OREGON HEALTH & SCIENCE UNIVERSITY
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ETHNIC DIFFERENCES IN DECEASED ORGAN DONOR MANAGEMENT AND ORGAN UTILIZATION

By

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CERTIFICATE OF APPROVAL

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LIST OF ABBREVIATIONS

BMI	Body mass index
DCDD	Donor after circulatory determination of death
DMG	Donor management goal
DNDD	Donor after neurologic determination of death
ECD	Expanded criteria donor
H-L	Hosmer-Lemeshow
HLA	Human leukocyte antigen
HRSA	Health Resources and Services Administration
OPTN	Organ Procurement and Transplantation Network
OTPD	Organs transplanted per donor
SCD	Standard criteria donor
SRTR	Scientific Registry of Transplant Recipients
UNOS	United Network for Organ Sharing
VIF	Variance inflation factor

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ABSTRACT

Introduction: Ethnic differences in organ transplant recipient outcomes are well documented, but research in organ donors are lacking. Given the current shortage of organs available for transplantation in the United States, it is important to ensure the optimal utilization of organs from every group of donors. The current average number of organs transplanted per deceased donor (OTPD) is three, and meeting present critical care endpoints known as donor management goals (DMGs) has been shown to be associated with higher OTPD. The specific aims of this thesis were to 1) assess whether there are differences in the attainment of ≥4 OTPD between White and non-white deceased organ donors, and 2) assess whether there are differences in meeting DMG bundles between White and non-White deceased organ donors.

Methods: Data were prospectively collected on all deceased organ donors from ten Organ Procurement Organizations (OPO) in United Network for Organ Sharing Regions 4, 5, and 6 from March 2012 to November 2014. Specific aim 1: Logistic regression was used to test the association between donor ethnicity and ≥4 OTPD after controlling for known predictors of OTPD. Specific aim 2: Potential confounders in the relationship between donor ethnicity and DMG bundle attainment were identified by two separate variable selection methods: 1) assessing for greater than 10% change in crude odds ratio, and 2) assessing for an association (p-value <0.05) between the potential confounder and outcome. Two separate logistic regression models were built based on these two strategies, and the models were compared based on their effects on the crude odds ratio.

Results: Data were collected from 3476 donors, 55% of whom were White, 30% Hispanic, 9% Black, and 6% Asian. After controlling for known predictors of OTPD, Asian donors had higher odds of achieving ≥4 OTPD (OR 1.46, p=0.04) while Black donors had lower odds (OR 0.71, p=0.03), when compared to White donors. Hispanic donors had lower odds of liver transplantation; Black donors had lower odds of kidney transplantation; and both Hispanic and Asian donors had higher odds of lung transplantation. Donor type and OPO were identified as confounders of the relationship between donor ethnicity and DMG bundle attainment. However, on multivariate logistic regression, there were no statistically significant differences in the odds of attaining the DMG bundle between White and non-White donors.

Conclusion: There are ethnic differences in deceased organ donor organ utilization that are not explained by corresponding differences in achieving critical care endpoints as measured by DMG bundle attainment. These results suggest that donor ethnicity affects organ utilization in an alternate pathway where regional demographics and socioeconomic status may play important roles. Future studies are needed to better understand the relationship between socioeconomic status, regional demographics, and donor ethnicity in organ utilization.

INTRODUCTION

Health differences by ethnicity in solid organ transplantation have been well documented. Disparity is evident throughout the entire transplant process, from transplant waitlist acceptance rates to post-transplant recipient outcomes. Ethnic differences are also present in each of the top three solid organs transplanted in the United States (kidney, liver, heart), which account for 90% of all transplantations[1, 2]. Patients who are ethnic minorities have decreased access to organ transplantations and are at higher risk of dying while waiting for a transplant[3-5]. Non-White organ recipients also have higher rates of graft failure after heart, kidney, and liver transplantation[2,6-8].These health differences in recipient outcomes persist despite controlling for recipient socioeconomic status and medication compliance[9].Furthermore, while there have been improvements in long term survival for heart recipients who are White, this has not been the case for Black or Hispanic recipients[5].

While much is known about ethnic differences in organ recipients, very few studies have examined ethnic differences related to organ donors. Some studies have described lower rates of living organ donation in non-White donors and other studies have found that the donor-recipient ethnicity pairing may affect recipient outcomes[10, 11]. However, we do not know whether donor ethnicity affects the likelihood of organ transplantation or the management of the organ donor. Our healthcare system strives for equality across all patient groups and organ transplantation not only benefits the recipient, but the family of the donor as well.

An additional consideration is the national shortage of organs available for transplantation. On average, 21 people die each day while waiting for an organ transplantation in the United

States[11].The number of patients on the national waiting list has been growing over the last decade while the number of organs transplanted have been relatively stagnant[12]. In an effort to address the national shortage of organs available for transplantation, The US Health Resources and Services Administration (HRSA) has set goals for organ donation and transplantation. The target number of organs transplanted per donor (OTPD) for a standard criteria donor (a donor who is relatively young with few comorbidities at the time of death) is 4.3. The current national average OTPD is three. Given the national shortage of organs available for transplantation it is important to ensure the optimal utilization of organs from every group of donors**.**

The organ donation process

In the United States, organ donation and transplantation is overseen by the Health Resources and Services Administration of the Department of Health and Human Services. Organ donation and transplantation operates through the Organ Procurement and Transplantation Network (OPTN), a non-profit, private entity which has standardized the organ donation and sharing process. The OPTN includes all US transplant centers, histocompatibility laboratories, and organ procurement organizations (OPOs). OPOs are federally designated organizations responsible for coordinating the donation process in their service area. There are 58 OPOs in the United States[13].

The OPTN is managed by United Network for Organ Sharing (UNOS), a private non-profit organization under contract with HRSA. The US is divided into eleven geographic UNOS regions each with its own administrative body[14] (Figure 1)[15].

Figure 1 Map of UNOS regions[15]

Hospitals are required by federal regulations to notify its local OPO of every patient that has died or is nearing death. Clinical triggers for referral include mechanically ventilated patients with a neurological injury who have lost one of more brainstem reflexes or have a Glasgow Coma Score less than or equal to five. Patients who have undergone cardiopulmonary death are also referred to the OPO for potential organ donation. It is important to point out that a referral does not mean that a patient's care is de-escalated. It simply makes organ donation a possibility should the patient's condition worsen. When a patient fails to respond despite all medical efforts, neurologic death may then be determined by hospital guidelines. The hospital then gives the OPO information about the deceased to confirm his or her potential to be a donor. If the patient is a potential candidate for donation, an OPO representative travels to the hospital and obtains authorization for donation through either the state's donor registry if the deceased is a registered donor, or through the deceased's next of kin. Once authorization is obtained, the OPO assumes responsibility of the care of the donor. After

authorization and if the evaluation does not rule out donation, the OPO will search for matching recipients through the OPTN. Donor organs are matched with recipients through a computer program which takes into account the recipient and donor's blood type, tissue type, height, and weight as well as the recipient's length of time on the waitlist, the severity of the recipient's illness, and the distance between the donor's and recipient's hospitals. Organ offers are made to the matched patients generated by the computer and may be accepted or refused by the recipient's transplant surgeon based on the medical suitability of the organ and the recipient's condition. The OPO representative then arranges the timing of organ recovery by the transplant surgical teams and the transportation of the organs to the hospitals of the recipients[13].

From the time authorization for donation is obtained until the time of organ recovery, the OPO is responsible for managing the donor and works with the hospital staff to optimize the donor care for organ transplantation[13]. The timeframe for donor management generally lasts 24-48 hours.

Donor management goals

Prior to the declaration of death, potential donors are managed with the goal of optimizing brain tissue perfusion and clinical outcomes. However, after death, donor management focuses on maximizing the well-being of as many organs as possible to increase the chances of achieving organ donation. To this end, critical care of the potential donor requires maintaining a balance between the needs of different organ systems[16].

One effort made to increase the number of OTPD is to standardize the critical care received during the donor management phase by using donor management goals (DMGs). DMGs are preset critical care endpoints and are physiologic parameters that reflect the normal hemodynamic, acid-base, cardiovascular, respiratory, endocrine, and renal status of the donor. In this study, there are nine DMGs that are measured at three standardized time points that reflect different phases of care: time of donation authorization, 12-18 hours after authorization, and immediately prior to organ recovery (prior to OR). The time of authorization is when the OPO assumes responsibility and begins targeting the DMG and reflects the donor's condition just prior to OPO managements. 12 to 18 hours after authorization reflects the approximate time when organ offers are being made and organs are being evaluated for acceptance by transplant centers. Immediately prior to organ recovery reflects the end result of donor management.

Achieving any seven of the nine DMGs at a time point is considered to be meeting the DMG bundle. Multiple studies have demonstrated that meeting the DMG bundle between the time of referral for organ donation and the time of organ procurement is associated with higher OTPD and improved graft outcomes[17-19]. The specific DMG parameters are listed in **Table 1.**

Table 1 Donor Management Goals

Donor Management Goal	Parameter
Mean arterial pressure, mm Hg	60-110
Central venous pressure, mm Hg	4-12
Ejection fraction, %	≥50
Low-dose vasopressors*, no. agents	≤1
Arterial blood gas, pH	7.3-7.5
PaO_2:FiO_2** ratio	≥300
Serum sodium, mEq/L	≤155
Urine output, mL/kg/hr over 4 hr	≥0.5
Glucose, mg/dL	≤150

*dopamine at 10ug/kg/min or less, neosynephrine at 60ug/min or less, and norepinephrine at 10 ug/min or less

**Fraction of inspired oxygen:partial pressure of oxygen, arterial

Below is a figure adapted from Sally et al. (2013) that demonstrates the course of events for a potential organ donor with neurological determination of death and the time points at which donor management goals are recorded (**Figure 2**).

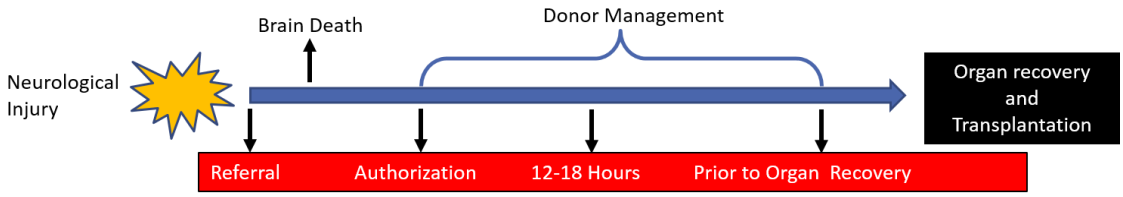

Figure 2 Timeline of events for a potential organ donor[16]

Donor type

Deceased organ donors can be categorized as standard criteria donor (SCD), expanded criteria donor (ECD), or donor after circulatory determination of death (DCDD). Both SCDs and ECDs are considered donors after neurologic determination of death (DNDDs), where donors have primary brain death but whose cardiac and respiratory function are intact or are maintained by medical measures. DNDDs make up the majority of deceased organ donors. Under the category of DNDD, SCDs are relatively young and have fewer comorbidities than ECDs. ECDs are aged ≥ 60 years or aged 50 to 59 years and has any two of the following three criteria: 1. cause of death is cerebrovascular accident; 2. preexisting history of systemic hypertension; 3. terminal serum creatinine > 1.5 mg/dl. DNDDs who do not meet criteria for ECD are classified as SCDs.

DCDDs are donors who do not meet the criteria for brain death but whose cardiopulmonary function ceased prior to organ procurement[20]. Similar to DNDDs, the process for DCDDs begin with the notification of a potential donor to the OPO and then obtaining authorization for withdrawal of care and organ procurement. The timeline of events for DCDDs differ from

that of DNDDs (**Figure 2**) in that the loss of cardiopulmonary function in DCDDs means that organ procurement needs to occur relatively quickly after declaration of death. Thus, the period of donor management by the OPO is much shorter for DCDDs[21]. **Figure 3** summarizes the different donor types.

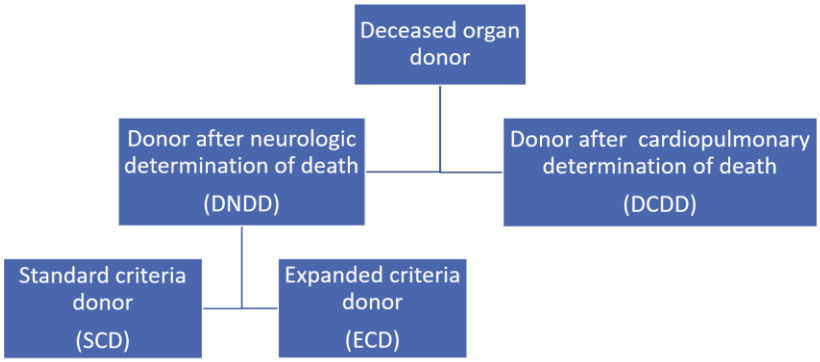

Figure 3 Summary of deceased organ donor types

Directed Acyclic Graph

The directed acyclic graph below (**Figure 4**) frames the relationships between the predictor, outcome, and covariables that are examined in this study. The primary relationships of interest are those between donor ethnicity and OTPD (upper portion of figure) and between donor ethnicity and DMG attainment (lower portion of figure). The relationship between donor ethnicity and OTPD is affected by known predictors of OTPD (age, weight, BMI, serum creatinine, blood type, cause of death, donor type, OPO) and will be controlled for as political variables. Proposed confounders of the relationship between donor ethnicity and DMG are age, BMI, serum creatinine, thyroid hormone use, cause of death, donor type, and OPO. Since there are no previous studies on the relationship between donor ethnicity and DMG bundle attainment, the proposed confounders will be evaluated individually for their effect on the relationship of interest. These potential confounders were chosen because they

are variables that may reflect a donor's health status (age, BMI, serum creatinine), are markers of critical care interventions that may affect DMG attainment (thyroid hormone use), and are factors that have been shown to be important in organ utilization and transplant outcomes (cause of death, donor type, OPO). DMG bundle attainment in turn, as described above, is causally associated with higher OTPD (solid arrow).

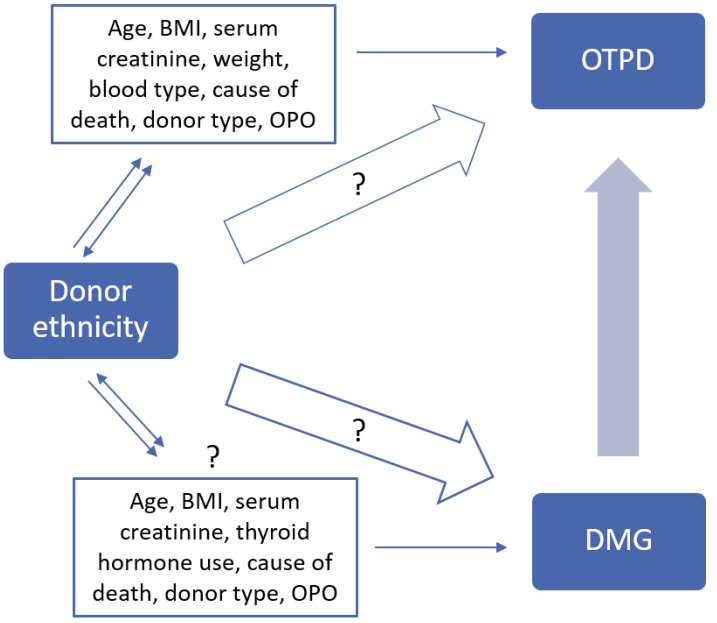

Figure 4 Directed acyclic graph of the relationship between donor ethnicity, OTPD, and DMG

Specific aims

1. Assess whether there are differences in the attainment of **four or more OTPD (≥4 OTPD)** between White and non-white deceased organ donors.

   Hypothesis: Compared to White donors, non-White donors will have lower odds of achieving ≥ 4 OTPD

   Sub-aim 1a. Assess whether there are differences in having **individual organ transplanted** between White and non-white deceased organ donors.

   Hypothesis: Compared to White donors, non-White donors will have lower odds of having individual organ transplantations

2. Assess whether there are differences meeting **DMG bundle** at three time points between White and non-white deceased organ donors.

   Hypothesis: Compared to White donors, non-White donors will have lower odds of meeting the DMG bundle.

METHODS

Data were prospectively collected on all deceased patients who had authorization for organ donation by ten OPOs from UNOS regions 4, 5, and 6 from March 2012 to November 2014 (**Table 2**). Data collected by the OPOs included donor demographics, critical care measurements and treatments, and the disposition of each organ, and were recorded in a web-based system, the UNOS Donor Management Goals Web Portal. All data were tied to the sequential UNOS identification number of each deceased donor.

Table 2 Summary of OPOs in present study

OPO Name	OPO abbreviation	UNOS region	State
Donor Network of Arizona	AZOB	5	Arizona
Donor Network West	CADN	5	California
Sierra Donor Services	CAGS	5	California
OneLegacy	CAOP	5	California
Lifesharing	CASD	5	California
New Mexico Donor Services	NMOP	5	New Mexico
Nevada Donor Network	NVLV	5	Nevada
Pacific Northwest Transplant Bank	ORUO	6	Oregon
LifeGift Organ Donation Center	TXGC	4	Texas
Intermountain Donor Services	UTOP	5	Utah

Subjects

Inclusion criteria: Deceased organ donors who are classified as White, Black or African American, Hispanic/Latino, or Asian.

Exclusion criteria: Donors who are classified as American Indian or Alaskan Native, Native Hawaiian or other Pacific Islander, or those with multiple ethnic backgrounds.

Outcome Variables

Specific Aim 1

The primary outcome variable for specific aim 1 was achieving ≥4 OTPD out of a possible eight (liver, left kidney, right kidney, left lung, right lung, heart, pancreas, and intestine).

Secondary outcome variables were mean OTPD and achieving transplantation for each of the following organs: liver, any kidney, any lung, heart, and pancreas. Transplantation of any kidney included transplantation of left kidney only, right kidney only, or both kidneys. Similarly, transplantation of any lung included transplantation of left lung only, right lung only, or both lungs. Outcome variables are summarized in **Table 3** below.

Table 3 Outcome Variables for Specific Aim 1

Variable	Variable Type	Values
Achieving 4 or more OTPD	Binary	Yes; no
Mean OTPD	Continuous	0-8
Liver transplantation	Binary	Yes; No
Any kidney transplantation	Binary	Yes (left kidney, right kidney, or both kidneys transplanted); no
Heart transplantation	Binary	Yes; no
Any lung transplantation	Binary	Yes (left lung, right lung, or both lungs transplanted); no
Pancreas transplantation	Binary	Yes; no

OTPD: organs transplanted per donor

Specific Aim 2

The outcome variables for specific aim 2 were meeting the DMG bundle at any of three standardized time points (authorization, 12-18 after authorization, and prior to organ recovery). The DMG bundle was defined as achieving seven or more DMGs out of a possible nine. Secondary outcome variable were mean number of DMGs met at each of three standardized time points. Specific Aim 2 outcome variables are summarized in **Table 4.**

Table 4 Outcome Variables for Specific Aim 2

Variable	Variable Type	Values
Meeting DMG bundle at authorization	Binary	Yes; no
Meeting DMG bundle at 12-18 hours after authorization	Binary	Yes; no
Meeting DMG bundle prior to organ recovery	Binary	Yes; no
Mean DMGs met at authorization	Continuous	0-9
Mean DMGs met at 12-18 hours after authorization	Continuous	0-9
Mean DMGs met prior to organ recovery	continuous	0-9

Predictor Variables

The predictor variable of interest for both specific aims was donor ethnicity as identified on the online portal. This was a categorical variable. Values for donor ethnicity were: White, Black or African American, Hispanic/Latino, or Asian.

Covariables and Potential Confounders

Specific Aim 1

Covariables were donor age, weight, body mass index (BMI), serum creatinine prior to organ recovery, blood type, cause of death, donor type, and OPO. These are summarized in **Table 5**.

