19.7)	
Cystic kidney disease	680 (13.5)	109 (15.1)	127 (14.0)	153 (12.7)	201 (14.4)	90 (11.2)	
Renal vascular	553 (11.0)	58 (8.1)	65 (7.2)	146 (12.1)	171 (12.3)	113 (14.0)	
Other	733 (14.6)	102 (14.1)	134 (14.7)	150 (12.4)	202 (14.5)	145 (18.0)	
Unknown	397 (7.9)	46 (6.4)	122 (13.4)	132 (10.9)	62 (4.4)	35 (4.3)	<.0001
BMI, mean (SD)	26.6 (5.7)	27.1 (6.1)	27.6 (6.1)	25.5 (5.3)	26.4 (5.6)	26.8 (5.4)	<.0001
Missing, n (%)	850 (16.9)						
Charlson comorbidity index							
Mean (SD)	2.7 (1.3)	2.8 (1.3)	2.9 (1.3)	2.6 (1.3)	2.7 (1.4)	2.8 (1.3)	<.0001
Missing, n (%)	275 (5.5)						
Pretransplant dialysis modality, n (%)							
Preemptive	515 (10.2)	95 (13.2)	94 (10.3)	135 (11.2)	162 (11.6)	29 (3.6)	
Hemodialysis	3379 (67.1)	443 (61.5)	664 (73.1)	809 67.1)	917 (65.7)	546 (67.7)	
Peritoneal dialysis	1143 (22.7)	182 (25.3)	151 (16.6)	262 (21.7)	316 (22.7)	232 (28.8)	<.0001
Time on dialysis prior to transplant, y[b]							
Median (IQR)	2.7 (1.1-5.1)	2.4 (0.8-4.1)	2.8 (1.3-5.0)	4.2 (1.3-6.6)	3.2 (1.2-5.5)	1.8 (1.1-3.0)	<.0001
Comorbidity prevalence, n (%)							
Diabetes	1406 (27.9)	226 (31.4)	264 (29)	302 (25)	392 (28.1)	222 (27.5)	.04
Hypertension	3807 (75.6)	499 (69.3)	702 (77.2)	917 (76)	1054 (75.6)	635 (78.7)	.0003
Congestive heart failure	961 (19.1)	144 (20.0)	184 (20.2)	222 (18.4)	271 (19.4)	140 (17.4)	.5
Coronary artery disease	2049 (40.7)	186 (25.8)	717 (78.9)	394 (32.7)	532 (38.1)	220 (27.3)	<.0001
COPD	NR	≤5	19 (2.1)	19 (1.6)	8 (0.6)	25 (3.1)	.0001
PVD	720 (14.3)	62 (8.6)	193 (21.2)	175 (14.5)	207 (14.8)	83 (10.3)	<.0001
Chronic liver disease	595 (11.8)	76 (10.6)	77 (8.5)	126 (10.5)	210 (15.1)	106 (13.1)	<.0001
Cancer	1326 (26.3)	184 (25.6)	222 (24.4)	306 (25.4)	379 (27.2)	235 (29.1)	.18
Stroke	46 (0.9)	12 (1.7)	15 (1.7)	10 (0.8)	9 (0.7)	9 (1.1)	.08
TIA	25 (0.5)	7 (0.9)	7 (0.7)	NR	6 (0.4)	NR	.1
Live rural, n (%)[c]	559 (11.1)	135 (18.7)	70 (7.7)	53 (4.4)	114 (8.2)	187 (23.2)	<.0001
Donor type, n (%)							
Deceased/missing[d]	2922 (58.0)	392 (54.4)	511 (56.2)	701 (58.1)	694 (49.7)	624 (77.3)	
Living	2115 (42.0)	328 (45.6)	398 (43.8)	505 (41.9)	701 (50.3)	183 (22.7)	<.0001
Living only							
Age, mean (SD)	44.5 (13.3)	46.6 (13.5)	45.8 (14.5)	42.8 (12.2)	43.4 (12.4)	46.9 (15.3)	<.0001
Male, n (%)	845	137 (41.8)	158 (39.7)	175 (34.7)	299 (42.7)	76 (41.5)	.22
Deceased only							
Age, mean (SD)	45.5 (15.9)	43.8 (15.9)	43.6 (14.7)	46.3 (16.3)	48.8 (16.2)	43.4 (15.9)	<.0001
Male, n (%)	1680	203 (53)	293 (57.6)	405 (48.6)	399 (58.3)	380 (61.7)	.29

(Continued)

Table 1. (continued)

Patient characteristics	Overall cohort (N = 5037)	Center A (n = 720)	Center B (n = 909)	Center C (n = 1206)	Center D (n = 1395)	Center E (n = 807)	*P* value[a]
Most common causes of donor death, n (%)							
CNS[e]	1461 (29.0)	200 (52.1)	246 (48.3)	355 (51.3)	385 (56.1)	275 (44.6)	
Trauma[f]	708 (14.1)	100 (26)	128 (25.2)	158 (22.8)	124 (18.1)	198 (32.1)	
Anoxia/hypoxia	417 (8.3)	51 (13.3)	84 (16.5)	104 (15.0)	90 (13.1)	88 (14.3)	<.0001
Class 1 PRA peak, %							
Median (IQR)	0 (0-11)	4 (1-12)	0 (0-0)	0 (0-15)	0 (0-20)	0 (0-7)	<.0001
Missing, n (%)	925 (18.4)						

