Published in final edited form as:

Ann Thorac Surg. 2014 December ; 98(6): 2138–2144. doi:10.1016/j.athoracsur.2014.06.103.

Epidemiology and Outcomes After In-Hospital Cardiac Arrest After Pediatric Cardiac Surgery

Punkaj Gupta, MBBS, Jeffrey P. Jacobs, MD, Sara K. Pasquali, MD, MHS, Kevin D. Hill, MD, MS, J. William Gaynor, MD, Sean M. O'Brien, PhD, Max He, MS, Shubin Sheng, MS, Stephen M. Schexnayder, MD, Robert A. Berg, MD, Vinay M. Nadkarni, MD, Michiaki Imamura, MD, PhD, and Marshall L. Jacobs, MD

Division of Pediatric Critical Care, Department of Pediatrics, and Division of Cardiothoracic Surgery, Arkansas Children's Hospital, University of Arkansas for Medical Sciences, Little Rock, Arkansas; Johns Hopkins Children's Heart Surgery, All Children's Hospital, St. Petersburg, Florida; Division of Cardiac Surgery, Johns Hopkins School of Medicine, Baltimore, Maryland; Division of Pediatric Cardiology, Department of Pediatrics, University of Michigan, C.S. Mott Children's Hospital, Ann Arbor, Michigan; Division of Pediatric Cardiology, Department of Pediatrics, Duke University Medical Center, and Duke Clinical Research Institute, Durham, North Carolina; and Departments of Cardiothoracic Surgery and Anesthesia and Critical Care, The Children's Hospital of Philadelphia, Philadelphia, Pennsylvania

Abstract

Background—Multicenter data regarding cardiac arrest in children undergoing heart operations are limited. We describe epidemiology and outcomes associated with postoperative cardiac arrest in a large multiinstitutional cohort.

Methods—Patients younger than 18 years in the Society of Thoracic Surgeons Congenital Heart Surgery Database (2007 through 2012) were included. Patient factors, operative characteristics, and outcomes were described for patients with and without postoperative cardiac arrest. Multivariable models were used to evaluate the association of center volume with cardiac arrest rate and mortality after cardiac arrest, adjusting for patient and procedural factors.

Results—Of 70,270 patients (97 centers), 1,843 (2.6%) had postoperative cardiac arrest. Younger age, lower weight, and presence of preoperative morbidities (all $p < 0.0001$) were associated with cardiac arrest. Arrest rate increased with procedural complexity across common benchmark operations, ranging from 0.7% (ventricular septal defect repair) to 12.7% (Norwood operation). Cardiac arrest was associated with significant mortality risk across procedures, ranging from 15.4% to 62.3% (all $p < 0.0001$). In multivariable analysis, arrest rate was not associated with center volume (odds ratio, 1.06; 95% confidence interval, 0.71 to 1.57 in low- versus high-volume centers). However, mortality after cardiac arrest was higher in low-volume centers (odds

Address correspondence to Dr Gupta, University of Arkansas for Medical Sciences, 1 Children's Way, Slot 512-3, Little Rock, AR 72202; pgupta2@uams.edu.

Presented at the Fiftieth Annual Meeting of The Society of Thoracic Surgeons, Orlando, FL, Jan 25–29, 2014. Winner of the Richard E. Clark Award for Congenital Heart Surgery.

ratio, 2.00; 95% confidence interval, 1.52 to 2.63). This association was present for both high- and low-complexity operations.

Conclusions—Cardiac arrest carries a significant mortality risk across the stratum of procedural complexity. Although arrest rates are not associated with center volume, lower-volume centers have increased mortality after cardiac arrest. Further study of mechanisms to prevent cardiac arrest and to reduce mortality in those with an arrest is warranted.

Cardiac arrest is reported in 2% to 6% of children admitted to pediatric and cardiac intensive care units [1–3]. Cardiac arrest rates are particularly high in children with cardiac disease, with a greater than tenfold reported increased rate of cardiac arrest compared with children hospitalized with other diseases and conditions [4]. The relationship between cardiac arrest and risk of subsequent mortality among pediatric cardiac patients is incompletely understood.