Table 5 Covariables for Specific Aim 1

Variable	Variable Type	Values
Donor age (years)	Continuous	≥ 0
Donor weight (kg)	Continuous	> 0
Donor BMI (kg/m^2)	Continuous	> 0
Donor serum creatinine (mg/dL)	Continuous	≥ 0
Donor blood type	Categorical	A; B; AB; O
Donor cause of death	Categorical	Anoxia; cerebrovascular/stroke; CNS tumor; head trauma; other
Donor type	Categorical	SCD; ECD; DCDD
OPO	Categorical	AZOB, CADN, CAGS, CAOP, CASD, NMOP, NVLV, ORUO, TXGC, UTOP

BMI: body mass index; CNS: central nervous system; SCD: standard criteria donor; ECD: expanded criteria donor;DCDD: donor after circulatory determination of death

Specific Aim 2

Potential confounders for specific aim 2 were: donor age, BMI, serum creatinine at the corresponding DMG time point, thyroid hormone use at the corresponding DMG time point, cause of death, donor type, and OPO. These are summarized in **Table 6**.

Table 6 Potential confounders for Specific Aim 2

Variable	Variable Type	Values
Donor age (years)	Continuous	≥ 0
Donor BMI (kg/m^2)	Continuous	> 0
Donor serum creatinine (mg/dL)	Continuous	≥ 0
Thyroid hormone use	Binary	Yes; No
Donor cause of death	Categorical	Anoxia; cerebrovascular/stroke; CNS tumor; head trauma; other
Donor type	Categorical	SCD; ECD; DCDD
OPO	Categorical	AZOB, CADN, CAGS, CAOP, CASD, NMOP, NVLV, ORUO, TXGC, UTOP

BMI: body mass index; CNS: central nervous system; SCD: standard criteria donor; ECD: expanded criteria donor; DCDD: donor after circulatory determination of death

Analysis

All continuous variables were assessed for normality with density plots.

Descriptive statistics, including breakdowns of characteristics by donor ethnicity and outcome variables (≥4 OTPD status, DMG bundle status), were used to analyze the baseline characteristics of the study population. Continuous predictor variables (age, weight, BMI, creatinine) were tested for association with outcome variables by Student's t-test if data were normal. The Satterthwaite approximation was used for data with unequal variances. For non-normal continuous variables, the Wilcoxon rank sum test was used.

Continuous predictor variables were tested for association with donor ethnicity by ANOVA if data were normal and equal variance (among ethnicities) assumptions were reasonable. If data were non-normal or had non-equal variance, Kruskal-Wallis test was used.

Categorical predictor variables were tested for association with outcome variables and donor ethnicity by Chi^2 test. Fischer's exact test was used for data where the expected outcome was less than five.

Specific Aim 1

The crude association between donor ethnicity ≥4 OTPD status as well as organ-specific transplantation were tested with Chi^2 tests. Fischer's exact test was used for data where the expected outcome was less than five. Crude associations between donor ethnicity and mean OTPD were tested with ANOVA model.

Logistic regression was conducted with donor ethnicity as the primary predictor variable of interest. Donor age, weight, BMI, creatinine, blood type, cause of death, donor type, and OPO were included as adjusting/political covariables. The adjusted odds ratios of achieving ≥4 OTPD and each specific organ transplantation for Hispanic, Black, and Asian donors were reported, with White donors as the reference group.

Specific Aim 2

Association between ≥4 OTPD status and DMG bundle status at each time point was tested with Chi^2 tests. The crude associations between donor ethnicity DMG bundle statuses were tested with Chi^2 tests. Fischer's exact test was used for data where the expected outcome was less than five observations. Crude associations between donor ethnicity and mean number of DMGs met at each time point were tested with ANOVA model.

Association models for donor ethnicity and DMG bundle status at each time point were built with two separate approaches: 1). Assessing for change in crude odds ratio, and 2). Assessing for association with outcome. These two methods of variable selection were used because unlike in specific aim 1, the adjusting variables between donor ethnicity and DMG bundle status were unknown and it would have been in appropriate to simply add the proposed potential confounders (**Table 6**) into a final model. In fact, since this is the first study to examine the relationship between donor ethnicity and DMG bundle status, two variable selection methods were used to better understand the effects of the potential confounders on the relationship of interest.

For assessing for change in crude odds ratio, a simple logistic regression model between DMG bundle status and donor ethnicity (using all donors) was built to determine the crude odds ratios for each ethnicity. Each potential confounder was added to the bivariate (or crude) model separately to assess for changes in the crude odds ratios. Variables that resulted in a greater than 10% change in the odds ratio for any donor ethnicity was considered a confounder. The final model included donor ethnicity and the identified confounders.

For assessing for association with the outcome, each the association between each potential confounder and DMG bundle status was tested with t-tests for continuous variables and Chi^2 tests for categorical variables. Wilcoxon rank sum test was used for creatinine due to non-normal distribution. Variables that were associated with DMG bundle status (p-value <0.05) were included in the final model.

The two final models were compared by their effect on the crude odds ratios. The model that controlled for more clinical/donor parameters was chosen as the preferred model if both models had similar effects on the odds ratios. If the two models had dissimilar effects on the crude odds ratios, the model with the greatest changes in the crude odds ratios was chosen as the preferred model. Model diagnostics were conducted on the preferred models.

Model diagnostics

Collinearity detection among predictor variables were conducted with analysis of the variance inflation factor (VIF). VIF greater than 10 was considered concerning for presence of collinearity.

Influential point detection was conducted by calculating the change in standardized Pearson residual, change in standardized deviance residual, and change in estimated coefficients. These were graphed in scatterplots against the predicted probability of the outcome of interest. Observations in the extremes of the predicted probability of the outcome (close to 0 or 1) and with high changes in values in change in residuals, or a change in the estimated coefficients greater than 1, were identified as influential. These were points visually identified in the upper left or upper right quadrants of the scatterplots.

Outliers in predictor variables were detected by calculating leverage, which were also plotted against the predicted probability of the outcome of interest. Observations that appeared visually distant from the where the majority of observations clustered were considered to have high leverage.

Descriptive analysis of influential points and outliers were conducted. For each variable, the association with the influential point and/or outlier status was tested with t-test for continuous variables and Chi^2 test for categorical variables. Satterthwaite approximation, Fischer's exact test and Wilcoxon rank sum test were used where appropriate.

For sensitivity analysis, logistic regression of each model without the identified influential points and/or outliers were conducted. The odds ratios of these models were compared with that of the models with all observations.

The Hosmer-Lemeshow and R-squared statistic were calculated to assess the fit of the model and the C-statistic was obtained from Receiver Operator Characteristic (ROC) curves to determine the accuracy of the model in predicting the outcome of interest.

RESULTS

Specific aim 1: Assess whether there are differences in the attainment of **four or more OTPD (≥4 OTPD)** between White and non-white deceased organ donors.

Hypothesis: Compared to White donors, non-White donors will have lower odds of achieving ≥ 4 OTPD

Sub-aim 1a. Assess whether there are differences in having **individual organ transplanted** between White and non-white deceased organ donors.

Hypothesis: Compared to White donors, non-White donors will have lower odds of having individual organ transplantations

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Donor age, weight, BMI, and OTPD were found to be normally distributed by assessment of density plots (APPENDIX A). Serum creatinine prior to organ recovery was not normally distributed (skewness 3.75) and thus non-parametric methods were used for this variable.

Donor characteristics

Data were collected on 3555 donors between March 2012 and November 2014. Seventy-nine donors (2.2%) who did not fulfill our ethnicity criteria were excluded from analysis. Of the remaining 3476 donors, 55% were White, 30% Hispanic, 9% Black, and 6% Asian. Across all donors, the mean age was 39.4±17 years, mean weight was 77.7±26 kg, mean BMI was 27.2±6.9 kg/m^2, and mean serum creatinine prior to organ recovery was 1.51±1.7 mg/dL. The majority of donors were male, the most frequent blood type was O, the most frequent

cause of death was cerebrovascular/stroke, and the most frequent donor type was standard criteria donor (SCD, **Table 7**).

Table 7 Organ donor characteristics by ≥4 OTPD status

	All donors (n= 3476)	OTPD < 4 (n=2152)	OTPD ≥ 4 (n=1324)	p-value
All donors		62%	38%	
Age (years)	39.4 ± 17.7	44.4 ± 18	31.3 ± 15	<0.001
Weight (kg)	77.7 ± 25.9	79.7 ± 27	74.6 ± 24	<0.001
BMI (kg/m^2)	27.2 ± 6.9	28.0 ± 7	25.9 ± 6	<0.001
Creatinine (mg/dL)*	1.5±1.7	1.68 ± 2	1.22 ± 1	<0.001
Blood type*				0.004
A	36%	37%	35%	
B	12%	12%	11%	
AB	3%	4%	2%	
O	49%	47%	51%	
Cause of death				<0.001
Anoxia	30%	33%	24%	
Cerebrovascular/ stroke	35%	41%	25%	
CNS tumor	0.3%	0.3%	0.3%	
Head trauma	33%	23%	49%	
Other	2.2%	3%	1%	
Donor Type*				<0.001
SCD	66%	50%	93%	
ECD	21%	30%	6%	
DCDD	13%	21%	0.8%	
Ethnicity				<0.001
White	55%	57%	50%	
Hispanic	30%	28%	35%	
Black	9%	8%	8%	
Asian	6%	6%	7%	
OPO				0.004
AZOB (n=357)	10%	11%	9%	
CADN (n=778)	22%	22%	23%	
CAGS (n=165)	5%	4%	6%	
CAOP (n=1071)	31%	30%	32%	
CASD (n=247)	7%	8%	6%	
NMOP (n=100)	3%	4%	2%	
NVLV (n=211)	6%	6%	6%	
ORUO (n=64)	2%	2%	2%	
TXGC (n=252)	7%	7%	8%	
UTOP (n=231)	7%	6%	7%	

BMI: body mass index; SCD: standard criteria donor; ECD: expanded criteria donor; DCDD: donor after circulatory determination of death

*Creatinine-missing 6 values, Wilcoxon rank-sum test; blood type: missing 1 value; donor type: missing 1 value.

Donor characteristics also differed by ethnicity for all variables (**Table 8**). Hispanic and Black donors were younger while Asian donors were older. Asian donors also weighed less and had lower BMI. Black donors had higher creatinine. For blood type, White donors were more likely to be type A, Black and Asian donors were more likely to be type B. For cause of death, White donors were more likely to have died from anoxia and less likely to have died from stroke. Hispanic donors were more likely to have died from head trauma and less likely from anoxia. Asian donors were most likely to have died from stroke and least from head trauma. For donor type, Hispanic donors were more likely to be SCD, Asian donors more likely to be expanded criteria donors (ECDs), and White donors more likely to be donors after circulatory determination of death (DCDDs). White donors were more likely to be from Intermountain Donor Services (UTOP), Hispanic donors from OneLegacy (CAOP), black donors from LifeGift (TXGC), and Asian donors from California Transplant Donor Network (CADN).

Table 8 Donor characteristics by ethnicity

	White (n=1901)	Hispanic (n=296)	Black (n=1058)	Asian (n=221)	p-value
All donors	55%	30%	9%	6%	
Age (years)	41 ± 18	37 ±17	37±18	45±18	<0.001
Weight (kg)	79±26	77±25	80±31	68±20	<0.001
BMI (kg/m^2)	27±6.8	28±6.7	28±9.2	26±4.8	<0.001
Creatinine (mg/dL)*	1.38±1.4	1.60±1.8	1.93±2.2	1.60±1.8	<0.001
Blood type*					<0.001
A	43%	29%	23%	27%	
B	10%	10%	20%	26%	
AB	4%	2%	3%	6%	
O	43%	59%	53%	41%	
Cause of death					<0.001
anoxia	36%	22%	24%	23%	
cerebrovascular/ stroke	30%	37%	44%	54%	
CNS tumor	0.3%	0.2%	1%	0.5%	
Head trauma	32%	39%	29%	22%	
Other	2%	2%	2%	1%	
Donor Type*					<0.001
SCD	61%	75%	70%	65%	
ECD	21%	17%	24%	30%	
DCDD	18%	8%	6%	5%	
OPO					<0.001
AZOB (n=357)	13%	7%	8%	2%	
CADN (n=778)	22%	19%	23%	43%	
CAGS (n=165)	6%	3%	6%	5%	
CAOP (n=1071)	21%	48%	33%	31%	
CASD (n=247)	8%	6%	5%	7%	
NMOP (n=100)	3%	4%	1%	0%	
NVLV (n=211)	7%	3%	8%	9%	
ORUO (n=64)	3%	0.2%	0%	0%	
TXGC (n=252)	6%	7%	15%	3%	
UTOP (n=231)	11%	2%	0.3%	1%	

BMI: body mass index; SCD: standard criteria donor; ECD: expanded criteria donor; DCDD: donor after circulatory determination of death

*Creatinine-missing 6 values, Kruskal-Wallis test; blood type: missing 1 value; donor type: missing 1 value

OPOs also differed in their distribution of donors by ethnicity (**Table 9**). ORUO (Pacific Northwest Transplant Bank) and UTOP had White donors predominantly, CAOP had a high proportion of Hispanic donors, TXGC had a relatively high proportion of Black donors, and CADN had relatively high proportion of Asian donors.

Table 9 Donor ethnicity proportions by OPO

	White (n=1901)	Hispanic (n=296)	Black (n=1058)	Asian (n=221)	p-value
All donors	55%	30%	9%	6%	
OPO					<0.001
AZOB (n=357)	71%	21%	7%	1%	
CADN (n=778)	53%	26%	9%	12%	
CAGS (n=165)	64%	19%	11%	7%	
CAOP (n=1071)	37%	47%	9%	6%	
CASD (n=247)	62%	26%	6%	6%	
NMOP (n=100)	54%	43%	3%	0%	
NVLV (n=211)	64%	15%	12%	9%	
ORUO (n=64)	97%	3%	0%	0%	
TXGC (n=252)	48%	31%	18%	2%	
UTOP (n=231)	90%	9%	0.4%	1%	

OPO: organ procurement organization

Analysis of OTPD

On bivariate analysis, donors who attained ≥ 4 OTPD differed significantly from those who did not attain ≥4 OTPD in all variables (all p-values <0.004). Donors who attained ≥4 OTPD were younger, had lower weight, lower BMI, and lower creatinine. They were also more likely to have died from head trauma, be SCDs, and identify as Hispanic. Donors with ≥4 OTPD were less likely to be blood type AB, identify as White, and differed in their distribution across the OPOs compared to donors with ≤ 4 OTPD (**Table 7)**.

Hispanic donors had the highest unadjusted proportion of donors with ≥ 4 OTPD (44%), followed by Asian donors (39%), Black donors (36%), and White donors (35%, p<0.001 across all ethnicities). Similarly, Hispanic donors also had the highest mean OTPD (3.41±1.8), followed by Asian donors (3.2± 1.9), Black donors (3.17±1.8), and White donors (3.08±1.7, p<0.001 across all ethnicities, **Table 10**).

Table 10 Crude OTPD and individual organ transplantation proportions by donor ethnicity

	All donors (n=3476)	White (n=1901)	Hispanic (n=1058)	Black (n=296)	Asian (n=221)	p-value
Mean OTPD	3.19 ± 1.8	3.08 ± 1.7	3.41 ± 1.8	3.17 ± 1.8	3.2 ± 1.9	<0.001
OTPD ≥ 4	38%	35%	44%	36%	39%	<0.001
Liver	71%	70%	69%	81%	74%	<0.001
Any kidney	82%	84%	83%	74%	77%	<0.001
Any lung	24%	20%	30%	25%	29%	<0.001
Heart	33%	29%	41%	32%	30%	<0.001
Pancreas	11%	11%	12%	13%	10%	0.66

OTPD: organs transplanted per donor

On multivariate analysis, donor ethnicity was found to be associated with achieving ≥ 4 OTPD after controlling for other donor factors. Compared to White donors, Asian donors were more likely to achieve ≥ 4 OTPD (OR: 1.47 (1.03-2.10), p=0.035) while Black donors were less likely (OR: 0.70 (0.51-0.97), p=0.030). The proportion of Hispanic donors with ≥ 4 OTPD was not significantly different from White donors (OR: 1.05 (0.89-1.30), p=0.620, **Table 11**).

Table 11 Multivariate Analysis: Adjusted odds ratios of ≥ 4 OTPD and individual organ transplantations by donor ethnicity

	Hispanic OR (95% CI)	p-value	Black OR (95% CI)	p-value	Asian OR (95% CI)	p-value
OTPD ≥ 4 (n=3468)	1.05 (0.89-1.30)	0.620	**0.70** (0.51-0.97)	0.030	**1.47** (1.03-2.10)	0.035
Liver (n=3468)	**0.76** (0.62-0.93)	0.008	1.38 (0.97-1.95)	0.071	0.95 (0.67-1.36)	0.795
Any kidney (n=3468)	1.13 (0.87-1.46)	0.356	**0.64** (0.45-0.92)	0.016	1.04 (0.69-1.55)	0.851
Any lung (n=3468)	**1.27** (1.03-1.56)	0.023	0.91 (0.64-1.25)	0.571	**1.56** (1.10-2.20)	0.012
Heart (n=3006)	1.24 (1.00-1.54)	0.055	0.81 (0.58-1.14)	0.236	1.46 (0.99-2.15)	0.056
Pancreas (n=2755)	0.93 (0.69-1.26)	0.645	0.83 (0.52-1.31)	0.419	1.42 (0.80-2.52)	0.234

White ethnicity is reference group; OR: odds ratio; CI: confidence interval; OTPD: organs transplanted per donor.
Bolded values have p-value <0.05

Analysis of organ-specific transplantations

On crude analysis, the likelihood of organ-specific transplantations were significantly different across ethnicities for all organs except pancreas **(Table 10)**. Black donors had the

highest proportion of liver transplantation (81%) while Asian donors had the lowest (74%). White donors had the highest proportion of kidney transplantations (84%) while Black donors had the lowest (74%). Hispanic donors had the highest proportion of lung transplantations (30%) while White donors had the lowest (20%). Similarly, Hispanic donors also had the highest proportion of heart transplantations (41%) while White donors had the lowest (29%)**.**

On multivariate analysis, donor ethnicity remained an independent predictor for the transplantation of liver, kidneys, and lungs, but not heart or pancreas (**Table 11)**. Compared to White donors, Hispanic donors were less likely to achieve liver transplantation (OR 0.76 (0.62-0.93), p<0.008), Black donors were less likely to achieve kidney transplantation (OR: 0.64 (0.45-0.92), p=0.016), and both Hispanic (OR 1.27 (1.03-1.56), p=0.023) and Asian donors (OR 1.56 (1.10-2.20), p=0.012) were more likely to achieve lung transplantation**.** Hispanic (OR: 1.24 (1.00-1.54), p=0.055) and Asian (OR: 1.46 (0.99-2.15), p=0.056) donors were also more likely to achieve heart transplantation, but these odds ratios did not reach statistical significance.

MODEL DIAGNOSTICS

Primary outcome measure: ≥ 4 OTPD

Collinearity

Analysis of the variance inflation factor (VIF) did not detect collinearity between predictor variables. Mean VIF was 1.52 and no variable had VIF >10 (max VIF = 4.42, for weight, APPENDIX B table 1).

Influential points and outliers

Thresholds for influential point detection were: change in Pearson's residual > 30 (**Figure 5a**), change in standardized deviance residual > 7 (**Figure 5b**), or change in estimated coefficients >1 (**Figure 5c**). The threshold for outlier detection was leverage >0.05 (**Figure 5d**).

