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The impact of morbid obesity on resource utilization after renal transplantation

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Abstract

Background—A growing number of renal transplant recipients have a body mass index ≥ 40 . While previous studies have shown that patient and graft survival are significantly decreased in renal transplant recipients with body mass indexes ≥ 40 , less is known about perioperative outcomes and resource utilization in morbidly obese patients. We aimed to analyze the effects of morbid obesity on these parameters in renal transplant.

Methods—Using a linkage between the Scientific Registry of Transplant Recipients and the databases of the University HealthSystem Consortium, we identified 29,728 adult renal transplant recipients and divided them into 2 cohorts based on body mass index (<40 vs ≥ 40 kg/m²). The body mass index ≥ 40 group comprised 2.5% ($n = 747$) of renal transplant recipients studied.

Results—Body mass index ≥ 40 recipients incurred greater direct costs (\$84,075 vs \$79,580, $P < .01$), index admission costs (\$91,169 vs \$86,141, $P < .01$), readmission costs (\$5,306 vs \$4,596, $P = .01$), and combined costs (\$99,590 vs \$93,939, $P < .001$). Thirty-day readmission rates were also greater among body mass index ≥ 40 recipients (33.92% vs 26.9%, $P < .01$). Morbid obesity was not predictive of stay (odds ratio 1.01, $P = .75$).

Conclusion—Morbidly obese renal transplant recipients incur greater costs and readmission rates compared with nonobese patients. Recognition of increased resource utilization should be accompanied by appropriate, risk-adjustment reimbursement.

The epidemic of obesity is a major contributor to the rising cost of health care in the United States.¹ The prevalence of obesity, defined as a body mass index (BMI) >30 kg/m², is $>30\%$ across various age groups, sexes, and ethnic populations.^{2,3} Obesity can be further subdivided into class I (BMI 30–34.9), class II (BMI 35–39.9), class III (BMI ≥ 40), or morbid obesity. According to the National Health and Nutrition Examination Survey, nearly 5% of adults aged 20 years and older can be classified as morbidly obese.³

Obesity portends poor operative outcomes. As our group described previously in the liver transplant population, morbidly obese recipients have more comorbidities during the

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peritransplant period and incur greater hospital costs.⁴ Various other studies have documented a greater incidence of cardiovascular, pulmonary, thromboembolic, and infectious complications among obese, operatively treated patients.^{5,6} In addition to increased postoperative complication rates, a higher BMI has also been linked to prolonged duration of intensive care unit (ICU) length of stay (LOS) and prolonged ventilator support.⁷ Not unsurprisingly, obesity has been identified as an independent risk factor for multiple medical comorbidities, including type 2 diabetes mellitus (DM), hypertension (HTN), dyslipidemias, and the development of end-stage renal disease (ESRD).^{8,9}

Renal transplantation (RT) is the treatment of choice for ESRD. Unfortunately, morbid obesity prognosticates inferior long-term outcomes in the RT recipient population, including acute graft rejection and delayed graft function.^{10,11} Several studies have ascribed an increased BMI as an independent predictor for both allograft and patient survival.^{12–14} Given these suboptimal findings in morbidly obese recipients, subsequent trials have compared RT to lifelong maintenance dialysis for this patient population. Both concluded that while RT had greater complication rates, transplantation was more favorable than lifelong dialysis.^{15,16}

While morbid obesity has been associated with inferior patient and allograft survival in RT recipients, little is known about its effects on perioperative outcomes and resource utilization. Given previous findings linking a greater BMI with poor operative outcomes, we hypothesized that morbid obesity would be associated with worse perioperative outcomes and increased resource utilization in RT recipients. Thus, using recipient BMI as the primary predictor variable, our primary outcomes were direct cost, LOS, 30-day readmission rate, and peritransplant mortality.

METHODS

Study population

A retrospective cohort study was performed for RT recipients in the United States between January 1, 2007, and December 31, 2011. Data were obtained for RT recipients from 2 separate sources. The first source, the Scientific Registry of Transplant Recipients (SRTR), collects data on organ donors, recipients, and wait-listed candidates in the United States. This database is gathered from the Organ Procurement and Transplantation Network. The second source, the University HealthSystem Consortium (UHC) Clinical Database/Resource Manager (CDB/RM), is a coalition of 118 nonprofit academic medical centers and 298 of their associated hospitals.