Note. "≤5" implies n is smaller than or equal to 5 and thus cannot be reported due to privacy concerns. NR = not reported to prevent unblinding of small cell numbers in other columns. ESRD = end-stage renal disease; BMI = body mass index; IQR = interquartile range; COPD = chronic obstructive pulmonary disease; PVD = peripheral vascular disease; TIA = transient ischemic attack; PRA = panel reactive antibody; CNS = central nervous system.
[a]Chi-square test for categorical variables, ANOVA for normally distributed continuous variables (age, BMI, Charlson comorbidity index, deceased, and living age), and Kruskal-Wallis test for nonnormal (time on dialysis and PRA).
[b]This time includes those who did not spend time on dialysis as well.
[c]Rural is defined as living in an area with <10 000 people.
[d]The total under deceased also includes those with missing status.
[e]CNS related includes cerebrovascular, CNS tumor, ruptured cerebral aneurysm, spontaneous intracranial hemorrhage, intracranial event, CNS infection, and cerebral edema.
[f]Trauma includes trauma not from motor vehicle, trauma from motor vehicle and gunshot.

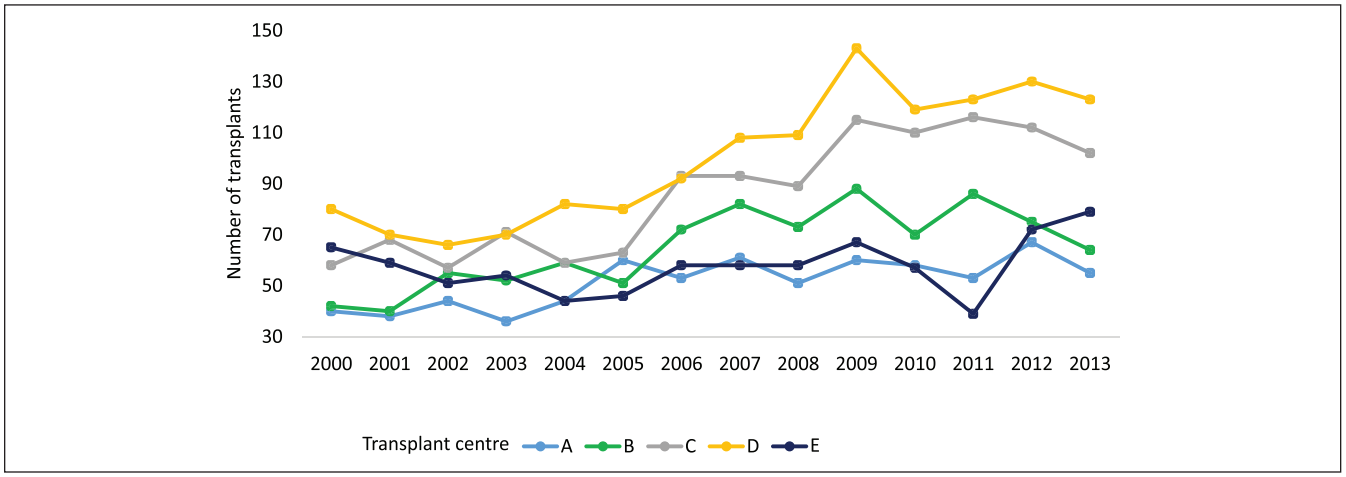

Figure 2. Kidney transplant volume performed per year over the study period at individual transplant center.

2000-2004, 8 (7-11) in 2005-2009, and 7 (6-10) in 2009-2013 ($P < .0001$). There were less than 31 in-hospital deaths, and the proportion of deaths did not vary significantly across centers ($P = .3$). There were 25.1% of recipients who required posttransplant dialysis in hospital; the percentage ranged significantly between centers from 18.3% to 34.5% ($P < .0001$). The majority of patients who required dialysis were those who had received a deceased donor graft (71.8% [909 of 1266]). The proportion of patients requiring dialysis in hospital fluctuated with time: 26.0% in 2000-2004, 25.9% in 2005-2009, and 23.8% in 2009-2013 ($P = .12$). Overall, 24.6% of recipients transplanted after March 30, 2002, required admission to intensive care including the step-down unit; this percentage ranged between 5.7 and 58.0 across centers ($P < .0001$). The proportion requiring admission to the ICU increased significantly with time: 8.4% in 2002-2004, 25.3% in 2005-2009, and 30.6% in 2009-2013 ($P < .0001$).

Adjusted HRs—Length of Stay Censoring at Time of Death

Center-specific HRs for length of stay censored at the time of death obtained from Cox proportional hazards regression models revealed statistically significant differences across centers, after accounting for patient case mix only ($P < .0001$), adding center volume ($P < 0.0001$) and provider characteristics ($P < .0001$). Center-specific HRs ranged between 0.75 (95% CI: 0.69-0.82) and 1.29 (95% CI: 1.20-1.38) in the full models. Patient characteristics found to be statistically significantly associated with this outcome

Table 2. Percentage of Patients Overall and Across Each Center Who Saw the Listed Provider Type.