Previous studies evaluating cardiac arrest in pediatric patients undergoing cardiac operations consist primarily of single-center reports [1, 2]. Larger studies include limited information regarding specific cardiac diagnoses and procedures, such that there are limited multicenter data regarding the epidemiology and outcomes associated with cardiac arrest across the spectrum of congenital heart surgery [3–5]. For this reason, there are also limited benchmark data regarding the cardiac arrest rate after commonly performed operations, as well as very limited information regarding variation in cardiac arrest rates (or survival after an arrest) across hospitals. Previous studies have demonstrated that higher-volume hospitals tend to have better outcomes after congenital heart surgery [6, 7]; however, the relationship between center volume and cardiac arrest rate (or survival after an arrest) in particular has not been investigated to date.

To address these knowledge gaps, this study evaluated epidemiology and outcomes associated with cardiac arrest after pediatric heart operations using the Society of Thoracic Surgeons Congenital Heart Surgery Database (STS-CHSD), a large multiinstitutional registry with comprehensive diagnostic and procedural complexity coding. In addition to evaluating the prevalence of cardiac arrest and associated mortality after several common benchmark operations, we also assessed variation in these outcomes across hospitals of varying surgical volume.

Material and Methods

Data Source

The STS-CHSD contains deidentified data on more than 292,000 operations conducted since 2000, and currently represents approximately 90% of all US centers performing congenital heart surgery [8]. Preoperative, operative, and outcomes data are collected on all patients undergoing pediatric and congenital heart surgery at participating institutions [9, 10]. The Duke Clinical Research Institute serves as the data warehouse and analysis center for all of the STS National Databases [8–10]. This study was not considered human subjects research by the Duke University Institutional Review Boards in accordance with the Common Rule (45 CFR 46.102(f)).

Patient Population

Analysis was restricted to cardiovascular operations (with or without cardiopulmonary bypass) reported in the STS-CHSD between 2007 and 2012 in children younger than 18 years. To ensure data integrity, centers with more than 10% missing data for in-hospital mortality or complications were excluded ($n = 18$ centers). Cases were classified on the basis of the first cardiovascular operation of each hospital admission (the index operation). The resultant population included 73,089 patients from 97 centers. We excluded 1,933 patients whose operation was not classified into one of the Society of Thoracic Surgeons–European Association for Cardiothoracic Surgery (STS-EACTS) Mortality Categories (category 1, lowest mortality risk; category 5, highest mortality risk) [11]. An additional 836 patients were excluded because of missing mortality ($n = 158$), postoperative length of stay ($n = 335$), or complications ($n = 393$) data. Thus the final patient population included 70,270 patients from 97 centers.

Data Collection

Data collection included demographics, chromosomal or noncardiac anomalies, other preoperative risk factors as defined in the STS-CHSD, preoperative length of stay, and number of previous cardiothoracic surgeries [12]. The primary procedure of each index operation performed was classified by STS-EACTS Mortality Category [11] and STS Congenital Heart Surgery Morbidity Category [13]. Center characteristics included region of the country and average annual center surgical volume of STS-EACTS classified index cardiovascular operations during the study period. Operative data included duration of cardiopulmonary bypass. The primary outcome was postoperative cardiac arrest. According to STS-CHSD specifications, a cardiac arrest is defined as the cessation of effective cardiac mechanical function [12]. Hospital mortality before discharge in those with cardiac arrest was also evaluated.

Analysis

Patient characteristics and outcomes were summarized for patients with and without postoperative cardiac arrest using standard summary statistics. Values were compared in the arrest and no arrest groups using the Wilcoxon rank sum and χ^2 tests. In addition, the rate of cardiac arrest was evaluated for the eight previously described STS-CHSD benchmark operations: ventricular septal defect (VSD) repair, tetralogy of Fallot repair (excluding those with pulmonary atresia or absent pulmonary valve, or atrioventricular canal repair), complete atrioventricular canal repair, arterial switch operation, arterial switch operation with VSD repair, Fontan operation (including lateral tunnel and extracardiac conduit with or without fenestration; excluding Fontan revision), truncus arteriosus repair (excluding concomitant truncal valve repair or replacement or interrupted aortic arch repair), and the Norwood operation (including either systemic-to-pulmonary artery shunt or right ventricle-to-pulmonary artery conduit) [14]. For each benchmark operation, the cardiac arrest rate and rate of death in those with a cardiac arrest were described.