The UHC CDB/RM collects data on patient demographics, ICD-9 diagnoses, and financial and procedural data from affiliated medical centers. Financial data for each patient encounter are translated to estimated cost based on 2 variables---federally reported wage indices and hospital-specific, Medicare, cost-to-charge ratio. Costs accumulated prior to transplantation were removed from our analyses, and direct costs (RT to discharge) were generated based on encounter-specific data as described previously.^{17,18}

The SRTR and UHC data sets were linked using recipient age, procedure date, and transplant center, as described previously.^{17,18} A 100% concordance was obtained with the matched variables comprising available UHC members performing RT. The final matched cohort between these 2 databases consisted of 29,728 RT recipients between January 1, 2007, and December 31, 2011. After comparing our data set with the complete SRTR data set, we found similar characteristics of the organ donors, recipients, and centers. We then divided our linked data set into 2 cohorts based on recipient BMI ($<40 \text{ kg/m}^2$ vs $\geq 40 \text{ kg/m}^2$), excluding those who were underweight with BMI $<18 \text{ kg/m}^2$ in order to compare morbidly obese patients against nonobese, nonunderweight patients.

Variables defined

The following RT recipient characteristics were obtained: sex, race, age, etiology of kidney disease, severity of illness, subjective functional status, and medical comorbidities. Regarding socioeconomic status (SES), recipients were divided into quintiles for statistical analysis.

Our data set was arranged according to time and location of organ procurement. Center-specific characteristics collected included the following: total LOS, ICU LOS, in-hospital mortality, 30-day readmission rates, and direct cost (from RT to discharge). Index admission cost, readmission cost, and combined cost were also collected. Transplant center volume was assessed using methods described previously.^{17,18} Briefly, the SRTR data set was used to determine the annual number of RT procedures performed at each transplant center. After excluding centers performing <5 RTs per year, each center was ranked according to its case volume. Transplant centers were then divided into tertiles and arranged into 3 groups: high-volume centers, middle-volume centers, and low-volume centers. Tertile designations were recalculated annually for each year studied.

Statistical analysis

Nominal categorical variables were tested for significance using the Pearson χ^2 test. Ordinal categorical variables were tested similarly using the Mantel-Haenszel χ^2 test. Data were described using estimates of central tendency (median value), interquartile range (IQR) for continuous variables, and percentages (%) for categorical variables. Given that variation of median values between BMI groups did not follow a normal distribution, they were evaluated using the nonparametric Wilcoxon rank sum test. Univariate analysis of recipient and graft survival was performed using Kaplan-Meier estimates, and differences between BMI groups were analyzed using the log-rank test. Multivariate analysis was performed using logistic regression techniques to identify predictors of 30-day readmission, Gamma regression techniques for perioperative cost, and Poisson regression techniques for LOS.

Random intercept hierarchical models were used in all analyses in order to account for the clustering effect of transplant centers. Models were adjusted for the following recipient and donor characteristics: recipient BMI, age, sex, race, SES, DM, chronic obstructive pulmonary disease (COPD), peripheral vascular disease (PVD), polycystic kidney disease (PKD), donor type, cold ischemia time, and warm ischemia time. All statistical analyses were performed using JMP Pro and SAS software (JMP Pro version 11 and SAS version 9.4;

SAS Institute, Cary, NC). This study was approved by the University of Cincinnati Institutional Review Board and conducted according to their criteria.

RESULTS

Morbidly obese recipient characteristics

Recipient characteristics and demographic information are outlined in Table I. The BMI ≥ 40 group comprised 2.5% ($n = 747$) of all RT recipients during the study period. Morbidly obese recipients were notable for being women more commonly (51.9%, $P < .0001$) vs 38.8% in the BMI < 40 group. Recipient age was less in the BMI ≥ 40 group ($P < .0001$). Among the morbidly obese cohort, hypertension (27.0% vs 22.3%) and diabetes (32.2% vs 23.2%) were more prevalent as the underlying etiology of kidney disease ($P < .0001$). BMI ≥ 40 recipients also carried a higher percentage of type 2 DM (43.9% vs 31.1%, $P < .001$) and COPD (3.1% vs 1.1%, $P < .0001$).

Morbidly obese recipients are less healthy at time of transplant

Recipient characteristics during the perioperative period are summarized in Table II. Prior to transplantation, the BMI ≥ 40 group had a somewhat greater percentage of moderate (64.9% vs 57.8%) and major (26.5% vs 19.8%) severity of illness, while the BMI < 40 group had a greater percentage of minor severity of illness (21.5% vs 7.9%, $P < .0001$). Morbidly obese recipients were not more likely to receive allografts from donors with higher BMI (27.3 kg/m² vs 26.5 kg/m²). Cold ischemic time was not significantly different between the 2 groups, but BMI ≥ 40 recipients had a somewhat greater warm ischemic time prior to revascularization (41 minutes vs 35 minutes, $P < .0001$).

