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Costs and Outcomes of Privately-Insured Kidney Transplant Recipients by Body Mass Index

Patrick M Ercole[1]*, Paula M Buchanan[2], Krista L Lentine[2,3], Thomas E Burroughs[2], Mark A Schnitzler[2] and Kian A Modanlou[4]

[1]*Goldfarb School of Nursing, Barnes-Jewish College, St. Louis, MO, USA*
[2]*Center for Outcomes Research, Saint Louis University, St. Louis, MO, USA*
[3]*Division of Nephrology, Saint Louis University School of Medicine, St. Louis, MO, USA*
[4]*Division of Transplantation, University of Tennessee / Methodist Transplant Institute, Memphis, TN, USA*

Abstract

Background: Obesity presents an additional challenge to the procedure of and recovery from kidney transplantation. As the prevalence of transplant candidates with an elevated body mass index (BMI) grows, researchers need to examine and quantify the increased risks and additional costs associated with the full spectrum of body composition.

Study design: A retrospective cohort study design was used.

Setting and participants: Data from a private health insurance provider were linked with records from the Organ Procurement and Transplantation Network to examine costs and health outcomes following kidney transplantation.

Factor: BMI was used to predict costs and outcomes.

Outcomes: The primary outcome of interest was posttransplant cost defined as insurance charges. Secondary outcomes of interest included delayed graft function, graft failure, patient survival, and length of transplant hospitalization.

Measurements: Categories of BMI followed selected cutoffs from World Health Organization International Classifications. Charges from recipient dialysis center, health providers, and treatment centers following transplant were summed during transplant hospitalization as well as each of three years following transplantation.

Results: Rates of graft failure were significantly increased for underweight, overweight, obese, and morbidly obese recipients. Recipients with elevated BMI had a significantly longer length of transplant hospitalization and an increased rate of delayed graft function.

Limitations: Our analysis was limited to the quality and availability of the data included in the registry. Though inexpensive and easy to calculate, BMI may not be the best measure of body composition. Finally, BMI measurement is cross-sectional at time of transplant thereby limiting the potential for fluctuation of BMI before and after transplantation.

Conclusions: The study results highlight the exponential concern associated with non-normal BMI for kidney transplant recipients. Transplant centers and insurance companies should consider funding weight management programs for transplant candidates as a means of obtaining preferred BMI and reducing costs associated with follow-up care.

Keywords: Renal transplantation; Body mass index; Obesity; Outcomes; Cost

Introduction

The obesity epidemic in the United States has tempered progress in health outcomes made during the past several decades [1-5]. Studies have documented that operating on obese patients leads to longer and more difficult operations with greater complications [6-8]. Furthermore, the requirement to report outcomes and the push to contain costs may lead to shying away from operating on patients who are perceived as having the potential for worse outcomes and increased costs of care.

Reports queried from national databases have confirmed that the prevalence of obese patients added to the kidney transplant (KT) waiting list has sharply increased over the last several years [9-11]. Although there is disagreement, studies have shown that obese recipients can improve survival compared to continued dialysis despite increased risks of mortality and peritransplant complications including delayed graft function, elevated transplant costs, and allograft loss [12-20]. Although benefits of kidney transplantation have been demonstrated among obese dialysis patients, registry-based analyses indicate that overweight and obese transplant candidates are less likely to receive an organ offer than candidates with normal body mass index (BMI) and are more likely to be bypassed when an organ becomes available [11,14].

Inpatient hospital days are the largest contributor to costs in KT [21]. Furthermore, an increased length of hospitalization post-KT has been shown to predict inferior graft and patient survival [22]. The aim of this study was to assess the impact of recipient BMI on the outcome and cost of KT in the first three years posttransplant in a private healthcare system. We examined a novel database linking Organ Procurement and Transplantation Network (OPTN) identifiers for a national sample of renal allograft recipients to administrative data

***Corresponding author:** Patrick M Ercole, 4483 Duncan Ave, Mailstop 90-36-697, Saint Louis, MO 63110, Tel: 314-454-7538; E-mail: percole@bjc.org

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from a private insurance provider. The methods and dataset used in this study replicate previously reported research [23-25].

Methods

Study sample

Upon approval from the institutional review board at Saint Louis University, records from the OPTN, which is overseen by the Health Resources and Services Administration (HRSA), were merged with clinical claim data from a large, private U.S. health insurance provider to form the retrospective cohort of this study. The link between the two sources was made using name, Social Security number, date of birth, and gender. The dataset was limited and de-identified prior to analysis in compliance with the Health Insurance Portability and Accountability Act (HIPAA).

