Massive donor transfusion potentially increases recipient mortality after lung transplantation

Catherine F. Borders, BA,^a Yoshikazu Suzuki, MD,^a Jared Lasky, BA,^a Christian Schaufler, BA,^a Djamila Mallem, MA,^a James Lee, MD,^b Kevin Carney, NP,^c Scarlett L. Bellamy, ScD,^d Christian A. Bermudez, MD,^a A. Russell Localio, JD, MA, MPH, MS, PhD,^d Jason D. Christie, MD, MSCE,^{b,d} Joshua M. Diamond, MD, MSCE,^b and Edward Cantu, MD, MSCE^a

ABSTRACT

Objective: Donor blood transfusion has been identified as a potential risk factor for primary graft dysfunction and by extension early mortality. We sought to define the contributing risk of donor transfusion on early mortality for lung transplant.

Methods: Donor and recipient data were abstracted from the Organ Procurement and Transplantation Network database updated through June 30, 2014, which included 86,398 potential donors and 16,255 transplants. Using the United Network for Organ Sharing 4-level designation of transfusion (no blood, 1-5 units, 6-10 units, and >10 units, massive), we analyzed all-cause mortality at 30-days with the use of logistic regression adjusted for confounders (ischemic time, donor age, recipient diagnosis, lung allocation score and recipient age, and recipient body mass index). Secondary analyses assessed 90-day and 1-year mortality and hospital length of stay.

Results: Of the 16,255 recipients transplanted, 8835 (54.35%) donors received at least one transfusion. Among those transfused, 1016 (6.25%) received a massive transfusion, defined as >10 units. Those donors with massive transfusion were most commonly young trauma patients. After adjustment for confounding variables, donor massive transfusion was associated significantly with an increased risk in 30-day ($P = .03$) and 90-day recipient mortality ($P = .01$) but not 1-year mortality ($P = .09$). There was no significant difference in recipient length of stay or hospital-free days with respect to donor transfusion.

Conclusions: Massive donor blood transfusion (>10 units) was associated with early recipient mortality after lung transplantation. Conversely, submassive donor transfusion was not associated with increased recipient mortality. The mechanism of increased early mortality in recipients of lungs from massively transfused donors is unclear and needs further study but is consistent with excess mortality seen with primary graft dysfunction in the first 90 days posttransplant. (J Thorac Cardiovasc Surg 2017;153:1197-203)

30-day mortality risk of transplant recipients stratified by amount of blood transfused.

Central Message

Only massive donor transfusion (>10 units) should be considered a risk factor for early mortality and use should be considered depending on individual centers risk tolerance.

Perspective

Donor transfusion is considered a risk factor for primary graft dysfunction and death. In this study, only massive donor transfusion (>10 units) was associated with increased risk in perioperative mortality. This finding suggests donors with submassive transfusion alone should be used for transplant and massively transfused donors should be considered and transplanted depending on individual centers risk tolerance.

See Editorial Commentary page 1204.

From the ^aDivision of Cardiovascular Surgery, ^bPulmonary, Allergy, and Critical Care Division, and ^cCenter for Clinical Epidemiology and Biostatistics, University of Pennsylvania School of Medicine; and ^dTransplant Institute, University of Pennsylvania, Philadelphia, Pa.

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Drs Diamond and Cantu contributed equally to this work.

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Address for reprints: Edward Cantu, MD, MSCE, Division of Cardiovascular Surgery, University of Pennsylvania Perelman School of Medicine, 3400 Spruce St, 6 Silverstein Pavilion, Philadelphia, PA 19104 (E-mail: edward.cantu@uphs.upenn.edu).