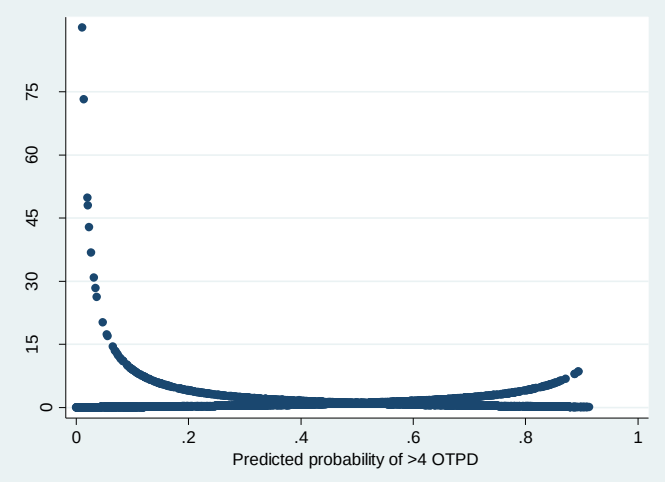

Figure 5a Scatterplot of change in standardized Pearson's residual vs. predicted probability of ≥4 OTPD

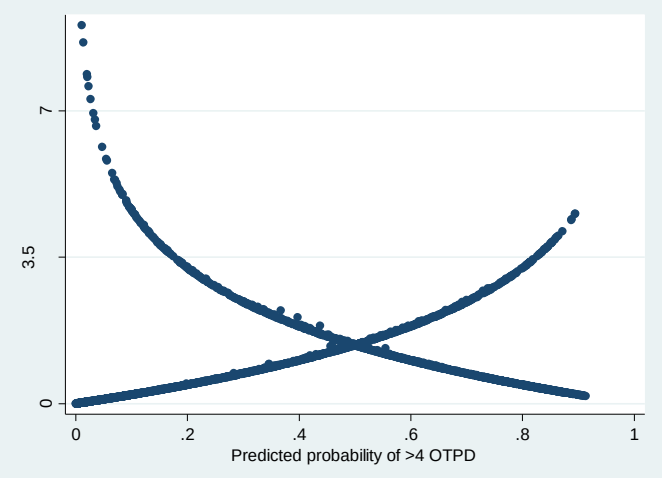

Figure 5b Scatterplot of change in standardized deviance residual vs. predicted probability of ≥4 OTPD

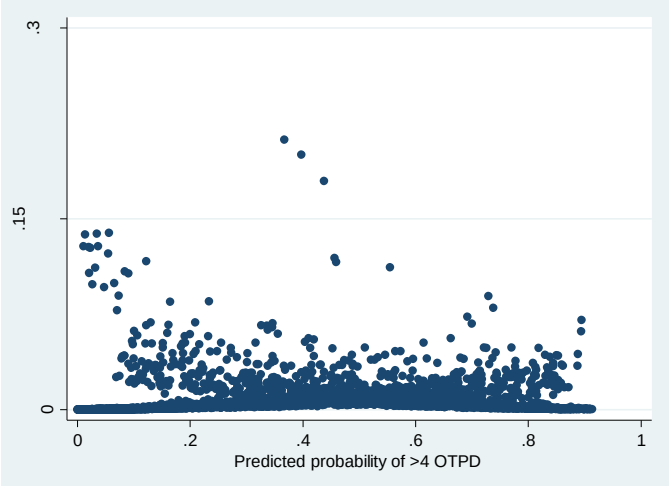

Figure 5c Scatterplot of change in standardized estimated coefficients vs. predicted probability of ≥4 OTPD

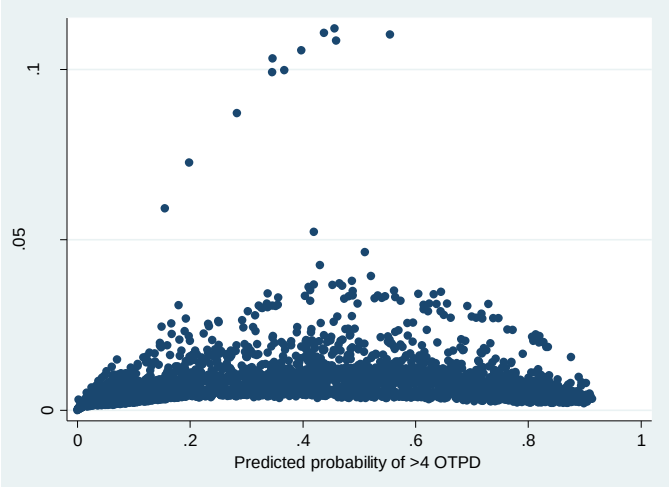

Figure 5d Scatterplot of leverage vs. predicted probability of ≥4 OTPD

Seven donors were identified as influential points by change in standardized Pearson's residual, six by change in standardized deviance residual, and none by change in estimated coefficient. Twelve donors were identified as outliers by leverage, but none of these donors were identified as influential points based on any other criteria (APPENDIX B, table 2).

Analysis of donor characteristics of the influential and outlier observations showed that they differed significantly from the rest of the observations in creatinine, cause of death, and

donor type (**Table 12**). These donors had lower creatinine levels, were more likely to have died from a CNS tumor and were more likely to be DCDDs. In fact, all 11 donors with CNS tumor as the cause of death were identified as having high leverage. Removing the 19 influential and outlier observations from the multivariate model did not significantly affect the estimated odds ratios (**Table 13**)

Table 12 Characteristics of outliers and influential observations for ≥ 4 OTPD model

	Influential (n=19)	Non-influential (n=3449)	p-value
Age (years)	40.1 ± 13	39.4 ± 17.7	0.86
Weight (kg)	81.1 ± 21	77.8 ± 25.9	0.57
BMI (kg/m^2)	28.8 ± 6.4	27.2 ± 6.9	0.31
Creatinine (mg/dL)	0.90 ± 0.56	1.5±1.7	0.04*
Blood type			0.29**
A	26%	36%	
B	11%	12%	
AB	11%	3%	
O	53%	49%	
Cause of death			<0.001**
anoxia	16%	30%	
cerebrovascular/ stroke	11%	35%	
CNS tumor	58%	0	
Head trauma	11%	33%	
Other	5%	2.2%	
Donor Type			0.04**
SCD	63%	66%	
ECD	5%	21%	
DCDD	32%	13%	
Ethnicity			0.54**
White	58%	55%	
Hispanic	21%	31%	
Black	16%	8%	
Asian	5%	6%	
OPO			0.60**
AZOB (n=357)	16%	10%	
CADN (n=778)	26%	22%	
CAGS (n=165)	0%	5%	
CAOP (n=1071)	21%	31%	
CASD (n=247)	16%	7%	
NMOP (n=100)	0%	3%	
NVLV (n=211)	11%	6%	
ORUO (n=62)	0%	2%	
TXGC (n=252)	11%	7%	
UTOP (n=230)	0%	7%	
≥4 OTPD	58%	38%	0.1**

*Satterthwaite's approximation for unequal variances **Fisher's exact test

Table 13 Odds ratios of full model, and model without influential points or outliers for ≥4 OTPD

	Hispanic OR (95% CI)	p-value	Black OR (95%CI)	p-value	Asian OR (95%CI)	p-value	H-L	C statistic
All donors (n=3468)	1.05 (0.86-1.30)	0.620	**0.70** (0.51-0.97)	0.030	**1.47** (1.03-2.10)	0.035	0.704	0.84
Reduced donors (n=3449)	1.06 (0.86-1.31)	0.591	**0.71** (0.51-0.98)	0.037	**1.52** (1.06-2.18)	**0.021**	0.515	0.85

Bolded values have p-value<0.05; H-L: Hosmer-Lemeshow

Only 0.5% of donors were identified as influential points or outliers and the range of values of continuous variables in this subpopulation were within known biological limits: age 18-64 years; weight 51-124 kg; BMI 19-43 kg/m^2; creatinine 0.2-3 mg/dL. Removal of these donors from multivariate analysis did not affect the interpretation of the predicted odds ratio, they were retained in analyses.

Hosmer-Lemeshow tests showed that both models fit the data well. C statistic of both models showed excellent accuracy in predicting ≥4 OTPD (**Table 13)**.

Liver transplantation

Collinearity

Analysis of the variance inflation factor (VIF) did not detect collinearity between predictor variables. Mean VIF was 1.52 and no variable had VIF >10 (max VIF = 4.42, for weight, APPENDIX B table 1).

Thresholds for influential point detection were: change in Pearson's residual> 15 (**Figure 6a**) or change in estimated coefficients >1 (**Figure 6c**). No influential points were observed visually on the graph for change in standardized deviance residual (**Figure 6b).** The threshold for outlier detection was leverage >0.05 (**Figure 6d)**.

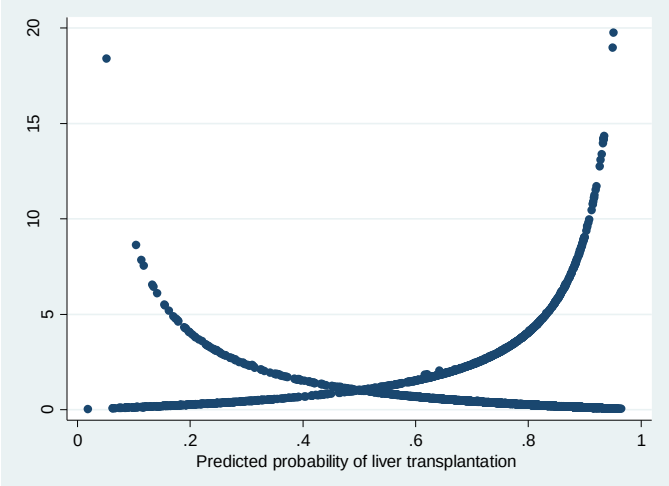

Figure 6a Scatterplot of change in standardized Pearson's residual vs. predicted probability of liver transplantation

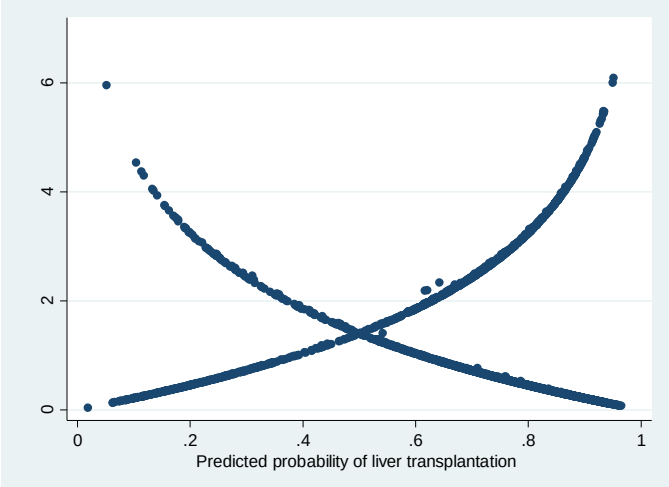

Figure 6b Scatterplot of change in standardized deviance residual vs. predicted probability of liver transplantation

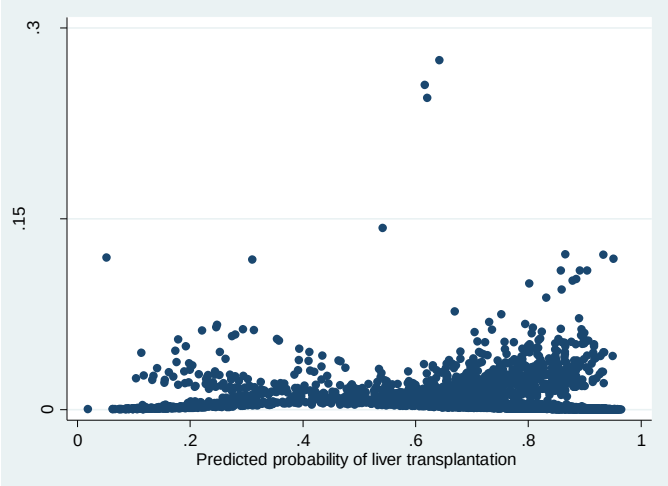

Figure 6c Scatterplot of change in standardized estimated coefficients vs. predicted probability liver transplantation

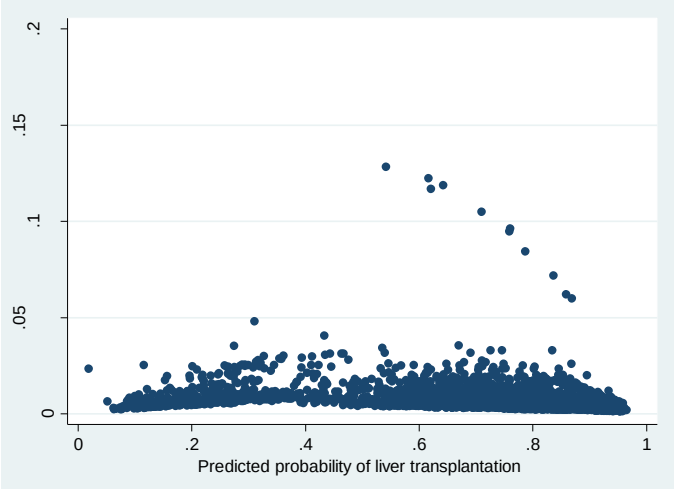

Figure 6d Scatterplot of leverage vs. predicted probability of liver transplantation

Three influential points were identified by change in standardized Pearson's residual threshold and eleven outliers were identified by leverage. The donors identified by leverage were different from donors identified by change in standardized Pearson's residual (APPENDIX B table 3).

Analysis of donor characteristics of the influential and outlier observations showed that they differed significantly from the rest of the observations in cause of death (**Table 14**).

Influential points and outliers were more likely to have died from a CNS tumor. In fact, all were donors with CNS tumor as the cause of death were identified as having high leverage.

Table 14 Donor characteristics of outliers and influential points for liver transplantation

	Influential (n=14)	Non-influential (n=3449)	p-value
Age (years)	39.4±13	39.4±18	0.99
Weight (kg)	84.0±32	77.8±26	0.37
BMI (kg/m^2)	30.3±13	27.2±6.8	0.40*
Creatinine (mg/dL)	0.96±0.62	1.51±1.67	0.12*
Blood type			0.81**
A	29%	36%	
B	7%	12%	
AB	0%	3%	
O	64%	49%	
Cause of death			<0.001**
anoxia	7%	30%	
cerebrovascular/ stroke	0%	35%	
CNS tumor	79%	0%	
Head trauma	14%	33%	
Other	0%	2%	
Donor Type			
SCD	93%	66%	0.08**
ECD	0%	21%	
DCDD	7%	13%	
Ethnicity			0.19**
White	57%	55%	
Hispanic	14%	31%	
Black	21%	8%	
Asian	7%	6%	
OPO			0.459**
AZOB (n=357)	7%	10%	
CADN (n=778)	29%	22%	
CAGS (n=165)	0%	5%	
CAOP (n=1071)	21%	31%	
CASD (n=247)	7%	7%	
NMOP (n=100)	0%	3%	
NVLV (n=211)	14%	6%	
ORUO (n=62)	7%	2%	
TXGC (n=252)	14%	7%	
UTOP (n=230)	0%	7%	
Liver transplantation	43%	38%	0.570**

*Satterthwaite's approximation ** two-sided Fisher's exact test

Only 0.4% of donors were identified as influential points or outliers and the range of values of continuous variables in this subpopulation were within known biological limits: age 19-59 years; weight 52-177 kg; BMI 19-72 kg/m^2; creatinine 0.5-3 mg/dL. Removal of these donors from multivariate analysis did not affect the interpretation of the predicted odds ratios

(**Table 15**). Although the Hosmer-Lemeshow tests showed that the model without influential points and outliers fits the data better, the removed donors reflected the true characteristics of our population, and therefore they were kept in the analyses. The C statistics suggest that the models have acceptable accuracy in predicting liver transplantation (**Table 15)**.

Table 15 Odds ratios for models with all donors and models without influential points or outliers for liver transplantation

	Hispanic OR (95% CI)	p-value	Black OR (95% CI)	p-value	Asian OR (95% CI)	p-value	H-L	C statistic
All donors (n=3468)	**0.76** (0.62-0.93)	0.008	1.38 (0.97-1.95)	0.071	0.95 (0.95-1.36)	0.795	0.056	0.75
Reduced donors (n= 3454)	**0.75** (0.62-0.92)	0.007	**1.44** (1.01-2.05)	0.043	0.97 (0.68-1.38)	0.859	0.301	0.76

Bolded values have p-value<0.05; H-L: Hosmer-Lemeshow

Kidney transplantation

Collinearity

Analysis of the variance inflation factor (VIF) did not detect collinearity between predictor variables. Mean VIF was 1.52 and no variable had VIF >10 (max VIF = 4.42, for weight, APPENDIX B table 1).

Thresholds for influential point detection were: change in Pearson's residual > 50 (**Figure 7a**), or change in standardized deviance residual >10 (**Figure 7b**), or change in estimated coefficients >1 (**Figure 7c**). The threshold for outlier detection was leverage >0.1 (**Figure 7d)**.

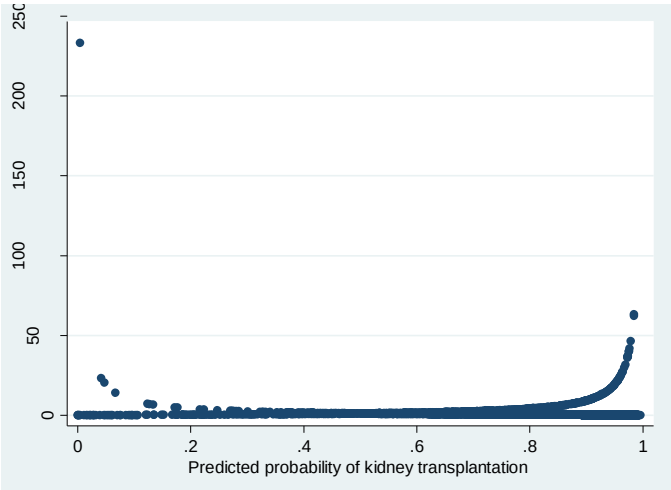

Figure 7a Scatterplot of change instandardized Pearson's residual vs. predicted probability of kidney transplantation

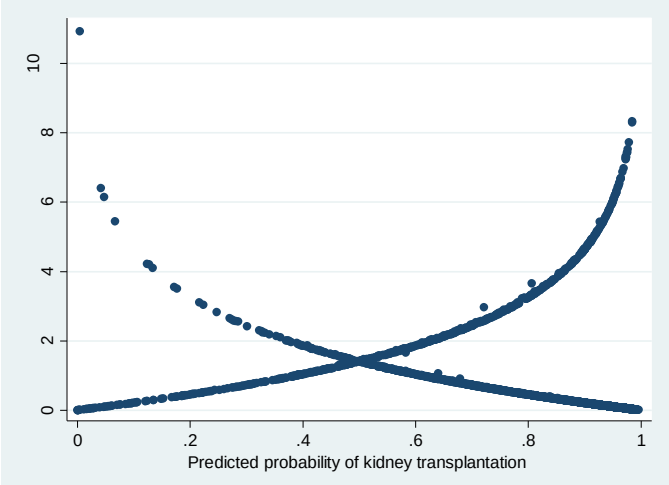

Figure 7b Scatterplot of change in standardized deviance residual vs. predicted probability of kidney transplantation

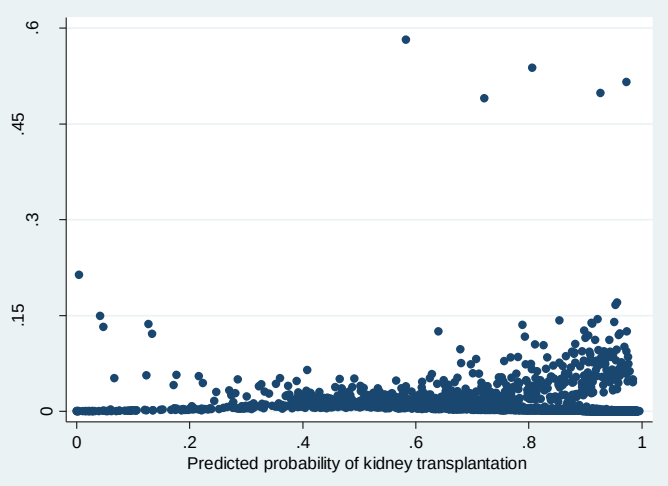

Figure 7c Scatterplot of change in estimated coefficients vs. predicted probability of kidney transplantation

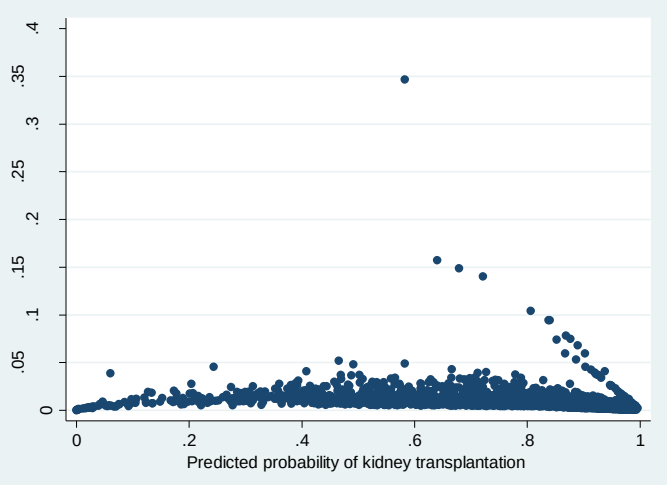

Figure 7d Scatterplot of leverage vs. predicted probability of kidney transplantation

Three influential points were identified by change in standardized Pearson's residual; one of these donors was also identified by change in deviance residual. Five donors were identified as outliers by leverage. None of the donors with high leverage were identified as influential points (APPENDIX B, table 4).