The sample included all adult (age ≥18 years old) cadaveric-donor renal transplant recipients in the dataset from 2000 to 2007. Individuals with multiple-organ transplants or previous transplants were excluded. Recipients were excluded if the total charges of initial transplant hospitalization failed to exceed $30,000.

Definitions and assumptions

BMI was calculated using measurements at time of transplant. BMI groups followed selected cutoffs from World Health Organization (WHO) International Classifications [26]: *underweight* (<18.50 kg/m^2), *normal* (18.50 – 25.00), and *overweight* (25.00 – 29.99). WHO obese (≥30.00) sub classifications were used to further stratify BMI for analysis into *obese* (30.00 – 34.99), *morbidly obese* (35.00 – 40.00), and *extremely morbidly obese* (≥40.00). Recipients with a BMI of less than 10 or greater than 70 were excluded from analysis as invalid outliers.

The primary outcome of interest was posttransplant cost, defined as charges on billing claims submitted to the insurance provider. Claims following recipient transplant were summed during transplant hospitalization as well as each of three years following transplantation. Charges from recipient dialysis center, health providers, and treatment centers comprised costs. All costs were adjusted for inflation with the medical component of the consumer price index using 2004 as the base year.

All claims were included from the date of transplantation until three years of follow-up, death, or end of study date (December 31, 2007). Recipients with incomplete follow-up data due to loss of insurance coverage or end of study within an interval of analysis were excluded from that and subsequent intervals. Recipients who died were included in the interval of analysis and had all charges following death set to zero dollars. In the instance where time between transplant and the end of study date was less than the follow-up time, posttransplant cost was set to missing.

Hospitalization for a kidney transplant was indicated using a diagnosis-related group (DRG) code of "302." Study cost estimates summed all transplant and posttransplant claims until censoring (after which was set to zero dollars). Transplant hospitalization costs were summed from the date of transplant to ninety days following transplant. Posttransplant costs at one-, two- and three-year follow-up times were summed from transplant hospitalization to the end of the time interval.

Secondary outcomes of interest included delayed graft function (DGF), graft failure, patient survival, and length of transplant hospitalization. DGF indicates the organ does not immediately perform properly following transplantation. Graft failure includes the outcome of patient death.

The analysis included covariates on patient gender, race, ethnicity, age at transplant, primary cause of end-stage renal disease (ESRD), pre-transplant dialysis duration, diabetes, and peripheral vascular disease (PVD). Donor-related covariates were donor gender, race, age, BMI category, stroke cause of death, terminal creatinine ≥1.5 mg/dL, history of hypertension, diabetes, and sero-positive cytomegalovirus (CMV). Transplant-related covariates included donor type (standard- and expanded- criteria donor [SCD, ECD] and donation after cardiac death [DCD]), peak panel reactive antibody (PRA) percentage, donor-recipient CMV sero-pairing, number of human leukocyte antigens (HLA) mismatches, sensitization, cold ischemia time, and year of transplant.

Statistical analysis

Unadjusted mean costs, presence of DGF, length of transplant hospitalization as well as recipient, donor, and transplant characteristics between BMI categories were examined for association using the non-parametric Kruskal-Wallis method of one-way analysis of variance by ranks for continuous variables. Post-hoc comparisons were made using Wilcoxon rank sum test with a continuity correction. Chi-square analysis, or a Monte Carlo estimate for Fisher's exact test for small expected cell size, were used to analyze the independence of categorical variables by BMI levels. Multivariate linear regression analysis was utilized to examine costs within each interval of interest according to BMI category while adjusting for the study covariates. Graft failure and patient survival were estimated using the Kaplan-Meier method. Cox proportional hazards analysis, both full and stepwise models, was used to measure the adjusted effect of BMI category on graft and patient survival. Average accumulated costs of care according to BMI were calculated using a modification of the Kaplan-Meier methodology for continuous data [27] utilized in similar analyses [23, 24, 28-30]. Alpha was set at 5% for all significance tests. Data management and analyses were performed using SAS® v.9.2 (SAS Institute, Cary, NC). Tables and figures were created using Microsoft Office Excel® 2007 (Microsoft Corporation, Redmond, WA).

Results

767 privately-insured adult renal transplant recipients were identified by the selection criteria. Among the eligible subjects, the distribution of transplant BMI was 23 *underweight* (3.0%), 267 *normal* (34.8%), 264 *overweight* (34.4%), 161 *obese* (19.7%), 51 *morbidly obese* (6.6%), and 11 *extremely morbidly obese* (1.4%). Recipient, donor, and transplant characteristics by BMI category are summarized in (Table 1). A significant p-value indicates that the variable of interest was not independent by BMI category.