Finally, variation in cardiac arrest rates, and the rate of death in those with a cardiac arrest, across hospitals of varying surgical volume was examined. Center volume was evaluated as fewer than 150, 150 to 250, 250 to 350, and more than 350 cases per year, consistent with

previous analyses [15]. Multivariable logistic regression models were used to evaluate the relationship between center volume and both the rate of cardiac arrest and rate of death in those with cardiac arrest. Generalized estimating equations with robust standard error estimates were used to account for within-center correlation. All models were adjusted for important patient characteristics including age at surgery; weight-for-age z score; any chromosomal, genetic, or noncardiac abnormality; any preoperative risk factor; any previous cardiothoracic surgeries; year of surgery; and case complexity. Case complexity was determined on the basis of STS-EACTS Mortality Category for analyses with the outcome of mortality in those with cardiac arrest [11], and by STS Morbidity Category for analyses with the outcome of cardiac arrest [13]. Finally, stratified analysis was performed to evaluate whether the relationship of center volume with outcome differed across varying levels of surgical risk. For this analysis, patients were grouped on the basis of STS-EACTS Mortality or STS Morbidity Categories (categories 1, 2, and 3 representing “low” risk and 4 and 5 representing “high” risk). Adjusted odds ratios and 95% confidence intervals are reported for all models. Missing data were rare (<0.5% for all variables). Missing values were imputed to median for continuous variables and to “no” for dichotomous variables. Procedures that could not be assigned to an STS Morbidity Category (1.0%) were excluded from the model of postoperative cardiac arrest. All analyses were performed using SAS version 9.3 (SAS Institute, Inc, Cary, NC). A probability value of less than 0.05 was considered statistically significant.

Results

Study Population Characteristics

A total of 70,270 patients from 97 centers were included. The overall rate of cardiac arrest was 2.6% (n = 1,843), and overall mortality rate was 4.0% (n = 2,808). Mortality in those with cardiac arrest was 49.4% (n = 910), and was 2.8% (n = 1,898) in those without cardiac arrest. Patient characteristics are displayed in Table 1. Patients who had a cardiac arrest were younger, smaller, and more likely to have preoperative risk factors, and underwent higher complexity operations.

Cardiac Arrest Rates and Mortality for The Society of Thoracic Surgeons Benchmark Operations

Among eight common benchmark operations, the overall prevalence of cardiac arrest was 3.2% and increased with greater case complexity, ranging from 0.7% for VSD repair to 12.7% for the Norwood operation (Table 2). Overall, cardiac arrest occurred in more than 5% of patients undergoing three of these eight common operations (arterial switch operation with VSD repair, truncus arteriosus repair, and Norwood operation). Regardless of case complexity, cardiac arrest was associated with significant mortality risk, ranging from 15.4% in patients undergoing VSD repair to 62.3% in patients undergoing Norwood operation (all $p < 0.0001$ versus patients with no arrest; Table 2).

Variation in Rates of Cardiac Arrest and Mortality After Cardiac Arrest Across Hospitals of Varying Surgical Volume

Of 97 included centers, there were 43 centers (44%) with average annual cardiac surgery index case volume fewer than 150 cases per year, 26 centers (27%) with 150 to 250 cases per year, 21 centers (22%) with 250 to 350 cases per year, and 7 centers (7%) with more than 350 cases per year.

Unadjusted and adjusted results regarding the relationship between center volume and cardiac arrest rate, and rate of mortality in those with a cardiac arrest, are presented in Tables 3 and 4. In unadjusted analysis, there was no significant relationship between center volume and cardiac arrest rate (Table 3). Results were similar in adjusted analysis and when the analysis was stratified by operation complexity. In contrast, lower-volume centers had higher odds of mortality in those with a cardiac arrest in both unadjusted and adjusted analyses (Table 4). Compared with high-volume centers (>350 cases/y), adjusted mortality in those with a cardiac arrest was significantly higher at centers with fewer than 150 cases/y (odds ratio, 2.00; 95% confidence interval, 1.52 to 2.63) and 150 to 250 cases/y (odds ratio, 1.39; 95% confidence interval, 1.09 to 1.77). This relationship approached but did not reach statistical significance for centers with 250 to 350 cases/y (odds ratio, 1.24; 95% confidence interval, 0.99 to 1.56). Findings were similar in analysis stratified by operation complexity (Table 4).