Analysis of donor characteristics of the influential and outlier observations showed that they differed significantly from the rest of the observations in cause of death and kidney transplantation (**Table 16**). Influential points and outliers were more likely to have died from

a CNS tumor and less likely to have achieved kidney transplantation. All eleven donors with CNS tumor as the cause of death were identified as having high leverage.

Table 16 Characteristics of influential points and outliers in kidney transplantation model

	Influential (n=8)	Non-influential (n=3460)	p-value
Age (years)	36.3±23	39.4±18	0.62
Weight (kg)	66.1±25	77.8±25.9	0.20
BMI (kg/m^2)	34.0±26	27.2±6.8	0.48*
Creatinine (mg/dL)	2.4±4.8	1.5±1.6	<0.12*
Blood type			0.306**
A	13%	36%	
B	25%	12%	
AB	0	3%	
O	63%	49%	
Cause of death			<0.001**
anoxia	13%	30%	
cerebrovascular/ stroke	0%	35%	
CNS tumor	50%	0.2%	
Head trauma	38%	33%	
Other	0%	2%	
Donor Type			
SCD	100%	66%	0.200**
ECD	0%	21%	
DCDD	0%	13%	
Ethnicity			0.075*
White	38%	55%	
Hispanic	25%	30%	
Black	38%	8%	
Asian	0%	6%	
OPO			0.692**
AZOB (n=357)	13%	10%	
CADN (n=778)	25%	22%	
CAGS (n=165)	0%	5%	
CAOP (n=1071)	25%	31%	
CASD (n=247)	0%	7%	
NMOP (n=100)	0%	3%	
NVLV (n=211)	13%	6%	
ORUO (n=62)	0%	2%	
TXGC (n=252)	25%	7%	
UTOP (n=230)	0%	7%	
Kidney transplantation	13%	38%	0.037

*Satterthwaite's approximation **2-tailed Fischer's exact test

Only 0.2% of donors were identified as influential points or outliers and the range of values of continuous variables in this subpopulation were within known biological limits: Age 1-59 years; weight: 11-85 kg; BMI 23-97 kg/m^2; creatinine 0.3-14 mg/dL. Removal of these

donors from multivariate analysis did not affect the interpretation of the predicted odds ratios (**Table 17**). Since these donors reflected the true characteristics of our population, they were kept in the analyses.

Hosmer-Lemeshow tests showed that both models fit the data well. The C statistics suggest that the models have excellent accuracy in predicting kidney transplantation (**Table 17)**.

Table 17 Odds ratios for models with all donors and models without influential points or outliers for kidney transplantation

	Hispanic OR (95% CI)	p-value	Black OR (95% CI)	p-value	Asian OR (95% CI)	p-value	H-L	C statistic
All donors (n=3468)	1.13 (0.87-1.46)	0.356	**0.64** (0.45-0.92)	0.016	1.04 (0.69-1.55)	0.851	0.910	0.83
Reduced donors (n=3453*)	1.16 (0.89-1.51)	0.262	**0.62** (0.43-0.89)	0.009	1.05 (0.70-1.57)	0.826	0.900	0.83

Bolded values have p-value<0.05; H-L: Hosmer-Lemeshow
*7 additional donors were dropped from analysis because all donors with cause of death as CNS donors achieved kidney transplantation

Lung transplantation

Collinearity

Analysis of the variance inflation factor (VIF) did not detect collinearity between predictor variables. Mean VIF was 1.52 and no variable had VIF >10 (max VIF = 4.42, for weight, APPENDIX B table 1).

Thresholds for influential point detection were: change in Pearson's residual > 25 (**Figure 8a**), or change in standardized deviance residual >7 (**Figure 8b**), or change in estimated coefficients>1 (**Figure 8c**). The threshold for outlier detection was leverage >0.05 (**Figure 8d)**.

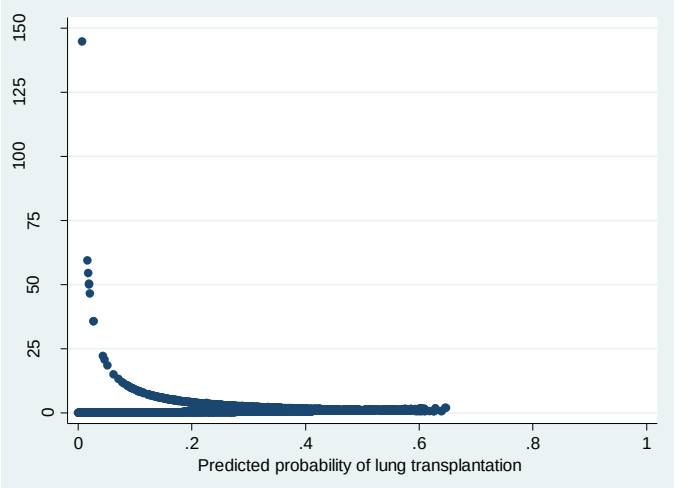

Figure 8a Scatterplot of change in standardized Pearson's residual vs. predicted probability of lung transplantation

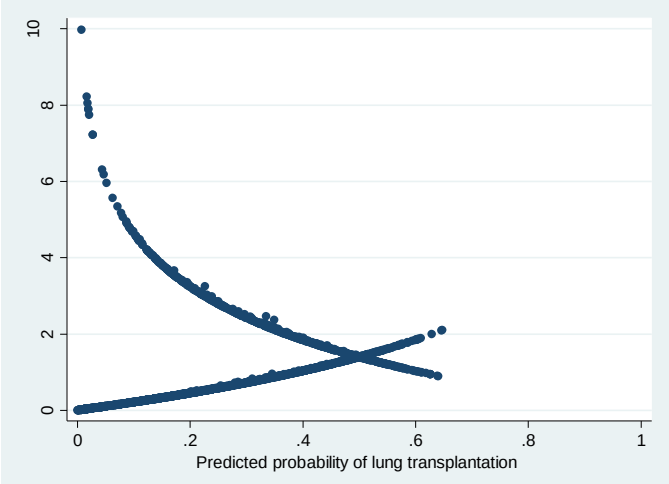

Figure 8b Scatterplot of change in standardized deviance residual vs. predicted probability of lung transplantation

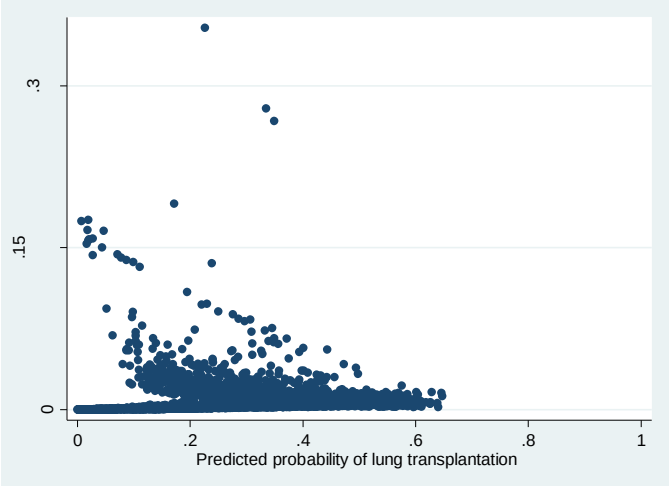

Figure 8c Scatterplot of change in standardized estimated coefficients vs. predicted probability of lung transplantation

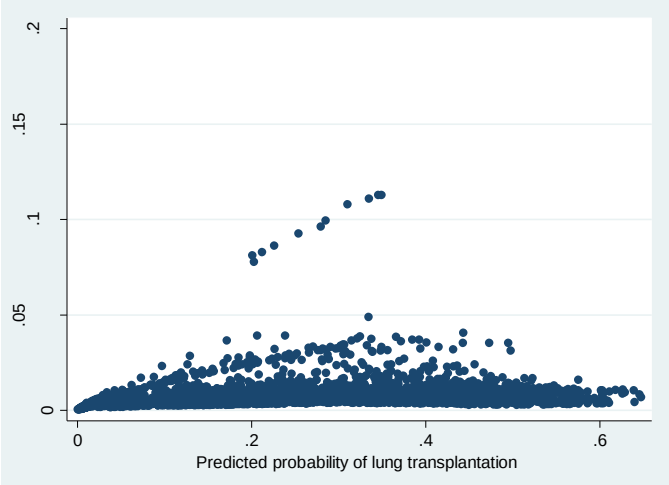

Figure 8d Scatterplot of leverage vs. predicted probability of lung transplantation

Eight donors were identified as influential points by change in standardized Pearson's residual; the same eight were also identified by change in standardized deviance residual. Eleven donors were identified as outliers by leverage. None of the donors with high leverage were identified as influential points (APPENDIX B, table 5).

Analysis of donor characteristics of the influential and outlier observations showed that they differed significantly from the rest of the observations in creatinine, cause of death, donor

type, and lung transplantation (**Table 18**). Influential points and outliers had lower creatinine, were more likely to have died from a CNS tumor and to have achieved lung transplantation, and more likely to have been ECDs and less likely to have been DCDDs. All donors whose cause of death was CNS tumor were found to have high leverage.

Table 18 Characteristics of influential points and outliers in lung transplantation model

	Influential (n=19)	Non-influential (n=3449)	p-value
Age (years)	40.7±13	39.4±18	0.75
Weight (kg)	78.7±19	77.8±26	0.88
BMI (kg/m^2)	28.2±5.7	27.2±6.9	0.54
Creatinine (mg/dL)	0.88±0.56	1.51±1.7	<0.02*
Blood type			0.728**
A	32%	36%	
B	5%	12%	
AB	0%	3%	
O	63%	49%	
Cause of death			<0.001**
anoxia	11%	30%	
cerebrovascular/ stroke	16%	35%	
CNS tumor	58%	0%	
Head trauma	16%	33%	
Other	0%	2%	
Donor Type			
SCD	66%	58%	0.001**
ECD	21%	0%	
DCDD	13%	42%	
Ethnicity			0.075*
White	55%	42%	
Hispanic	30%	32%	
Black	8%	16%	
Asian	6%	11%	
OPO			0.278**
AZOB (n=357)	11%	11%	
CADN (n=778)	32%	22%	
CAGS (n=165)	0%	5%	
CAOP (n=1071)	16%	31%	
CASD (n=247)	21%	7%	
NMOP (n=100)	0%	3%	
NVLV (n=211)	11%	6%	
ORUO (n=62)	0%	2%	
TXGC (n=252)	11%	7%	
UTOP (n=230)	0%	7%	
Lung transplantation	58%	24%	0.002**

*Satterthwaite's approximation ** 2-sided Fisher's exact test

Only 0.5% of donors were identified as influential points or outliers and the range of values of continuous variables in this subpopulation were within known biological limits: Age 20-59

years; weight 51-120 kg; BMI 19-40 kg/m^2; creatinine 0.2-3 mg/dL. Removal of these donors from multivariate analysis did not affect the interpretation of the predicted odds ratios (**Table 19**). Since these donors reflected the true characteristics of our population, they were kept in the analyses.

Hosmer-Lemeshow tests showed that both models fit the data well. The C statistics suggest that the models have acceptable accuracy in predicting lung transplantation (**Table 19)**.

Table 19 Odds ratios for models with all donors and models without influential points or outliers for lung transplantation

	Hispanic OR (95% CI)	p-value	Black OR (95% CI)	p-value	Asian OR (95% CI)	p-value	H-L	C statistic
All donors (n=3468)	**1.27** (1.03-1.56)	0.023	0.91 (0.66-1.25)	0.571	**1.56** (1.10-2.20)	0.012	0.624	0.75
Reduced donors (n=2995)*	**1.23** (0.90-1.00)	0.045	0.87 (0.63-1.20)	0.409	**1.52** (1.08-2.16)	0.018	0.890	0.70

Bolded values have p-value<0.05; H-L: Hosmer-Lemeshow
*454 additional donors were dropped from analysis because no DCDDs achieved lung transplantation

Heart transplantation

Collinearity

Analysis of the variance inflation factor (VIF) did not detect collinearity between predictor variables. Mean VIF was 1.52 and no variable had VIF >10 (max VIF = 4.42, for weight, APPENDIX B table 1).

Thresholds for influential point detection were: change in Pearson's residual > 30 (**Figure 9a**), or change in standardized deviance residual >7 (**Figure 9b**), or change in estimated coefficients >1 (**Figure 9c**). The threshold for outlier detection was leverage >0.05 (**Figure 9d)**.

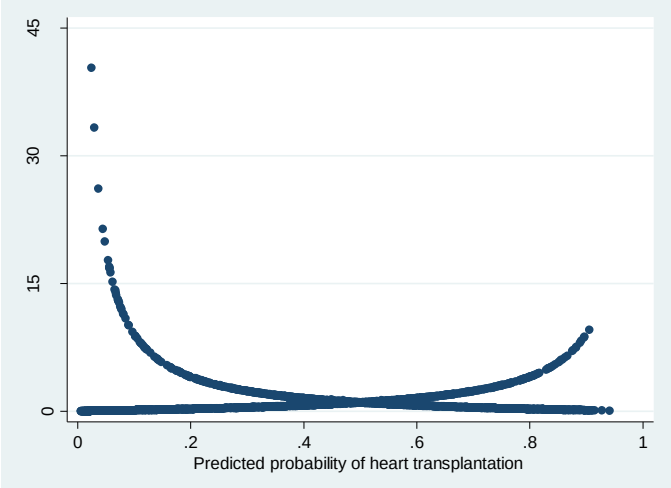

Figure 9a Scatterplot of change in standardized Pearson's residual vs. predicted probability of heart transplantation

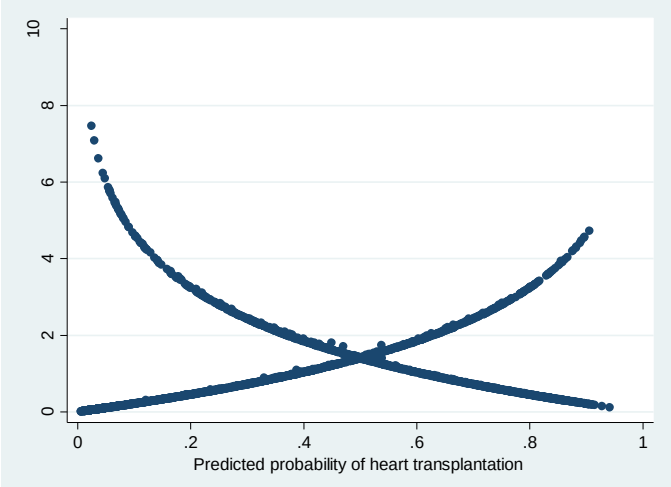

Figure 9b Scatterplot of change in standardized deviance residual vs. predicted probability of heart transplantation

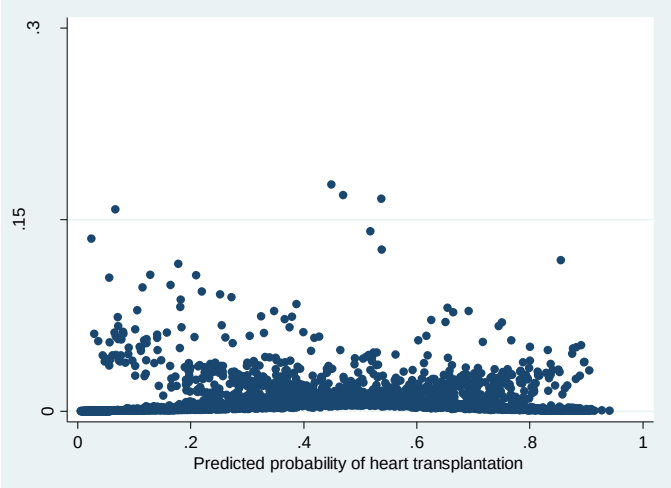

Figure 9c Scatterplot of change in estimated coefficients vs. predicted probability of heart transplantation

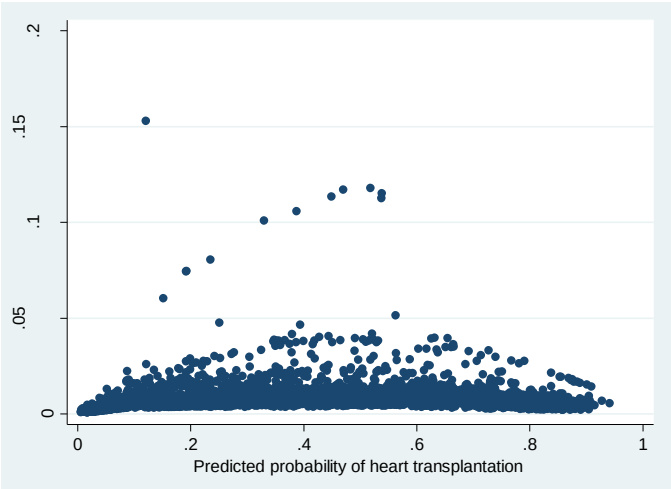

Figure 9d Scatterplot of leverage vs. predicted probability of heart transplantation

Two donors were identified as influential points by change in standardized Pearson's residual; the same two were also identified by change in standardized deviance residual. Thirteen donors were identified as outliers by leverage- none of these donors were also identified as influential points (APPENDIX B, table 6).

Analysis of donor characteristics of the influential and outlier observations showed that they differed significantly from the rest of the observations in creatinine and cause of death

(**Table 20**). Influential points and outliers had lower creatinine, were more likely to have died from a CNS tumor. All donors whose cause of death was CNS tumor were found to have high leverage.

Table 20 Characteristics of influential points and outliers in heart transplantation model

	Influential (n=15)	Non-influential (n=3449)	p-value
Age (years)	39.8±18	39.9±18	0.98
Weight (kg)	70.3±25	77.9±25	0.25
BMI (kg/m^2)	32.0±19	27.2±6.7	0.34*
Creatinine (mg/dL)	0.89±0.62	1.58±1.7	<0.01*
Blood type			0.43**
A	27%	36%	
B	20%	12%	
AB	7%	4%	
O	47%	49%	
Cause of death			<0.001**
anoxia	0%	27%	
cerebrovascular/ stroke	13%	38%	
CNS tumor	73%	0%	
Head trauma	7%	33%	
Other	7%	2%	
Donor Type			0.54**
SCD	87%	76%	
ECD	13%	24%	
DCDD	--	--	
Ethnicity			0.198**
White	47%	52%	
Hispanic	20%	32%	
Black	20%	9%	
Asian	13%	7%	
OPO			0.770**
AZOB (n=357)	7%	9%	
CADN (n=778)	27%	24%	
CAGS (n=165)	0%	5%	
CAOP (n=1071)	27%	32%	
CASD (n=247)	7%	6%	
NMOP (n=100)	7%	3%	
NVLV (n=211)	13%	7%	
ORUO (n=62)	0%	1%	
TXGC (n=252)	13%	7%	
UTOP (n=230)	0%	6%	
Heart transplantation	47%	38%	0.596**

*Satterthwaite's approximation ** 2-sided Fisher's exact test

Only 0.5% of donors were identified as influential points or outliers and the range of values of continuous variables in this subpopulation were within known biological limits: Age 1-60

years; weight 11-120 kg; BMI 21-97 kg/m^2; creatinine 0.3-3 mg/dL. Removal of these donors from multivariate analysis did not affect the interpretation of the predicted odds ratios (**Table 21**). Since these donors reflected the true characteristics of our population, they were kept in the analyses.

Hosmer-Lemeshow tests showed that both models fit the data poorly, likely a result of poor variable selection. The C statistics suggest that the models have acceptable accuracy in predicting heart transplantation (**Table 21)**.