Female transplant recipients differed statistically by BMI and accounted for over three quarters of the *underweight* BMI category. Racial composition illustrated African American recipients generally increased away from *normal* weight. Age group was statistically associated with BMI. The majority of *underweight* recipients were comprised of 31- to 44-year olds with a shift to 45-to 59-year olds in the *overweight* through *extremely morbidly obese* categories. Diabetes mellitus was the most prevalent cause of ESRD for those with a BMI in the *normal* through *morbidly obese* range. Amongst the *underweight*

group, glomerulonephritis was the most common cause of ESRD. The proportion of pre-emptive transplantations, those with no pre-transplant dialysis, was largest for *normal* BMI recipients. Diabetes at time of transplant was less common for *underweight* recipients. PVD was rare across all BMI groups. Distribution of BMI category approached statistical significance for donor age. *Underweight* and *normal* BMI recipients received more of the SCD organs than other BMI groups. Transplant prevalence by BMI category over time is displayed graphically in (Figure 1).

Secondary outcomes of interest by BMI category are displayed in (Figure 2). The prevalence of both DGF and graft failure escalate away from *normal* BMI category. Though graft failure is approaching statistical significance (p = 0.052), only DGF has a significant association with BMI (p = 0.024). Patient death is lowest for *overweight* and *obese* recipients. Length of transplant hospitalization was longest for *extremely morbidly obese* recipients and differed statistically from each BMI level except *underweight*. No additional comparisons of length of transplant hospitalization by BMI group were statistically significant. Of the secondary outcomes, only DGF is significantly different by recipient BMI category distribution.

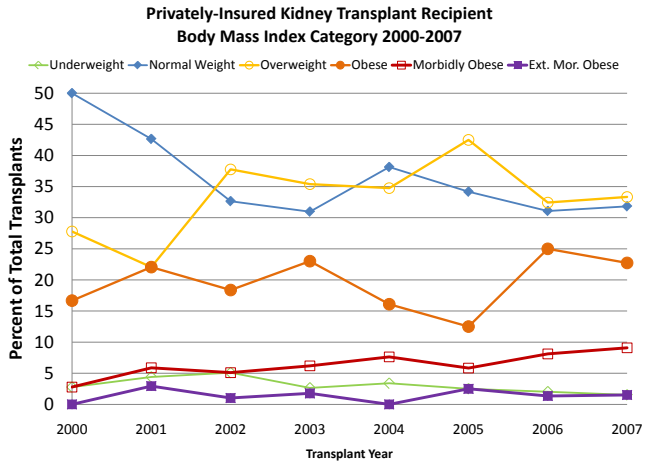

Figure 1: Privately-Insured Kidney Transplant Recipient Body Mass Index Category 2000 – 2007. Description: The proportion of transplant recipients with elevated BMI increased, while the *normal* BMI group decreased, during the study period. This trend is reflected in the general US population over the same time period.

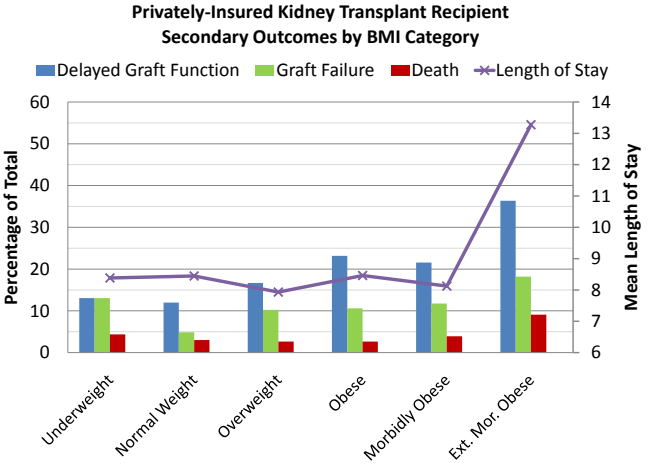

Figure 2: Privately-Insured Kidney Transplant Recipient Secondary Outcomes by BMI Category. Description: The prevalence of both DGF and graft failure increased for *underweight* and elevated BMI categories. Patient death is lowest for *overweight* and *obese* recipients. Length of transplant hospitalization was longest for *extremely morbidly obese* recipients and differed statistically from each BMI level except *underweight*. Of these secondary outcomes, only DGF is significantly different by recipient BMI category distribution.

Average accumulated costs associated with transplant recipient are summarized by BMI categories as well as recipient, donor, and transplant characteristics during the transplant hospitalization and each of the three follow-up periods in (Table 2). When controlling for study covariates, none of the BMI categories were significantly different compared to *normal* BMI recipients during the transplant hospitalization or any of the yearly follow-up periods.