Comment

Data from this large, multicenter study establish that postoperative cardiac arrest occurs in approximately 3% of patients undergoing pediatric heart operations with an associated overall mortality of approximately 50%. The prevalence of cardiac arrest increases with case complexity, although arrest is associated with a significant mortality risk across the spectrum of procedural complexity. Although center volume was not significantly associated with cardiac arrest rate, lower-volume centers had a higher rate of mortality in those with cardiac arrest. These associations were similar across both low- and high-complexity operations.

In previous studies, the reported prevalence of cardiac arrest in hospitalized children with cardiac disease has been in the range of 4% to 6% [1, 3–5]. Most previous studies reporting on the prevalence of cardiac arrest in children with cardiovascular disease include both medical and surgical patients [3–5]. Our data demonstrate that overall arrest rate is only partially informative, as the rate of cardiac arrest is directly related to case complexity, and therefore dependent on the type of cases included in the study. Our analyses also provide previously unavailable benchmark data describing prevalence of cardiac arrest and mortality in those with cardiac arrest among patients undergoing common surgical procedures across the spectrum of complexity.

Differences across centers with respect to rates of cardiac arrest, and mortality in those with cardiac arrest after heart surgery have not been previously evaluated in the pediatric population. The present analysis suggested that center volume was not significantly associated with the rate of cardiac arrest. Importantly, however, lower center volume was

significantly associated with higher mortality in those who experienced a postoperative cardiac arrest. This is consistent with previous studies across a variety of surgical specialties, demonstrating that higher-volume centers may not necessarily have lower complication rates, but tend to have lower mortality in those patients who experience postoperative complications [6, 7, 16]. Thus, there is a growing recognition that high-volume hospitals may perform better in terms of “rescuing” patients with complications, whereas complications in some cases may be more related to high-risk patient characteristics rather than reflective of hospital quality [16]. Failure-to-rescue, or the rate of death in those with a complication, is now recognized as an important factor underlying variation in mortality across hospitals for several surgical procedures [16, 17]. In the field of pediatric heart surgery, Pasquali and colleagues [6] recently demonstrated similar findings, showing that high-volume centers had a lower rate of mortality in those who experience complications. That study did not evaluate specific postoperative complications. Together with the data from the present study, these findings suggest that in addition to reducing prevalence of postoperative complications such as cardiac arrest after heart operations, quality improvement may also require attention to initiatives aimed at improved management of cardiac arrest and other complications once they occur. Surgical and intensive care teams must develop targeted initiatives and specific care practices not only to prevent cardiac arrest but also to rescue patients after cardiac arrest.

The limitations of the presented study are related to the nature of the STS-CHSD. Not all US centers participate; therefore, our results may not be generalizable to all pediatric heart programs. Nonetheless, the present report represents the most inclusive evaluation of cardiac arrest in this population to date, with 97 pediatric heart centers included. Although there are data audits to verify STS-CHSD data quality, there may still be variation in coding of complications such as cardiac arrest across centers. To address this in the present study, we excluded centers with poor data quality regarding the capture of complications. We were also limited to evaluation of variables collected in the database, and were not able to assess the potential impact of training or availability of intensive care unit personnel on cardiac arrest rates, for example. In addition, complications in the database are currently not “timestamped,” and we were unable to evaluate the temporal relationships between events such as cardiac arrest, use of extracorporeal membrane oxygenation, and subsequent mortality.

Data in our analysis are reflective of the definition of cardiac arrest currently used in the STS-CHSD, which differs in some respects from international Utstein guidelines. According to those guidelines, pulseless cardiac arrest is defined as the cessation of cardiac mechanical activity, determined by the absence of a palpable central pulse, unresponsiveness, and apnea [18]. Our study also lacked data on some of Utstein’s outcomes, such as return of spontaneous circulation longer than 20 minutes, 24-hour survival, and survival to discharge with favorable neurologic outcomes. One potential solution that may address these limitations and allow for more-comprehensive future analyses would be linkage of the STS-CHSD with the American Heart Association’s Get With the Guidelines–Resuscitation registry, a large multicenter registry of in-hospital cardiac arrests [18, 19]. This linkage would mitigate many of the limitations outlined above by improving data granularity for patients having a cardiac arrest.