Table 21 Odds ratios for models with all donors and models without influential points or outliers for heart transplantation

	Hispanic OR (95% CI)	p-value	Black OR (95% CI)	p-value	Asian OR (95% CI)	p-value	H-L	C statistic
All donors (n=3006)	1.24 (1.00-1.54)	0.055	0.81 (0.58-1.14)	0.236	1.46 (0.99-2.15)	0.056	0.007	0.83
Reduced donors (n=2991)	1.24 (1.00-1.55)	0.053	0.82 (0.58-1.15)	0.242	1.40 (0.95-2.08)	0.090	0.006	0.83

H-L: Hosmer-Lemeshow

Pancreas transplantation

Collinearity

Analysis of the variance inflation factor (VIF) did not detect collinearity between predictor variables. Mean VIF was 1.44 and no variable had VIF >10 (max VIF = 4.53, for weight, APPENDIX B table 7).

Thresholds for influential point detection were: change in Pearson's residual > 50 (**Figure 10a**), or change in standardized deviance residual>8 (**Figure 10b**), or change in estimated coefficients>1 (**Figure 10c**). The threshold for outlier detection was leverage >0.14 (**Figure 10d)**.

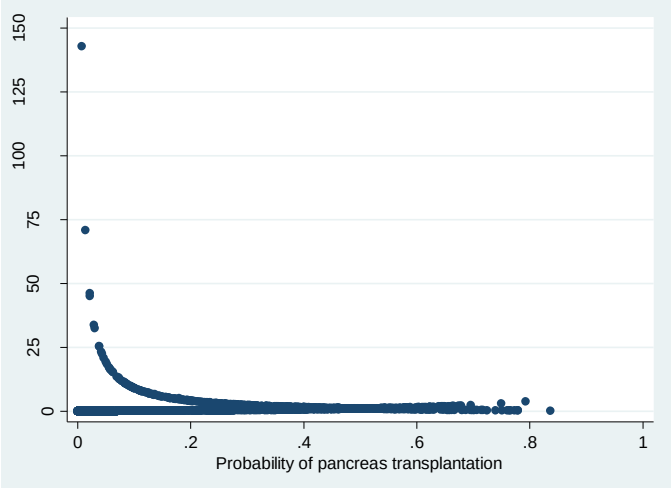

Figure 10a Scatterplot of change in standardized Pearson's residual vs. predicted probability of pancreas transplantation

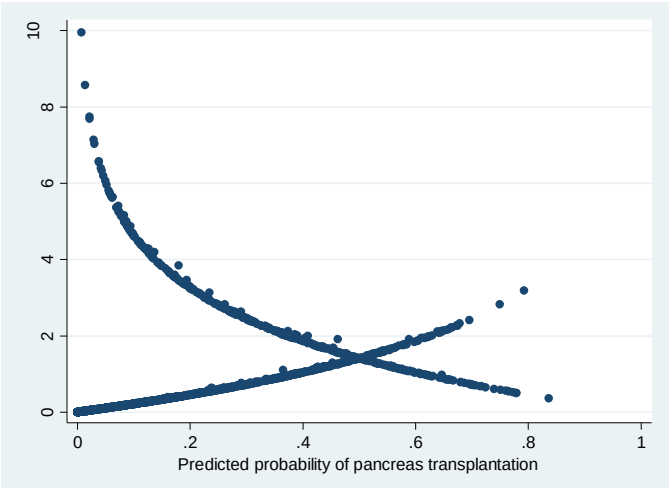

Figure 10b Scatterplot of change in standardized deviance residual vs. predicted probability of pancreas transplantation

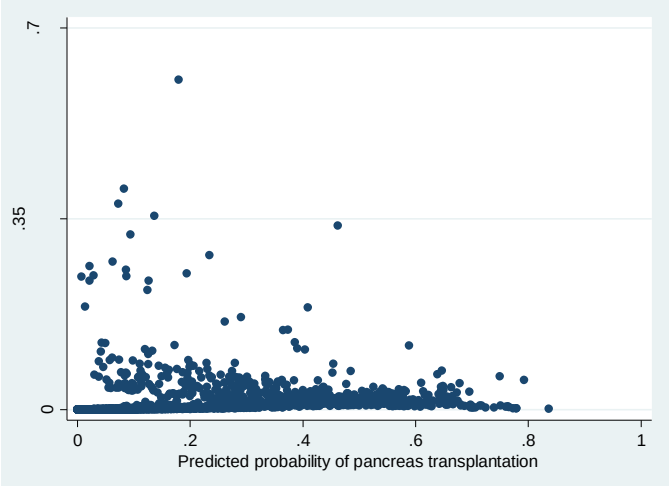

Figure 10c Scatterplot of change in estimated coefficients vs. predicted probability of pancreas transplantation

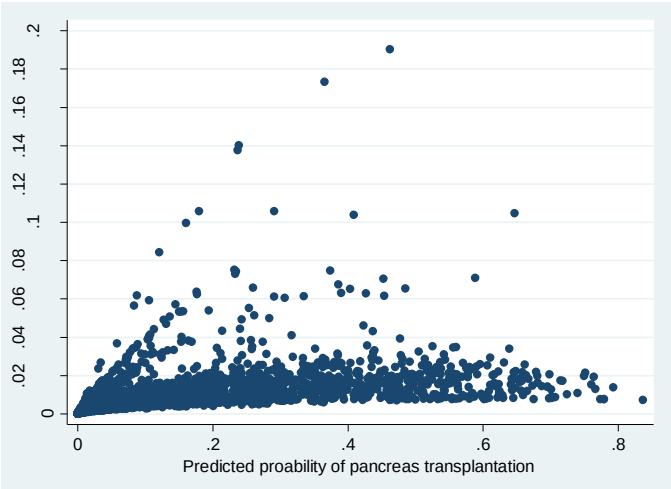

Figure 10d Scatterplot of leverage vs. predicted probability of pancreas transplantation

Two donors were identified as influential points by change in standardized Pearson's residual; these two donors also had high change in standardized deviance residual. Three donors were identified as outliers by leverage- none of these donors were influential points (APPENDIX B, table 8). Due to the extremely small sample size, statistical tests between the five identified points against the rest of donors were not conducted.

Only 0.2% of donors were identified as influential points or outliers and the range of values of continuous variables in this subpopulation were within known biological limits: Age 18-53 years; weight 57-91 kg; BMI 22-30 kg/m^2; creatinine 0.7-5.3 mg/dL. Removal of these donors from multivariate analysis did not affect the interpretation of the predicted odds ratios (**Table 22**) and therefore were retained in the analyses.

Hosmer-Lemeshow tests showed that both models fit the data well. The C statistics suggest that the models have excellent accuracy in predicting pancreas transplantation (**Table 22)**.

Table 22 Odds ratios for models with all donors and models without influential points or outliers for pancreas transplantation

	Hispanic OR (95% CI)	p-value	Black OR (95% CI)	p-value	Asian OR (95% CI)	p-value	H-L	C statistic
All donors (n=2755)	0.93 (0.69-1.26)	0.645	0.83 (0.52-1.31)	0.419	1.42 (0.80-2.52)	0.234	0.092	0.86
Reduced donors (n=2750)	0.94 (0.69-1.27)	0.682	0.80 (0.50-1.27)	0.334	1.43 (0.81-2.56)	0.221	0.093	0.86

H-L: Hosmer-Lemeshow

RESULTS

Specific aim 2: Assess whether there are differences meeting **DMG bundle** at three time points between White and non-white deceased organ donors.

Hypothesis: Compared to White donors, non-White donors will have lower odds of meeting the DMG bundle.

Donor age, BMI, and number of DMGs met were found to be normally distributed. Serum creatinine at each time point were not normally distributed and thus non-parametric methods were used for these variables (APPENDIX A).

Analysis of ≥4 OTPD at each of the three time points (authorization, 12-18 hours after authorization, prior to organ recovery) showed that meeting the DMG bundle was significantly associated with ≥4 OTPD (p-value>0.005). Of the donors who achieved ≥4 OTPD, the proportion who had also achieved the DMG bundle increased at each subsequent time point (19% at referral to 82% prior to organ recovery, **Table 23**).

Table 23 Proportion of donors with DMG bundle met at each time point by ≥ 4 OTPD status

	< 4 OTPD	≥ 4 OTPD	p-value
Referral	15%	19%	0.005
Authorization	19%	31%	<0.001
12-18 hours	33%	62%	<0.001
Prior to OR	45%	82%	<0.001

OTPD: organs transplanted per donor

Across all donors, 23% achieved the DMG bundle at authorization and this increased to 44% at 12-18 hours after authorization, and 59% prior to organ recovery. The proportion of donors who achieved the DMG bundle differed by donor ethnicity prior to organ recovery (p-value =

0.002) where Asian donors had the highest proportion at 67% and White and Black donors had the lowest proportion at 57% (**Table 24)**.

The mean number of DMGs met was 5.5 at authorization and increased to 6.2 at 12-18 hours after authorization and 6.74 prior to organ recovery. The mean number of DMGs met were different by donor ethnicity at authorization and prior to organ recovery, but not at 12-18 hours after authorization. Black donors had the highest mean number of DMGs met at authorization (5.59±1.30) while Asian donors had the highest mean number of DMGs met prior to organ recovery (7.07 ± 1.35, **Table 24**)

Table 24 Mean DMGs met and DMG bundle status by donor ethnicity

	All donors (n=3476)	White (n=1901)	Hispanic (n=1058)	Black (n=296)	Asian (n=221)	p-value
Proportion of DMG bundle met						
Authorization	23%	24% (463)	21% (227)	25% (73)	21% (46)	0.233
12-18 hours	44%	44% (836)	43% (460)	43% (126)	48% (107)	0.549
Prior to OR	59%	57% (1086)	62% (661)	57% (170)	67% (149)	0.002
Mean number DMGs met						
Authorization	5.50 ± 1.36	5.55 ± 1.33	5.38 ± 1.42	5.59 ± 1.30	5.54 ± 1.34	0.006
12-18 hours	6.20 ±1.43	6.20 ± 1.42	6.17 ± 1.48	6.17 ± 1.42	6.36 ± 1.28	0.365
Prior to OR	6.74 ± 1.44	6.64 ± 1.43	6.84 ± 1.45	6.75 ± 1.43	7.07 ± 1.35	<0.001

DMG: donor management goal; OR: organ recovery

Association models

Density plots of donor age and BMI demonstrate that data are approximately normally distributed. Skewness for age is -0.25; skewness for BMI is 1.25. Use of t-test is appropriate for determining the association between these variables and the DMG bundle status at each time point.

Density plots of creatinine at each DMG time point show that data are skewed and not normally distributed. Skewness for each time point: authorization: 4.5; 12-18 hours after

authorization: 4.0; prior to organ recovery: 3.8. Non-parametric (Wilconxon rank-sum) test is appropriate for testing the association between creatinine and DMG bundle status.

Authorization

Bivariate logistic regression found that Hispanic donors trended towards being less likely to achieve the DMG bundle (OR 0.85, p-value 0.07) while Black and Asian donors did not significantly differ from White donors in their likelihood of meeting the DMG bundle (**Table 25**). OPO was identified as a confounder by assessing for a greater than >10% change in the crude OR by adding each covariable separately. After adjusting for OPO, the proportion of non-White donors who achieved the DMG bundle did not differ significantly from White donors (**Table 25**).

Table 25 Analysis of potential confounders by change in crude OR for DMG bundle met at authorization

Variable(s)	Hispanic OR (95% CI), p-value	Change in crude OR	Black OR (95% CI), p-value	Change in crude OR	Asian OR (95% CI), p-value	Change in crude OR
Crude model	0.85 (0.71-1.02), 0.07	--	1.02 (0.77-1.35), 0.91	--	0.82 (0.58-1.15), 0.24	--
+age	0.82 (0.68-0.98), 0.03	-3.5%	0.98 (0.74-1.31), 0.92	-3.9%	0.85 (0.60-1.19), 0.34	3.7%
+BMI	0.87 (0.72-1.04), 0.12	2.4%	1.03 (0.78-1.38), 0.82	1%	0.79 (0.56-1.11), 0.18	-3.7%
+creatinine	0.87 (0.73-1.05), 0.15	2.4%	1.09 (0.82-1.46), 0.55	6.9%	0.83 (0.59-1.17), 0.29	1.2%
+thyroid hormone use	0.84 (0.70-1.00), 0.06	-1.2%	1.00 (0.76-1.34), 0.95	-2.0%	0.82 (0.58-1.15), 0.25	0%
+Cause of death	0.84 (0.70-1.00), 0.06	-1.2%	1.03 (0.78-1.38), 0.82	1%	0.85 (0.60-1.20), 0.37	3.7%
+Donor type	0.84 (0.70-1.00), 0.06	-1.2%	1.03 (0.77-1.36), 0.87	1%	0.84 (0.59-1.18), 0.31	2.4%
+OPO	**0.94** (0.78-1.14), 0.52	11%	**1.14** (0.85-1.52), 0.39	12%	0.84 (0.59-1.19), 0.33	2.4%

OPO: Organ Procurement Organization
Variables with >10% change in crude OR are in **bold**

Variable selection by testing the association between each variable and DMG bundle status found all variables to be significantly associated with achieving the bundle at authorization (**Table 26**).

Table 26 Donor characteristics by DMG bundle status at authorization

	Bundle met (n=809)	Bundle not met (n=2667)	p-value
Age	37±18	40±18	<0.001
BMI	26.3±6.4	27.5±7.0	<0.001
Creatinine	1.5±1.6	1.2±1.2	<0.001
Thyroid hormone use	17%	13%	0.002
Cause of death			0.004
Anoxia	29%	30%	
Stroke	31%	36%	
CNS Tumor	0.5%	0.3%	
Head Trauma	38%	31%	
Other	2%	2%	
Donor type			0.025
SCD	68%	65%	
ECD	17%	22%	
DCDD	14%	13%	
OPO			<0.001
AZOB (n=357)	10%	10%	
CADN (n=778)	21%	26%	
CAGS (n=165)	4%	6%	
CAOP (n=1071)	32%	26%	
CASD (n=247)	7%	8%	
NMOP (n=100)	3%	3%	
NVLV (n=211)	7%	4%	
ORUO (n=64)	2%	2%	
TXGC (n=252)	8%	6%	
UTOP (n=230)	6%	10%	

BMI: body mass index; SCD: standard criteria donor; ECD: expanded criteria donor; DCDD: donor after circulatory determination of death; OPO: organ procurement organization

In comparing the two multivariate models, there was not a large discrepancy in the change in crude odds ratios between the two models (**Table 27**). Since the models appeared to be comparable in their effect on the crude odds ratio, the more parsimonious model, which only contained OPO as a covariable, was preferred

Table 27 Multivariate models for DMG bundle met at authorization

Covariables	Hispanic OR (95% CI), p-value	Change in crude OR	Black OR (95% CI), p-value	Change in crude OR	Asian OR (95% CI), p-value	Change in crude OR
OPO (n=3476)	0.94 (0.78-1.14), 0.52	11%	1.14 (0.85-1.52), 0.39	12%	0.84 (0.59-1.19), 0.33	2.4%
Age, BMI, creatinine, thyroid hormone, cause of death, donor type, OPO (n=3470)	0.93 (0.77-1.14), 0.49	9%	1.17 (0.87-1.58), 0.30	15%	0.85 (0.59-1.21), 0.36	4%

OPO: organ procurement organization; BMI: body mass index

12-18 hours after authorization

Bivariate logistic regression found that non-White donors did not significantly differ from White donors in their likelihood of meeting the DMG bundle 12-18 hours after authorization (**Table 28**). Creatinine, donor type, and OPO were identified as confounders by assessing for a greater than >10% change in the crude OR by adding each covariable separately. After adjusting for these confounders, the odds of meeting the DMG bundle was not different between non-White and White donors (**Table 28**).

Table 28 Analysis of potential confounders and change in crude OR for DMG bundle met 12-18 hours after authorization

Variable(s)	Hispanic OR (95% CI), p-value	Change in crude OR	Black OR (95% CI), p-value	Change in crude OR	Asian OR (95% CI), p-value	Change in crude OR
Crude model	0.98 (0.84-1.14), 0.79	--	0.94 (0.74-1.21), 0.21	--	1.20 (0.90-1.58), 0.21	--
+Age	0.93 (0.80-1.08), 0.35	-5.1%	0.90 (0.70-1.15), 0.41	-4.3%	1.27 (0.96-1.68), 0.10	5.8%
+BMI	1.01 (0.87-1.18), 0.87	3.1%	0.97 (0.76-1.25), 0.81	3.2%	1.14 (0.86-1.51), 0.35	-5%
+Creatinine	1.02 (0.87-1.19), 0.83	4.1%	**1.04** (0.81-1.33), 0.77	10.6%	1.23 (0.93-1.62), 0.15	2.5%
+Thyroid hormone use	0.97 (0.83-1.12), 0.65	-1.0%	0.93 (0.71-1.17), 0.47	-1.1%	1.15 (0.87-1.53), 0.32	-4.2%
+Cause of death	0.94 (0.80-1.09), 0.41	-4.1%	0.94 (0.73-1.20), 0.62	0%	1.22 (0.92-1.61), 0.17	1.7%
+Donor type	**0.86** (0.73-1.00), 0.05	-12.2%	**0.84** (0.66-1.09), 0.19	-10.6%	1.10 (0.83-1.46), 0.52	-8.3%
+OPO	**1.11** (0.95-1.31), 0.20	13.3%	0.99 (0.77-1.28), 0.95	5.3%	1.24 (0.93-1.66), 0.14	3.3%
Adjusted model	1.01 (0.86-1.20), 0.89	--	0.98 (0.75-1.28), 0.88	--	1.18 (0.88-1.58), 0.28	--

BMI: body mass index; OPO: Organ Procurement Organization
Variables with >10% change in crude OR are in **bold**

Variable selection by testing the association between each variable and DMG bundle status found all variables to be significantly associated with achieving the bundle at authorization (**Table 29**).

Table 29 Donor characteristics by DMG bundle status at 12-18 hours after authorization

	Bundle met (n=1529)	Bundle not met (n=1947)	p-value
Age	37±17	41±18	<0.001
BMI	26.2±6.2	28.0±7.3	<0.001
Creatinine	1.3±1.3	1.6±1.8	<0.001
Thyroid hormone use	55%	46%	<0.001
Cause of death			<0.001
Anoxia	26%	32%	
Stroke	33%	36%	
CNS Tumor	0.3%	0.3%	
Head Trauma	38%	29%	
Other	2%	3%	
Donor type			<0.001
SCD	76%	58%	
ECD	17%	24%	
DCDD	7%	18%	
OPO			<0.001
AZOB (n=357)	12%	9%	
CADN (n=778)	27%	19%	
CAGS (n=165)	5%	4%	
CAOP (n=1071)	25%	36%	
CASD (n=247)	7%	7%	
NMOP (n=100)	2%	3%	
NVLV (n=211)	4%	8%	
ORUO (n=62)	1%	2%	
TXGC (n=252)	9%	6%	
UTOP (n=230)	8%	6%	

BMI: body mass index; SCD: standard criteria donor; ECD: expanded criteria donor; DCDD: donor after circulatory determination of death; OPO: organ procurement organization

In comparing the two multivariate models, there was not a large discrepancy in the change in crude odds ratios or their statistical significance between the two models (**Table 30**). Since the models appeared to be comparable in their effect on the crude odds ratio, the more parsimonious model, which only contained creatinine, donor type and OPO as covariables, was preferred.

Table 30 Multivariate models for DMG bundle met 12-18 hours after authorization

Covariables	Hispanic OR (95% CI), p-value	Change in crude OR	Black OR (95% CI), p-value	Change in crude OR	Asian OR (95% CI), p-value	Change in crude OR
Creatinine, donor type, OPO (n=3467)	1.01 (0.86-1.20), 0.89	3%	0.98 (0.75-1.28), 0.88	4%	1.18 (0.88-1.58), 0.28	-2%
Age, BMI, creatinine, thyroid hormone, cause of death, donor type, OPO (n=3467)	0.96 (0.81-1.14), 0.66	-2%	0.93 (0.71-1.22), 0.59	-1%	1.10 (0.82-1.49), 0.52	-8%

OPO: organ procurement organization; BMI: body mass index

Prior to organ recovery

Bivariate logistic regression found that Hispanic and Asian donors had significantly higher odds of meeting the DMG bundle prior to organ recovery compared to White donors (**Table 31**). Donor type, and OPO were identified as a confounder by assessing for a greater than >10% change in the crude OR by adding each covariable separately. After adjusting for donor type and OPO, the odds of meeting the DMG bundle were not significantly different between non-White and White donors (**Table 31**).