A summary of Cox proportional hazard models is reported in (Table 3). A full regression model of graft failure using Cox proportional hazard analysis showed a significant adjusted increase in effect for *underweight*, *overweight*, *obese*, and *morbidly obese* recipients. A stepwise Cox model on graft failure, with forced entry for the BMI categories, also had significant adjusted increase in effects for *underweight*, *overweight*, *obese*, and *morbidly obese* recipients. No significant adjusted effect was found for patient survival by BMI category using Cox proportional hazards analysis.

Discussion

This study analyzed the impact of BMI on outcomes and cost of care for privately-insured adult kidney transplant recipient between 2000 and 2007 during transplant hospitalization and at one-, two-, and three-years following transplant. We observed that costs of care do not differ statistically by recipient BMI following transplantation when adjusting for numerous patient, donor, and transplant covariates. We also observed that non-*normal* BMI recipients, except the *extremely morbidly obese*, have significantly increased risks for graft failure following transplantation.

The increase in prevalence of obesity in the United States is reflected in the swell of transplant recipients with elevated BMI from 2000 to 2007 (Figure 1) [10]. The dramatic shift and trajectory should be alarming to patients, insurance providers, and transplant centers alike. As the challenge of finding quality organs and healthy kidney recipients escalates, attention on modifiable risk-factors, like BMI, should an integral part of the pre-transplant evaluation system.

Normal BMI recipients had a pre-emptive transplant, thus bypassing dialysis, more often than non-*normal* groups. As less than ideal candidates, non-*normal* BMI recipients utilized dialysis between two and five years more often than *normal* BMI recipients. While the study limits BMI measured at time of transplant, this finding suggests that recipients may have sustained their BMI through candidacy.

Non-*normal* BMI recipients did not fare well in the secondary outcome measures. DGF was not independent of BMI group (p = 0.024). The relative percentage of DGF escalated considerably away from *normal* BMI. The proportion of DGF was smallest for *normal* BMI recipients (11.99%) and swelled steadily as BMI increased to *extremely morbidly obese* (36.36%). Even *underweight* recipients had an increased rate of DGF (13.04%). The proportion of graft failure was increased for non-*normal* BMI recipients, though the difference was slightly

	Underweight		Normal Weight		Overweight		Obese		Morbidly Obese		Ext. Mor. Obese		
Variable	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	p-value
Recipient Characteristics													
Gender													<.001
Female	18	78.26	126	47.19	89	33.71	62	41.06	20	39.22	3	27.27	
Race													<.001†
African American	5	21.74	38	14.23	53	20.08	30	19.87	14	27.45	4	36.36	
Other	3	13.04	37	13.86	43	16.29	15	9.93	3	5.88	1	9.09	
White	15	65.22	192	71.91	168	63.64	106	70.20	34	66.67	6	54.55	
Ethnicity													0.388†
Hispanic	1	4.35	19	7.12	30	11.36	12	7.95	2	3.92	0	0.00	
Age (years)													0.007†
18 - 30	2	8.70	25	9.36	17	6.44	5	3.31	1	1.96	0	0.00	
31 - 44	12	52.17	113	42.32	83	31.44	41	27.15	14	27.45	4	36.36	
45 - 59	7	30.43	92	34.46	114	43.18	79	52.32	25	49.02	6	54.55	
≥ 60	2	8.70	37	13.86	50	18.94	26	17.22	11	21.57	1	9.09	
Primary cause of ESRD													0.727†
Diabetes mellitus	6	26.09	115	43.07	107	40.53	56	37.09	19	37.25	4	36.36	
Glomerulonephritis	8	34.78	50	18.73	53	20.08	31	20.53	11	21.57	1	9.09	
PKD	3	13.04	24	8.99	30	11.36	17	11.26	3	5.88	2	18.18	
Hypertension	3	13.04	36	13.48	44	16.67	25	16.56	6	11.76	3	27.27	
Unknown	0	0.00	1	0.37	3	1.14	1	0.66	0	0.00	0	0.00	
Other	3	13.04	41	15.36	27	10.23	21	13.91	12	23.53	1	9.09	
Pre-Transplant Dialysis Duration													0.446†
None (pre-emptive)	3	13.04	68	25.47	52	19.70	25	16.56	8	15.69	2	18.18	
> 0 - 12 months	5	21.74	51	19.10	52	19.70	29	19.21	7	13.73	1	9.09	
> 12 - 24 months	4	17.39	60	22.47	62	23.48	28	18.54	9	17.65	3	27.27	
> 25 - 60 months	7	30.43	66	24.72	77	29.17	51	33.77	22	43.14	5	45.45	
> 60 months	4	17.39	22	8.24	21	7.95	18	11.92	5	9.80	0	0.00	
Diabetes	7	30.43	120	44.94	125	47.35	64	42.38	20	39.22	6	54.55	0.546
PVD	0	0.00	7	2.62	10	3.79	7	4.64	1	1.96	0	0.00	0.847†
Donor Characteristics													
Gender													0.331
Female	11	47.83	98	36.70	116	43.94	65	43.05	17	33.33	6	54.55	
Race													0.182†
African American	6	26.09	21	7.87	23	8.71	16	10.60	5	9.80	0	0.00	
White	5	21.74	32	11.99	37	14.02	21	13.91	8	15.69	3	27.27	
Other	12	52.17	214	80.15	204	77.27	114	75.50	38	74.51	8	72.73	
Age (years)													0.051†
≤ 18	4	17.39	50	18.73	41	15.53	11	7.28	8	15.69	0	0.00	
19 - 30	6	26.09	81	30.34	62	23.48	44	29.14	11	21.57	2	18.18	
31 - 44	7	30.43	72	26.97	80	30.30	42	27.81	12	23.53	4	36.36	
45 - 59	6	26.09	57	21.35	68	25.76	48	31.79	15	29.41	3	27.27	
≥ 60	0	0.00	7	2.62	13	4.92	6	3.97	5	9.80	2	18.18	
Missing													
BMI category (kg/m²)													0.720
≥ 10 to < 25	11	47.83	147	55.06	132	50.00	73	48.34	24	47.06	3	27.27	
≥ 25 to < 30	7	30.43	77	28.84	80	30.30	45	29.80	18	35.29	4	36.36	
≥ 30	5	21.74	43	16.10	52	19.70	33	21.85	9	17.65	4	36.36	

