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Racial and ethnic variation in pediatric cardiac extracorporeal life support survival

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Abstract

Objective—Previous studies have suggested an association between non-white race and poor outcomes in small subsets of cardiac surgery patients who require extracorporeal life support (ECLS). This study aims to examine the association of race/ethnicity with mortality in pediatric patients who receive ECLS for cardiac support.

Design/Setting—Retrospective analysis of prospectively collected multi-institutional registry data.

Patients—Data from all North American pediatric patients in the Extracorporeal Life Support International Registry who received ECLS for cardiac support between 1998 and 2012 were analyzed. Multivariate regression models were constructed to examine the association between race/ethnicity and hospital mortality, adjusting for demographics, diagnosis, pre-ECLS care, ECLS variables, and ECLS-related complications.

Measurements and Main Results—Of 7,106 patients undergoing cardiac ECLS, the majority of patients were of white race (56.9%) with black race (16.7%), Hispanic ethnicity (15.8%) and Asian race (2.8%) comprising the other major race/ethnic groups. The mortality rate was 53.9% (n=3831). After adjusting for covariates, multivariate analysis identified black race (Relative Risk (RR)=1.10, 95% Confidence Interval (CI)=1.04-1.16) and Hispanic ethnicity (RR = 1.08, 95% CI = 1.02-1.14) as independent risk factors for mortality.

Conclusions—Black race and Hispanic ethnicity are independently associated with mortality in children who require cardiac ECLS.

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Keywords

Congenital heart disease, CHD; Database; Extracorporeal membrane oxygenation, ECMO; Extracorporeal Life Support, ECLS; Outcomes; Resuscitation

Introduction

Extracorporeal membrane oxygenation (ECLS) is a lifesaving and highly specialized therapy used for cardiac, respiratory and extracorporeal resuscitative support. Variable access to highly specialized therapies such as ECLS may result in racial and ethnic disparities in ECLS-related clinical outcomes. The impact of race on survival has been previously characterized in several forms of advanced therapy, including cardiac surgery, in which non-white patients have increased odds of mortality (1–6). Non-white race/ethnicity has also been identified as a risk factor in limited subsets of cardiac ECLS, patients who received extracorporeal cardiopulmonary resuscitation (ECPR), and in reports that dichotomously categorize race/ethnicity as white vs. non-white (7–10). However, a comprehensive evaluation of the overall impact of race/ethnicity in ECLS patients who require cardiac support has not been previously performed. In this study, we investigate the association of race/ethnicity with mortality in children undergoing ECLS for cardiac support using data from the Extracorporeal Life Support Organization (ELSO) international registry (11). In addition, we examine factors that potentially contribute to race/ethnicity-related variability in clinical outcomes in these patients.

Materials and Methods

The ELSO international registry is the largest database of prospectively collected, de-identified clinical ECLS data, containing data from over 50,000 ECLS patients from over 200 international centers (12). The Institutional Review Board at the University of Washington exempted this study from human subjects research guidelines. The ELSO registry categorizes indication for ECLS as cardiac, respiratory, or ECPR. All North American pediatric patients (<19 years) who received ECLS for a cardiac indication between 1998 and 2012 were included. Data analyses were limited to the index cardiac ECLS exposure for patients who experienced multiple periods of ECLS. The independent variable of race/ethnicity was categorized as white race, black race, Hispanic ethnicity, Asian race, or other race/ethnicity. The primary dependent variable of interest was hospital mortality, defined as death prior to hospital discharge. We also explored the timing of death in patients supported with ECLS. Secondary outcomes included mortality during the initial ECLS exposure (“Death during ECLS”) and surviving the initial ECLS exposure but dying prior to hospital discharge, including dying during subsequent ECLS exposures (“Death after ECLS”). ELSO records outcomes of each ECLS run, including recovery from ECLS, and death due to: catastrophic hemorrhage, diagnosis incompatible with life, irreversible organ failure or withdrawal of ECLS.

