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Impact of Deceased Donor Multidrug-Resistant Bacterial Organisms on Organ Utilization

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Abstract

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DATA AVAILABILITY

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article. It includes the Institutional Review Board approvals for each participating site, the criteria used to define the multidrug-resistant organisms, further details on the clinical data collected, and the results of sensitivity analyses.

The extent to which donor multidrug-resistant organisms (MDROs) affect organ utilization remains unclear. We performed a retrospective cohort study at four transplant centers between 2015 and 2016 to evaluate this question. All deceased donors who donated at least one organ were included. Exposed donors had at least one MDRO on culture. Unexposed donors had no MDRO-positive cultures. Only cultures obtained during the donor's terminal hospitalization were evaluated. Multivariable regression was used to determine the association between donor MDRO and (1) number of organs transplanted per donor and (2) the match run at which each organ was accepted. Subsequently, we restricted the analysis to donors with MDR-Gram negative (GN) organisms. Of 440 total donors, 29 (7%) donors grew MDROs and 7 (2%) grew MDR-GNs. There was no significant association between donor MDRO and either measure of organ utilization. However, donor MDR-GNs were associated with a significant reduction in the number of organs transplanted per donor (incidence rate ratio 0.43, 95% CI 0.39–0.48, $P<0.01$), and organs were accepted significantly further down the match list (relative count 5.08, 95% CI 1.64–15.68, $P=0.01$). Though donor MDR-GNs were infrequent in our study, their growing prevalence could meaningfully reduce the donor pool over time.

1. INTRODUCTION

One of the most significant issues facing solid organ transplantation (SOT) is the limited supply of organ donors. It is estimated that approximately 20 people die per day while on the waitlist in the United States (US)[1]. Consequently, there is significant clinical and public health interest in expanding the donor pool to include those organs that have historically been discarded.

Donors with positive bacterial cultures have been utilized inconsistently in the past due to concerns about the potential for donor-derived bacterial infections (DDBIs) in the recipient[2–6]. DDBIs have been associated with significant morbidity, including vascular anastomosis dehiscence, overwhelming infection, and death[2–5]. In recent years, the field has moved towards utilizing such donors while providing antibacterial prophylaxis to the recipient[6], as observational studies have reported low rates of DDBIs with this approach[7,8].

There remains significant controversy, however, about whether organs should be accepted from potential donors who are colonized or infected with a multidrug-resistant organism (MDRO)[6]. With MDROs, it may be more difficult to select appropriate empiric antibiotics for the recipient while awaiting susceptibilities and to administer such antibiotics without incurring antibiotic-related toxicity[9,10]. Further, a DDBI due to an MDRO may be more difficult to treat once established[11–13]. This concern has been supported by several case series describing transmission of MDROs from donors to recipients with notably poor outcomes[7,11]. Because of such reports, the current national transplant guidelines recommend exercising caution when considering the use of organs that may be infected or colonized with an MDRO[6], though no explicit recommendations are provided on (1) which organisms, (2) which antibiotic resistance profiles, or (3) which sites of infection/colonization should be cause for concern.

Because there is no consensus on whether donors carrying MDROs should be utilized, and the rate of MDROs among potential deceased donors has not been previously described in

the US, the true impact of MDROs on the donor pool has yet to be established. In this study, we sought to determine the impact that donor MDROs have on organ utilization.

2. MATERIALS AND METHODS

2.1 Study design and setting.

A retrospective cohort study was performed at four transplant centers in the Philadelphia region: the Hospital of the University of Pennsylvania (HUP), Temple University Hospital (TUH), Hahnemann University Hospital (HUH), and Albert Einstein Medical Center (AEMC).

2.2 Study population.

The initial source population included all deceased donors who were evaluated by the local organ procurement organization (OPO)—the Gift of Life Donor Program (GLDP)—and who ultimately donated at least one organ to a recipient at one of the participating transplant centers between January 1, 2015 and July 1, 2016. Eligible donors were identified by the GLDP, which evaluates all deceased organ donors in eastern Pennsylvania, southern New Jersey, and Delaware.