This study suggests that postoperative cardiac arrest occurs in 3% of children undergoing heart surgery. Although prevalence increases with case complexity, cardiac arrest is associated with significant mortality risk regardless of level of complexity. The rate of cardiac arrest does not appear to be a function of center case volume. However, high-volume centers have lower mortality in those who experience an arrest. Thus, initiatives aimed at improving outcomes in children undergoing heart surgery may need to focus on not only reducing cardiac arrest but also improving postarrest management. Further study in this area could be facilitated by linkage of the STS-CHSD with the American Heart Association's Get With the Guidelines-Resuscitation registry.

Acknowledgments

This research was supported in part by National Heart, Lung, and Blood Institute grant K08HL103631 (S.K.P.).

References

1. Parra DA, Totapally BR, Zahn E, et al. Outcome of cardio-pulmonary resuscitation in a pediatric cardiac intensive care unit. *Crit Care Med*. 2000; 28:3296–300. [PubMed: 11008995]
2. Rhodes JF, Blaufox AD, Seiden HS, et al. Cardiac arrest in infants after congenital heart surgery. *Circulation*. 1999; 100(19 Suppl):II194–9. [PubMed: 10567303]
3. Ortmann L, Prodhon P, Gossett J, et al. American Heart Association's Get With the Guidelines-Resuscitation Investigators. Outcomes after in-hospital cardiac arrest in children with cardiac disease: a report from Get With the Guidelines-Resuscitation. *Circulation*. 2011; 124:2329–37. [PubMed: 22025603]
4. Lowry AW, Knudson JD, Cabrera AG, Graves DE, Morales DL, Rossano JW. Cardiopulmonary resuscitation in hospitalized children with cardiovascular disease: estimated prevalence and outcomes from the kids' inpatient database. *Pediatr Crit Care Med*. 2013; 14:248–55. [PubMed: 23462352]
5. Matos RI, Watson RS, Nadkarni VM, et al. American Heart Association's Get With The Guidelines-Resuscitation (Formerly the National Registry of Cardiopulmonary Resuscitation) Investigators. Duration of cardiopulmonary resuscitation and illness category impact survival and neurologic outcomes for in-hospital pediatric cardiac arrests. *Circulation*. 2013; 127(12):1442–51. [PubMed: 23339874]
6. Pasquali SK, Li JS, Burstein DS, et al. Association of center volume with mortality and complications in pediatric heart surgery. *Pediatrics*. 2012; 129:e370–6. [PubMed: 22232310]
7. Pasquali SK, Jacobs JP, He X, et al. The complex relationship between center volume and outcome in patients undergoing the Norwood operation. *Ann Thorac Surg*. 2012; 93:1556–62. [PubMed: 22014746]
8. Jacobs ML, Mavroudis C, Jacobs JP, Tchervenkov CI, Pelletier GJ. Report of the 2005 STS Congenital Heart Surgery Practice and Manpower Survey. *Ann Thorac Surg*. 2006; 82:1152–9. [PubMed: 16928571]
9. Clarke DR, Breen LS, Jacobs ML, et al. Verification of data in congenital cardiac surgery. *Cardiol Young*. 2008; (18 Suppl 2):177–87. [PubMed: 19063789]
10. The Society of Thoracic Surgeons. [Accessed December 1, 2013] STS National Database. Available at: <http://www.sts.org/sections/stsnationaldatabase/>
11. O'Brien SM, Clarke DR, Jacobs JP, et al. An empirically based tool for analyzing mortality associated with congenital heart surgery. *J Thorac Cardiovasc Surg*. 2009; 138:1139–53. [PubMed: 19837218]
12. The Society of Thoracic Surgeons. [Accessed December 1, 2013] Adult Cardiac Surgery Database V2.73. Congenital Diagnoses and Procedures Lists. Available at: http://www.sts.org/sites/default/files/documents/STSCongenitalDiagnosesProceduresLists_V2_73_0.pdf