	Overall cohort (N = 5016)	Center A (n = 717)	Center B (n = 905)	Center C (n = 1200)	Center D (n = 1387)	Center E (n = 807)	*P* value[a]
Provider type							
Nephrologist, n (%)	4277 (85.3)	569 (79.4)	756 (83.5)	990 (82.5)	1198 (86.4)	764 (94.7)	<.0001
Fellow,[b] n (%)	567 (11.3)	7 (0.98)	24 (2.7)	282 (23.5)	19 (1.4)	235 (29.1)	<.0001
Internist, n (%)	222 (4.4)	72 (10.0)	26 (2.9)	62 (5.2)	38 (2.8)	24 (3.0)	<.0001
Urologist, n (%)	3746 (74.7)	502 (70.0)	858 (94.8)	1138 (94.8)	603 (43.5)	645 (79.9)	<.0001
General surgeon, n (%)	1125 (22.4)	251 (35.0)	0	0	711 (51.3)	163 (20.2)	<.0001
Combination							
Nephrologist + Urologist, n (%)	3186 (63.5)	410 (57.2)	710 (78.5)	933 (77.8)	520 (37.5)	613 (76.0)	<.0001
Nephrologist + General surgeon, n (%)	932 (18.6)	176 (24.5)	0	0	601 (43.3)	155 (19.2)	<.0001
Internist + Urologist, n (%)	161 (3.2)	46 (6.4)	26 (2.9)	60 (5.0)	11 (0.8)	18 (2.2)	<.0001
Internist + General surgeon, n (%)	NR	32 (4.5)	0	0	27 (1.9)	≤5	<.0001
Fellow + Urologist, n (%)	485 (9.7)	7 (1.0)	23 (2.5)	269 (22.4)	9 (0.6)	177 (21.9)	<.0001
Fellow + General surgeon, n (%)	47 (0.9)	≤5	0	0	<10	37 (4.6)	<.0001

Note. The sample size in this table includes those participants who had at least 1 physician (medical or surgical) billing code associated with their admission. The proportions for surgical providers do not sum up to 100 at a given center as more than 1 provider may have billed. "≤5" implies n is smaller than or equal to 5 and thus cannot be reported due to privacy concerns. NR = not reported to prevent unblinding of small cell numbers in other columns.

[a]*P* value was calculated using chi-square or Fisher exact test.

[b]Fellows which means qualified specialist undertaking further training.

Table 3. Characteristics of Physicians Providing Care to the Included Kidney Transplant Recipients Across Centers.

Physician characteristics	Overall cohort	Center A	Center B	Center C	Center D	Center E	*P* value[a]
Nephrologists	N = 66	18	19	12	6	11	
Encounters	N = 4328	570	776	1009	1208	765	
Male, n (%)	3798 (87.7)	396 (69.5)	555 (71.5)	945 (93.7)	1137 (94.1)	765 (100)	<.0001
Canadian graduate, n (%)	3509 (80.9)	536 (94.0)	546 (70.4)	711 (70.5)	1208 (100)	508 (66.4)	<.0001
Age, mean (SD)	47.0 (10.2)	41.8 (7.0)	46.7 (8.9)	43.2 (6.6)	51.6 (12.6)	49.2 (9.3)	<.0001
Years since graduation, mean (SD)	21.3 (10.3)	16.6 (7.2)	19.1 (9.2)	18.5 (6.2)	26.2 (12.7)	23.0 (9.9)	<.0001
Urologists[b]	N = 42	<10	8	13	7	<10	
Encounters	N = 4401	524	975	1503	616	783	
Male, n (%)	4175 (98.2)	524 (100)	975 (100)	1345 (94.7)	614 (100)	717 (100)	<.0001
Canadian graduate, n (%)	3378 (79.5)	515 (98.3)	946 (97.0)	989 (69.6)	611 (99.5)	717 (100)	<.0001
Age, mean (SD)	46.7 (11.6)	41.6 (6.9)	45.9 (6.5)	46.5 (12.9)	62.8 (5.3)	38.0 (6.0)	<.0001
Years since graduation, mean (SD)	20.9 (11.6)	15.7 (6.0)	20.2 (6.8)	20.5 (12.3)	37.8 (5.5)	12.4 (6.7)	<.0001
General surgeons[b]	N = 25	<10	0	0	14	<10	
Encounters	N = 1189	252	0	0	757	180	
Male, n (%)	1167 (99.8)	252 (100)	NA	NA	738 (99.7)	175 (100)	.4
Canadian graduate, n (%)	713 (61.0)	0	NA	NA	669 (90.4)	41 (23.4)	<.0001
Age, mean (SD)	50.4 (10.6)	65.6 (3.0)	NA	NA	46.1 (7.7)	46.3 (7.8)	<.0001
Years since graduation, mean (SD)	25.6 (11.0)	41.6 (3.0)	NA	NA	20.7 (7.5)	22.9 (8.5)	<.0001
Fellows[c]	N = 32	≤5	≤5	8	11	8	
Encounters	N = 582	7	24	286	20	244	
Male, n (%)	471 (71.8)	7 (100)	24 (100)	179 (62.6)	17 (85)	244 (100)	<.0001
Canadian graduate, n (%)	568 (97.8)	≤5	24 (100)	285 (99.7)	15 (75)	241 (98.8)	<.0001
Age, mean (SD)	32.9 (2.3)	34.6 (2.1)	39.1 (2.5)	32.4 (1.6)	37.3 (5.3)	32.6 (1.1)	<.0001
Years since graduation, mean (SD)	6.2 (1.8)	9.7 (3.2)	7.5 (1.0)	5.9 (0.8)	10.7 (6.8)	6.1 (1.1)	<.0001

Note. NA = not applicable as there are no providers of that type at the given center. "≤5" implies n is smaller than or equal to 5 and thus cannot be reported due to privacy concerns.

[a]Chi-square test or Fisher's exact test for categorical variables and ANOVA for continuous variables (age and years since graduation).

[b]For some provider types, the physician characteristic was missing and, therefore, the denominator used is different than total encounters. For example, the denominator used for urologists was 4250 as this was the sample size who had information.

[c]Fellows which means qualified specialist undertaking further training.