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Abbreviations and Acronyms

CI	= confidence interval
LAS	= lung allocation score
OR	= odds ratio
PGD	= primary graft dysfunction
TRALI	= transfusion-related acute lung injury
UNOS	= United Network for Organ Sharing

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Lung transplantation is an established therapeutic option for select patients with end-stage lung disease. There is a large discrepancy, however, between the number of suitable lung donors for transplant and the number of patients on the waiting list, resulting in many potential recipients dying on the waiting list or being removed as the result of clinical decline.¹ Given this challenge, there is increasing pressure to expand the donor pool. Compared with other solid organs, however, overall survival after lung transplantation is limited, and efforts to reduce primary graft dysfunction (PGD) risk may cause reticence with respect to certain lung donors, thus potentially further reducing the donor pool. In the United States, only about 20% of potential donor lungs are used for transplant.^{2,3}

Donor blood transfusion is considered by many as a risk factor for lung injury and potential PGD; however, there is little published evidence available within the lung transplant literature. An association with PGD and blood product transfusion in lung transplant recipients has been established, but the mechanism has yet to be elucidated.⁴ Within the critical care literature, significant blood transfusion can cause transfusion-related acute lung injury (TRALI), which is similar to PGD in clinical and radiographic presentation.⁵ Whether the initiation of the inflammatory cascade responsible for reperfusion injury of PGD in the lung could result from the lung injury seen in donor TRALI has not been established.⁶ PGD is the major cause of early mortality, and thus important effects of donor transfusion may be reflected in excess mortality risk. Because of the absence of literature available to guide decision making with respect to donor transfusion, we initiated this study to define donor blood product transfusion risk for posttransplant mortality. We also sought to evaluate the comparative use of blood transfusions in organ donors who were not used for transplant because blood transfusion may disproportionately decrease donor suitability.

METHODS**Data Source**

After obtaining institutional review board approval, we queried the United Network for Organ Sharing (UNOS) database for lung transplant recipients and their respective donors from March 20, 1996, through June 30, 2014. Analysis included a total of 86,398 lung donor offers, which resulted in 16,255 lung transplants. None were excluded.

Exposure Variable

In the UNOS database, donor transfusion exposure was defined and categorized on the basis of the receipt of blood transfusions during the terminal hospitalization period: no blood ($n = 7420$), 1 to 5 units ($n = 6197$), 6 to 10 units ($n = 1622$), and greater than 10 units (massive) ($n = 1016$).

Outcome Definition

The primary outcome of interest was all-cause 30-day mortality. We evaluated 90-day and 1-year mortality and length of stay as secondary outcomes. We examined both the overall length of hospital stay, the length of stay conditional on 30-day survival, and hospital-free days to account for early deaths posttransplant.

Statistical Analysis

Categorical variables are expressed as percentages and continuous variables as means ($\pm$ standard deviations) when appropriate. Logistic regression was used to analyze the unadjusted all-cause mortality at 30 days and 90 days among the different donor groups. Because many factors contribute to risk and decisions for transplant, we used a multivariable logistic model to control for confounders. Confounding variables were chosen based on the strength of association and consistency of findings with risk of post-operative mortality in the literature.^{7,8} This included ischemic time (>6 hours), donor age (>40 years), recipient diagnosis, lung allocation score (LAS) score, and recipient age (>60 years), recipient body mass index (>30), and transplant era (binary or ordinal variable). Donor mechanism of death was omitted due to collinearity with the frequency of blood transfusions. PGD status was not controlled for in the analysis because it was not available consistently in the UNOS dataset and furthermore is one of the most common causes of death within the first 90 days and as such can be considered to be part of the causal pathway. To further evaluate the association of transfusion and mortality, inverse probability weighting using a propensity score (probability of treatment assignment conditional on observed baseline characteristics used in logistic model) sensitivity analysis was performed. Logistic regression was used to evaluate early mortality. Inverse probability weighted Kaplan-Meier was used for survival analysis.⁹

Results of logistic regression models are displayed as odds ratios (ORs) and 95% confidence intervals (CIs). Predictive margins were used to compare the risk of mortality per transfusion level using the “margins” command in STATA (StataCorp LP, College Station, Tex). Length of stay values are presented as means ($\pm$ standard deviation). A 2-sample t test was used to determine whether differences among groups were significant. The level of statistical significance was $P < .05$. All statistical analyses were conducted with STATA 12.0 software (StataCorp LP).