Death due to stroke	4	17.39	94	35.21	109	41.29	60	39.74	20	39.22	6	54.55	0.173
Terminal Creatinine ≥ 1.5	3	13.04	27	10.11	34	12.88	18	11.92	8	15.69	2	18.18	0.825
Hypertension history	4	17.39	47	17.60	56	21.21	31	20.53	9	17.65	2	18.18	0.925
Diabetes	0	0.00	4	1.50	9	3.41	7	4.64	3	5.88	0	0.00	0.276†
CMV Status													0.619†
Sero-positive	13	0.00	156	1.50	153	0.76	102	0.66	33	0.00	5	0.00	
Missing	0	56.52	4	58.43	2	57.95	1	67.55	0	64.71	0	45.45	
Transplant Factors													
Donor type													0.028†
SCD	22	95.65	238	89.14	220	83.33	128	84.77	40	78.43	9	81.82	
ECD	1	4.35	16	5.99	35	13.26	10	6.62	8	15.69	2	18.18	
DCD	0	0.00	13	4.87	9	3.41	13	8.61	3	5.88	0	0.00	
Peak PRA													0.331†
0-10%	16	69.57	215	80.52	209	79.17	112	74.17	42	82.35	10	90.91	
11-30%	1	4.35	22	8.24	21	7.95	16	10.60	5	9.80	1	9.09	
>30%	4	17.39	27	10.11	31	11.74	20	13.25	2	3.92	0	0.00	
Unknown	2	8.70	3	1.12	3	1.14	3	1.99	2	3.92	0	0.00	
CMV sero-pairing													0.668†
Unknown	1	4.35	23	8.61	17	6.44	7	4.64	2	3.92	1	9.09	
Donor - / Recipient -	5	21.74	48	17.98	43	16.29	19	12.58	6	11.76	3	27.27	
Donor - / Recipient +	5	21.74	49	18.35	61	23.11	28	18.54	12	23.53	2	18.18	
Donor + / Recipient -	5	21.74	72	26.97	66	25.00	35	23.18	15	29.41	3	27.27	
Donor + / Recipient +	7	30.43	75	28.09	77	29.17	62	41.06	16	31.37	2	18.18	
HLA Mismatches													0.884†
0 HLA mismatches	1	4.35	46	17.23	38	14.39	31	20.53	8	15.69	0	0.00	
1 HLA mismatches	0	0.00	4	1.50	4	1.52	1	0.66	0	0.00	0	0.00	
2 HLA mismatches	0	0.00	19	7.12	16	6.06	8	5.30	2	3.92	0	0.00	
3 HLA mismatches	8	34.78	38	14.23	41	15.53	18	11.92	7	13.73	3	27.27	
4 HLA mismatches	7	30.43	58	21.72	54	20.45	36	23.84	14	27.45	3	27.27	
5 HLA mismatches	5	21.74	69	25.84	81	30.68	40	26.49	14	27.45	4	36.36	
6 HLA mismatches	2	8.70	33	12.36	30	11.36	17	11.26	6	11.76	1	9.09	
Sensitized	3	13.04	23	8.61	22	8.33	11	7.28	1	1.96	0	0.00	0.486†
Cold Ischemia Time													0.448†
0 to < 15 hours	8	34.78	111	41.57	99	37.50	64	42.38	25	49.02	7	63.64	
15 to < 20 hours	4	17.39	57	21.35	54	20.45	29	19.21	9	17.65	1	9.09	
20 to < 26 hours	3	13.04	32	11.99	36	13.64	23	15.23	10	19.61	0	0.00	
26+ hours	3	13.04	14	5.24	24	9.09	15	9.93	3	5.88	0	0.00	
Unknown	5	21.74	53	19.85	51	19.32	20	13.25	4	7.84	3	27.27	
Year‡													0.696†
2000	1	2.78	18	50.00	10	27.78	6	16.67	1	2.78	0	0.00	
2001	3	4.41	29	42.65	15	22.06	15	22.06	4	5.88	2	2.94	
2002	5	5.10	32	32.65	37	37.76	18	18.37	5	5.10	1	1.02	
2003	3	2.65	35	30.97	40	35.40	26	23.01	7	6.19	2	1.77	
2004	4	3.39	45	38.14	41	34.75	19	16.10	9	7.63	0	0.00	
2005	3	2.50	41	34.17	51	42.50	15	12.50	7	5.83	3	2.50	
2006	3	2.03	46	31.08	48	32.43	37	25.00	12	8.11	2	1.35	
2007	1	1.52	21	31.82	22	33.33	15	22.73	6	9.09	1	1.52	