Table 4. Description of In-Hospital Patient Outcomes Among Kidney Transplant Recipients During Their Transplant Admission 2000-2013 Across Centers.

In-hospital outcome	Overall cohort (N = 5037)	Center A (n = 720)	Center B (n = 909)	Center C (n = 1206)	Center D (n = 1395)	Center E (n = 807)	*P* value[a]
Length of transplant admission, d, median (IQR)	8 (7-12)	8 (7-12)	7 (6-10)	7 (6-9)	9 (7-13)	9 (7-13)	<.0001
Proportion requiring dialysis posttransplant, n (%)	1266 (25.1)	133 (18.5)	166 (18.3)	296 (24.5)	468 (33.5)	203 (25.2)	<.0001
Time to dialysis, d, median (IQR)	4 (2-5)	3 (2-5)	5 (3-6)	4 (3-5)	3 (2-5)	4 (2-5)	<.0001
Number of deaths during admission, n (%)	<31	≤5	≤5	12 (0.9)	7 (0.5)	≤5	.3
Number transplanted after March 2002	N = 4405	n = 634	n = 809	n = 1061	n = 1230	n = 671	
Admission to ICU,[b] n (%)	1088 (24.7)	36 (5.7)	147 (18.2)	112 (10.6)	714 (58.0)	79 (11.8)	<.0001

Note. "≤5" implies n is smaller than or equal to 5 and thus cannot be reported due to privacy concerns. IQR = interquartile range; ICU = intensive care unit.

[a]Chi-square test for categorical variables and Kruskal-Wallis test for continuous variables (length of admission, length of stay in ICU, time to dialysis, and time to death).

[b]This was determined based on billing codes and only among those transplanted after April 1, 2002 (n = 4405) and includes the step-down unit (see Appendix).

included recipient sex, age, BMI, Charlson comorbidity index, time on dialysis, donor type, donor age, and time era. Center volume, provider experience, and all provider types were not significantly associated with the outcome with the exception of fellow (Table 5).

Discussion

To our knowledge, this is the first Canadian study to assess variation in inpatient outcomes, practice patterns, and provider characteristics in kidney transplantation. In this population-based retrospective cohort study, we found substantial heterogeneity in not only patient factors but also patterns of care defined by provider characteristics in a single Canadian province. Furthermore, the length of hospital admission post kidney transplantation varied significantly across Ontario transplant centers, and this variation was not explained by patient factors, center volume, or provider experience.

Our study found significant between-center differences in patient-level factors. For example, the prevalence of medical comorbidities, such as diabetes, hypertension, and peripheral vascular disease varied substantially across centers, as did average Charlson comorbidity index. Our findings are similar to an earlier Canadian study by Kim et al in which the range in the proportion of transplant recipients over the age of 65 varied across centers (between 1.1% and 13.8%), as did the proportion of recipients with diabetes mellitus as the primary cause of ESRD (between 5.5% and 23.9%) and those receiving a graft from a living donor (between 1.3% and 32.2%).[22] It is well known that kidney transplant recipients commonly have at least 1, if not multiple comorbid conditions at the time of transplant and that these comorbidities are associated with an increased length in hospital stay post transplantation.[8,12] In our study, the HR for Charlson comorbidity index was 0.92 (95% CI: 0.90-0.94), implying that each 1-unit increase in the score was associated with a 9% decreased risk of being discharged from the hospital and therefore increased length of stay.

Our study observed substantial variation in kidney transplant volume and the type of physician providing care during the posttransplant admission at the center level. Center volume was not independently associated with length of stay post kidney transplantation. This is similar to what has been found in prior studies. Weng et al did not find a significant association between center volume (using a categorical threshold of 95 patients) and length of hospital stay.[14] Neither did the study by Tsao et al which used a categorical threshold of 72 transplants.[13] In contrast to our study, which used multivariable modeling, neither of these studies adjusted for patient factors when testing for significance.

The majority of the studies published to date, within the field of kidney transplantation, assessing center-level variables have included center volume (generally defined as the number of transplants over a given time period or a categorical threshold) and proportion of recipient and donor types transplanted at a center.[9,22,23] For example, the US-based study by Orandi et al which aimed to determine center-level variables associated with the incidence of delayed graft function (DGF) found significant heterogeneity even after adjusting for patient- and center-level characteristics.[23] Center-level variables found to impact DGF incidence included a center's proportion of donation after cardiac death, of imported kidneys, of preemptive transplants and kidneys with cold ischemia time greater than 30 hours. Interestingly, center volume was not associated with DGF incidence. The hypothesis by Orandi et al was that differences in these variables reflect a center's experience managing the kidney transplant population; however, these variables may simply represent

Table 5. Center-Specific Hazard Ratios From Multivariable Cox Proportional Hazards Regression Analysis of Hospital Discharge, Censoring for Death.