RESULTS**Patient Demographics**

Recipient and donor demographics are detailed in Table 1. Donors tended to be male (59.67%), slightly overweight (25.55 ± 5.28 kg), and have a history of cigarette use (11.4%). The most common mechanism of death was trauma (48.07%) and most were younger than 40 years

TABLE 1. Donor and recipient demographics

Characteristics	Overall population (n = 16,255)	Number of transfusions (units)			
		0 (n = 7420)	1-5 (n = 6197)	6-10 (n = 1622)	>10 (n = 1016)
Donor					
Age, y, mean (SD)	33.57 (14.60)	37.51 (14.61)	31.76 (14.25)	27.44 (12.48)	25.67 (10.48)
Female, %	40.33	41.64	43.42	28.91	30.02
Ethnicity, %					
White	61.93	64.37	59.92	61.59	56.99
Black	19.13	18.22	20.14	18.19	21.06
Hispanic	15.17	13.45	16.22	16.89	18.6
Asian	2.41	2.56	2.34	1.97	2.46
American Indian	0.39	0.4	0.45	0.12	0.39
Native Hawaiian	0.22	0.28	0.18	0.25	—
Multiracial	0.74	0.71	0.76	0.99	0.49
Smoking history, %	11.4	13.1	10.8	8.1	7.9
BMI, mean (SD)	25.55 (5.28)	26.17 (5.46)	25.10 (5.25)	24.71 (4.59)	25.17 (4.60)
Mode of death, %					
Anoxia	13.79	19.74	10.78	3.51	5.02
CVA	34.9	51.09	27.71	7.34	4.53
Trauma	48.07	25.18	58.43	87.73	88.78
CNS tumor	0.8	1.01	0.74	0.43	0.2
Other	2.44	2.98	2.34	0.99	1.48
Recipient					
Age, mean (SD)	52.98 (15.06)	53.62 (14.32)	52.26 (15.91)	52.92 (14.90)	52.74 (15.09)
Female, %	41.91	41.08	44.31	38.96	37.99
Ethnicity, %					
White	83.89	84.84	82.59	83.42	85.73
Black	8.32	7.99	9	8.08	6.89
Hispanic	5.71	5.16	6.34	5.98	5.41
Asian	1.35	1.29	1.42	1.36	1.38
American Indian	0.31	0.3	0.39	0.18	0.2
Native Hawaiian	0.08	0.08	0.05	0.18	0.1
Multiracial	0.33	0.34	0.21	0.8	0.3
BMI, mean (SD)	24.86 (4.97)	24.92 (4.90)	24.78 (5.06)	24.96 (5.02)	24.76 (4.79)
Diagnosis, %					
Obstructive	32.42	32.36	31.83	34.07	34.55
Vascular	3.52	3.41	3.83	3.09	3.15
CF/immunodeficiency	13.22	12.71	13.7	13.33	13.88
Restrictive	50.84	51.62	50.64	49.51	48.43
LAS	46.53 (17.25)	46.96 (17.48)	46.44 (17.27)	45.85 (17.03)	44.89 (15.56)

All comparisons were significant ($P < .05$) between transfusion groups except for all comparisons within recipient BMI, recipient diagnosis, and a few comparisons within donor BMI (1-5 vs >10 or 6-10 vs > 10 not significant), recipient age (only 0 vs 1-5 significant) and LAS (only 0 vs >10 significant). Based on Organ Procurement and Transplantation Network data as of September 5, 2014. *SD*, Standard deviation; *BMI*, body mass index; *CVA*, cerebrovascular accident; *CNS*, central nervous system; *CF*, cystic fibrosis; *LAS*, lung allocation score.

of age (33.57 ± 14.60 years) at the time of donation. Donors who received massive blood transfusions also tended to be younger, and nearly 90% suffered from trauma (Figure 1 and Table E1). Most recipients were male (58.09%), of normal weight (24.86 ± 4.97 kg), and suffered from pulmonary fibrosis (50.84%). At the time of transplant, the average LAS score was 46.53 ± 17.25 , and most recipients were older than 50 years of age (52.98 ± 15.06 years).