A donor was determined to be “exposed” if he/she grew at least one MDRO on a bacterial culture that was taken during the donor’s terminal hospitalization (hereafter referred to as a “hospital culture”). MDROs included: vancomycin-resistant *Enterococcus* species (VRE), methicillin-resistant *Staphylococcus aureus* (MRSA), extended-spectrum cephalosporin-resistant (ESC-R) Enterobacterales (EB), carbapenem-resistant Enterobacterales (CRE), multidrug-resistant (MDR)-*Pseudomonas* species, and MDR-*Acinetobacter* species. The Centers for Disease Control and Prevention (CDC) National Healthcare Safety Network (NHSN) definitions for each MDRO were used (see Supporting Information)[14]. Only cultures that were obtained as part of routine clinical care during the donor’s terminal hospitalization were evaluated, since this is the only microbiology data that is available to recipient transplant centers at the time of donor evaluation. Cultures taken at the time of organ procurement were not considered because the results of these cultures would not have been finalized at the time of donor evaluation. Hospital cultures from any anatomic site were considered. A donor was determined to be “unexposed” if he/she did not grow any MDROs on any hospital cultures (though could have grown non-MDROs on culture). Where possible, the distinction between infection versus colonization with the MDRO was determined using CDC/NHSN surveillance criteria[15]; this determination was made by an infectious diseases-trained physician (J.A.A.) based on the clinical data contained in the GLDP donor chart that was available at the time of donor evaluation.

Subsequently, we restricted the exposure to only those donors with an MDR Gram-negative (GN) organism on hospital culture. We postulated that donors with MDR-GNs may be approached differently during the donor evaluation process, since DDBIs due to MDR-GNs have been associated with particularly poor recipient outcomes[7,16,17]. In this analysis, the exposed group was limited to donors who grew an ESC-R EB, CRE, MDR-*Pseudomonas*, or MDR-*Acinetobacter* organism on hospital culture. The unexposed group included those

donors who did not grow an MDR-GN on hospital culture (but could have grown a non-MDRO or MDR-GP organism on culture). Finally, in a sensitivity analysis, we redefined the exposure into four mutually exclusive groups—donors with no positive cultures, donors with non-MDRO positive cultures, donors with an MDR-Gram positive (GP) on culture, and donors with an MDR-GN on culture—to assess whether this grouping would alter our findings.

If an MDRO was isolated on multiple occasions in the same donor, only the first MDRO was considered; for the MDR-GN analysis, any donor who grew an MDR-GN was included (whether it was the first MDRO or not). The study was approved by the Institutional Review Board at each of the participating transplant centers (see Supplementary Material).

2.3 Outcomes.

There were two primary outcomes. First, we evaluated the number of organs transplanted per donor, which ranged from one (if only one organ was transplanted) to eight (if the heart, liver, both lungs, both kidneys, pancreas, and small intestine were all transplanted). Only donors who donated at least one organ were included, as these are the only donors on whom detailed microbiological and clinical data were available from the GLDP. Only organs that were confirmed as transplanted were counted towards the outcome (i.e. if an organ was procured but not transplanted, it was not counted).

Second, we evaluated the match run, or sequence number, at which each organ was accepted for transplant. For this analysis, only donors who gave organs to a recipient at HUP were included, as this was the only subgroup for which this data was feasible to collect. Donors were included once for each organ donated. Donors were considered exposed if any of their hospital cultures grew an MDRO; we did not restrict the exposure to those that grew an MDRO at the site of the allograft under consideration.

Finally, in a secondary analysis, we evaluated whether each donor successfully donated a liver, heart, at least one kidney, and at least one lung (each as binary outcome), using the full cohort. We sought to evaluate whether the association between MDRO status and organ utilization was specific to one or more organ groups. We did not evaluate pancreas transplants due to the small number of these procedures performed at the participating centers.

2.4 Data collection.

Data on exposed and unexposed donors were abstracted from the GLDP medical record system. Information was collected on demographics, comorbidities, medications, and details of their microbiological results (see Supporting Information for complete list of data collected).