† Fisher's Exact Test
‡ Proportion displayed by rows. All other variables displayed by column.
PKD – Polycystic Kidney Disease

Table 1: Summary statistics of variables of interest by BMI category for privately-insured transplant recipients 2000-2007 (N=767).

Variable	Transplant Hospitalization		1-year posttransplant		2-years posttransplant		3-years posttransplant	
Base Cost	70070	*	-28380		-31799		37576	
BMI Category								
Underweight	-8540		5596		3730		43801	
Normal	Reference		Reference		Reference		Reference	
Overweight	-12870		7826		4637		-10162	
Obese	-12905		-3617		5642		33218	
Morbidly Obese	-19996		-3474		20418		55592	
Extremely Morbidly Obese	-20175		40702		22776		-34014	
Recipient Characteristics								
Gender								
Female	26497	**	2399		-3035		-8265	
Race								
African American	-10098		-9595		-4070		3148	
Other	-15977		-16584		3978		-1857	
White	Reference		Reference		Reference		Reference	
Ethnicity								
Hispanic	19276		22279		10252		44235	
Age (years)								
18 - 30	Reference		Reference		Reference		Reference	
31 - 44	-7828		13417		11734		6	
45 - 59	-16835		17260		27629		21223	
≥ 60	-14957		14268		42366	*	59930	
Primary cause of ESRD								
Diabetes mellitus	3121		25316	*	26713		25959	
Glomerulonephritis	-6184		-7223		7426		16076	
PKD	-7337		-1802		-1562		-13481	
Hypertension	-12870		-6970		2356		-14428	
Unknown	-45876		-20190		25560		44470	
Other	Reference		Reference		Reference		Reference	
Pre-Transplant Dialysis Duration								
None (pre-emptive)	Reference		Reference		Reference		Reference	
0-12 months	12652		12901		-2024		-16203	
13-24 months	6231		7864		-12766		-21853	
25-60 months	-18621		-16540	*	-13491		-4378	
More than 60 months	-51686	**	-9010		-6444		-27753	
Diabetes	15439		-11413		4493		371	
PVD	-6220		-14875		-23073		16680	
Donor Characteristics								
Gender								
Female	8272		14402	*	9032		465	
Race								
African American	-18107		8120		31607	*	21420	
Other	-6863		-4212		-7077		-12514	
White	Reference		Reference		Reference		Reference	
Age (years)								
≤ 18	6518		13501		10236		1749	
19 - 30	Reference		Reference		Reference		Reference	
31 - 44	-14405		1579		10937		-7917	
45 - 59	-20417		-5060		16748		928	
≥ 60	-35394		16802		906		-68840	