Comparison of Donor Offers by Transplant Status

Of 86,398 total lung donor offers, 16,255 were transplanted (18.8%). Of the 16,255 transplanted, 8835 (54.35%) donors received at least one unit of blood, and 1016 (6.25%) received a massive blood transfusion whereas 7420 (45.65%) received none. When we compared transplanted with nontransplanted lungs, the distribution of donors by units of blood transfused tended to be similar (Figure 2).

FIGURE 1. Cause of death and number of blood transfusions (units) received. Based on Organ Procurement and Transplantation Network data as of September 5, 2014. CNS, Central nervous system; CVA, cerebrovascular accident.

Risk of Blood Transfusion on 30-Day Mortality

In unadjusted analyses, massive blood transfusion in organ donors demonstrated a trend for increased risk for 30-day mortality (OR, 1.32; 95% CI, 0.98-1.77; $P = .064$) in lung transplant recipients. This trend continued to 90 days but was diminished by 1 year (OR, 1.09; 95% CI, 0.92-1.30; $P = .98$). Survival analysis at 1 year also demonstrated no significant difference between groups ($P = .64$). After we adjusted for confounding variables, massive donor blood transfusion was associated independently with increased risk of 30-day mortality (OR, 1.41; 95% CI, 1.03-1.92; $P = .03$) (Figure 3 and

Table 2). This risk remained elevated at 90 days (OR, 1.36; 95% CI, 1.06-1.73; $P = .01$). The predicted mortality of each transfusion category adjusted for confounders demonstrated significant increase risk of mortality only for recipients who receive organs from massively transfused donors ($P = .03$). This risk remained elevated for 90-day mortality as well (Figure E1). A sensitivity analysis taking into consideration era as a binary (pre/post LAS) or ordinal variable in the model (pre-LAS, 2005-2010, 2011-2014) demonstrated only small changes to the point estimate, CIs, or significance (binary: 1.47 [1.01-2.15] $P = .046$; ordinal: 1.47 [1.00-2.14] $P = .047$). Additional sensitivity analysis evaluating 4 potentially confounding variables (suspected donor pulmonary infection, chest radiograph, and left and right bronchoscopic results) did not substantially change the magnitude or significance of the risk estimates (1.47 [1.001-2.15] $P = .046$ to 1.54 [1.04-2.30] $P = .032$). A final sensitivity analysis evaluating blood transfusion risk in donors who died of intracerebral hemorrhage/stroke was performed and demonstrated a similar mortality risk with OR 1.39 and 1.47 for 30- and 90-day mortality, respectively. Adjusted survival analysis at 1 year did not reach significance in Cox regression model ($P = .09$) (Figure E2 and Table E2).

Length of Stay

There was no significant difference in length of stay with respect to transfusion. This remained true whether the

FIGURE 2. Displays comparative use of blood transfusions in lung donors that have received (0) no blood, (1) 1 to 5 units, (2) 6 to 10 units, (3) >10 units in both transplanted and discarded lungs. Based on Organ Procurement and Transplantation Network data as of September 5, 2014.

FIGURE 3. 30-day mortality risk. Plots of predicted 30-day mortality risk of transplant recipients when given lungs from donors who have received no blood, 1 to 5 units, 6 to 10 units, and >10 units of blood. Bars depict predicted mortality by blood transfusion with 95% confidence intervals. Comparisons among groups demonstrated significant difference in risk between the no transfusion group and the >10 units group ($P = .03$), all other comparisons were not significant. Based on Organ Procurement and Transplantation Network data as of September 5, 2014.

analysis was conditioned on 90-day survival or 90-day hospital-free days (Figure 4).