13. Jacobs ML, O'Brien SM, Jacobs JP, et al. An empirically based tool for analyzing morbidity associated with operations for congenital heart disease. *J Thorac Cardiovasc Surg.* 2013; 145:1046–57. [PubMed: 22835225]
14. Jacobs JP, O'Brien SM, Pasquali SK, et al. Variation in outcomes for benchmark operations: an analysis of the Society of Thoracic Surgeons Congenital Heart Surgery Database. *Ann Thorac Surg.* 2011; 92:2184–92. [PubMed: 22115229]
15. Welke KF, O'Brien SM, Peterson ED, Ungerleider RM, Jacobs ML, Jacobs JP. The complex relationship between pediatric cardiac surgical case volumes and mortality rates in a national clinical database. *J Thorac Cardiovasc Surg.* 2009; 137:1133–40. [PubMed: 19379979]
16. Ghaferi AA, Birkmeyer JD, Dimick JB. Hospital volume and failure to rescue with high-risk surgery. *Med Care.* 2011; 49:1076–81. [PubMed: 22002649]
17. Wright JD, Herzog TJ, Siddiq Z, et al. Failure to rescue as a source of variation in hospital mortality for ovarian cancer. *J Clin Oncol.* 2012; 30:3976–82. [PubMed: 23032619]
18. Suominen P, Olkkola KT, Voipio V, Korpela R, Palo R, Räsänen J. Utstein style reporting of in-hospital paediatric cardiopulmonary resuscitation. *Resuscitation.* 2000; 45:17–25. [PubMed: 10838235]
19. American Heart Association's. [Accessed December 1, 2013] Get With the Guidelines–Resuscitation (GWTG-R) registry Full Specifications. Available at: <http://www.heart.org/resuscitation>

Table 1**Patient Characteristics^a**

Variable	Overall (n = 70,270)	Cardiac Arrest (n = 1,843)	No Cardiac Arrest (n = 68,427)	p Value
Patient characteristics				
Male sex	38,008 (54.1%)	980 (53.2%)	37,028 (54.1%)	0.003
Age (days)	156 (21, 1359)	15 (6, 96)	162 (22, 1414)	<0.0001
Weight (kg)	5.7 (3.3, 14.9)	3.3 (2.7, 4.4)	5.9 (3.4, 15.0)	<0.0001
Weight-for-age z score	-1.2 (-2.4, -0.1)	-1.5 (-2.4, -0.7)	-1.2 (-2.4, -0.1)	<0.0001
Prematurity ^b	6,275 (30.5%)	224 (20.0%)	6,051 (31.1%)	<0.0001
Any chromosomal, genetic, or non-CV abnormality	19,813 (28.2%)	690 (37.4%)	19,123 (28.0%)	<0.0001
Preoperative length of stay (days)	0 (0, 5)	5 (1, 10)	0 (0, 5)	<0.0001
STS-defined preoperative factors				
Any preoperative risk factor	22,846 (32.5%)	1,012 (54.9%)	21,834 (31.9%)	<0.0001
Mechanical ventilation	10,970 (15.6%)	667 (36.2%)	10,303 (15.1%)	<0.0001
Sepsis	1,085 (1.5%)	53 (2.9%)	1,032 (1.5%)	<0.0001
Shock	2,382 (3.4%)	190 (10.3%)	2,192 (3.2%)	<0.0001
Renal failure	693 (1.0%)	43 (2.3%)	650 (1.0%)	<0.0001
Cardiopulmonary resuscitation	295 (0.8%)	26 (2.6%)	269 (0.8%)	<0.0001
Operative data				
CPB time (min)	95 (63, 140)	142 (96, 200)	94 (63, 138)	<0.0001
1 previous cardiothoracic surgery	12,153 (17.3%)	149 (8.1%)	12,004 (17.5%)	<0.0001
STS-EACTS mortality category				
Low risk ^c	54,071 (76.9%)	645 (34.9%)	53,426 (78.1%)	<0.0001
High risk ^c	16,199 (23.1%)	1,198 (65.1%)	15,001 (21.9%)	
STS morbidity category				
Low risk ^c	56,811 (80.8%)	754 (40.9%)	56,057 (81.9%)	<0.0001
High risk ^c	12,781 (18.1%)	1,039 (56.3%)	11,742 (17.1%)	

^aContinuous variables are summarized by median and interquartile range (25th to 75th percentiles). Categorical variables are summarized as n (percent).

^bPrematurity reported in neonates only (overall, n = 20,555; cardiac arrest, n = 1,118; no cardiac arrest, n = 19,437).

^cCategories 1, 2, and 3 represent "low" risk and categories 4 and 5 represent "high" risk.

CPB = cardiopulmonary bypass; CV = cardiovascular; EACTS = European Association for Cardiothoracic Surgery; STS = The Society of Thoracic Surgeons.