Patients were divided into three age categories: neonates (< 29 days), infants (29 days to 365 days), and children (1 to 18 years). Using International Classification of Diseases-9th Edition (ICD-9) codes and Current Procedural Terminology (CPT) codes, patients were

assigned to unique diagnostic categories: congenital cardiac surgery (stratified by the Society of Thoracic Surgeons-European Association for Cardio-Thoracic Surgery Categories (STAT)(13)), unknown cardiac surgical procedure, myocarditis/cardiomyopathy, structural heart disease without documented procedure, other cardiac disease (including arrhythmias and pulmonary embolism), and no documented cardiac disease (including etiologies such as sepsis and trauma). An additional unique indicator variable was utilized for single ventricle physiology based on diagnosis or procedure codes. ECLS exposures were divided into three eras: 1998 – 2004, 2005 - 2008, and 2009 - 2012. Pre-ECLS variables included time interval from endotracheal intubation to ECLS, lowest pre-ECLS pH, and pre-ECLS medications. ECLS variables included duration and mode of ECLS, ECLS cannulation sites, and ECLS complications. Mode of support was categorized as veno-arterial, veno-venous, or other. Cannulation sites were categorized as chest, cervical, femoral, or other. The total number of complications and number of complications for each organ system, as classified by the ELSO Registry Form, were analyzed.

Univariate analysis of baseline demographics, pre-ECLS factors and ECLS variables across race/ethnicity groups and hospital survival was performed. The Chi-square test or Fisher-Freeman-Halton test were performed for dichotomous or categorical data. Ordinal and continuous data were analyzed by Wilcoxon- Rank Sum or Kruskal-Wallis tests and t-tests or analysis of variance (ANOVA) tests, respectively. Statistical significance was defined as p-value <0.05. Variables determined to be significantly different by univariate analysis were included in multivariate models. Given that death was a frequent outcome in this cohort, multivariate modified Poisson regression models estimating the relative risk (RR) were created to examine the association between race/ethnicity and hospital mortality. Initial baseline models included only race/ethnicity as the predictor variable. Subsequent regression models sequentially added age group and ECLS era, diagnostic category, pre-ECLS mechanical ventilation time, pre-ECLS medications, ECLS factors (cannulation site, ECLS mode, ECLS duration), and ECLS complications. An additional regression model was constructed to examine the association between race/ethnicity and death during ECLS, using the same covariates as the hospital mortality model. Interactions between race/ethnicity and other covariates were evaluated in the hospital mortality model. STATA 12.1 (Stata Corp LP, College Station, TX) was used for the analysis.

Results

Univariate Analyses

Data from 7,106 patients meeting inclusion criteria were included in the analysis. The largest proportion of patients were of white race (56.9%), with black race (16.7%), Hispanic ethnicity (15.8%) and Asian race (2.8%) comprising the other major racial/ethnic groups. Baseline characteristics, ECLS variables and outcomes by race/ethnicity groups are reported in Table 1 and 2. When compared to white race, non- white race/ethnicity groups had a higher proportion of infants and children, patients with myocarditis/cardiomyopathy, ECLS during later eras, lower rates of chest cannulation and a lower pre- ECLS pH ($p < 0.05$ for all comparisons). Race/ethnicity was not associated with duration of mechanical ventilation before ECLS.

Non-white race/ethnicity was associated with increased risk of ECLS neurological complications (21.8% vs. 18.5%, $p<0.01$) (Table 2). Additionally, non-white race/ethnicity was associated with increased hospital mortality (55.9% vs. 52.5%, $p=0.005$). Non-white patients were also at increased risk of death during ECLS (33.8% vs. 29.4%, $p<0.01$) but not death after ECLS (21.7% vs. 22.7%, $p=0.65$). There was a significant variation in ECLS run outcomes across race/ethnic groups ($p<0.01$). Non-white patients had a lower rate of recovery during ECLS (66.2% vs. 70.4%) and lower rate of withdrawal of ECLS (4.6% vs. 5.7%) when compared to white patients. Non-white patients had higher rates of catastrophic hemorrhage (3.4% vs 2.4%), diagnoses incompatible with life (4.9% vs 4.3%), and irreversible organ failure (20.3% vs. 16.9%) than white patients.