	Adjusting for patient case mix only (n = 5037)	Adjusting for patient case mix and center volume (n = 5037)	Adjusting for patient case mix, center volume, and provider characteristics (n = 5037)
Covariate	HR (95% CI)	HR (95% CI)	HR (95% CI)
Age, (per 5-year increase)	0.95 (0.94-0.97)	0.95 (0.94-0.97)	0.95 (0.94-0.97)
Sex			
Female	0.91 (0.86-0.96)	0.91 (0.85-0.96)	0.90 (0.85-0.96)
Male	Reference	Reference	Reference
Race			
Caucasian	0.96 (0.88-1.05)	0.96 (0.88-1.05)	0.96 (0.88-1.05)
African	0.93 (0.82-1.06)	0.93 (0.82-1.06)	0.93 (0.81-1.05)
Asian	0.97 (0.85-1.11)	0.97 (0.85-1.11)	0.96 (0.84-1.09)
Other[a]	Reference	Reference	Reference
Cause of ESRD			
GN	1.02 (0.93-1.11)	1.02 (0.93-1.11)	(0.93-1.11)
Diabetes	1.00 (0.90-1.12)	1.00 (0.90-1.12)	(0.90-1.12)
Cystic	1.09 (0.98-1.22)	1.09 (0.98-1.22)	1.09 (0.98-1.22)
RVD	1.03 (0.92-1.16)	1.03 (0.92-1.16)	1.04 (0.92-1.16)
Other	Reference	Reference	Reference
BMI (per 1 unit)	0.99 (0.98-0.99)	0.99 (0.98-0.99)	0.99 (0.98-0.99)
Charlson comorbidity Index (1 unit)	0.92 (0.90-0.95)	0.92 (0.90-0.95)	0.92 (0.90-0.94)
Preemptive transplant	(0.91-1.12)	(0.90-1.12)	(0.91-1.12)
Pretransplant dialysis[b]	Reference	Reference	Reference
Time on dialysis pretransplant (per 1-year increase)	0.94 (0.93-0.95)	0.94 (0.93-0.95)	0.94 (0.93-0.95)
Donor type			
Living	1.27 (1.18-1.37)	1.27 (1.18-1.36)	1.25 (1.15-1.34)
Deceased	Reference	Reference	Reference
Donor age (per 5-year increase)	0.98 (0.97-0.99)	0.98 (0.97-0.99)	0.97 (0.96-0.98)
Time era of transplant			
2000-2004	Reference	Reference	Reference
2005-2009	1.33 (1.24-1.44)	1.30 (1.21-1.41)	1.33 (1.22-1.44)
2009-2013	1.84 (1.71-1.98)	1.75 (1.58-1.94)	1.80 (1.62-2.01)
Center[c]			
A	0.93 (0.87-0.99)	0.95 (0.88-1.03)	0.95 (0.87-1.03)
B	1.31 (1.24-1.40)	1.33 (1.25-1.41)	1.28 (1.20-1.37)
C	1.32 (1.25-1.40)	1.29 (1.21-1.38)	1.29 (1.20-1.38)
D	0.76 (0.72-0.80)	0.73 (0.67-0.79)	0.75 (0.69-0.82)
E	0.81 (0.76-0.87)	0.83 (0.77-0.90)	0.85 (0.79-0.92)
Center volume (per 25 patients)		1.04 (0.98-1.10)	1.03 (0.98-1.09)
Average provider experience (per 5 years experience)			0.99 (0.97-1.01)
Provider type			
Urologist			1.00 (0.91-1.11)
General surgeon			0.91 (0.83-1.03)
Fellow			0.86 (0.78-0.96)
Nephrologist			0.99 (0.90-1.09)
Internist			1.08 (0.92-1.27)

Note. HR = hazard ratio; CI = confidence interval; ESRD = end-stage renal disease; GN = glomerulonephritis; RVD = renal vascular disease; BMI = body mass index.

[a]Includes Aboriginal, Indian subcontinent, Pacific Islander, Multiracial.

[b]Includes both peritoneal dialysis and hemodialysis.

[c]The reference is the average across all centers.

differences in case mix and do not necessarily reflect differences in patient care.[23]

To our knowledge, only 1 study has evaluated differences in provider types across kidney transplant centers. Israni et al studied the structure and delivery of care in 208 adult kidney transplant centers in the United States using surveys.[6] Similar to our study, they found significant variation in the type of provider caring for kidney transplant recipients in hospital immediately after transplantation. For example, most of the centers surveyed in their study had nephrology subspecialty trainees (60.3%) and general surgery trainees (71.8%) providing inpatient care, whereas only 24.4% of centers had urology trainees. In their study, 60.2% of the nephrologists and 48.1% of the transplant surgeons surveyed had worked at the transplant center for more than 10 years. Provider experience and characteristics across the centers were not studied. Little is known about differences in provider experience (years in practice) and provider volume (physician caseload) in kidney transplantation in association with length of hospital stay. In our study, we found that both the type of surgeons (urologist vs general surgeon) patients had for their transplant and provider years of experience (defined as years since graduation) varied significantly across centers. Interestingly, the average provider experience was not associated with length of stay. Only 1 prior study assessed for a similar association. Weng et al found greater provider volume (defined as more than 33 transplants) was associated with a shorter length of hospital stay; this analysis did not adjust for patient case mix.[14]

Our study is the first Canadian study to characterize differences in center- and provider-level care during kidney transplantation. The strengths of our study include the large sample size of transplant patients obtained from a validated kidney transplant registry[17] and our ability to describe provider characteristics across transplant centers in a large Canadian province with a universal health care system. There are several limitations to this study, the majority of which relate to the provider information. First, we did not incorporate all inpatient transplant-related provider encounters as we elected to include only the billing codes that were used on the day of transplant. The provider information was captured by using transplant-specific OHIP billings linked to IPDB which has not yet been validated in the transplant setting. Although a prior study[24] which used administrative databases also found the number of new and active nephrologists in Ontario was similar when defined using OHIP billings compared with IPDB listing thus supporting the use of IPDB for identifying providers. Second, we were unable to identify the type of specialty a fellow was part of and therefore do not have information on who is intimately involved in the day-to-day care. However, the overall objective was to provide a brief overview and not specific details which we admit is not possible with administrative data. Third, we included data from only 1 province and therefore cannot generalize our results to the rest of the country; however, Ontario has the greatest number of transplant centers and performs the highest volume in the country. For example, between 2005 and 2014, there were 5000 kidney transplants performed in Ontario alone representing 42% of Canada's kidney transplant volume.[3] Finally, as we relied on the use of administrative data, and we were limited to the detail provided within the registry, there were missing data for some of the variables of interest including cold ischemia time, HLA mismatch, and ABO-incompatible status which precluded our ability to compare these factors. Furthermore, clinical information on immunosuppressive medications and biopsy results used in a given center are not available within this administrative dataset.