2.5 Statistical analysis.

Continuous variables were compared using the Student t-test or Wilcoxon rank-sum test, and categorical variables were compared using the χ^2 or Fisher exact test. For the adjusted analyses, multivariable regression was employed. Specifically, multivariable zero-truncated

Poisson regression was employed when evaluating the number of organs transplanted per donor; multivariable negative binomial regression was used when evaluating the match run at which an organ was accepted; and multivariable logistic regression was used when evaluating whether each organ type was transplanted. For the analysis of match run, since several donors were included more than once in the dataset, we employed a mixed effects negative binomial regression with a random effect for the donor to account for the relatedness of the outcomes. For each of the multivariable regression analyses, bivariable regression was used to examine the relationship between the primary exposure (MDRO on culture), as well as other baseline donor factors, and the outcome. Variables from bivariable analyses with P values <0.20 or those that were a confounder of the primary association (i.e. changed the effect estimate of the primary association by 15% or more) were considered for inclusion in the final multivariable model. We evaluated whether a statistical interaction was present between MDROs on culture and the anatomic site of bacterial growth. Variables were retained in the final model if they were confounders of the primary association or had a P value of <0.05 in the multivariable model. Interaction terms were retained in the final model if they had a P value <0.05. The strength of the association was measured using an incidence rate ratio (IRR) for the Poisson regression model; a relative count for the negative binomial regression model; and an odds ratio (OR) for the logistic regression models. A 95% confidence interval (CI) was also calculated for each effect estimate. All analyses were performed using STATA v.15.0 (StataCorp, College Station, Texas).

3. RESULTS

3.1 Study population.

A total of 440 deceased organ donors were included, of which 29 (7%) had an MDRO grow on a hospital culture. The median age in the cohort was 37 years (interquartile range [IQR] 27–52), and 183 (41%) were women. Sixty-four (15%) were DCD, 84 (19%) were ECD, and 150 (34%) met the PHS-increased risk criteria (Table 1).

3.2 Overview of donor hospital cultures.

Of the 440 donors included in the study, 267 (60%) had at least one positive bacterial culture, and 29 (7%) had an MDRO grow on a hospital culture. The most common MDRO was MRSA (22, 5% of donors). Seven (2%) donors had an MDR-GN grow on hospital culture: four with ESC-R EB on urine culture, one with ESC-R EB on respiratory culture, one with CRE and ESC-R EB on respiratory culture, and one with MDR-*Pseudomonas* on respiratory culture. One donor grew two different MDROs (ESC-R EB and CRE on respiratory culture); and two donors had the same MDRO identified from multiple sites (both with MRSA on blood and respiratory cultures).

3.3 Association between donor MDRO and number of organs transplanted per donor.

The median number of organs transplanted per donor was 3 (IQR 2–5). On multivariable analysis, there was not a significant association between the presence of an MDRO on donor culture and the number of organs transplanted per donor (IRR 1.15, 95% CI 0.99–1.33, P=0.07) (Table 2A). When specific anatomical sites of MDRO growth were evaluated, none were significantly associated with the outcome (data not shown). When the exposure was

restricted to only MDR-GNs, we found that the presence of an MDR-GN on donor culture was associated with a significantly reduced rate of organ recovery and transplantation (IRR 0.43, 95% CI 0.39–0.48, $P<0.001$) (Table 2B). Of note, there was a significant statistical interaction between MDR-GNs and presence of lower respiratory tract infection (LRTI); though numbers were small, there appeared to be an attenuation of the association between MDR-GNs and the number of organs transplanted when there was a LRTI present (IRR 0.99, 95% CI 0.64–1.55, $P=0.97$) (data not shown). The results were similar when the exposure was further stratified into four categories (no positive cultures, non-MDRO positive culture, an MDR-GP on culture, or an MDR-GN on culture) (Supporting Information Table 1): there was a significant reduction in the number of organs transplanted per donor among those with an MDR-GN on culture, but no significant changes in utilization among the other groups.

3.4 Association between donor MDRO and match run.

There were 300 donors who donated an organ to a recipient at HUP and were included in this analysis. Of these, 21 (7%) grew an MDRO on hospital culture, and three (1%) grew an MDR-GN. More specifically, two donors grew ESC-R EB on urine culture, and one donor grew both ESC-R EB and CRE on respiratory culture. In this HUP subgroup, the median match run at which organs were accepted was 12 (IQR 5–36). The median match run at acceptance was 20 (IQR 7–192) for kidneys, 18 (IQR 8–41) for livers, 5 (IQR 2–9) for hearts, and 7 (IQR 3–15) for lungs.