The hospital mortality rate was 53.9% ($n=3831$) and varied significantly across most baseline characteristics (Table 3). Neonatal age category, STAT 5 procedures, early ECLS era, chest cannulation, increased duration of pre-ECLS mechanical ventilation, lower blood pH, increased duration of ECLS, and multiple complications were more common in non-survivors. These risk factors generally remained associated with hospital mortality when hospital mortality was examined by race/ethnicity (online Table 4). Among white, black and Hispanic patients, neonatal age group, earlier ECLS era, increased duration of ECLS and multiple complications were associated with increased mortality. Interestingly, the survival rate for black patients undergoing STAT 5 procedures (25%) was significantly lower than white (41%) and Hispanic patients (41%). The distribution of risk factors for mortality varied across age groups (online Table 5), with STAT 5 procedures, longer duration of pre-ECLS mechanical ventilation, chest cannulation, hospital mortality, death during ECLS and death after ECLS being more common among neonates.

Multivariate Analyses

In all additive iterations of the hospital mortality model, black race (Relative Risk (RR) range: 1.07-1.13) and Hispanic ethnicity (RR range: 1.08-1.12) (Figure 1) were associated with increased mortality. After adjusting for all co-variables (ECMO Complications in Figure 1), black race (RR = 1.10, 95% Confidence Interval (CI) = 1.04 - 1.16), and Hispanic ethnicity (RR = 1.08, 95% CI = 1.02 - 1.14) were associated with increased hospital mortality when compared to white patients. Additionally, black and Hispanic patients were also at increased risk of death during ECLS (black: RR = 1.12, 95% CI = 1.02 - 1.23; Hispanic: RR=1.11, 95%CI=1.01 - 1.21) in the fully adjusted model. While the point estimate of black race and Hispanic ethnicity changed with additional co-variables, none of the co-variables altered the point estimate of race/ethnicity for black or Hispanic patients by more than 10%. Pre-ECLS blood pH was not included in the final model due to missing data in 15% of patients. When pH was tested in the multivariate models, the point estimate of black race or Hispanic ethnicity did not substantively change. No significant interaction was noted between age group and race/ethnicity. There was a significant interaction between black race and STAT category 5 procedures (Interaction term: RR=1.29, 95%CI=1.07-1.57) but not for Hispanic ethnicity or any other diagnostic categories and black race.

Discussion

In this analysis of pediatric patients who received cardiac ECLS, black race and Hispanic ethnicity were identified as independent risk factors for hospital mortality. Variability in medical care before, during, and after ECLS may have contributed to observed race/ethnicity-related differences in survival. Nevertheless, black and Hispanic patients continue to experience increased risk of death after adjusting for these covariates. Although non-white race previously has been identified as a risk factor for hospital mortality in limited subgroups of cardiac and respiratory ECLS patients (7–10, 14–16), an association between individual race/ethnicity and clinical outcomes has not been previously established in a large, unrestricted cohort of cardiac ECLS patients.

The reason for racial and ethnic disparities in ECLS survival is unknown but is likely to be multifactorial in nature. Disparate access to pre-ECLS care, differences in pre-ECLS clinical status, variability in ECLS and post-ECLS management, cultural preferences, and socioeconomic factors may individually or collectively impact ECLS survival and risk for ECLS complications. Race and ethnicity-based differences in access to care are well established in several non-ECLS patient populations. Previous studies have reported that non-white adults are less likely to receive timely and appropriate care for acute myocardial infarction (2, 4, 17, 18) and critically ill Hispanic children have higher severity of illness than their white counterparts (19). In the current study, black and Hispanic patients did not have significantly longer periods of pre-ECLS mechanical ventilation, a previously demonstrated risk factor for poor survival (14). Additionally, while there was a statistically significant difference in blood pH across race/ethnicity groups, the clinical difference was small. Finally, the addition of pre-ECLS care into regression model did not substantively alter the association of race/ethnicity and mortality. These findings suggest that while there may be slight differences in pre-ECLS care, they are unlikely to be the driving force in ECLS survival disparities.

Variations in care during ECLS may contribute to racial/ethnic disparities in hospital survival. Complications during ECLS are commonly associated with increased mortality (7, 10, 15) and previous studies have demonstrated race/ethnicity-based differences in complication rates in congenital heart surgery patients (6). We demonstrated that non-white patients were at increased risk of experiencing a neurological ECLS complication. However, the addition of ECLS complications into the regression model, while attenuating the association between race/ethnicity and mortality, did not significantly alter the association. Thus, while complications may be one mechanism for the black and Hispanic patients to experience ECLS disparities, it is not the only or main mechanism that may be driving this disparity.