BMI category (kg/m²)								
≥ 10 to < 25	Reference		Reference		Reference		Reference	
≥ 25 to < 30	18357	*	7544		12205		-5331	
≥ 30	-4106		8494		19060		24686	
Death due to stroke	9548		15654	*	-1515		-10131	
Terminal Creatinine ≥ 1.5	-8113		-11567		-18094		-43371	
Hypertension history	5024		8208		-2891		-13125	
Diabetes	-2332		-2561		-29683		-30886	
CMV sero-positive	-21471		-33716	*	14793		-6232	
Transplant Factors								
Donor type								
SCD	Reference		Reference		Reference		Reference	
ECD	30973		-2688		-15660		54694	
DCD	-35675	*	224		1002		5077	
Peak PRA %								
0-10%	Reference		Reference		Reference		Reference	
11-30%	9475		-3482		-8659		-10004	
>30%	-8005		1138		8841		-7005	
Unknown	8640		-9641		-3474		-56647	
CMV sero-pairing								
Unknown	23107		15345		-14562		18459	
Donor - / Recipient -	Reference		Reference		Reference		Reference	
Donor - / Recipient +	37938		47374	**	-5895		40650	
Donor + / Recipient -	12872		8342		-1149		23114	
Donor + / Recipient +	28850		39048	*	-25844		18631	
HLA Mismatches								
0 HLA mismatches	Reference		Reference		Reference		Reference	
1 HLA mismatches	948		-3249		53996		34729	
2 HLA mismatches	-17763		2325		-10494		-45940	
3 HLA mismatches	-1603		3625		-5230		-35855	
4 HLA mismatches	10476		8458		-9789		-13697	
5 HLA mismatches	3610		19038	*	-7846		-29259	
6 HLA mismatches	-12607		15003		-2082		-23253	
Sensitized	1909		10080		25081		12253	
Cold Ischemia Time								
0 to < 15 hours	Reference		Reference		Reference		Reference	
15 to < 20 hours	4044		-4373		-4315		7743	
20 to < 26 hours	-18178		5433		4093		1000	
26+ hours	-16712		7057		7845		5421	
Unknown	-34181	**	15804	*	16992		17583	
Year								
2000	Reference		Reference		Reference		Reference	
2001	39772		-10997		68370	***	-50162	*
2002	41913	*	40669	***	18727		-19618	
2003	47434	*	97		6065		-41465	*
2004	41061	*	2885		17926		-14581	
2005	72463	***	-721		4239			
2006	73810	***	9535					
2007	72630	**						
Length of Stay	4150		1304	*	1403		1571	

* P-value < 0.05
** P-value < 0.01
*** P-value < 0.001

Table 2: Total accumulated cost (in dollars) at transplant hospitalization as well as one, two, and three year for privately-insured transplant recipients 2000-2007 (N=767).

	Graft Survival				Patient Survival			
Variable	**Full**		**Stepwise**		**Full**		**Stepwise**	
BMI Category								
Underweight	5.383	*	6.159	**	10.168		1.565	
Normal	Reference		Reference		Reference		Reference	
Overweight	2.283	*	2.578	**	1.002		0.942	
Obese	2.681	*	2.846	**	0.393		0.671	
Morbidly Obese	4.279	*	4.351	**	2.559		1.762	
Extremely Morbidly Obese	3.434		2.754		3.229		1.551	
Recipient Characteristics								
Gender								
Female	0.812				0.520			
Race								
African American	1.385				0.582			
Other	0.000				0.000			
White	Reference				Reference			
Ethnicity								
Hispanic	3.026E+06				1.726E+07			
Age (years)								
18 - 30	Reference				Reference			
31 - 44	2.993				9.893E+07			
45 - 59	2.459				5.784E+07			
≥ 60	3.613				5.141E+07			
Primary cause of ESRD								
Diabetes mellitus	2.227				47.176			
Glomerulonephritis	0.779				1.004			
PKD	1.798				4.130			
Hypertension	1.172				1.623			
Unknown	20.783	*			0.000			
Other	Reference				Reference			
Pre-Transplant Dialysis Duration								
None (pre-emptive)	Reference				Reference			
0-12 months	1.691				14.737	*		
13-24 months	1.906				20.687	*		
25-60 months	1.784				13.530			
More than 60 months	2.325				31.123	*		
Diabetes	0.402				0.028			
PVD	0.878				1.226			
Donor Characteristics								
Gender								
Female	1.855				1.069			
Race								
African American	0.965				0.088			
Other	0.652				0.229			
White	Reference				Reference			
Age (years)								
≤ 18	2.052				0.915			
19 - 30	Reference		Reference		Reference		Reference	
31 - 44	0.571		0.482	*	0.363			
45 - 59	1.336				1.291			
≥ 60	0.694				0.797		4.984	**
BMI category (kg/m²)								
≥ 10 to < 25	Reference				Reference			
≥ 25 to < 30	0.751				0.713			
≥ 30	0.583				0.345			
Death due to stroke	2.405	*	2.716	***	4.714			
Terminal Creatinine ≥ 1.5	1.196				4.134			
Hypertension history	0.806				0.275			
Diabetes	1.864				32.789			
CMV sero-positive	4.087E+05				2.723E+06			