Prevalence of Cardiac Arrest and Associated Mortality in Eight Society of Thoracic Surgeons Benchmark Operations^a

Table 2

Variable	VSD Repair (n = 6,845)	TOF Repair (n = 3,732)	CAVC Repair (n = 2,608)	ASO (n = 1,773)	ASO + VSD Repair (n = 656)	Fontan (n = 1,923)	Truncus Arteriosus Repair (n = 478)	Norwood Operation (n = 2,757)
Cardiac arrest rate	52 (0.7%)	52 (1.4%)	66 (2.5%)	43 (2.4%)	44 (6.7%)	17 (0.9%)	32 (6.7%)	350 (12.7%)
Mortality in patients without cardiac arrest	33 (0.5%)	20 (0.6%)	47 (1.8%)	41 (2.3%)	39 (6.4%)	27 (1.4%)	18 (4.1%)	302 (12.5%)
Mortality in patients with cardiac arrest	8 (15.4%)	12 (23.1%)	20 (30.3%)	11 (25.6%)	18 (40.9%)	7 (41.2%)	17 (53.1%)	218 (62.3%)
p value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

^aCategorical variables are summarized as n (percent).

ASO = arterial switch operation; CAVC = complete atrioventricular canal; TOF = tetralogy of Fallot; VSD = ventricular septal defect.

Table 3

Relationship Between Center Volume and Cardiac Arrest

Center Volume (cases/y)	Cardiac Arrest			
	Unadjusted OR (95% CI)	<i>p</i> Value	Adjusted OR (95% CI) ^a	<i>p</i> Value
Overall				
<150	0.86 (0.54–1.36)	0.51	1.06 (0.71–1.57)	0.78
150–250	1.14 (0.71–1.83)	0.60	1.28 (0.83–1.98)	0.26
250–350	0.80 (0.48–1.31)	0.37	0.86 (0.55–1.35)	0.52
>350	Reference		Reference	
STS Morbidity Categories 1–3				
<150	0.89 (0.57–1.41)	0.62	0.93 (0.61–1.43)	0.75
150–250	1.13 (0.70–1.82)	0.62	1.18 (0.74–1.88)	0.49
250–350	0.83 (0.51–1.35)	0.46	0.84 (0.53–1.33)	0.46
>350	Reference		Reference	
STS Morbidity Categories 4–5				
<150	1.23 (0.76–2.00)	0.39	1.20 (0.78–1.85)	0.40
150–250	1.39 (0.83–2.33)	0.21	1.40 (0.87–2.23)	0.16
250–350	0.87 (0.52–1.46)	0.61	0.89 (0.55–1.43)	0.63
>350	Reference		Reference	

^a Adjusted OR are adjusted for the patient and operative characteristics specified in the Methods section.

CI = confidence interval; OR = odds ratio; STS = The Society of Thoracic Surgeons.

Table 4

Relationship Between Center Volume and Mortality in Those With Cardiac Arrest

Center Volume (cases/y)	Mortality in Those With Cardiac Arrest			
	Unadjusted OR (95% CI)	<i>p</i> Value	Adjusted OR (95% CI) ^a	<i>p</i> Value
Overall				
<150	1.85 (1.38–2.49)	<0.0001	2.00 (1.52–2.63)	<0.0001
150–250	1.30 (1.03–1.64)	0.03	1.39 (1.09–1.77)	0.008
250–350	1.15 (0.92–1.44)	0.23	1.24 (0.99–1.56)	0.06
>350	Reference		Reference	
STS-EACTS Mortality Risk Categories 1–3				
<150	2.17 (1.14–4.13)	0.02	2.29 (1.19–4.41)	0.01
150–250	1.36 (0.78–2.37)	0.28	1.52 (0.87–2.64)	0.14
250–350	1.78 (1.04–3.03)	0.03	1.88 (1.12–3.18)	0.02
>350	Reference		Reference	
STS-EACTS Mortality Risk Categories 4–5				
<150	1.87 (1.23–2.83)	0.003	2.00 (1.37–2.90)	0.0003
150–250	1.32 (0.97–1.79)	0.07	1.41 (1.03–1.94)	0.03
250–350	0.96 (0.71–1.30)	0.79	1.07 (0.78–1.46)	0.67
>350	Reference		Reference	

^a Adjusted OR are adjusted for the patient and operative characteristics specified in the Methods section.

CI = confidence interval; EACTS = European Association for Cardiothoracic Surgery; OR = odds ratio; STS = The Society of Thoracic Surgeons.