DISCUSSION

In the current era, there is considerable pressure to maximize the assessment and use of donors for lung

transplantation. Perceived risk of perioperative mortality, however, affects donor selection and can influence organ use. Because PGD is a major cause of early mortality posttransplant,¹⁰⁻¹² acceptable risk for PGD varies between center and by surgeon, and evidence has demonstrated increased risk of lung injury in lung transplant recipients who have received blood transfusions posttransplantation.⁵ Therefore, this study was conducted to define more fully the risk to the recipient associated with blood transfusions in organ donors. We have demonstrated that recipients of lungs from donors who have received massive blood transfusions (>10 units) are independently associated with increased 30- and 90-day all-cause mortality. This risk is still present but attenuated by 1-year, thereby potentially implicating PGD as a likely cause of this early risk.

Given that PGD is a major cause of early mortality¹⁰⁻¹² and the clinical similarities between PGD and TRALI,^{5,13,14} further studies looking at the cause of recipient death for those who received lungs from donors given massive blood transfusions are warranted. Perhaps a small portion of transplant recipients who have received lungs from donors given more than 10 units of blood and are defined as having PGD actually may have donor-derived TRALI. This is plausible, given that TRALI has been hypothesized to be the result of 2 insults, with the first being related to the underlying condition of the patient (surgery or infection) and the second hit being the transfusion of damaging blood products.¹⁵ In this study,

TABLE 2. ORs for 30-day mortality OR

Characteristics	Full model		Final model		Propensity-adjusted model	
	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value
Donor variables						
No. transfusions (units)						
0	Reference	—	Reference	—	Reference	—
1-5	1.04 (0.87-1.25)	.65	1.02 (0.86-1.22)	.78	1.04 (0.87-1.26)	.66
6-10	1.11 (0.83-1.47)	.48	1.07 (0.81-1.42)	.62	1.05 (0.76-1.44)	.79
>10	1.47 (1.10-2.02)	.017	1.41 (1.03-1.92)	.03	1.54 (1.04-2.30)	.032
Ischemic time >6 h	1.30 (1.10-1.54)	.003	1.31 (1.10-1.54)	.002	—	—
Donor age >40 y	1.12 (0.95, 1.33)	.18	—	—	—	—
Recipient variables						
Diagnostic group*						
Obstructive	Reference	—	Reference	—	—	—
Vascular	2.51 (1.77-3.57)	<.001	2.55 (1.80-3.61)	<.001	—	—
CF/immunodeficiency	0.59 (0.41-0.83)	.003	0.60 (0.43-0.85)	.004	—	—
Restrictive	1.23 (0.99-1.52)	.056	1.23 (0.99-1.52)	.059	—	—
LAS	1.01 (1.01-1.02)	<.001	1.01 (1.01-1.02)	<.001	—	—
Recipient BMI >30	1.38 (1.13-1.69)	.002	1.38 (1.13-1.69)	.002	—	—
Recipient age >60 y	0.93 (0.78-1.10)	.38	—	—	—	—
Era	0.81 (0.69-0.96)	.016	0.81 (0.69-0.96)	.016	—	—

The full model includes all the variables listed. The final model is optimized using Bayesian information criterion statistic to drop less informative factors. The propensity-adjusted model uses all variables listed (ischemic time, donor age, recipient diagnostic group, era, pulmonary infection, chest radiograph result, and right bronchoscopy result and left bronchoscopy result) to weight the effects of transfusion. Based on Organ Procurement and Transplantation Network data as of September 5, 2014. OR, Odds ratio; CI, confidence interval; CF, cystic fibrosis; LAS, lung allocation score; BMI, body mass index. *LAS diagnosis categories.

FIGURE 4. Length of stay, conditional length of stay, and hospital-free days. Plots showing the length of stay (A) overall; (B) conditioned on 90-day survival; and (C) hospital-free days in transplant recipients when given lungs from donors who have received no blood, 1 to 5 units, 6 to 10 units, >10 units of blood transfused. Lines display medians; error bars indicate interquartile ranges. Based on Organ Procurement and Transplantation Network data as of September 5, 2014.