Morbidly obese recipients incur greater resource utilization

Clinical and cost-related variables during the perioperative period are detailed in Table III. The BMI ≥ 40 group incurred greater direct costs (\$84,075 vs \$79,580), index admission costs (\$91,169 vs \$86,141), readmission costs (\$5,306 vs \$4,596), and combined costs (\$99,590 vs \$93,939) compared to BMI < 40 recipients ($P = .01$ each). Thirty-day readmission rates were greater among morbidly obese recipients (33.9% vs 26.9%, $P < .0001$). Transplant center volume, discharge to home, and mortality were not significantly different between the 2 groups.

Morbid obesity is not predictive of readmission

A multivariate analysis was performed analyzing recipient characteristics predictive of greater readmission rates (Table IV). Recipient BMI was not a significant predictor of readmission. Characteristics predictive of readmission included black race (odds ratio [OR] 1.09, $P = .03$), DM (OR 1.28, $P < .0001$), and PVD (OR 1.31, $P < .01$). Subjective measures of functional status were also predictive of readmission, including dependent recipients (OR 1.27, $P < .0001$) and severely ill recipients (OR 1.79, $P = .03$). Perioperative characteristics associated with greater readmission rates include deceased donor grafts (OR 1.24, $P < .0001$) and greater warm ischemic times (OR 1.00, $P < .001$).

Morbid obesity is not predictive of LOS

Table V summarizes characteristics predictive of overall LOS. Recipient BMI was not significantly predictive of greater hospital stay. Characteristics predictive of prolonged hospital stay included DM (OR 1.05), recipient age (OR 1.00), poor functional status, including dependent recipients (OR 1.11) and severely ill recipients (OR 3.33), and deceased donor grafts (OR 1.27) ($P = .01$ each). Both cold ischemic time and warm ischemic time were not clinically predictive.

Morbid obesity is predictive of increased cost

Recipient characteristics predictive of increased resource utilization are detailed in Table VI. Predictive factors included morbid obesity (OR 1.04), Hispanic race (OR 1.04), dependent status (OR 1.08), severely ill status (OR 1.86), and deceased donor graft use (OR 1.19) ($P = .04$ each).

DISCUSSION

This large, retrospective, national study provides insight into the effect of increased BMI on perioperative and resource utilization outcomes after RT. We have found that morbidly obese recipients incur greater direct costs, index admission costs, readmission costs, and combined costs compared with BMI <40 patients. Thirty-day readmission rates were also greater among morbidly obese RT recipients, further exacerbating the cost of readmission.

In addition to greater readmission rates, obese patients also incur greater direct cost per transplant (RT to discharge) despite similar LOS with nonobese patients. Thus, daily expenditure is greater among morbidly obese RT recipients. This observation is reconfirmed on a national level through analysis of national cost estimates calculated from the Healthcare Cost and Utilization Project's Nationwide Inpatient Sample, which has demonstrated greater cost per day among obese, operatively treated patients.¹⁹ We speculate that increased direct cost and daily expenditure may be attributed to higher rates of comorbid conditions among the BMI ≥ 40 cohort. To support this hypothesis, on multivariate analysis, functional status was found to be a greater predictor of readmission and perioperative cost than morbid obesity.

Additionally, we have shown that morbidly obese RT recipients harbor more comorbidities during the peri-transplant period compared to nonobese patients. This cohort had a greater rate of diabetes and COPD, which contribute to an increased severity of illness at time of transplant. The underlying etiology for renal failure more frequently is due to hypertension or diabetes, which are both chronic disease processes. Previous analyses have linked diabetes, hypertension, and metabolic syndrome (defined as BMI ≥ 30 kg/m², medication-dependent hypertension, or medication-dependent diabetes) to increased health care cost in various patient populations.^{20–22} Further research is needed to clarify the exact etiology of increased resource expenditure among RT recipients.