Social factors, such as implicit racial biases and cultural preferences, may also be a contributing factor in worse outcomes observed in some groups. Implicit racial bias among health care professionals has been associated with variations in therapeutic decision making (20, 21) and may influence provider decisions in initiating ECLS, treating complications and post-ECLS care. These cumulative variations in decision-making may ultimately impact overall hospital survival for black and Hispanic patients. Furthermore, cultural preferences

among patient families may also impact ECLS outcomes. Previous adult studies have suggested that non-white patients and families may be more likely to utilize highly invasive therapies (22, 23). In our study, black and Asian patients had lower rates of withdrawal of ECLS and higher rates of death during ECLS due to other reasons such as hemorrhage, irreversible organ failure and diagnoses that were incompatible with life. While these represent mutually exclusive outcome categories in the ELSO registry, the distinction may be less clear in many clinical situations. Nevertheless, racial and ethnic differences in cause of death during ECLS may reflect the impact of varying cultural preferences related to end-of-life decision-making.

We found an interaction between black race and STAT category 5 procedures, the highest risk category for congenital heart surgery, suggesting that these patients are at increased risk of disparities in hospital mortality. Increased risk of mortality for black patients undergoing high risk congenital heart surgery appears to be the main driver of overall disparities for black children. High risk procedures are associated with increased risk of ECLS usage, mortality with and without ECLS support and experiencing a complication (24, 25). In this population, delays in access to care, variations in care delivery and implicit bias may have a profound impact on outcomes. A similar pattern of increased risk in high risk surgical procedures was not seen for Hispanic patients. This suggests that Hispanic patients may remain at increased risk of mortality regardless of the reasons for requiring ECLS.

Previous studies of congenital heart surgery patients have demonstrated that non-white patients are at increased risk of experiencing a complication, failure-to-rescue and hospital mortality (5, 6, 26). The findings of this study provide further understanding of the previously documented disparities. This study demonstrates one mechanism, increased ECLS-associated mortality, by which non-white patients experience post-surgical survival disparities. It is possible that common factors (delays in care, complications, implicit bias) contribute to both increased surgical mortality and ECLS mortality. However, after adjustment for these variables (with the exception of implicit bias), black and Hispanic patients continued to experience increased risk of hospital mortality, suggesting that this is not the only mechanism for ECLS disparities. Furthermore, it should be noted that ECLS-associated mortality accounts for less than 1/3rd of all peri-operative deaths in congenital heart surgery (25). As such, while ECLS-associated disparities may contribute to post-surgical survival disparities, it is unlikely that these disparities are the sole etiology for racial/ethnic differences in cardiac surgical mortality.

This analysis is subject to several important limitations inherent to all retrospective studies. ELSO registry data is collected from > 100 deidentified ECLS centers and information related to center geography, clinical resources, cardiac care volume, and local patient population is unknown. It is not possible to examine within-hospital and inter-hospital models of disparity. Additionally, many registry data fields are structured as mutually exclusive categories (e.g., mechanism of death during ECLS) and therefore, may not reflect the complexity and intricacies of medical decision-making related to ECLS. Finally, while we adjusted for many variables that might influence the association of race/ethnicity with mortality, there may be other important confounders that were not measured or known that might explain our findings.

Conclusions

Black and Hispanic pediatric patients who require ECLS for cardiac indications are at increased risk of dying when compared to white patients. It is unknown whether race/ethnicity-based differences in ECLS survival reflect disparities in access to care, differences in socioeconomic status, or regional variability in ECLS care. Future studies to explore the impact of these factors on race/ethnicity-related differences in ECLS survival are warranted.

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Figure 1.
Iterative multivariate models for hospital mortality by race/ethnicity.