Table 31 Analysis of potential confounders and change in crude OR for DMG bundle met prior to organ recovery

Variable(s)	Hispanic OR (95% CI), p-value	Change in crude OR	Black OR (95% CI), p-value	Change in crude OR	Asian OR (95% CI), p-value	Change in crude OR
Crude model	1.25 (1.07-1.46), 0.005	--	1.01 (0.79-1.29), 0.92	--	1.55 (1.16-2.09), 0.004	--
+Age	1.20 (1.03-1.40), 0.02	-4.0%	0.98 (0.76-1.25), 0.85	-3.0%	1.63 (1.21-2.19), 0.001	5.2%
+BMI	1.29 (1.10-1.50), 0.002	3.2%	1.04 (0.81-1.34), 0.75	3.0%	1.49 (1.11-2.01), 0.008	-3.9%
+Creatinine	1.29 (1.11-1.51), 001	3.2%	1.08 (0.84-1.38), 0.57	7.0%	1.61 (1.19-2.17), 0.002	3.9%
+Thyroid hormone use	1.25 (1.07-1.46), 0.005	0%	1.00 (0.78-1.28), 0.99	-1%	1.54 (1.14-2.07), 0.004	-1%
+Cause of death	1.17 (1.00-1.37), 0.049	-6.4%	0.99 (0.77-1.27), 0.92	-2.0%	1.54 (1.15-2.08), 0.004	-1%
+Donor type	**1.02** (0.86-1.19), 0.86	-18.4%	**0.82** (0.64-1.07), 0.14	-18.8%	**1.31** (0.96-1.78), 0.084	-15.5%
+**OPO**	1.21 (1.02-1.42), 0.027	-3.2%	0.97 (0.75-1.25), 0.80	-4.0%	**1.30 (**0.95-1.76), 0.096	-16.1%
Adjusted model	0.99 (0.83-1.18), 0.94	--	0.81 (0.62-1.06), 0.12	--	1.13 (0.82-1.55), 0.45	--

BMI: body mass index OPO: Organ Procurement Organization
Variables with >10% change in crude OR are in **bold**

Variable selection by testing the association between each variable and DMG bundle status found all variables to be significantly associated with achieving the bundle at authorization (**Table 32**).

Table 32 Donor characteristics by DMG bundle status prior to organ recovery

	Bundle met (n=2066)	Bundle not met (n=1410)	p-value
Age	38±17	41±18	<0.001
BMI	26.6±6.4	28.1±7.5	<0.001
Prior to OR creatinine	1.4±1.3	1.7±2.0	<0.001
Thyroid hormone use	41%	35%	0.002
Cause of death			<0.001
Anoxia	26%	35%	
Stroke	35%	35%	
CNS Tumor	0.2%	0.4%	
Head Trauma	37%	27%	
Other	2%	3%	
Donor type			<0.001
SCD	77%	51%	
ECD	18%	24%	
DCDD	5%	25%	
OPO			<0.001
AZOB (n=357)	10%	10%	
CADN (n=778)	28%	14%	
CAGS (n=165)	4%	5%	
CAOP (n=1071)	31%	31%	
CASD (n=247)	6%	9%	
NMOP (n=100)	2%	4%	
NVLV (n=211)	5%	8%	
ORUO (n=62)	1%	3%	
TXGC (n=252)	7%	8%	
UTOP (n=230)	6%	7%	

BMI: body mass index; OR organ recovery; SCD: standard criteria donor; ECD: expanded criteria donor: DCDD: donor after circulatory determination of death; OPO: organ procurement organization

In comparing the two multivariate models, there was not a large discrepancy in the change in crude odds ratios or their statistical significance between the two models (**Table 11**). Since the models appeared to be comparable in their effect on the crude odds ratio, the more parsimonious model, which only contained donor type and OPO as covariables, was preferred.

Table 33 Multivariate models for DMG bundle met prior to organ recovery

Covariables	Hispanic OR (95% CI), p-value	Change in crude OR	Black OR (95% CI), p-value	Change in crude OR	Asian OR (95%CI), p-value	Change in crude OR
Donor type, OPO (n=3467)	0.99 (0.83-1.18), 0.94	-21%	0.81 (0.62-1.06), 0.12	-20%	1.13 (0.82-1.55), 0.45	-27%
Age, BMI, creatinine, thyroid hormone, cause of death, donor type, OPO (n=3469)	0.96 (0.80-1.15), 0.66	-23%	0.82 (0.62-1.08), 0.16	-19%	1.07 (0.77-1.47), 0.70	-31%

OPO: organ procurement organization; BMI: body mass index

MODEL DIAGNOSTICS

Authorization

Collinearity

Analysis of the variance inflation factor (VIF) did not detect collinearity between predictor variables. Mean VIF was 1.16 and no variable had VIF >10 (max VIF = 1.39, for OPO CADN, APPENDIX B table 9).

Influential points and outliers

The threshold for influential point detection was change in estimated coefficients greater than 1 (**Figure 11c**). No influential points were detected on visual inspection by change in standardized Pearson residual or change in standardized deviance residual (**Figure 11a,b)**. No outliers were detected by visual inspection of leverage scatterplot (**Figure 11d).**

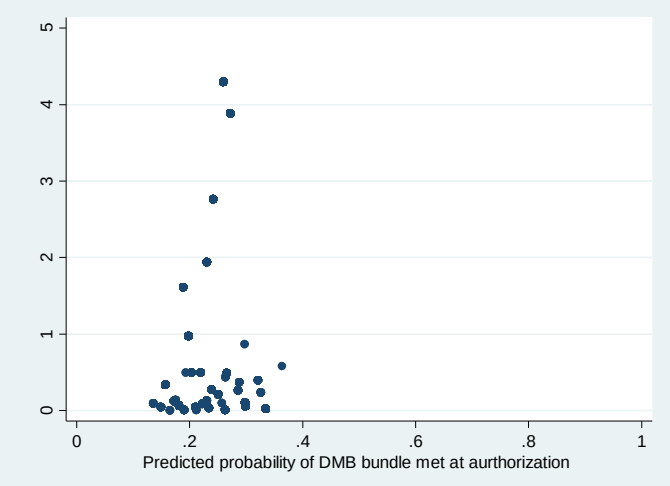

Figure 11a Scatterplot of change in standardized Pearson residual vs. predicted probability of DMG bundle met at authorization

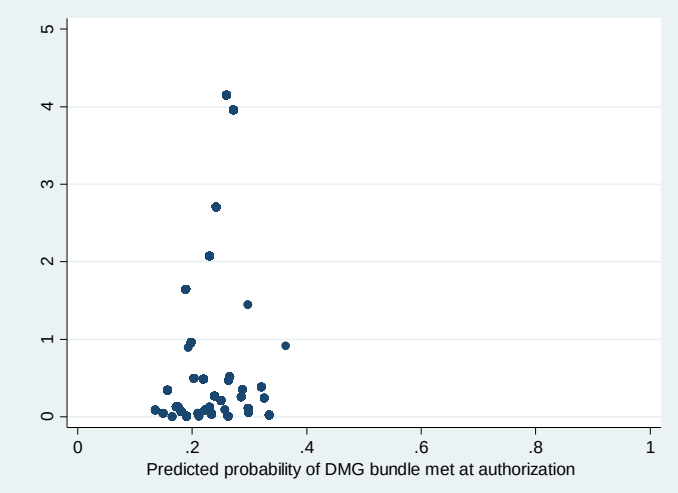

Figure 11b Scatterplot of change in standardized deviance residual vs. predicted probability of DMG bundle met at authorization

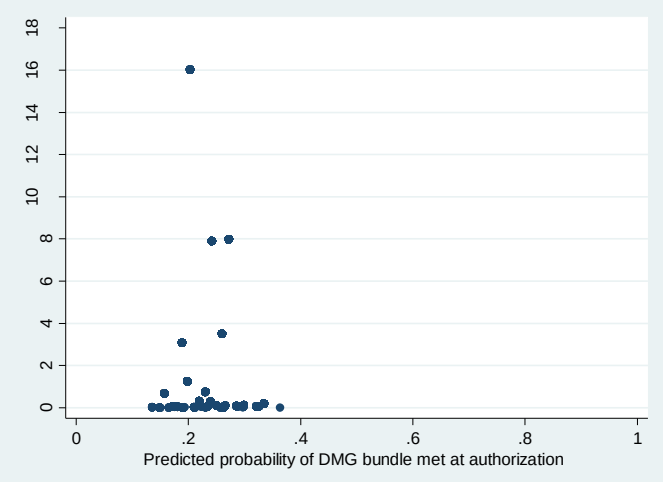

Figure 11c Scatterplot of change in estimated coefficients vs. predicted probability of DMG bundle met at authorization

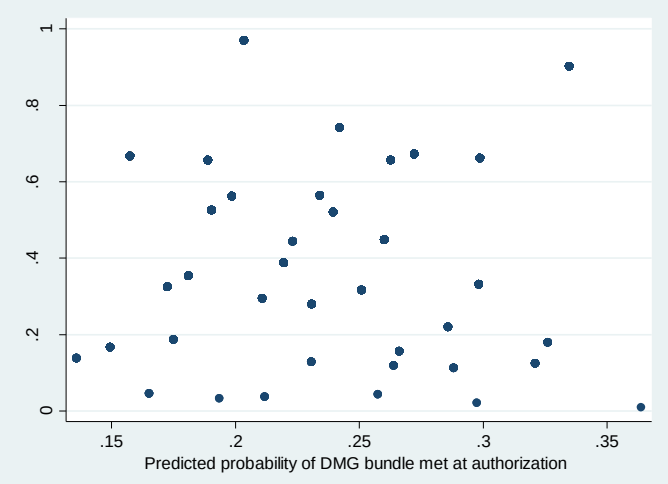

Figure 11d Scatterplot of leverage vs. predicted probability of DMG bundle met at authorization

1835 influential points were detected by change in estimated coefficients. Analysis of donor distribution across predictor variables showed that influential points consisted only of White and Hispanic donors and were from only four OPOs (**Table 34**).

Table 34 Characteristics of influential observations for DMG bundle met at authorization model

	Influential (n=1835)	Non-influential (n=1641)	p-value
Ethnicity			<0.001
White	61%	47%	
Hispanic	39%	21%	
Black	0%	18%	
Asian	0%	13%	
OPO			<0.001
AZOB	14%	6%	
CADN	34%	10%	
CAGS	0%	10%	
CAOP	49%	10%	
CASD	0%	15%	
NMOP	0%	6%	
NVLV	0%	13%	
ORUO	3%	0.1%	
TXGC	0%	15%	
UTOP	0%	14%	

OPO: organ procurement organization

53% of donors were identified as influential points by change in estimated coefficients. However, removing these donors from the multivariate model did not affect the interpretation of the predicted odds ratios (**Table 35)**. Donor ethnicity and OPO in this subgroup were kept in the analysis.

Hosmer-Lemeshow tests showed that both models fit the data well. C-statistic of both models showed that they had poor accuracy in predicting DMG bundle status at authorization (**Table 35**).

Table 35 Odds ratios of full model, and model without influential points for DMG bundle met at authorization

	Hispanic OR (95% CI)	p-value	Black OR (95% CI)	p-value	Asian OR (95% CI)	p-value	H-L	C statistic
All donors (n=3467)	0.94 (0.78-1.14)	0.52	1.14 (0.85-1.52)	0.39	0.84 (0.59-1.19)	0.33	0.74	0.58
Reduced donors (n=1639)*	0.98 (0.70-1.36)	0.88	1.15 (0.75-1.77)	0.52	0.83 (0.50-1.39)	0.48	1.00	0.59

H-L: Hosmer-Lemeshow

*2 additional donors were excluded from analysis because neither donor from ORUO met the DMG bundle

12-18 hours after authorization

Collinearity

Analysis of the variance inflation factor (VIF) did not detect collinearity between predictor variables. Mean VIF was 1.15 and no variable had VIF >10 (max VIF = 1.39, for OPO CADN, APPENDIX B table 10).

Influential points and outliers

The threshold for influential point detection were change in standardized Pearson residual > 10, or change in standardized deviance residual >6, or change in estimated coefficients greater than 1 (**Figures 12a-c**). The threshold for outlier detection was leverage >0.1 (**Figure 12d).**

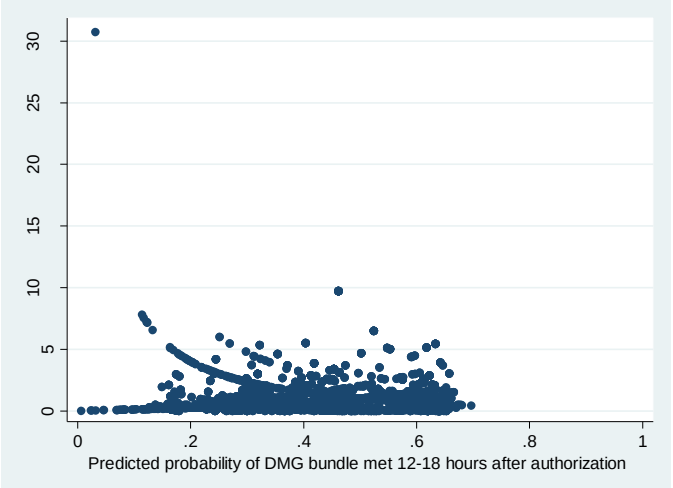

Figure 12a Scatterplot of change in standardized Pearson residual vs. predicted probability of DMG bundle met 12-18 hours after authorization

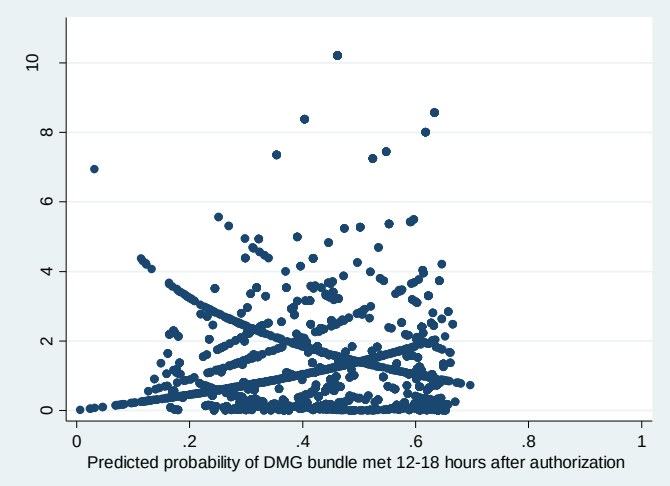

Figure 12b Scatterplot of change in standardized deviance residual vs. predicted probability of DMG bundle met 12-18 hours after authorization

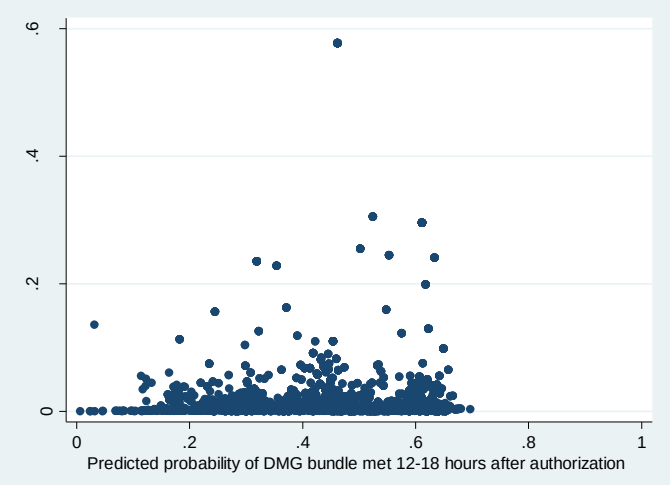

Figure 12c Scatterplot of change in estimated coefficients vs. predicted probability of DMG bundle met 12-18 hours after authorization

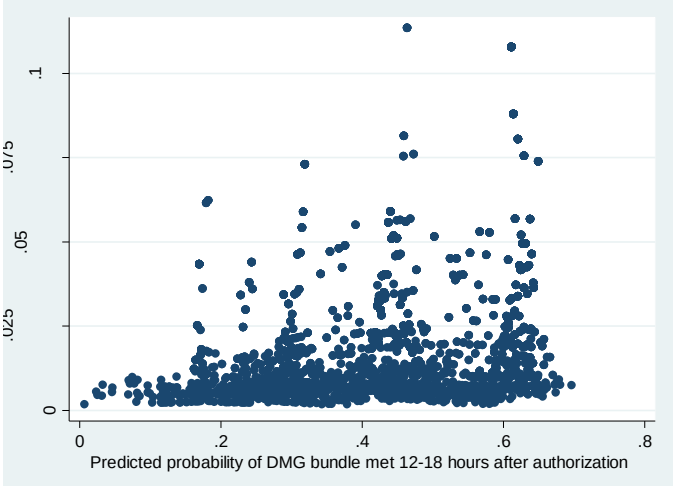

Figure 12d Scatterplot of change in leverage vs. predicted probability of DMG bundle met 12-18 hours after authorization

Sixty-nine influential points were detected by change in standardized deviance residual, one of which also had high change in standardized Pearson residual. Sixty-four outliers were detected by leverage, none of which were identified as influential points.

Influential points and outliers had lower mean creatinine level and were predominantly White donors and SCDs compared to non-influential points. The majority of these donors were also from CADN (**Table 36**).

Table 36 Characteristics of influential observations and outliers for DMG bundle met 12-18 hours after authorization

	Influential (n=133)	Non-influential (n=3334)	p-value
Creatinine	1.07±1.2	1.50±1.6	0.003
Ethnicity			<0.001
White	93%	53%	
Hispanic	7%	31%	
Black	0%	9%	
Asian	0%	7%	
Donor type			<0.001
SCD	84%	65%	
ECD	16%	21%	
DCDD	0%	14%	
OPO			<0.001
AZOB	0%	11%	
CADN	59%	21%	
CAGS	0%	5%	
CAOP	7%	32%	
CASD	11%	7%	
NMOP	0%	3%	
NVLV	6%	6%	
ORUO	5%	2%	
TXGC	6%	7%	
UTOP	7%	7%	

OPO: organ procurement organization

3.8% of donors were identified as influential points or outliers. Removal of donors from the multivariate model did not affect the interpretation of the predicted odds ratios (**Table 37)**. Since the distribution of donor ethnicity donor type, and OPO in this subgroup reflects the true characteristics of our population, and the range of creatinine values were within known biologic limits (0.5-14.6 mg/dL), these donors were kept in the analysis.

Table 37 Odds ratios of full model, and model without influential points for DMG bundle met 12-18 hours after authorization

	Hispanic OR (95% CI)	p-value	Black OR (95% CI)	p-value	Asian OR (95% CI)	p-value	H-L	C statistic
All donors (n=3467)	1.01 (0.86-1.20)	0.89	0.98 (0.75-1.28)	0.88	1.18 (0.88-1.58)	0.28	0.001	0.67
Reduced donors (n=3334)	1.02 (0.86-1.22)	0.78	0.99 (0.76-1.29)	0.93	1.18 (0.88-1.59)	0.27	0.006	0.67

H-L: Hosmer-Lemeshow

Hosmer-Lemeshow tests showed that neither model fit the data well, likely a reflection of poor variable selection. C-statistic of both models showed that they had poor accuracy in predicting DMG bundle status 12-18 hours after authorization (**Table 37**).

Prior to organ recovery

Collinearity

Analysis of the variance inflation factor (VIF) did not detect collinearity between predictor variables. Mean VIF was 1.16 and no variable had VIF >10 (max VIF = 1.39, for OPO CADN, APPENDIX B table 11).

Influential points and outliers

Threshold for influential point detection were: change in standardized deviance residual >6, or change in estimated coefficients >1 (**Figures 13b, c)**. No influential points were detected by visual examination of change in standardized Pearson residual plot (**Figure 13a)**. No outliers were detected by visual examination of leverage plot (**Figure 13d)**.