VIDEO 1. Discussion of results by senior authors. Video available at: [http://www.jtcvsonline.org/article/S0022-5223\(16\)31669-5/addons](http://www.jtcvsonline.org/article/S0022-5223(16)31669-5/addons).

massive blood transfusions typically are given to donors who have experienced trauma. It is possible that trauma and massive blood transfusions in donors could be a predisposing clinical condition making the lung prone to further injury after transplantation.

There are several potential limitations to this study. Although we have reported the risks of massive transfusion on mortality using a cohort of transplanted recipients, there is the potential for selection bias by not including massively transfused donors who were not accepted for transplant. Although we cannot predict mortality risk on donors not used for transplant, the distribution of transfusion among untransplanted donors was similar to donors included in our study cohort, which suggests that either transfusion is not necessarily a factor in the decision to use donors or our cohort is representative of all potential donors. Another issue is the inherent limitation of retrospective analysis of an administrative database. As such, we are unable to validate the recorded data, and this dataset does not capture all potential factors that may influence recipient risk or surgical decision making. However, the UNOS data set is used for quality assessment of programs and organ procurement organizations and therefore is audited by those organizations to ensure accurate assessment. It also is possible that decisions for transplant may be influenced by the recipient's severity of illness. To control for this, we used the end match LAS as a surrogate marker of illness severity with the understanding that this variable is not a perfect surrogate. In addition,

sensitivity analyses including and excluding this variable had minimal impact of risk estimates for massive transfusion and remained independently associated with increased risk. It also should be noted that blood transfusion may be a surrogate marker of trauma or some other unmeasured informative marker that was not captured within this dataset. Should this be the case, it is still helpful to understand this association, although it may not be causal. In addition, approximately 10% of massively transfused donors died from anoxia and intracranial hemorrhage, raising the question of whether there was unrecorded trauma or exposure misclassification in this subpopulation. It also is possible that intraoperative transfusion may not be captured or accurately reported. Finally, given the ordinal nature of the transfusion variable within the UNOS dataset, it is impossible to define the true inflection point in units of blood that results in increased risk of mortality. Perhaps alterations in the methods of collection of transfusion variables to define preoperative and intraoperative blood transfusion in a continuous fashion could result in precise estimates of risk.

In summary, we have demonstrated that massive blood transfusions (>10 units) of lung donors is associated with a significantly increased 30- and 90-day mortality risk that is not sustained at 1 year. Conversely, submassive transfusion (<10 units) is not associated with 30-day, 90-day, or 1-year mortality or length of stay. Taken together, we would recommend using nonmassively transfused donors for transplantation provided there are no other contraindications and selective use of massively transfused donors based on individual centers risk tolerance and experience with early management of PGD.

A video of the senior authors discussing the results is available online ([Video 1](#)).

Conflicts of Interest Statement

Authors have nothing to disclose with regard to commercial support.

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Key Words: lung transplantation, blood transfusion

FIGURE E1. Plots of 90-day mortality risk of transplant recipients when given lungs from donors who have received no blood, 1 to 5 units, 6 to 10 units, and >10 units of blood. Bars depict predicted mortality by blood transfusion with 95% confidence intervals. Comparisons among groups demonstrated a significant difference in risk between the no-transfusion group and the >10 units group ($P = .02$), all other comparisons were not significant. Based on Organ Procurement and Transplantation Network data as of September 5, 2014.