Table 1

Baseline characteristics by race/ethnicity

Characteristic	White N = 4040	Black N = 1188	Hispanic N = 1126	Asian N = 199	Other N = 411	Missing N = 142
Age						
Neonate (< 29 days)	2057 (51)	516 (43)	556 (49)	85 (43)	192 (47)	72 (51)
Infant (29 - 365 days)	1097 (27)	364 (31)	339 (30)	54 (27)	125 (30)	46 (32)
Child (1 - 18 years)	886 (22)	308 (26)	231 (21)	60 (30)	94 (23)	24 (17)
Sex						
Female	1755 (43)	539 (45)	494 (44)	93 (47)	187 (45)	39 (27)
Diagnostic Category						
STAT ^a 1-3	779 (19)	160 (13)	206 (18)	29 (15)	81 (20)	17 (12)
STAT 4	1210 (30)	326 (27)	358 (32)	76 (38)	140 (34)	47 (33)
STAT 5	748 (19)	212 (18)	192 (17)	25 (13)	52 (13)	17 (12)
Unknown Cardiac Procedure	114 (3)	29 (2)	28 (2)	5 (3)	6 (1)	15 (10)
Myocarditis & Cardiomyopathy	317 (8)	177 (15)	112 (10)	30 (15)	52 (13)	8 (6)
Structural Heart Disease, No Procedure	377 (9)	123 (10)	100 (9)	11 (5)	38 (9)	14 (10)
Other Cardiac Disease	315 (8)	104 (9)	89 (8)	11 (5)	28 (7)	13 (9)
No Cardiac Disease	180 (4)	57 (5)	41 (4)	12 (6)	14 (3)	11 (8)
Era						
1998 - 2004	1674 (41)	416 (35)	386 (34)	52 (26)	147 (36)	45 (32)
2005 - 2008	1216 (30)	344 (29)	366 (33)	63 (32)	143 (35)	43 (30)
2009 - 2012	1150 (28)	428 (36)	374 (33)	84 (42)	121 (29)	54 (38)
Pre-ECLS Factors						
Pre-ECLS Mechanical						
Ventilation (hrs) Median (IQR) ^b	20 (8-90)	23 (8-94)	24 (10-97)	19 (8-48)	18 (7-80)	24 (10-96)
Pre-ECLS pH Median (IQR)	7.29 (7.19-7.39)	7.29 (7.17-7.39)	7.27 (7.15-7.37)	7.27 (7.16-7.38)	7.29 (7.17-7.37)	7.3 (7.19-7.41)

^aSociety of Thoracic Surgeons-European Association for Cardio-Thoracic Surgery Congenital Heart Surgery Mortality Categories^bInterquartile Range

Table 2

Extracorporeal life support (ECLS) characteristics and outcomes by race/ethnicity

Characteristic	White N = 4040	Black N = 1188	Hispanic N = 1126	Asian N = 199	Other N = 411	Missing N = 142
ECLS Factors						
ECLS Mode						
Veno-arterial	3962 (98)	1164 (98)	1093 (97)	193 (97)	402 (98)	136 (96)
Veno-venous	44 (1)	14 (1)	17 (2)	3 (1)	6 (1)	3 (2)
Other	34 (1)	10 (1)	16 (1)	3 (1)	3 (1)	3 (2)
Cannula Site						
Chest	2554 (63)	674 (57)	738 (66)	115 (58)	254 (62)	80 (56)
Cervical	1261 (31)	418 (35)	310 (27)	62 (31)	139 (34)	30 (21)
Femoral	93 (2)	47 (4)	31 (3)	15 (8)	9 (2)	6 (4)
Other/Unknown	132 (3)	49 (4)	47 (4)	7 (3)	9 (2)	26 (18)
Hours during ECLS Median (IQR) ^a	112 (63-181)	118.5 (68-211)	106.5 (63-189)	112.5 (61-177)	112 (66-192)	108 (53-174)
ECLS Complications						
Total Number of Complications Median (IQR)	3 (1-5)	3 (1-5)	3 (1-5)	3 (1-5)	3 (1-5)	2 (1-4)
Any Cardiac	2810 (70)	804 (68)	810 (72)	139 (70)	280 (68)	82 (58)
Any Hematological	1930 (48)	555 (47)	517 (46)	93 (47)	200 (49)	60 (42)
Any Infectious	313 (8)	89 (7)	74 (7)	16 (8)	35 (9)	4 (3)
Any Mechanical	1229 (30)	375 (32)	355 (32)	68 (34)	137 (33)	36 (25)
Any Metabolic	924 (23)	242 (20)	251 (22)	53 (27)	102 (25)	29 (20)
Any Neurological	748 (19)	245 (21)	264 (23)	42 (21)	86 (21)	28 (20)
Any Pulmonary	352 (9)	105 (9)	109 (10)	19 (10)	59 (14)	6 (4)
Any Renal	1575 (39)	466 (39)	476 (42)	77 (39)	165 (40)	40 (28)
ECLS Termination and Survival ^b						
Overall Mortality	2121(53)	665 (56)	646 (57)	102 (51)	221 (54)	76 (54)
Died during ECLS	1191 (29)	398 (34)	385 (34)	64 (32)	137 (33)	50 (35)
Withdrawal	229 (6)	45 (4)	72 (6)	4 (2)	12 (3)	7 (5)
Hemorrhage	95 (2)	38 (3)	35 (3)	11 (5)	15 (4)	4 (3)
Diagnosis Incompatible with Life	174 (4)	57 (5)	62 (6)	6 (3)	18 (4)	8 (6)
Irreversible Organ Failure	681 (17)	250 (21)	210 (19)	43 (22)	90 (22)	25 (18)
Died After ECLS	918 (23)	261 (22)	257 (23)	36 (18)	81 (20)	26 (18)