On multivariable analysis, there was no significant association between the presence of an MDRO on culture and the match run at which organs were accepted (Relative count 3.26, 95% CI 0.94–11.28, $P=0.06$) (Table 3A). When the exposure was restricted to MDR-GNs, however, we found that the presence of an MDR-GN on donor culture was associated with a significantly higher match run at which organs were accepted (i.e. organs were accepted further down the match list) (Relative count 5.08, 95% CI 1.64–15.68, $P=0.01$) (Table 3B). There was again a significant statistical interaction between MDR-GNs and presence of a LRTI, where we observed a possible attenuation of the association between MDR-GNs and the match run when a LRTI was present (IRR 0.91, 95% CI 0.39–2.13, $P=0.84$) (data not shown) though numbers were small. The results were again similar when the exposure was stratified into four groups (no positive cultures, non-MDRO positive culture, MDR-GP on culture, or MDR-GN on culture) (Supporting Information Table 2): there was a significant increase in the match run at which organs were accepted from donors with an MDR-GN, but no significant changes in match run among the other groups.

3.5 Association between donor MDR-GNs and transplantation of each organ type.

We secondarily evaluated the association between MDR-GNs on donor culture and whether each organ type was transplanted, in order to assess whether there was a specific organ group that was driving the reduction in utilization associated with donor MDR-GNs. Of the entire cohort of 440 donors, 379 donated at least one kidney, 357 donated a liver, 172 donated a heart, and 130 donated at least one lung. On multivariable analysis, we found that that the presence of an MDR-GN on donor culture was associated with a significant reduction in the odds of liver transplantation (OR 0.08, 95% CI 0.006–0.93, $P=0.04$),

regardless of site of MDRO growth (data not shown). Further, only one lung and two hearts were transplanted from donors with MDR-GNs. Conversely, all of the donors with an MDR-GN had at least one kidney transplanted.

4. DISCUSSION

In this retrospective cohort study, we found that donor MDROs, when considered altogether, do not significantly impact organ utilization, but there may be a reduction in organ utilization associated with donor MDR-GNs. More specifically, we found that the presence of an MDR-GN on donor culture was associated with an approximately 57% reduction in the number of organs transplanted per donor, even after adjusting for other donor factors that affect organ utilization. This appeared to be driven particularly by reduced liver, heart, and lung procurement. We also found, in a small subgroup analysis, that the presence of an MDR-GN was associated with organs being accepted significantly further down the match list than comparable organs without an MDR-GN. Interestingly, MDR-GNs did not impact organ utilization when a LRTI was present in the donor, suggesting that MDR-GNs on respiratory tract culture are considered less concerning than MDR-GNs isolated from other sites (e.g., blood, urine); this may be related to the high frequency of positive respiratory cultures among donors and the difficulty in distinguishing true infection from colonization.

This data represents the first formal analysis of the effect of MDROs among deceased donors on the donor pool. Though MRSA was regularly identified among donors (5%), it did not appear to have a significant impact on organ utilization. MDR-GNs, on the other hand, were infrequently identified (1–2%) but were associated with reduced organ utilization. Given the small number of donors with MDR-GNs in this cohort, it is difficult to draw any definitive conclusions, but it is a concerning observation, particularly because MDR-GN infections and colonization are steadily increasing in incidence among hospitalized patients, and particularly in intensive care units (ICUs)[18,19]. The deceased donor population is necessarily admitted to an ICU during their terminal hospitalization, so their risk for MDR-GNs is likely to increase in alignment with secular trends. It is also important to note that our study likely underestimates the impact of MDROs on the donor pool because donors who were entirely declined (i.e. did not donate any organs) due to an MDRO would not have been captured in this study, thus attenuating our estimate of the impact of MDROs on the donor pool. Taking this all together, MDR-GNs have the potential to meaningfully reduce the donor pool over time.