While our data highlight the suboptimal outcomes among morbidly obese recipients, we believe that increased cost and readmission rates should not serve as an impediment to transplantation. Previous studies have found RT to have a significantly lesser mortality rate

compared with lifelong hemodialysis among this population.¹⁵ Therefore, despite greater resource utilization, RT should not be withheld based on BMI. With respect to poorer fiscal outcomes, two adjustments may be made to improve current policy. First, greater reimbursements can offset the greater resource utilization required for this patient population. Providers should not be penalized for treating this greater-risk patient population. Second, treatment of morbid obesity prior to transplantation may result in better outcomes. While the benefits of diet and exercise are well documented, operative treatment with bariatric approaches should also be considered. Several studies have analyzed bariatric options, such as sleeve gastrectomy, in morbidly obese RT recipients with promising results.^{23–25}

The strengths of this study derive from the unique nature of the SRTR and UHC data set linkage. This linkage contributes a large sample size ($n = 29,728$) as well as data from multiple transplant centers across the nation. After comparing our linked database with the entire SRTR database, we found similar characteristics of the organ donors, recipients, and transplant centers, implying that our data are representative of the national experience. Another strength of this study is the hospital resource data unique to the linked data set.

There are limitations to our study that must be considered. One limiting factor is the retrospective nature of the data-gathering methods. As with all retrospective analyses, there is the potential for selection bias and measuring error. Second, our linked data set of RT recipients between January 1, 2007, and December 31, 2011, represents 33.8% of total RT recipients when compared to the entire SRTR experience. Thus, there is the potential that our sample may not be representative of the entire population.

Third, the use of BMI to classify different grades of obesity BMI may not be reflective of obesity in certain conditions, including pregnancy, fluid overload, and excessive muscle mass, but, in our linked data set, BMI is the only metric available to grade obesity. Fourth, while our results demonstrate increased cost in transplanting morbidly obese patients, our data lack the granularity to be able to attribute this finding to a specific cause. We may assume that increased costs are related to greater rates of comorbidities, but the lack of specific variables precludes us from making a definitive conclusion. Finally, we lack data related to outpatient factors of resource utilization.

In summary, morbidly obese renal transplant recipients incur greater resource utilization in the initial and readmission encounters compared to the BMI <40 cohort. These data show that providers should not be penalized for treating this greater risk patient population, and greater reimbursement for their care should be considered by insurance payors.

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Table I

Recipient characteristics of 29,728 kidney transplant recipients

Characteristic	BMI 40 (<i>n</i> = 747)	BMI 18–39 (<i>n</i> = 28,981)	<i>P</i> value
Male sex	359 (48.1%)	17,728 (61.2%)	<.0001
Race			<.0001
White	380 (50.9%)	15,515 (53.5%)	
Black	261 (34.9%)	7,656 (26.4%)	
Hispanic	87 (11.7%)	3,595 (12.4%)	
Asian	11 (1.5%)	1,854 (6.4%)	
Other	747 (2.5%)	361 (1.3%)	
Age (years)			<.0001
18–29	41 (5.5%)	2,282 (7.8%)	
30–39	111 (14.9%)	3,723 (12.9%)	
40–49	183 (24.5%)	6,050 (20.9%)	
50–59	227 (30.4%)	7,934 (27.4%)	
60–69	163 (21.8%)	6,929 (23.9%)	
70	22 (3.0%)	2,063 (7.1%)	
Etiology of kidney disease			<.0001
Cancer	1 (0.1%)	116 (0.4%)	
DM	240 (32.2%)	6,668 (23.2%)	
Drug toxicity	2 (0.3%)	409 (1.4%)	
Glomerular/inflammatory	166 (22.3%)	7,487 (26.0%)	
HTN	201 (27.0%)	6,418 (22.3%)	
PKD	52 (7.0%)	3,025 (10.5%)	
Infectious/obstructive	10 (1.3%)	678 (2.4%)	
Other	73 (9.8%)	4,004 (13.9%)	
Medical history			
DM	328 (43.9%)	9,016 (31.1%)	<.001
Angina	52 (8.7%)	1,694 (8.0%)	.50
CVD	16 (2.5%)	646 (2.7%)	.50
PVD	31 (4.2%)	913 (3.2%)	.22
COPD	23 (3.1%)	315 (1.1%)	<.0001
HTN	561 (86.6%)	20,178 (85.8%)	.81

CVD, Cerebrovascular disease.