^aInterquartile Range^bTiming and cause of death was not available for all patients

Table 3

Characteristics by hospital discharge status

Characteristic	Survivors N = 3275	Non-Survivors N = 3831	p-value
Age			<0.01
Neonate (< 29 days)	1396 (40)	2082 (60)	
Infant (29 days - 1 year)	1008 (50)	1017 (50)	
Child (1 - 18 years)	871 (54)	732 (46)	
Sex			0.443
Female	1414 (46)	1693 (54)	
Male	1827 (46)	2107 (54)	
Diagnostic Category			<0.01
STAT ^a 1-3	600 (47)	672 (53)	
STAT 4	1008 (47)	1149 (53)	
STAT 5	468 (38)	778 (62)	
Unknown Cardiac Procedure	91 (46)	106 (54)	
Myocarditis/Cardiomyopathy	420 (60)	276 (40)	
Structural Heart Disease, No Procedure	291 (44)	372 (56)	
Other Cardiac Disease	242 (43)	318 (57)	
No Cardiac Disease	155 (49)	160 (51)	
Era			<0.01
1998 - 2004	1134 (42)	1586 (58)	
2005 - 2008	987 (45)	1188 (55)	
2009 - 2012	1154 (52)	1057 (48)	
Pre-ECLS Factors			
Pre-ECLS Mechanical Ventilation (hrs) Median (IQR) ^b	17 (7-59)	26 (10-125)	<0.01
Pre-ECLS pH Median (IQR)	7.3 (7.19-7.39)	7.28 (7.16-7.38)	<0.01
ECLS Factors			
ECLS Mode			0.293
Veno-arterial	3201 (46)	3749 (54)	
Veno-venous	46 (53)	41 (47)	
Other	28 (41)	41 (59)	
Cannula Site			<0.01
Chest	1900 (43)	2515 (57)	
Cervical	1157 (52)	1063 (48)	
Femoral	116 (58)	85 (42)	
Other/Unknown	102 (38)	168 (62)	
Hours during ECLS Median (IQR)	95 (63-148)	133 (66-224)	<0.01
ECLS Complications			
Total Number of Complications	2 (1-4)	4 (2-6)	<0.01
No Complications	571 (67)	282 (33)	<0.01

^aSociety of Thoracic Surgeons-European Association for Cardio-Thoracic Surgery Congenital Heart Surgery Mortality Categories