In summary, this study found significant variation in important patient outcomes such as length of hospital stay, following kidney transplantation. We also showed that there were differences at the patient-, center-, and provider-level among Ontario kidney transplant centers. The variation seen across centers in the length of stay was not explained by patient case mix, center volume, or provider characteristics alone which implies that additional unmeasured factors may be involved. The results of our study have important clinical implications as they confirm that Ontario transplant centers vary substantially in the type of patient deemed acceptable for transplantation and certain patient characteristics such as greater BMI, comorbidities, and older donor age are associated with an increased length of hospital stay. Future studies are needed to examine the influence of length of stay and practice patterns on long-term outcomes such as patient/graft survival and quality of life.

Appendix

Table A1. Strobe Checklist.

	Item No.	Recommendation	Reported on Page No.
Title and abstract	1	a. Indicate the study's design with a commonly used term in the title or the abstract	Title/Abstract
		b. Provide in the abstract an informative and balanced summary of what was done and what was found	Abstract

(continued)

Table A1. (continued)

	Item No.	Recommendation	Reported on Page No.
Introduction			
Background/ rationale	2	Explain the scientific background and rationale for the investigation being reported	Introduction
Objectives	3	State specific objectives, including any prespecified hypotheses	Introduction
Methods			
Study design	4	Present key elements of study design early in the paper	Methods
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Methods
Participants	6	a. Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	Methods, Figure 1
		b. For matched studies, give matching criteria and number of exposed and unexposed	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Methods
Data sources/ measurement	8	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than 1 group	Supplemental table
Bias	9	Describe any efforts to address potential sources of bias	Methods
Study size	10	Explain how the study size was arrived at	Methods, Figure 1
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Methods
Statistical methods	12	a. Describe all statistical methods, including those used to control for confounding	NA
		b. Describe any methods used to examine subgroups and interactions	Methods
		c. Explain how missing data were addressed	Methods
		d. If applicable, explain how loss to follow-up was addressed	NA
		e. Describe any sensitivity analyses	NA
Results			
Participants	13	a. Report numbers of individuals at each stage of study—for example, numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analyzed	Figure 1
		b. Give reasons for nonparticipation at each stage	Figure 1
		c. Consider use of a flow diagram	Figure 1
Descriptive data	14	a. Give characteristics of study participants (eg, demographic, clinical, social) and information on exposures and potential confounders	Table 1
		b. Indicate number of participants with missing data for each variable of interest	Table 1/Results
		c. Summarize follow-up time (eg, average and total amount)	Results/Table 4
Outcome data	15	Report numbers of outcome events or summary measures over time	Results, Table 4
Main results	16	a. Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	NA
		b. Report category boundaries when continuous variables were categorized	Table 1
		c. If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—for example, analyses of subgroups and interactions, and sensitivity analyses	Figure 2, Results
Discussion			
Key results	18	Summarize key results with reference to study objectives	Discussion
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Discussion
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Discussion
Generalizability	21	Discuss the generalizability (external validity) of the study results	Discussion
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	After discussion

Note. NA = not applicable.

Table A2. Coding Definitions for Recipient Demographic and Comorbid Conditions.

Characteristic	Database	Codes used
Baseline characteristic of transplant recipients and donors		
Age, sex, rural	RPDB	
Renal transplant	CORR	Treatment_Code: 171 Transplanted_Organ_Type_Code[1-3]: 10, 11, 12, 18, 19
Date of transplant	CORR	Treatment_Date
Cause of primary renal disease	CORR	Glomerulonephritis/Autoimmune disease: 05, 06, 07, 08, 09, 10, 11, 12, 13, 14, 15, 16, 17, 19, 73, 74, 84, 85, 86, 88 Diabetes: 80, 81 Cystic kidney disease: 40, 41, 42, 43, 49 Renal vascular disease: 70, 71, 72, 79 Other: 20, 21, 22, 23, 24, 25, 29, 30, 31, 32, 33, 39, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 66, 78, 82, 83, 87, 89, 90, 91, 92, 93, 94, 95, 96, 97, 99 Unknown: 00, 98
Race	CORR	Caucasian: 01 Asian: 02 African American: 03 Indian: 05 Other: 08, 09, 10, 11, 99 Unknown: 98
Body mass index	CORR	Initial_Height Initial_Weight
Dialysis modality	CORR	Hemodialysis: 111, 112, 113, 121, 122, 123, 131, 132, 133, 211, 221, 231, 311, 312, 313, 321, 322, 323, 331, 332, 333, 413, 423, 433 Peritoneal dialysis: 141, 151, 152, 241, 242, 251, 252, 443, 453 Other: 060
Time on dialysis	CORR	TRANSPLANT ([Treatment_Date] & [Treatment_Code]) – DIALYSIS ([Treatment Date] & [Treatment_Code])
Preemptive	CORR	
Donor source	CORR	Living: 02, 03, 04, 05, 06, 07, 10, 12, 15 Deceased: 01 Unknown/Out-of-country transplant: 98
Donor age	CORR	Donor Age_Units
Donor sex	CORR	
Cause of donor death	CORR	CNS related: 01,02,06,07,08,10,11,13 Motor vehicle/trauma: 03,04,09 Poison: 05,12 Unknown: 98 Other: 99
Diabetes	CIHI-DAD/ OHIP	ICD9: 250 ICD10: E10, E11, E13, E14 OHIP diagnosis: 250 OHIP fee: Q040, K029, K030
Hypertension	CIHI-DAD/ OHIP	ICD9: 401, 402, 403, 404, 405 ICD10: I10, I11, I12, I13, I15 OHIP diagnosis: 401, 402, 403
Congestive heart failure	CIHI-DAD/ OHIP	ICD9: 425, 5184, 428, 514 ICD10: I500, I501, I509, I255, J81 CCP: 4961, 4962, 4963, 4964 CCI: 1HP53, 1HP55, 1HZ53GRFR, 1HZ53LAFR, 1HZ53SYFR OHIP fee: R701, R702, Z429 OHIP diagnosis: 428
Coronary artery disease without angina	CIHI-DAD/ OHIP	ICD9: 410, 411, 412 ICD10: I21, I22, T82.2, Z95.5 CCP: 48.01, 48.02, 48.03, 48.04, 48.05, 48.1, 48.2, 48.3 CCI: 1IJ50, 1IJ76 OHIP diagnosis code: 410, 412 OHIP fee code: E646, E651, E652, E654, E655, G298, R741, R742, R743, Z434, Z448