There are several limitations of our study. The most significant limitation is that because the study was performed retrospectively, we were not able to confirm that the transplant centers were aware of the positive culture results at the time of donor evaluation. We would expect that this limitation would bias the results toward the null, however. Second, the analysis of the match run was limited to the subset of donors who donated an organ to a HUP recipient; however, the majority of the donor pool (300 of the original 440) was included in this subcohort. Third, it is not possible to retrospectively measure the proportion of potential donors who were deemed unsuitable for donation due to MDROs, as these data are not maintained by the GLDP; this may have resulted in an underestimate of the impact of MDROs on organ utilization in this study. Finally, there were few donors with MDR-GNs in

the cohort (1–2%), limiting the conclusions that can be drawn about this population. Further study of donor MDR-GNs is needed to better characterize and substantiate these findings.

In conclusion, the results of our study demonstrate that MDROs among deceased organ donors do not substantially impact organ utilization, save for MDR-GNs, which may reduce organ procurement and transplantation. Given the recent development of novel antimicrobials with activity against MDR-GNs, and a paucity of data evaluating recipient outcomes in the setting of donor MDR-GNs, it is not known whether this avoidance is truly necessary. Our data suggest that there is a need for additional studies evaluating recipient outcomes and mechanisms for preventing transmission of donor MDROs to recipients so that such organs may be safely and widely utilized.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations:

AEMC	Albert Einstein Medical Center
CDC	Centers for Disease Control and Prevention
CI	confidence interval
CRE	carbapenem-resistant Enterobacterales
DBD	donation after brain death
DCD	donation after circulatory death
DDBI	donor-derived bacterial infection
EB	Enterobacterales
ECD	expanded criteria donor
ECMO	extracorporeal membrane oxygenation
ESC-R	extended-spectrum cephalosporin-resistant
GLDP	Gift of Life Donor Program
HBV	hepatitis B virus

HCT	hematopoietic cell transplant
HCV	, hepatitis C virus
HUH	Hahnemann University Hospital
HUP	Hospital of the University of Pennsylvania
ICU	intensive care unit
IDU	injection drug use
IQR	interquartile range
IRR	incidence rate ratio
KDPI	Kidney Donor Profile Index
LRTI	lower respiratory tract infection
MDR	multidrug-resistant
MDRO	multidrug-resistant organism
MDR-GN	multidrug-resistant Gram-negative
MRSA	methicillin-resistant *Staphylococcus aureus*
NHSN	National Healthcare Safety Network
OPO	organ procurement organization
OR	odds ratio
PHS	Public Health Service
SOT	solid organ transplantation
SCD	standard criteria donor
T4	thyroxine
TUH	Temple University Hospital
US	United States
VRE	vancomycin-resistant *Enterococcus*

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Table 1.

Baseline characteristics of the deceased organ donors, stratified by donor culture results.