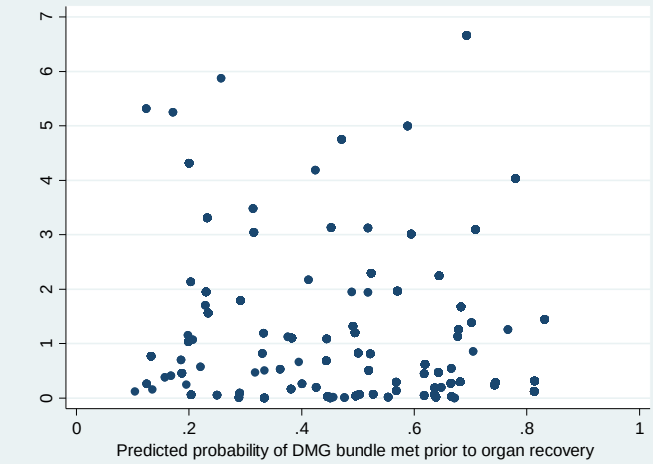

Figure 13a Scatterplot of change in standardized Pearson residual vs. predicted probability of DMG bundle met prior to organ recovery

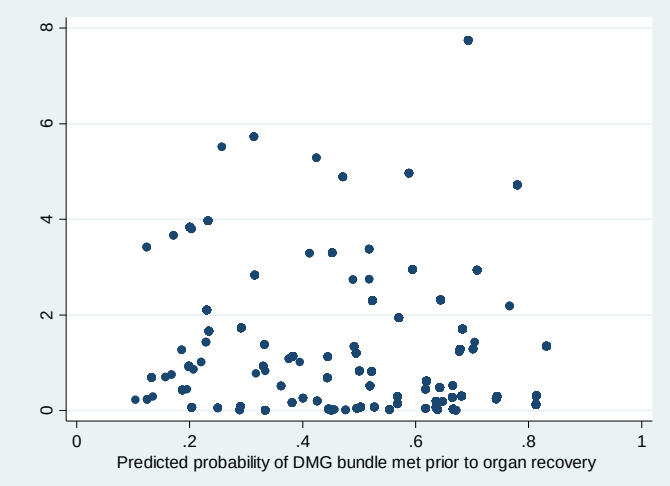

Figure 13b Scatterplot of change in standardized deviance residual vs. predicted probability of DMG bundle met prior to organ recovery

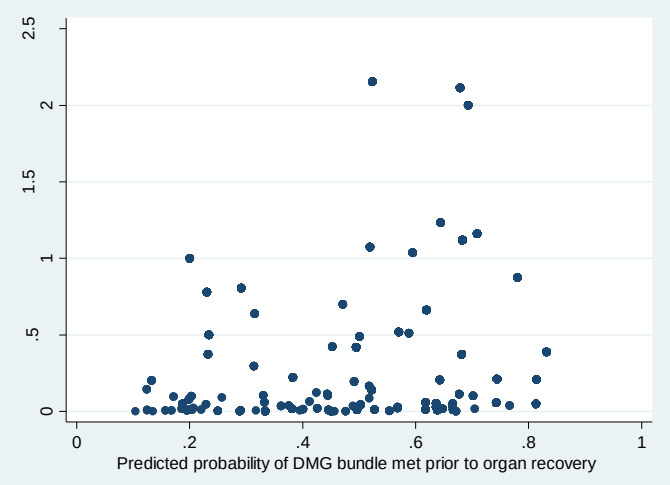

Figure 13c Scatterplot of change in estimated coefficients vs. predicted probability of DMG bundle met prior to organ recovery

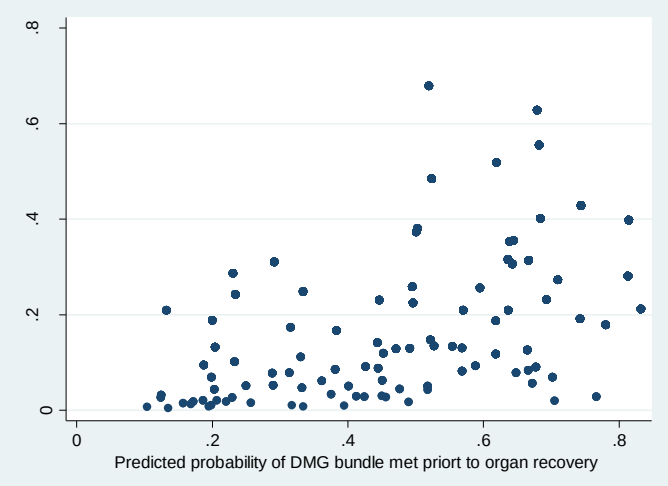

Figure 13d Scatterplot of leverage vs. predicted probability of DMG bundle met prior to organ recovery

Thirty-seven donors were identified as influential points by change in standardized deviance residual, 697 by change in estimated coefficients. All donors identified by change in standardized deviance residual also had high change in estimated coefficients.

Analysis of donor characteristics found that influential points and outliers differed significantly from other observations in donor ethnicity, donor type, and OPO. The vast majority of influential points and outliers were White donors and SCDs (none were Hispanic donors or DCDDs). Nearly half of the donors were from OneLegacy in California (**Table 38**).

Table 38 Characteristics of influential observations and outliers for DMG bundle met prior to organ recovery

	Influential (n=697)	Non-influential (n=2778)	p-value
Ethnicity			<0.001
White	83%	5%	
Hispanic	0%	9%	
Black	5%	38%	
Asian	12%	48%	
Donor type			<0.001
SCD	95%%	59%	
ECD	5%	24%	
DCDD	0%	17%	
OPO			<0.001
AZOB	0%	13%	
CADN	5%	27%	
CAGS	0%	6%	
CAOP	42%	28%	
CASD	0%	9%	
NMOP	0%	4%	
NVLV	13%	4%	
ORUO	5%	1%	
TXGC	16%	5%	
UTOP	19%	4%	

OPO: organ procurement organization

20% of donors were identified as influential points or outliers. Removal of these donors from multivariate analysis did not affect the interpretation of the predicted odds ratios (**Table 39)** and they were kept in the analysis.

Hosmer-Lemeshow tests showed that both models fit the data well. C statistic of both models showed acceptable accuracy in predicting DMG bundle status prior to organ recovery (**Table 39**).

Table 39 Odds ratios of model with all donors and model without influential observations and outliers prior to organ recovery

	Hispanic OR (95% CI)	p-value	Black OR (95% CI)	p-value	Asian OR (95% CI)	p-value	H-L	C statistic
All donors (n=3475)	0.99 (0.83-1.18)	0.94	0.81 (0.62-1.06)	0.12	1.13 (0.82-1.55)	0.45	0.45	0.74
Reduced donors (n=2778)	1.04 (0.84-1.28)	0.74	0.90 (0.67-1.22)	0.49	1.08 (0.72-1.62)	0.71	0.87	0.72

H-L: Hosmer-Lemeshow

DISCUSSION

Ethnic differences in deceased organ donor management and organ utilization is an unexplored and important issue to understand given the shortage of organs available for transplantation and the fact that organ transplantation not only benefits the organ recipient, but the family of the donor as well[22, 23]. This study of 10 OPOs in the western and southern Unite States found that there are ethnic differences in odds of achieving ≥4 OTPD as well as individual organ transplantation rates. In examining the relationship between donor ethnicity and meeting DMG bundle attainment, there were no differences in the odds of attaining the DMG bundle between White and non-White donors at any of the three time points in during donor management.

On crude analysis, Hispanic donors had the highest proportion of achieving ≥4 OTPD while White donors had lowest. This is likely due to the fact that Hispanic donors tended to be younger and SCDs. White donors, on the other hand, had the highest proportion of DCDDs, who were much less likely to achieve ≥4 OTPD (2% versus 53%). White donors were also most likely to have died from anoxia, and had much lower proportion of donors achieving ≥4 OTPD than head trauma (31% versus 56%), the most likely cause of death in Hispanic donors.

The differences in ≥4 OTPD attainment by donor ethnicity observed after controlling for donor characteristics and OPO suggest that perhaps that there are differences in the critical care endpoints achieved by donor ethnicity. However, there was no significant association between donor ethnicity and DMG bundle attainment at any of the time points on

multivariate analysis. It is possible that other factors, such as donor socioeconomic status, geographical region, and human leukocyte antigen (HLA) matching might affect ≥4 OTPD attainment but were uncontrolled for in our analysis. Studies of transplant recipients have found that geographical region is associated with determining waitlist status and achieving organ transplantation[4, 24, 25]. Although OPO may serve as a proxy for donor region in this study, it may not have captured the relevant regional characteristics such as population density or demographics. Regional differences may also reflect variations in socioeconomic status. Some studies have used patient insurance status as a proxy for socioeconomic status but this was not included in this dataset.

The findings on kidney transplantation are consistent with some of the trends found in transplant recipient outcomes. Multiple studies have shown that Black kidney transplant recipients have lower rates of graft survival[2, 6, 26]. Given the persistently high prevalence of diabetes, hypertension, and renal disease in African Americans in general, the lower rates of kidney transplantation from Black donors found in this study may be a reflection of poor renal health at a population level that is inadequately controlled for by the available measures of serum creatinine and urine output in the acute care setting.

The results for liver, lung, heart, and pancreas transplantation can be compared to the odds ratios obtained from the national Scientific Registry of Transplant Recipients (SRTR)[27]. The SRTR develops risk adjustment models to predict OPO organ yield based on donor factors. The model developed for liver, lung, heart, and pancreas in the December 2015 report included donor ethnicity as a variable which was categorized as Black, Hispanic, or other,

with White as the reference group. Although confidence intervals and p-values were not reported in the SRTR model data, the adjusted odds ratios for liver transplantation followed the same trend as this study. Black donors were more likely to achieve liver transplantation (OR=1.70) while Hispanic donors were less likely (OR=0.68). For thoracic organ transplantation, the results of the SRTR models differed from that of this study. The SRTR models reported odds ratios around one for heart transplantation (Black donors= 0.91; Hispanic donors= 1.03; other donors= 1.04) and below one for lung transplantation (Black donors= 0.77; Hispanic donors= 0.75; other donors= 0.86). However, the results of this study suggested that the trend for heart and lung transplantation were similar, where both Hispanic and Asian donors had higher odds of transplantation than White donors. For pancreas transplantation, the SRTR model found that Hispanic and other donors were less likely to achieve transplantation (Black donors= 1.11; Hispanic donors= 0.70; other donors= 0.78). The differences between the results of this study and those of the SRTR models may be due to differences in patient population (regional versus national), the covariables included, and the categorization of donor ethnicity.

In evaluating the relationship between donor ethnicity and DMG bundle status, the confounding effect of OPO was mixed for different donor ethnicities at each critical care time point. OPO was a negative confounder (adjusted OR away from 1) for Hispanic donors and a positive (adjusted OR towards the 1) for Black donors at time of authorization, a qualitative confounder for Hispanic donors 12-18 hours after authorization, and a positive confounder for Asian donors at prior to organ recovery. That OPO has a pervasive effect as a confounder is not surprising. The attainment of critical care endpoints as measured by DMG

bundle status likely varies across different management practices adopted by each OPO. While each OPO is trying to achieve the DMGs in their donors, there is no one protocol that dictate how all the OPOs should reach these critical care endpoints.

Donor type was a negative confounder for Hispanic and Black donors at 12-18 hours after authorization, and a positive confounder for Hispanic donors but negative confounder for Black and Asian donor prior to organ recovery. These observations are consistent with the distribution of donor ethnicities across donor types as the adjusted values were all lower than the crude values. The benefit of having a higher proportion of SCDs (who are younger and healthier) in non-White donors compared to White donors was attenuated after controlling for donor type.

After controlling for confounders, no significant difference was observed in the odds of meeting the DMG bundle between White donors and non-White donor at any of the time points. The observed crude associations were likely a result of differences in the distribution of donor type across ethnicities and not a result of differences in the ability to achieve DMG bundles inherent to different ethnic groups. The role of OPO in the association between donor ethnicity and DMG bundle status is less clear. Although OPO affects the crude association, there is not a consistency in the directionality of the effect or a pattern across ethnicities or time points. As in the case of ≥4 OTPD, it may be that the OPO is acting as a sub-optimal proxy for differences in regional demographics and donor management practices.

Another consideration in the link between organ utilization and DMG attainment is the role of specific DMG goals in the transplantation of individual organs. While DMG bundle attainment used to maximize overall OTPD, the DMGs themselves may be more specific to the condition of individual organs. For example, ejection fraction is more direct indicator of cardiac health than urine output, which may better reflect the donor's renal function status. The differences by ethnicity found in the transplantation of individual organs may be due to differences in the attainment of specific DMGs as opposed to the DMG bundle. Future studies may identify DMGs that when met, result in greater ethnic parity in organ utilization.

Currently, the association between donor ethnicity and transplantation outcomes are less understood than those focused on recipient ethnicity. Some studies have found that donor-recipient ethnicity pairing is associated with recipient outcomes[10, 11, 28, 29]. While the application of these observations to donor management and organ allocation practices is unclear, these studies highlight the importance of understanding ethnic differences in the organ donor which may ultimately affect transplant recipient outcomes.

This study was limited in the lack of data on donor socioeconomic status, as described above. Variations in regional demographics was not taken into account which have been shown to be related to transplant outcomes. The extent to which OPO acts as a proxy for differences in donor management practices, socioeconomic status, or regional demographics, or a combination of these factors is unclear. As a result of this uncertainty, and taking into account that the variable OPO consists of ten categories which may cause model over-specification, it may be more appropriate to use OPO as a random effects (as opposed to

fixed effects) variable. The study population is localized to the western and southern United States and is under represented in White and Black donors, while over represented in Hispanic and Asian donors when compared to the national distribution of deceased organ donors (67% White, 16% Black, 13% Hispanic, 2% Asian). The differences in distribution of donor ethnicity may limit the generalizability of the findings in this study.

CONCLUSION

There are ethnic differences in overall organ utilization as well as specific organ transplantation rates even after controlling for donor characteristics. However, there are not corresponding differences in the attaining DMG bundles which have previously been shown to be associated with ≥4 OTPD. These results suggest that donor ethnicity affect organ utilization in an alternate pathway where regional differences and socioeconomic status may play important roles. Future studies are needed to better understand the relationship between socioeconomic status, regional differences, and donor ethnicity in organ utilization.

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APPENDIX A- ASSESSMENT OF NORMALITY

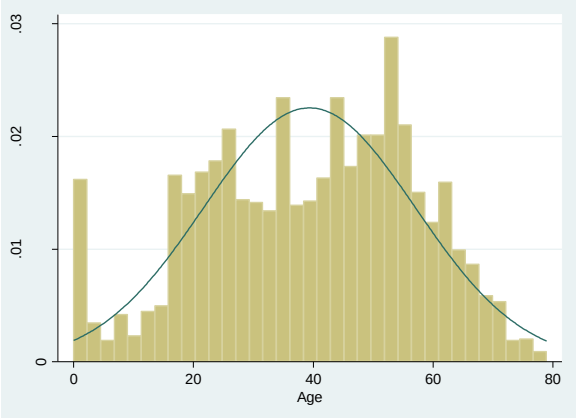

Figure 1 Density plot with overlayed normal curve for donor age

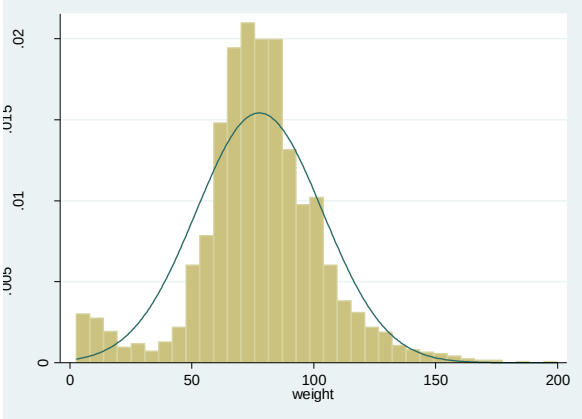

Figure 2 Density plot with overlayed normal curve for donor weight

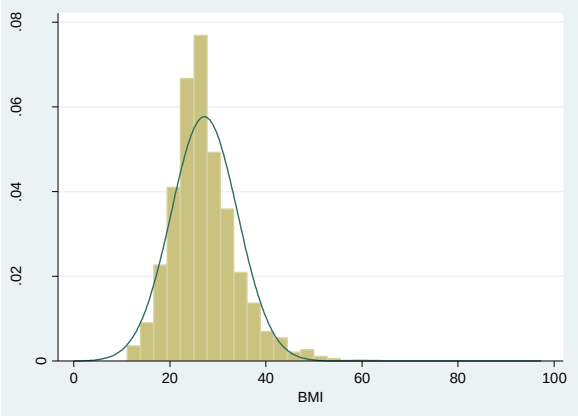

Figure 3 Density plot with overlayed normal curve for donor BMI

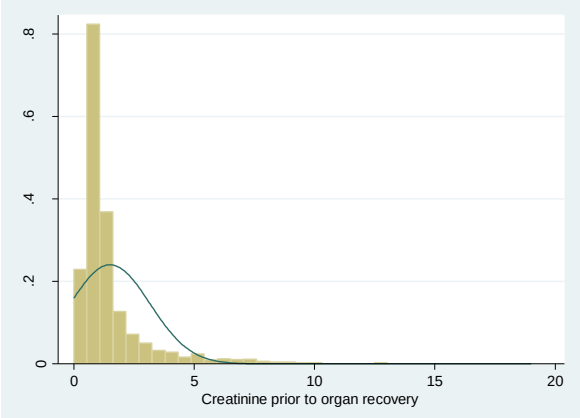

Figure 4 Density plot with overlayed normal curve for creatinine prior to organ recovery

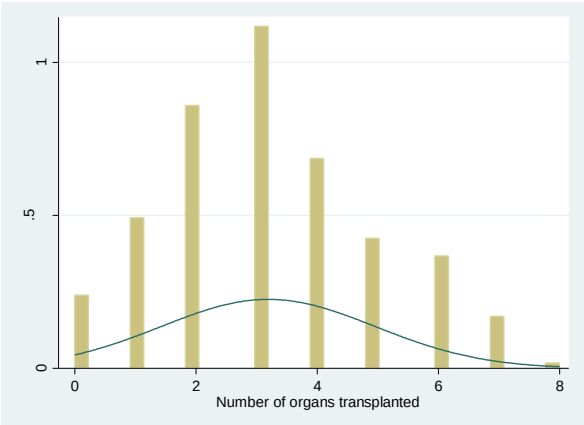

Figure 5 Density plot with overlayed normal curve for number of organs transplanted

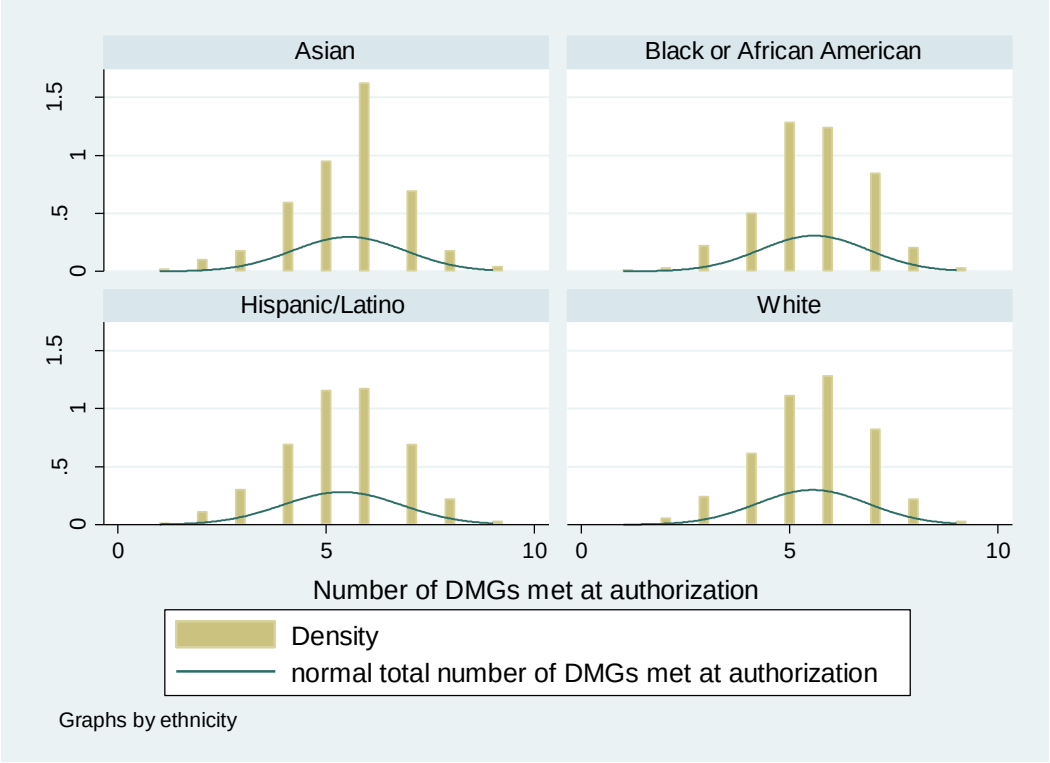

Figure 6 Density plot of number of DMGs met at authorization for each donor ethnicity overlaid with normal curve