^bInterquartile Range

Table 4

Characteristics by hospital discharge status and race/ethnicity

Characteristic	White Survivors N=1919	White Non- Survivors N=2121	Black Survivors N=523	Black Non- Survivors N=665	Hispanic Survivors N=480	Hispanic Non- Survivors N=646	Asian Survivors N=97	Asian Non- Survivors N=102	Other Survivors N=190	Other Non- Survivors N=221
Age										
Neonate (< 29 days)	875 (43) *	1182 (57)	167 (32) *	349 (68)	214 (38) *	342 (62)	34 (40)	51 (60)	74 (39) *	118 (61)
Infant (29 days - 1 year)	564 (51)	533 (49)	180 (49)	184 (51)	151 (45)	188 (55)	28 (52)	26 (48)	62 (50)	63 (50)
Child (1 - 18 years)	480 (54)	406 (46)	176 (57)	132 (43)	115 (50)	116 (50)	35 (58)	25 (42)	54 (57)	40 (43)
Sex										
Female	824 (47)	931 (53)	237 (44)	302 (56)	210 (43)	284 (57)	46 (49)	47 (51)	81 (43)	106 (57)
Male	1094 (48)	1188 (52)	285 (44)	360 (56)	269 (43)	361 (57)	51 (48)	55 (52)	108 (49)	113 (51)
Diagnostic Category										
STAT ^a 1-3	375 (48) *	404 (52)	80 (50) *	80 (50)	85 (41)	121 (59)	13 (45)	16 (55)	40 (49)	41 (51)
STAT 4	587 (49)	623 (51)	134 (41)	192 (59)	158 (44)	200 (56)	39 (51)	37 (49)	66 (47)	74 (53)
STAT 5	306 (41)	442 (59)	53 (25)	159 (75)	78 (41)	114 (59)	7 (28)	18 (72)	16 (31)	36 (69)
Unknown Cardiac Procedure	51 (45)	63 (55)	15 (52)	14 (48)	11 (39)	17 (61)	5 (100)	0 (0)	3 (50)	3 (50)
Mycarditis/Cardiomyopathy	189 (60)	128 (40)	118 (67)	59 (33)	60 (54)	52 (46)	17 (57)	13 (43)	32 (62)	20 (38)
Structural Heart Disease, No Procedure	173 (46)	204 (54)	52 (42)	71 (58)	36 (36)	64 (64)	6 (55)	5 (45)	18 (47)	20 (53)
Other Cardiac Disease	148 (47)	167 (53)	42 (40)	62 (60)	32 (36)	57 (64)	6 (55)	5 (45)	8 (29)	20 (71)
No Cardiac Disease	90 (50)	90 (50)	29 (51)	28 (49)	20 (49)	21 (51)	4 (33)	8 (67)	7 (50)	7 (50)
Era										
1998 - 2004	736 (44) *	938 (56)	159 (38) *	257 (62)	141 (37) *	245 (63)	23 (44)	29 (56)	58 (39)	89 (61)
2005 - 2008	552 (45)	664 (55)	146 (42)	198 (58)	160 (44)	206 (56)	32 (51)	31 (49)	73 (51)	70 (49)
2009 - 2012	631 (55)	519 (45)	218 (51)	210 (49)	179 (48)	195 (52)	42 (50)	42 (50)	59 (49)	62 (51)
Pre-ECLS Factors										
Pre-ECLS Mechanical Ventilation (hrs) Median (IQR) ^b	16 (7-54) *	26 (9-128)	19 (7-65) *	27 (9-132)	21 (9-76)	28 (11-115)	15 (6-32) *	25 (10-69)	13 (6-61) *	25 (10-113)
Pre-ECLS pH Median (IQR)	7.3 * (7.20-7.40)	7.29 (7.17-7.38)	7.3 (7.17-7.39)	7.28 (7.16-7.39)	7.29 * (7.18-7.38)	7.25 (7.14-7.36)	7.28 (7.17-7.39)	7.26 (7.14-7.38)	7.30 (7.18-7.38)	7.29 (7.16-7.37)
ECLS Factors										
ECLS Mode										