Transfusion	30-days	90-days	1-year
None	0.96 [0.96, 0.97]	0.93 [0.92, 0.94]	0.84 [0.83, 0.85]
1-5 units	0.96 [0.95, 0.97]	0.93 [0.92, 0.94]	0.85 [0.84, 0.86]
6-10 units	0.96 [0.95, 0.97]	0.93 [0.92, 0.95]	0.86 [0.84, 0.88]
>10 units	0.94 [0.92, 0.96]	0.90 [0.87, 0.93]	0.81 [0.77, 0.84]

Number at Risk	0-days	30-days	90-days	1-year
None	7420	6931	6583	5203
1-5 units	6197	5800	5507	4465
6-10 units	1622	1519	1447	1185
>10 units	1016	934	890	702

FIGURE E2. Propensity-matched survival analysis by donor transfusion status. Depicted is the inverse probability-weighted survival analysis of blood transfusion with discrete 30-day, 90-day, and 1-year mortality point estimates and confidence intervals with corresponding number at risk. There are no significant differences between groups ($P = .09$). Based on Organ Procurement and Transplantation Network data as of September 5, 2014.

TABLE E1. Mechanisms of donor death and number of blood transfusions

	n (%)	Number of transfusions (units)			
		0	1-5	6-10	>10
Trauma	7516 (46.2)	1758 (10.8)	3455 (21.3)	1396 (8.6)	907 (5.6)
Blunt injury	4316 (26.6)	1020 (6.3)	2039 (12.5)	775 (4.8)	482 (3.0)
GSW	3164 (19.5)	737 (4.5)	1404 (8.6)	617 (3.8)	406 (2.5)
Stab	36 (0.2)	1 (0.01)	12 (0.07)	4 (0.02)	19 (0.1)
ICH/stroke	5931 (36.5)	3818 (23.5)	1872 (11.5)	162 (1.0)	79 (0.5)
Cardiovascular	904 (5.6)	555 (3.4)	316 (1.9)	24 (0.1)	9 (0.0006)
Drug intoxication	613 (3.8)	459 (2.8)	146 (0.9)	22 (0.0001)	6 (0.0004)
Asphyxiation	468 (2.9)	327 (2.0)	130 (0.8)	11 (0.1)	0 (0)
Natural causes	237 (1.5)	159 (1.0)	72 (0.4)	5 (0.0003)	1 (0.00006)
Seizure	173 (1.1)	115 (0.7)	54 (0.3)	4 (0.0002)	0 (0)
Drowning	53 (0.3)	32 (0.2)	20 (0.1)	1 (0.00006)	0 (0)
Electrical	6 (0.04)	3 (0.0002)	2 (0.0001)	0 (0)	1 (0.00006)
SIDS	1 (0.01)	0 (0)	0 (0)	1 (0.00006)	0 (0)
Other	353 (2.2)	194 (1.2)	130 (0.8)	16 (0.1)	13 (0.1)
Total	16,255	7420 (45.6)	6197 (38.1)	1622 (10.0)	1016 (6.3)

Based on Organ Procurement and Transplantation Network data as of September 5, 2014. GSW, Gunshot wound; ICH, intracerebral hemorrhage; SIDS, sudden infant death syndrome.

TABLE E2. Sensitivity analysis of early mortality risk based on transplant status

	Inclusive		Retransplant excluded	
	OR (95% CI)	P value	OR (95% CI)	P value
30-d mortality				
No. of transfusions (units)				
0	Reference	—	Reference	—
1-5	1.04 (0.87-1.26)	.66	1.04 (0.85-1.26)	.70
6-10	1.05 (0.76-1.44)	.79	0.99 (0.71-1.39)	.95
>10	1.54 (1.04-2.30)	.03	1.56 (1.03-2.37)	.04

The inclusive model adjusts for recipient diagnostic group, LAS, recipient BMI, ischemic time, era, pulmonary infection, chest radiograph result, and right bronchoscopy result and left bronchoscopy result to weight the effects of transfusion regardless for transplant status (equivalent to propensity model in text). The retransplant excluded includes the same variables but excludes all re-transplants from analysis. Based on Organ Procurement and Transplantation Network data as of September 5, 2014. OR, Odds ratio; CI, confidence interval; LAS, lung allocation score; BMI, body mass index.