(continued)

Table A2. (continued)

Characteristic	Database	Codes used
Peripheral vascular disease	CIHI-DAD/ OHIP	ICD9: 4402, 4408, 4409, 5571, 4439, 444 ICD10: I700, I702, I708, I709, I731, I738, I739, K551 CCP: 5125, 5129, 5014, 5016, 5018, 5028, 5038 CCI: 1KA76, 1KA50, 1KE76, 1KG26, 1KG50, 1KG57, 1KG76MI, 1KG87 OHIP: R787, R780, R797, R804, R809, R875, R815, R936, R783, R784, R785, E626, R814, R786, R937, R860, R861, R855, R856, R933, R934, R791, E672, R794, E672, R794, E672, R813, R867, E649
Chronic obstructive lung disease	CIHI-DAD	ICD9: 491, 492, 496 ICD10: J41, J43, J44
Chronic liver disease	CIHI-DAD/ OHIP	ICD9: 4561, 4562, 070, 5722, 5723, 5724, 5728, 573, 7824, V026, 2750, 2751, 7891, 7895, 571 ICD10: B16, B17, B18, B19, I85, R17, R18, R160, R162, B942, Z225, E831, E830, K70, K713, K714, K715, K717, K721, K729, K73, K74, K753, K754, K758, K759, K76, K77 OHIP diagnosis code: 571, 573, 070 OHIP fee code: Z551, Z554
Cancer		ICD9: V10, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 170, 171, 172, 173, 174, 175, 176, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 230, 231, 232, 233, 234 ICD10: 80003, 80006, 80013, 80023, 80033, 80043, 80102, 80103, 80106, 80113, 80123, 802, 803, 80413, 80423, 80433, 80443, 80453, 80502, 80503, 80513, 80523, 807, 808, 80903, 80913, 80923, 80933, 80943, 80953, 81103, 81202, 81203, 81213, 81223, 81233, 81243, 81303, 81402, 81403, 81406, 81413, 81423, 81433, 81443, 81453, 81473, 81503, 81513, 81523, 81533, 81543, 81553, 81603, 81613, 81623, 81703, 81713, 81803, 81903, 82003, 82013, 82102, 82103, 82113, “82203”, 82213, 823, 82403, 82413, 82433, 82443, 82453, 82463, 82473, 82503, 82513, 82603, 82612, 82613, 82623, 82632, 82633, 82703, 82803, 82813, 82903, 83003, 83103, 83123, 83143, 83153, 83203, 83223, 83233, 83303, 83313, 83323, 83403, 83503, 83703, 83803, 83813, 83903, 84003, 84013, 84103, 84203, 84303, 84403, 84413, 84423, 84503, 84513, 84603, 84613, 84623, 84703, 84713, 84723, 84733, 84803, 84806, 84813, 849, 85002, 85003, 85012, 85013, 85023, 85032, 85033, 85042, 85043, 851, 852, 85303, 854, 85503, 85603, 85623, 857, 85803, 86003, 86203, 86303, 86403, 86503, 86803, 86933, 87003, 87103, 87202, 87203, 87213, 87223, 87233, 87303, 87403, 87412, 87413, 87422, 87423, 87433, 87443, 87453, 87613, 87703, 87713, 87723, 87733, 87743, 87803, 88003, 88006, 88013, 88023, 88033, 88043, 88103, 88113, 88123, 88133, 88143, 88303, 88323, 88333, 88403, 88503, 88513, 88523, 88533, 88543, 88553, 88583, 88903, 88913, 88943, 88953, 88963, 89003, 89013, 89023, 89103, 89203, 89303, 89333, 89403, 89413, 895, 89603, 89633, 89643, 897, 89803, 89813, 89903, 89913, 90003, 90203, 90403, 90413, 90423, 90433, 90443, 90503, 90513, 90523, 90533, 906, 90703, 90713, 90723, 90803, 90813, 90823, 90833, 90843, 90853, 90903, 91003, 91013, 91023, 91103, 91203, 91243, 91303, 91333”, 91403, 91503, 91703, 91803, 91813, 91823, 91833, 91843, 91853, 91903, 92203, 92213, 92303, 92313, 92403, 92503, 92513, 92603, 92613, 92703, 92903, 93103, 93303, 93623, 93643, 93703, 93803, 93813, 93823, 93903, 93913, 93923, 940, 941, 942, 94303, 944, 945, 94603, 947, 948, 94903,95003,95013, 95023, 95033, 95043, 951, 952, 95303, 95393, 95403, 95603, 95613, 95803, 95813, 959, 965, 966, 967, 968, 969, 970, 971, 972, 973, 97403, 97413, 97603, 97613, 97623, 97633, 97643, 980, 982, 98303, 984, 98503, 986, 98703, 98803, 989, 99003, 99103, 993, 994, C00, C01, C02, C03, C04, C05, C06, C07, C08, C09, C10, C11, C12, C13, C14, C15, C16, C17, C18, C19, C20, C21, C22, C23, C24, C25, C26, C30, C31, C32, C33, C34, C37, C38, C39, C40, C41, C43, C44, C45, C46, C47, C48, C49, C50, C51, C52, C53, C54, C55, C56, C57, C58, C60, C61, C62, C63, C64, C65, C66, C67, C68, C69, C70, C71, C72, C73, C74, C75, C76, C77, C78, C79, C80, C81, C82, C83, C84, C85, C86, C88, C90, C91, C92, C93, C94, C95, C96, C97, D00, D01, D02, D03, D04, D05, D06, D07, D09, Z85 OHIP Diagnosis code: 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164,165, 170, 171, 172, 173, 174, 175, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 230, 231, 232, 233, 234