Transplant Factors								
Donor type								
SCD	Reference				Reference			
ECD	1.475				1.622			
DCD	0.549				0.265			
Peak PRA %								
0-10%	Reference							
11-30%	0.531				0.000			
>30%	0.298				0.000			
Unknown	0.404				0.000			
CMV sero-pairing								
Unknown	0.000				0.000			
Donor - / Recipient -	Reference		Reference		Reference			
Donor - / Recipient +	0.000		1.949	*	0.000			
Donor + / Recipient -	0.673				1.901			
Donor + / Recipient +	0.000				0.000			
HLA Mismatches								
0 HLA mismatches	Reference		Reference		Reference		Reference	
1 HLA mismatches	7.395		5.344	*	0.010			
2 HLA mismatches	0.000				0.076			
3 HLA mismatches	1.925				2.253E+07			
4 HLA mismatches	1.387				5.460E+06			
5 HLA mismatches	1.880				1.660E+07			
6 HLA mismatches	3.451				9.818E+07		3.204	*
Sensitized	16.315	*	4.564	***	1.445E+09		7.116	***
Cold Ischemia Time								
0 to < 15 hours	Reference				Reference			
15 to < 20 hours	1.029				0.251			
20 to < 26 hours	0.888				0.154			
26+ hours	1.838				0.000			
Unknown	0.730				0.313			
Year								
2000	Reference				Reference			
2001	1.022				0.719			
2002	0.719				0.219			
2003	0.553				0.026	*		
2004	0.688				0.074			
2005	0.429				0.555			
2006	1.352				1.764			
2007	0.000				0.000			
Length of Stay	1.128	***	1.105	***	1.118	*	1.085	*

* P-value < 0.05
** P-value < 0.01
*** P-value < 0.001

Table 3: Cox proportional hazards full and stepwise models for graft and patient survival of privately-insured transplant recipients 2000-2007 (N=767).

out of range for statistical significance (p = 0.052). The percentage of deceased recipients was lowest for *overweight* (2.65%) and *obese* (2.65%) recipient. Patient survival was not statistically significant by BMI group. Length of hospitalization differed statistically by BMI (p < 0.001). *Overweight* recipients had the shortest average length of transplant hospitalization stay (7.93) while *extremely morbidly obese* recipients had the longest average stay (13.27 days).

Kidney transplantation rates for *normal* BMI recipients have dramatically shifted from 2000 to 2007 towards *overweight* and *obese* recipients. As this analysis has shown, increased costs and inferior outcomes are associated with unfavorable BMI at time of transplantation. While no differences in adjusted cost were detected, the increased risks and inferior outcomes associated with unfavorable BMI at time of transplantation provide ample evidence for policy-makers to encourage transplant candidates to obtain a *normal* BMI by the time of transplantation.

Limitations

This study has several limitations. Our analysis was limited to the quality and availability of the data included in the registry. Despite utilizing elements related to costs and clinical outcomes found in prior studies [23,31], other sources of cost or variation may be absent. Though inexpensive and easy to calculate, BMI may not be the best measure of body composition [32-35]. The cross-sectional assessment of BMI does not allow for dynamic examination reported in previous research [36]. Finally, BMI measurement is cross-sectional at time of transplant thereby limiting the potential for fluctuation of BMI before and after transplantation.

Implications

There are a number of implications as a result of this analysis. Transplant centers and insurance companies may consider directing funds towards weight management programs for transplant candidates as a means of preventing posttransplantation weight gain [37] and reducing costs associated with follow-up care. Using primary data collection might provide a more accurate assessment of costs and risks associated with kidney transplant recipient BMI by using factors not available in this retrospective study. Prospective studies might consider more in-depth cost variables as well as more representative or precise measures of body composition, such as waist-to-hip ratio or body-fat percentage [32]. Future prospective studies might examine the impact of bariatric surgery as a tool for improving posttransplant outcomes and costs. A previous retrospective analysis showed that significant weight loss can be obtained in the ESRD and kidney transplant population undergoing bariatric surgery, although not without risk [38]. Replicating this analysis using recipients with public insurance, or with different graft transplantation, might produce distinctive or confirmatory results. Future studies should obtain body composition measures at multiple points in time to assess stability and change as a result of transplantation. Finally, the results from this analysis may also be used to determine whether the well-accepted survival benefit of kidney transplantation over dialysis remains cost-effective for each BMI category.

Conclusion

We found that privately-insured kidney transplant recipients significantly varied by BMI category in posttransplant outcomes but not costs. The growing demand for transplant recipients with non-normal BMI is at risk for greater healthcare costs and adverse health outcomes following transplant. To reduce preventable costs to the healthcare system and improve posttransplant outcomes, resources should be invested into developing methods to help transplant candidates obtain a normal BMI by the time of transplantation.

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