Table II

Recipient status at transplant

Characteristic	BMI 40 (<i>n</i> = 747)	BMI 18–39 (<i>n</i> = 28,981)	<i>P</i> value
Severity of illness			<.0001
Minor	59 (7.9%)	6,237 (21.5%)	
Moderate	485 (64.9%)	16,743 (57.8%)	
Major	198 (26.5%)	5,749 (19.8%)	
Extreme	5 (0.7%)	252 (0.9%)	
Listing time (days)	552 (43–1,061 [*])	526 (60–992 [*])	.12
Donor BMI (kg/m ²)	27.3 (23.4–31.2 [*])	26.5 (23.0–30.1 [*])	<.0001 [†]
Cold ischemia (h)	11.4 (2.9–20.0 [*])	11.3 (2.7–20.0 [*])	.05 [†]
Warm ischemia (min)	41 (32.5–49.5 [*])	35 (26.5–43.5 [*])	<.0001

^{*} Interquartile range.

[†] Not clinically relevant.

Table III

Overall hospital characteristics and resource utilization

Characteristic	BMI 40 (<i>n</i> = 747)	BMI 18–39 (<i>n</i> = 28,981)	<i>P</i> value
LOS (days)			
Total LOS	5 (1–9 [*])	5 (2–8 [*])	<.001 [†]
ICU LOS	0 (0–1.5 [*])	0 (0–1 [*])	<.0001 [†]
Discharge to home	724 (97.4%)	28,021 (97.8%)	.49
Readmission (30-day)	252 (33.9%)	7,755 (26.9%)	<.0001
Mortality	4 (0.5%)	150 (0.5%)	.95
Cost (median; IQR)			
Direct cost (RT to discharge)	\$84,075 (\$62,525–102,896 [*])	\$79,580 (\$60,636–98,525 [*])	<.01
Index admission cost	\$91,169 (\$68,327–114,011 [*])	\$86,141 (\$64,777–107,506 [*])	<.01
Readmission cost	\$5,306 (\$643–9,969 [*])	\$4,596 (\$1,198–7,994 [*])	.01
Combined cost	\$99,590 (\$75,860–123,321 [*])	\$93,939 (\$62,727–125,151 [*])	<.001

* Interquartile range.

[†] Not clinically relevant.

Table IV

Predictors of readmission

Characteristic	Odds ratio (95% CI)	P value
Recipient BMI		
BMI 18–39	Ref	
BMI 40	1.20 (0.98–1.46)	.08
Recipient race		
White	Ref	
Black	1.09 (1.01–1.18)	.03
Hispanic	0.88 (0.79–0.98)	.02
Other	0.73 (0.63–0.84)	<.0001
Medical history		
DM	1.28 (1.19–1.38)	<.0001
PVD	1.31 (1.09–1.56)	<.01
PKD	0.82 (0.73–0.92)	<.001
Functional status		
Independent	Ref	
Dependent	1.27 (1.14–1.42)	<.0001
Severely ill	1.79 (1.06–3.03)	.03
Unknown	0.97 (0.76–1.23)	.78
Donor type		
Living donor	Ref	
Deceased donor	1.24 (1.15–1.33)	<.0001
Warm ischemia time	1.00 (1.00–1.01)	<.001

Table V

Predictors of LOS

Characteristic	Odds ratio (95% CI)	P value
Recipient BMI		
BMI 18–39	Ref	
BMI 40	1.01 (0.93–1.10)	.75
Medical history		
DM	1.05 (1.02–1.08)	<.01
PKD	0.93 (0.88–0.97)	<.01
Recipient age	1.00 (1.00–1.01)	<.0001
Functional status		
Independent	Ref	
Dependent	1.11 (1.06–1.15)	<.0001
Severely ill	3.33 (2.98–3.73)	<.0001
Unknown	0.96 (0.88–1.06)	.40
Donor type		
Living donor	Ref	
Deceased donor	1.27 (1.22–1.32)	<.0001
Cold ischemia time	1.00 (1.00–1.01)	
Warm ischemia time	1.00 (1.00–1.01)	

Table VI

Predictors of perioperative cost at time of kidney transplant

Characteristic	Odds ratio (95% CI)	P value
Recipient BMI		
BMI 18–39	Ref	
BMI 40	1.04 (1.00–1.07)	.04
Recipient race		
White	Ref	
Black	0.98 (0.96–0.99)	<.001
Hispanic	1.04 (1.02–1.06)	<.0001
Other	1.07 (1.04–1.09)	<.0001
Medical history		
PKD	0.98 (0.96–0.99)	<.01
Functional status		
Independent	Ref	
Dependent	1.08 (1.06–1.10)	<.0001
Severely ill	1.86 (1.72–2.01)	<.0001
Unknown	0.93 (0.90–0.96)	<.0001
Donor type		
Living donor	Ref	
Deceased donor	1.19 (1.18–1.21)	<.0001