(continued)

Table A2. (continued)

Characteristic	Database	Codes used
Stroke/TIA	CIHI-DAD	ICD9: 434, 435, 436 ICD10: H341, I630, I631, I632, I633, I634, I635, I638, I639, I64, H340, G450, G451, G452, G453, G458, G459
Charlson comorbidity index	CIHI-DAD	Charlson Macro
Peak panel reactive antibody	CORR	PRA_1_PEAK_RESULT CORR
Transplant center	CORR	TREATMENT_FACILITY_NUM
Baseline characteristic of physicians		
Provider type	IPDB	MAINSPEC*
Sex	IPDB	Sex
Provider age	IPDB	BIRTHYR
Provider years since graduation	IPDB	GRADYR
Country of graduation	IPDB	CMG, IMG, USMG

Note. RPDB = Registered Persons Database; CORR = Canadian Organ Reporting Register; CNS = central nervous system; CIHI = Canadian Institute for Health Information Discharge Abstract Database; OHIP = Ontario Health Insurance Plan; CCP = Canadian Classification of Diagnostic Therapeutic and Surgical Procedures; CCI = Canadian Classification of Interventions; TIA = thrombotic ischemic stroke; IPDB = ICES Physician Database; ICES = Institute for Clinical Evaluative Sciences.

Table A3. Coding Definitions for Renal Recipient Outcomes.

Outcomes	Database	Codes used
Death	RPDB	
Length of stay	CIHI-DAD	DCSDATE-ADMDATE
Intensive care unit	CIHI-DAD[a]	SCU: 10, 20, 30, 40, 45, 60, 90, 93, 95, 99
Dialysis post transplant	CIHI-DAD/OHIP	CCP: 5195, 6698 CCI: 1PZ21 OHIP fee: R849, G323, G325, G326, G860, G863, G866, G330, G331, G332, G861, G082, G083, G085, G090, G091, G092, G093, G094, G095, G096, G294, G295

Note. All comorbidities had a 5-year lookback window with the exception of diabetes. RPDB = registered person's database; CIHI = Canadian Institute for Health Information Discharge Abstract Database; SCU = special care unit; CCP = Canadian Classification of Diagnostic Therapeutic and Surgical Procedures; CCI = Canadian Classification of Interventions; OHIP = Ontario Health Insurance Plan.
[a]Prior to March 30 2002, SCU codes were hospital-specific and varied across institutions and cannot be relied upon. Therefore, our analyses for that variable are limited to those recipients who were transplanted after March 30, 2002.

List of Abbreviations

ESRD, end-stage renal disease; ICU, intensive care unit; ICES, Institute for Clinical Evaluative Sciences; CORR, Canadian Organ Replacement Register; ORPB, Ontario Registered Persons Database; CIHI-DAD, Canadian Institute for Health Information Discharge Abstract Database; OHIP, Ontario Health Insurance Plan; IPDB, ICES Physician Database; SD, standard deviation; IQR, interquartile range.

Ethics Approval and Consent to Participate

This study was approved by the institutional review board at Sunnybrook Health Sciences Centre (Toronto, Canada).

Consent for Publication

Not applicable

Availability of Data and Materials

The full data set creation plan is available from the authors upon request however the data sets supporting this article cannot be made available due to privacy restrictions of the Institute for Clinical Evaluative Sciences.

Author Contributions

AT helped conceive the idea and design of the study, performed all statistical analyses, interpreted the results, and drafted the manuscript. SD participated in the study design, data cleaning, statistical analyses, and interpretation of results. MT participated in the design of the study, statistical analyses and interpretation of results, and drafting of the manuscript. CVW participated in the statistical analysis and interpretation of results. SE and DM participated in the study design and interpretation of results. GK and DF helped conceive the idea and design of the study, interpreted the results, and

helped to draft the manuscript. All authors read and approved the final manuscript.

Declaration of Conflicting Interests

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