Donor characteristic[a,b]	No MDRO on donor culture (N 411)		MDRO on donor culture (N 29)		*P* value[c]
	Negative (N 173)	Non-MDRO positive (N 238)	MDR-GP (N 22)	MDR-GN (N 7)	
Demographics, comorbidities					
Age (median, IQR) (years)	41 (26–53)	36 (27–52)	32 (25–43)	40 (23–50)	0.102
Chronic kidney disease	4 (2%)	4 (2%)	1 (5%)	0 (0%)	0.789
Diabetes mellitus	21 (12%)	26 (11%)	3 (14%)	1 (14%)	0.961
HCT	1 (1%)	1 (0.5%)	0 (0%0	0 (0%)	0.978
DCD	32 (19%)	26 (11%)	2 (9%)	4 (57%)	0.001
ECD	41 (24%)	40 (17%)	3 (14%)	0 (0%)	0.154
PHS-increased risk	52 (30%)	84 (35%)	11 (50%)	2 (29%)	0.263
KDPI	52 (32–79)	48 (27–73)	46 (30–69)	54 (23–73)	0.920
Death mechanism					
Drug intoxication	25 (14%)	62 (26%)	8 (36%)	0 (0%)	0.005
Asphyxiation	12 (7%)	12 (5%)	0 (0%)	3 (43%)	<0.001
Cardiovascular	46 (27%)	56 (24%)	5 (23%)	2 (29%)	0.895
Gunshot wound	14 (8%)	13 (5%)	1 (5%)	1 (14%)	0.583
Drug use					
Opiates (IDU or non-IDU)	40 (23%)	73 (31%)	10 (45%)	3 (43%)	0.079
IDU	32 (19%)	49 (21%)	10 (45%)	1 (14%)	0.032
Serologies and laboratory testing					
HCV seropositive	14 (8%)	14 (6%)	4 (18%)	1 (14%)	0.167
HCV viremia	9 (6%)	9 (4%)	3 (16%)	0 (0%)	0.167
HBV core antibody positive	7 (4%)	13 (5%)	1 (5%)	0 (0%)	0.849
Albumin (median, IQR) (g/dL)	2.6 (2.3–2.9)	2.5 (2.2–2.9)	2.5 (2.1–2.8)	1.9 (1.7–2.5)	0.901
Procedures					
ECMO	4 (2%)	7 (3%)	0 (0%)	0 (0%)	0.811
Open abdomen	1 (1%)	0 (0%)	0 (0%)	0 (0%)	0.671
Intra-aortic balloon pump	1 (1%)	3 (1%)	0 (0%)	0 (0%)	0.849
Exploratory laparotomy	3 (2%)	4 (2%)	0 (0%)	0 (0%)	0.918
Infections					
Lower respiratory tract infection	30 (19%)	97 (41%)	13 (59%)	4 (67%)	<0.001
Meningitis	0 (0%)	1 (0.4%)	0 (0%)	0 (0%)	0.837
Donor management					
Length of stay (median, IQR) (days)	3 (2–4)	4 (3–6)	5 (3–10)	7 (4–25)	<0.001
T4 protocol	133 (77%)	206 (87%)	20 (91%)	3 (43%)	0.002
Antibiotics during terminal hospitalization					
Any antibiotic	165 (96%)	235 (99%)	21 (95%)	6 (86%)	0.076

Donor characteristic[a,b]	No MDRO on donor culture (N 411)		MDRO on donor culture (N 29)		*P* value[c]
	Negative (N 173)	Non-MDRO positive (N 238)	MDR-GP (N 22)	MDR-GN (N 7)	
Number of antibiotics per donor (median, IQR)	2 (1–2)	2 (1–3)	3 (2–3)	2 (1–3)	0.566
Antibiotic days per donor (median, IQR) (days)	4 (2–7)	5 (4–8)	7 (5–14)	5 (4–8)	<0.001
Length of antibiotics per donor (median, IQR) (days)	2 (2–4)	3 (2–4)	3 (2–7)	3 (2–4)	<0.001

[a] Data are presented as numbers (percentages) except where noted.

[b] Only those variables with a *P* value <0.20, those of notable biologic importance, and those included in the final multivariable models are shown in this table.

[c] The provided *P* value reflects a comparison of all four exposure groups.

Abbreviations: DCD, donation after circulatory death; ECD, expanded criteria donor; ECMO, extracorporeal membrane oxygenation; HBV, hepatitis B virus; HCT, hematopoietic cell transplant; HCV, hepatitis C virus; IDU, injection drug use; IQR, interquartile range; KDPI, Kidney Donor Profile Index; MDRO, multidrug-resistant organism; MDR-GN, multidrug-resistant Gram-negative; MDR-GP, multidrug-resistant Gram-positive; PHS, Public Health Service

Table 2.

Multivariable Poisson regression evaluating the association between the number of organs transplanted per donor and (a) MDRO or (b) MDR-GN on donor hospital cultures