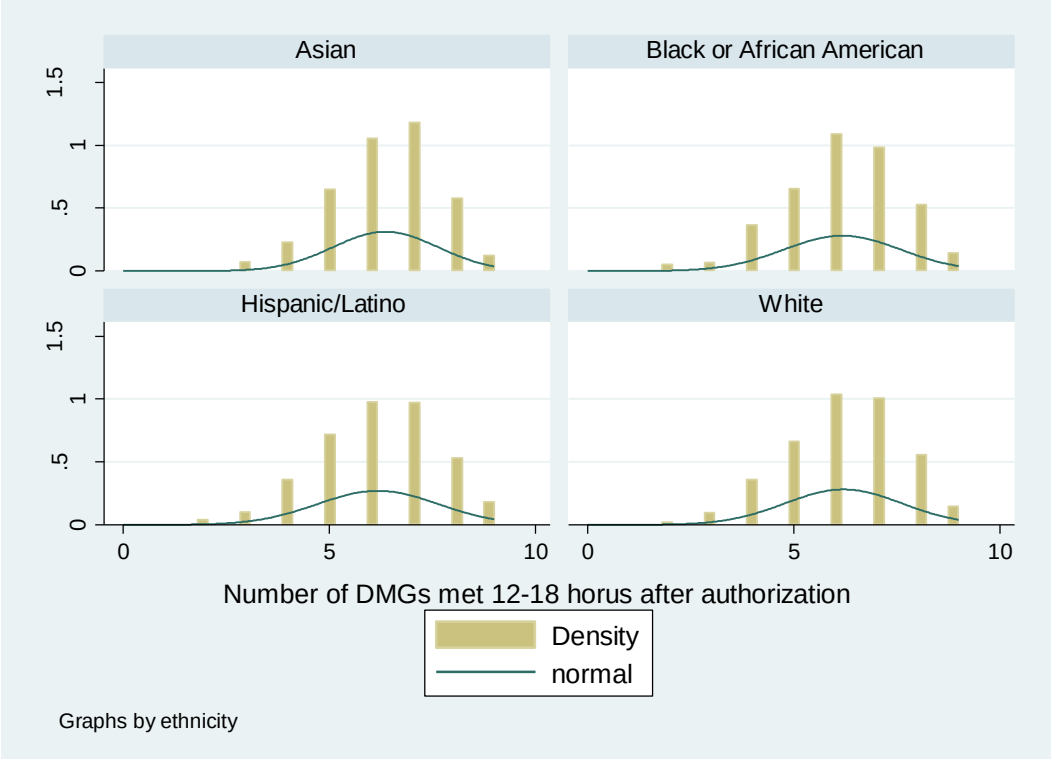

Figure 7 Density plot of number of DMGs met 12-18 hours after authorization for each donor ethnicity overlaid with normal curve

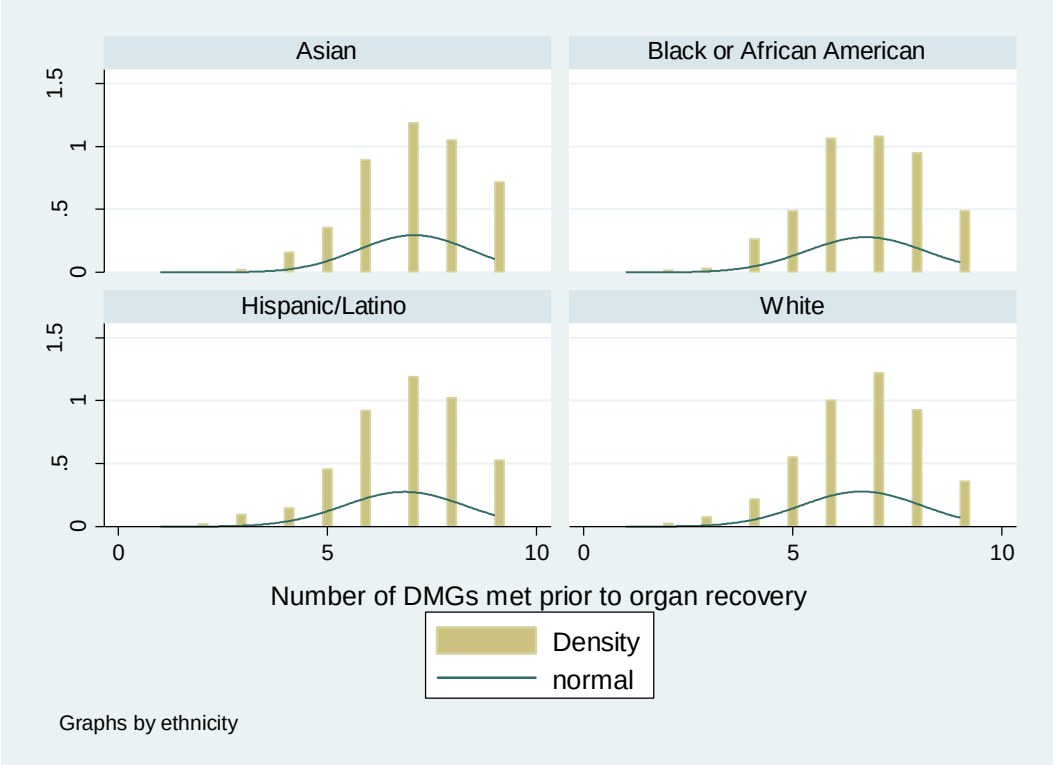

Figure 8 Density plot of number of DMGs met prior to organ recovery for each donor ethnicity overlaid with normal curve

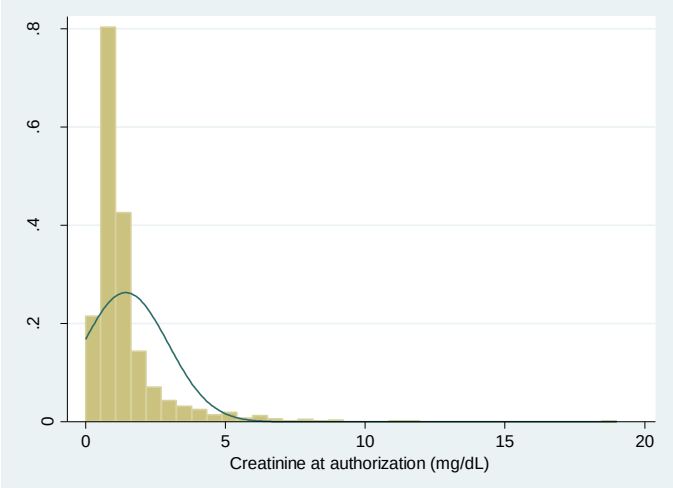

Figure 9 Density plot of creatinine at authorization overlaid with normal curve

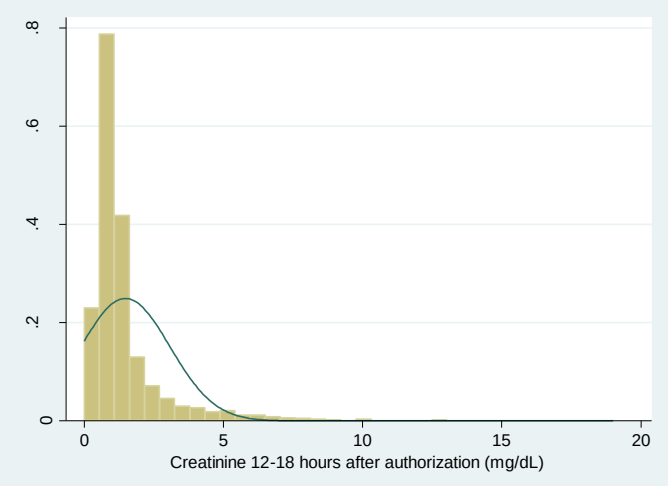

Figure 10 Density plot of creatinine 12-18 hours authorization overlaid with normal curve

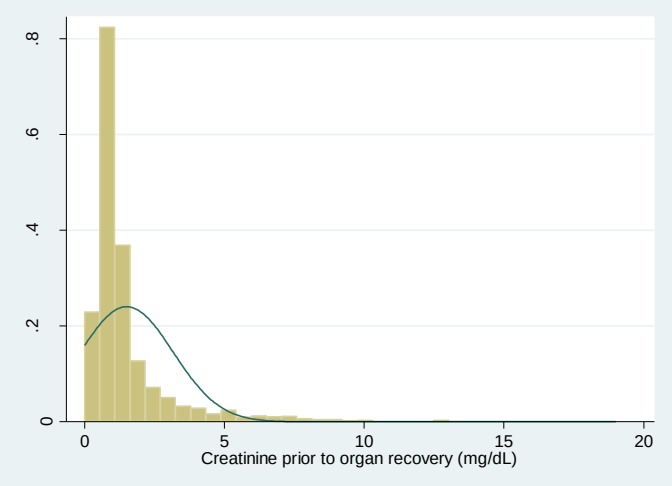

Figure 11 Density plot of creatinine prior to organ recovery overlaid with normal curve

APPENDIX B- MODEL DIAGNOSTICS

Table 1 Collinearity analysis for ≥4 OTPD, liver transplantation, kidney lung, and heart transplantation models

Variable	VIF
Ethnicity	
Asian	1.14
Black or African American	1.15
Hispanic/Latino	1.32
Age	2.27
Weight	4.42
BMI	3.91
Creatinine	1.10
Donor type	
ECD	1.15
DCDD	1.92
Blood type	
A	1.15
AB	1.04
B	1.12
Cause of death	
Anoxia	1.71
CNS tumor	1.01
Head trauma	1.72
Other	1.10
OPO	
AZOB	1.26
CADN	1.40
CAGS	1.13
CASD	1.19
NMOP	1.08
NVLV	1.17
ORUO	1.08
TXGC	1.17
UTOP	1.23
Mean VIF	1.52

Table 2 Influential point and outlier detection for ≥4 OTPD model

UNOS ID	$\Delta\chi^2$	ΔD	$\Delta\beta$	Leverage	Probability of 4≥ OTPD	≥ 4 OTPD
AABC215	42.86	7.58	0.13	0.0030	0.023	Yes
AABZ382	48.04	7.80	0.11	0.0020	0.020	Yes
AAEQ042	36.77	7.28	0.01	0.0027	0.027	Yes
AAJM178	30.83	6.94	0.11	0.0036	0.031	Yes
ABAI355	49.79	7.87	0.13	0.0026	0.020	Yes
ABBY362	73.22	8.63	0.14	0.0019	0.013	Yes
ABIB082	90.23	9.04	0.13	0.0014	0.011	Yes
AABE402	0.43	0.73	0.04	0.087	0.28	No
AABH004	0.20	0.36	0.01	0.059	0.16	No
AADX084	0.59	0.94	0.65	0.099	0.35	No
AAEN334	0.76	1.15	0.04	0.052	0.42	No
AAIE234	0.90	1.33	0.11	0.11	0.56	Yes
AALM345	1.70	2.07	0.20	0.11	0.40	Yes
AALT395	0.59	0.95	0.07	0.10	0.50	No
ABA3253	1.44	1.86	0.18	0.11	0.44	Yes
ABGX094	1.92	2.23	0.21	0.10	0.37	Yes
ABJ4396	0.94	1.37	0.12	0.11	0.46	No
ZE4374	0.27	0.48	0.02	0.07	0.20	No
ZKA115	0.95	1.34	0.12	0.11	0.46	No

$\Delta\chi^2$: change in standardized Pearson's residual; ΔD: change in standardized deviance residual; $\Delta\beta$: change in estimated coefficients

Table 3 Outliers and influential points for liver transplantation model

UNOS ID	$\Delta\chi^2$	ΔD	$\Delta\beta$	Leverage	Probability of liver transplantation	Liver transplanted
AABE402	1.86	2.2	0.24	0.12	0.62	NO
AABH004	2.04	2.33	0.27	0.12	0.64	NO
AADX084	0.46	0.77	0.05	0.1	0.71	YES
AAFX455	19	6	0.04	0.002	0.95	NO
AAH2139	18.4	6	0.12	0.006	0.05	YES
AAIE234	0.16	0.3	0.01	0.06	0.87	YES
AALM345	0.35	0.61	0.04	0.09	0.76	YES
AALT395	0.35	0.61	0.04	0.1	0.76	YES
ABA3253	0.21	0.39	0.02	0.07	0.84	YES
ABGX094	0.3	0.52	0.03	0.08	0.79	YES
ABIW242	19.7	6.09	0.12	0.006	0.95	NO
ABJ4396	1.83	2.19	0.26	0.12	0.62	NO
ZE4374	0.97	1.41	0.14	0.13	0.54	YES
ZKA115	0.18	0.32	0.01	0.06	0.86	YES

$\Delta\chi^2$: change in standardized Pearson's residual; ΔD: change in standardized deviance residual; $\Delta\beta$: change in estimated coefficients

Table 4 Outliers and influential points for kidney transplantation model

UNOS ID	$\Delta\chi^2$	ΔD	$\Delta\beta$	Leverage	Probability of kidney transplantation	Kidney transplanted
AAK367	233.1	10.9	0.21	0.001	0.004	Yes
AABE402	4.6	3.7	0.54	0.104	0.806	No
AABH004	0.7	1.1	0.12	0.157	0.640	Yes
AAI1299	1.1	1.7	0.58	0.346	0.582	Yes
AAK3124	63.3	8.3	0.05	0.001	0.984	No
AALT395	3.0	3.0	0.49	0.140	0.721	No
ABA3253	0.6	0.9	0.97	0.149	0.679	Yes
ZLO446	62.3	8.3	0.50	0.001	0.984	No

$\Delta\chi^2$: change in standardized Pearson's residual; ΔD: change in standardized deviance residual; $\Delta\beta$: change in estimated coefficients

Table 5 Outliers and influential points for lung transplantation model

UNOS ID	$\Delta\chi^2$	ΔD	$\Delta\beta$	Leverage	Probability of lung transplantation	Lung transplanted
AABC215	46.5	7.74	0.16	0.003	0.02	Yes
AABE402	0.43	0.73	0.05	0.10	0.28	No
AABH004	0.29	0.52	0.03	0.08	0.21	No
AADX084	0.38	0.65	0.04	0.09	0.25	No
AAIE234	2.23	2.46	0.28	0.11	0.33	No
AAJM178	35.6	7.22	0.14	0.004	0.03	Yes
AALM345	3.75	3.25	0.35	0.09	0.22	Yes
AALT395	0.50	0.83	0.06	0.11	0.31	No
ABA3253	2.10	2.37	0.27	0.11	0.35	Yes
ABBY362	144.8	9.97	0.14	0.001	0.007	Yes
ABD1077	50.3	7.9	0.18	0.003	0.02	Yes
ABGX094	0.28	0.49	0.02	0.08	0.20	No
ABIB082	49.9	7.88	0.16	0.003	0.02	Yes
ABIK345	35.6	7.22	0.16	0.004	0.03	Yes
ABJ4396	0.59	0.96	0.08	0.11	0.35	No
ABJZ478	59.4	8.22	0.15	0.003	0.07	Yes
ZE4374	0.27	0.49	0.02	0.08	0.20	No
ZEA115	0.44	0.75	0.05	0.10	0.29	No
ZLJ170	54.5	8.05	0.17	0.003	0.02	Yes

$\Delta\chi^2$: change in standardized Pearson's residual; ΔD: change in standardized deviance residual; $\Delta\beta$: change in estimated coefficients

Table 6 Outliers and influential points for heart transplantation model

UNOS ID	$\Delta\chi^2$	ΔD	$\Delta\beta$	Leverage	Probability of heart transplantation	Heart transplanted
AABE402	0.33	0.58	0.03	0.08	0.24	NO
AABH004	0.19	0.35	0.01	0.06	0.15	NO
AADX084	0.55	0.89	0.06	0.10	0.33	NO
AAI1299	0.16	0.30	0.03	0.15	0.12	NO
AAIE234	0.97	1.40	0.13	0.12	0.54	YES
AALM345	1.39	1.81	0.18	0.11	0.45	YES
AALT395	0.26	0.46	0.02	0.07	0.19	NO
ABA3253	1.28	1.71	0.17	0.12	0.47	YES
ABCQ095	40.3	7.46	0.14	0.003	0.02	YES
ABEX291	33.3	7.08	0.06	0.002	0.03	YES
ABGX094	0.71	1.10	0.08	0.11	0.39	NO
ABJ4396	1.05	1.49	0.14	0.12	0.52	YES
ZC4253	0.82	1.21	0.04	0.05	0.56	YES
ZE4374	0.26	0.46	0.02	0.07	0.19	NO
ZKA115	1.31	1.74	0.17	0.11	0.54	NO

$\Delta\chi^2$: change in standardized Pearson's residual; ΔD: change in standardized deviance residual; $\Delta\beta$: change in estimated coefficients

Table 7 Collinearity detection for pancreas transplantation model

Variable	VIF
Ethnicity	
Asian	1.14
Black or African American	1.14
Hispanic/Latino	1.32
Age	1.50
Weight	4.53
BMI	3.91
Creatinine	1.10
Donor type	
ECD	1.12
Blood type	
A	1.14
AB	1.04
B	1.12
Cause of death	
Anoxia	1.35
CNS tumor	1.43
Head trauma	1.02
Other	1.07
OPO	
AZOB	1.27
CADN	1.36
CAGS	1.14
CASD	1.18
NMOP	1.07
NVLV	1.14
ORUO	1.09
TXGC	1.18
UTOP	1.25
Mean VIF	1.44

Table 8 Outliers and influential points for pancreas transplantation model

UNOS ID	$\Delta\chi^2$	ΔD	$\Delta\beta$	Leverage	Probability of pancreas transplantation	Pancreas transplanted
	142.8	9.95	0.24	0.002	0.007	YES
	1.43	1.91	0.34	0.19	0.46	YES
	70.9	8.57	0.19	0.003	0.014	YES
	0.36	0.63	0.06	0.14	0.24	NO
	0.70	1.10	0.15	0.17	0.37	NO

$\Delta\chi^2$: change in standardized Pearson's residual; ΔD: change in standardized deviance residual; $\Delta\beta$: change in estimated coefficients

Table 9 Collinearity detection for DMG bundle met at authorization model

Variable	VIF
Ethnicity	
Asian	1.08
Black or African American	1.09
Hispanic/Latino	1.20
OPO	
AZOB	1.25
CADN	1.39
CAGS	1.12
CASD	1.16
NMOP	1.07
NVLV	1.16
ORUO	1.07
TXGC	1.16
UTOP	1.21
Mean VIF	1.16

Table 10 collinearity detection for DMG bundle met 12-18 hours after authorization

Variable	VIF
Ethnicity	
Asian	1.09
Black or African American	1.11
Hispanic/Latino	1.22
Creatinine	1.04
Donor type	
ECD	1.11
DCDD	1.07
OPO	
AZOB	1.26
CADN	1.39
CAGS	1.12
CASD	1.18
NMOP	1.07
NVLV	1.16
ORUO	1.08
TXGC	1.16
UTOP	1.22
Mean VIF	1.15

Table 11 Collinearity detection for DMG bundle met prior to organ recovery

Variable	VIF
Ethnicity	
Asian	1.09
Black or African American	1.10
Hispanic/Latino	1.22
Donor type	
ECD	1.11
DCDD	1.07
OPO	
AZOB	1.26
CADN	1.39
CAGS	1.12
CASD	1.17
NMOP	1.07
NVLV	1.17
ORUO	1.08
TXGC	1.16
UTOP	1.22
Mean VIF	1.16