Characteristic	White Survivors N=1919	White Non- Survivors N=2121	Black Survivors N=523	Black Non- Survivors N=665	Hispanic Survivors N=480	Hispanic Non- Survivors N=646	Asian Survivors N=97	Asian Non- Survivors N=102	Other Survivors N=190	Other Non- Survivors N=221
Veno-arterial	1884 (48)	2078 (52)	509 (44) [*]	655 (56)	462 (42)	631 (58)	96 (50)	97 (50)	188 (47)	214 (53)
Veno-venous	19 (43)	25 (57)	11 (79)	3 (21)	12 (71)	5 (29)	1 (33)	2 (67)	1 (17)	5 (83)
Other	16 (47)	18 (53)	3 (30)	7 (70)	6 (37)	10 (63)	0 (0)	3 (100)	1 (33)	2 (67)
Cannula Site										
Chest	1161 (45) [*]	1393 (55)	251 (37) [*]	423 (63)	298 (40)	440 (60)	47 (41) [*]	68 (59)	106 (42)	148 (58)
Cervical	661 (52)	600 (48)	222 (53)	196 (47)	148 (48)	162 (52)	36 (58)	26 (42)	74 (53)	65 (47)
Femoral	50 (54)	43 (46)	31 (66)	16 (34)	16 (52)	15 (48)	11 (73)	4 (27)	5 (56)	4 (44)
Other/Unknown	47 (36)	85 (64)	19 (39)	30 (61)	18 (38)	29 (62)	3 (43)	4 (57)	5 (56)	4 (44)
Hours during ECLS Median (IQR)	94 [*] (60-145)	134 (66-217)	111 [*] (67-178)	133 (68-240)	92 [*] (63-140)	123 (59-224)	95 [*] (61-137)	137 (62-232)	96 [*] (63-148)	135 (72-234)
ECLS Complications										
Total Number of Complications	2 (1-4) [*]	4 (2-6)	2 (1-3) [*]	4 (2-6)	2 (1-4) [*]	4 (2-6)	3 (1-4) [*]	4 (2-6)	2 (1-4) [*]	4 (2-7)
No Complications	332 (69) [*]	152 (31)	89 (63) [*]	52 (37)	80 (64) [*]	45 (36)	14 (61) [*]	9 (39)	39 (78) [*]	11 (22)

^a Society of Thoracic Surgeons-European Association for Cardio-Thoracic Surgery Congenital Heart Surgery Mortality Categories

^b Interquartile Range

^{*} p<0.05 for comparison of survivors versus non-survivor for specific race/ethnicity

Table 5

Characteristics by Age Group

Characteristic	Neonates N=3478	Infants N=2025	Children N=1603	p-value
Sex				
Male	2023 (58)	1078 (53)	833 (52)	<0.01
Race/Ethnicity				<0.01
White	2057 (59)	1097 (54)	886 (55)	
Black	516 (15)	364 (18)	308 (19)	
Hispanic	556 (16)	339 (17)	231 (14)	
Asian	85 (2)	54 (3)	60 (4)	
Other	192 (6)	125 (6)	94 (6)	
Diagnostic Category				<0.01
STAT ^a 1-3	329 (9)	612 (30)	331 (21)	
STAT 4	1189 (34)	610 (30)	358 (22)	
STAT 5	1041 (30)	183 (9)	22 (1)	
Unknown Cardiac Procedure	83 (2)	67 (3)	47 (3)	
Myocarditis/Cardiomyopathy	134 (4)	161 (8)	401 (25)	
Structural Heart Disease, No Procedure	403 (12)	178 (9)	82 (5)	
Other Cardiac Disease	185 (5)	165 (8)	210 (13)	
No Cardiac Disease	114 (3)	49 (2)	152 (9)	
Era				<0.01
1998 - 2004	1314 (38)	786 (39)	620 (39)	
2005 - 2008	1135 (33)	583 (29)	457 (28)	
2009 - 2012	1029 (29)	656 (32)	526 (33)	
Pre-ECLS Factors				<0.01
Pre-ECLS Mechanical Ventilation (hrs) Median (IQR) ^b	31 (10-127)	18 (8-78)	14 (6-36)	
Pre-ECLS pH Median (IQR)	7.29 (7.18-7.39)	7.3 (7.18-7.39)	7.29 (7.18-7.38)	0.28
ECLS Factors				
ECLS Mode				0.09
Veno-arterial	3405 (98)	1981 (98)	1564 (98)	
Veno-venous	47 (1)	25 (1)	15 (1)	
Cannula Site				<0.01
Chest	2423 (70)	1349 (67)	643 (40)	
Cervical	936 (27)	586 (29)	698 (44)	
Femoral	2 (0)	6 (0)	193 (12)	
Hours during ECLS Median (IQR)	112 (64-188)	113 (66-186)	114 (57-186)	0.52
Total Number of Complications	3 (1-5)	3 (1-5)	3 (1-5)	0.03
ECLS and Hospital Survival ^c				
Overall Mortality	2082 (60)	1017 (50)	732 (46)	<0.01
Died during ECLS	1161 (33)	592 (29)	472 (29)	<0.01
Died After ECLS	905 (26)	418 (21)	256 (16)	<0.01

^aSociety of Thoracic Surgeons-European Association for Cardio-Thoracic Surgery Congenital Heart Surgery Mortality Categories

^bInterquartile Range

^cTiming was not available for all patients