A. Any MDRO[a]					**B. MDR-GN**[b]			
Donor variable	**IRR**	**95% CI**	***P* value**		**Donor variable**	**IRR**	**95% CI**	***P* value**
MDRO on culture	*1.15*	*0.99–1.33*	*0.068*		*MDR-GN on culture*	*0.43*	*0.39–0.48*	*<0.001*
DCD	0.44	0.37–0.52	<0.001		Albumin	1.03	1.03–1.04	<0.001
ECD	0.70	0.57–0.86	0.001		DCD	0.44	0.37–0.53	<0.001
HCV seropositive	0.50	0.39–0.64	<0.001		ECD	0.65	0.52–0.81	<0.001
Albumin	1.04	1.03–1.05	<0.001		KDPI	0.99	0.992–0.996	<0.001
KDPI	0.996	0.994–0.997	<0.001		HCV seropositive	0.47	0.35–0.61	<0.001
ECMO	0.67	0.52–0.85	0.001		ECMO	0.64	0.49–0.85	0.002
Open abdomen	0.81	0.69–0.97	0.019		Open abdomen	0.77	0.65–0.92	0.003
Diabetes mellitus	0.63	0.47–0.84	0.002		Death due to cardiovascular cause	0.85	0.77–0.94	0.002
Death due to cardiovascular cause	0.85	0.77–0.94	0.001		Intra-aortic balloon pump	0.69	0.58–0.82	<0.001
Death due to gunshot wound	1.16	1.03–1.31	0.018		Confounders/Interaction terms			
Confounders					LRTI	0.90	0.82–0.98	0.019
Length of stay	1.00	0.994–1.01	0.990		MDR-GN by LRTI interaction term	2.31	1.66–3.23	<0.001
Age	0.999	0.997–1.003	0.996					

[a]The comparator group in this analysis was comprised of those donors with no MDROs on culture (which could include donors with no positive cultures or those with non-MDRO positive cultures).

[b]The comparator group in this analysis was comprised of those donors with no MDR-GNs on cultures (which could include donors with no positive cultures, those with non-MDRO positive cultures, or those with an MDR-GP on culture).

Abbreviations: CI, confidence interval; DCD, donation after circulatory death; ECD, expanded criteria donor; ECMO, extracorporeal membrane oxygenation; HCV, hepatitis C virus; IRR, incidence rate ratio; KDPI, Kidney Donor Profile Index; MDR-GN, multidrug-resistant Gram-negative; MDRO, multidrug-resistant organism; LRTI, lower respiratory tract infection

Table 3.

Mixed effects multivariable negative binomial regression evaluating the association between the match run at which an organ was accepted and (a) MDRO and (b) MDR-GN on donor hospital cultures

A. MDRO[a]					**B. MDR-GN**[b]			
Donor characteristic	**Relative count**	**95% CI**	**P value**		**Donor characteristic**	**Relative count**	**95% CI**	**P value**
MDRO on culture	*3.26*	*0.94–11.28*	*0.062*		*MDR-GN on culture*	*5.08*	*1.64–15.68*	*0.005*
KDPI	1.02	1.01–1.03	<0.001		KDPI	1.03	1.02–1.04	<0.001
DCD	2.63	1.01–6.86	0.049		HCT	18.91	7.41–48.22	<0.001
Exploratory laparotomy	8.2	1.93–34.83	0.004		Exploratory laparotomy	9.29	2.86–30.19	<0.001
HCV seropositive	0.14	0.069–0.27	<0.001		HBV core antibody positive	2.15	1.03–4.50	0.043
Confounders and interaction terms					HCV seropositive	0.09	0.05–0.19	<0.001
LRTI	1.24	0.79–1.96	0.345		Age	0.97	0.95–0.98	<0.001
MDRO by LRTI interaction	0.12	0.03–0.49	0.003		Confounders and interaction terms			
					LRTI	1.18	0.76–1.83	0.47
					MDR-GN by LRTI interaction	0.12	0.03–0.45	0.002
					DCD	1.42	0.40–5.09	0.589
					ECD	1.53	0.71–3.32	0.279
					T4 protocol	0.84	0.29–2.40	0.745

[a]The comparator group in this analysis was comprised of those donors with no MDROs on culture (which could include donors with no positive cultures or those with non-MDRO positive cultures).

[b]The comparator group in this analysis was comprised of those donors with no MDR-GNs on cultures (which could include donors with no positive cultures, those with non-MDRO positive cultures, or those with an MDR-GP on culture).

Abbreviations: CI, confidence interval; DCD, donation after circulatory death; ECD, extended-criteria donor; HBV, hepatitis B virus; HCT, hematopoietic cell transplant; HCV, hepatitis C virus; KDPI, Kidney Donor Profile Index; LRTI, lower respiratory tract infection; MDR-GN, multidrug-resistant Gram-negative; MDRO, multidrug-resistant organism; T4, thyroxine